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VOLUME VII

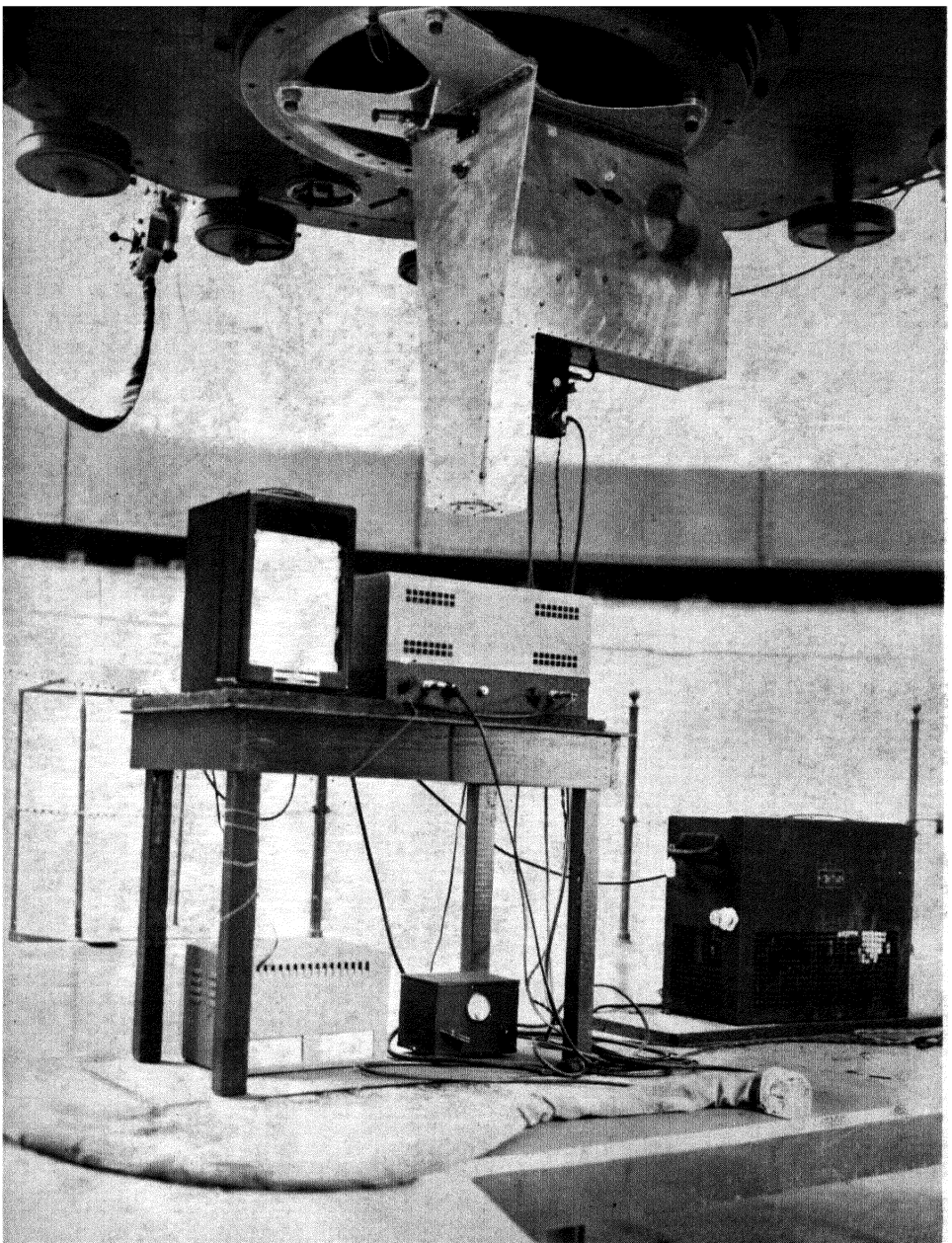


Fig. 1. *Infra-red equipment at McDonald Observatory.* Top: 82 in. cell + spectrometer and pre-amplifier. On table: amplifier (right) and recording meter. On floor (right): constant frequency unit with oscillating crystal; 60 cycles per sec. output, accurate to 1: 200,000. Under table: control box of above unit, and (left) condenser box, to lengthen period of recording meter at will from $\frac{1}{2}$–6 sec.

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

INTERNATIONAL ASTRONOMICAL UNION

(UNION ASTRONOMIQUE INTERNATIONALE)

TRANSACTIONS

OF THE

INTERNATIONAL ASTRONOMICAL UNION

Vol. VII

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HELD AT

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AUGUST 11 to AUGUST 18, 1948

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J. H. OORT

(General Secretary)

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PART I

INAUGURAL CEREMONY

&

GENERAL ASSEMBLY

REPORT OF THE EXECUTIVE COMMITTEE

EXECUTIVE COMMITTEE

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Sir HAROLD SPENCER JONES, Astronomer Royal of England, Director of the Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.

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Prof. A. A. MIKHAILOV, Pulkovo Observatory, Fontanka 34, Leningrad, U.S.S.R.

Prof. G. TIERCY, Directeur de l'Observatoire d'Astronomie, Genève, Suisse.

GENERAL SECRETARY:

Prof. J. H. OORT, Sterrewacht, Leiden, Netherlands.

INAUGURAL CEREMONY

August 11, 10.30

THE Inaugural Ceremony took place in the Auditorium Maximum of the Swiss Federal Institute of Technology, in the presence of Regierungsrat Dr E. Vaterlaus. Addresses of welcome were given by Dr E. Vaterlaus, former rector Prof. Dr F. Tank, the President of the I.A.U. Sir Harold Spencer Jones and Prof. Dr M. Waldmeier, director of the Federal Observatory, Zürich.

Address by REGIERUNGSRAT Dr E. VATERLAUS.

MESDAMES, MESSIEURS,

Après une longue série d'années, pendant lesquelles il a été impossible d'assembler des congrès internationaux à cause de l'affreuse et funeste guerre mondiale, l'Union astronomique internationale tient, ces jours-ci, son Assemblée générale à Zürich. Depuis la fondation de l'Union astronomique internationale, en 1919, des congrès eurent lieu à Rome, à Cambridge (Angleterre), à Leyde, à Cambridge (États-Unis), à Paris et, pour la dernière fois, en 1938, à Stockholm. Le fait que vous vous êtes décidés, après ces années de guerre et d'après-guerre pleines de lutte et de détresse, à convoquer votre Assemblée générale ici, sur notre territoire, signifie pour nous autres Suisses une joie et un honneur tout particuliers. Par une bienveillante destinée, notre patrie est restée intacte aussi pendant la deuxième guerre mondiale de sorte que vous pouvez prendre part à vos délibérations et à vos excursions dans un pays où rien ne vous rappelle toujours les horribles et sinistres temps de guerre.

Mesdames, messieurs, j'ai le grand honneur, et le grand plaisir de vous souhaiter cordialement la bienvenue au nom du conseil du Gouvernement cantonal zürichois et au nom du conseil municipal de la ville de Zürich. Malheureusement monsieur le conseiller fédéral Etter, chef du Département de l'Intérieur, est empêché d'assister à la fête d'ouverture d'aujourd'hui et au banquet officiel du 17 août. Il m'a chargé de vous transmettre, pour la journée d'aujourd'hui, les meilleurs vœux et compliments du Conseil fédéral.

MEINE DAMEN UND HERREN,

Ich darf wohl ohne Ueberhebung feststellen, dass die Wahl Zürichs als Ort Ihrer 7. Tagung als eine Anerkennung der wertvollen Mitarbeit der eidgenössischen Sternwarte in Zürich an den Organisationen der Internationalen Astronomischen Union gewertet werden darf. Diese Mitarbeit bezieht sich im besonderen auf die Beobachtungen der Erscheinungen auf der Sonne. Seit dem Bestehen der eidg. Sternwarte haben sich alle Direktoren dieses Institutes ganz besonders intensiv und erfolgreich der Sonnenforschung gewidmet. Prof. Rud. Wolf, der erste Direktor der eidg. Sternwarte von 1855–93, Prof. Alfred Wolfer 1894–1926, Prof. William Brunner 1926–45 und Prof. Waldmeier seit 1945.

Das Aroser Observatorium der Eidgenössichen Technischen Hochschule das Sie auf einer Exkursion besuchen werden, ist nach Instrumentation und Zielsetzung zu einem recht modernen Institut der Sonnenforschung ausgebaut worden. Nachdem erkannt wurde, dass zwischen Sonnenaktivität und der Ausbreitungsmöglichkeit der Kurzwellen enge Zusammenhänge bestehen, ist der Problemkreis, mit dem Prof. Wolf vor bald 100 Jahren seine Forschungen begonnen hat, noch lange nicht erschöpft, sondern erscheint heute von grösserer Aktualität als je zuvor.

Meine Damen und Herren, da Sie in Zürich tagen, darf ich Sie wohl erinnern an einen hervorragenden Gelehrten, dessen Forschungsresultate auch für Ihre Wissenschaft von

ganz besonderer und entscheidender Bedeutung waren: Prof. Albert Einstein. In Zürich studierte Prof. Einstein an der E. T. H. Mathematik und Physik und hier hat der Forscher, der durch seine Relativitätstheorie das geistige Gesichtsfeld entscheidend erweiterte, als Lehrer an beiden Hochschulen gewirkt. Leider war diese Lehrtätigkeit nur von kurzer Dauer, aber für alle, die den Vorzug hatten, wie der Sprechende, Schüler einer für die Wissenschaft so bedeutenden Persönlichkeit zu sein, war der Kontakt mit einem der genialsten Geister ein Erlebnis ganz besonderer Art.

Meine sehr verehrten Damen und Herren, Ihr Kongress fällt in eine Zeit, in der wir in unserem Lande das 100-jährige Bestehen unserer Verfassung und unseres Bundesstaates feiern können. Wir Schweizer, die wir in viele Teile getrennt sind nach Sprache, Rasse und Konfession, haben uns doch im Bunde der Eidgenossenschaft zusammengefunden, in einem Bunde, in dessen Schutz wir in glücklichem Frieden haben leben dürfen. Wir haben dadurch bewiesen, dass bei gutem Willen, bei Achtung von Eigenart und Lebensrecht der andern, ein friedliches Zusammenleben verschiedener Völker möglich sein muss. Am heutigen Kongress der Internationalen Astronomischen Union sind 30 Staaten aus der ganzen Welt vertreten. Sie beweisen damit, dass auch auf wissenschaftlichem Gebiet eine Zusammenarbeit der verschiedensten Völker möglich ist. Wir möchten doch alle wünschen und hoffen, dass auch auf wirtschaftlichem und politischem Gebiete der Weg zu einer friedlichen Verständigung gefunden werden kann. Möge Ihr Kongress, dem ich einen vollen Erfolg wünsche, auch dazu beitragen, dem ersehnten Ziele eines dauernden Friedens näher zu kommen.

Mit diesem aufrichtigen Wunsche habe ich die Ehre, den Kongress der Internationalen Astronomischen Union zu eröffnen.

Address by ALT-REKTOR PROF. DR. F. TANK.

MONSIEUR LE PRÉSIDENT, MESDAMES, MESSIEURS,

Au nom de l'Ecole Polytechnique Fédérale et de son conseil, j'ai l'honneur de souhaiter à l'Union Astronomique Internationale la bienvenue la plus chaleureuse. Nous sommes très heureux et très fiers de pouvoir accueillir au sein de notre Ecole les nombreux savants venus de toutes les parties du monde, prendre part à ce présent congrès. Et, nous espérons vivement que cette réunion saura resserrer les liens sacrés de l'amitié qui, aujourd'hui plus que jamais, est la base d'une loyale collaboration, si nécessaire à tout progrès scientifique.

L'Ecole Polytechnique Fédérale où les cours sont donnés dans deux de nos langues nationales, s'est toujours distinguée et par le libéralisme avec lequel elle accueille les élèves et les maîtres de toutes nations, et par le libéralisme de son enseignement. Quoique notre Ecole soit destinée, en premier lieu, à former des ingénieurs, elle n'a jamais négligé les sciences exactes, sachant combien celles-ci ont aidé à développer ce qu'on peut appeler les sciences de l'ingénieur. Elle continue à affermir cette harmonieuse et si féconde alliance de l'application et de la théorie. Dans cet esprit, nous enseignons les mathématiques pures, la physique, les sciences naturelles et, nous l'ajoutons avec un plaisir tout particulier, aussi l'astronomie.

L'astronomie, comme la plus ancienne des sciences naturelles, peut non seulement regarder sur un passé historique des plus grandioses, mais peut se vanter d'avoir exercé une influence ineffaçable sur le raisonnement scientifique, et sur le penser humain en général. Aucune science, en effet, ne saurait mieux nous apprendre le respect devant la merveille de la création. Ce que le simple être humain ressent à la vue du ciel nocturne, l'astronome, explorant l'infini, le précise: L'univers est régi par des lois imposantes et immuables, et ne respire qu'ordre et majesté. L'astronomie, la première à nous révéler ces vérités, nous rapproche en quelque sorte des astres, et nous fait réaliser que notre terre n'est, en somme, qu'une minuscule parcelle dans toute l'œuvre de la création. Celui qui, tant soit peu, est empreint de cet esprit ne peut manquer de modifier profondément ses considérations sur toutes les choses de la vie.

L'astronomie nous a non seulement enrichi d'une science nouvelle, mais elle a elle-même contribué extraordinairement au développement des mathématiques, de la

mécanique, de l'optique physique et technique, de la construction d'instruments de précision, et tant d'autres. L'astronomie a bien, en premier, conduit à la méthode scientifique. C'est à elle que nous devons la coordination réciproque d'observation et déduction, la fertile synthèse d'hypothèse et théorie, l'adaptation de notre raisonnement à de nouvelles possibilités, les considérations d'erreur, la systématique et l'organisation dans la recherche scientifique, sans oublier son influence sur la collaboration internationale.

Les mérites de l'astronomie ne sont pourtant pas uniquement du domaine du passé. L'astronomie est une science vivante, une science qui a toujours su se rajeunir et qui, aujourd'hui, se voue à des problèmes de plus en plus ardus. Nous attendons d'elle d'importantes contributions en astrophysique, et sur l'histoire et l'architecture de notre univers. Quoiqu'elle emprunte toutes les possibilités que la technique et les temps modernes peuvent lui offrir, quoiqu'elle s'appuie fortement sur toutes les sciences sœurs, l'astronomie restera une science modèle, par son but tout idéal de servir l'humanité, de développer la connaissance humaine, et de nous rappeler sans cesse combien petits nous sommes.

Puissez-vous donc, chers collègues, pendant ce congrès de l'Union Astronomique Internationale, enrichir votre savoir, et faire progresser votre science bien-aimée. Puissez-vous resserrer davantage vos liens d'amitié, en nouer de nouveaux, inspirés par le sentiment d'appartenir tous à une même et grande famille. Nous vous souhaitons un agréable séjour dans notre pays, un séjour qui, par ses fruits, restera longtemps gravé dans votre mémoire.

Address by SIR HAROLD SPENCER JONES, *President of the Union.*

HERR REGIERUNGSRAT DR VATERLAUS, HERR ALT-REKTOR PROF. DR TANK, LADIES AND GENTLEMEN,

Ten years have passed since the International Astronomical Union last met in General Assembly. At the meeting in Stockholm in 1938 an invitation was given to the Union, in the name of the Swiss National Committee of Astronomy and with the authority of the Swiss Federal Government, to hold the next General Assembly in Zürich. The invitation was accepted with acclamation. Though the international situation was at that time an uneasy one and clouds were already gathering on the horizon, it was hoped that the General Assembly would be held in Zürich in 1941. But that was not to be. In a war-devastated world, astronomers had to leave their telescopes and lay aside their calculations in order to concentrate on sterner things. Many observatories have been damaged or destroyed; many have lost their equipment and libraries. After the end of the war the Executive Committee of the Union met in Copenhagen early in 1946, with a few representatives of a number of the adhering countries, to piece together again the broken strands of international co-operation, which is so essential for the progress of astronomy. The invitation from Switzerland to hold the next General Assembly in Zürich was then renewed; as it was felt that the difficulties of travel and of hotel accommodation would be considerable in 1947, it was decided to defer the General Assembly until 1948.

So here we are at last assembled. It is my pleasing duty to express our grateful thanks to the Federal Government for the invitation and for the hospitality provided, to the Swiss National Committee for Astronomy, and to the Local Committee, under the chairmanship of Dr Waldmeier, for the excellent arrangements which have been made for our meeting in this beautiful city of Zürich. The Federal Institute of Technology, where we are now assembled and where all our meetings will be held, has a world-wide reputation. I believe that it was here that Einstein laid the first foundations of his generalized theory of relativity, besides doing much other important theoretical work.

On this occasion it is fitting to recall some of the important contributions that Switzerland has made to our science. Leonard Euler, the greatest man of science whom Switzerland has produced and the most prolific mathematician of all time, was the first to attempt the development of physical astronomy beyond the point at which Newton had left it. He made important contributions to lunar theory, solving the problem of three bodies for the special case of the system of the Earth, Moon and Sun, in which the distance apart of two bodies is small compared with their distances from the third. His most

valuable contribution to celestial mechanics was his method of the variation of the elements or parameters of an orbit. Amongst his contributions to planetary theory were his proofs that the diminution in the obliquity of the ecliptic and the advance of the earth's apse-line were caused by perturbations due to the other planets.

In an entirely different field, but of equal importance for the advancement of astronomy, was the work of the Swiss artisan, P. L. Guinand. After the invention of the achromatic lens by Chester Moor Hall and by Dollond, the development of the refracting telescope was restricted by the impossibility of obtaining pieces of pure flint glass of diameters greater than a few inches. For larger apertures reflecting telescopes had to be used. In 1784 Guinand commenced to improve the quality of optical glass and by 1799 had succeeded in making flint disks of high quality, as large as 6 inches in diameter and also in producing denser types of flint. To his association with Fraunhofer the modern refracting telescope may be attributed; Guinand produced the glass, Fraunhofer devised the methods of working it on automatic machines. These developments were to make it possible for achromatic objectives of large size to be constructed. In conjunction with Fraunhofer's perfection of the equatorial mounting, the refracting telescope was brought substantially into its present form. To Guinand was due the establishment of a true optical glass industry. He founded the industry in Germany, his sons established the industry in France and their successors established it in England.

Zürich will always be associated by astronomers with solar observations. It was Rudolf Wolf who initiated the preparation of relative sunspot numbers, which has been continued by his successors, Wolfer, Brunner and Waldmeier at Zürich, thereby providing data of the greatest value in many geophysical investigations. Wolf and Gautier, also in Switzerland, independently called attention, at about the same time as Sabine in England, to the remarkable correlation between the variations of sunspot frequency and of certain magnetic disturbances on the earth. To-day the Federal Observatory in Zürich, with its associated high altitude station at Arosa, where coronal observations are made, is one of the most active and most important centres of solar research.

International co-operation is essential for the progress of astronomy. Observatories widely scattered both in longitude and in latitude are essential so that the whole of the skies can be kept under observation and so that a fairly continuous watch can be kept on the Sun and other objects of special interest. The meetings of the International Astronomical Union provide the occasions for astronomers from all parts of the world to gather together, to discuss what has been achieved since last they met, and to formulate new programmes for the future. Not the least of the advantages of such meetings are the opportunities which they afford for personal contacts and discussions. There is a brotherhood amongst astronomers; they are members of one large family and the family reunions are eagerly looked forward to. During the next few days we shall have many matters to discuss, many problems to consider. We look forward to a meeting which will be rich in its scientific results; I feel sure that when the meeting is over all who have had the good fortune to be here will retain the happiest memories of the Seventh General Assembly of the International Astronomical Union in these delightful surroundings.

Address by PROF. DR. M. WALDMEIER, *Direktor der Eidgenössischen Sternwarte, Zürich.*

MONSIEUR LE CONSEILLER D'ETAT, MONSIEUR LE CONSEILLER MUNICIPAL, MONSIEUR LE RECTEUR, MESDAMES, MESSIEURS ET CHERS COLLÈGUES,

J'ai le très grand honneur de saluer à mon tour, nos hôtes de quelques jours sur le sol helvétique et dans notre ville. Nous vous accueillons ici de la façon la plus cordiale; nous espérons que vous vous sentirez à votre aise dans nos murs et qu'après une semaine de travail, lorsque vous vous séparerez à nouveau, ce sera avec le sentiment de vous être enrichis: intellectuellement, socialement, universellement et amicalement.

Ce sont plus de 400 astronomes, venant de trente pays différents, qui ont répondu à notre invitation. Je n'ignore pas que pour beaucoup d'entre vous, la participation à notre congrès n'allait pas sans entraîner de grands sacrifices. Mais ces sacrifices, nous

pouvons dire, qu'ils sont une preuve de votre idéalisme. Plus grand est l'idéalisme des savants, plus fructueuse et magnifique est leur recherche. Idéalisme, liberté personnelle, telles sont les conditions essentielles des progrès de la Science.

Je salue particulièrement la présence de ceux des participants à cette assemblée qui ont dû faire le plus long chemin pour venir ici retrouver leurs collègues. C'est notamment pour nous une joie de constater le grand nombre des représentants des Etats-Unis d'Amérique; qu'ils sachent que tous ici sont reconnaissants envers leur grand pays pour l'aide accordée à notre continent meurtri et pour l'intérêt actif que leurs autorités continuent à porter aux choses de l'Europe; le mouvement scientifique international ne peut qu'en être favorablement influencé.

Vous êtes, Messieurs et chers Collègues, venus tenir votre septième assemblée générale en Suisse, au cœur de l'Europe, dans ce pays petit mais riche en beautés naturelles, sur cette terre de stabilité dans les tempêtes; voilà une des raisons profondes pour laquelle nous nous trouvons réunis à Zürich aujourd'hui.

L'Union internationale d'Astronomie est née de l'Union internationale pour les recherches solaires. De tout temps, l'étude du soleil a été activement cultivée dans notre observatoire; et parmi tous les instituts qui se vouent aux phénomènes solaires, l'observatoire fédéral présente la plus longue des traditions: il y a cent ans que Rudolf Wolf, son premier directeur, a commencé ses célèbres recherches sur les taches solaires, recherches qui constituent aujourd'hui encore une partie essentielle de nos travaux. Une des trois sections de l'exposition organisée à l'occasion de cette assemblée est consacrée à ce jubilé centenaire.

Mais les débuts de l'astronomie à Zürich remontent beaucoup plus loin dans le temps. Il y a deux ans, dans cette même salle, la Société Zürichoise des Sciences Naturelles a fêté le 200me anniversaire de sa fondation en 1746, dans ce 18me siècle qui a vu naître tant d'académies scientifiques nationales ou locales poursuivant les mêmes buts. La première entreprise de cette Société des Sciences Naturelles fut de relever astronomiquement la région du Canton de Zürich, ce qui exigea la construction d'un premier observatoire zürichois. Quant à l'actuel, il date de 1863. En 1939 fut construit à Arosa l'observatoire d'astronomie physique, et pour l'heure nous nous trouvons devant de nouvelles taches de construction. Les prochains mois verront une transformation totale de notre observatoire et quelque part en marge de la ville sera élevée une nouvelle station pour l'observation du Soleil.

L'Union internationale d'Astronomie a été fondée après la première guerre mondiale; mais son activité a été interrompue durant presqu'une dizaine d'années par le fait de la deuxième. Nous allons donc à Zürich faire un nouveau commencement; et après l'épouvantable misère des années qui viennent de s'écouler faisons le vœu de pouvoir défendre fermement les idéals de l'humanité. Durant les années de guerre, au milieu d'une Europe déchirée, notre pays subsista comme une île de paix, comme un asile de la culture européenne. Aussi sommes-nous heureux de voir se renouer, sur notre sol de pays neutre les liens de l'amitié et les fils de la collaboration scientifique. Hélas, les nations ne sont pas encore ouvertes les unes aux autres selon notre désir; c'est ainsi que font défaut ici les astronomes de nombreux pays. Notre devoir est d'autant plus indiqué, de maintenir les contacts personnels au sein de la grande famille des astronomes, afin qu'ils se connaissent mieux, et que règne parmi eux une amitié durable.

A beaucoup d'entre vous, notre pays semblera une sorte de paradis — voire un paradis de vie chère — . Oui, nos villes ont été singulièrement épargnées par la catastrophe universelle. Nous devons ce privilège à la bienveillance du destin — qui a fait de nous, pour la troisième fois en un siècle, une île de paix, — mais nous le devons aussi à l'unité de notre peuple. Et nous le devons encore aux précautions militaires que nous nous sommes imposées, à cette armée moderne qui nous a coûté plus qu'on ne peut le dire. A cause d'elle, nous voilà engagés dans d'énormes dettes. Vous qui venez d'outre-frontières, vous ne vous apercevez pas, sans doute, du fardeau que notre peuple a dû assumer, et pour de longues années. Du moins, grâce à cet effort, nous avons pu conserver ce qui nous tient le plus à cœur, le plus précieux des biens: la liberté. Ce pays, nous l'aimons de toute

ɔtre âme, mais à cause de ce lien fédératif qui nous unit, régions de langues, cultures et ligions diverses, cet amour du pays suisse ne risque pas de nous entraîner à un ıtionalisme étroit et fermé à la collaboration internationale.

En dépit des soucis qui la tourmentent, la Suisse fait effort pour garder toujours son eur ouvert, et sa main ouverte aux peuples qui souffrent autour d'elles. Ce que la Suisse ɔudrait être: une terre de liberté, de travail, de bienfaisance.

Le comité d'organisation a trouvé auprès des autorités constituées de la Confédération, ı Canton et de la ville de Zürich, non pas seulement un appui moral, mais aussi un appui atériel. Ces appuis assurés par les autorités civiles ont été complétés par l'appui, moral financier lui aussi, accordé par certains milieux industriels, notamment par la Chambre ıisse de l'Horlogerie. Ce sont ces appuis généreux qui nous ont permis de faire face aux fficultés de notre tâche. Malgré cela, nos moyens financiers sont restés modestes, comme seront aussi nos cérémonies et nos réceptions. Le comité d'organisation a fait pour le ieux, dans la mesure des moyens dont il disposait; et il vous demande d'être indulgents ɔur lui si vous apercevez une insuffisance quelconque dans la préparation des différentes tivités ou réjouissances du congrès.

Pour terminer, il ne me reste plus, Mesdames, Messieurs et chers Collègues, qu'à uhaiter à chacun de vous de trouver dans nos murs tout le plaisir et toute la satisfaction ientifique possibles.

Performances by the wind sextet of the Tonhalle Orchestra of Zürich, at the beginning ıd the end, added greatly to the charm of the ceremony.

The Ceremony was followed by a luncheon by invitation of the Swiss National Committee of Astronomy, where Professor G. Tiercy spoke in the name of this Committee.

ONSIEUR LE PRÉSIDENT DE L'UNION, MESDAMES, MESSIEURS,

C'est au nom du Comité National Suisse d'Astronomie que je salue les participants à lunch inaugural.

Vous êtes ici, Mesdames et Messieurs, les hôtes de ce comité. Il n'est donc pas ɔplacé que son président, en accord avec le comité d'organisation de cette réunion, ait ıoisi cet instant pour vous dire à son tour avec quel enthousiasme vous êtes accueillis r notre sol.

Tout à l'heure, vous avez entendu les paroles éloquentes des représentants des autorités ı pays et du Comité d'organisation. Permettez maintenant au président du Comité ational d'Astronomie de la Société helvétique des Sciences naturelles, qui est notre cadémie des Sciences, de vous exprimer sa joie de vous voir tenir ces assises dans une ; nos cités.

Lorsque, dans quelques jours, vous rentrerez dans vos foyers, emporterez-vous un bon ıuvenir de votre séjour ici? Nous l'espérons; je tiens à vous dire en tout cas, que nous ʼons fait tous nos efforts pour cela, et que nos autorités nous ont donné leur appui.

Lorsque, en 1938, après la brillante Assemblée générale de l'Union à Stockholm, le ɔnseil fédéral autorisait la Société helvétique des Sciences naturelles à vous inviter à ːnir tenir en Suisse la 7me assemblée générale, prévue pour 1941, les astronomes suisses rendaient bien compte de la modestie de leurs moyens; ils savaient qu'ils devaient se soudre à vous recevoir en toute simplicité. Cette 7me assemblée a dû être repoussée squ'à 1948 pour les raisons que vous savez; les conditions n'ont pas changé — nous ɔus recevons simplement.

Mais soyez assurés que nous le faisons avec entrain, fiers que nous sommes de la conıce que vous avez mise en nous.

Permettez-moi, Mesdames et Messieurs, d'insister un instant sur l'idée féconde de ıllaboration internationale. C'est un lieu commun, aujourd'hui, de dire que le travail ientifique ne peut plus rester morcelé comme autrefois, alors que les chercheurs pouvaient availler en solitaires. L'association pour la recherche scientifique est une nécessité

actuelle; elle entraîne d'ailleurs avec elle le bienfaisant principe d'émulation, bienfaisant parce que cette émulation ne peut avoir que d'heureux effets, à condition qu'elle reste loyale, bien entendu.

Je pense que ce fut en général le cas jusqu'ici, du moins en ce qui concerne l'Astronomie. Vous avez en effet compris depuis longtemps, mes chers Collègues, que les travaux individuels ne suffisent plus, et qu'ils doivent être coordonnés; qu'il n'y a pas de distinction entre la Science pure et la Science appliquée, qu'il ne peut y avoir qu'une Science, se proposant l'étude des phénomènes et la recherche des lois de ceux-ci.

Par une de ces coincidences heureuses, qui marquent de temps à autre le marche de l'histoire, les astronomes ont commencé à comprendre l'urgence de cette coopération générale en abordant le problème des taches solaires, qui est aujourd'hui encore la préoccupation principale de l'observatoire fédéral de Zürich. L'étude régulière des taches solaires avait, en effet, été entreprise en 1826 par Schwabe qui, dès 1843, assignait à la variation de leur nombre une allure cyclique, avec une période moyenne d'une dizaine d'années. Vers la même époque, des observations du magnétisme terrestre conduisirent Rudolf Wolf à Zürich, Alfred Gautier à Genève, d'autres encore, à la conclusion d'un cycle équivalent et correspondant.

Et l'éminent astronome B. Baillaud, qui fut directeur de l'observatoire de Paris, n'hésitait pas à voir dans ces résultats le premier essai de coopération internationale.

Depuis lors, en un siècle, cette coopération a été considérablement étendue; elle est maintenant la loi dans tous les domaines de l'Astronomie. Celle-ci a reçu, avec l'analyse spectrale en 1860 et la photographie dès 1885, de nouvelles possibilités de recherches; et ces nouveaux moyens furent si puissants et si riches en résultats qu'ils ont rendu aveuglante la nécessité de rendre de plus en plus fréquentes les réunions internationales; il suffit de rappeler ici la création du Comité permanent de la carte photographique du Ciel, celle de la Conférence des éphémérides astronomiques, de l'association pour les études solaires, d'autres encore.

Et vous savez comment, en 1919, la 3^{me} Conférence des Académies alliées et associées, réunie à Bruxelles, a constitué un Conseil international de recherches, devenu depuis le Conseil international des Unions scientifiques, et a organisé plusieurs Unions, dont celle qui nous est chère et qui tient présentement sa 7^{me} assemblée générale.

J'ai pensé qu'il n'était pas dénué d'intérêt d'esquisser devant vous, à grands traits, le développement dans le temps de cette idée féconde de la collaboration internationale qui, pour les astronomes, est apparue pour la première fois 'à la lumière du Soleil'.

Et maintenant, mes chers collègues, je voudrais évoquer devant vous une question qui me paraît essentielle, et qui touche à ce que nous avons de plus cher, la liberté pleine et entière des recherches scientifiques.

Vous connaissez les reproches que, dans certains milieux, on a dirigés contre les physiciens et les chimistes coupables, aux yeux des représentants de ces milieux, d'avoir fait servir leur science aux œuvres malfaisantes et destructrices.

C'est un lieu commun que de rappeler l'injustice de ces reproches; sans doute les techniciens militaires ont-ils mis à contribution certaines découvertes physico-chimiques; et cela n'a pas été sans dégâts pour l'humanité. Peut-être même cela fut-il nécessaire à un moment donné. Mais c'est méconnaître les faits que d'en faire grief aux chercheurs désintéressés, dont les travaux apportent à la collectivité une série de progrès et d'enrichissements de tout genre; ce n'est pas leur faute si les hommes ou leurs gouvernements en font parfois un emploi détestable. Si je rappelle ces critiques injustifiées, c'est que la récente histoire des développements de l'astronomie pourrait exposer les astronomes à des reproches du même genre. Je songe à ces recherches solaires dont nous parlions tout à l'heure; elles ont pris depuis 1930, depuis la mise en jeu de cet admirable coronagraphe imaginé par M. Lyot, un développement extraordinaire; et je ne dévoile pas un secret en disant que, durant la dernière guerre, les belligérants ont porté un intérêt très grand à ces recherches; la marine américaine n'avait-elle pas établi à Climax, à près de 3000 mètres d'altitude et à plus de 1500 km. des côtes, un observatoire qui leur était consacré?

Si les milieux dont je parlais plus haut connaissaient cet argument, ils ne manqueraient

pas de reprocher aux astronomes d'avoir participé au perfectionnement des moyens de destruction.

Ce serait évidemment aussi injuste que de critiquer aveuglement les physiciens de l'énergie nucléaire, comme il le serait encore de critiquer les astronomes qui s'occupent de la mesure du temps, essentielle aussi bien pour les militaires que pour les civils.

La vérité (et c'est à quoi j'en veux venir à la suite de ces remarques) est que pour leurs recherches désintéressées, les hommes de science, les astronomes comme les autres, doivent disposer d'une liberté sans réserve. Quand il s'agit de découvrir les lois naturelles, nous n'avons pas à nous préoccuper de savoir si les militaires en tireront des armes nouvelles; il est possible que cela soit encore; mais par contre, il est certain que toutes nos recherches finissent par concourir à l'augmentation du bien-être de l'humanité. C'est cela qui compte et qui l'emporte finalement.

Et pour nous astronomes pour qui cette 7^{me} assemblée générale de l'Union va permettre une mise au point de nos travaux et une orientation pour l'avenir immédiat, qu'il me soit permis d'émettre ici le vœu que nous puissions toujours œuvrer en toute liberté, comme il en est depuis longtemps déjà.

Et puisque je parle de liberté, je prendrai en terminant celle de souhaiter que vous accomplissiez un travail joyeux et fécond dans cette bonne ville de Zürich, cette Athènes de la Limmat comme on l'a parfois dénommée, et que, dans quelques jours, en regagnant vos pays respectifs, vous ayez conscience d'avoir bien mérité de l'Astronomie et de notre Union internationale.

GENERAL ASSEMBLY

Meeting of August 11, 1948, 15.00, in the Auditorium Maximum of the Swiss Federal Institute of Technology

SIR HAROLD SPENCER JONES, President, in the Chair

The president opened the meeting with the following words:

It is a great privilege for me to declare open the seventh General Assembly of the International Astronomical Union. We are very grateful to our Swiss colleagues for the invitation to meet in Zürich in these delightful surroundings. We recognize that there are special difficulties at the present time in the organization of arrangements for a congress such as this. It has meant a great deal of hard work for the Local Committee, under Dr Waldmeier, and to them we express our thanks. Almost exactly ten years have passed since the last General Assembly of the International Astronomical Union terminated. On that occasion Sir Arthur Eddington, who had been elected President but was not able to be present at the concluding meeting, sent a message in which he said:

> My uppermost feeling is a great responsibility to deserve the trust you have placed in me. We cannot foresee what may happen before we meet again in Zürich. On the astronomical side we can make some guess. The 200-inch reflector will be completed or nearing completion. The marvellous advance in the photography of the corona and prominences, which has been so memorable a feature of this meeting, will bear fruit in advancing knowledge. And our numerous commissions will patiently extend their researches. But on the international side no one dares prophesy. But, if in international politics the sky seems heavy with clouds, such a meeting as this at Stockholm is as when the sun comes forth from behind the clouds. Here we have formed and renewed bands of friendship which will resist the forces of disruption.

The skies, indeed, were heavy with gathering storm clouds at that time and a year later the storm burst. Astronomers in many parts of the world left their telescopes and laid aside their books and their calculations to devote their skill and talent to fighting the forces of evil that had been let loose. The peaceful pursuit of knowledge was slowed down and the forces of destruction held sway. Yet, often in spite of incredible difficulties, astronomical research was continued and the reports of the Commissions, presented at this meeting, show that much was achieved. One consequence of the war was, perhaps, unexpected. Under black-out conditions many saw the skies as they had never seen them before; and it was consoling, in a war-torn world, to find distraction in the contemplation of the order and majesty of the Universe. Never before, I think, has there been such a widespread general interest in astronomy.

The ten years that have elapsed since we last met have taken a heavy toll of our colleagues, including many who have occupied an eminent position in astronomy and in the Union. First among these I mention Sir Arthur Eddington, President of the Union, whose untimely death while still in the fulness of his powers was an irreparable loss to our science and our Union. We also have to deplore the deaths of Prof. Frank Schlesinger and of Sir Frank Dyson, both past Presidents of the Union, and of Prof. Alfred Fowler, the first General Secretary. These three men, all eminent in astronomy and friends of many present to-day, took a great share in the formation of the International Astronomical Union; to their wisdom in establishing it on sure foundations and to their guidance in steering it in the right direction the success of the Union is in no small measure due. I should like to refer also to Dr H. Deslandres, former Vice-President of the Union and the doyen of astronomers, whose name was honoured not only in France but throughout

the astronomical world, and to Prof. Elis Strömgren, who in the face of great difficulties carried on through the war the Astronomical Telegram Bureau and who was the host at the meeting of the Executive Committee and representatives of a number of countries held in Copenhagen in 1946. Mention must also be made of Dr A. Lambert, who was brutally murdered by the Nazis, and of Dr A. de Sitter and Dr W. C. Martin, who succumbed to starvation in a Japanese concentration camp.

To these names there is unfortunately a very long list to be added. Time will not permit the list to be read in full. It includes many whose names are known throughout the astronomical world and many whose faces have been familiar at past assemblies. Amongst them are Prof. Emilio Bianchi, Prof. Charles Fabry, and Prof. H. F. Newall, former Vice-Presidents of the Union; Dr Felix de Roy, Prof. R. S. Dugan, Dr H. Kimura, Prof. M. Maggini, General Perrier, Presidents of Commissions; E. M. Antoniadi, Dr J. M. Baldwin, Prof. A. Bemporad, Dr G. Bennett, Miss M. A. Blagg, Prof. H. Buisson, Dr Annie Cannon, Dr A. C. D. Crommelin, Prof. H. D. Curtis, Prof. F. M. da Costa Lobo, Dr N. Dneprovsky, Prof. P. Emanuelli, Prof. R. Emden, M. H. Grouiller, Mr J. C. Hammond, Dr W. E. Harper, Mr A. R. Hinks, Prof. K. Hirayama, Prof. Shin Hirayama, Prof. A. Ivanov, Sir James Jeans, M. N. V. Komendantoff, Dr J. Krassowski, Dr G. N. Neuymin, Prof. T. Niethammer, Prof. C. Parvulesco, Rev. T. E. R. Phillips, Dr J. S. Plaskett, Prof. H. C. Plummer, Father Luis Rodés, Prof. R. A. Sampson, Prof. F. Slocum, Prof. J. Svoboda, Dr A. van Maanen, Dr J. Woltjer Jr., Dr H. E. Wood.

I ask you to stand for a few moments in silent tribute to the memory of all the colleagues whom we have lost since we last met.

After the death of Sir Arthur Eddington, I had the honour to be elected President by the Executive Committee. Prof. Fabry, Prof. Bergstrand and Prof. Brunner retired after the end of the war from the office of Vice-President, at their own request. The Executive Committee elected Prof. Danjon, Prof. A. A. Mikhailov, and Prof. G. Tiercy in their place.

We regret that Dr W. S. Adams, late Director of the Mount Wilson Observatory and a Vice-President of the Union is unable to be present. I propose that a telegram should be sent to Dr Adams on behalf of this General Assembly conveying our greetings and good wishes. The Executive Committee has elected Prof. Stebbins as a Vice-President for this meeting. I propose also that telegrams of greetings and good wishes should be sent to Miss Eddington; to Prof. Esclangon, former President of the Union; and to Prof. Russell, Dr van Rhijn, and Prof. Carnera, Director of the Central Latitude Bureau, who have been unable to be with us because of ill-health.

Since the last General Assembly Australia, Chile, Eire, Finland, Hungary and India have joined the Union, making a total of thirty-one countries adhering to the Union.

When the end of the war arrived, international co-operation had been sadly interrupted and there was a need for new arrangements to be made for the organization of certain fields of work, particularly in variable stars and minor planets. As difficulties of travel and of obtaining hotel accommodation were too great to permit a General Assembly to be called, the Executive Committee met in Copenhagen in March 1946, together with other representatives from thirteen countries in order to discuss questions on which decisions could not be deferred. The decisions which were reached are set out in full in the report of the Executive Committee and require the formal approval of this General Assembly, though it has been necessary to take action on many of the decisions. The Union has assumed the responsibility, through Commission 27, for the naming of variable stars and for the publication of name-lists, and for the publication every five years of the *Catalogue and Ephemerides of Variable Stars*. The offer of the Academy of Sciences of the U.S.S.R. and of the Sternberg Astronomical Institute to prepare the name-lists and to prepare and publish, under the auspices of the Union, both the Catalogue and Ephemerides was gratefully accepted.

Arrangements for the organization of the work on minor planets have been satisfactorily made. The Union is much indebted to M. Delporte and to Prof. Brouwer for the detailed planning of the work, in accordance with the general decisions of the Executive Committee. A centre of information has been established at the Cincinnati Observatory,

under the direction of Prof. Paul Herget; the minor planet circulars issued from Cincinnati give announcements of new discoveries, observed positions of minor planets, computed orbits and other relevant information. This service is one of great value and the Union is very much indebted to Prof. Herget for the efficient way in which the centre is conducted, without any grant from the funds of the Union.

At the meeting in Copenhagen a new standing commission was appointed, under the presidency of Prof. Stratton, for facilitating the exchange of astronomers. The Commission has already proved to meet a real need; a wide and useful field of work lies before it, which cannot fail to assist in promoting international understanding and thus to serve the cause of peace.

The question of the establishment of an international observatory, suggested independently by the Polish delegation and by Prof. Harlow Shapley, was also discussed at Copenhagen. The project was strongly supported in principle and Prof. Shapley undertook to interest U.N.E.S.C.O. in it. A new standing commission, under the Presidency of Prof. Shapley, has been formed by the Executive Committee to deal with this project and to formulate plans in greater detail. The matter has been referred to U.N.E.S.C.O. and has received wide support as a means of promoting good will among scientists the world over. Though U.N.E.S.C.O. has not been able to give the proposal the highest priority, the establishment of an international observatory not being a matter of vital urgency, it stands high on the list of U.N.E.S.C.O. priorities.

The International Council of Scientific Unions was formerly the parent and controlling body of the various international scientific unions. But as the Unions became well organized and reached maturity, they found the need to develop along individual lines, in the way that seemed best to meet their requirements. They became free from the control of the International Council. The Council, under the able guidance of Prof. Stratton, has found a new field of usefulness as a co-ordinating body. Thus, for instance, there are many borderline subjects in science which concern two or more Unions. The establishment of Joint Commissions to deal with such subjects, on which the Unions concerned shall each be represented, is a useful function of the International Council. The International Astronomical Union and the International Union for Geodesy and Geophysics saw the advantage of such Joint Commissions many years ago and, under their own auspices, formed Joint Commissions on Time, on Longitudes, and on Latitude Variation. The International Council has recently formed a Joint Commission on the Ionosphere, to which each of the Unions of Astronomy, Geodesy and Geophysics, Radio Science, and Physics nominates four members.

The International Council forms also a co-ordinating body for discussions with U.N.E.S.C.O. on matters concerning individual Unions. As the result of discussions between the International Council and U.N.E.S.C.O. it has been agreed that U.N.E.S.C.O. shall assume the financial responsibility for international scientific organizations which are of a permanent and substantial nature. The Bureau de l'Heure and the Central Bureau of the International Latitude Service have been accepted by U.N.E.S.C.O. as coming into this category. These Bureaus were formerly supported jointly by the Unions of Astronomy and of Geodesy and Geophysics. U.N.E.S.C.O. now makes grants, through the two Unions, to these two Bureaus, thereby relieving the budget of the two Unions. The Unions retain full control of the scientific work of these Bureaus. U.N.E.S.C.O. has also made grants to our Union for publications, for the Commission on the Exchange of Astronomers, and towards the travelling expenses of Presidents of Commissions attending this General Assembly. Particularly valuable has been a block grant towards the travelling expenses of a number of younger astronomers from war-damaged countries. There is naturally a general tendency for the official delegates to a General Assembly from the various countries adhering to the Union to be selected from the senior astronomers and from those holding official positions. The younger astronomers are often not able to defray the expenses of coming to a General Assembly, though it will be agreed, I think, that it must be a great stimulus for a young astronomer to have the opportunity of meeting astronomers from all parts of the world. I am very glad to welcome here

the young astronomers, whose attendance has been made possible by the grant from U.N.E.S.C.O.

U.N.E.S.C.O. has appointed a Scientific Liaison Officer, M. Establier, through whom matters affecting the Unions can be discussed with U.N.E.S.C.O.

The Union appoints two representatives to the Executive Committee of the International Council. Because of the increased importance of the Council in relation to the Union, it was decided by the Executive Committee at Copenhagen, as a matter of principle, that in future the President and General Secretary should represent the Union but that, if either of them was unable to attend a meeting of the Council, he should designate another member of the Union to take his place. The representatives of the Union to the International Council are appointed by the General Assembly, the Executive Committee will submit nominations in accordance with this decision at the final General Assembly.

Besides delegates from most of the countries adhering to the Union there are present also at this General Assembly, by invitation, some astronomers from Germany and Austria. I extend a cordial greeting to them and particularly to Prof. Kopff, who, I am glad to say, has sufficiently recovered from a serious illness to be able to be present. We look forward to the renewal of collaboration with German and Austrian colleagues.

The President next invited Miss Kluyver, and Messrs Kourganoff, Minnaert and Swings as recorders and interpreters for the meeting. He next formally moved the adoption of the report of the Executive Committee.* The adoption of this report implies the approval by the General Assembly of the decisions made by the Executive Committee at the meeting in Copenhagen.

It was accepted without alterations.

The following astronomers were then nominated by the official delegates of their respective countries to act as members of the Finance Committee:

Argentine	Mr S. MANGARIELLO
Australia	Dr R. v. d. R. WOOLLEY
Belgium	Prof. J. F. COX
Canada	Dr C. S. BEALS
China	Mr TCHENG MAO LIN
Czechoslovakia	Dr V. V. HEINRICH
Denmark	Miss J. M. VINTER HANSEN
Egypt	Dr M. R. MADWAR
Eire	Prof. H. A. BRÜCK
Finland	Prof. G. JÄRNEFELT
France	Dr A. COUDER
Great Britain	Mr D. H. SADLER
Greece	Prof. S. PLAKIDIS
Hungary	Dr L. DEZSÖ
Italy	Prof. F. ZAGAR
Netherlands	Prof. H. ZANSTRA
Norway	Mr L. OWREN
Poland	Prof. E. RYBKA
Portugal	Dr G. S. DA COSTA LOBO
South Africa	Dr W. H. VAN DEN BOS
Spain	Dr R. CARRASCO
Sweden	Dr Y. ÖHMAN
Switzerland	Prof. M. SCHÜRER
U.S.A.	Prof. J. J. NASSAU
U.S.S.R.	Prof. E. K. KHARADZE†
Vatican City State	Dr J. JUNKES

The President then nominated Dr Beals to act as chairman of the Finance Committee.

* This report may be found on pp. 27–52 of the present volume.

† Nominated August 12.

It was announced that the Executive Committee had appointed a committee on the personnel of the standing commissions consisting of Prof. Struve (chairman) and Messrs P. Couderc, Dziewulski, Greaves, J. Jackson, Lindblad, Mangariello, Mikhailov,* Minnaert, Nechvíle,† Pearce, Silva, Strömgren, Swings, Tinoco, Waldmeier and Woolley.

The President remarked that, although according to the by-laws of the Union chairmen of commissions are re-eligible, the Executive Committee took the view that it was not desirable in general that presidents of commissions serve during more than two periods. It should, however, be possible to make exceptions to this rule, hence no change of by-laws was proposed.

The President reported that four presidents of commissions were unable to attend the General Assembly. The General Secretary then announced that the Executive Committee had nominated Dr Bourgeois to act as president of Commission 5 for the time of the meeting, and similarly Dr Watts for Commission 8, Prof. Oort for Commission 32 and Prof. Milne for Commission 35.

The General Secretary read a telegram from Prof. Lundmark, expressing his good wishes for the meeting.

The following motions submitted by National Committees of Astronomy and by the Executive Committee were then presented for discussion:

(*a*) That Statute IV, 9 shall be replaced by the following: There shall be eight categories of membership of the Union, numbered 1 to 8. Each adhering country shall pay annually a number of units of subscription equal to the number of its category of membership. A country offering to adhere to the Union shall specify in which category it proposes to be classed. The offer to adhere may be refused by the Executive Committee if the proposed category is judged to be manifestly inadequate. In each country the organization adhering to the Union shall be responsible for the payment of the contribution.

That Statutes III, 5 and 6 shall be replaced by the following:

5. On scientific matters, each delegate present shall have one vote. In questions of administrative or of mixed administrative and scientific character, not involving questions of finance, voting shall be by countries, each country having one vote, with the provision that its subscription shall have been paid up to the end of the year preceding the voting.

In questions involving finance, voting shall be by countries, with the same provision as for administrative questions. The number of votes for each country shall be one greater than the number of its category of membership, as defined in article IV, 9.

6. No delegate shall represent more than two countries. An adhering country not represented by a delegate may forward by post its vote on any specific question of the agenda. (Great Britain.)

(*b*) Que l'Union accorde un appui financier à la Bibliographie Mensuelle de l'Astronomie. (France.)

(*c*) Que l'Union entreprenne des démarches auprès de la Commission Economique Interalliée de Berlin pour que les recherches soient continuées en vue de retrouver le télescope Zeiss, de un mètre d'ouverture de l'Observatoire Royal de Belgique, réquisitionné par l'armée allemande en juin 1940. (Belgique.)

(*d*) Que l'U.A.I. organise la radiodiffusion des nouvelles astronomiques scientifiques. (Pologne.)

(*e*) That a Commission be created to revise the structure of the standing commissions of the Union, so that by 1951 plans may be proposed for a new and more effective organization of the standing commissions. (U.S.A.)

(*f*) That the first paragraph of By-Law I, 1, which now reads:

The Union shall be composed of three classes of members: (*a*) all the members of the National Committees of Astronomy of countries adhering to the Union, (*b*) members nominated

* At Prof. Mikhailov's suggestion Dr Ambartsumian later took his place on this committee.

† As Dr Nechvíle did not attend the Assembly, he was later replaced by Dr Link.

by adhering organizations or by National Committees, and (*c*) all the members of the standing committees of the Union.

be changed as follows:

The Union shall be composed of two classes of members: (*a*) all the members of the standing committees of the Union, and (*b*) members nominated by adhering organizations or by National Committees. (Executive Committee.)

(*g*) The International Union of Radio-Science draws the attention of the I.A.U. to the importance of precise measures of the velocity of transmission of long waves, and requests the astronomical observatories to co-operate with the radio-technicians, in order to organize common experiments of the highest possible precision. In particular, it would be desirable to organize experiments on either side of the Atlantic, which would permit measuring differences between the times of transmission in the two directions.

(*h*) Que l'Union se charge de donner une définition plus exacte de l'unité de temps. (Bureau National, Scientifique et Permanent des Poids et Mesures, Paris.)

(*i*) Que l'U.A.I. considère de nouveau la résolution prise au congrès de 1928 sur la désignation du temps civil de Greenwich, donne à cette résolution une rédaction plus nette, et lui donne la publicité nécessaire pour la faire admettre universellement. (Comité Exécutif.)

(*j*) That the I.A.U. recommend that an abstract in English or French be attached to all scientific astronomical publications. (Executive Committee.)

Speaking for the British delegation the President commented on resolution (*a*) proposed by the British National Committee. The change in the statutes was intended to enable countries with a large population but with relatively few astronomers, and similarly countries that had been seriously impoverished by the war, to join the Union on a more reasonable financial basis than was possible under the present statutes.

Prof. Struve moved the acceptance of the resolution, which was then carried unanimously.

The President proposed to refer (*b*) to Commission 5. This being accepted he invited one of the Belgian astronomers to speak on the resolution (*c*) proposed by the Belgian National Committee of Astronomy. Dr Moreau explained that during a visit to Germany in the autumn of 1947 in order to locate the instruments which were taken away from the Uccle Observatory by the German occupation forces, he had recovered the Uccle meridian circle, which had been installed at the Leipzig Observatory. No trace, so far, had been found of the 40-inch mirror. He thought that action by the Union with the Interallied Economic Council in Berlin might be of help in this matter. The President in expressing the immense regret that all members of the Union must feel concerning the loss caused to the Uccle Observatory, assured the Belgian Delegation that the Executive Committee would take action in the matter.

With regard to (*d*) the President remarked that this is a very difficult thing to realize in practice. Asked for comments Dr Rybka explained that a radio distribution of astronomical discoveries would serve a useful purpose. The General Secretary said that the Union's Telegram Bureau in Copenhagen takes care of the more urgent astronomical news. The President was of the opinion that the Union could take no action on this proposal; he suggested, however, that whenever this seemed desirable, astronomers make endeavours to have discoveries distributed by the radio stations in their own countries.

The next resolutions on the agenda were not received in time to be circulated with the agenda four months before the meeting. Consent of at least half of the countries represented was required before these could be considered. As nobody opposed the proposal to proceed with these discussions, the further resolutions were then considered.

The President remarked that (*e*) involved many technical discussions. His proposal to leave this in the hands of the Executive Committee, which appears to be the natural body to deal with this matter, met with no objection.

(*f*) The President said that each country should have full freedom to appoint a National Committee in the way it thinks best. The result is that some countries have very small

National Committees of Astronomy, others very large ones. In order not to increase unduly the membership of the Union it was proposed that members of National Committees be no longer automatically members of the Union. But the National Committees retain the power to nominate members of the Union. The resolution was accepted without discussion.

The President announced that the Executive Committee proposed to refer resolution (*g*) to Commissions 18 and 31 for further consideration, (*h*) to Commissions 4 and 31, and (*i*) to Commission 4.

A vivid discussion then developed around the recommendation (*j*), proposed by the Executive Committee. Shapley considered that the resolution would be untimely; if it were insisted upon he would propose to add German and Russian, but he would prefer to drop it altogether. Minnaert proposed to add Esperanto. Milne desired to omit the specifications English or French. Answering Shapley's comments the President said that it had not at all been intended to be discriminatory; the only purpose of the resolution was to enable astronomers all over the world to learn something of the work of their colleagues. Jackson then proposed to change the wording of the resolution, so that it would express satisfaction over what is already being done in this direction and would encourage further extension of this practice. It was decided that the Executive Committee should reformulate the resolution in this sense, and bring the amended resolution before a subsequent General Assembly.

After the General Secretary had announced that Dr Lyot had installed his new monochromatic filter at the Federal Observatory and that all members interested were invited to observe the Sun through this filter, the President adjourned the General Assembly.

Meeting on August 18, 1948, 10.30, in the Eidgenössische Technische Hochschule

Opening the Assembly the President announced that replies had been received from Miss Eddington, Mrs van Rhijn and Messrs Carnera and Russell to the messages sent after the General Assembly of August 11.

He next announced the recommendations which the Executive Committee wished to make in order to fill the vacancies in this Committee arising because Dr Adams, Prof. Mikhailov, the President himself and the General Secretary would retire, according to the By-Laws, at the end of this meeting. Profs. Ambartsumian and Struve were proposed as new Vice-Presidents for the next two terms, and Prof. Strömgren as new General Secretary.

The Executive Committee proposed to elect Prof. Lindblad as President for the following three years.

In the absence of Dr Beals, who had presided over the Finance Committee, the following report of this Committee was presented by its vice-chairman Dr Sadler:

In accordance with the Statutes (Section IV, no. 8) the Finance Committee presents separate reports on the accounts for the years 1938–47 and on the estimates for 1948–51. The following report, prepared by a sub-commission, has been unanimously adopted by the full committee:

We have examined the account of Income and Expenditure for the years 1938 to 1947 in conjunction with the Auditor's certificate and with the books and vouchers made available to us; we are satisfied that they represent a true account of the operations of the Union during that period.

The circumstances have necessarily been difficult and we would wish to record our appreciation of the manner in which the General Secretary has handled the accounts of the Union; he has afforded us all facilities.

For the first time, the accounts have been audited professionally; this has greatly simplified our work. It would seem to us that the activities of the Union would be more

readily seen if a brief analysis of income and expenditure could be appended to the accounts.

We note that there is a formidable list of countries in arrear with their subscriptions, some for many years; with the introduction of the new rate of subscription, it is desirable that a fresh start should be made and it is hoped that the countries concerned will make every effort to pay off these arrears.

(*Signed*) J. J. NASSAU
Y. ÖHMAN
D. H. SADLER

The complete Committee has had before it a list of applications for grants provisionally approved by the Executive Committee and estimates of income from various sources. There are two difficulties in arriving at a firm estimate of income: The newly adopted method for determining the number of units of subscription makes the total number of units available to some extent uncertain; and the assistance that may be expected from U.N.E.S.C.O. cannot be accurately assessed. The grants provisionally approved were estimated to require an annual sum of about 13,000 dollars (40,000 gold francs) in addition to the minimum reasonably expected to be made available from U.N.E.S.C.O. This can be provided by 80 units of 163.30 dollars (500 gold francs) and the Committee therefore unanimously accepted the suggestion of the Executive Committee that the unit of the subscription should be increased to 500 gold francs, which is the maximum permissible under the Statutes.

The Finance Committee proposes to the General Assembly:

1. That the following grants be made during the period 1948–51:

(*a*) ANNUAL GRANTS

		Dollars	*Gold Francs*
Commission	5 (Bibliographie mensuelle)	163	500
,,	6 (Telegram Bureau)	392	1,200
,,	10 (Cartes héliographiques de la photosphère) ...	327	1,000
,,	11 (Cartes synoptiques)	882	2,700
,,	19 (Central Latitude Bureau)	980	3,000
,,	20 (Minor Planet Centre at Cincinnati)	980	3,000
,,	27 (Name list of variable stars)	261	800
,,	27 (Ephemerides of eclipsing binaries)	327	1,000
,,	31 (Bureau de l'Heure)	4,409	13,500
,,	38 (Exchange of Astronomers)	3,919	12,000
Bureau of the Union		3,266	10,000
		15,906	48,700

(*b*) SPECIAL GRANTS (once only)

	Dollars	*Gold Francs*
Commission 12 (Solar spectrum tables)	1,960	6,000
,, 18 (Publication of longitude results 1933) ...	816	2,500
,, 19 (Publication of latitude results to the end of 1948	2,613	8,000
,, 19 (Expenses of moving the central bureau to Turin)	327	1,000
,, 23 (Carte du Ciel)	6,859	21,000
,, 24 (Publication of 3rd edition of the Parallax Catalogue)	1,633	5,000
,, 27 (Charts of variable stars in the Southern Hemisphere)	261	800
,, 27 (Translation and printing of introduction to *Catalogue and Ephemerides...*)	261	800
Executive Committee—grant towards expenses of joint symposium of I.A.U. with the Union of Theoretical and Applied Mechanics	3,266	10,000
	17,996	55,100

2. That until the next meeting the unit of subscription should be 500 gold francs.

(*Signed*) C. S. BEALS
President

(*Signed*) D. H. SADLER
Vice-Chairman of the Finance Committee

The adoption of the report and the resolutions contained in it was moved by Dr Sadler; it was seconded by Dr Shapley, and carried without discussion.

The President said that among the resolutions proposed by the Executive Committee there was one implying a change of By-Laws. In order to promote the continuity in the Union affairs also at the time of a change of General Secretary, when both President and General Secretary retire at the same time, it was proposed that the retiring President and General Secretary remain members of the Executive Committee in a consultative capacity. This resolution would require at least two-thirds of the votes of the countries present. He proposed that this change of By-Laws be discussed at the present Assembly though it had not figured on the official agenda. As none of the countries objected, the resolution itself was put before the Assembly and carried without any opposing vote.

The other resolutions and recommendations proposed by the Executive Committee and by the various standing commissions which had been distributed to those present (see pp. 59–70) were then read.

The President said that as all resolutions had been amply discussed in the commissions concerned, he would move their adoption *en bloc*. The motion was carried without objection. The meeting was then adjourned to 14.30.

Meeting on August 18, 1948, 14.30, in the Eidgenössische Technische Hochschule

The President announced that the resolutions of Commission 15 had become available too late to be read at the morning's meeting. These resolutions were now read and agreed to.

The President said that the next business of the Assembly was to elect the new President. He moved the election to this office of Prof. Lindblad, which was carried by acclamation. Following the proposals made in the morning's Assembly by the Executive Committee Profs. Ambartsumian and Struve were then elected as Vice-Presidents, and Prof. B. Strömgren as General Secretary.

The next item was the election of representatives of the Union on the Executive Committee of the International Council of Scientific Unions. The President said that, on account of the much more intimate relation of the affairs of the Union with the International Council which had developed as a consequence of the interest U.N.E.S.C.O. is taking in the various Unions (the International Council being the intermediary between the Unions and U.N.E.S.C.O.), it was desirable that the Union be represented on the International Council by its new President and General Secretary, or, in case either of these is unable to attend a meeting of the Council, by another member of the Union designated by him. The proposal was accepted without objection.

At the President's request the General Secretary then read the list of the members appointed by the Executive Committee to represent the Union in various mixed commissions. A new joint commission on spectroscopy was proposed, containing representatives of the Astronomical Union and of the Union of Pure and Applied Physics. This will be a working commission, its first field of work will be the analysis of atomic and molecular spectral terms (including hyperfine structure). The joint committees on Time, Longitude and Latitude are being dropped, because it had been found more practical to include some geodesists in the corresponding ordinary commissions of the Astronomical Union, and vice versa. The representatives in the various mixed commissions are indicated on p. 527.

In putting the list of members of various standing commissions before the meeting the President said that he wanted in the first place to thank Prof. Struve, the chairman of the Nominating Committee, for having so ably directed this Committee's arduous task of composing the present list. The list had also been considered and slightly amended by the Executive Committee. No doubt there might be some omissions. But these could easily be amended by subsequent co-option. He called attention to the following changes in the list of commissions:

Commission 7, on Celestial Mechanics, had been revived, as several workers in this field found no place in the existing commissions. Three new commissions were proposed, No. 40 on Radar Methods, No. 41 on History of Astronomy, and No. 42 on Photometric Double Stars.

Prof. Mitchell moved the adoption of the list of members as circulated to all present. The motion was seconded by Prof. H. H. Plaskett, and carried.

The place of the next General Assembly, to be held in 1951, was then discussed. The President stated that an invitation had been received from the Academy of Sciences of the U.S.S.R. to hold a meeting in Leningrad, while another invitation had been received from Dr Bowen for a meeting in Pasadena, in connection with the 200-inch telescope. A provisional invitation had already been extended by Prof. Mikhailov in 1946. The President invited Professor Mikhailov to address the Assembly. A translation of Prof. Mikhailov's speech follows:

I have the honour to transmit the invitation of the Academy of Sciences of the U.S.S.R. to hold the next General Assembly of the I.A.U. in Leningrad and Pulkovo. It is well known that the famous Pulkovo Observatory, which was called the astronomical capital of the world, was totally destroyed by the German invaders during the Second World War. We are rebuilding it on its old historical place, and hope that in 1951 it will have been erected in its former size. It seems proper that the inauguration of this observatory should be made in presence of the most authoritative scientific body—the I.A.U.

The President explained that the Executive Committee had not yet found it possible to take a definite decision in this matter, but that it hoped to be able to decide within a few months.

He then remarked how greatly indebted the Union was to the hosts for the splendid reception in Zürich. In particular thanks were due to Prof. and Mrs Waldmeier for the manner in which the meeting and the social events around it had been arranged. The President called on Prof. Minnaert to address the hosts; he would ask Miss Harwood to speak more especially on behalf of the ladies.

PROF. MINNAERT:

MES CHERS COLLÈGUES,

Nous voici donc réunis pour la dernière fois dans cette même salle où nous nous sommes assemblés il y a huit jours, lors de l'ouverture du 7e Congrès de l'U.A.I.

Après avoir été séparés pendant 10 ans, après avoir lutté et souffert, nous sommes venus de tous les côtés du monde pour nous retrouver ici, nous nous sommes regardés dans les yeux d'un regard qui disait plus que ce que les paroles pouvaient exprimer; et nous avons fait ensemble du bon travail. Dès le premier jour, la cordialité et la bonne entente ont régné dans toutes nos assemblées; nous nous sommes donné bien de la peine, et cependant, à la fin de ce congrès, nous nous sentons rafraîchis et rajeunis. L'air même qui nous entoure semble nous avoir stimulés, c'est comme s'il y avait ici un bon génie, un *genius loci* particulier, qui rend heureux ceux qui vivent et travaillent sous son inspiration.

Eh bien, mes chers collègues, nous savons tous que ce bon esprit qui nous a entourés ici, c'est *l'hospitalité de la Suisse*, l'hospitalité du pays même et l'hospitalité de ses habitants. C'est cette hospitalité que nous avons sentie dès notre arrivée dans la merveilleuse gare centrale de Zürich. Nous avons fait connaissance avec cette ville; nous avons admiré la grande allure de ses avenues, nous nous sommes perdus dans ses anciens quartiers si pittoresques, et nous avons commencé à comprendre la synthèse qui s'est opérée dans ce pays entre la bonne tradition et le progrès moderne. Pour nos assemblées, nous avons pu faire usage du bâtiment de la Technische Hochschule, qui domine la ville entière du haut de sa terrasse. Mais c'est au bord du lac que nous avons apprécié entièrement la situation magnifique de la ville, quand nous l'avons vu s'étendre d'un côté le long de la Limmatt impétueuse, de l'autre côté sur les collines de part et d'autre du lac, tandis que dans le lointain surgissaient les cîmes neigeuses de la haute-montagne. Le soir, les mille lumières dispersées de tous côtés, réflétées dans le lac, donnaient au paysage un aspect de féerie. Cet entourage est un des imponderabilia qui sans aucun doute a contribué puissamment à nous rendre ce congrès inoubliable.

Vous souvenez-vous encore de cette première réception, le mardi soir, quand nous nous sommes rencontrés dans le vestibule du Kongresshaus? Il était presque impossible de rassembler les participants dans la salle de réception, tant nous étions émus et enthousiastes en retrouvant nos amis qui entraient l'un après l'autre dans le vestibule, tant nous avions à nous raconter.

Ensuite nous avons eu le plaisir immense de collaborer pour l'étude d'une foule de problèmes scientifiques avec les collègues dont tant de fois nous avions lu les savants mémoires, et qui maintenant se révélaient à nous, très humains somme toute, chacun avec son caractère particulier. Un tel congrès a nécessairement un caractère mixte: on y discute les dernières découvertes scientifiques, mais aussi on y traite de l'organisation même de notre travail. L'une partie est aussi indispensable que l'autre, personnellement je crois que la proportion relative a été réglée d'une manière très heureuse. Les différents colloques auxquels nous avons pu assister ont été d'une grande importance pour comparer et élucider les résultats des recherches. L'exposition des instruments et des documents scientifiques était extrêmement intéressante et très réussie. Nous avons pu jouir de visites répétées à ce bel Observatoire de Zürich, qui, lui aussi, est basé sur la tradition des longues années d'observations fidèles, mais qui s'est rajeuni et renouvelé et prend une place importante dans le développement moderne de la science solaire. Les démonstrations de la chromosphère et des protubérances, faites à cet observatoire par notre infatigable collègue, Monsieur le Dr B. Lyot, nous ont révélé d'une manière inoubliable la beauté des phénomènes solaires.

Mais nos hôtes n'ont pas seulement mis à notre disposition un entourage admirable pour le travail, ils ont encore songé au repos, nécessaire de temps en temps. Ils nous ont prodigué tantôt des rafraîchissements, tantôt un lunch, ou un Imbiss, ou même un banquet. La musique nous a fait entendre les harmonies dont l'homme de science sent le besoin profond. Des excursions très agréables nous ont donné le temps de prendre haleine et nous ont montré quelques-unes des beautés de la Suisse, ainsi que son développe-

ment industriel moderne. (Je relève très particulièrement l'excursion des dames à la fabrique de chocolat!) La grande excursion de dimanche dernier a certainement été le point culminant; c'est alors que la Suisse nous a réellement ouvert son cœur, et il était bien intéressant d'entendre le soir les impressions des différents collègues qui avaient pris part à l'une ou à l'autre des trois excursions, chacun étant d'avis que l'excursion choisie par lui avait certainement été la plus belle des trois. Elles nous ont toutes conduit vers le Lac des Quatre Cantons, où s'est fondée l'unité de la Suisse, et où s'est ressuscitée dans notre mémoire la légende inoubliable de Wilhelm Tell, qui nous fait encore tressaillir d'émotion, tant est beau l'idéal de la liberté à travers les siècles.

La Suisse a même pris soin de nous procurer un état du ciel parfaitement adapté au but de notre séjour. En nous accueillant par des nuages et même de la pluie, elle a voulu nous recommander de ne pas perdre de temps et de nous mettre au travail. D'autre part elle nous a récompensé en nous octroyant pour le dimanche de l'excursion un soleil éblouissant et un ciel bleu, dont l'effet était encore plus puissant par le contraste avec les jours précédents.

Enfin, le banquet de clôture, hier soir, a terminé tout ce beau programme par une festivité inoubliable. Après les rencontres fréquentes des derniers jours, nous avions vraiment l'impression d'être à un grand diner de famille, avec le charme un peu mélancholique qu'ont toujours les dernières conversations avant le départ.

L'hospitalité dont nous avons joui ici, quoique due au pays tout entier, a été exercée tout particulièrement par les comités et par les personnes qui nous ont entourés de leurs soins. Je nomme en premier lieu le Comité d'Honneur, qui a bien voulu nous faire souhaiter la bienvenue par un de ses membres; le Comité d'Organisation, qui a si bien rédigé le programme; le Comité des Dames, qui a prodigué l'hospitalité la plus gracieuse (au sens litéral du mot); le Comité Suisse d'Astronomie, qui nous a accueillis par un lunch que nous avons su apprécier. Mais l'âme de toute cette organisation a certainement été le Dr Waldmeier, secondé par Mme Waldmeier, qui a su inspirer tous ces Comités d'un grand enthousiasme et coordonner leurs activités. Avec un personnel restreint il est parvenu à une organisation réellement parfaite et qui fait honneur à la Suisse. Il a fait un travail dont il peut être fier et qui a été de grande utilité pour le développement de l'astronomie internationale. Nous le remercions chaleureusement de toute la peine qu'il s'est donnée et nous lui en témoignons notre profonde gratitude. Nous remercions en même temps tous ceux qui l'ont assisté au bureau d'information, à l'observatoire et en maintes autres occasions.

Permettez-moi de conclure par une petite réflexion personnelle. Lorsque nous sommes arrivés ici, nous avons reçu un bulletin donnant 'Les Faits de la Semaine' à Zürich. On y trouvait même l'horoscope astrologique, qui prédisait pour la période du 24 juillet au 23 août: 'Une semaine tranquille — rien d'important'. Et bien, j'avais toujours été enclin à croire un peu à l'astrologie....Mais maintenant je suis bien convaincu de sa fausseté. Comment donc: 'une semaine tranquille'! Mais qu'en pensez-vous, mesdames et messieurs? Et qu'en pensez-vous, monsieur le secrétaire général, mon cher Oort? Et 'rien d'important'? Mais n'est-il pas important que nous avons pu accomplir ce que tous les diplomates du monde ont vainement cherché d'atteindre jusqu'ici? Des représentants de plus de 25 nationalités réunis fraternellement, inclus l'Amérique et la Russie—et le droit de véto n'était pas même nécessaire puisque tout le monde était d'accord!

Ainsi donc, nous partons, reconnaissants et heureux, en regrettant de devoir nous séparer, mais en nous réjouissant déjà à l'idée de nous retrouver dans trois ans, à une réunion qui peut-être, par les circonstances où elle aura lieu, sera un véritable climax dans la série des congrès astronomiques.

Au revoir dans trois ans!

MISS HARWOOD:

It would seem that this fine, substantial building of the Technische Hochschule, with its comfortable conference and assembly rooms, would be all that is necessary for a successful meeting of the International Astronomical Union. And that this beautiful city

of Zürich with its ever varying and even more lovely surroundings would alone afford sufficient recreation. But a Committee of Ladies has handled our mail, given us information of all kinds, and has attended to every possible need, including mid-morning refreshment, and the details of every extra-curricular activity. This Committee has also entertained the visiting ladies by personally conducted tours of the museums and other places of interest, both near and far.

Be it resolved, therefore, that the I.A.U. extend an expression of our heart-felt gratitude to Mrs Dr Waldmeier, Miss Dr Müller, and Mrs E. Lindt and to each and all of their assistants.

SIR HAROLD SPENCER JONES then addressed the meeting as follows:

All who have attended this General Assembly will have appreciated the excellent arrangements that have been made for the meeting and the generous hospitality that has been provided for us. The preparations for a meeting such as this, including the arrangements for hotel accommodation, for excursions and other functions necessarily entail a great deal of work for the Local Committee. It has functioned most efficiently under the chairmanship of Prof. Waldmeier. To all the members and to him in particular we express our grateful thanks.

Two of the Vice-Presidents of the Union now retire, Dr W. S. Adams and Dr A. A. Mikhailov. Dr Adams was unfortunately not able to come to this meeting and in his stead Prof. Stebbins has acted as Vice-President, as he did also at the meeting of the Executive Committee in Copenhagen in 1946. But Dr Adams has been available for consultation at all times during the past 10 years and his advice has been of great value in the many special post-war problems that have arisen. I propose a vote of thanks to Dr Adams, Dr Mikhailov and also to Prof. Stebbins for their valuable services.

The International Astronomical Union has been well served by the three General Secretaries whom it has had in the course of its 26 years of existence—Prof. Alfred Fowler, Prof. Stratton, and Prof. Oort. For half of this time, the last 13 years, this important office has been held by Prof. Oort. To-day he hands over his charge to the safekeeping of Prof. Bengt Strömgren and the occasion should not pass without a tribute to the devoted service which he has given to the Union throughout these years. As President of the Union for the past few years I have worked in close association with Prof. Oort and I know how heavy is the work of the General Secretary. Much of the time which Prof. Oort could otherwise have given to his own research has necessarily been occupied with the affairs of the Union. Some considerable self-denial is necessarily involved in the acceptance of this office; but there is no doubt that the advancement of our science in the field of international co-operation is greatly dependent upon having a capable and efficient General Secretary of the Union. To Prof. Oort's unwearied labours, to his wise handling of the affairs of the Union, and to his sound judgement the Union owes much. It is fitting that we should express our gratitude to Prof. Oort for his services as General Secretary; I have therefore much pleasure in proposing from the Chair a warm vote of thanks.

This was received with loud applause, everybody standing.

The work of this Assembly has been greatly helped by the services of Miss Kluyver. As private secretary to Prof. Oort, Miss Kluyver has had much to do with the affairs of the Union and this has been a great asset. The secretarial work in connection with a meeting such as this is very heavy; reports, recommendations, and lists of members of Commissions have to be typed and duplicated at short notice and there is much other burdensome detail. Miss Kluyver has not only looked after this necessary secretarial work, but she has always been ready to answer inquiries, to provide information and to assist the members in every possible way. I propose that we express by acclamation our appreciation of Miss Kluyver's services.

The new members of the Executive Committee then took their places, with Prof. Lindblad in the Chair.

PROF. LINDBLAD:

LADIES AND GENTLEMEN,

I thank the members of the Union for the great honour which they have bestowed upon me by electing me President of the Union for the next three-year period.

After this wonderfully successful meeting here in Zürich our expressions of deep gratitude have gone to those who have had the burden of arranging this meeting.

There is one person, however, to whom it remains for me to give our warm and sincere thanks, namely our President himself, the Astronomer Royal, Sir Harold Spencer Jones. You, Sir Harold, took over the presidency at a critical time in the history of the Union, and you have led the proceedings at two meetings of the Union, the small but very important reorganizing meeting at Copenhagen in 1946 and now this great General Assembly of the Union here. We have all deeply appreciated and admired the eminent way in which you have presided on these occasions. Your great authority and your genial and kind personality have made us look up to you with the greatest confidence. Your contribution as President in the service of the Union is certainly one of the most important in the Union's records, and will always be remembered in grateful memory. On this occasion we can only express to you our grateful feelings by giving you our warmest thanks for what you have done for our Union.

During the past week a considerable part of the world's active astronomers have been assembled here at Zürich. We astronomers think highly of our science, and are devoted to it in a quite particular way. From a philosophical point of view one may ask what drives us in our research and what kindles our enthusiasm for the exploration of the heavens. One may point at the parts of Astronomy which have great and undeniable practical importance. But we know that this is not the answer. There is in reality in this world nothing for us worth while compared to the development, soundness and perfection of the human mind. We know that the science of Astronomy has been, is, and will be one of the sources of health for the human mind. The bird's-eye view of our conditions of life on this Earth which Astronomy gives may scare us with its immensity in time and space, but is also at the same time deeply comforting, even though we still understand so little of the deep mysteries of the Universe.

The peoples of the Earth are still divided among themselves by questions and problems which involve a great number of difficulties and conflicts. There is at least one field where we may all meet without reservation in entire friendliness—in our science of Astronomy. I am sure that this meeting which has just ended has been very successful in the way of personal contacts as well as from a purely scientific point of view, like the other meetings preceding it, and we hope sincerely that our next meeting will carry us further on this way for the growth and development of our old, glorious, and free science of Astronomy.

I hereby declare the General Assembly of the International Astronomical Union closed.

REPORT OF THE EXECUTIVE COMMITTEE, 1938–47

After the interruption caused by the war in international co-operation the desire was felt to organize the Union's affairs anew as soon as possible, and to enable the Union to resume its activities at an early date.

As circumstances did not yet permit a General Assembly to be called, the Executive Committee met at Copenhagen, from March 7 to 13, 1946, together with other representatives from thirteen countries to discuss problems for which decisions were required immediately.

After consultation with the delegates the Executive Committee decided as follows:*

(*a*) *Solar Phenomena*

1. That the annual grant of 2700 gold francs for the Cartes Synoptiques be continued and that an additional annual payment of the same amount be made to make up for the arrears in payment during the war years, in order to assist the Meudon Observatory to bring these publications up to date as far as possible.

2. That a grant be made to Prof. Abetti to cover the cost of publication of the records already prepared for 1935 and 1936, and that the Union cease to subsidize the publication of *Immagini Spettroscopiche* after that date.

3. That no attempt be made to combine the *Quarterly Bulletin* with other publications, the *Bulletin* being a summary publication giving results as early as possible, the other publications necessarily involving a delay in publication.

4. That Dr Fesenkov, Dr Lyot, Dr Menzel and Dr Woolley be nominated to the Joint Commission on the Ionosphere formed by the International Council of Scientific Unions. Each of the Unions of Astronomy, Geodesy and Geophysics, Radio-Science and Physics will nominate four members in this Commission.

5. That the form of the *Quarterly Bulletin* should be modified as follows. The characteristic numbers should be dropped, except only the sunspot number. That the question be referred to Commission 11 of the I.A.U. of adding as soon as can be arranged to the daily records details of coronal phenomena, radio noises of solar origin, and the luminescence of the night sky, and of securing a better index of prominence activity than the present one. That the details of solar eruptions continue to be published as at present, and that the President of Commission 11 arrange for the details of the publication during the transition stages, 1945 onwards.

6. That Commission 11 be also asked to study the question of the prediction of terrestrial phenomena of solar origin and the determination of zones of activity on the Sun's disk. That the Commission also be reminded of the importance of arranging when possible for a continuous cinematographic study of the Sun from stations spaced round the globe.

(*b*) *Variable Stars*

1. That Commission 27 assume responsibility for the Naming of Variable Stars. A sub-committee has been nominated for this purpose.

2. That Commission 27 assume responsibility for the publication every five years of the *Catalogue and Ephemerides of Variable Stars* with intervening annual supplements, as well as for the publication of the third volume of Prager's *Bibliography*.

3. That the offer of the Academy of Sciences of the U.S.S.R. and of the Sternberg Astronomical Institute be accepted to prepare the Name-list and to prepare and publish both the *Catalogue and Ephemerides*, and Prager's third volume, with the afore-mentioned sub-committee of Commission 27 acting in an advisory capacity, the Name-list itself to be published by the I.A.U.

* The decisions had the approval of the General Meeting of Delegates, but are subject to subsequent approval by a regular General Assembly.

4. That an annual grant of 500 gold francs be made to the President of Commission 27 for the publication of this Name-list.

5. That additional bibliographic plans be postponed to the next meeting of the I.A.U. and that the publication of a new check-list be postponed, or incorporated in the five-year Catalogue.

6. That the two payments not yet made to the Cracow Observatory on the agreement of 1938 be now made for work in Poland on variable stars in the years 1946–48 inclusive.

(*c*) *Exchange of Astronomers*

1. That a standing Commission be appointed for facilitating the exchange of astronomers.

2. That the attention of U.N.E.S.C.O. be drawn to the existence of this Commission, as an advisory body to whom U.N.E.S.C.O. could refer questions of the exchange of astronomers.

(*d*) *Fundamental Astronomy and Minor Planets*

1. That the Executive Committee draw the attention of National Committees to the project initiated by Commodore Hellweg and supported by a Commission of the American Astronomical Society to install a number of photographic zenith-tubes in different latitudes and longitudes for the purpose of obtaining better information on latitude variation as well as on the systematic errors of existing systems of proper motion.

2. That an information centre for this project be formed at the Naval Observatory, Washington.

3. That a grant of $3 \times £300$ be made to the Leiden Observatory towards the expense of a second expedition for the measurement of fundamental declinations by means of azimuth observations, subject to the balance of the funds required being obtained.

4. That the computation of ephemerides of known Minor Planets be shared by the Institute of Theoretical Astronomy at Leningrad and by the Rechen-Institut at Heidelberg.

5. That the Berkeley Observatory be approached on the subject of the computation of newly discovered Minor Planets.

6. That the ephemerides computed at Leningrad be published there as suggested, and that the copy for press for the ephemerides and orbits computed at Heidelberg or Berkeley be sent to a centre arranged by the Union, and that these be published by the Union.*

7. That provisions be made for the sending out by the selected centre of circulars of observations.

(*e*) *Latitude Variation*

1. That the annual grant of 2250 gold francs for the Central Bureau be resumed if the Bureau remains in Italy.

2. That a special grant of 4000 gold francs be made towards the publication of the *Latitude Results* 1935–41.

(*f*) *Further Annual Grants*

That the annual grants of 1200 gold francs to the Telegram Bureau, of 7200 gold francs to the Bureau de l'Heure, and of 6000 gold francs to the Bureau of the Union be continued.

(*g*) *International Observatory*

That Dr Shapley be invited to emphasize to the United Nations Educational, Scientific and Cultural Organization (U.N.E.S.C.O.) that this organization envisage the foundation

* The Executive Committee has further voted an annual grant of 2500 gold francs for this purpose to the President of Commission 20.

of one or more International Observing Stations at which astronomers of all countries could be enabled to use instruments that are beyond the possibilities available in most countries. It was emphasized that such an observatory, internationally planned, internationally staffed and internationally operated, would effectively promote good will among scientists the world over, and thus serve the cause of peace.*

(*h*) *Delegates to International Council of Scientific Unions*

That in the future the President and General Secretary represent the Union on this Council, and that, in case either of these is unable to attend a meeting of the Council, he designate another member of the Union to take his place.

The report of a special committee designated to advise the Executive Committee on Bibliography was read at a General Session of Delegates. In this report the desirability was stressed of having two bibliographies: (1) an annual bibliography, such as the *Jahresbericht*, giving fairly extended abstracts, but being published inevitably with a somewhat long delay; (2) a bibliography such as the *Bibliographie Mensuelle*, giving only very short abstracts, but published quickly. Attention was further drawn to the importance of publishing a series of monographs on recent progress in the different branches of astronomy.

The Executive Committee has further voted a new grant of 500 gold francs towards the completion of the *Bibliographie Mensuelle* up to 1948, and a grant of 500 gold francs to the President of Commission 33, to cover part of the expense of the publication under the auspices of the Union of tables prepared by Dr Link for correcting radial velocities for the effect of the Sun's motion.

At the same time the various Standing Committees were composed anew; the new composition is given at the top of the Draft Report of the Commission concerned, the names of members afterwards co-opted under By-Law IV, 15, having been added.

It was also decided that Commission 28, which was formerly called 'Commission on Nebulae and Star Clusters', will in future concern itself with extra-galactic nebulae only, whereas a new Commission, No. 37, Chairman Dr Shapley, on Star Clusters, has been formed. Galactic nebulae will be treated by Commission 34, which is now called: 'Commission on Interstellar Matter and Galactic Nebulae.' Prof. Stratton presides over the new Commission, No. 38, on Exchange of Astronomers.

In 1947 a new Commission, No. 39, on International Observatories, was formed, of which Dr Shapley is President.

The Executive Committee has allotted in each of the years 1939 and 1940 a grant of 2000 gold francs to Dr R. Prager, in order to enable him to finish at the Harvard College Observatory the 'Geschichte und Literatur der veränderlichen Sterne'.

Countries adhering to the Union

Since the last General Assembly Australia, Chili, Eire, Hungary and India have adhered to the Union.

The following is the list of countries adhering to the Union and of the adhering organizations.

Country	Year of Adherence	Adhering Organization
Argentine Republic	1927	Government.
Australia	1939	National Research Council.
Belgium	1920	Académie Royale de Belgique.
Canada	1920	National Research Council, Ottawa.

* The idea of an international observatory was suggested independently by the Polish delegation and by Dr Shapley. It received the unanimous support of the Meeting of Delegates.

Country	Year of Adherence	Adhering Organization
Chili	1947	Observatorio Astronómico de la Universidad de Chile, Santiago de Chile.
China	1935	National Committee of Astronomy, Nanking.
Czechoslovakia ...	1922	Conseil National de Recherches, Prague.
Denmark	1922	Kongelige Danske Videnskabernes Selskab, København.
Egypt	1925	Government.
Eire	1947	Dublin Institute for Advanced Studies.
Finland	1948	National Committee of Astronomy, Helsinki.
France	1920	Académie des Sciences, Paris.
Great Britain ...	1920	Royal Society, London.
Greece	1920	Académie d'Athènes, Athènes.
Hungary	1947	Hungarian Academy of Sciences, Budapest.
India	1946	The National Institute of Sciences of India, New Delhi.
Italy	1921	Consiglio Nazionale delle Ricerche, Roma.
Mexico	1921	National University of Mexico.
Netherlands ...	1922	Koninklijke Nederlandsche Akademie van Wetenschappen, Amsterdam
Norway	1922	Det Norske Videnskaps-Akademi, Oslo.
Poland	1922	Polska Akademia Umiejetności, Cracovie.
Portugal	1924	Government.
Roumania ...	1928	Comitetul National Astronomic.
South Africa ...	1938	The Council for Scientific and Industrial Research, Pretoria.
Spain	1922	Academia de Ciencias Exactas, Madrid.
Sweden	1925	Kungl. Vetenskapsakademien, Stockholm.
Switzerland ...	1923	Schweizerische Naturforschende Gesellschaft, Bern.
United States ...	1920	National Research Council, Washington.
U.S.S.R.	1935	Academy of Sciences of the U.S.S.R., Moscow.
Vatican City State	1932	Pontifica Accademia delle Scienze i Nuovi Lincei, Roma.
Yugoslavia ...	1935	National Committee of Astronomy, Belgrade.

Deceased Members

The Executive Committee regret to record the loss by death of the following members of the Union:

E. M. Antoniadi, Member of Commission 16. Died February 10, 1944.
Dr J. M. Baldwin, Member of Commission 23.
Prof. A. Bemporad, Member of Commissions 23, 25. Died January 11, 1945.
Dr G. Bemporad, Member of Commission 19. Died July 10, 1945.
A. F. Bennett, Member of Commission 25. Died May 14, 1937.
V. R. Berg, Member of Commission 19. Died January 4, 1942.
Prof. Emilio Bianchi, former Vice-President of the Union, Member of Commissions 18, 19, 24, 31. Died September 11, 1941.
Miss M. A. Blagg, Member of Commission 16. Died April 14, 1944.
Dr K. Boda, Member of Commission 20. Died February 25, 1942.
Prof. K. Bohlin, Swedish National Committee. Died May 25, 1939.
Général R. Bourgeois, French National Committee. Died November 10, 1945.
Dr W. Bowie, Member of Commissions 18, m. Died August 28, 1940.
G. Bratu, Member of Commission 23. Died September, 1941.
Prof. G. Bruhat, French National Committee. Died January 1, 1945.
Prof. H. Buisson, Member of Commission 14. Died January 6, 1944.
Miss Dr Annie J. Cannon, Member of Commission 29. Died April 13, 1941.
Mme Dr Ed. Chandon, Member of Commissions 8, 9. Died March 8, 1944.
Dr A. C. D. Crommelin, Member of Commissions 15, 20. Died September 20, 1939.
Prof. H. D. Curtis, Member of Commission 13. Died January 9, 1942.
Prof. Comte F. M. da Costa Lobo, Member of Commissions 13, m. Died April 29, 1945.
E. de la Villemarqué, S.J., Member of Commission 20. Died July 21, 1946.

Dr Félix de Roy, President of Commission 22, Member of Commission 27. Died May 15, 1942.
Dr A. de Sitter, Member of Commission 25. Died September 15, 1944.
Dr H. Deslandres, late Vice-President of the Union; Honorary President of Commission 11. Died January 15, 1948.
Dr N. Dneprovsky, Member of Commissions, 8, 31.
Prof. R. S. Dugan, President of Commission 27. Died August 31, 1940.
Sir Frank W. Dyson, Past President of the Union, Honorary President of Commission 8, Member of Commission 23. Died May 25, 1939.
Prof. G. Eberhard, Member of Commission 25. Died January 3, 1940.
Sir Arthur S. Eddington, President of the Union, Member of Commissions 3, 33, 34, 35, 36. Died November 22, 1944.
Prof. P. Emanuelli, Member of Commission 5. Died July 2, 1946.
Prof. R. Emden, Member of Commission 35. Died October 8, 1940.
Prof. Ch. Fabry, late Vice-President of the Union, Honorary President of Commission 9, Member of Commissions 14, 36. Died December 11, 1945.
Prof. Ph. Fauth, Member of Commission 16. Died January 4, 1941.
Prof. A. Fowler, late General Secretary of the Union, Member of Commission 14. Died June 25, 1940.
Prof. R. Furuhjelm, Member of Commission 23. Died November 15, 1944.
W. F. Gale, Australian National Committee. Died June 1, 1945.
Prof. L. Grabowski, Member of Commission 3. Died October 24, 1941.
H. Grouiller, Member of Commissions 5, 22, 27. Died November 7, 1943.
J. C. Hammond, Member of Commission 20. Died May 12, 1940.
Dr W. E. Harper, Member of Commissions 24, 30. Died June 4, 1940.
A. R. Hinks, Member of Commissions 20, m. Died April 14, 1945.
Prof. K. Hirayama, Member of Commission 20. Died April 8, 1943.
Prof. Shin Hirayama, Member of Commission 33. Died June 2, 1945.
Prof. A. Ivanov, Member of Commission 18. Died September 22, 1939.
Sir James H. Jeans, Member of Commission 35. Died September 16, 1946.
Prof. F. C. Jordan, Member of Commissions 24, 27. Died February 15, 1941.
Lou Kao, Member of Commission 3. Died in 1947.
Dr H. Kimura, Honorary President of Commission 19. Died September 26, 1943.
Prof. H. Kobold, Member of Commission 20. Died June 11, 1942.
Prof. E. Kohlschütter, Member of Commission 18. Died October 18, 1942.
N. V. Komendantov, Member of Commission 20.
Dr J. Krassowski, Member of Commissions 3, 18. Died January 24, 1947.
Dr A. Lambert, Member of Commissions 8, 18, 31. Died August 15, 1944.
E. Loreta, Member of Commission 22. Died February 2, 1945.
K. Lous, Norwegian National Committee.
Prof. H. Ludendorff, Member of Commissions 3, 27. Died June 26, 1941.
Prof. M. Maggini, President of Commission 16, Member of Commission 25. Died May 8, 1941.
Dr W. Chr. Martin, Member of Commission 27. Died June 29, 1945.
Prof. W. J. H. Moll, Member of Commission 9. Died March 10, 1947.
R. M. Motherwell, Canadian National Committee. Died September 30, 1941.
Prof. J. J. A. Muller, Netherlands National Committee. Died June 6, 1946.
Dr K. Müller, Member of Commission 16. Died October 22, 1942.
J. Nangle, Member of Commission 23. Died February 22, 1941.
Prof. P. V. Neugebauer, Member of Commission 5. Died March 3, 1940.
Dr G. N. Neuymin, Member of Commission 20. Died December 17, 1946.
Prof. H. F. Newall, late Vice-President of the Union, Member of Commission 10. Died February 22, 1944.
Prof. T. Niethammer, Member of Commissions 18, 19, 31. Died July 28, 1947.
Prof. C. Parvulesco, Member of Commissions 28, 33.
Prof. E. J. Perepelkin, Member of Commissions 10, 12.

Général G. Perrier, President of Commission 18, Member of Commission 31. Died February 23, 1946.
Rev. T. E. R. Phillips, Member of Commission 16. Died May 13, 1942.
D. B. Pickering, Member of Commission 27. Died June 13, 1946.
Dr J. S. Plaskett, Member of Commissions 9, 29, 30, 34. Died October 17, 1941.
Prof. H. C. Plummer, British National Committee. Died September 30, 1946.
Prof. R. Prager, Member of Commission 27. Died July 21, 1945.
F. F. Rents, Member of Commission 8.
Mme Dr D. Klumpke Roberts, French National Committee. Died October 5, 1942.
Rev. Luis Rodés, S.J., Member of Commissions 10, 11. Died June 7, 1939.
Prof. H. Rosenberg, Member of Commission 25. Died July 26, 1940.
Dr G. Rougier, Member of Commissions 16, 23. Died March 10, 1947.
Prof. R. A. Sampson, Member of Commissions 5, 31. Died November 7, 1939.
Dr Frank Schlesinger, Past President of the Union, Honorary President of Commission 24, Member of Commissions 3, 19, 23, 32. Died July 10, 1943.
Prof. F. Slocum, Member of Commissions 20, 24. Died December 4, 1944.
C. C. Smith, Canadian National Committee. Died July 10, 1940.
Prof. Elis Strömgren, President of Commission 3, Member of Commissions 6, 17, 20, 27. Died April 5, 1947.
Prof. J. Svoboda, Member of Commissions 9, 18, 19, 22. Died May 12, 1941.
Dr M. Tremblot, Member of Commission 25. Died April 19, 1944.
Dr H. van Gent, Member of Commission 27. Died March 29, 1947.
Dr A. van Maanen, Member of Commissions 24, 28, 32, 33. Died January 26, 1946.
Dr A. Wilk, Member of Commission 15. Died February 14, 1940.
E. G. Williams, Member of Commissions 29, 34, 36. Died May 31, 1940.
Prof. C. W. Wirtz, Member of Commission 28. Died February 18, 1939.
Dr J. Woltjer, Jr., Member of Commission 35. Died January 28, 1946.
Dr H. E. Wood, Member of Commissions 6, 13, 20. Died February 28, 1946.
P. J. Yashnov, Member of Commission 5.
Dr M. L. Zimmer, Member of Commissions 8, 18. Died February 5, 1945.

New Members

After the meeting in Stockholm, before the war, the following were co-opted by the various Commissions under By-Law IV, 15:

K. Araki (22), W. Baade (25, 28, 32, 34), J. M. Baldwin (23), F. Becker (32), S. J. Belyawsky (20), T. P. Bhaskaran (23), L. Biermann (35), K. Boda (20), N. Boneff (17), R. B. Bousfield (22), H. Brück (12), S. Chandrasekhar (12, 35), H. B. Curlewis (23), S. S. da Gama (19), G. F. Dodwell (19), G. Eberhard (25), R. Emden (35), Ph. Fauth (16), R. Furuhjelm (23), K. Graff (25, 27), W. Grotrian (13, 29), H. Grouiller (5), P. Guthnick (25, 27, 30), O. Heckmann (33), J. Hellerich (25), C. Hoffmeister (22, 27), J. Kaplan (22), H. Kayser (14), H. Kienle (25, 36), H. Kobold (20), A. Kohlschütter (29, 32, 33), E. Kohlschütter (18), A. Kopff (4, 8, 15, 20), A. Kuwaki (5), H. Ludendorff (3, 27), R. A. McIntosh (22), K. Müller (16), J. Nangle (23), A. L. Narayan (10, 11), P. V. Neugebauer (5), E. J. Öpik (22), R. Prager (27), Lord Rayleigh (22), K. Reinmuth (20, 28), H. Rosenberg (25), E. Schoenberg (34), R. Schorr (8, 20), R. Schumann (19), M. Schwarzschild (35), A. Schwassmann (32), L. Sommer (22), T. E. Sterne (35), G. Stracke (20), P. ten Bruggencate (12), O. Thomas (22), A. Unsöld (11, 12, 29, 36), H. Vogt (35), E. von der Pahlen (33), H. von Klüber (12, 13), K. Walter (27), C. F. Weizsäcker (35), R. Wildt (16), C. W. Wirtz (28), G. Witt (20), W. M. Worssell (17).

After the meeting in Copenhagen the following were co-opted by the various Commissions under the same By-Law:

Akbar Ali (23), J. Ashbrook (27), Miss I. Barney (8), H. Barrell (14), I. Bonsdorff (17), D. Brouwer (8), R. P. de Kock (27), M. dos Reis (11), W. J. Eckert (8), R. Grandón (20),

H. O. Grönstrand (13), Miss D. Hoffleit (24), G. J. Järnefelt (23, 36), D. S. Kothari (35), L. La Paz (22), Mrs S. Levy McDonald (20), R. A. McIntosh (22), H. A. Martinez (8), G. Merton (20), F. D. Miller (33), P. M. Millman (13), O. Mohler (11), E. Öpik (22), A. J. Orlov (8), L. C. Peltier (27), F. Rutllant (12), M. N. Saha (11), R. F. Sanford (29), F. P. Scott (8), C. D. Shane (8), H. S. Spigl (23), R. H. Stoy (8), B. Strömgren (34), K. F. Sundman (17), J. Tuominen (35), Frank Bradshaw Wood (27), H. W. Wood (23).

The following, not being members of Commissions, became members on being elected to national committees of astronomy of adhering countries:

Sir Edward Appleton, Prof. Z. Bay, Prof. D. Brunt, H. E. Butler, Dr L. Detre, Prof. L. Dezsö, M. M. Dujisin, Prof. J. Egerváry, Prof. G. R. Goldsbrough, Prof. P. Gombás. Dr C. Graef, Prof. G. Haro, F. M. Holborn, Prof. H. Jeffreys, Miss H. A. Kluyver, H. E. Krumm, Prof. K. Lassovsky, T. L. MacDonald, Dr B. Mašek, P. J. Melotte, Dr W. J. Miller, S.J., Dr T. E. Nevin, J. J. Nolan, Prof. Fr. Nušl, F. J. O'Connor, Dr L. Plaut, Dr J. G. Porter, G. Romero, Prof. R. O. Sandoval, Dr M. Sandoval Vallarta, F. J. Sellers, Dr R. Stoneley, W. S. Tai, Sir Edmund Whittaker, A. Zirwes, S.J.

The following were nominated as members by national committees of astronomy:

Poland: Dr W. Gorczyński, Dr W. Iwanowska, Dr W. Koebcke, Dr J. Mergentaler, Dr S. Piotrowski, Dr S. Szeligowski, Mgr W. Tecza, Dr S. Wierzbiński.
South Africa: A. W. J. Cousins.
U.S.S.R.: N. I. Idelson, V. A. Krat, K. A. Kulikov, B. A. Orlov.

Appointments made by the Executive Committee

After the death of Sir Arthur Eddington Sir Harold Spencer Jones was appointed to succeed him as President of the Union.

Prof. Ch. Fabry, Prof. Ö. Bergstrand and Prof. W. Brunner, who wished to retire from their function as Vice-President, have been replaced by Prof. A. Danjon, Prof. A. A. Mikhailov and Prof. G. Tiercy respectively.

Prof. M. Waldmeier has been appointed as successor to Prof. W. Brunner as Chairman of Commission 10.

Prof. B. J. Bok was nominated to represent the Union in the Committee on Science and its Social Relations of the I.C.S.U.

Dr Deslandres (honorary member), Drs Abbot, Abetti, d'Azambuja, Newton, Nicholson and Waldmeier have been appointed by the I.A.U. as members of the Mixed Commission on Solar and Terrestrial Relations of the I.C.S.U.

In July 1946 and July 1947 the President and the General Secretary represented the I.A.U. at meetings of the Executive Committee of the I.C.S.U., in London and Paris respectively. On both occasions the General Secretary read a report on recent activities of the Union.

Income and Expenditure

During the occupation of the Netherlands by the Germans, from May 10, 1940, to May 5, 1945, the General Secretary was not able to perform fully his secretarial duties. Dr W. S. Adams was kind enough to carry out all transactions concerning countries outside the German sphere of influence.

Some time before the war the General Secretary opened a dollar account for the I.A.U. at the Corn Exchange Bank Trust Co., New York, so that at present the Union has three accounts: one in dollars in New York, one in pounds at Barclays Bank, Cambridge, England, and one in guilders at the Amsterdamsche Bank, Leiden.

Moreover, a somewhat fictitious, fourth account has been formed, expressed in gold francs. This has originated from the difficulties inherent in transferring money from one country to another during the war. On account of these difficulties the Executive Committee decided that countries in which a Bureau to which grants had been allotted by

the I.A.U., had its seat, might pay their subscription directly to that Bureau. In this way Denmark, and for analogous reasons Sweden and afterwards Norway, paid their subscriptions to the Telegram Bureau in Copenhagen, France to the Director of the Paris Observatory for the Bureau de l'Heure and the Cartes Synoptiques, Italy to Prof. Abetti and Prof. Carnera for the Immagini Spettroscopiche and the Latitude Bureau. No account was taken of the actual exchange, which would have been almost impossible, but the subscriptions paid were assumed to represent the amounts in gold francs actually due. This system has worked satisfactorily.

In May 1940, on the invasion of the Netherlands, the I.A.U.'s sterling account at Barclays Bank, Cambridge, was blocked by the Custodian of Enemy Property; it was released in June 1946.

At its meeting in Copenhagen in March 1946 the Executive Committee decided that the unit of contribution for the years 1942–48 be fixed at 300 gold francs, the gold franc being defined, in accordance with the Statutes of the International Council of Scientific Unions, Vol. **3**, 1937, p. 107, as 0·2903225 grammes fine gold, or 0·3266 U.S. dollars.

It was also decided to request payment for the war years, because the various bureaux supported by the Union had continued their work during these years. It was judged to be all the more necessary because a number of the countries which were occupied during the war were unable to pay their contributions for these years. The possibility of having their dues for the war years annulled was offered to those countries which had suffered so badly from the war that they were not able to pay. A number of such countries have actually availed themselves of this opportunity, while several others have paid their contributions in full.

On January 1, 1948, the unexpended balance was about $38,000. This does not, however, represent the true balance, $21,000 being already allotted to various Commissions. Furthermore, the total of the grants for 1948 plus estimated costs for the Bureau in this year (total $12,000 in round figures) should be available at the beginning of the year. The true balance is, therefore, approximately $5000.

In future the financial status of the I.A.U. will be entirely different, on account of the interest taken by U.N.E.S.C.O. in international organization. This body intends to give grants for undertakings which are of a sufficiently wide scope. In fact, for 1947 U.N.E.S.C.O. has already allotted the following grants to the I.A.U.:

Commission 19, Latitude Variation	$ 980.
Commission 31, Bureau International de l'Heure	$8800.
Commission 38, Exchange of Astronomers	$1960.

INCOME AND EXPENDITURE, 1938

POUNDS

INCOME	£	s.	d.	EXPENDITURE nil	£	s.	d.
Balance, Jan. 1, 1938	2664	2	8	Balance, Jan. 1, 1939	2677	2	8
Interest	13	0	0				
	£2677	2	8		£2677	2	8

INCOME AND EXPENDITURE, 1939

POUNDS

INCOME	£	s.	d.	EXPENDITURE	£	s.	d.
Balance, Jan. 1, 1939	2677	2	8	Nov. 18 Général Perrier (⅔ special grant to Commission 18)	410	10	0
Interest	16	7	3	Oct. 21 Cambridge University Press (*Trans.* 6)	537	1	5
				Oct. 30 Lund Humphries (*Hyderabad Cat.* II)	297	9	6
				Balance, Jan. 1, 1940	1448	9	0
	£2693	9	11		£2693	9	11

INCOME AND EXPENDITURE, 1940

POUNDS

INCOME	£	s.	d.	EXPENDITURE	£	s.	d.
Balance, Jan. 1, 1940	1448	9	0	May 15 Prof. Nörlund (grant to Commission 31, first semester, 1940)	329	0	3
Subscriptions:				Mar. 13 International Council of Scientific Unions	18	13	6
Mar. 2 Australia (1940) 47 0 11				May, June, transferred to Custodian of Enemy Property	1203	18	1
June 8 Egypt (1939) 53 19 9							
	101	0	8				
Interest	2	2	2				
	£1551	11	10		£1551	11	10

INCOME AND EXPENDITURE, 1946

POUNDS

INCOME

	£ s. d.	£ s. d.
Balance, Jan. 1, 1946		
Subscriptions:		
Sept. 17 Australia (1941–46)	292 3 6	
June 6 Great Britain (1940–46) ...	1361 10 0	
June 19 Norway (1941–46)	146 0 0	
		1799 13 6
June 21 From Custodian of Enemy Property		1237 3 7*
		£3036 17 1

EXPENDITURE

	£ s. d.	£ s. d.
Bank expenses		2
Charges re release		2 2 0
Miss Wadsworth (travelling expenses General Secretary to Meeting I.C.S.U.)		18 0 0
Balance, Jan. 1, 1947		3016 14 11
		£3036 17 1

* In this sum is included an amount of £33. 5*s.* 6*d.*, which represents interest for the time the money was in the hands of the Custodian of Enemy Property.

INCOME AND EXPENDITURE, 1947

POUNDS

INCOME

	£ s. d.	£ s. d.
Balance, Jan. 1, 1947		3016 14 11
Subscriptions:		
June 28 Great Britain (1947)	192 18 7	
		192 18 7
Cambridge University Press (sale *Trans.* etc.)		41 4 10
Sale, lunar maps		15 0
		£3251 13 4

EXPENDITURE

	£. s. d.	£ s. d.
Grants to Commissions:		
Commission 8:		
Special grant for Kenya Expedition:		
Aug. 26 To Leiden Observatory ...	900 0 0	
Commission 23:		
Mar. 21 Lund Humphries (*Astr. Cat. Hyderabad*, vol. 12) ...	327 5 5	
Dec. 31 Wrigley (for work on Edinburgh volume)	130 0 0	
Commission 38:		
Nov. 1 Prof. Stratton (part grant 1947)	200 0 0	
		1557 5 5
International Council of Scientific Unions		41 12 0
Balance, Jan. 1, 1948		1652 15 11
		£3251 13 4

INCOME AND EXPENDITURE, 1938

GUILDERS

INCOME

Balance, Jan. 1, 1938			Fl. 7502·41
Subscriptions:			
Feb. 18	Argentine (1937)	Fl. 521·51	
Aug. 24	Argentine (1938)	534·58	
May 19	Belgium (1938)	339·36	
Mar. 4	Canada (1938)	512·29	
Dec. 31	China (1938)	359·17	
Sept. 23	Denmark (1938)	180·74	
Nov. 11	Egypt (1938)	538·84	
July 13	Great Britain (part 1938) ...	993·70	
July 28	Great Britain (to complete 1938)	411·09	
Dec. 14	Greece (1931–38)	1527·27	
Mar. 15	Italy (1937)	1404·18	
Apr. 25	Japan (1937)	1402·35	
Jan. 27	Netherlands (1937)	352·40	
Jan. 28	Norway (1938)	170·30	
Jan. 4	Poland (to complete 1935; 1936 and 1937)	2369·25	
May 4	Poland (1938)	1402·94	
Feb. 26	Portugal (1938)	348·51	
May 4	Roumania (part 1937) ...	559·06	
Apr. 1	South Africa (1938)	175·00	
Jan. 13	Sweden (1937)	350·39	
June 14	Switzerland (1938)	175·16	
Apr. 14	U.S.A. (1937)	1405·92	
Dec. 31	U.S.A. (1938)	1436·09	
Nov. 24	U.S.S.R. (1938)	1430·13	
June 29	Vatican City State (1936, 1937, 1938)	528·66	
			19428·89
Sale, lunar maps			11·22
Cambridge University Press			79·07
Sale, supplement Stroobant			1·60
Interest			14·00
			Fl. 27037·19

EXPENDITURE

Grants to Commissions:		
Commission 6:		
Dec. 30	Prof. E. Strömgren (1939)	Fl. 725·79
Commission 11:		
Feb. 28	Prof. Abetti (1938)	882·46
Mar. 1	Prof. Esclangon (1938)	1764·17
Commission 12:		
Nov. 8	Prof. Minnaert (special grant, Utrecht Atlas)	842·00
Commission 19:		
Mar. 4	Dr Spencer Jones (1938)	1468·43
Commission 20:		
Mar. 4	Dr Spencer Jones (special grant, Eros) ...	881·14
Commission 27:		
Jan. 6	Prof. Banachiewicz (1938)	472·79
Commission 31:		
Feb. 25	Prof. Nörlund (part first semester, 1938) ...	1664·35
Mar. 11	Prof. Nörlund (to complete first semester, 1938)	687·90
July 8	Prof. Nörlund (second semester, 1938) ...	2348·09
International Council of Scientific Unions		188·79
Travelling expenses, Oort		210·00
Travelling expenses, de Haan		4·12
Expenses General Assembly, Prof. Lindblad (stationery, clerical assistance, telegrams, etc.) ...		509·10
Cost report, Prof. van Rhijn		50·00
Clerical assistance		617·85
Stamps, etc.		281·08
Stationery and printing		129·57
Bank expenses, cheque books		29·06
Balance, Jan. 1, 1939		13280·50
		Fl. 27037·19

INCOME AND EXPENDITURE, 1939

GUILDERS

INCOME

Balance, Jan. 1, 1939				Fl. 13280·50
Subscriptions:				
Jan. 11	Argentine (1934, 1935, 1936)	Fl. 1976·29		
Apr. 28	Australia (1939)	363·97		
June 21	Belgium (1939)	368·15		
Feb. 6	Canada (1939)	544·13		
Nov. 29	Denmark (1939)	183·74		
Jan. 11	France (part 1938)	813·37		
May 10	France (part 1939)	835·26		
Sept. 13	France (to complete 1937)	326·38		
Jan. 10	Great Britain (1939)	1385·80		
Mar. 16	Italy (1938, 1939)	2941·62		
Jan. 23	Japan (1938)	1438·56		
Feb. 16	Norway (1939)	173·72		
May 5	Poland (1939)	1464·48		
Mar. 3	Portugal (1939)	366·69		
Apr. 28	South Africa (1939)	183·90		
Jan. 9	Sweden (1938)	358·69		
June 23	Switzerland (1939)	181·35		
			13906·10	
Sale, *Brit. Ass. Math. Tables* II			152·01	
Cambridge University Press			66·96	
Interest			22·60	
			Fl. 27428·17	

EXPENDITURE

Grants to Commissions:			
Commission 6:			
Nov. 21	Prof. E. Strömgren (advance)		Fl. 546·00
Dec. 28	Prof. E. Strömgren (1940)		736·00
Commission 11:			
Jan. 5	Prof. Esclangon (1939)		1627·29
Jan. 5	Prof. Abetti (1939)		813·64
Commission 19:			
Jan. 5	Dr Spencer Jones (1939)		1356·08
Commission 27:			
Jan. 5	Prof. Banachiewicz (1939)		481·55
Commission 31:			
Jan. 5	Prof. Nörlund (first semester, 1939)		2169·72
May 11	Prof. Nörlund (second semester, 1939)		2199·87
International Council of Scientific Unions			194·28
Cambridge University Press, Draft Reports			676·86
Dr Comrie, expenses Comm. 4 and 20			173·17
Clerical assistance			282·00
Stamps, postage, telegrams, telephone			83·04
Stationery and printing			109·19
Bank expenses, etc.			37·66
Transferred to dollar account			15120·30
Balance, Jan. 1, 1940			821·52
			Fl. 27428·17

INCOME AND EXPENDITURE, 1940

GUILDERS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1940		Fl. 821·52	Grants to Commissions:	
Subscriptions:			*Commission* 11:	
Dec. 11 Belgium (1940)	Fl. 347·15		Feb. 15 Abetti (Imm. Spettr., 1940)	Fl. 833·14
Apr. 13 Canada (1940)	553·50		Feb. 21 d'Azambuja (Cartes Syn., 1940)	1662·57
Jan. 18 China (¼, 1939)	367·00		*Commission* 19:	
Apr. 23 Italy (1940)	1472·70		Feb. 21 Carnera (Latitude Bureau, 1940)	1385·48
Feb. 23 Japan (1939)	1467·42		Bank expenses	19·81
Jan. 8 Netherlands (1939)	369·31		Stamps, etc.	5·92
Mar. 15 Netherlands (1938)	352·40		Stationery and printing	14·13
Feb. 10 Norway (1940)	183·07		Clerical assistance	114·90
Apr. 30 Roumania (to complete 1937, part 1938)	321·65		Transferred to dollar account ($1500)	2833·73
Apr. 1 South Africa (1940)	184·55		Balance, Jan. 1, 1941	3619·36
Feb. 2 Sweden (1939)	367·58			
Apr. 1 Switzerland (1940)	183·78			
May 9 U.S.A. (1939)	1470·74			
Jan. 4 U.S.S.R. (1939)	1445·57			
May 1 Yugoslavia (1938)	551·49			
		9637·91		
Interest		12·10		
Sale, lunar maps		9·26		
Reprints, Schumann		8·25		
		Fl. 10489·04		Fl. 10489·04

INCOME AND EXPENDITURE, 1941

GUILDERS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1941		Fl. 3619·36	Grants to Commissions:	
Subscriptions:			*Commission* 6:	
July 8 Netherlands (part 1941) ...	Fl. 185·00		Mar. 15 Prof. E. Strömgren (½, 1941)	Fl. 363·70
Sept. 3 Netherlands (1940)	369·31		Dec. 2 Prof. E. Strömgren (¼, 1942)	184·55
Sept. 29 Netherlands (to complete 1941)	185·00		*Commission* 11:	
		739·31	June 20 Prof. Esclangon (Cartes Syn., ⅓, 1941) ...	553·64
Interest		16·47	Dec. 2 Prof. Esclangon (Cartes Syn., ¼, 1942) ...	415·23
Sale, lunar maps		8·60	*Commission* 31:	
			June 20 Prof. Esclangon (Bureau de l'Heure, ⅓, 1941)	1476·36
			Dec. 2 Prof. Esclangon (Bureau de l'Heure, ¼, 1942)	1107·27
			Bank expenses	9·64
			Clerical assistance	53·25
			Stationery	1·10
			Stamps, duty, etc.	5·30
			Balance, Jan. 1, 1942	213·70
		Fl. 4383·74		Fl. 4383·74

INCOME AND EXPENDITURE, 1942

GUILDERS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1942		Fl. 213·70	Bank expenses	Fl. 3·47
Subscriptions:			Stamps	0·52
June 19 Netherlands (½, 1942) ...	Fl. 185·00		Clerical assistance	21·75
Sept. 29 Netherlands (½, 1942) ...	185·00		Balance, Jan. 1, 1943	562·02
		370·00		
Interest		4·06		
		Fl. 587·76		Fl. 587·76

INCOME AND EXPENDITURE, 1943

GUILDERS

INCOME		EXPENDITURE	
Balance, Jan. 1, 1943	Fl. 562·02	Grant, Bureau des Télégrammes (½, 1943) (Comm. 6)	Fl. 399·30
Subscription: Netherlands (1943)	370·00	Bank expenses	4·25
Interest	2·69	Stamps	2·52
For cheques	1·30	Clerical assistance	6·75
Sale, lunar maps and *Transactions*	16·10	Balance, Jan. 1, 1944	539·29
	Fl. 952·11		Fl. 952·11

INCOME AND EXPENDITURE, 1944

GUILDERS

INCOME		EXPENDITURE	
Balance, Jan. 1, 1944	Fl. 539·29	Grant, Bureau de l'Heure (Comm. 31)	Fl. 462·15
Interest	1·05	Bank expenses	3·00
Sale, lunar maps	27·77	Stamps	4·70
		Clerical assistance	4·75
		Balance, Jan. 1, 1945	93·51
	Fl. 568·11		Fl. 568·11

INCOME AND EXPENDITURE, 1945

GUILDERS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1945		Fl. 93·51	Bank expenses	Fl. 1·50
Subscriptions: Netherlands (1944)	370·00		Stamps	46·48
Netherlands (1945)	370·00		Stationery	4·80
		740·00	Clerical assistance	49·25
Interest		0·68	Balance, Jan. 1, 1946	732·16
		Fl. 834·19		Fl. 834·19

INCOME AND EXPENDITURE, 1946

GUILDERS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1946		Fl. 732·16	Bank expenses	Fl. 7·79
Subscriptions:			Stamps, etc.	251·30[5]
Nov. 11 Belgium (1945, 1946) ...	Fl. 1040·06		Stationery	29·70
May 1 Netherlands (1946)	521·36		Clerical assistance	575·87[5]
		1561·42	Expenses, Prof. Danjon, Prof. Oort, Copenhagen meeting	200·00
Sale, lunar maps		24·25	Printing circular VI, 2	331·39
			Printing 42nd *Name-list of Variable Stars*	289·21
			Balance, Jan. 1, 1947	632·56
		Fl. 2317·83		Fl. 2317·83

INCOME AND EXPENDITURE, 1947

GUILDERS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1947		Fl. 632·56	Bank expenses	Fl. 11·52
Subscriptions:			Stamps, telegrams	154·57
Dec. 16 Belgium (1947)	Fl. 520·03		Stationery, etc.	10·32
Aug. 8 Netherlands (1947)	521·36		Printing	1526·89
Apr. 14 South Africa (1941–47) ..	1820·00		Clerical assistance	237·50
		2861·39	Advance to H. A. Kluyver, in connection with absence of General Secretary	500·00
Interest		2·63	Balance, Jan. 1, 1948	1055·78
		Fl. 3496·58		Fl. 3496·58

INCOME AND EXPENDITURE, 1939

DOLLARS

INCOME		EXPENDITURE	
Apr. 28 Transferred from guilder account	$5000·00	Grants:	
Sept. 23 Transferred from guilder account	3000·00	*Commission* 19:	
Interest	19·71	Nov. 22 Prof. Kimura (special grant, lat. results) ...	$1178·94
		Commission 27:	
		Nov. 6 Dr Shapley (for work of Dr Prager on *Gesch. u. Lit.*)	653·50
		Balance, Jan. 1, 1940	6187·27
	$8019·71		$8019·71

INCOME AND EXPENDITURE, 1940

DOLLARS

INCOME		EXPENDITURE	
Balance Jan. 1, 1940	$6187·27	*Commission* 27, special grant: Dr Prager (*Gesch. u. Lit.*)	$653·50
Apr. 25 Transferred from guilder account	1500·00	Stamps	10·00
Interest	39·35	Balance, Jan. 1, 1941	7063·12
	$7726·62		$7726·62

INCOME AND EXPENDITURE, 1941

DOLLARS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1941		$7063·12	Cambridge University Press	$518·82
Subscriptions:			Balance, Jan. 1, 1942	7147·09
July 21 Mexico (part 1934)	$ 98·02			
July 21 Sweden (1940, 1941)	392·00			
June 24 Switzerland (1941)	98·02			
		588·04		
Interest		14·75		
		$7665·91		$7665·91

INCOME AND EXPENDITURE, 1942

DOLLARS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1942		$7147·09	Balance, Jan. 1, 1943	$7973·15
Subscription:				
Aug. 14 U.S.A. (1940)	$784·08			
		784·08		
Interest		41·98		
		$7973·15		$7973·15

INCOME AND EXPENDITURE, 1943

DOLLARS

INCOME			EXPENDITURE	
Balance, Jan. 1, 1943		$7973·15	Balance, Jan. 1, 1944	$9372·59
Subscriptions:				
May 27 Argentine (1939, 1940) ...	$588·16			
Mar. 8 U.S.A. (1941)	$784·08			
		1372·24		
Interest		27·20		
		$9372·59		$9372·59

INCOME AND EXPENDITURE, 1944

DOLLARS

INCOME			EXPENDITURE	
Balance, Jan. 1. 1944		$9372·59	Balance, Jan. 1, 1945	$10945·45
Subscriptions:				
Mar. 4 U.S.A. (1942)	$784·08			
July 11 U.S.A. (1943)	784·08			
		1568·16		
Interest		4·70		
		$10945·45		$10945·45

INCOME AND EXPENDITURE, 1945

DOLLARS

INCOME			EXPENDITURE		
Balance, Jan. 1, 1945		$10945·45	Grants to Commissions:		
Interest		25·12	*Commission* 6:		
			Dec. 31 Prof. E. Strömgren ...	$446·66	
			Commission 19:		
			Jan. 3 Prof. Carnera	247·06	
					693·72
			Balance, Jan. 1, 1946		10276·85
		$10970·57			$10970·57

INCOME AND EXPENDITURE, 1946

DOLLARS

INCOME			EXPENDITURE		
Balance, Jan. 1, 1946		$10276·85	Grants to Commissions:		
Subscriptions:			*Commission* 6:		
Oct. 7 Mexico (part 1935)	$ 246·91		Nov. 6 Prof. E. Strömgren (advance)	$1004·35	
Oct. 25 U.S.A. (1944, 1945, part 1946)	2090·83		*Commission* 11:		
Aug. 16 U.S.S.R. (1940–46)	5487·00		May 5 Prof. A. Danjon (Cartes syn.)	1772·80	
		7824·74	*Commission* 31:		
From Dr Adams, balance postage stamps		3·58	June 26 Prof. Shapley*	200·00	
Interest		15·74	Oct. 1 Dr Lyot*	500·00	
					3477·15
			Prof. Danjon, Prof. Oort, travelling expenses, Copenhagen		386·30
			Prof. Oort, part expenses, meeting, Copenhagen		28·00
			Prof. E. Strömgren, further expenses, meeting		149·57
			Balance, Jan. 1, 1947		14079·89
		$18120·91			$18120·91

* At the request of Prof. Danjon part of the grant for the Bureau de l'Heure was paid in the U.S.A. to Drs Shapley and Lyot.

INCOME AND EXPENDITURE, 1947

DOLLARS

INCOME			EXPENDITURE		
Balance, Jan. 1, 1947		$14079·89	Grants:		
Subscriptions:			*Commission* 11, Cartes synoptiques 1947:		
Mar. 26 China (1940–47)	$1568·00		July 17 To Harvard Coll. Obs. for Prof. Danjon ...		882·25
July 14 Czechoslovakia (1934/35 part, 1937, 1938, 1946 part, 1947)	1198·00		*Commission* 20:		
Aug. 21 Hungary (1947)	196·00		Aug. 25 Prof. Brouwer, for Minor Planet Centre ...		1000·25
July 1 Poland (1945, 1946)	1566·72		Balance, Jan. 1, 1948		30883·65
Oct. 1 Switzerland (1942–47) ...	588·12				
Aug. 20 U.S.A. (to complete 1946) ...	261·36				
Oct. 24 U.S.A. (1947)	784·06				
Sept. 22 U.S.S.R. (1947)	784·00				
		6946·26			
U.N.E.S.C.O., grants-in-aid 1947 ...		11740·00			
		$32766·15			$32766·15

INCOME AND EXPENDITURE, 1941

GOLD FRANCS

INCOME	Gold frs.
Subscriptions:	
Denmark (1940)	300·0
Italy (1941)	2400·0
France (to complete 1938 and 1939)	1689·2
France (1940)	2400·0
Denmark (1941)	300·0
Gold frs.	7089·2

EXPENDITURE	Gold frs.
Grants:	
Bureau des Télégrammes (¼ grant 1941) (Comm. 6)	300·0
Immagini Spettroscopiche (⅝ grant 1941) (Comm. 11)	900·0
Latitude Bureau (⅝ grant 1941) (Comm. 19)	1500·0
Bureau International de l'Heure (part 1941) (Comm. 31)	2974·0
Cartes synoptiques (part 1941) (Comm. 11)	1115·2
Bureau des Télégrammes (¼ grant 1941) (Comm. 6)	300·0
Gold frs.	7089·2

INCOME AND EXPENDITURE, 1942

GOLD FRANCS

INCOME	Gold frs.
Subscriptions:	
Italy (1942)	2400·0
Denmark (1942)	300·0
France (1941)	2400·0
Gold frs.	5100·0

EXPENDITURE	Gold frs.
Grants:	
Latitude Bureau (⅝ grant 1942) (Comm. 19)	1500·0
Immagini Spettroscopiche (⅝ grant 1942) (Comm. 11)	900·0
Bureau des Télégrammes (¼ grant 1942) (Comm. 6)	300·0
Bureau International de l'Heure (part 1942) (Comm. 31)	1745·5
Cartes synoptiques (part 1942) (Comm. 11)	654·5
Gold frs.	5100·0

INCOME AND EXPENDITURE, 1943

GOLD FRANCS

INCOME	Gold frs.
Subscriptions:	
Sweden (1942)	600
Denmark (1943)	300
Sweden (1943)	600
Italy (1943)	2400
Gold frs.	3900

EXPENDITURE	Gold frs.
Grants:	
Bureau des Télégrammes (½ grant 1942) (Comm. 6)	600
Bureau des Télégrammes (¼ grant 1943) (Comm. 6)	300
Bureau des Télégrammes (¼ grant 1943 and ¼ grant 1944) (Comm. 6)	600
Latitude Bureau (⅝ grant 1943) (Comm. 19)	1500
Immagini Spettroscopiche (⅝ grant 1943) (Comm. 11)	900
Gold frs.	3900

INCOME AND EXPENDITURE, 1944

GOLD FRANCS

INCOME	Gold frs.	EXPENDITURE	Gold frs.
Subscriptions:		Grants:	
Sweden (1944)	600	Bureau des Télégrammes (¾ grant 1944) (Comm. 6) ...	900
Denmark (1944)	300		
Gold frs.	900	Gold frs.	900

INCOME AND EXPENDITURE, 1945

GOLD FRANCS

INCOME	Gold frs.	EXPENDITURE	Gold frs.
Subscriptions:		Grants:	
Sweden (1945)	600	Bureau des Télégrammes (¾ grant 1945) (Comm. 6) ...	900
Denmark (1945)	300		
Gold frs.	900	Gold frs.	900

INCOME AND EXPENDITURE, 1946

GOLD FRANCS

INCOME	Gold frs.
Subscriptions:	
Italy (1943)	2400
France (1946)	2400
Sweden (1946)	600
Denmark (1946)	300
Gold frs.	5700

EXPENDITURE	Gold frs.
Grants:	
Latitude Bureau (⅔ grant 1943) (Comm. 19)	1500
Immagini Spettroscopiche (⅔ grant 1943) (Comm. 11)	900
Bureau International de l'Heure (part 1946) (Comm. 31)	2400
Bureau des Télégrammes (¼ grant 1946) (Comm. 6)	900
Gold frs.	5700

INCOME AND EXPENDITURE, 1947

GOLD FRANCS

INCOME	Gold frs.
Subscriptions:	
Italy (1944, 1945, 1946, part)	4050
Denmark (1947)	300
Norway (1947)	300
Sweden (1947)	600
France (1947)	2400
Gold frs.	7650

EXPENDITURE	Gold frs.
Grants:	
Latitude Bureau (Comm. 19)	2250
Immagini Spettroscopiche (grant allotted in Copenhagen) (Comm. 11)	1800
Bureau des Télégrammes (1947) (Comm. 6)	1200
Bureau International de l'Heure (part 1947) (Comm. 31)	2400
Gold frs.	7650

Total Expenditure and Income, 1938–1947

The following table shows, roughly, the amounts expressed in gold francs, paid on the annual grants:

Comm.	6	11	11	19	20	23	27		31	38			
Year		Cartes syn.	Imm. Sp.				Ephem. Ecl. stars	Name List			I.C.S.U.	Bureau	Total
1938	1,200	2,700	1,350	2,250	—	—	800	—	7,200	—	325	3,100	18,925
1939	2,100	2,700	1,350	2,250	—	3,900	800	—	7,200	—	300	8,900	29,500
1940	—	2,700	1,350	2,250	—	—	—	—	3,600	—	225	300	10,425
1941	1,500	2,700	900	1,500	—	—	—	—	7,150	—	—	2,700	16,450
1942	300	650	900	1,500	—	—	—	—	1,750	—	—	50	5,150
1943	2,100	—	900	1,500	—	—	—	—	—	—	—	25	4,525
1944	900	—	—	—	—	—	—	—	750	—	—	25	1,675
1945	2,250	—	—	750	—	—	—	—	—	—	—	150	3,150
1946	3,950	5,400	900	1,500	—	—	—	350	4,550	—	—	3,550	20,200
1947	1,200	2,700	1,800	2,250	3,050	5,600	—	1,600	2,400	2,450	525	1,200	24,775
Total...	15,500	19,550	9,450	15,750	3,050	9,500	1,600	1,950	34,600	2,450	1,375	20,000	134,775

Moreover, the following special grants have been paid:

1947, Commission 8, expedition of Leiden Observatory to Kenya	11,200 gold frs.
1938, Commission 12, Atlas of Solar Spectrum	1,400
1939, Commission 18, Longitudes mondiales	5,000
1939, Commission 19, Publication of Latitude Results	3,600
1938, Commission 20, Orbit of Eros	1,500
1939, Commission 27, Grant to Dr Prager for GuL	2,000
1940, Commission 27, Grant to Dr Prager for GuL	2,000
	26,700

The total expenditure is 161,475 *gold francs.*

The subscriptions received are given below:

1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Total
32,900	22,500	17,150	10,100	8,100	8,700	5,700	2,100	53,650	34,650	195,550

Moreover, 1150 gold francs have been received by sale of publications, and 1500 gold francs as interest, whereas U.N.E.S.C.O. paid in 1947 grants-in-aid to a total amount of 36,000 gold francs.

The income hence equals 234,200 gold francs.

It should be remarked that the gold franc equivalents given above are only approximate. Besides, in several cases a country has paid somewhat less than the subscription actually due.

Publications

In addition to Vol. VI of the *Transactions* of the I.A.U. the following volumes have been published under the auspices of and with financial support from the Union:

Commission 11. *Immagini Spettroscopiche del Borde Solare.* Abetti.

Cartes synoptiques de la Chromosphère et Catalogue des Filaments de la Couche supérieure. d'Azambuja.

Commission 19. *Results of the International Latitude Service from* 1922.7 *to* 1935.0. (VIII.) Kimura.

Commission 23. *Astrographic Catalogue* 1900.0. *Hyderabad Section (Part III). Dec.* +35° *to* +40°, *vol. XI: Measures of Rectangular Co-ordinates and Diameters of* 50,907 *star-images on plates with centres in Dec.* +37°. BHASKARAN.

Astrographic Catalogue 1900.0. *Hyderabad Section (Part III). Dec.* +35° *to* +40°, *vol. XII: Measures of rectangular Co-ordinates and Diameters of* 60,144 *star-images on plates with centres in Dec.* +36°. BHASKARAN.

Commission 27. *Minima of Eclipsing Variables*, 1939, 1947. BANACHIEWICZ.

42*nd Name-list of Variable Stars.* KUKARKIN, PARENAGO.

43*rd Name-list of Variable Stars.* KUKARKIN, PARENAGO.

Commission 31. *Bulletins horaires du Bureau de l'Heure.* ESCLANGON, DANJON.

THE MEETING AT ZÜRICH

At the Stockholm meeting the Union was invited to hold its next General Assembly in Switzerland in 1941, an invitation which was very cordially received. Notwithstanding the difficult economic conditions the invitation was renewed after the war, and it was finally decided that the General Assembly would be held in Switzerland, from August 11–18, 1948. Prof. Waldmeier kindly offered to undertake the task of organizing the meeting in Zürich.

Draft Reports of the various commissions were asked for by January 1, 1948, and those received in time have been bound together and issued in advance of the meeting to all members who had notified their intention of being present.

The Agenda for the first meeting of the General Assembly was fixed as follows:

1. Official opening of the Congress.
2. Address by the President of the Union.
3. Appointment of Recorders for the Meeting.
4. Report of the Executive Committee.
5. Appointment of Finance Committee—one member to be nominated by each adhering country.
6. Appointment of Committee to advise the Executive Committee in the selection of members of standing commissions.
7. Resolutions submitted by National Committees of Astronomy:

(*a*) 'That Statute IV, 9 shall be replaced by the following:

'There shall be eight categories of membership of the Union, numbered 1 to 8. Each adhering country shall pay annually a number of units of subscription equal to the number of its category of membership. A country offering to adhere to the Union shall specify in which category it proposes to be classed. The offer to adhere may be refused by the Executive Committee if the proposed category is judged to be manifestly inadequate. In each country the organization adhering to the Union shall be responsible for the payment of the contribution.

'That Statutes III, 5 and 6 shall be replaced by the following:

'5. On scientific matters each delegate present shall have one vote. In questions of administrative, or of mixed administrative and scientific character, not involving questions of finance, voting shall be by countries, each country having one vote, with the provision that its subscription shall have been paid up to the end of the year preceding the voting. In questions involving finance, voting shall be by countries, with the same provision as for administrative questions. The number of votes for each country shall be one greater than the number of its category of membership, as defined in article IV, 9.

'6. No delegate shall represent more than two countries. An adhering country not represented by a delegate may forward by post its vote on any specific question of the agenda.' (Great Britain.)

(*b*) 'Que l'Union accorde un appui financier à la Bibliographie Mensuelle de l'Astronomie.' (France.)

(*c*) 'Que l'Union Astronomique Internationale entreprenne des démarches auprès de la Commission Economique Interalliée de Berlin, pour que les recherches soient continuées en vue de retrouver le télescope Zeiss de un mètre d'ouverture de l'Observatoire Royal de Belgique, réquisitionné par l'armée allemande en juin 1940.' (Belgique.)

(*d*) 'Que, au sein de l'Union Astronomique Internationale, une Commission d'Histoire de l'Astronomie soit créée.' (Belgique.)

(*e*) 'That the I.A.U. organize the broadcasting of astronomical scientific news.' (Poland.)

(*f*) 'That a Commission be created to revise the structure of the standing commissions of the Union, so that by 1951 plans may be proposed for a new and more effective organization of the standing commissions.' (U.S.A.)

8. The following resolutions, which had reached the General Secretary too late to be circulated in advance of the meeting, were added to the Agenda:

(*g*) 'That the first paragraph of By-Law 1, 1, which now reads:

'The Union shall be composed of three classes of members: (*a*) all the members of the National Committees of Astronomy of countries adhering to the Union, (*b*) members nominated by adhering organizations or by National Committees, and (*c*) all the members of the standing committees of the Union',

be changed as follows:

'The Union shall be composed of two classes of members: (*a*) all the members of the standing committees of the Union, and (*b*) members nominated by adhering organizations or by National Committees.' (Executive Committee.)

(*h*) 'The International Union of Radio-Science draws the attention of the I.A.U. to the importance of precise measures of the velocity of transmission of long waves, and requests the astronomical observatories to co-operate with the radio-technicians, in order to organize common experiments of the highest possible precision. In particular, it would be desirable to organize experiments on either side of the Atlantic, which would permit measuring differences between the times of transmission in the two directions.'

(*i*) 'Que l'Union se charge de donner une définition plus exacte de l'unité de temps.' (Bureau National, Scientifique et Permanent des Poids et Mesures, Paris.)

(*j*) 'Que l'U.A.I. considère de nouveau la résolution prise au congrès de 1928 sur la désignation du temps civil de Greenwich, donne à cette résolution une rédaction plus nette, et lui donne la publicité nécessaire pour la faire admettre universellement.' (Comité Exécutif.)

(*k*) 'That the I.A.U. recommend that an abstract in English or French be attached to all scientific astronomical publications.' (Executive Committee.)

MEMBRES ET HÔTES

ayant assisté au Congrès de l'Union à Zürich, 11–18 *août* 1948

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PART II
RESOLUTIONS ADOPTEES

RESOLUTIONS ADOPTEES

Comité Exécutif

1. Que l'article IV, 9 des Statuts soit remplacé par:

Les pays adhérents à l'Union sont répartis en 8 catégories numérotées de 1 à 8. Chaque pays adhérent paye annuellement un nombre d'unités de souscription égal à l'indice de sa catégorie. Un pays désireux d'adhérer à l'Union doit spécifier dans quelle catégorie il propose d'être classé. Sa demande d'adhésion peut être refusée par le Comité Exécutif de l'Union si la catégorie choisie est jugée manifestement inadéquate.

Que les articles III, 5 et 6 soient remplacés par:

5. Pour toute question scientifique chaque délégué présent dispose d'une voix.

Pour les questions d'ordre administratif, ou à la fois administratif et scientifique, mais sans répercussion financière, le vote se fait par pays, chaque pays disposant d'une voix, sous la réserve que ce pays ait acquitté ses cotisations jusqu'à la fin de l'année qui précède le vote.

Pour toutes les questions financières le vote se fait également par pays, sous la même réserve que pour les questions d'ordre administratif, le nombre de voix attribué à chaque pays étant égal à l'indice de sa catégorie (défini dans l'article IV, 9), augmenté d'une unité.

6. Un même délégué ne peut représenter plus de deux pays à la fois. Un pays adhérent, non représenté à l'Assemblée Générale par son propre délégué, peut voter par correspondance sur toute question figurant explicitement à l'ordre du jour.

2. Que le premier paragraphe de l'article I, 1 du règlement, dont la forme actuelle est la suivante:

L'Union est constituée par des membres de trois catégories: (*a*) tous les membres des Comités Nationaux d'Astronomie des pays adhérents, (*b*) les personnes désignées par les organismes adhérents ou par les Comités Nationaux d'Astronomie, et (*c*) tous les membres des commissions de l'Union.

soit remplacé par:

L'Union est constituée par des membres de deux catégories: (*a*) tous les membres des commissions de l'Union, (*b*) les personnes désignées par les organismes adhérents ou par les Comités Nationaux d'Astronomie.

3. Qu'il soit ajouté à la fin de l'article 11 du règlement:

Le Président sortant et le Secrétaire général sortant restent membres du Comité Exécutif avec voix consultative, lorsque leur mandat prend fin et jusqu'à la fin de l'Assemblée Générale ordinaire suivante.

4. Que l'U.A.I. entreprenne des démarches auprès de la Commission Economique Interalliée de Berlin pour que les recherches soient continuées en vue de retrouver le télescope Zeiss de un mètre d'ouverture de l'Observatoire Royal de Belgique, réquisitionné par l'armée allemande en juin 1940.

5. Le progrès de l'astronomie étant entravé lorsque les résultats des observations et des recherches sont publiés dans une langue que les astronomes ne connaissent pas en général, l'Union recommande que toute publication faite dans l'une de ces langues soit accompagnée d'un sommaire dans l'une des langues généralement comprises.

L'Union constate avec satisfaction que cette règle est déjà très largement acceptée, mais, comme elle souffre encore des exceptons, l'Union exprime le vœu qu'elle devienne générale.

6. L'Union considère que la publication des 17 volumes qui restent à publier de la partie sud de la *Geschichte des Fixsternhimmels* a une grande importance pour l'astronomie et espère que des moyens pourront être trouvés pour compléter cet ouvrage.

7. L'Union désire attirer l'attention sur la grande importance pour l'astronomie de la publication des 15 volumes de la nouvelle observation photographique des zones de l'A.G. Du personnel et de l'argent existent en Allemagne pour compléter ce travail, ainsi que pour l'impression et pour la correction des épreuves, mais la publication est retardée par le manque de papier en Allemagne. L'Union espère que les fonds nécessaires à l'achat du papier et à la reliure pourront être trouvés pour la publication.

8. L'Union attire l'attention de ses membres sur l'importance d'obtenir une photocopie des parties nord et sud de la Bonner Durchmusterung et exprime l'espoir que la quantité de papier nécessaire sera mise à la disposition de l'Observatoire de Bonn.

Commission des Finances

La Commission des Finances propose à l'Assemblée Générale:

1. Que les subventions suivantes soient allouées pour la période s'écoulant du 1 janvier 1949 jusqu'au 31 décembre 1951.*

	(*a*) *Subventions annuelles*	*Dollars*	*Francs-or*
Commission 5	(Bibliographie mensuelle)	163	500
,, 6	(Bureau des Télégrammes)	392	1,200
,, 10	(Cartes héliographiques de la photosphère) ...	327	1,000
,, 11	(Cartes synoptiques)	882	2,700
,, 19	(Bureau central de la Variation des Latitudes)	980	3,000
,, 20	(Centre des Petites Planètes, à Cincinnati) ...	980	3,000
,, 27	(Liste des Noms d'Etoiles variables)	261	800
,, 27	(Ephémérides des Etoiles doubles à Eclipses)	327	1,000
,, 31	(Bureau International de l'Heure)	4,409	13,500
,, 38	(Echange des Astronomes)	3,919	12,000
Bureau de l'Union		3,266	10.000
		15,906	48,700

	(*b*) *Subventions uniques spéciales*	*Dollars*	*Francs-or*
Commission 12	(Tables du Spectre solaire)	1,960	6,000
,, 18	(Publication des Résultats des Longitudes Mondiales 1933)	816	2,500
,, 19	(Publication des Résultats de la Variation des Latitudes jusqu'à la fin de 1948)	2,613	8,000
,, 19	(Dépenses du Déménagement du Bureau Central à Turin)	327	1,000
,, 23	(Carte du Ciel)	6,859	21,000
,, 24	(Publication de la 3ème Edition du *Parallax Catalogue*)	1,633	5,000
,, 27	(Cartes d'Etoiles variables dans l'Hémisphère sud)	261	800
,, 27	(Traduction et Impression de l'Introduction du *Catalogue and Ephemerides*)	261	800
Comité Exécutif	(Colloque organisé par l'U.A.I. et l'Union de Mécanique Théorique et Appliquée)... ...	3,266	10,000
		17,996	55,100

2. Que l'unité de cotisation pour les années de 1949 jusqu'à la prochaine Assemblée Générale soit fixée à 500 francs-or.

* Les montants définitivement accordés comme subventions sont ceux exprimés en francs-or dans les résolutions de la Commission des Finances, le franc-or étant défini comme 0·290 3225 grammes d'or fin, ou $0·3266 au cours actuel.

Commission 3. (NOTATIONS, UNITÉS ET ECONOMIE DES PUBLICATIONS)

1. La Commission recommande que la liste des notations publiée dans les *Transactions of the I.A.U.* **6**, 345–55, 1938, soit réimprimée et qu'un nombre suffisant d'exemplaires soit mis à la disposition des éditeurs des journaux astronomiques et des instituts astronomiques afin de les distribuer aux auteurs de rapports astronomiques.

2. Au cas où ce projet serait approuvé, la Commission recommande que la réimpression contienne une courte introduction annonçant que la Commission 3 a l'intention de revoir la liste des notations avant la prochaine Assemblée Générale et demandant que des critiques et des suggestions soient addressées au Président de la Commission 3.

Commission 4. (EPHÉMÉRIDES)

1. La Commission recommande que la désignation 'Temps Universel' (Universal Time; Weltzeit) soit seule utilisée par les astronomes pour désigner le temps solaire moyen, compté à partir de minuit du méridien de Greenwich.

Elle exprime le vœu que cette désignation remplace aussitôt que possible les autres expressions encore employées.

2. La Commission appuie très favorablement le projet formé par l'Observatoire National de Prague, de publier annuellement un Supplément international fournissant des données détaillées concernant les éclipses de lune et les occultations d'étoiles faibles pendant ces éclipses.

Commission 5. (ANALYSE DE TRAVAUX ET BIBLIOGRAPHIE)

1. La Commission prend acte avec grand intérêt de ce que la Bibliographie Mensuelle de l'Astronomie reprend la publication de son bulletin mensuel en liaison avec le *Bulletin Analytique du Centre National de la Recherche Scientifique* (Paris) et envisage de combler la lacune due à la guerre.

La Commission estime que la subvention attribuée à la B.M.A. devrait être continuée à concurrence de 1500 francs-or pour la période des trois années à venir (1949, 1950 et 1951) et que la subvention prévue antérieurement et qui n'a pas encore été touchée, devrait être mise à la disposition de la B.M.A. pour aider à combler la lacune due à la guerre.

2. La Commission a appris également avec un vif intérêt que le Jahresbericht pour les années 1941 et 1942 a été publié et que le premier des deux volumes consacrés aux années 1943–46 est imprimé; elle souhaite voir la publication du Jahresbericht se continuer régulièrement.

Elle recommande qu'un exemplaire des publications soit adressé dès parution à l'Astronomisches Rechen-Institut, (17*a*) Heidelberg, Seminarienhaus, Augustinergasse 15, Baden, U.S. Zone, Allemagne, ainsi qu'un exemplaire des publications éditées au cours des années 1943–46 et suivantes pour autant que cela n'ait pas été fait.

3. La Commission ayant pris connaissance de l'état d'avancement du travail entrepris pour combler la lacune entre la Bibliographie de Houzeau-Lancaster et le Jahresbericht, serait désireuse de voir le Comité National Belge prendre toutes mesures possibles pour mener ce travail à bien.

4. La Commission est heureuse d'apprendre que, suite à sa recommandation 4, prise lors du Congrès de Stockholm en 1938, Monsieur A. N. Vyssotsky a terminé la traduction de la partie astronomique des chroniques russes médiévales, que le manuscrit en est prêt et que la publication en sera assurée par l'Observatoire de Lund.

5. La Commission, qui avait demandé par sa recommandation 5 prise lors du Congrès de Stockholm en 1938 que l'Observatoire de Lund établisse un catalogue sur fiches des astronomes et des observatoires, estime qu'il serait fort utile de publier dès que possible une liste des observatoires et des astronomes, telle qu'elle avait été éditée antérieurement par l'Observatoire Royal de Belgique.

6. La Commission apprend avec satisfaction qu'une commission a été créée par la Royal Society de Londres pour assurer la publication des lettres de Newton, publication qu'elle souhaitait dans sa recommandation 8 prise lors du Congrès de Stockholm en 1938.

Commission 6. (TÉLÉGRAMMES)

1. La Commission recommande qu'une subvention annuelle de mille deux cents francs-or soit allouée au Bureau des Télégrammes astronomiques.

2. La Commission recommande que le code des télégrammes astronomiques (p. 477 ou 483 des *Transactions of the I.A.U.* **6**, 1938), soit modifié de la manière suivante:

(1°) nom de l'auteur de la découverte;
(2°) nature de l'objet;
(3°) nom de l'observateur;
(4°) groupes habituels donnant la position, suivis de remarques, s'il y a lieu;
(5°) noms des transmetteurs.

Le Bureau Central des Télégrammes astronomiques décidera s'il convient de communiquer aussi le nom de l'observatoire, ainsi que les noms de tous les intermédiaires.

Commission 8. (ASTRONOMIE MÉRIDIENNE)

La Commission tient à exprimer sa satisfaction pour les programmes en cours d'exécution aux Etats-Unis et dans l'Union Soviétique, et qui ont pour but de relier le système des nébuleuses extragalactiques avec celui des étoiles fondamentales. La Commission considère que ce travail sera de la plus grande importance pour l'astronomie de position.

Commission 10. (PHÉNOMÈNES PHOTOSPHÉRIQUES)

1. La Commission propose d'accorder à l'Observatoire fédéral de Zürich pour la période qui s'étendra jusqu'au prochain congrès une subvention annuelle de S. frs. 1500, destinée à la publication des cartes héliographiques de la photosphère, qui sont élaborées avec l'aide d'un grand nombre d'observatoires de divers pays.

2. La Commission propose que l'on change son nom actuel de 'Commission des taches solaires et des nombres caractéristiques' en celui plus approprié aux travaux qu'elle réalise actuellement de 'Commission des phénomènes photosphériques'.

3. La Commission recommande que l'on organise une collaboration internationale, sous la direction de l'Observatoire de Zürich, en vue d'une meilleure investigation du développement des taches solaires, soit par l'utilisation des photographies déjà existantes, soit par l'obtention systématisée de photographies fréquentes des détails des groupes.

Commission 11. (PHÉNOMÈNES CHROMOSPHÉRIQUES ET COURONNE SOLAIRE)

1. La Commission recommande que la subvention annuelle de 2700 francs-or accordée par la dernière Assemblée Générale de l'U.A.I. à l'Observatoire de Paris-Meudon pour la publication des cartes synoptiques de la chromosphère solaire, soit renouvelée pour la période qui s'étendra jusqu'au prochain congrès de l'Union.

2. La Commission invite les directeurs des établissements possédant un des spectrohélioscopes standards que G. E. Hale avait fait construire en 1930, et qui ne l'utilisent pas actuellement, à le remettre en service pour la recherche des éruptions chromosphériques ou, éventuellement, à le prêter à d'autres observatoires mieux placés pour les utiliser.

3. La Commission s'associe à la recommandation de la Commission mixte du Conseil International des Unions Scientifiques pour l'étude des relations entre les phénomènes solaires et terrestres, relative à l'envoi d'ursigrammes sur l'activité solaire par plusieurs

observatoires convenablement répartis en longitude, afin d'éviter les lacunes dues au mauvais temps.

Elle attire l'attention sur la nécessité de diffuser ces ursigrammes quotidiens suivant le même code, à des heures voisines, mais ne se recouvrant pas.

Commission 12. (Radiation et Spectroscopie solaires)

1. La Commission considère que la publication d'une table révisée du spectre solaire dans le plus court délai possible est de la plus haute importance pour les astronomes qui s'occupent de recherches sur le soleil et sur les spectres stellaires. Pour réduire le délai de publication, la Commission 12 recommande que la table révisée soit limitée à l'intervalle spectral encore inédit de λ3063 à λ6600, et que les longueurs d'onde soient données dans l'échelle de 1928. À cet effet, la Commission recommande que l'U.A.I. accorde une subvention de £500 ou de $2000 pour la publication de la table solaire révisée.

Commission 16. (Observations physiques des Planètes)

1. La Commission décide de ne donner des nouveaux noms qu'à des formations lunaires importantes parmi celles qui n'ont pas encore été désignées.

Elle propose de donner le nom de Deslandres à la grande dépression rectangulaire située au sud du mur droit et qui contient les cratères Hell et Lexell.

2. La Commission recommande aux observateurs de la Lune de travailler uniquement sur des gabarits tracés au moyen de photographies à très grande échelle prises dans des conditions d'éclairement appropriées.

Elle recommande aux sections lunaires des associations astronomiques de s'entendre directement entre elles et avec les observatoires bien équipés pour l'obtention de telles photographies.

3. La Commission recommande aux observateurs qui étudient les colorations des planètes, d'utiliser des dispositifs corrigeant la dispersion atmosphérique, lorsque les observations sont faites à une faible hauteur.

Commission 17. (Mouvement et Figure de la Lune)

1. La Commission est unanime à estimer qu'il serait important d'entreprendre la réduction de l'ensemble des observations relatives à la libration de la lune par une méthode rigoureuse. L'exécution de cette grande tâche serait facilitée par la création d'un laboratoire mathématique international, qui serait une section de l'Observatoire International projeté.

2. La Commission est unanime à estimer que les travaux poursuivis par M. C. B. Watts (Washington) sur les irrégularités du limbe lunaire sont importants et méritent tout l'appui de la Commission.

3. La Commission est unanime à donner acte au 'Nautical Almanac Office' de ce que les prédictions d'occultations telles qu'elles sont calculées par ses soins sont fort utiles et contribuent au progrès de la branche de l'Astronomie dont s'occupe la Commission.

Commission 18. (Longitudes par Télégraphie sans Fil)

1. Comme suite aux décisions prises lors de l'Assemblée Générale de Stockholm en 1938, la Commission demande à l'Assemblée Générale que la publication déjà entreprise des Résultats de l'Opération mondiale des Longitudes de 1933 soit liquidée aux moindres frais dans les conditions qui sont précisées dans le Rapport de son Président (voir 'Draft Reports', pp. 87–90) et qui correspondent à un partage exact des dépenses avec l'Association Internationale de Géodésie.

Elle demande que la somme de 800 dollars prévue dans ce Rapport soit mise par le Comité Exécutif à la disposition du Bureau Central de l'Association Internationale de Géodésie, qui assurera la publication et la diffusion des résultats finaux et des conclusions.

2. La Commission 18 (Longitudes par Télégraphie sans Fil) a décidé de demander à l'Assemblée Générale de l'Union sa transformation en une *Commission de détermination des positions géographiques*.

A cette extension sensible de ses attributions actuelles devra correspondre une composition de ses membres également plus étendue, pour laquelle la Commission s'en remet au Comité Exécutif de l'Union.

Commission 19. (VARIATION DES LATITUDES)

1. La Commission tient à exprimer sa sincère gratitude pour le travail de Monsieur Carnera, en particulier pendant la période difficile que nous avons traversée.

2. La Commission recommande que le Bureau Central soit transféré de Capodimonte, où M. Carnera le dirigeait, à Turin, où M. Cecchini se chargera de la direction.

3. La Commission sollicite la coopération du Gouvernement du 'Commonwealth of Australia', afin d'obtenir que les observations de variation de latitude soient continuées à Adelaide, à cause de leur grande valeur pour le programme international d'observations concertées. Une aide financière pour la construction d'un bâtiment et l'exécution du travail pour une période provisoire de 7 ans, assurerait que ce travail important soit repris.

4. La Commission demande une subvention spéciale de huit mille frans-or pour la publication des résultats des observations de variation de latitude jusqu'à la fin de cette année.

5. La Commission recommande que la subvention annuelle de trois mille francs-or, précédemment allouée au Bureau Central, soit renouvelée.

6. La Commission demande une subvention spéciale de mille francs-or pour couvrir les frais de déménagement des archives, documents, machines à calculer, etc. du Bureau Central de Naples à Turin.

7. Il est instamment recommandé que les cahiers d'observation soient transmis par les stations de latitude au Bureau Central aussi rapidement que possible, afin que le Bureau Central puisse exécuter son travail et en publier les résultats assez tôt pour satisfaire les besoins des usagers.

8. Il est proposé que l'U.A.I. exprime à l'Instituto para a Alta Cultura et à l'Observatoire astronomique de Lisbonne le grand intérêt qu'elle porte à l'exécution d'observations de variation de la latitude au moyen du grand télescope zénithal Askania, appartenant à l'Instituto Geografica e Cadastral de Lisbonne.

9. L'attention est appelée sur le grand intérêt qu'il y aurait à établir des lunettes photographiques zénithales en différents points de la terre, non seulement pour améliorer nos connaissances sur le mouvement du pôle, mais aussi pour receuillir les données indispensables relativement aux mouvements propres en déclinaison, ainsi que des données utiles pour la détermination des constantes du système solaire. Pour déterminer le mouvement du pôle, il faudrait disposer de plusieurs stations de même latitude, tandis que pour déterminer les mouvements propres des stations de latitudes différentes seraient nécessaires.

Commission 20. (PETITES PLANÈTES, COMÈTES ET SATELLITES)

1. La Commission recommande que désormais la comète périodique Pons-Coggia-Winnecke-Forbes soit dénommée comète Crommelin.

2. La Commission recommande que l'adjonction de nombres au noms des comètes soit seulement pratiquée dans le but de faire une distinction entre les comètes périodiques

portant le même nom (ou ensemble de noms) qu'une comète antérieurement découverte et que les autres comètes périodiques, ainsi que toutes les comètes non périodiques, soient désignées simplement par l'année et une lettre (ou l'année et un nombre), cette désignation étant complétée par le nom du découvreur. Par exemple, les comètes du Toit seraient ainsi désignées, dans l'ordre de leur découverte (*P*/ indiquant une comète périodique): 1941 VII *P*/ du Toit-Neujmin-Delporte, 1944 III *P*/ du Toit (1), 1945 *c P*/ du Toit (2), 1945 *d* du Toit, et 1945 *g* du Toit.

3. La Commission recommande qu'à partir des éphémérides de Petites Planètes pour 1950, l'intervalle de ces éphémérides publiées dans les volumes annuels, soit de 10 jours, le choix des dates étant fait de manière à s'accorder avec la règle relative aux dates standard échelonnées de 40 en 40 jours, le nombre des dates d'éphémérides restant fixé à six.

4. La Commission recommande qu'à partir du début de l'année 1950, l'intervalle utilisé normalement pour les éphémérides de comètes, soit de 10 ou de 5 jours, les dates étant choisies de manière à correspondre aux dates standard échelonnées de 40 en 40 jours. Toutefois, dans tous les cas où en raison d'un mouvement à grande vitesse ou d'un changement rapide de mouvement, l'interpolation des positions ou la détermination des vitesses instantanées du mouvement seraient incommodes pour l'observateur, le calculateur devrait fournir des éphémérides comportant des intervalles de 2 jours où de 1 jour.

5. La Commission recommande que dans les éphémérides de Petites Planètes la variation soit donnée sous deux formes. D'une part on la donnerait sous la forme habituelle, et d'autre part on donnerait le rapport $\Delta\delta\ (1°)/\Delta\alpha\ (1°)$, le numérateur et le dénominateur correspondant respectivement aux variations de déclinaison et d'ascension droite, pour une variation de $+1°$ de l'anomalie moyenne.

6. La Commission recommande que toutes les observations soient publiées avec toute la précision que comportent les mesures et les réductions; de plus, que les éphémérides de Petites Planètes pour lesquelles on demande des observations précises, soient pourvues d'un signe qui indique aux observateurs que, dans ce cas, ils ne doivent pas se contenter de positions approximatives.

7. La Commission recommande que des numéros définitifs soient assignés aux nouvelles petites planètes, lorsqu'elles ont été observées à deux oppositions et qu'une orbite satisfaisante a été obtenue. Dans le cas d'une planète qui passe plus près de la Terre que l'orbite de Mars, un numéro définitif peut être donné après une seule opposition, à la condition que la planète ait été bien observée, et qu'une orbite satisfaisante ait été obtenue.

8. La Commission recommande que le volume annuel des éphémérides de Petites Planètes contienne un appendice indiquant les éléments orbitaux et la documentation leur ayant servi de base.

Lorsque de nouveaux éléments sont donnés pour la première fois dans un volume annuel, on donnera le nombre des observations sur lesquelles repose l'orbite et l'intervalle de temps qu'elles embrassent, la nature des perturbations utilisées, l'importance des résidus et une référence à la publication relative à la correction de l'orbite.

Lorsque les données de base n'auront pas été publiées, le nom de l'institution ou du calculateur responsable sera donné. Lors des années suivantes, on indiquera dans quelle éphéméride annuelle cette information a été publiée, ainsi que les nouvelles références, s'il y a lieu.

9. La Commission recommande que les observateurs soient invités à effectuer un plus grand nombre d'observations de l'éclat des comètes, et surtout des mesures plus sûres. De plus, les détails relatifs aux méthodes d'observation employées devraient être fournis dans la publication définitive.

10. La Commission recommande que le centre des Petites Planètes à Cincinnati soit maintenu; qu'il continue la publication des *Minor Planet Circulars* et que, à partir des

éphémérides pour l'année 1950, le centre publie le volume annuel d'éphémérides sous les auspices de l'U.A.I.

11. La Commission recommande qu'une subvention annuelle de mille dollars soit donnée au centre des Petites Planètes pour la publication de ces circulaires et éphémérides.

12. La Commission recommande que le centre des Petites Planètes à Cincinnati soit autorisé à attribuer des désignations provisoires et des numéros définitifs aux Petites Planètes, et à approuver et confirmer les noms proposés pour elles par les auteurs de leur découverte.

13. La Commission attire l'attention sur le manque d'observations des comètes faibles par les observatoires de l'hémisphère sud et recommande que des mesures soient prises par les observatoires convenablement équipés, pour obtenir spécialement dans le cas des comètes périodiques, au moins les observations essentielles de positions et de magnitude, lorsque les comètes ne sont pas observables dans l'hémisphère nord. Elle recommande que ces observations soient communiquées sans délai au Bureau de l'U.A.I.

14. La Commission émet le vœu que soit poursuivie la recherche entreprise à l'Observatoire de Nice, en vue d'identifier les astéroïdes découverts depuis 1900 et dont on n'a pu obtenir que deux positions.

15. La Commission exprime de nouveau un vif intérêt pour les *Research Surveys of Minor Planets*, préparés et publiés sous la direction de son président d'honneur A. O. Leuschner, et recommande qu'ils soient continués. Elle exprime le vœu que les moyens puissent être trouvés pour la réalisation de cette œuvre.

Commission 22. (MÉTÉORES)

1. La Commission recommande que des observations de météores faites simultanément par les méthodes électroniques (radar) et visuelles ou photographiques soient étendues, parce que cette commission est convaincue que la continuation et l'extension des observations électroniques (radar) sont actuellement essentielles pour le progrès de l'astronomie relative aux météores et les recherches qui s'y rattachent.

2. La Commission recommande que des cartes stellaires destinées aux observations visuelles de météores soient préparées, et qu'une sous-commission soit constituée pour étudier la forme de ces cartes et les modalités de leur publication; cette commission sera présidée par M. Millman et elle comprendra MM. Bečvář, Olivier et Prentice.

3. Que les astronomes appellent l'attention des physiciens sur l'application des méthodes nouvelles de recherche à l'étude des météorites faite dans les laboratoires; de telles recherches doivent embrasser d'une façon systématique toutes les classes représentatives de météorites.

Commission 22. (MÉTÉORES)

Sous-commission de la lumière zodiacale et de la lumière du ciel nocturne

1. En vue de la recherche d'une influence possible de matériaux extra-terrestres sur l'ionisation anormale de l'ionosphère, il y a lieu d'effectuer des mesures aussi précises que possible des variations saisonnières et autres de la brillance de la lumière zodiacale.
(Résolution transmise par la commission mixte de l'ionosphère du Conseil International des Unions Scientifiques.)

2. Pour permettre la compréhension des processus atomiques dans l'ionosphère, il est nécessaire d'obtenir des spectres des aurores polaires et du ciel nocturne avec une meilleure définition et une plus grande dispersion que ceux obtenus jusqu'à présent.
(Résolution transmise par la commission mixte de l'ionosphère du Conseil International des Unions Scientifiques.)

3. La sous-commission, prenant en considération le plan de travail étendu, suggéré par le Dr Whipple, estime qu'elle doit être tenue au courant de tous les progrès réalisés dans l'étude de la haute atmosphère, quelles que soient les méthodes utilisées.

Elle souhaite qu'à cet effet une liaison étroite soit établie entre elle et les commissions de l'Union Géophysique Internationale et de l'U.R.S.I., s'occupant de problèmes connexes.

Commission 23. (Carte du Ciel)

1. L'Assemblée Générale de l'U.A.I. et la Commission de la Carte du Ciel attirent l'attention des Gouvernements du Commonwealth et des Etats Australiens sur l'importance qui s'attache à l'achèvement des zones du *Catalogue Photographique du Ciel* confiées aux observatoires australiens; elles leur demandent d'en favoriser l'exécution en programme d'urgence.

Les dernières lacunes du *Catalogue Photographique* nuisent à l'utilisation globale de cet instrument scientifique précieux, qui a demandé tant d'efforts internationaux; elles sont d'autant plus regrettables que l'essentiel du travail a déjà été fourni. L'U.A.I. serait reconnaissante à Monsieur H. W. Wood, Government Astronomer, Sydney, New South Wales, d'accepter la direction de cet achèvement et à Monsieur le Dr R. v. d. R. Woolley, Directeur de l'Observatoire du Commonwealth, Canberra, de lui fournir les aides nécessaires.

La Commission de la Carte du Ciel s'engage à demander l'aide financière de l'U.A.I. pour la publication des derniers volumes, lorsque les manuscrits seront prêts pour l'impression.

2. La Commission de la Carte du Ciel, désireuse de voir se terminer la publication du *Catalogue Photographique*, demande à l'U.A.I. de mettre à sa disposition, en plus des fonds qui lui ont été attribués et qui ne sont pas encore dépensés, une somme de vingt-et-un mille francs-or pour couvrir les frais d'impression de 5 volumes du Catalogue, appartenant aux zones laissées en souffrance par les Observatoires de Potsdam, de Perth et de Rio-de-Janeiro et dont les manuscrits, préparés par les Observatoires d'Oxford et d'Edimbourg, pourraient être imprimés d'ici 1951.

Commission 24. (Parallaxes stellaires et Mouvements propres)

La Commission recommande que le Comité Exécutif soit prié d'allouer un montant de $1500 pour les frais d'impression et de reliure de la troisième édition du *General Catalogue of Parallaxes*. L'Observatoire de Yale a entrepris la compilation et la préparation du manuscrit dactylographié pour l'impression.

Commission 27. (Étoiles variables)

1. La Commission recommande que de petites cartes soient publiées pour chaque étoile variable nouvellement découverte, quand cette étoile ne figure dans aucun catalogue méridien.

2. La Commission recommande qu'une subvention de $250 soit mise à la disposition de son président pour rétribuer un dessinateur qui serait chargé de préparer des cartes d'étoiles variables australes pour les astronomes amateurs.

3. La Commission tient à mettre en relief l'importance des observations visuelles de certaines classes d'étoiles variables.

4. La Commission approuve les trois résolutions proposées par MM. H. N. Russell, J. E. Merrill et N. L. Pierce:

1°. Les époques des minima des variables à éclipses doivent être publiées individuellement, en Temps Moyen de Greenwich, c'est-à-dire, en faisant commencer le jour à midi moyen de Greenwich. Ces époques seront héliocentriques, et exprimées en jours et fractions décimales du jour. En aucun cas, la publication ne pourra être limitée à celle d'une époque normale. Si l'on veut donner les résidus des observations par rapport à une

éphéméride, on fournira le résidu correspondant à chaque minimum observé, ainsi que la formule numérique ayant servi au calcul de l'éphéméride.

2°. Pour remédier autant que possible au manque d'observations pendant les dernières années, il est recommandé de déterminer, au cours des deux ou trois années à venir, les minima de toutes les variables à éclipses intéressantes, non seulement de celles qui offrent un mouvement de la ligne des apsides, mais encore de celles dont la période semble présenter des fluctuations. Les observations visuelles peuvent rendre ici de grands services.

3°. L'étude détaillée des systèmes binaires à éclipses les plus intéressants exigeant la connaissance de leurs variations spectrales, il est recommandé de mener autant que possible simultanément les observations photométriques et les observations spectrographiques. Les unes et les autres devront être concentrées sur le plus court intervalle de temps possible. La même recommandation s'applique aussi à l'étude des céphéides brillantes, pour lesquelles on peut obtenir des spectrogrammes à grande dispersion.

5. La Commission signale l'importance des observations spectrographiques d'étoiles variables dans l'hémisphère sud.

6. La Commission a approuvé les règles pour la dénomination des étoiles variables, qui ont été provisoirement adoptées par la sous-commission de la dénomination des étoiles variables.

Ces règles sont:

Doivent être dénommées:

(*a*) les variables périodiques dont le type, la période et la courbe de lumière sont connus;

(*b*) les variables non périodiques dont le type a été bien établi;

(*c*) les variables dont le type paraît être évident, bien qu'aucun autre détail ne soit donné.

Le choix des étoiles, satisfaisant aux règles mentionnées ci-dessus, doit reposer sur une discussion stricte de toutes les données.

7. La Commission propose que la subvention annuelle accordée à M. Banachiewicz pour la publication des éphémérides des étoiles doubles à éclipses, soit continuée à raison de 1000 (mille) francs-or, à la condition que les dates soient données exclusivement dans la période julienne.

8. La Commission a décidé de demander à l'Assemblée Générale de faire imprimer et distribuer une traduction en anglais de l'introduction, de la liste des auteurs russes et des remarques du nouveau catalogue général des étoiles variables, publié par MM. Kukarkin et Parenago à la demande de l'U.A.I. Le nombre des pages données en langue et caractères russes est d'environ vingt. Une subvention unique de 250 dollars serait nécessaire probablement.

9. La Commission a décidé de demander à l'Assemblée Générale de faire imprimer et distribuer la 44ième liste des noms d'étoiles variables, dont le manuscrit a été préparé par MM. Kukarkin et Parenago. La liste contient la dénomination de 266 étoiles variables nouvelles. Une subvention annuelle de 250 dollars suffira probablement pour couvrir les frais.

10. La Commission demande que le Bureau de l'Union entreprenne la publication de la liste des observations inédites des étoiles variables, dont M. Grouiller avait été chargé en 1938. M. Brun a communiqué que le manuscrit se trouve à l'Observatoire de Lyon prêt pour la publication.

11. La Commission approuve la formation d'une commission nouvelle (42) sur les étoiles doubles photométriques.

Commission 28. (NÉBULEUSES EXTRA-GALACTIQUES)

La Commission attire l'attention sur le fait que les remarquables photographies de nébuleuses faites par le docteur C. O. Lampland de l'Observatoire Lowell n'ont pas encore

été publiées. La Commission considère qu'il serait d'une grande valeur scientifique de publier au moins des photographies sélectionnées parmi ce matériel étendu. Elle espère sincèrement que les fonds nécessaires à cette publication pourront être obtenus de l'une ou l'autre des organisations astronomiques américaines intéressées.

Commission 29. (SPECTRES STELLAIRES)

1. La Commission recommande au Comité Exécutif que la Sous-commission des spectres des novae soit étendue afin d'embrasser les spectres de toutes les étoiles variables; que la Commission 27 (Etoiles variables) ainsi que la Commission 29 (Spectres stellaires) désignent chacune deux ou trois membres qui feraient partie de cette nouvelle sous-commission, et que son nom soit: 'Sous-commission des spectres des étoiles variables.'

2. La Commission recommande qu'une compilation et un atlas des spectres moléculaires obtenus au laboratoire présentant un intérêt astrophysique soient faits et publiés aussitôt que possible.

3. La Commission recommande que le projet de M. Schwassmann de photographier le ciel entier avec de grands télescopes Schmidt pourvus d'un prisme objectif soit exécuté autant que possible. Si plusieurs observatoires collaborent à ce plan, des rapports ainsi qu'un échange d'informations seront nécessaires. Le président de la Commission 29 servira d'intermédiaire.

Commission 31. (HEURE)

1. M. A. Danjon est proposé comme représentant de la Commission 31 (C.I.H.) auprès du C.C.I.R. (Comité Consultatif International des Radiocommunications).

2. La Commission recommande que les observateurs veuillent bien mentionner en publiant leurs résultats, si les observations ont été faites dans les deux positions de la lunette et s'il a été tenu compte de l'inégalité et des irrégularités des tourillons.

3. La Commission recommande, suivant la suggestion qui lui est faite par l'U.R.S.I. (Union Radio-Scientifique Internationale), que les astronomes déterminent, en collaboration avec les radio-électriciens, la vitesse de propagation des ondes longues. Dans ce but, il serait très désirable que la station d'émission d'Annapolis (N.S.S.) reprenne ses émissions horaires sur ondes longues (16.000 m.).

4. La Commission émet le vœu que le *Bulletin Horaire* reprenne la publication des comparaisons mutuelles des garde-temps, publication qui a été interrompue en 1936.

5. Il serait souhaitable que les observatoires qui commandent les émissions des signaux horaires scientifiques prennent toutes dispositions pour que, d'un jour à l'autre, les corrections de ces signaux ne varient pas d'une manière trop sensible. (Cette demande est faite par les géodésiens qui désirent déterminer immédiatement les marches de leurs garde-temps.)

6. Une subvention annuelle de $4.400 est demandée pour le fonctionnement du Bureau International de l'Heure.

Commission 34. (MATIÈRE INTERSTELLAIRE ET NÉBULEUSES GALACTIQUES)*

Les spectres des étoiles des premiers types dans l'hémisphère sud devront être déterminés aussitôt que possible.

* Cette résolution a été reçue par le Secrétaire Général après la dernière Assemblée Générale; par conséquent elle n'a pas pu être approuvée par celle-ci.

Commission 36. (SPECTROPHOTOMÉTRIE)

La Commission reconnaît l'utilité d'exprimer les intensités des raies en unités Fraunhofer $10^6.\Delta\lambda/\lambda$, comme cela a été proposé par le Dr Dunham et par la sous-commission des unités d'intensité. D'autre part elle est convaincue que pour beaucoup de problèmes les unités de largeur équivalente $\Delta\lambda$ conservent leur valeur. Elle demande qu'on évite d'employer d'autres unités en dehors de celles ici mentionnées, excepté dans des cas exceptionnels.

Les termes et les symboles suivants devront être employés:

largeur équivalente W, exprimée en général en milli-Ångström (mA.);

largeur réduite A, exprimée en Fraunhofer (F).

Commission 38. (ÉCHANGE DES ASTRONOMES)

La Commission a résolu de demander a l'U.A.I. une subvention annuelle de quatre mille dollars pour l'aider dans ses efforts pour développer les échanges d'astronomes.

PART III

RAPPORTS ET COMPTES RENDUS

3. COMMISSION DES NOTATIONS, DES UNITES ET DE L'ECONOMIE DES PUBLICATIONS

PRÉSIDENT INTÉRIMAIRE: B. STRÖMGREN, *Director of the University Observatory, Copenhagen, Denmark.*

MEMBRES: MM. Bosler, Chant, Horn d'Arturo, McCrea, Shaw.

At the Stockholm meeting of I.A.U. in 1938 the General Assembly at the recommendation of Commission 3 adopted a list of notations proposed by the Commission. The list was published in the *Transactions* of the I.A.U., **6**, 345–55, 1938.

It would appear desirable now to reconsider the list, and the problem of standardization of astronomical notation.

A survey of astronomical papers and publications that have appeared after the adoption of the list of notations, with a view to determining to what extent standardization has been achieved, might be useful as a guide to future work of the Commission in this field.

Renewed discussion by the Commission of the following three general questions would seem of importance:

1. To what extent does it appear desirable that notation in the various branches of astronomy be standardized?
2. How should a revised list of notation covering the fields for which unification is desirable be worked out?
3. How could actual standardization of the notation used in astronomical publications best be obtained?

B. STRÖMGREN
Acting President of the Commission

Report of Meetings

ACTING PRESIDENT: Prof. B. STRÖMGREN.

SECRETARY: Prof. W. H. MCCREA.

The Commission held two meetings and adopted the draft report. The Commission heard a summary of the view of the International Geodetic Union presented by M. P. Tardi, President of the Union's Commission on Notations, and noted with satisfaction that the Union has adopted part of the I.A.U. list of notations.

In the discussion of the Draft Report it was agreed that the object of the Commission's work on standardization of notation is not to interfere with the liberty of authors but to help authors, when preparing their work for publication, by providing them with a comprehensive list of approved notations. Several speakers pointed out, however, that the existence of the I.A.U. list is not well known and also that it is not easily accessible to authors in a convenient format. The Commission resolved therefore to recommend to the Executive Committee the distribution, in adequate numbers, of reprints of the list. The Commission believes also that, by thus making authors more familiar with the list, its revision from time to time will become more practicable and also more effective.

The discussion concerned itself also with the scope and methods to be adopted by the Commission in reconsidering the existing list during the interval before the next General Assembly of the Union. The Commission took note of a number of particular suggestions to which it agreed to give sympathetic consideration in its work. Among these was a suggestion by Prof. E. Hertzsprung that an agreed abbreviation for the name of any particular observer be fixed for use in *all* lists (double stars, variable stars, etc.) in which such an abbreviation is required. The Commission agreed to give similar consideration to Dr C. W. Allen's suggested adoption of a term for general astronomical, physical and

mathematical use which will be analogous to the terms *decibel* and *magnitude* but having 10 as the base: the word *dex* is suggested, so that for example 10^{39} would be written 39 dex.

The Commission also endorsed the view of Prof. E. Hertzsprung that authors should state explicitly the meaning of any error quoted, i.e. whether it is the probable error, mean error, etc.

Dr F. Link informed the Commission of plans of the National Observatory, Prague, for publishing lists of astronomical and astrophysical constants. While such lists mainly concern matters outside the scope of Commission 3, it recognizes that they will aid its work by encouraging the use of standard notations.

4. COMMISSION DES EPHEMERIDES

PRÉSIDENT: M. G. FAYET, *Bureau des Longitudes, 3 Rue Mazarine, Paris (6e).*

MEMBRES: MM. Benitez, Carnera, Clemence, Comrie, Michkovitch, Sadler, Sconzo, Subbotin.

Les circonstances critiques dues à la guerre ont eu pour conséquences, particulièrement en ce qui concerne l'office de la *Connaisance des Temps*, d'entraver fréquemment la réalisation des calculs assumés à la suite d'une entente internationale et, en outre, d'empêcher, ou tout au moins de retarder, la communication des résultats aux autres instituts de calcul.

Le volume annuel des positions apparentes des étoiles fondamentales, dont l'office du *Nautical Almanac* assure la publication depuis 1941, a paru régulièrement. Plusieurs modifications touchant sa confection ont été envisagées; elles ont rapport aux valeurs adoptées pour les *Day numbers* et aux corrections de parallaxe. Il conviendra sans doute de procéder à une nouvelle répartition des calculs entre les divers offices participants. Il est désirable, d'autre part, que des mesures soient prises afin que cette publication indispensable puisse être mise à la disposition d'un plus grand nombre d'observatoires.

Les offices américain et anglais se sont entendus pour donner prochainement, dans leurs volumes respectifs, des éphémérides précises de Pluton et des quatre principaux astéroïdes Cérès, Pallas, Junon, Vesta.

Les publications aéronautiques annuelles (*Air Almanac*; *American Air Almanac*; *Éphémérides Aéronautiques*) ont profité de nombreuses améliorations et leur forme actuelle peut être considérée comme à peu près définitive.

D'importantes contributions, dues à nos collègues américains et concernant, soit les constantes astronomiques, soit la théorie du Soleil ou des grosses planètes, sont venues accroître d'une manière très appréciable nos connaissances sur ces questions. Les imperfections ou lacunes, que ces recherches ont mises en évidence, ont démontré la nécessité de reconsidérer le problème général du mouvement des planètes principales. Il s'agit d'une œuvre considérable qui exigera une collaboration de grande étendue.

Plusieurs tables fort utiles ont été élaborées et publiées par les soins de l'office du *Nautical Almanac*.

En complet accord avec mes collègues, MM. Clemence et Sadler, j'estime qu'un changement vraiment utile (et qui devra porter sur l'ensemble) ne pourra être apporté aux constantes astronomiques fondamentales, si l'on n'a pas, au préalable, expliqué d'une façon absolument satisfaisante, les écarts qui existent entre la théorie et l'observation.

Le programme de la prochaine Réunion comporte l'examen des questions suivantes:

PROPOSITIONS FAITES PAR MM. CLEMENCE ET SADLER

1. Questions concerning the volume *Apparent Places of Fundamental Stars.*

(*a*) *Day Numbers.* It is considered desirable that the apparent places should all be based on the same Day Numbers, which could be circulated in advance by the Nautical Almanac Office, as at present. The Office of the American Ephemeris is at present engaged in a new expansion of the nutation including all terms to $0''.0001$, and it is recommended that the Day Numbers A, B, A′ and B′ should eventually be deduced from the nutation so calculated, including terms to $0''.0002$, and published to $0''.001$.

As regards the aberration it is recommended that the Day Numbers C and D should be computed directly from the motion of the Earth referred to a suitable fixed frame of reference (instead of from multiples of the sine and cosine of the Sun's longitude as at present); it is hoped that specific proposals will be available for discussion at the meeting. It is further recommended that the terms in the aberration depending on the eccentricity of the Earth's orbit should continue to be omitted.

(*b*) *Parallaxes.* The apparent places are corrected for annual parallax only when this is not less than 0".100: it is suggested that it would be more logical to include corrections for parallax in all cases where it is sensible. It will be several years before this can be brought into practice; if adopted, the year 1954 is suggested.

(*c*) *Circumpolar Stars.* From time to time suggestions have been made that the number of circumpolar stars is insufficient (*Trans. I.A.U.* **6**, 359 (1938)).

(*d*) *Distribution.* There is some evidence that copies of the volume are not reaching all observatories that have a need for it. The British Government pays for the cost of printing and expects to recover part of the cost from the very small sales; free distribution must therefore be limited to one copy to the principal observatory in each country, with a further supply of copies to the Offices contributing to the calculations. If there is, in fact, a shortage of copies due to monetary restrictions it is suggested that the Union might be able to facilitate payment.

2. Questions concerning the *Nautical Almanac* and other ephemerides.

(*a*) *Number of Apparent Places of Stars.* Surveyors have been complaining that the number of stars retained in the *Nautical Almanac* is insufficient for their purpose, while the separate volume is unnecessary except for geodesists. It is therefore suggested that the number of 200 recommended in the resolution adopted at the Paris meeting as a limit for the number of stars in the ephemerides should be amended to 'about 300'; the reduced accuracy should be retained, since it is ample for navigators and surveyors.

3. General astronomical questions:

(*a*) *Fundamental Constants.* It is our opinion that no change should be made in the system of fundamental astronomical constants until at least some explanation is forthcoming of the discrepancies between theory and observation; and that any change should be introduced as a part of a systematic revision of the whole system.

(*b*) *Distribution of Astronomical Calculations.* It is felt that the present distribution of astronomical calculations between the five contributing countries is far from satisfactory, particularly in regard to the apparent places of stars. Apart from other considerations, the Institute of Theoretical Astronomy in Leningrad is at present duplicating the computation of 420 FK3 stars. With modern computing equipment the completion of a large routine programme (such as, for instance, the calculation of apparent places of stars) involves little extra work in excess of the planning, preparation and completion of a small programme; centralization would further help to secure that uniformity which is an essential to obtaining the fullest information from the discussion of observations. It would therefore appear that any redistribution should take advantage of this, to enable the routine work to be done more efficiently, and thus to permit the contributing Offices more time for non-routine work. This would appear to be a question which could properly be discussed between the Directors of the National Ephemerides prior to the meeting.

M. le Dr F. LINK, de Prague, adresse les propositions suivantes:

Les renseignements fournis par les Ephémérides, relativement aux éclipses de Lune, devraient être complétés et modifiés de la manière qui suit:

1° Comporter les instants principaux de l'éclipse avec les angles de position et la grandeur maxima de l'éclipse.

2° Les éléments de l'éclipse, qui supposent l'uniformité du mouvement du Soleil, et surtout de la Lune, pendant plusieurs heures, seraient remplacés par un tableau donnant par exemple, de 10 en 10 m. de temps, la position relative du centre de la Lune au centre de l'ombre, en coordonnées polaires et rectangulaires rapportées à l'équateur. Ces valeurs seraient calculées à partir des positions exactes des deux corps.

3° Le même tableau contiendrait, en intervalles de temps plus espacés, les parallaxes, les rayons du Soleil et de la Lune, ainsi que la libration et l'angle de position de l'axe du dernier corps.

4° On donnerait la carte avec les terminateurs de l'ombre calculés comme on vient de l'indiquer. La carte serait complétée par un tableau fixant la position géographique du

terminateur entier, à l'heure ronde la plus voisine du milieu de l'éclipse. Ce tableau serait disposé d'une façon analogue au tableau IV figurant dans l'article que M. Link a consacré à cette question, dans le *Bulletin Astronomique* (Tome XIII, fascicule 3).

Voici maintenant les rapports concernant l'activité des divers instituts de calcul chargés de la publication des volumes nationaux d'ephémérides.

Report of the Office of the 'American Ephemeris' to Commission 4, I.A.U.

This Report covers the years 1938–47, inclusive. A. J. Robertson retired in 1940 and was succeeded as director by W. J. Eckert, who resigned in 1945 and was succeeded by G. M. Clemence.

The following changes have occurred in the construction of the *American Ephemeris and Nautical Almanac*, in addition to those mentioned in the 1938 report. From 1941 onwards the authority for the places of fundamental stars is the FK3, and the authority for the places of stars occulted by the Moon is the *Catalogue of* 3539 *Zodiacal Stars for the Equinox* 1950.0, *Astr. Papers Amer. Eph.* Vol. **10**, pt. II. From 1942 the angular distance of the Moon from the Sun is given to the nearest minute of arc, twice daily. From 1948 the ephemerides of Jupiter's satellites VI and VII are based on improved elements; and occultation predictions for a fifth station in the U.S.A. are included. The Introduction was rewritten in the volume for 1944 in order to remove some ambiguities and to correct some erroneous statements. Where disagreement exists between the Introductions in the volumes for 1944 and 1943, the Introduction is correct in the volume for 1944 and incorrect in 1943 and some preceding years, but it has not been possible in all instances to determine the exact year when a statement in the Introduction ceased to be true; the Office will make a specific investigation of any specific matter on request. The most serious example is the statement that the nutation used in computing the ephemerides of the Sun, Moon, and planets is taken from Newcomb's tables of the Sun, which has not been done since about 1918.

Emergencies resulting from the war in Europe prevented or delayed the fulfilment of the international exchange agreements in some cases. In consequence, the conjunctions, phenomena, and configurations of Jupiter's satellites I–IV, customarily supplied by the Office of the *Connaissance des Temps*, were computed here for the years 1945, 1946, and 1947; this was also the case with the apparent places of 32 circumpolar stars for the years 1942–47, inclusive. The apparent places of 166 10-day stars, customarily supplied by the Office of the *Berliner Jahrbuch*, were computed here for 1948, as have been the mean places of 1535 stars for the years 1951–60, inclusive. It should be mentioned that some of this work proved to be duplication which might have been avoided if prompt communication had been possible.

The following changes will be made in the *American Ephemeris and Nautical Almanac* for 1951. The Washington transit ephemeris of the Sun, Moon, and planets will be omitted. The equatorial rectangular co-ordinates of the Sun will be given at intervals of 1 day, and the reduction to the true equinox of date will be omitted. The occultation data will be extended to include stars to magnitude 7·54, and the apparent places of occulted stars will be given. Tables A and B will be omitted as being no longer useful. The list of mean places of fundamental stars will be extended to include about 1550 stars for the convenience of users who desire spectral types and approximate positions of more stars than are now given.

Under a co-operative agreement with the Office of the *Nautical Almanac*, a precise ephemeris of Pluto will be given in the *American Ephemeris and Nautical Almanac* beginning with 1950 or 1951; and precise ephemerides of Ceres, Pallas, Juno, and Vesta as soon as possible, probably 1951 or 1952. Heliocentric positions of Pluto to 1960 have been obtained by numerical integration. For the four asteroids use is being made of approximate integration orbits supplied by the Yale Observatory and the Cincinnati

Observatory. These are being corrected and the numerical integration of the definitive orbits will be undertaken by the Cincinnati Observatory.

The *American Air Almanac* has been published in three volumes a year beginning 1941, with little change in content or arrangement. The introduction of automatic methods of preparation and proof reading has resulted in a standard of accuracy never hitherto attained in a similar publication. The calculations are performed by means of punched cards, which are then used to control a special card-operated typewriter. Plates for printing the book are obtained photographically from the typewritten copy. New punched cards are prepared from the proofs, and these cards are compared by machine with the cards that actuated the typewriter. This method has so far been used for the publication of nearly 20,000,000 separate figures, without a known error. Similar methods will be used for the *American Nautical Almanac* from 1950.

The introduction of punched-card methods of computing has resulted in significant economy and appreciable gains in reliability. More than two-thirds of the routine work of the Office has been adapted to these methods.

Supplements to the *American Ephemeris and Nautical Almanac* were issued for the total solar eclipses of 1940 October 1, 1945 July 9, and 1947 May 20. Another supplement, entitled *Tables of Sunrise, Sunset, and Twilight*, gives the time of sunrise and sunset for every day of the year and for every degree of latitude from the equator to 75° North. The durations of daylight and civil, nautical, and astronomical twilight are given at 2-day intervals. Charts extend these data to the pole; and auxiliary tables extend them to every place on earth throughout the present century.

The apparent places of 162 10-day stars have been supplied annually for the volume *Apparent Places of Fundamental Stars*.

The apparent places of star-pairs for the use of the International Latitude Service in the years 1947, 1948, and 1949 on their northern and southern parallels have been calculated and supplied to the Joint Latitude Commission, by special arrangement with its President, as a result of the emergency occasioned by the war.

The manuscript for *Kleine Planeten* for 1946, received from Prof. Kopff, was reproduced photographically and distributed. Further information on this publication will be found in the report of Commission 20.

A number of contributions have increased our knowledge of motions in the solar system and of the constants of astronomy since 1938. Extensive discussions of observations of the Sun have been made by H. R. Morgan and F. P. Scott, and of Mercury by Clemence. These have led to improved knowledge of the mass of Venus and the mass of the Moon, and have confirmed Spencer Jones's result that the fluctuations in the mean longitudes of the Sun, Moon, and planets are proportional to their mean motions. The relativity effect in the motion of Mercury is precisely confirmed, and the effect in the motion of the Earth has been detected. Observations of Uranus and Neptune have been extensively discussed by L. R. Wylie, and compared with Newcomb's tables. The orbits of these planets from 1780 to 1950 have been obtained by numerical integration and compared with Newcomb's tables by Brouwer, and with observations through Wylie's discussion. In the case of Neptune the numerical integration confirms Newcomb's theory in general, the principal discordance being in the coefficient of the synodic term produced by the action of Jupiter. In the case of Uranus it appears that the numerical integration is not in complete agreement with either the observations or the theory. Appreciable deficiencies in Newcomb's theory are indicated. The work of Brouwer and of Wylie has resulted in a good determination of the mass of Pluto. The solar theories of Newcomb and Leverrier have been compared by K. P. Williams. Clemence and Scott have shown that appreciable inadequacies exist in Newcomb's theory of Mars, of a sort that vitiate the determination of the mass of Venus from its action on Mars. A new determination of the constant of nutation has been made by Morgan.

The defects in existing theories just mentioned, as well as other known inadequacies, indicate that a new attack on the whole problem of the motions of the principal planets is needed. In view of the tremendous mass of observational material accumulated since

Newcomb's time, and of the extensive theoretical and computational work needed to utilize it and to improve the form of the theory, it is evident that a concerted effort is necessary. Accordingly, early in 1947, a joint enterprise was undertaken by the Yale Observatory, the Watson Scientific Computing Laboratory, and this Office, with support for two years assured by the Office of Naval Research. Work is now proceding at these three institutions along several lines simultaneously.

As a first step in the improvement of the general theories, an experimental development is being carried out on the motions of Jupiter and Saturn with the purpose of determining whether it is practicable with modern techniques of calculation to develop these theories with the same degree of perfection as the lunar theory, that is, to express the co-ordinates as sums of strictly periodic functions of the time. The analytic developments have been completed and the first approximation in the numerical work is about half finished.

With the object of improving the mass of Saturn a discussion of photographic observations of the satellites is in progress. A conventional theory of the motion of Mars by Hansen's method is being constructed; and also a new development of the theory of precession and nutation, which will extend Oppolzer's work on the subject to a higher order of accuracy. It is intended shortly to undertake a discussion of observations of Venus to improve the mass of Mercury, and of Jupiter to improve the mass of Saturn. The secular perturbations of Pluto will be determined by a method similar to that used by Brouwer for Encke's comet. Preliminary work on a new fundamental star catalogue is in progress.

Among the results to be expected is a determination of the constant of precession with a precision comparable to that obtained by analysis of stellar proper motions.

An examination of the entire system of astronomical constants is in progress with the object of determining whether it is yet possible to introduce a perfectly consistent system which would not be contradicted by observations, and if so, to determine what corrections to the lunar, solar, and planetary tables would be necessary.

G. M. CLEMENCE

REPORT OF THE (BRITISH) NAUTICAL ALMANAC OFFICE TO COMMISSION 4 OF THE INTERNATIONAL ASTRONOMICAL UNION

This Report covers the period since the 1938 Stockholm meeting, i.e. the years 1938–47 inclusive.

As indicated in the 1938 report the *Nautical Almanac* for 1941 conformed to the resolutions passed at the Paris meeting relating to the publication of a separate volume of apparent places of stars; since then the authority for the fundamental stars is the FK3, and that for occulted stars the *New Zodiacal Catalogue*.

Considerable changes were made in the edition for 1942, when many sections were omitted, including the Occultation Reduction Elements; these were subsequently published for 1942 by the American Section of the Union. From 1943 onwards, it was decided to stop the computation of these Elements and, in lieu, to undertake the reduction of all observed occultations; at the same time it was agreed to undertake responsibility for the annual compilation and discussion previously done by Prof. Brouwer. The discussion for 1943 is in course of publication; the work of reduction is still considerably behind schedule, but it is hoped that the whole occultation programme will shortly be brought up to date. It is intended to publish all observations received, properly reduced, in one central list in the Greenwich Observatory publications, whether or not they have been previously published elsewhere. The programme of predictions, somewhat restricted during the war, is now being continued at its former level with minor modifications.

Many detailed changes have been made in the *Nautical Almanac*, and these are listed, as they occur, in the Preface to each edition. The stress of war and its aftermath has so far made it impossible to publish the *Supplement*, promised in the Preface to the edition for 1942, which is to contain all the permanent tables and explanations, previously given in the *Almanac* itself, together with such added information as can be conveniently

included in the wider scope of a separate publication; in particular, it will contain a summary of the authorities for the data in the *Nautical Almanac* since the first edition of 1767.

It has not been possible to advance the date of publication of the *Nautical Almanac* in accordance with the intention reported at the 1938 meeting, and with the resolution then adopted. Vigorous steps are now being taken to expedite publication and to make the *Almanac* available sufficiently early for the preparation of the minor 'annuaires'. However, the first part of the *Nautical Almanac*, containing the fundamental ephemerides of the Sun, Moon and planets, is now circulated three years in advance to the principal observatory in each country. In co-operation with the Office of the *American Ephemeris*, an astrometric ephemeris of Pluto will be introduced into the *Almanac* from 1951 (or 1950) onwards, while ephemerides of Ceres, Pallas, Juno and Vesta will be included as soon as possible. Other projected changes include the gradual introduction of U.T. as an alternative terminology to G.M.T.

The first edition of *Apparent Places of Fundamental Stars* was issued in 1940 for the year 1941; it has been published annually since then, the scheduled date of publication being April in the year preceding. It contains the apparent places of 1483 10-day and 52 circumpolar stars, based on the FK3 (and its supplement). Its form follows, with but minor amendments, that discussed and agreed at the 1938 meeting of the Union. Difficulties of communication during the war led to temporary redistributions of the calculations; for the years 1942–46, the Nautical Almanac Office computed the apparent places of the 426 stars normally contributed by the Office of the *Connaissance des Temps*. As regards the mean places, it has been decided to print and circulate these to the contributing almanac offices, for each year, in time to serve as a basis for the calculation of the apparent places; for 1948–50 they were computed by the Nautical Almanac Office, and for 1951 and 1952 are based on the calculations made by the Office of the *American Ephemeris*. Now that similar data are available from the Astronomisches Rechen-Institut at Heidelberg a decision as to the authority to be adopted for 1953 onwards will shortly be required. Various other questions regarding the content and distribution of the volume are being brought forward for discussion at the Zürich meeting.

The second volume of *Planetary Co-ordinates for the Equinox* 1950·0 covering the years 1940–60 was published in September 1939; the distribution was consequently interrupted, though every effort was made to send copies through those channels that were open. During 1940, the type, plates and stock for this publication were destroyed (as well as much material for the *Nautical Almanac* itself) leaving only a very small number of copies at the disposal of the Office, for meeting essential astronomical requirements by loan. A photographic reprint is now available.

The navigational work of the Office has been greatly increased, in many directions, not all concerned with astronomical navigation. The *Air Almanac* was redesigned a second time in 1944, and continues to be published in what may now be regarded as an essentially permanent form.

The fifteen volumes of *Astronomical Navigation Tables* covering latitudes S. 69° to N. 79° originally prepared for use by the Royal Air Force, are now generally available; their general content and arrangement were described in the report of the Stockholm meeting. A final volume covering latitudes N. 80° to 89° is under consideration. The *Abridged Nautical Almanac*, which has remained essentially unchanged since 1929, is being revised, while consideration is being given to the preparation of new tables for the reduction of astronomical observations at sea.

At a recent conference of surveyors a requirement was put forward for a separate *Surveyor's Almanac* and this project is at present being examined; the main requirement is for the positions of a large number of stars to a small degree of accuracy. Neither the almanac for surface navigation nor the volume of apparent places fulfils the requirements.

Various tables have been prepared and published. The *Tables of Depression and Azimuth of the Sun* for latitudes N. 45° to 60° were issued in 1945, giving depressions to 0°·1 at a small interval of time. The *Seven-figure Trigonometrical Tables for every second of time*,

mentioned in the previous report, was published in August 1939. No publisher has yet been found for the 7-figure table prepared by the late Prof. Peters and Dr Comrie, and it has not been possible to implement the resolution regarding these tables adopted by the Union in 1938. The corresponding 8-figure table was published in Germany during 1939 and has since been photographically reproduced both in Britain and U.S.A. During the war, the Office had occasion to produce, for special purposes, two five-figure tables: *Five-Figure Logarithm Tables* is merely a reprint of three existing tables conveniently bound together; the argument for the trigonometrical functions is in degrees and decimals; *Five-Figure Tables of Natural Trigonometrical Functions* has the argument in degrees, minutes and seconds, with an interval of 10″ (1″ for the cotangent to 7° 30′).

Since 1938, the Office has done no fundamental astronomical work.

D. H. SADLER

BUREAU DES LONGITUDES (PARIS)

Lorsque furent définitivement arrêtées les modalités concernant la publication du volume international *Apparent Places of Fundamental Stars*, la *Connaissance des Temps* se chargea de calculer annuellement 426 étoiles de 10 en 10 jours et 32 circompolaires.

Les grandes difficultés résultant de la guerre n'ont pas permis, durant cette période, d'assurer régulièrement la collaboration convenue: certains calculs n'ont pu être effectués et les résultats, portant sur d'autres, n'ont pu être transmis en temps utile à l'office du *Nautical Almanac*, qui assure l'impression.

La publication de la *Connaissance des Temps* elle-même a subi des retards considérables, que nous nous sommes efforcés de rattraper peu à peu, malgré le nombre restreint de nos calculateurs et le manque de machines à calculer: on escompte que le volume de 1949 pourra paraître avant la fin de 1948.

Notre office a assumé, d'autre part, la tâche de calculer et publier, d'après les Tables de R.-A. Sampson, des éphémérides détaillées pour les quatre premiers satellites de Jupiter. Ce travail a toujours été réalisé, mais à plusieurs reprises, pendant la guerre, nous n'avons pu faire parvenir les résultats aux offices anglais et américain.

La publication annuelle du volume des *Ephémérides Aéronautiques*, commencée en 1935, a été poursuivie régulièrement. D'assez nombreuses modifications, dont voici un résumé des principales, ont été apportées depuis 1938, à la forme primitive.

Dans les feuilles quotidiennes relatives au Soleil, aux grosses planètes et à la Lune, on ne donne plus l'ascension droite verse, mais l'angle horaire du méridien de Greenwich. L'intervalle de temps universel, argument de ces feuilles, a été ramené de 20 minutes à 10 minutes. La correction de parallaxe, qui doit être appliquée aux hauteurs lunaires, est fournie maintenant, pour chaque jour, en marge de toutes les feuilles quotidiennes, sous la forme d'un tableau où l'argument est la hauteur.

Depuis 1947, en raison des difficultés d'impression, l'ouvrage est édité en fascicules; à la fin de chacun d'eux se trouvent des tables dont quelques-unes figuraient auparavant dans l'annexe. Je signale les tables nouvelles qui, sous une forme condensée, permettent d'obtenir les heures du lever et du coucher du bord supérieur du Soleil et de la Lune, en un point quelconque situé à l'altitude zéro, entre les latitudes 0° et $\pm 67°$. Enfin, un petit tableau, ajouté récemment, fournit la correction de Coriolis, en fonction de la vitesse et de la latitude.

INSTITUTO Y OBSERVATORIO DE MARINA, SAN FERNANDO, ESPAGNE (M. W. BENITEZ)

Conformément aux conventions arrêtées au Congrès International des Ephémérides tenu à Paris, en octobre 1911, l'office calcule les positions moyennes et les positions apparentes, de 10 en 10 jours, de 396 étoiles non circompolaires dont 377 figurent dans la publication internationale *Apparent Places of Fundamental Stars*, ainsi qu'il en a été décidé lors de la Réunion de l'U.A.I., en 1932.

G. FAYET
Président de la Commission

Report of meeting. 10.30 a.m. on Thursday, August 12, 1948.

PRESIDENT: Dr FAYET.

SECRETARY: Prof. KOPFF.

With Dr Fayet in the chair there were present the following members: MM. Benitez, Clemence, Comrie, Sadler, Sconzo. M. Kopff was present by invitation.

M. Kopff was appointed as secretary and interpreter to the Commission.

M. Fayet read the two resolutions of the General Assembly that had been referred to Commission 4; he proposed that only the first should be considered at the present meeting, namely:

'Que l'Union se charge de donner une définition plus exacte de l'unité de temps.'

After discussion the following recommendation, proposed by Dr Clemence, was adopted for consideration by Commission 31 and, if agreed, then for submission to the General Assembly:

'It is recommended that when it is desired to adopt an invariable unit of time with the greatest possible exactitude, the mean solar second for 1900 January 1 Greenwich Mean Noon should be used.'

The Commission then proceeded to discuss the proposals made by MM. Clemence and Sadler in the Report concerning the volume *Apparent Places of Fundamental Stars* (p. 75).

It was agreed to adopt the Day Numbers as proposed in 1 (*a*), subject to the condition that they will not be used for the calculation of apparent places of fundamental stars before 1956.

The Commission agreed to include corrections for annual parallax for certain stars even when this is less than 0″·100, the details to be arranged and circulated by M. Sadler, if possible in time for introduction for 1954.

No action was considered to be necessary as regards (*c*), the provision of a greater number of circumpolar stars.

Second meeting. The Commission held its second meeting at 11.30 a.m. on August 14, 1948. M. Fayet referred to the proposals by Dr Link relative to lunar eclipses (see p. 76) and stated that Dr Link wished to calculate and publish the data without cost to the Union. It was resolved that:

'La Commission appuie très favorablement le projet formé par l'Observatoire National de Prague, de publier annuellement un Supplément international fournissant des données détaillées concernant les éclipses de lune et les occultations d'étoiles faibles pendant ces éclipses.'

Discussion then took place on the number of stars for which apparent places should be given in the national ephemerides. MM. Kopff and Sadler outlined the plans for the publication of an 'Astronomisch-Geodaetisches Jahrbuch' and a 'Star Almanac', specially designed for surveyors. It was generally agreed to select the limit of 200 suggested in the resolution at the Paris (1935) meeting.

On the question of the revision of the system of fundamental constants, Dr Jackson informed the Commission that the Nominating Committee was appointing a special sub-commission of Commission 4 on this subject; it was agreed to take no further action at this stage. M. Fayet stated that he found it increasingly difficult to calculate the apparent places of all the 10-day stars for which the Office of the 'Connaissance des Temps' was responsible. He suggested that some at least might be taken over by the Institute for Theoretical Astronomy in Leningrad. M. Sadler was of the opinion that it was too soon to enter into any formal agreement, but suggested that the (British) Nautical Almanac Office, which is responsible for the publication, should also accept responsibility for the calculation of these stars as well; he would make informal arrangements for the actual calculations with Dr Subbotin at Leningrad and Dr Hagihara in Tokyo, with a view to formal confirmation at the 1951 meeting of the Union. M. Mikhailov indicated his agreement to this suggestion, which was generally approved.

In the discussion Prof. Banachiewicz remarked that a preliminary suggestion had been made for an international astronomical computing organization.

The President opened discussion on the following resolution referred to the Commission by the General Assembly:

'Que l'U.A.I. considère de nouveau la résolution prise au congrès de 1928 sur la désignation du temps civil de Greenwich, donne à cette résolution une rédaction plus nette, et lui donne la publicité nécessaire pour la faire admettre universellement.'

Both M. Clemence and M. Sadler stated that there were considerable difficulties in the introduction of the terminology U.T. into the navigational almanacs. After discussion it was agreed to recommend the following resolution to the General Assembly:

'La Commission recommande que la désignation "Temps Universel" (Universal Time, Weltzeit) soit seule utilisée par les astronomes pour désigner le temps solaire moyen, compté à partir de minuit au méridien de Greenwich.

'Elle exprime le vœu que cette désignation remplace aussitôt que possible les autres expressions encore employées.'

Third meeting. The third meeting of the Commission was held on August 16, 1948, at 10.30 a.m.

M. Clemence recalled that the Executive Committee referred a question concerning the unit of time to Commissions 4 and 31, and that at the first meeting a resolution on the subject was passed to be referred to Commission 31. Commission 31 has not passed this resolution but M. Danjon has stated that he does not regard action on this matter as urgent. M. Clemence accordingly proposed that Commission 4 should withdraw its resolution on the unit of time, with the intention of dealing with the matter when the whole subject of the system of astronomical constants is discussed in 1951; the sub-commission of Commission 4 would doubtless discuss the question.

M. Kepinski proposed that two pages of the national Almanacs should be devoted to the barycentric co-ordinates of the Sun referred to the equinox of the beginning of the current year. It was agreed that, as these co-ordinates depend on the masses of the planets, it would be desirable to defer the introduction of this ephemeris until improved masses are available as a result of the forthcoming revision of the system of fundamental constants.

M. Mikhailov presented a report of the work done by the Institute for Theoretical Astronomy in Leningrad: he referred to the fact that until 1948 the Institute had performed all the calculations for the 'Annuaire Astronomique de l'U.R.S.S.', but that from 1948 onwards material had been exchanged with the British Nautical Almanac Office. He gave details of the calculations to be undertaken in the future. It was agreed that the Commission thank the Institute for Theoretical Astronomy for its offer of collaboration and that the Directors of the several almanac offices be authorized to arrange among themselves the details of the collaboration, during the next few months.

M. Clemence showed a specimen copy of the new (G.H.A.) form of the American Nautical Almanac and MM. Fayet and Sadler stated that both the French and British almanacs for surface navigation were undergoing revision.

M. Sadler informed the Commission that a request had been received from Commission 20 for the accepted 10-day dates (midnights of which have the integral parts of the Julian Day Number multiples of 10) to be distinguished (by asterisks, special type or in other ways) in the ephemerides of the Sun's equatorial rectangular co-ordinates, particularly those referred to the equinox of 1950.0. The Directors of the national ephemerides agreed to make the necessary arrangements for this to be done.

M. Sadler informed the meeting that satisfactory arrangements had been made between M. Clemence and Prof. Kopff for the calculation of the mean places of the FK3 stars (see p. 80).

M. Fayet then declared the meeting closed and thanked the members of the Commission for their attendance.

5. COMMISSION DES ANALYSES DE TRAVAUX ET DE BIBLIOGRAPHIE

PRÉSIDENT: M. K. LUNDMARK, *Directeur de l'Observatoire, Lund, Suède.*

MEMBRES: MM. Baldet, Bok, Bourgeois, Brasch, Collinder, Mme d'Azambuja, MM. Dittrich, Gabba, E. Gastardi, Guyot, Kukarkin, Neubauer, Nordenmark, Norman, Selga, Seydl, Witkowski.

No report has been received.

Procès-verbal de la séance. Lundi, 16 août 1948

PRÉSIDENT INTÉRIMAIRE: M. P. BOURGEOIS.

SECRÉTAIRE: M. A. DERMUL.

M. le Prof. Lundmark, président de la Commission, sérieusement malade, est empêché d'assister au Congrès et n'a pu établir de rapport. M. E. Holmberg annonce, que ce dernier envisage de publier en langue anglaise une liste des observatoires et des astronomes. La commission fait des vœux pour le prompt rétablissement du Prof. Lundmark.

La première question à l'ordre du jour est la proposition du Comité National Français, transmise à la Commission par l'Assemblée Générale, d'accorder un appui financier à la Bibliographie mensuelle de l'Astronomie (B.M.A.).

A ce sujet, M. F. Baldet soumet à la Commission une demande tendant à obtenir le renouvellement de la subvention annuelle de 500 Frs-or, attribuée antérieurement et la liquidation de la subvention de 1500 Frs prévue pour les années précédentes.

M. Baldet explique que la publication de la B.M.A., incorporée dans le *Bulletin analytique* du Centre National de la Recherche Scientifique, se fera à l'avenir sous forme de tirés à part de ce *Bulletin*.

M. Bourgeois communique à M. Baldet en tant que Président de la B.M.A. que le Comité National des Etats-Unis serait désireux de voir cette bibliographie conçue sur le plan des 'Science Abstracts'.

A la suite d'un échange de vues la recommandation no. 1 est adoptée et sera transmise au Comité des Finances.

M. le Prof. Kopff, Directeur de l'Astronomisches Rechen-Institut fait part de la situation du Jahresbericht: les volumes comportant la littérature de 1941 et 1942 ont été publiés et le premier des deux volumes consacrés aux années 1943–46 est imprimé. M. le Prof. Kopff demande qu'un exemplaire des publications soit adressé dès leur parution à son Institut afin de faciliter le travail de préparation du Jahresbericht.

La Commission appréciant le travail effectué par le Rechen-Institut dans ce domaine, adopte la recommandation no. 2.

Le président fait alors part de l'état d'avancement du travail entrepris pour combler la lacune entre la bibliographie de Houzeau-Lancaster et le Jahresbericht. Il signale qu'une grosse partie des fiches sont déjà rassemblées à Bruxelles et classées.

M. von Klüber lui a communiqué que la moitié du travail dont il avait accepté la charge est terminée et que les fiches se trouvent à l'Observatoire de Potsdam.

M. Slouka, qui avait assumé le dépouillement de la littérature tchécoslovaque, annonce que le travail est pour ainsi dire terminé.

La Commission désireuse de voir l'entreprise se terminer dès que possible adopte la recommandation 3.

La Commission très satisfaite de la communication de M. A. N. Vyssotsky relative à la traduction de la partie astronomique des chroniques médiévales russes dont la publication sera assurée par l'Observatoire de Lund, adopte à ce sujet la recommandation 4.

Suite à la déclaration de M. E. Holmberg concernant la publication par l'Observatoire de Lund, en langue anglaise, d'une liste des observatoires et des astronomes, telle qu'elle fut éditée autrefois par l'Observatoire Royal de Belgique, la question est soulevée de

l'état d'avancement du répertoire sur fiches prévu à l'Observatoire de Lund, au Congrès de Stockholm en 1938 (recommandation 5 de la Commission). M. Holmberg ne peut donner de précisions à ce sujet. M. Bourgeois fait alors part de ce qu'il entrait dans les intentions de l'Observatoire Royal de Belgique de publier une nouvelle édition du travail de M. le Prof. Stroobant et de ses collaborateurs, un travail analogue pour la séismologie étant du reste déjà en cours à cet observatoire.

Etant donné les intentions du Prof. Lundmark, l'Observatoire Royal de Belgique ne mettra son projet à exécution qu'au cas où M. Lundmark se trouverait empêché de mener à bien le sien. Ce qui importe c'est que la liste soit publiée.

La Commission adopte à ce sujet la recommandation 5.

En dernier lieu, la Commission marque par sa recommandation 6, tout l'intérêt qu'elle porte à la création par la Royal Society de Londres d'une commission chargée d'assurer la publication des lettres de Newton, publication qu'elle soutint par sa recommandation 8 prise lors du Congrès de Stockholm, en 1938.

La séance est clôturée à 12 heures.

6. COMMISSION DES TELEGRAMMES ASTRONOMIQUES

PRÉSIDENT: Sir H. SPENCER JONES, *Astronomer Royal, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England*

DIRECTRICE DU BUREAU: MLLE VINTER HANSEN.

MEMBRES: MM. B. H. Dawson, Mikhailov, Shapley, van den Bos.

REPORT OF THE CENTRAL BUREAU FOR ASTRONOMICAL TELEGRAMS

The Bureau suffered a sad loss, through the death on April 5, 1947, of its director Prof. Elis Strömgren who had conducted its work with never failing enthusiasm and with great efficiency since 1922. In June 1947 the supervision of the Bureau was entrusted to the writer. The following report may not be altogether complete owing to my absence, for 6 years, in the U.S.A., when I was out of touch with the activities of the Bureau. The last report by Prof. E. Strömgren was dated February 26, 1938; for the rest of the year very few data have been found, hence my report will cover the period January 1, 1939 to December 1, 1947.

The leading principle of the Bureau has been to procure provisional data for the continuous observation of new objects. The news, if urgent, is transmitted by telegrams, in all other cases through printed circulars, in order to make the services of the Bureau as cheap as possible to our subscribers. A few subscribers have expressed the desire to have all information transmitted to them by telegraphic service, and such an arrangement, costly to the recipients, can be made with any subscriber who desires it.

The work of the Bureau was greatly hampered by the war, but through the persevering initiative of Prof. Strömgren it was possible to keep up the service, even after the invasion of Denmark, on April 9, 1940, by the German armed forces. From October 1941 the Observatory at Lund in neutral Sweden acted as a branch-Bureau. In a few cases the Bureau could not get in touch even with Lund, but succeeded in having the telegrams transmitted via Zürich.

The financial status of the Bureau was often rather precarious on account of the impossibility of collecting the annual dues from many subscribers; but some Danish foundations, particularly the Rask-Örsted foundation, came to the assistance of the Bureau, supplying loans and annual grants. Unfortunately, the international money exchange is as yet not in order, and some subscribers are still much in arrear as regards payments, which prevents the Bureau from repaying the above-mentioned debts incurred during the war.

Prof. B. Strömgren and the staff of the Copenhagen Observatory, particularly the late Mr J. P. Möller, Mr Thernöe and Miss E. Mackeprang have assisted effectively in the work of the Bureau together with some young Danish astronomers of whom Messrs Lorensen, Hesselberg and Naur may be mentioned.

Below is given a list of the telegrams received and transmitted to our subscribers as also of the circulars printed:

	Telegrams		Circulars printed	
Year	Received	Sent		
1939	52	345	72	(Nos. 735–806)
1940	8	33	33	(Nos. 807–839)
1941	39	117	55	(Nos. 840–894)
1942	41	181	37	(Nos. 895–931)
1943	23	140	45	(Nos. 932–976)
1944	14	30	21	(Nos. 977–997)
1945	15	123	27	(Nos. 998–1024)
1946	33	207	51	(Nos. 1025–1075)
1947 (to Dec. 1)	28	306	43	(Nos. 1076–1118)
	253	1482	384	

It is interesting to note that the above figures of telegrams received and sent show in a marked degree the development of the war and of the severities of the German occupation of Denmark, which reached their peak in 1943–44.

The following list gives the names of institutions and astronomers subscribing to the telegrams and circulars. A bracket has been placed around those with whom it has been impossible to establish any connection.

ACTUAL LIST OF SUBSCRIBERS TO TELEGRAMS AND CIRCULARS

Harvard College Observatory, Cambridge, Mass., U.S.A.
Union Observatory, Johannesburg, South Africa.
Commonwealth Observatory, Canberra, Australia.
Royal Observatory, Edinburgh, Scotland.
Royal Greenwich Observatory, Herstmonceux, England.
Norman Lockyer Observatory, Sidmouth, England.
Isidro Polit, Observatorio Fabra, Barcelona, Spain.
Observatorio astronomico, Madrid, Spain.
Observatorio Marina, San Fernando, Spain.
Observatoire, Floirac-Bordeaux, France.
Observatoire, Marseille, France.
Observatoire, Nice, France.
Observatoire National, Paris, France.
Observatoire, Strasbourg, France.
Observatoire, Alger, North Africa.
Sterrewacht, Leiden, Holland.
Osservatorio Capodimonte, Napoli, Italy.
Osservatorio, Milano, Italy.
Osservatorio, Padova, Italy.
Osservatorio, Pinotorinese, Italy.
Observatoire, Bucarest, Roumania.
Observatoriet, Saltsjöbaden-Stockholm, Sweden.
Observatoire, Genève, Switzerland.
Observatory, Helwán, Egypt.
Observatoire, Uccle, Belgium.
(Observatory, Tokyo, Japan).
Observatoire d'Astronomie physique, Meudon, France.
Royal Astronomical Society, London, England.
Osservatorio Monte Mario, Roma, Italy.
Observatoire, Athènes, Greece.
Osservatorio Astronómico, Trieste.
Observatory, Poznań, Poland.
Observatory, Uppsala, Sweden.
Astronomitscheskij Institut, Sternberga, Moscow, Russia.
Observatoire, Beograd, Yugoslavia.
Specola Vaticana, Roma, Italy.
Observatorio, Coimbra, Portugal.
Observatory, Lund, Sweden.
Y. Väisälä, Observatory, Turku, Finland.
Observatorio Nacional, Rio de Janeiro, Brazil.
Institut Astronomique, Sofia, Bulgaria.
Ole Römer-Observatoriet, Aarhus, Denmark.
Institut d'Astrophysique, Paris, France.
Observatoire de Haute Provence, Saint-Michel l'Observatoire, France.
L. E. Cunningham, Students' Observatory, Berkeley, Calif., U.S.A.
Astronomisches Institut, Bern, Switzerland.
The University of London Observatory, London, England.
Osservatorio, Bologna, Italy.
Štátne Observatórium, Skalnaté Pleso, Czechoslovakia.
University Observatory, Oxford, England.
Obserwatorium Warszawa, p.t. Cracow, Poland.
Sternwarte der Thurgauischen Kantonsschule, Frauenfeld, Switzerland.

ACTUAL LIST OF SUBSCRIBERS TO CIRCULARS ONLY

Institute for Theoretical Astrophysics, Blindern (Oslo), Norway.
Observatoire Astronomique, Jassy, Roumania.
National Observatory of the Czechoslovak Republic, Ondřejov, Czechoslovakia.
Lick Observatory, Mt Hamilton, Calif., U.S.A.
Yerkes Observatory, Williams Bay, Wis., U.S.A.
Mt Wilson Observatory, Pasadena, Calif., U.S.A.
U.S. Naval Observatory, Washington, D.C., U.S.A.
Students' Observatory, Berkeley, Calif., U.S.A.
Astronomical Observatory, Cracow, Poland.
Observatoire, Lyon, St Genis Laval, France.
(Issei Yamamoto, Sigaken, Japan).

Société astronomique tchèque, Observatoire Stefanik, Prague-Petřín, Czechoslovakia.
Carter Observatory, Wellington, W. 1, New Zealand.
Brown University Library, Providence, R.I., U.S.A.
Observatoire de Juvisy, Seine et Oise, France.
Astronomical Institute, University, Lwów, Russia.
Astronomical Observatory, Taschkent, Russia.
Sterrewacht, Lembang, Java.
Observatory of the University of Michigan, Ann Arbor, Michigan, U.S.A.
J. F. Cox, Laboratoire d'Astronomie de l'Université, Bruxelles, Belgium.
Observatoire de Toulouse, Toulouse, France.
Institut d'Astrophysique de l'Université de Liège, Cointe-Sclessin, Belgium.
Oswald Thomas, Wien III, Austria.
H.M. Nautical Almanac Office, Bath, Somerset, England.
Hans Q. Rasmusen, Værslev, Denmark.
Solar Physics Observatory, Cambridge, England.
G. F. Kellaway, Yeovil, England.
Nizamiah Observatory, Hyderabad-Deccan, India.
Glavnaja Astronomiceskaja Observatorija, Pulkovo, near Leningrad, Russia.
E. M. Lindsay, Armagh Observatory, Northern Ireland.
The Astronomical Society of Edinburgh, Edinburgh 9, Scotland.
Nils Tamm, Bro, Uppsala län, Sweden.
Royal Observatory, Capetown, South Africa.
Astrophysikal. Observatorium, Potsdam, Germany.
Astronomiceskaja Observatorija, Engelgardta, Kazan, Russia.
Hamburger Sternwarte, Bergedorf, Germany.
Universitäts-Sternwarte, Babelsberg 2, Germany.
Sternwarte, Wien XIII, Austria.
Sternwarte, Sonneberg, Thüringen, Germany.
(Joe Ueta, Kyoto, Japan).
Observatoire, Besançon, France.
Astronomisches Institut der Universität, Würzburg, Germany.
R. Rigollet, Paris 16, France.
J. Peridier, Observatoire Le Houga, Les Arousettes, Gers, France.
Observatorio Astronómico, Córdoba, Argentina.
Case School of Applied Science, Warner and Swasey Observatory, Cleveland, Ohio, U.S.A.
Biblioteka Akademii Nauk, Leningrad, Russia.
(Nankodo Kyoto Branch, Kyoto City, Japan).
C. Luplau Janssen, Copenhagen, Denmark.
R. Henseling, Berlin-Frohnau, Germany.
Observatory, Helsingfors, Finland.
Eidgenössische Sternwarte, Zürich, Switzerland.
Observatoire Astrophysique privée, Josefov, Czechoslovakia.
McDonald Observatory, Fort Davis, Texas, U.S.A.
B. Polesný, Astronomical Society, Čes. Budějovice, Czechoslovakia.
Astronomical Institute, Karlovy University, Prague XVI, Czechoslovakia.
University of California at Los Angeles, Library, Los Angeles 24, Calif., U.S.A.
Lowell Observatory, Flagstaff, Arizona, U.S.A.
Astronomical Institute of the Masaryk University, Brno, Czechoslovakia.
Astronomical Observatory of Wroclaw University, Wroclaw, Poland.
Robert A. Naef, Zürich 38, Switzerland.
Knizhnij Otdel, Akademii Nauk SSSR, Moskva 34, Russia.
Glavnoe Upravlenie, Geodesii i Kartografii, Moskva, Russia.
Institut d'Astronomie Pratique de l'Ecole Polytechnique de Varsovie, Warszawa, Poland.

JULIE M. VINTER HANSEN
Director of the Bureau

Dec. 1, 1947

Report of meeting, Thursday, August 12, 1948. 10.30 a.m.

PRESIDENT: Sir HAROLD SPENCER JONES.

SECRETARY: Miss J. M. VINTER HANSEN.

MEMBERS PRESENT: Sir Harold Spencer Jones, Dr Harlow Shapley, Miss Vinter Hansen.

The president expressed his regret at the sad death of Prof. Elis Strömgren, who for 25 years, including the difficult war years, had conducted the affairs of the Telegram Bureau in the most satisfactory way.

Miss Vinter Hansen, the present director of the Bureau, asked for the usual annual grant of 1200 gold frs., and the Commission agreed to send the following recommendation to the Executive Committee:

'The Commission recommends that an annual grant of 1200 gold francs be given to the Bureau of Astronomical Telegrams.'

Miss Vinter Hansen further mentioned that since the printing of her report in the Draft Report, the list of subscribers to telegrams and circulars had been augmented by five institutions, and the list of subscribers to circulars only, by seven. As a whole the payments to the Bureau from the subscribers had occurred fairly satisfactorily, although a few subscribers were still badly in debt. A couple of subscribers had died leaving small amounts of debt to the Bureau, and she asked permission to place these amounts under General Expenses. This permission was granted.

A proposal by Dr H. M. Jeffers, of the Lick Observatory, to make a minor change in the code for astronomical telegrams was discussed and the following resolution was adopted:

'The Commission recommends that the following modifications be made to the code of astronomical telegrams as approved on p. 477 (or 483) of the *Trans. I.A.U.*, **6**, 1938: first, name of discoverer; second, nature of object; third, name of observer; fourth, the accepted sequence of the position message followed by remarks, if any; fifth, the name or names of the communicators.

'It is left to the discretion of the Telegram Bureau whether the site of the observatory where the observation has taken place should be communicated, and whether all the names of the intermediary communicators should be transmitted.'

It was decided that this minor change of code did not necessitate the reprinting of the whole code, but that the change, if accepted by the General Assembly, should be communicated to the subscribers through a notice on the I.A.U. circulars.

A proposal by Dr G. Merton, Oxford, that in the telegraphic transmission of ephemerides the figures giving the 'light' of the object should be substituted by figures giving the supposed magnitude of the object was referred to Commission 20.

8. COMMISSION DE L'ASTRONOMIE MERIDIENNE

PRÉSIDENT: M. H. R. MORGAN, *U.S. Naval Observatory, Washington, D.C., U.S.A.*

MEMBRES: MM. Armellini, R. Baillaud, Boss, Brouwer, Carnera, Cullen, Danjon, Dyukov, Fayet, Guyot, Gyllenberg, Hins, J. Jackson, Spencer Jones, Meyer, Moreau, Orlov, Procházka, Sémirot, R. M. Stewart, van Herk, Watts, Zverev.

SOUS-COMMISSION POUR LES OBSERVATIONS VISUELLES ET PHOTOGRAPHIQUES DES ETOILES JUSQU'À LA NEUVIÈME GRANDEUR

PRÉSIDENT: M. BROUWER.

MEMBRES: Mlle Barney, MM. Eckert, Martinez, Scott, Shane, Stoy.

The inability to obtain information about work in other countries, under present world conditions, necessarily makes this report incomplete. The conditions since the 1938 meeting have interfered seriously with major programmes of observation, and have delayed reductions, such that there are now several series of observations of the Sun, Moon, and Planets, and many catalogues of stars awaiting final reduction and publication.

The Sun, Moon, and Planets. Fundamental observations of these objects and of the fundamental stars have been carried on regularly at Cape and Washington, and at Greenwich except for part of the time during the war. The Greenwich and Cape results 1925–44 have been reduced; and summaries of the results have been published in reports. The Washington series 1928–32 is published; the series 1925–40 is about reduced; and the series 1935–45 is to be printed this year. The Sun and Planets have been observed also, in shorter series, at Algiers, Besançon, Brussels, Ottawa, Strasbourg, Toulouse, and elsewhere; but much of this work is not reduced, or not available. A complete reduction and publication of such observations is needed. There is a need also for an additional series of continual fundamental observations of the Sun, Moon, and Planets, with 24-hour star work, preferably at a government observatory in the southern hemisphere. There are unsatisfactory discrepancies between different instruments in observations of the Sun.

Beginning probably in 1952, the American *Ephemeris* and the British *Almanac* will give ephemerides of Ceres, Pallas, Juno, and Vesta, with the recommendation that these objects be observed with meridian instruments. Baillaud and Maître suggest a need for additional meridian observations of the Sun and Minor Planets.

Recent observations of the Sun and Planets give a normal correction to Newcomb's equinox, $\Delta N = -0^s.041$ (1936). And a general solution, 1750–1945, gives $\Delta N = -0^s.034 + 0^s.016$ (T–1936). This motion is relative to a small number of bright stars and it should not be confused with precession. Apparently the earlier results, with hand-controlled moving threads, over-corrected the right ascension. The more recent and improved methods, including the synchronous motor control and use of screens, with more study of day terms, uphold the equinox of the *Albany General Catalogue*, $(N - 0^s.040)$. For such investigations the results from the reduction of Hornsby's observations, 1774–94, by Jackson and others, have been helpful, as have also the differences between the tables of the Sun by Leverrier and the tables by Newcomb computed for each month of last century by Williams. It should be noted that the ephemerides of the Sun, Moon, and Planets do not include the short-period terms in nutation, whereas these terms are included in the clock corrections for the Washington right ascension since 1903, and the declinations are reduced with nadir observations. The published individual corrections to the ephemerides require, therefore, small corrections (see *Astr. Jour.* **47**, 193, 1939).

Corrections to the Moon's longitude and latitude have been determined both from meridian observations and from occultations. Corrections for irregularities of the Moon's limb have been included in the Washington results, and these show decided improvement with such corrections. A new determination of the limb irregularities is being undertaken at Washington.

The fluctuation in longitude continues, and being unpredictable it must be studied continually, as variable time is now taken into account in planetary motions. This is

clearly shown in the recent determination of the *Motion of Mercury*, 1765–1937, by Clemence (*Astr. Pap.* vol. **11**, 1943), where the fluctuation in Mercury's longitude is found to correlate closely with that of the Moon. Fluctuation of the Earth's rotation and the secular acceleration of the Sun, Moon, and Planets has been discussed by Spencer Jones (*M.N.* **99**), and by others. Discussions of the solar parallax and of other constants are given by the Astronomer Royal in *Mem. R.A.S.* Vol. **66**, pt. II (1939), and in the *Results from the Cookson Floating Zenith Tube*, 1911–36 (1939). And Jeffreys, Oort, and others have discussed the precession, nutation, and aberration, and related constants. The determinations of the fundamental constants are not satisfactory, but those in use are not far wrong. Newcomb's precession requires a correction of 1″·00. Dr Spencer Jones writes that the values of the solar parallax and of the nutation constant cannot be reconciled. De Sitter and Brouwer have published a classical paper on the subject (*B.A.N.* 1938), with the caution that the system of constants and the motions of the Planets should be revised as a homogeneous whole. Many recent discussions of observations have indicated various discrepancies in the tables, masses, and adopted constants, and in star places; and a comprehensive research programme under the joint direction of Brouwer at Yale, Clemence at Washington, and Eckert at New York has been set up for studying these subjects (see Report, Commission 4). It is urgently recommended that no changes be made in adopted constants until a general solution of the system can be made.

The Fundamental Catalogue. The 1535 fundamental stars—the FK3 catalogue—are being regularly observed in all standard programmes. The results from thirteen recent series, all in good agreement, show the following variation with magnitude in the corrections to the right ascension between $+40°$ and $-30°$:

Mag.	$\Delta\alpha m$	Mag.	$\Delta\alpha m$	Mag.	$\Delta\alpha m$
0·0–2·4	$-0^s·0020$	3·7–3·9	$-0^s·0002$	4·7–5·0	$+0^s·0007$
2·5–3·0	$-0^s·0016$	4·0–4·2	$+0^s·0005$	5·1–5·5	$+0^s·0014$
3·1–3·6	$-0^s·0010$	4·3–4·6	$+0^s·0003$	5·6–6·6	$+0^s·0016$

If these be taken as magnitude errors in the proper motions in the thirty years since mean epoch, then $100\,\Delta\mu = +0^s·0030$ (M $-4·0$). Many instruments are now using screens and reversing-prism eyepieces, and with these and the moving threads there are practically no magnitude equations. Further studies of magnitude errors are being made.

The *Albany General Catalogue* (G.C.) with its large number of stars is being used extensively as a comparison catalogue for reducing catalogues to a standard system; and it is again recommended that all individual catalogues give comparisons with this catalogue. Moreover, the differences for the individual stars derived in such comparisons are very useful to others, especially in proper-motion work; and their publication saves other computers the necessity of duplicate computation. Some catalogues give them, and it is recommended that when possible the comparisons for the individual stars be published. To assist in comparing other catalogues with the *General Catalogue*, this catalogue has been put on punch-cards at the Watson Astronomical Computing Bureau; and by this means the positions in the *General Catalogue* may be carried to any desired epoch.

Results of observations in all the recent fundamental series up to 1945 give normal corrections for periodic errors in the *General Catalogue*, between $+30°$ and $-30°$ declination, as follows (epoch 1936):

$$\Delta\alpha_\alpha = -0^s·0105 \sin\alpha + 0^s·0101 \cos\alpha - 0^s·0008 \sin 2\alpha + 0^s·0058 \cos 2\alpha$$
$$\Delta\delta_\alpha = -0''·114 \sin\alpha - 0''·068 \cos\alpha + 0''·040 \sin 2\alpha - 0''·012 \cos 2\alpha$$

and a general solution of all observations, 1750–1945, gives (1936):

$$\Delta\alpha_\alpha = -0^s·0103 \sin\alpha + 0^s·0108 \cos\alpha - 0^s·0002 \sin 2\alpha + 0^s·0058 \cos 2\alpha$$
$$100\Delta\mu_\alpha = -0^s·0087 \sin\alpha + 0^s·0076 \cos\alpha - 0^s·0000 \sin 2\alpha + 0^s·0048 \cos 2\alpha$$
$$\Delta\delta_\alpha = -0''·106 \sin\alpha - 0''·068 \cos\alpha + 0''·021 \sin 2\alpha - 0''·012 \cos 2\alpha$$
$$100\Delta\mu'_\alpha = -0''·120 \sin\alpha - 0''·114 \cos\alpha + 0''·048 \sin 2\alpha - 0''·023 \cos 2\alpha$$

Recent observations of the Sun and Planets give $+0''·12$ as the correction to the *General Catalogue* equatorial declinations. For a further examination into the errors in present

star systems, a fundamental normal position is now being formed using observations in the last 25 years.

The new *Catalogue of* 3539 *Zodiacal Stars* (1940) contains definitive positions and motions, for the equinox of 1950, of all stars in the zodiac to the 7th magnitude, and of many fainter ones. It is based upon 90 catalogues, and the final positions are reduced quite rigidly to the FK3 system.

Observations of the Brighter Stars. The Cape Observatory has four unpublished catalogues, including: all stars to mag. 7·5 (8400), between $-30°$ and $-90°$; and all to mag. 7·0 (3267), in the zodiac, 1925–32; all stars to mag. 7·5 (6597), between 0° and $-30°$, 1932–36; and the PGC and BH stars south of $+35°$ (5373), 1936–44. In the first three catalogues many fainter stars are included for better spacing. Comparisons of all these positions with the fundamental catalogues have been summarized in published reports. At Greenwich the observations, 1931–40, of all stars to mag. 7·5 and fainter (6053), in the zone 0° to $+24°$, and the PGC stars north of $+64°$ are ready for publication. At Washington, the observations, 1935–45, of the fundamentals north of $-35°$, and of a spaced list of 3000 standard stars, 0° to $-30°$ (5644), are being printed this year; the observations, 1925–40, of fundamental and standard stars north of $-30°$ (3500), are mostly reduced; and observations since 1940 of the FK3 stars and a list of standard stars $+50°$ to $+90°$ (4800), are being reduced. The stars $+50°$ to $+90°$ are spaced 83 per 100 square degrees, and include a considerable portion of the GC stars. Observations of 3520 zodiacal stars, and declinations of 2094 standard stars were published in 1938.

Melbourne and Ottawa both have long series of observations of standard stars not yet published. At Cordoba a fundamental catalogue was published in 1941. At La Plata the GC stars $-35°$ to $-82°$ are being observed; and a catalogue of 2123 Boss stars $-15°$ to $-80°$ was published in 1936. The observers at La Plata express a desire to co-operate with other southern observers in a programme of fundamental work at their new observatory in latitude $-50°$. Declinations of the GC stars $+24°$ to $+32°$ have been observed at Leiden; and their azimuth instrument has again been taken to Kenya in Africa for observing the FK3 stars $+50°$ to $-50°$. In Russia, five observatories completed observations of 1334 geodesic stars to the 6th magnitude $+90°$ to $-10°$. Four other volumes were published by Pulkovo before it was destroyed: Vol. **53**, *Right Ascensions of* 558 *Fundamental Stars*; Vol. **55**, *Proper Motions of* 18,000 *Faint Stars in the Areas*; Vol. **56**, 8820 *Schjellerup Stars*; and Vol. **57**, *Declinations of* 1904 *Fundamental Stars*.

About 1930, Pulkovo and eight observatories in Germany co-operated in observing the FK3 stars north of $-20°$. The results are mostly published, and Kopff has combined the observations of each of the BJ stars into mean positions, and published the results with the Anhaltsterne catalogue. Also some 13755 Anhaltsterne $+90°$ to $-5°$ were observed with the FK3 stars at these same observatories, and were reduced rigidly on the FK3 system. These results have been published in *Veröff. Koper. Inst.* No. 55 (1943). A more general circulation of this publication is needed. These positions were used in reducing the plates of the photographic re-observation of the AG catalogues. The stars represent a good spaced list of intermediary standards 6·5 to 9·5 magnitude, and they have been observed at several epochs.

The Faint Stars. The visual observation of all stars to the 9th magnitude in the southern sky is nearing completion. At Córdoba, the zone $-37°$ to $-47°$ is about completed, and their last zone, $-82°$ to $-90°$, is being observed and reduced. At La Plata the zone $-47°$ to $-52°$ was published in 1938 (Vol. **13**); and the zone $-72°$ to $-80°$, the last of their six volumes in the zone $-47°$ to $-82°$, is being reduced. Some 4800 north galactic stars have been observed in France, and 3700 south stars at La Plata (Vol. **19**, 1943). Stars in the areas have been observed on a number of instruments. At Bergedorf and Königstuhl a list of 3000 stars, 8th to 10th magnitude, is being observed, one purpose of which is to study the magnitude equations in old catalogues. Other observations include thousands of reference stars for plate reduction, and double stars or red stars not suitable for photographic observation.

A large portion of the stars to the 8th magnitude, and of those in the *General Catalogue*

have therefore been re-observed in recent years. Possibly the stars needing observations most are those within 60° of the poles. The BJ and Zusatz stars should be included, especially to the south, and to the north the PGC stars. The GC stars +24° to +32° need observing in right ascension. Jackson recommends that the re-observation of stars in the GC, especially many of those not in the PGC, should be undertaken as soon as possible, while methods for checking the FK3 system will probably be under discussion. Jones suggests that meridian instruments should determine the position of stars to be used on the several new photographic zenith-tubes which are to be brought into use in the next few years, as the observations on such instruments may provide controls on the errors in the fundamental star systems.

Photographic Work. Several extensive programmes for photographic positions of all stars to the 9th magnitude should be mentioned. The Yale programme covers three-fourths of the sky, some of it twice, with plates covering 100° to 150° square degrees. The zones already taken are −70° to −60°, −50° to −40°, −30° to +30°, +50° to +60°, and the zone +60° to +90° is to be taken soon. Since 1938, seven volumes have been published in the zone −30° to +20°, and the reductions are well advanced for the four remaining volumes in this zone. On this extensive work gratings are used, and positions are determined for stars as bright as magnitude 5·5 using the spectral images. It is possible therefore to reduce the plates using positions of the brighter stars taken from regular programmes on standard instruments, without special observations of the reference stars. This is a great saving for meridian observers; and furthermore, it decidedly improves the results by referring the faint stars directly to standard systems. The Yale plates −30° to +20° are being reduced with the Cape and Greenwich observations of all stars to the 7·5 magnitude with fainter stars in sparse places.

A new plan of work covering the northern sky has been initiated by Brouwer at Yale in co-operation with Eckert at the Watson Scientific Computing Laboratory in New York, who has developed a new photoelectric measuring device which, operated by punch-card machines, permits automatic measurement and recording. The plates +50° to +90°, part of which have been taken, will be reduced in this manner. The comparison stars are to be taken from the spaced list of brighter standard stars observed at Washington, where plans are made for covering the sky to −30° with such observations. The Washington observations are to be used also for reducing plates taken at Lick Observatory in a general plan to cover the sky with a series of large plates which with double exposure and the use of gratings will provide means of referring the bright stars to the spiral nebulae.

The Cape Observatory is carrying the photographic observations of all stars to the 9th magnitude south from −30°. The zone −30° to −40° and the zone −52° to −56° have been completed; the zone −56° to −64° is being reduced; and observations for the zone −64° to −80° are being taken. Special observations of reference stars have been taken for all these zones.

For the zone −40° to −52°, positions and proper motions were deduced from astrographic plates for 41,400 stars to 9·5 magnitude. These results have been published.

The photographic re-observation of the AG catalogues, −2° to +90°, carried out, at six or seven observatories in Germany and Pulkovo, about 1930, has been completed; and the publication of the 15 volumes of these results is being delayed partly through lack of paper for printing. It would seem desirable that, if possible, the Union aid in the publication of this work.

Shortly before the war nine Russian instruments began work on a general catalogue of 17,500 stars, 7·5 to 9·0 magnitude, which were to serve as comparison stars for photographic plates giving positions of some 700 extra-galactic nebulae. These faint stars were to be connected with the present system FK3 through an intermediary standard list of 900 stars of intermediate magnitude. The general problem of referring the fundamental system to the nebulae is similar to the one being undertaken at Lick Observatory. What progress was made on this work is not known.

Quite a number of lists of reference stars have been selected and observed in the past, commencing with those used in reducing the astrographic plates and continuing up to

the present lists for the Cape plates in the south, and the Yale and AG revision plates in the north. In further visual observations of fainter stars, the stars in such lists should be given preference. The reference stars for the astrographic plates have all been re-observed, and it is possible now to improve considerably the plate constants for that work.

Proper Motions. Catalogues of standard stars now give proper motions for all stars, and at Cape, Greenwich, and Washington several thousand proper motions have just been determined for standard stars not in the GC, and for some 4000 stars in the GC. The latter show that the motions for the fundamental stars are not greatly in error, but for the weaker stars the corrections may be rather large. Proper motion work has been continued at Lund, and Prof. Gyllenberg reports that systematic corrections have been determined for 108 old, and more recent, catalogues not used in the GC. These are to be published in 1948. Cincinnati has just published (1946) a catalogue of 2300 proper motion stars. This is the last of a valuable series of catalogues devoted to the proper motion programme inaugurated by Porter. The mass determination of motions of the fainter stars is reported on in Commission 24 and Commission 23. For the *Geschichte* of the southern stars, five of the twenty-four required volumes have been published. It is hoped that the records for this work have been preserved, and that the work may be completed.

A word further should be said in favour of publishing catalogues for a multiple 10-year equinox nearest the epoch of observation. When a position is run to an equinox 10 or 15 years from the epoch without proper motion, as is done generally in observational catalogues, the position becomes quite inaccurate if there is much proper motion; and the precession computed with this inaccurate position is wrong also. The advantage gained in the ease of comparison of many catalogues all at the same 25-year equinox is offset by the inaccuracy in bringing observed positions to that equinox.

The large amount of observational material unpublished is distressing. It is urged that special effort be made to remedy this. The building of new observatories; the construction and testing of new instruments; the completion of reductions; publication; a more exhaustive discussion of observations, for motions in the solar system and for proper motions; and the completion of present programmes, and the continuing of the fundamental work, seem to be our immediate problems.

Instrumental Equipment. The Greenwich Observatory is moving away from the city disturbances at Greenwich to Herstmonceux, where a new transit circle takes the place of the old Airy instrument used since 1851, which is to remain at Greenwich. A horizontal transit instrument has also been constructed; and a mirror transit circle has been designed. The Melbourne Observatory has moved to Canberra. The U.S. Naval Observatory is planning to move away from the city of Washington, and a new 7-inch transit circle is being constructed to replace the 9-inch instrument placed in service by Newcomb in 1865. The Pulkovo Observatory is being rebuilt, and fundamental observations are to be taken up there and at the Nikolaeff, Tashkent, and Engelhardt Observatories, with new instruments. At Pulkovo the photoelectric registration of transits of stars brighter than 5·7 magnitude has been successful (Vol. **59**). At the U.S. Naval Observatory the use of punch-card computing machines for reducing meridian work is proving a great saving of labour. Also the complete photographic registration on the 6-inch transit circle not only saves a very appreciable part of the observer's time and energy, but more especially it makes the records without errors, which observers cannot do.

H. R. MORGAN
President of the Commission

PRÉSIDENT: M. C. B. WATTS, *Astronome au Naval Observatory de Washington.*

PRÉSENTS: G. Armellini, R. d'E. Atkinson, M. Barros, C. S. Beals, D. Brouwer, G. M. Clemence, G. S. da Costa Lobo, A. Couder, R. T. Cullen, A. Danjon, Fleckenstein, A. Gougenheim, E. Guyot, W. Heinrich, C. H. Hins, H. M. Jeffers, A. Kopff, P. Lacroute, W. D. Lambert, M. R. Madwar, G. Meyer, A. A. Mikhailov, M. Maître, F. Moreau, G. F. Mulders, P. Muller, N. E. Nörlund, J. H. Oort, A. Orlov, V. Planelles, A. J. Robertson, G. M. Sisson, H. S. Smith, Sir Harold Spencer Jones, P. Sollenberger, N. Stoyko, W. M. Witchell, M. Zverev.

1ère Réunion (12 août 1948). SECRÉTAIRE: G. M. CLEMENCE.

Le Président donne, d'après les travaux du Dr H. R. Morgan, un aperçu des corrections systématiques des catalogues GC et FK 3. Ces considérations sont résumées à la page 91 du rapport. M. C. B. Watts ajoute que, d'après les observations modernes, il faudrait corriger, d'une manière assez sensible, la constante de la précession. Le Prof. A. Kopff mentionne la publication récente des comparaisons entre le FK 3 et le *General Catalogue.*

Le Président invite les membres de la Commission à exposer leurs travaux d'astronomie méridienne.

Sir Harold Spencer Jones signale que l'on poursuit, en ce moment, à Greenwich, l'étude du cercle méridien de 7 pouces. Aucun programme d'observation ne sera entrepris avant l'étude de cet instrument qui sera installé à Herstmonceux. L'un des premiers programmes à réaliser avec ce cercle méridien sera la détermination des positions des étoiles observables avec le P.Z.T. (Photographic Zenith Tube). En réponse à une question du Président, M. Cullen répond qu'aucune variation saisonnière de la distance focale n'a été constatée.

Le Prof. A. Danjon mentionne les travaux d'astronomie méridienne qui sont entrepris à l'Observatoire de Paris: catalogue d'étoiles de repère de la zone de la Carte du Ciel $+32°$ à $+36°$, en collaboration avec les observatoires de Besançon et d'Uccle. Le Directeur de l'Observatoire de Paris présente un oculaire nadiral qui permet d'observer les fils brillants sur fond sombre. (Cet oculaire a été décrit dans le *Bulletin Astronomique.* Paris, 1946.)

Après avoir rappelé les travaux d'astronomie méridienne réalisés ou entrepris à l'Observatoire Royal de Belgique M. Moreau dit que le Service Méridien d'Uccle envisage l'acquisition d'une lunette zénithale et exprime le vœu que des renseignements soient fournis au cours de cette séance par les astronomes qui construisent ou utilisent la lunette zénithale. En réponse à ce vœu, M. P. Sollenberger expose les avantages du P.Z.T.

Le Prof. A. Kopff signale qu'à l'Observatoire de Bergedorf, on a entrepris l'observation d'étoiles faibles du catalogue Küstner. On envisage surtout les étoiles faibles dont les mouvements propres n'ont pas pu être déterminés à cause des erreurs systématiques. Le Prof. Kopff recommande l'observation de ces étoiles, dont les magnitudes sont comprises entre 8 et 10. Grâce à l'observation de ces étoiles, on pourra déterminer l'équation de grandeur du *Albany General Catalogue.* Sir Harold Spencer Jones souligne l'importance de ce travail, particulièrement en vue du rattachement des étoiles zénithales au système FK 3 et il recommande aussi l'observation d'étoiles faibles de l'hémisphère austral.

Le Prof. Kopff attire l'attention sur l'importance de l'observation des étoiles supplémentaires du catalogue FK 3. Le Président annonce la formation d'une sous-commission, sous la présidence du Prof. D. Brouwer, en vue d'étudier les questions relatives aux étoiles faibles.

Le Dr C. S. Beals mentionne les travaux méridiens réalisés à l'Observatoire d'Ottawa et il propose d'observer les étoiles qui seront utilisées aux lunettes zénithales et qui devront être rattachées au système FK 3. Il insiste sur la nécessité des observations d'étoiles de types B et O de manière à faire la liaison entre les étoiles galactiques et les objets extragalactiques.

2ème Réunion (13 août 1948). SECRÉTAIRE: F. MOREAU.

Le Président a reçu de M. R. Brisse, de l'Observatoire de Paris, une demande de subvention pour la publication de tables classant les étoiles fondamentales d'après les déclinaisons, les grandeurs et d'autres arguments. La Commission reconnaît la valeur, l'intérêt et l'importance de ces tables, mais elle regrette que la situation financière de l'U.A.I. ne permette pas de recommander au Comité Exécutif l'attribution d'une subvention permettant de publier ces tables; la Commission espère qu'il sera possible de reproduire ces tables, par exemple par microfilms.

Le Prof. A. Kopff signale que la pénurie, en Allemagne, de papier de bonne qualité met certains observatoires de son pays dans l'impossibilité de publier des catalogues stellaires. La Commission recommande, sur la proposition du Président et de Sir Harold Spencer Jones, la publication de la revision photographique de l'*A.G. Catalogue*, publication qui a été retardée par suite du manque de papier. La Commission espère que les fonds nécessaires seront alloués par l'U.A.I. pour l'achat du papier.

M. Watts expose brièvement le système d'enregistrement photographique aux micromètres en ascension droite et en déclinaison du cercle méridien de 6 pouces du Naval Observatory de Washington. Il décrit ensuite l'appareil utilisé pour l'enregistrement photographique des lectures aux cercles de déclinaison, ainsi que le dispositif à cellules photoélectriques pour la mesure automatique des films. Le premier de ces dispositifs a été décrit dans l'*Astronomical Journal*, no. 1148 (1946).

Le Prof. A. Danjon demande si ce dispositif à cellules photoélectriques pourrait être appliqué directement au cercle divisé, sans passer par l'intermédiaire d'un film photographique. M. Watts répond qu'il est préférable d'utiliser un film.

M. A. Couder, de l'Observatoire de Paris, décrit brièvement la lunette zénithale visuelle qu'il est en train de construire. Cette description vient de paraître dans le volume publié, à Paris, à l'occasion du centenaire de la découverte de Neptune.

La Commission estime qu'il est important de poursuivre—au delà du volume 7—la publication de la partie sud de la *Geschichte des Fixsternhimmels*; elle espère que les moyens financiers seront trouvés pour continuer ce travail.

3ème Réunion (17 août 1948). SECRÉTAIRE: F. MOREAU.

Le Président demande s'il n'y a pas de remarques à faire au sujet du rapport du Dr Morgan sur l'astronomie méridienne, rapport publié dans les 'Draft Reports', pp. 42–6. Ce rapport est adopté.

Le Dr M. Zverev fait rapport sur les travaux d'astronomie de position en U.R.S.S.: (1) Observation des étoiles supplémentaires du catalogue FK 3 à Poulkovo et Nikolaev. (2) Catalogue de 1334 étoiles du catalogue Poulkovo 1925 d'après 5 observatoires: Poulkovo, Nikolaev, Moscou, Kazan et Tachkent. (3) Catalogue de 2957 étoiles (les étoiles du catalogue 1925 + étoiles Backlund-Hough dont les déclinaisons sont $> -10°$). (4) Recherches du Prof. Pavlov de Poulkovo sur l'application des cellules photoélectriques aux observations de passage. C'est pour ces recherches que le Prix Staline 1947 a été décerné au Prof. Pavlov. (5) Construction par M. Sucharev, d'après l'idée de Ilinic (1935), d'un instrument méridien horizontal semblable à celui présenté, par l'Observatoire de Greenwich, à l'exposition de ce congrès. (6) Une lunette zénithale visuelle qui vient d'être mise en service à l'Observatoire de Poulkovo. (7) Construction près de Kiev d'un grand Observatoire pour l'astronomie de précision. (8) Catalogue d'étoiles faibles; ce catalogue comporte 4 parties: (*a*) Catalogue fondamental de 900 étoiles; (*b*) Catalogue Général de 18 000 étoiles; (*c*) Catalogue de 300 nébuleuses extra-galactiques dont la magnitude $< 13^m$, les positions étant rapportées au système du catalogue général; (*d*) Observations méridiennes de petites planètes spécialement choisies.

Les étoiles observées au cercle méridien ont des magnitudes comprises entre 7·5 et 9·0. Celles observées photographiquement ont des magnitudes comprises entre 8·5 et 10·0. On a choisi les étoiles de type G 5, K et quelques étoiles de type M dont le mouvement propre $< 0''·04$.

Les observations au cercle méridien de Tachkent sont terminées. Celles de l'Observatoire d'Odessa seront bientôt achevées. Les observations photographiques sont faites à Poulkovo, Tachkent et Moscou. La qualité des images des nébuleuses dépend des caractéristiques de l'instrument et de la durée de la pose. Pour les nébuleuses choisies la précision est 20% plus faible que pour les étoiles. M. Zverev exprime le vœu que les autres observatoires entreprennent aussi l'observation des mêmes nébuleuses en utilisant les lunettes photographiques dont ils disposent actuellement, soit des lunettes à grand champ, soit des lunettes à grande distance focale. Il estime que si ces observations étaient répétées à 25 ans d'intervalle, elles seraient fécondes en résultats intéressants.

M. Kopff demande la liste de ces 300 nébuleuses. M. Zverev répond que cette liste a été donnée dans les publications de l'Observatoire de Kazan.

Le Prof. G. Armellini pense qu'il est difficile de déterminer avec précision la position des nébuleuses extra-galactiques. M. Mikhailov répond qu'il y a des nébuleuses à noyau dont la position peut être déterminée photographiquement avec précision; il importe donc de choisir les nébuleuses qui conviennent le mieux.

M. Jeffers parle des travaux entrepris au Lick Observatory où l'on fait des poses photographiques de 2 heures sur des plaques qui couvrent $6 \times 6°$. Le choix des nébuleuses n'est pas encore fait. La distance focale de l'instrument photographique utilisé est 3·50 m. M. Watts demande si ces projets du Lick Observatory sont semblables à ceux de l'U.R.S.S. M. Mikhailov répond qu'effectivement ces projets sont semblables.

La Commission constate avec satisfaction que ces programmes sont en voie de réalisation aux Etats-Unis d'Amérique et en U.R.S.S.; elle espère que ces travaux conduiront à une liaison entre le système des nébuleuses extra-galactiques et celui des étoiles fondamentales. La Commission considère ce travail comme ayant une grande importance pour l'astronomie de position.

M. Atkinson suggère de déterminer la position des amas globulaires. On choisira dans chaque amas quelques étoiles brillantes qui serviront d'étoiles de repère; elles seront choisies de telle façon que leurs mouvements propres relatifs soient négligeables.

Le Prof. Armellini présente ses observations en ascension droite des grosses planètes. Ces observations ont été effectuées avec la lunette coudée Bamberg (90 mm.–95 cm.). Il estime qu'il est avantageux d'éliminer l'influence de la collimation par le retournement de la lunette à chaque passage. M. Moreau fait remarquer que, dans ce cas, les observations sont différentielles; il estime qu'un cercle méridien de plus grande ouverture est mieux approprié pour l'observation des grosses planètes, particulièrement pour Mars et les planètes inférieures qui exigent une bonne définition de l'image à cause de la phase.

Le Président présente un rapport de l'Observatoire de Tokio (1938–47): Observations méridiennes de la Lune, des grosses et de petites planètes—Catalogue de 3000 étoiles zodiacales—Catalogue de 500 étoiles zénithales—Etude comparative des 2 lunettes de passage Bamberg.

Report of combined meeting of Commissions 8 (MERIDIAN ASTRONOMY), 19 (VARIATION OF LATITUDE) *and* 31 (TIME), August 21. 9.30 a.m.

PRESIDING: Sir HAROLD SPENCER JONES.

SECRETARY: PAUL SOLLENBERGER.

The President outlined the history of the Ross photographic zenith tube, saying that it was originally designed for measurement of the variation of latitude by Dr Ross, and later adapted to the determination of time by Dr Littel. The success of the instrument and its possible application to various problems in positional astronomy made it of interest to all three commissions attending the combined meeting.

Dr Schilt said that the zenith tube could not determine fundamental positions, but that it could determine fundamental proper motions in declination with a high degree

of accuracy. One instrument can observe only a narrow zone of stars, but several instruments, located at various latitudes, could obtain valuable data. The results obtained could be tied together by means of meridian transit circle observations so as to obtain proper motions for the whole sky. The President noted that the secular motion of the mean pole prevented absolute determinations of proper motion at a single station. Dr Schilt replied that two stations properly located could eliminate the effect of polar motion.

In response to an inquiry as to the accuracy obtainable with the zenith tube, Mr Sollenberger stated that in 25 years the Washington instrument had made possible the derivation of proper motions superior to those obtained with all available transit circle observations.

Dr Atkinson feared that the use of two-element objectives would result in systematic differences in the proper motions determined for stars of different colour. To overcome this he proposed the use of objectives having two elements, each corrected for colour. He noted, however, that no colour difference had been detected in the proper motions derived at Washington. Mr Clemence suggested that by determining the scale value for each colour type of star independently, the difficulty could be eliminated. Mr Sollenberger pointed out that the plates used at Washington were sensitive only at the blue end of the spectrum, thus reducing the effect of such an error. He also stated that the designers of the new zenith tube lens did not consider that the effect would be of importance. Dr Atkinson said the English lens designers had a different opinion. In conclusion he said that he would be satisfied on this matter only if a study of the derived proper motions showed no evidence of colour effect.

Mr Watts said that the transit circle workers used the variation of latitude determined with the zenith tube in the reduction of their work, and that they looked forward with pleasure to the prospect of getting within a relatively few years an accurate system of proper motions. In return for these advantages it would be the duty of the transit circles to observe the stars used by all the zenith tubes, so as to furnish fundamental positions for them.

The President urged that the observing programmes of the zenith tubes be arranged so that stars would be taken near to sunrise and sunset throughout the year. This he considered important for the control of periodic errors in the adopted system of right ascensions. Dr Lambert suggested that refraction differences between evening and morning might cause trouble. The President considered that the declination observations would be mainly affected by diurnal variation in refraction, and it was generally recognized that the constant of aberration, derived from latitude variation observations might be affected by systematic error.

Dr Atkinson discussed the question of suitable distribution of observing stations. For the determination of latitude three or more stations located in the same latitude are desirable. Four stations located ninety degrees apart would be most advantageous, since each one could correct its time observations by utilizing the latitude results at the adjacent stations.

Mr Sollenberger said that the new instrument under construction at the Naval Observatory was originally to be located in Cuba, but that the present plans were to put it in south Florida at a latitude of about 25° 30′. He pointed out that there were several advantages, especially from the standpoint of time determination, in locating the instrument in a low latitude. Mr Clemence said that as long as the total number of instruments was small, they should be welcome wherever located. Dr Schilt suggested that a list of present and contemplated stations should be kept available so that some judgement could be exercised in selecting new locations.

Dr Hins pointed out that there were conflicting requirements which affected the location of zenith tubes. Proper motion determinations required instruments in different latitudes, while latitude variation determinations required several instruments in the same latitude. He thought that the two requirements should be considered separately.

9. COMMISSION DES INSTRUMENTS ASTRONOMIQUES

PRÉSIDENT: M. J. A. CARROLL, *Admiralty, Whitehall, London, S.W. 1, England.*

MEMBRES: MM. Anderson, R. Baillaud, J. G. Baker, Burch, Chrétien, Couder, Danjon, Dimitroff, Dufay, Dunham, J. W. Evans, Gaviola, Hargreaves, Henyey, Lallemand, Linfoot, Link, Lyot, McKellar, McMath, Maksutov, Minnaert, Öhman, Perfect, Plaskett, Redman, Rösch, Ross, Rosseland, Schilt, Sternberk, Whitford, Yü.

I. NEW OBSERVATORIES AND TELESCOPES

The 200-inch telescope at Mt Palomar in California is complete and in process of adjustment prior to commencing a programme of observations. The large mirror, after successful figuring, has been transported to the observatory without mishap and it is expected that some months at least will be spent on adjustments to its supports and in testing its performance and that of the associated gear.

The Royal Observatory, Greenwich, is to move to Herstmonceux near the south coast of England. The conditions at Greenwich have deteriorated steadily over many years and the new site offers as good conditions climatically as can be found in Great Britain and is well removed from industrial glare or fog as there are no towns near the new site, which consists of a fine old moated brick castle in some 200 acres of ground.

A start has been made on the conversion of the castle and on new buildings for instruments. For some years observations will be carried on at both Greenwich and Herstmonceux.

Two new meridian instruments are under construction for the Royal Observatory, a horizontal transit instrument and an improved photographic zenith tube. In the horizontal transit instrument the telescopic system is stationary at all times. The system consists of two identical objectives having their optical axes coincident. These objectives face east and west respectively (that is to say their common axis is horizontal and normal to the meridian) and the distance between them is equal to the sum of their focal lengths.

Observations of a star are made by placing a two-mirror optical square alternately in front of each objective, before and after transit respectively. The fiducial wires in the common focal plane of the objectives are observed first from one side and then from the other.

Apart from the gain in stability due to the fixity of the telescopic system, the essential advantage of the instrument is that the adjustments of the optical square are not critical. Consequently, compared with what is demanded in the pivots of a normal transit instrument, the stringency of mechanical requirements in the only movable part of the instrument is enormously reduced.

This instrument has these further noteworthy features:

(1) The two objectives are mounted kinematically and are provided with micrometer adjustments for focusing and squaring. The mounts themselves are provided with additional adjusting means, consisting of a combination of micrometer screws and spring strips, to enable one objective to be moved vertically and the other horizontally. By these means the line joining the second nodal points of the two objectives can be adjusted so as to be precisely normal to the meridian.

(2) A mechanically driven achromatic optical wedge of variable deviation is mounted in front of the optical square. The direction of the stellar beam entering either objective is thereby maintained axial and errors due to maladjustment are minimized.

(3) The time-scale is produced photographically by means of an autocollimation system applied to mirrors attached to the moving elements of the wedge. It is thus made free from error due to mechanical imperfection in the motion of these elements.

(4) The adjustment and determination of level of the telescopic system is effected by means of nadir observations made successively on mercury reflectors placed beneath the two positions of the optical square. The azimuth is adjusted by successive approximation

and is afterwards determined in the normal manner. The equivalent of collimation error is eliminated provided the deviation due to the optical square is constant during the observation of a star.

The improved photographic zenith tube differs in the following respects from previous instruments of its type:

(1) The angle of reversal is observed by autocollimation instead of by means of a divided circle. Thus a fixed axis of rotation is unnecessary and accordingly the 'rotary' (the assembly which rotates in azimuth) is supported on a ball-bearing with plane races, greatly reducing friction and facilitating construction. At the same time, undesired rotation or tilting about horizontal axes is kept within the required limits. There being no definite constraint in the horizontal direction, it is possible to define each of the two working orientations by a pair of stops instead of by a single stop as in instruments provided with a fixed axis of rotation.

(2) Provision of adjusting means in the kinematic mounting of the objective enables the nodal plane and the plane of the photographic plate to be brought into precise coincidence.

(3) Automatic reversal is accomplished by means of a system of wires which exert a pure torque on the rotary and therefore no tilting torque on the tube. This system is such that unidirectional rotation of the driving shaft is converted into reciprocating rotation of the driving rotary. At each reversal, moreover, the angular velocity is initially and finally zero, as is the case in the Washington instrument.

(4) The diffraction pattern of the star image is rendered symmetrical by making the plate carriage annular, this carriage encircling the objective. The asymmetrical carriage constraints can therefore be made external to the aperture, while the inevitably obstructing plate-holder and its supports are easily made symmetrical with respect to the aperture. This annular construction, moreover, permits of more effective constraint of the carriage.

(5) Relative motion of the carriage and rotary is made to approximate to pure translation by means of a compensating system of flexed rods which constrain the carriage in the horizontal plane to which the motion is restricted by means of three balls that roll between horizontal plane races. This system secures good repetition of track, which is the essential requirement, and a good approximation to rectilinearity as is desirable.

(6) A method of achieving uniformity of rate in the relative translation of carriage and rotary is under investigation. In this method a differential roller and metallic tapes replace a direct screw drive.

(7) The time-scale is produced photographically by means of a clock-controlled lamp. Erratic mechanical linkage and backlash are thus avoided, as is also the use of an independent chronograph. Duplication of this system not only reduces error in the time-scale but provides a check on the repetition of carriage-track and will therefore probably be adopted.

(8) The shutter operates on the incident beam, above the objective, instead of operating on the reflected beam below the plate. It is a symmetrically-opening rotary shutter with provision for timing.

(9) As criterion of adjustment for constancy of scale-value, an optical null method has been introduced for use in conjunction with a suspended silica rod.

A new photographic zenith tube is being constructed at the U.S. Naval Observatory. The lower part will be enclosed in a well containing a pillar supporting the mercury trough, so that the working region at the top of the tube is conveniently accessible from ground level. The cell holding the two components of the 8-inch objective is fitted with stops and a spring to secure positive location of the lenses in a fixed position relative to their cell. Means are provided for rapid checking that the angle of reversal does not differ from 180° by more than five seconds of arc. The operation of the instrument is semi-automatic through a system of controlling relays. The mechanical design and method of manufacture incorporate several novel features.

The government of the U.K. has provided funds for the construction of a new 100-inch reflecting telescope to be called the Isaac Newton Telescope. It will be erected in the Royal Observatory at Herstmonceux and maintained by the observatory for the use of

British astronomers in general, the observing programme and claims for use of the telescope being under the control of a Board of Management nominated by the Royal Society and the Royal Astronomical Society.

The design of the telescope and its auxiliary gear is at present under discussion by the Board of Management. Very detailed consideration is being given to a form of universal telescope usable at will for wide-field photography, by means of a correcting plate or for axial spectroscopy. A new form of mounting termed an Inverted Fork Equatorial has been proposed and is being closely considered.

The design of this mounting is a collocation of features not new in themselves, and represents an attempt to satisfy three requirements, namely: (1) free access to any part of the sky, (2) great rigidity and stability, and (3) a minimum of two additional reflections (a total of four reflections) in the path of the light to the Coudé focus. The polar axis is a cone with a rim at its wider, upper end running on pressure-oil bearings. Projecting from the upper end of this cone is a short, unsymmetrical hollow column on one side of which is a large annular bearing on which the tube rotates. The counterweight, rotating on a bearing at the other side of the column, is rigidly attached to the upper part of the tube by connections external to the column, rendering unnecessary the usual declination-axis spindle. Consequently the interior of the column is unobstructed and two diagonals, one in the tube and the other in the column, direct the light down the interior of the polar-axis cone. Alternatively, the column may house a Cassegrain spectrograph supplied with light from the first of the two diagonals.

Among other novel features under consideration is a scheme to correct automatically for the changing deflections of the main telescope tube as its position changes.

A new astrophysical observatory has been erected in Haute-Provence to the south-west of Forcalquier by the Centre National de la Recherche Scientifique. The project was started towards the end of 1938, under an organizing committee presided over by M. Danjon, Director of the Paris Observatory. The director of the new observatory is M. Dufay, Director of the Observatory of Lyons and M. Fehrenbach of the Strasbourg Observatory is deputy director and resident astronomer in charge. The observatory is at an altitude of 600 metres and enjoys excellent observing conditions and has grounds of some 95 hectares. Three domes, 12 m., 8 m. and 6·5 m. in diameter, house respectively a telescope of 1·2 m., another of 81 cm., and an equatorial mounting. A large laboratory will be equipped during this year.

The 1·2 m. telescope has an old mirror from the Paris Observatory refigured by M. Couder. The telescope of 81 cm. aperture has been used to study the qualities of the stellar images obtainable with well-known excellent results.

The equatorial mounting based on plans by M. Couder comprises a large table of 1·5 m. side, sufficiently big to carry a telescope of 80 cm. aperture. At present a normal field direct-vision objective prism is mounted.

It is intended to install a telescope of 1·93 m. aperture housed in a dome of 24 m. diameter and there is hope that this instrument may be in action in 1952.

There are two spectroheliographs, one a conventional type and another with one of M. Lyot's filters registering continuously monochromatic solar images.

At the Pic-du-Midi M. Jules Baillaud has erected the 61 cm. large Coudé objective from the Paris Observatory. The focal length of the objective is 18·25 m. but the equatorial tube of the new mounting is kept to only 6 m. by using two plane mirrors. The performance is excellent. An account of the instrument will be published in *L'Astronomie*.

The 74-inch mirror for the Radcliffe Observatory, Pretoria, has at last been completed for shipment to South Africa. The mounting and dome have been ready since 1938.

In Canada in 1940 a new observatory was given to the University of Western Ontario by Mrs Frances Amelia Cronyn in memory of her husband the late Hume Cronyn. The telescope is a 10-inch refractor and has a small Schmidt type camera attached.

In Sweden the Uppsala Observatory has received a gift from Dr Nils Tamm which has provided for a station in Kvistaberg, some 40 km. south-west of Uppsala. The main instrument will be a Schmidt telescope of about 40 inches aperture.

Preparations are being made to extend the equipment of the Stockholm Observatory with a Schmidt telescope of 26 inches aperture and an objective prism of the same size. Several instruments for solar research are under construction including a spectroheliograph and monochromators.

It is intended to add to the existing equipment of the Helwan Observatory a new large reflector of about 94 inches aperture and a new photographic zenith tube of the same type as that for the Royal Observatory, Greenwich.

II. Developments in Optical Design and Optical Components

In the fabrication and working of optical components the most generally applicable new technique introduced since 1938 has been the blooming of surfaces by deposition *in vacuo* of a thin layer of material of suitable refractive index whereby the reflection of light incident on a refracting surface is reduced to a tenth or less of the reflection by the untreated surface. The deposition of reflecting films of aluminium has gained favour and is now widely used for mirrors up to the very largest.

The principal source for the manufacture of very large disks of low expansion glass at the present time appears to be the firm of Pilkington in Great Britain, where disks up to 60 inches diameter can now be cast and annealed, and within a year capacity up to 100 inches will be available. The St Gobain Works are not at present making large disks but may in the course of a year or so be able to undertake disks up to 2 m. diameter. In Germany at Jena, Zeiss and Schott have resumed manufacture of colour filters and will also be able to undertake manufacture of disks of low expansion glass up to 80 cm. diameter. In the U.S. during the war a number of large crystals of calcium fluoride were grown in sizes up to some 15 cm. Some of these have been deposited with the U.S. Bureau of Standards and might be made available for optical parts for special purposes.

In the field of telescope design, the most striking development has been the widespread adoption of the Schmidt optical system. Corrector plates up to 48 inches in diameter have been constructed, the largest to date being that of the Palomar 48–72-inch Schmidt telescope. The possibility of flattening the field of the Schmidt camera by adding a convex secondary mirror to the system has been discussed in a number of papers by J. G. Baker, H. Slevogt, C. R. Burch and E. H. Linfoot, and telescopes incorporating this modification are under construction for the St Andrews University Observatory, Scotland, and for the Armagh-Harvard-Dunsink station at Bloemfontein. To obtain the sharpest possible images, at least one of the mirrors must be non-spherical, but in some practical cases it is possible to keep both the mirrors spherical without loss of photographic performance.

A. Bouwers, D. Maksutov, A. Colacevich and others showed independently that a meniscus lens, nearly concentric with the spherical mirror surface and of nearly zero power, can effectively replace the Schmidt corrector plate in some designs. This is an advantage in small and medium-sized systems, since the meniscus lens, though rather sharply curved, is much easier to make than a Schmidt plate. Maksutov also designed meniscus-Cassegrain telescopes consisting of a meniscus lens, a concave primary mirror and a convex secondary mirror, and using only spherical surfaces. The practical usefulness of the meniscus design is probably limited at present to apertures not exceeding about 15 inches by the difficulty of producing large, steeply curved meniscus lenses. The thin aspheric plates of large Schmidt and Schmidt-Cassegrain telescopes can be made from selected sheets of ordinary plate glass, though special glass is also used.

Optical designs giving still higher performance in medium and small sizes have been obtained by combining a concentric meniscus system with an aspheric corrector plate which deals with the residual errors left by the meniscus. Such meniscus-Schmidt cameras have been designed by Bouwers and by Hawkins and Linfoot, with monochromatic errors only about 1/16 of those of the classical Schmidt camera. C. G. Wynne obtained comparable performance without the use of an aspheric surface by means of two near-concentric meniscus lenses, one on each side of the centre of curvature of the spherical mirror; his systems would seem to be especially well suited to spectrograph cameras.

Other new spectrograph camera designs are the solid Schmidt, which can work down to $f/0{\cdot}4$ or even lower, and an interesting system of M. Rösch, consisting of a plano-concave lens, its concave surface facing towards, and concentric with, a concave mirror. Constructed with aperture 75 mm., focal length 60 mm., this is said to be usable over a 60° field. Miniature Schmidt of 2- or 3-inch aperture and of speeds near $f/1$ are coming into more general use; in particular, one is being constructed by the Ealing Optical Company for the Cambridge University Observatory.

In co-operation with the Aga Company, Stockholm, Prof. B. Lindblad has devised a nebular spectrograph using a Schmidt $f/0{\cdot}6$ as a camera and a parabolic mirror as a collimator.

At Meudon M. F. Baldet has had constructed by the Société Générale d'Optique of Paris an objective of 17 cm. focal length, aperture ratio $f/1$. The field is some 20° and stellar images are sharp over about 6°. It will be used for cinematographic study of comets, using 35 mm. film.

An important and interesting development is the normal field objective prism devised by M. Charles Fehrenbach. It is a direct vision prism which allows, by returning the rays along the optic axis of the instrument the application of Pickering's method for determining radial velocities, but no field correction is required.

Seidel's and the chromatic aberrations of the Schmidt camera from a new standpoint have been studied theoretically by T. Matukuma (Tohoku Univ.) (to be published in *Mem. Astr. Soc. Japan*). H. Hirose (Tokyo Astr. Observatory) has directed the construction of Schmidt cameras in Japan. An $f/1$ camera of 18 cm. aperture is now under test at the Tokyo Astr. Observatory. H. Hirose and Y. Kobayashi (Kyoto Univ.) studied, independently, optical systems consisting of a spherical lens and a spherical mirror. The theoretical performance of these systems was verified by actual construction.

At Tokyo Astr. Observatory, H. Kubota (Tokyo Univ.) and Y. Yatabe (Fuji Chemical Industry Co.) have collaborated in the reproduction of diffraction gratings with methyl-acryl-resins. There remain some difficulties yet. (*Applied Physics*, **16**, 68, 1947; *Shizen*, 1947, no. 10—both in Japanese.)

III. Developments in Mechanical Design of Observing Instruments

M. Chalonge of the Paris Institute of Astrophysics has devised a mechanical means of broadening stellar spectra which allows the broadening to be varied from 0·3 mm. near 3100 A. to 0·9 mm. near Hα.

M. d'Azambuja installed at Meudon in 1941 an arrangement allowing spectroheliogrammes in Hα to be taken on 35 mm. film to show by subsequent cinema projection movements in the solar chromosphere, particularly the movements of prominences.

IV. New or Greatly Improved Instruments and Techniques

By far the most outstanding advance in observational astronomy for very many years has come from the application of developments in radio to the study of celestial phenomena. Towards the end of the war it was noticed that on certain short-wave highly directional radio receivers the background noise showed a very strong increase in certain directions and it was found that there was an incoming stream of radiation apparently of galactic origin and also that there were from time to time strong emissions of solar origin. The equipment originally used for these observations was not specially designed for such purposes but was normal service equipment. Since the original discoveries a number of workers have taken up investigation of these phenomena using first modified service equipment and later specially designed equipment of which the principal special features have been directed towards a lower or more stable set background noise or special directional aerial arrays. Some photographs displaying the equipment used and the results obtained by British pioneer workers will be on view during the assembly.

The other striking advance has been the use of radar for observation of meteor streams whereby it is possible to observe them in much greater detail and over longer times than heretofore and of course observations can be made in the daytime whereby swarms otherwise unobservable can be detected. Determination of velocity and of trajectory is possible now with great accuracy.

It is interesting that the first radar detection of meteors occurred during the use of radar for detecting 'V' weapons approaching Great Britain during the war.

Attempts are in hand to use radar to measure changes in lunar distance and possibly to effect determination of the absolute value of lunar distance at any time.

To turn to developments on more conventional lines, some of the most striking have been in the field of photoelectric photometry due to the development of successful commercial electron multiplier tubes and the development of sensitive infra-red detectors such as the lead sulphide cell. Various workers have constructed equipment for attachment to telescopes incorporating these devices for astronomical photometric observations or have applied them to laboratory photometers and microphotometers. At the National Observatory, Ondrejov, Czechoslovakia, Dr Link has made use of an anti-aircraft searchlight to make photoelectric measurements of the twilight and night sky, using an electron multiplier cell furnished by M. Lallemand of the Paris Observatory, and placed at the focus of a parabolic mirror of diameter 2 m. and focal length 84 cm. The incident light is interrupted by a rotating sector in order to allow the use of an A.C. amplifier, the amplified current being rectified for measurement. At the Leiden Observatory very successful photometric measurements have been made with a multiplier tube and an extensive programme is being carried out particularly on RR Lyrae in connection with spectroscope research at the Yerkes and McDonald Observatories. The sensitivity is amply sufficient to allow the use of colour filters so that variable stars may be followed in several colours. At Utrecht the photoelectric installation has been tried with incident light interrupted by a rotating sector to allow A.C. amplification.

Prof. Lyot has developed a number of devices. He has constructed a polarizing filter described by him in 1935, which allows observation over a field of about 2° in a region of the spectrum some 2 A. or 3 A. wide centred about two coronal radiations at 5303 A. and 6374 A. or chromospheric radiations $H\beta$, D_3, B_1 and $H\alpha$. With this he is able to photograph the corona in its own monochromatic radiations with exposures only of a few minutes. By reducing the transmission band to 1·5 A. he has been able to take cinema photos of the chromosphere up to the edge of the disk with sufficiently short exposures to get good images with a focal distance equivalent to 20 m. He has also used the polarizing filters to separate radiations and make cinematograph records simultaneously on three different films of the prominences in $H\alpha$, the corona in 6374 A. and the corona in 5303 A. He has also devised a direct-current amplifier which can cope with the extremely feeble electromotive force developed by thermocouples. The stability of this instrument is stated to exceed that of galvanometers and its sensitivity not to be limited by the Johnson effect in the circuit to which it is connected. With it can be detected a radiation of 10^{-10} W. It was mounted, in 1941, on the coronagraph at the Pic du Midi for a search for coronal infra-red radiations. No description of this equipment has so far been published because of war-time circumstances, but it is described in documents deposited with the Academy of Sciences in 1941. He has also used multiplier photo-cells and constructed a photoelectric polarimeter which allows the determination in a few seconds of a proportion of polarized light of one 10,000th part in a luminous flux of one microlumen. He has also constructed a photometer for coronal studies allowing the comparison of the intensity of coronal and solar radiations. A description of this device has not yet been published.

At the Pic du Midi M. Camichel has constructed a micrometer for the measurement of the apparent diameters of small objects. This is achieved by bringing into the field of view the image of the star under study encased between two images of a small circular aperture of known diameter reflected by a glass disk. By a polarizing device colour and brightness of the two images of the aperture can be varied and the diameter modified until they have precisely the same appearance as that of the object under examination. The device has

been applied to satellites of Jupiter and to the five satellites of Saturn using a 61 cm. refractor and it has given the diameters of these satellites with a probable error of one or two hundredths of one second.

A new microphotometer has been constructed at Utrecht Observatory, devised in the main by Dr Houtgast. The coupling between the plate and the drum is by means of a lever of variable ratio and the rectilinear movement of the lever is converted into a rotation of the recording drum by simple contact between a flat metal plate and a rotating cylinder, a gentle pressure being sufficient to avoid any slipping. The Philips Factories in Holland are now making Schmidt cameras of low price for television, the correcting plate being made out of gelatine by a special method. The image quality is good, the plates being devised either for an object at infinity or for an object at a distance of 2 m. At Utrecht they are using a small camera of this type in combination with a big prism for observation of the night sky.

The projection micrometer of the Dominion Astrophysical Observatory at Victoria, B.C., described in *Journal of the Royal Astronomical Society of Canada* for 1937, has been built with improved optical and mechanical features and has operated satisfactorily now for a number of years. At the same observatory R. M. Petrie has devised a projection comparator for rapid measurements of plates for determination of radial velocities. The machine is now in its final form, scales have been prepared for various dispersions and various spectral classes of stars. A preliminary description of it was given at a meeting of the American Astronomical Society in 1946 and there is a brief description in *Sky and Telescope* for 1946. At Victoria there has been constructed a semi-automatic intensitometer designed by C. S. Beals which allows the profiles of spectral lines to be derived rapidly and satisfactorily. A new Littrow form of the Victoria Stellar Spectrograph has been constructed.

For the Stockholm Observatory Dr Y. Öhman has devised a sensitive photoelectric colorimeter applying the flicker effect which appears when light is transmitted through a rotating polarizer and a fixed analyser. The measurements of colour are made by using two intermediate quartz plates, one cut parallel and one perpendicular to the axis. When the polarizer rotates two different spectral regions are alternately transmitted and by turning the analyser a setting may be found for which the alternating current of the phototube disappears. With a suitable rotatory dispersion and sensitivity range this provides a useful colour equivalent.

At the Institute of Theoretical Astrophysics, Blindern, Norway, plans for a new Solar Observatory have been worked out. The Institute's 12 Unit Differential Analyser has been provisionally completed and is now in use after having been idle through the war years.

At the Observatory at Toulouse, M. Paloque has constructed an astrograph of 150 mm. aperture and 1·72 m. focal length. A reduction of plates taken shows residuals corresponding to a probable error two or three times less than those given by meridian observations.

Dr Link reports modifications to a Hale type spectrohelioscope at Ondrejov, including the introduction of a grid system engraved on the metallic plate in the plane of the first slit to allow precision measurements. To observe the profiles of Hα he introduces a photoelectric multiplier cell of 14 stages and fed after amplification to the vertical plates of an oscillograph on the screen of which can be observed directly the profile of the line and its evolution during chromospheric eruptions.

At Bordeaux M. Rösch has constructed an instrument in which stars of different magnitudes are made to stand out at different distances in a stereoscopic comparator. The apparatus allows star counts to be made between assigned magnitudes without the necessity of counting the number of each magnitude. By making two exposures, one through a thin prism and the other through the prism turned through 180°, it is possible to obtain stereoscopic indication of effective wave-length to an accuracy of about 5 A.

At Meudon M. Servajean has constructed a photo-mechanical machine which reproduces selected portions of normal spectroheliograms either on Mercator's projection or in rectangular co-ordinates.

A new photometer for the measurement of star images by means of an iris micrometer has been constructed for the Rutherfurd Observatory. The beam sent through the plate is equalized to the control beam coming from the same light source by opening or closing the iris; a photoelectric cell follows using A.C. amplification to serve as the indicator of equality of the beams.

J. A. CARROLL
President of the Commission

Report of meeting

PRESIDENT: Dr J. A. CARROLL.

The Draft Report was adopted with some additions and amendments incorporated.

The Commission, in opening its session, paid respect to the memory of its former president, M. Ch. Fabry, a man outstanding in the field of physical optics and the father of the present very fertile school of younger French workers.

The Commission also recorded their appreciation of the exhibition of instruments and of photographs and diagrams of new astronomical instruments and records obtained with them and congratulated Prof. M. Waldmeier on its successful organization and display.

The President drew the attention of members of the Commission to the possible value of a big improvement in accuracy of line profile determinations. In the last decade or two much effort and ingenuity has gone to facilitating determination of profiles to an accuracy of about 2% and several devices have been designed to analyse spectra in large numbers with great speed to this order of precision. For some kinds of analyses of line profiles, however, a reduction of the error to 0·2% or better is needed and it would be of great value to develop means for determining at least a few lines in some stars to a high degree of precision.

At the request of the International Optical Union the attention of astronomers is drawn to the need for co-ordinating requirements for diffraction gratings and to the need felt by manufacturing opticians for selecting the most promising designs from among the very many variations made possible by recent developments of Schmidt cameras and lens-mirror systems generally.

For diffraction gratings the Optical Section of the Swedish National Committee for Physics will act as a co-ordinator and centre of information. Inquiries should be addressed to Dr E. Inglestam, Royal Institute of Technology, Stockholm 26, Sweden.

Dr E. Linfoot, Solar Physics Observatory, Cambridge, would be glad to receive views on lens-mirror systems and will attempt co-ordination of designs and requirements.

On the afternoon of Monday, August 16, Dr Hubble spoke informally on the 200-inch reflector. He described the new system of supports, devised in connection with the ribbed structure of the mirror, and the drive, which corrects automatically for refraction and flexure. Observations will not be begun before the tests are completed.

The prime focus, which will be used mainly for direct photography and spectrography without temperature control, will be in use first. The Coudé focus is intended for fixed spectrographs of dispersion down to 50 A./mm. Of the proposed programmes the cosmological problem will involve the establishment of good photometric sequences of nebular magnitudes, and work on the red-shifts and on the distribution of nebulae. The abundance problem will demand work with the highest dispersion at the Coudé focus.

It is expected that the radius of visibility will be doubled, as compared with the 100-inch, this being partly due to improvement in photographic plates.

10. COMMISSION DES TACHES SOLAIRES ET DES NOMBRES CARACTERISTIQUES

PRÉSIDENT: M. M. WALDMEIER, *Direktor der Eidgenössischen Sternwarte, Zürich, Schweiz.*

MEMBRES: MM. Abetti, Alfvén, Brunner, Brunner-Hagger, Burton, S. Chapman, d'Azambuja, Guth, Heines, Newton, Nicholson, Romañá, Rowland, Stratton.

RESEARCH WORK

Introduction. Ten years have passed since the last Congress and so much has been published since then in the field of photospheric and allied phenomena that this can only be a summary and not an exhaustive report.

Periodicity of Sunspot Activity. The long period already established by R. Wolf in 1862, has again been investigated by W. Gleissberg (*Publ. Istanbul Obs.* No. 14, 1941; No. 15, 1941; *Z. Ap.* **21**, 347, 1942; *Ap. J.* **96**, 234, 1942), with the result that the period amounts to approximately 70 years.

Prediction of Sunspot Activity. For the first time, thanks to the outburst hypothesis established by M. Waldmeier in 1935, it has been possible to predict the whole course of a new cycle at its beginning. The essential point of that hypothesis brings out the fact that the totality of the individual sunspot cycles forms a family of curves depending on chiefly one parameter. Later on, different analytical formulae have been suggested for these curves by Stewart and Panofsky (*Ap.J.* **88**, 385, 1938; **91**, 72, 1940) and by W. Gleissberg (*Z. Ap.* **18**, 199, 1939). These formulae have, however, proved less adequate for the prediction, because they contain as parameter the Sun's activity at its maximum, so that they only can be used after the maximum has been reached. M. Waldmeier's prediction having proved successful (*A.N.* **259**, 267, 1936), a new prediction with the help of the same method was set up at the beginning of the current cycle (*Terr. Mag.* **51**, 270, 1946), according to which the maximum should be extremely intensive and should take place in 1947.6. As far as can be judged from the observations at the present stage, this prediction was fully successful too. W. Gleissberg predicted the present sunspot cycle as follows (*Nature*, **156**, 539, 1945): With a probability of 95 % it can be predicted that the maximum will take place before May 1948 and will be greater than that of 1937.

Distribution of the Sunspot Groups on the Sun's Disk. An investigation of the latitude of the spot zone during 7 cycles by M. Waldmeier (*Astron. Mitt. Zürich*, No. 138, 470, 1939) has led to the result that, contrary to the frequency variation, the latitude variation is very regular; as a further consequence the average latitude of the spot zone during very intensive, that is to say premature maxima, is greater than during weak and thus late maxima. W. Gleissberg has come to the same conclusion (*Publ. Istanbul Obs.* No. 20, 1942 and *Ap. J.* **100**, 219, 1944).

The east-west asymmetry has been examined by W. Gleissberg (*A.N.* **268**, 81, 1939), M. G. J. Minnaert (*A.N.* **269**, 48, 1939) and M. Waldmeier (*Astron. Mitt. Zürich*, No. 138, 460, 1939). In all these three publications the excess of originating sunspots on the eastern side compared to the western side is explained by the variable visibility of sunspots, dependent on the distance from the centre of the Sun's disk, in connection with the Sun's rotation. If this theory proves to be correct, there must be a corresponding excess on the western hemisphere as compared to the eastern one for the dissolution of sunspots. In the last quoted publication this effect has likewise been examined, leading to the result that the points, at which sunspots are seen for the last time, show a distribution conforming exactly to what had to be expected from the theory. Concerning the visibility of spot groups it has been found that not only a geometrical foreshortening had to be taken into account, but that there exists a 'physical foreshortening' too; see Dobbie (*Obs.* **62**, 289, 1939) and G. H. A. Archenhold (*M.N.* **100**, 645, 1940 and **101**, 66, 1941).

A further east-west asymmetry, suspected by Maunder, according to which the groups

appearing on the eastern limb are more numerous than those disappearing on the western limb, has already been put into doubt by M. Waldmeier in his book *Ergebnisse und Probleme der Sonnenforschung*, Leipzig, 1941, and refuted by W. Gleissberg (*Obs.* **67**, 60, 1947).

A third east-west asymmetry maintains that the area occupied by the spots on the eastern side of the Sun is greater than that occupied on the western side. This effect has been confirmed by Gleissberg (*Publ. Istanbul Obs.* No. 12, 1940). It can be explained by a westerly inclination of the upper end of the spot's axis of approx. 0°·5. The reason for the small angle is apparently due to the fact that there are spots with easterly and others with westerly inclination, which are nearly equally frequent. In fact, according to W. Gleissberg (*Ap. J.* **102**, 133, 1945), there is for P-spots an area excess in the western hemisphere and for F-spots in the eastern hemisphere, which seems to indicate that the upper end of the P-spots' axis is directed towards the east and that of the F-spots towards the west. According to M. G. J. Minnaert (*M.N.* **106**, 98, 1946) the inclination is 0°·44 for all spots, 4°·3 to 6°·8 for those whose lifetime equals at least half a solar rotation and 7°·6 for lifetimes of at least one solar rotation.

Waldmeier has pointed out (*Ergebnisse und Probleme der Sonnenforschung*, Leipzig, 1941, Abb. 42) a relation between the northern and southern hemispheres. Recent, not yet published research work shows that, more often than should be expected from mere chance, a spot not only possesses a corresponding spot in the same longitude and symmetric to the equator, but that there often exists a corresponding pair of spots on the meridian situated 180° away from the one considered.

Romañá has discussed other suspected asymmetries in the distribution of the spot positions, especially with regard to a probable 'earth-effect' (*Asoc. Espan. para el Prog. Cienc.* XVII, *Cong. Córdoba*, 1944).

The lifetime of spot groups has been examined by M. N. Gnevishev (*Pulkova Obs. Cir.* No. 24, 1938; No. 30, 1940). For more than half the groups the lifetime is shorter than two days and for more than 90% shorter than 11 days.

Structure of the Spots. In a publication (*Astron. Mitt. Zürich*, No. 138, 439, 1939) Waldmeier showed that a normal sunspot consists of three different parts: umbra, penumbra and bright ring, and has determined the corresponding diameters of these three parts. A theoretical investigation yields a level difference of about 50 km. between photosphere and spot (*Helv. Phys. Acta*, **15**, 416, 1942), whereas E. Pettit (*Ann. Rep. Mt Wilson Obs.* p. 12, 1939) lately seems to have found a confirmation of the Wilson effect. The great level differences of 1000 to 2000 km. are ascribed to the bright ring.

Proper Motions. Using observations made in 1936 and 1937 M. Waldmeier (*Astron. Mitt. Zürich*, No. 138, 451, 1939) has made an investigation on a particular form of proper motions; of special interest are the groups with a strong meridional motion or which penetrate each other. J. Tuominen (*Z. Ap.* **21**, 96, 1942) ascertains a peculiar periodic increase and decrease of the meridional speed and he gives a model interpretation for the great meridional motions which occasionally occur at the birth of spot groups (*Obs.* **66**, 387, 1946).

Magnetic investigations, which for decades had been the privilege of the Mt Wilson Observatory, were included since 1942 by H. v. Klüber in the routine programme of the Einstein Institute at Potsdam (*Z. Ap.* **24**, 1, 121, 1947). R. S. Richardson (*Ann. Rep. Mt Wilson Obs.* p. 9, 1939/40) has proved that outside the spots there exists a magnetic field, opposite in sign to that of the umbra and with 5% of its intensity. T. G. Cowling (*M.N.* **106**, 218, 1947) finds from theoretical considerations that the growth of a magnetic field requires some hundred years so that the magnetic field of sunspots cannot have originated in the spot, but must have existed long before they reached the Sun's surface and thus became visible. S. Chapman (*Terr. Mag.* **49**, 37, 1944) has made calculations of the magnetic field at the sunspot ends of a semicircular electromagnet in the form of half an anchor-ring.

Solar Radiation at Radio-frequencies. In February 1942, J. S. Hey first noticed this radiation during the passage of a large spot group (*Nature*, **156**, 534, 1945; **157**, 47 and 296, 1946). Whereas there is no doubt that this radiation originates from the Sun, it is

quite clear that only a certain component of it is connected with the sunspots. From the available observations M. Waldmeier (*Astron. Mitt. Zürich*, No. 154, 1948) concludes to the existence of a component emitted continuously from the Sun, R_k, and a component emitted eruptively, R_e. R_k itself can again be decomposed in a component $R_{k,c}$ originating from the corona, and $R_{k,s}$ closely connected with the spots. We only have to report about the latter. This radiation shows an intensive 'limb darkening', as it reaches the earth only if the distance of its source from the centre of the Sun's disk is not greater than half the Sun's radius. Different authors confirm that this radiation is circularly polarized, and that its frequency is in accordance with the gyromagnetic frequency of the electrons in the magnetic field of the spots: D. F. Martyn (*Nature*, **158**, 308, 1946), E. V. Appleton and J. S. Hey (*Nature*, **158**, 339, 1946), Denisse (*Rev. Sci.* **84**, 259, 1946), K. O. Kiepenheuer (*Nature*, **158**, 340, 1946), L. L. McCready, J. L. Pawsey and R. Payne-Scott (*Proc. Roy. Soc.* **190**, 357, 1947), T. V. Garwick (*C.R.* **224**, 377, 551, 1947).

Photometry. New investigations made by R. S. Richardson (*Ap. J.* **90**, 230, 1939) on different wave-lengths at different distances from the Sun's centre show that the conditions observed in the umbra can best be represented by radiative equilibrium of a temperature of 4300°.

Theories about Spots and Spot-cycles. M. Waldmeier (*Helv. Phys. Acta*, **15**, 405, 1942) has given a qualitative and quantitative explanation of the Evershed effect, based on a model solar atmosphere for the undisturbed photosphere and for the sunspot.

G. J. Odgers tried to explain the structure of the sunspots on the assumption that a spot is a region in which the product of absorption coefficient and density is higher than that of the photosphere (*M.N.* **106**, 101, 1946). H. Alfvén brings the cooling in the sunspots in connection with their magnetic field (*Ark. Mat. Astron. Fysik*, **29** A, No. 11, 1943). As a consequence of the additional magnetic pressure the gas pressure in the spot must be smaller than in the photosphere in the state of equilibrium. Gas flowing up in the spot will thus undergo a much stronger process of cooling than in undisturbed regions.

An exhaustive theory about the 11-years cycle has been set up by H. Alfvén (*Ark. Mat. Astron. Fysik*, **29** B, No. 2, 1942 and **29** A, No. 12, 1943; *M.N.* **105**, 3 and 382, 1946) and H. Walén (*Ark. Mat. Astron. Fysik*, **30** A, No. 15, 1944), according to which the disturbances have their origin in the Sun's interior and move as magneto-hydrodynamic waves along the lines of force of the general magnetic field towards the Sun's surface, where they become visible as spots.

Faculae. Independently of one another P. ten Bruggencate (*Z. Ap.* **19**, 59, 1939) and M. Waldmeier (*Helv. Phys. Acta*, **13**, 14, 1939) have discovered the fine structure of the faculae. These consist of individual faculae granules which have a diameter of 1–2″ and a lifetime of about 2 hours. The faculae granules attain much greater intensities than the photospheric ones; P. ten Bruggencate (*Z. Ap.* **21**, 162, 1942) finds that the brightest faculae granules exceed the photospheric granules by about 40–50 %.

Granulation. In the year 1938 there was a great confusion concerning the granulation, as the works of Potsdam and Oxford yielded much larger granules than the classical investigations. The situation became clear, when in the following years Ph. C. Keenan (*Ap. J.* **88**, 360, 1938 and **89**, 604, 1939), P. ten Bruggencate and H. Müller (*Z. Ap.* **21**, 198, 1942) and M. Waldmeier (*Helv. Phys. Acta*, **13**, 14, 1939) succeeded in obtaining photographs of greater resolution and, in accordance with the classical works, found that the diameter of the granules is about 1100 km. The granulation theory, based on the hydrogen convection zone, has been further carried on by L. Biermann (*Z. Ap.* **21**, 320, 1942) and R. v. d. R. Woolley (*M.N.* **103**, 191, 1943).

Structure of the Solar photosphere. The discovery of the H^--absorption by R. Wildt (*Ap. J.* **89**, 295, 1939; **90**, 611, 1939) made a new calculation of the constitution of the Sun's atmosphere necessary. Such calculations have been carried out by B. Strömgren (*Festschrift für E. Strömgren*, p. 218, 1940), M. Waldmeier (*Helv. Phys. Acta*, **15**, 405, 1942) and G. Münch (*Ap. J.* **102**, 385, 1945). They are based on earlier theoretical determinations of the absorption coefficient of H^- and should be repeated with the results recently obtained by S. Chandrasekhar and F. M. Breen (*Ap. J.* **104**, 430, 1946).

Report on the 'Quarterly Bulletin on Solar Activity'

Up to the end of 1941 the *Bulletin* appeared regularly, then, owing to lack of communications, it had to be suspended. The *Bulletin* for the years 1942–44 appeared in autumn 1945, for the years 1945 and 1946 in summer 1947 and for the first quarter 1947 in December 1947. At the end of 1944 the publication of the character figures of solar phenomena was discontinued. Since 1947 the following indications are communicated in the *Bulletin*:

I. Sunspots:
   (1) Sunspot relative-numbers.
   (2) Evolution-tables of sunspot-groups.

II. Eruptions chromosphériques brillantes:
   (1) Eruptions signalées.
   (2) Régions actives.
   (3) Heures effectives d'observations au spectrohélioscope et au spectrohéliographe.

III. Intensité de la couronne solaire:
   (1) Observations d'Arosa.
   (2) Observations de Climax.
   (3) Observations du Pic du Midi.
   (4) Observations du Wendelstein.

IV. Rayonnement solaire de fréquence radioélectrique.
   (1) Flux et Bursts par heure.
   (2) Outbursts.

Up to now the *Bulletin* does not contain indications about the prominences.

Suggestions

1. As the character figures have been cancelled, the title of the Commission: 'Commission des taches solaires et des figures caractéristiques solaires' is no longer up to date. We therefore suggest the new title: 'Commission des phénomènes photosphériques.'

2. The heliographic maps of the photosphere have been published by the Federal Observatory since the year 1887. The latest maps appeared for the year 1946 (*Publ. der Eidgen. Sternwarte*, Bd. IX, Heft 1). The great increase of printing costs will no longer permit the publication of these important maps, if the I.A.U. cannot grant a subvention. By the collaboration of the observatories of Zürich, Arosa, Locarno, Istanbul, Kanzelhöhe, Madrid, Potsdam, Skalnate Pleso, Tsinan and Uccle the setting up of the heliographic maps of the Sun was made possible. These maps in connection with the evolution tables indicate the spots and faculae occurring at any time on the Sun as well as their distribution on the Sun's disk. A yearly subvention of S.fr. 1500 is suggested.

M. Waldmeier
President of the Commission

Compte rendu des séances

Président: Prof. Dr M. Waldmeier.

Secrétaire: Rév. Dr A. Romañá, S.J.

La Commission tint des séances le 12 et le 14 août, et conjointement avec la Commission 11 et la Sous-Commission pour la cinématographie des protubérances, le 14 et le 17. Après l'éloge des membres décédés depuis l'Assemblée de Stockholm (Rodés, Perepelkin, Newall), M. le Président rend compte de la désignation des nouveaux membres et propose

d'en augmenter le nombre, pour que d'autres observatoires, collaborant depuis quelque temps aux travaux de la Commission (Skalnaté Pleso, Uccle, Madrid) puissent y être représentés; l'augmentation est approuvée, et l'on nomme aussi par acclamation, sur la proposition de M. Waldmeier, M. Brunner Président d'honneur de la Commission.

On entre dans l'ordre du jour et on discute le changement de nom de la Commission. Il semble bien qu'elle doive s'appeler désormais 'des phénomènes photosphériques', puisqu'elle s'occupe d'autres phénomènes que les taches, tels que les plages faculaires, la granulation, etc. Dans la discussion M. Menzel envisage une nouvelle organisation des commissions s'occupant du Soleil, qui devraient être à son avis au nombre de quatre: de la variabilité solaire et de ses rapports avec les phénomènes terrestres, de l'atmosphère solaire, de l'astrophysique solaire, et des éclipses; mais cette réorganisation dépassant les attributions de la Commission, après l'intervention de MM. Minnaert, d'Azambuja, Royds et Kaplan, on adopte la proposition. On décide aussi de demander au Comité des Finances une subvention annuelle de 1500 francs suisses, jusqu'à la prochaine Assemblée, pour que la publication des cartes synoptiques de Zürich puisse être continuée. M. Brunner-Hagger suggère qu'il serait intéressant de remplir la lacune d'environ 20 ans existant avant 1926; mais il faut y renoncer pour le moment à cause du travail extraordinaire et des frais que cela exigerait. M. d'Azambuja dit que, dans le but de suivre les plages faculaires dans l'ensemble du disque, il serait à souhaiter que leur observation ne se fît plus désormais en lumière intégrale, mais avec la raie K à l'aide de spectrohéliographes à faible dispersion. M. Waldmeier craint qu'une telle recommandation diminuerait de beaucoup le nombre des collaborateurs et M. Öhman fait remarquer que le même résultat peut être obtenu plus facilement avec des filtres pour l'ultra-violet.

On s'occupe du problème créé par l'augmentation des frais d'impression du *Quarterly Bulletin*. Après une discussion très détaillée (Gallet, Waldmeier, d'Azambuja, Abetti, Roberts, Kiepenheuer, etc.) on décide de la continuer pour le moment sous la même forme que jusqu'à présent, même pour les données sur la couronne, le temps écoulé depuis le commencement des observations de celle-ci semblant trop court pour qu'une standardisation puisse être faite. M. le Président profite de l'occasion pour remercier M. Stratton pour l'aide que l'on reçoit toujours du Conseil des Unions Scientifiques grâce à son appui.

On étudie finalement une proposition de M. Waldmeier concernant l'organisation d'une collaboration internationale, sous la conduite de l'Observatoire de Zürich, dans le but de connaître en détail l'évolution des taches, soit par l'utilisation des données déjà existantes, soit par la prise systématique de photographies fréquentes de ces taches dans l'avenir. Après une discussion sur la forme la plus pratique de cette collaboration (Menzel, d'Azambuja, Romañá, Brunner-Hagger, Kiepenheuer, Ellison), suivie d'autres suggestions fort intéressantes sur la possibilité d'étudier les mouvements propres des taches aux régions boréales en été (Tuominen, Abetti, Atkinson, Fracastoro), la proposition est adoptée et l'on confie à M. Waldmeier son exécution.

II. COMMISSION DES PHENOMENES CHROMOSPHERIQUES ET DE LA COURONNE SOLAIRE

PRÉSIDENT: M. L. D'AZAMBUJA, *Astronome à l'Observatoire de Paris, Section d'Astrophysique, Meudon, Seine-et-Oise, France.*

MEMBRES: MM. Abetti, Brunner, Mme d'Azambuja, Mlle Dodson, MM. dos Reis, Edlén, Ellison, Evershed, Goldberg, A. R. Hogg, Lyot, McMath, Mohler, Newbegin, Newton, Nicholson, Öhman, Pettit, Richardson, Roberts, Royds, Megh Nad Saha, Thackeray, Viasanizyn, Waldmeier.

SOUS-COMMISSION POUR LA CINÉMATOGRAPHIE DES PROTUBÉRANCES

PRÉSIDENT: M. LYOT.

MEMBRES: MM. d'Azambuja, McMath, Roberts, Waldmeier.

La Commission vient d'être douloureusement éprouvée par la perte de son Président d'honneur, Henri Deslandres, décédé le 15 janvier 1948, dans sa 95me année. Son nom est et demeurera indissolublement lié à l'invention du spectrohéliographe et à la période de découvertes qui a suivi les premières réalisations de cet instrument. La Commission a perdu également le Père Luis Rodés, S.J., décédé le 7 juin 1939, à l'âge de 58 ans, au moment où il venait d'entreprendre la restauration de l'Observatoire de l'Ebre, qu'il dirigeait depuis 1919.

L'Assemblée restreinte de l'U.A.I., tenue à Copenhague en mars 1946, a modifié le titre de la Commission II, comme on peut le voir en tête de ce rapport. Elle a, en outre, pris plusieurs décisions concernant son activité:

1. La Commission est chargée de grouper pour la publication dans le *Quarterly Bulletin on solar activity*, des données nouvelles se rapportant aux phénomènes coronaux, au rayonnement solaire de fréquence radio-électrique (radio noises) et à la luminescence du ciel nocturne, qui remplaceront les nombres caractéristiques relatifs aux flocculi brillants du calcium, aux flocculi brillants et sombres de l'hydrogène, dont la détermination sera supprimée dans l'avenir.
2. Elle est invitée à rechercher un indice caractéristique qui représente mieux l'activité des protubérances que les indices utilisés actuellement.
3. Elle est invitée également à étudier la possibilité de prédire les phénomènes terrestres d'origine solaire et de déterminer, sur le disque, les zones d'activité.

L'Assemblée a, de plus, chargé le Président de la Commission de prendre les dispositions nécessaires pour hâter la mise à jour des listes d'éruptions chromosphériques dont la publication dans le *Quarterly Bulletin* s'arrêtait alors à 1941. Elle rappelait l'importance d'organiser, aussitôt que possible, l'étude cinématographique continue du Soleil dans des stations convenablement réparties autour du Globe.

Précisons dès maintenant où en est l'exécution de ces diverses décisions:

Au moment de la réunion de Copenhague, un fascicule du Bulletin, contenant les listes des éruptions observées en 1942, 1943 et 1944, était en préparation et a été distribué vers le milieu de 1946. Après accord avec le Directeur de l'Observatoire de Zurich, qui édite le Bulletin, il a été décidé que les nombres caractéristiques en seraient supprimés à partir de 1944, année qui marque justement le minimum d'activité solaire. Un numéro de transition, contenant seulement les nombres de Wolf et les éruptions, pour 1945 et 1946, a paru en octobre 1947. Puis, la périodicité trimestrielle a été reprise. Un premier fascicule, se rapportant aux observations des trois premiers mois de 1947, a été distribué à la fin de l'année. Il contient, non seulement les nombres de Wolf, des tables relatives à l'évolution des groupes de taches et les listes d'éruptions, mais aussi les intensités quotidiennes de la couronne, en des points espacés régulièrement de 5° en 5° autour du bord solaire et à une distance de celui-ci comprise entre 40″ et 2′, d'après les observations faites à Arosa (Suisse), à Climax (U.S.A.), au Pic du Midi (France) et au Wendelstein

(Allemagne). Enfin, il donne de brèves indications sur les variations du rayonnement solaire de fréquence radio-électrique, à l'aide des résultats obtenus à l'Observatoire de Canberra (Australie), au Laboratoire Cavendish (Angleterre) et à l'Université de Perth (Australie).

Les questions relatives à la luminescence du ciel nocturne et à l'élaboration d'un meilleur indice d'activité des protubérances ont été provisoirement réservées. A certains égards, la première relève moins d'un Bulletin consacré jusqu'ici à la publication des caractères de phénomènes spécifiquement solaires que d'un organe de documentation sur la haute atmosphère terrestre. Quant à la seconde, il semble difficile de lui donner une solution sans qu'elle ait, au préalable, fait l'objet d'une discussion approfondie au sein de notre Commission.

Les phénomènes terrestres visés par la décision 3 de l'Assemblée de Copenhague étaient essentiellement les perturbations ionosphériques, étroitement associées, comme l'on sait, aux éruptions chromosphériques. Or, on sait aussi que les éruptions se produisent à peu près toujours dans les régions du disque solaire où se trouvent des centres d'activité (taches, facules et plages faculaires) et pendant la phase de croissance de ces centres. Prédire l'apparition probable d'éruptions chromosphériques revenait donc, dans une large mesure, à annoncer la formation de centres d'activité nouveaux. Pour être efficace, une telle annonce devait être transmise immédiatement ou, au plus tard, le lendemain de l'apparition des centres. Dans les conditions actuelles des transmissions d'observatoire à observatoire, elle ne pouvait donc dépendre de la coopération entre plusieurs établissements.

Le Président de la Commission s'est alors entendu avec le Directeur du Bureau ionosphérique français qui, depuis le printemps 1947, fait radiodiffuser chaque jour un message du type *ursigramme* relatif aux perturbations ionosphériques à début brusque, pour joindre à ce message un Bulletin de renseignements sur l'activité solaire établi d'après les seules observations de Meudon et comportant essentiellement des indications sur la position, l'âge et l'importance des centres d'activité présents sur le disque de l'astre; le Bulletin étant complété par l'annonce de la disparition brusque de protubérances, que certains auteurs ont parfois associée à des perturbations du champ magnétique terrestre, par celle des éruptions observées à Meudon et, éventuellement, par des données sur les phénomènes coronaux. Ce nouveau message a été diffusé à partir du 1er juin 1947. En outre, sur la suggestion de l'Observatoire d'Utrecht, il a été convenu que le même message ferait connaître les éruptions d'importance exceptionnelle qui auraient été signalées par câble au centre de Meudon. Les Géophysiciens seraient ainsi informés à temps de l'apparition probable d'orages magnétiques et de phénomènes connexes. Cette organisation provisoire devra évidemment être améliorée par une coopération internationale.

La question de la cinématographie du Soleil est traitée plus loin dans le rapport du Président de la Sous-Commission.

Observations Courantes de la Chromosphère et de la Couronne. Relevés et Statistiques

Malgré la guerre et les conditions parfois extrêmement difficiles qu'elle a créées, la plupart des Observatoires assurant l'observation régulière des phénomènes chromosphériques ont maintenu sensiblement leur activité habituelle. Par contre, les relevés et statistiques établis à partir de cette observation ont subi, à cause notamment de la difficulté des échanges d'un établissement à l'autre, des retards plus ou moins grands qui ne pourront être regagnés que progressivement.

Les trois nouvelles stations de haute altitude, munies de coronagraphes du type Lyot, complétés par des spectrographes, et dont les déterminations de l'intensité de la couronne figurent, avec celles du Pic du Midi, dans le *Quarterly Bulletin*, ont été mises en service respectivement aux époques suivantes: Arosa, en 1938, Climax, en 1941, Wendelstein, en 1943. Leurs observations sont en outre publiées dans les Bulletins d'information nationaux suivants: *Astronomische Mitteilungen*, pour Arosa, *Ionospheric data*, éditées par le *Central Radio Propagation Laboratory* (C.R.P.L.) de Washington, pour Climax,

Observations ionosphériques et solaires, publiées par la Marine française, pour le Pic du Midi et les Observatoires allemands des zones américaine et française d'occupation.

L'Observatoire McMath-Hulbert, de l'Université de Michigan, primitivement spécialisé dans la cinématographie des protubérances, a développé ses installations, notamment par l'adjonction aux appareils existants d'un spectrohéliographe pour la détermination des vitesses radiales (*Publ. Obs. Univ. Michigan*, **8**, No. 4, 57, 1940 et No. 11, 141, 1941). A partir de 1942, il a enregistré régulièrement des images de la chromosphère avec la raie K_{232}.

La surveillance internationale de la chromosphère a été moins complète pendant les années de guerre qu'elle ne l'était auparavant. Toute activité a été suspendue en 1942 dans les Observatoires de Kharkov et de Simeis, en partie détruits. Le spectrohélioscope de l'Observatoire Cook n'a plus fonctionné après le décès du fondateur de l'établissement, en 1940. Mr Newbegin a cessé ses observations en 1947. Dans d'autres cas, les travaux intéressant la défense nationale n'ont permis d'effectuer que des observations partielles. Toutefois, à partir de 1946, l'activité a repris à peu près normalement et, grâce aux adhésions des Observatoires McMath-Hulbert et d'Ondrejov-Prague, les heures effectives de surveillance sont redevenues sensiblement ce qu'elles étaient en 1939.

Diverses améliorations ont été apportées aux dispositifs mécaniques ou optiques du spectrohélioscope: G. A. Mitchell remplace les prismes d'Anderson par un disque tournant dont l'axe est parallèle à l'axe optique de l'instrument et qui porte des fentes multiples, un seul couple de fentes étant découvert en même temps (*Ap. J.* **88**, 542, 1938). F. J. Sellers a perfectionné le mécanisme des fentes oscillantes employé par G. E. Hale; dans son procédé, les fentes sont l'une à côté de l'autre, de sorte que la tête de l'observateur n'est plus directement au-dessous du faisceau formant l'image initiale du Soleil (*Journal B.A.A.* **48**, 243, 1938). M. A. Ellison décrit son spectrohélioscope à deux prismes et retour de rayons, auquel il a adapté, lui aussi, le système de fentes oscillantes préconisé par Sellers (*Journal B.A.A.* **50**, 107, 1940). Helen W. Dodson propose de pointer une lunette sur le spectre de 1er ordre non utilisé du spectrohélioscope, pour suivre les variations d'aspect et d'intensité des raies au cours d'une éruption (*Ap. J.* **93**, 208, 1941). E. Pettit, prévoyant le cas où le dispositif optique employé ne permet pas que les fentes de l'instrument soient dans le prolongement l'une de l'autre, et utilisant néanmoins des prismes d'Anderson, remplace le moteur unique qui actionne habituellement leur arbre commun par deux moteurs synchrones portant chacun un prisme (*P.A.S.P.* **52**, 292, 1940). C'est le dispositif employé à Meudon depuis 1934 (*L'Astronomie*, **53**me année, 97, 1939) et qui donne en effet d'excellents résultats. F. Link indique une méthode simple pour la détermination précise des positions des détails chromosphériques observés avec l'instrument (*Annales d'Astroph.* **9**, 132, 1946).

Phénomènes Exceptionnels

Deux protubérances, l'une du type II b_2 (éruptive en arche) de la classification de E. Pettit, l'autre du type IV (tornade), observées au Mount Wilson, ont atteint des hauteurs record: la première (E. Pettit, *P.A.S.P.* **58**, 310, 1946), après avoir été visible pendant plusieurs jours comme un énorme flocculus sombre sur le disque, s'est élevée, le 4 juin 1946, alors que sa base n'avait pas encore atteint le bord, jusqu'à 1,22 diamètre solaire, dépassant ainsi de 0,11 diamètre la protubérance jusque là la plus haute photographiée au même Observatoire (*P.A.S.P.* **50**, 168, 1938). La seconde (R. S. Richardson, *P.A.S.P.* **52**, 326, 1940) s'est élevée jusqu'à $\frac{1}{8}$ du diamètre solaire, le 7 juillet 1940, alors que les phénomènes de ce type, assez rares, ne dépassent pas habituellement le $\frac{1}{20}$. C. W. Allen, de son côté, signale qu'une protubérance observée en projection sur le disque le 4 janvier 1938 a atteint la vitesse radiale d'ascension de 750 km./sec., qui constitue également une vitesse record (*The Observatory*, **61**, 136, 1938).

A Meudon, le 21 février 1942, on a observé au bord une éruption étendue et très brillante qui, s'élevant graduellement au-dessus de la surface, avec une vitesse d'ailleurs inférieure à 10 km./sec. (L. d'Azambuja, *L'Astronomie*, **56**me année, 97, 1942), a fini par présenter l'aspect d'une protubérance, bordée à sa partie supérieure d'une frange très

lumineuse. Il y a là, semble-t-il, un témoignage direct qu'une éruption importante peut quitter tout entière la chromosphère où elle a pris naissance et atteindre une hauteur notable avant de perdre son éclat.

Enfin, le 25 juillet 1946, une éruption d'une étendue et d'un éclat exceptionnels, est apparue vers le méridien central, près d'un groupe d'assez grosses taches. Elle a été décrite, notamment, par M. A. Ellison (*Nature*, **158**, 450, 1946 et *M.N.R.A.S.* **106**, 500, 1946) et par les observateurs de Meudon (*L'Astronomie*, **60me** année, 215, 1946). Sa durée a dépassé 3 heures. Au moment du maximum, la raie H_α éruptive avait une largeur de 12 A. et le spectre continu était renforcé (Ellison); la raie D_3 était visible en émission assez nettement pour marquer sa présence par une arête brillante sur un spectrohéliogramme obtenu à Meudon. L'aspect du phénomène, sur les photographies successives, indiquait comme très probable que des masses étendues de la vapeur lumineuse étaient très élevées au-dessus de la chromosphère.

Travaux de Recherches

Le cadre restreint de ce rapport ne peut évidemment permettre d'exposer, même sommairement, les résultats des très nombreuses recherches effectuées pendant la période de dix ans qui s'est écoulée depuis le dernier Congrès. Dans la sélection qu'il a été nécessaire de faire, nous avons surtout considéré l'antériorité, quand il s'agissait d'études analogues poursuivies par des auteurs différents, et les résultats les plus essentiels, dans la suite de notes écrites par un même auteur.

Chromosphère et protubérances. On sait que G. E. Hale avait trouvé que, dans deux cycles undécennaux consécutifs, le sens des *Solar vortices* que l'on observe sur les spectrohéliogrammes H_α ne change pas, alors que la polarité des taches est inversée. Il en avait conclu que les vortices résultent d'actions hydrodynamiques. R. S. Richardson, qui a repris le travail de Hale sur une période plus étendue, 1908–39 (*Ap. J.* **93**, 24, 1941) parvient au même résultat: le sens des tourbillons est indépendant de celui du champ magnétique des taches.

W. O. Roberts attire l'attention (*Ap. J.* **101**, 136, 1945) sur l'existence de *spicules chromosphériques*, qu'il a observés au bord solaire, principalement dans les régions polaires de l'astre, avec le coronagraphe de Climax muni d'un monochromateur transmettant la raie H_α. Ces spicules, dont le diamètre est de 3″ ou 4″ et la hauteur inférieure à 15″, ont une durée de vie très courte, 4 à 5 minutes au maximum. Ils peuvent être associés à la granulation photosphérique.

E. Pettit a exposé en détail (*Ap. J.* **98**, 6, 1943) les caractères des protubérances qui forment les différents types de sa classification. Celle-ci, comme on sait, est basée exclusivement sur l'aspect au bord et les mouvements des phénomènes. L'auteur décrit 19 types offrant des caractères distinctifs. Il est regrettable, à notre avis, qu'un travail aussi important et étendu ne tienne aucun compte de la forme spatiale des protubérances, maintenant bien connue. C'est ainsi que, par leur aspect au bord, les protubérances quiescentes sont comparées à des *meules de foin*, alors que Pettit lui-même, antérieurement, assimilait leur forme dans l'espace à celle de la flamme plate des brûleurs Bunsen appelés *queue de poisson*.

H. W. Newton (*M.N.R.A.S.* **102**, 2, 1942) et M. A. Ellison (*M.N.R.A.S.* **102**, 11, 1942) ont poursuivi indépendamment, au spectrohélioscope, l'étude des mouvements internes dans les petites protubérances, au bord ou projetées sur le disque, qui accompagnent les éruptions. Leurs résultats mettent en évidence un défaut inhérent au principe même de l'instrument: c'est qu'il est difficile de reconnaître, quand on observe un objet sombre à une certaine distance de l'axe de la raie, s'il s'agit d'un phénomène réel animé d'une vitesse radiale ou d'une simple apparence, due à un élargissement de la raie (A. Hunter, *The Observatory*, **64**, 201, 1942; A. D. Thackeray, ibid. **64**, 204, 1942).

E. Pettit a pu mesurer la vitesse de rotation périphérique et la durée de révolution de deux protubérances du type IV (tornade) (*P.A.S.P.* **53**, 289, 1941; **58**, 150, 1946). Dans le premier cas, il a utilisé la reconstitution cinématographique où les filets hélicoïdaux

du phénomène se mouvaient de bas en haut, comme ceux d'une vis, pour déterminer la durée de révolution. Il a trouvé 11,6 minutes. Le rayon de la protubérance étant d'environ 6000 km., la vitesse périphérique était de 54 km./sec. Pour la seconde protubérance, il a employé la méthode spectroscopique. La rotation des spires était beaucoup plus lente: trois heures en moyenne; la vitesse périphérique n'a pas dépassé 3 km./sec.

L. d'Azambuja et Marguerite d'Azambuja ont fait une étude étendue, non plus des mouvements internes des protubérances, mais de leurs mouvements d'ensemble, macroscopiques peut-on dire et de leur évolution (*Comptes rendus Paris*, **212**, 1128, 1941; *Annales Meudon*, **6**, fasc. 7, 1948). Leur travail s'appuie sur les *Cartes synoptiques de la chromosphère* de 1919 à 1937, publiées par l'Observatoire sous les auspices de l'U.A.I., et sur la collection correspondante des spectrohéliogrammes de l'Etablissement, où les protubérances, visibles comme *filaments*, peuvent être suivies pendant toute leur traversée du disque. Il concerne exclusivement les protubérances quiescentes. Voici leurs principaux résultats:

1. La latitude de formation des filaments suit exactement celle des taches, au cours de la période undécennale; à l'époque du minimum d'activité, elle subit l'augmentation brusque de 15° à 20° qui caractérise le changement de cycle. Un peu moins d'une fois sur deux, les filaments naissent même dans les régions faculaires qui accompagnent les taches.

2. D'abord petits et peu marqués, les filaments atteignent leur développement maximum vers le troisième passage sur le disque; ils disparaissent en général au cours du cinquième. Souvent, deux phénomènes, d'abord indépendants, se rejoignent, évoluent pendant quelque temps comme un seul objet, puis se séparent à nouveau. Cette propriété est à rapprocher de celle qui a fait donner par E. Pettit le nom d'inter-actives à certaines protubérances. Durant toute leur existence, les filaments se déplacent vers le pôle avec une vitesse de l'ordre de 2°·3 par rotation près de l'équateur et de 0°·8 aux latitudes élevées.

3. A leurs passages successifs sur le disque les filaments, d'abord sensiblement parallèles aux méridiens, s'incurvent de plus en plus vers l'est en vertu du ralentissement polaire de la vitesse angulaire de rotation du Soleil. Parfois, un filament de longue vie atteint la zone secondaire d'activité où circulent, à peu près parallèles à l'équateur, les protubérances polaires et se confond avec elles. Il y a là une indication que celles-ci ne sont pas réellement indépendantes, mais constituent le dernier stade de l'évolution des protubérances.

4. L'examen critique des déterminations spectroscopiques de la vitesse de rotation et les mesures sur les filaments semblent bien indiquer que l'augmentation de la vitesse angulaire avec l'altitude n'est pas réelle, et qu'aucun résultat, à l'heure actuelle, n'est en contradiction avec l'hypothèse que les diverses couches solaires accessibles à l'observation tournent avec des vitesses équatoriales et des ralentissements polaires sensiblement égaux.

Le déplacement régulier des protubérances vers le pôle a été reconnu indépendamment par W. Moss (*Annals Cambridge*, **3**, partie 3, 1946) d'après les clichés de protubérances au bord pris à Kodaikanal de 1905 à 1928, c'est-à-dire dans des conditions où il était particulièrement difficile à mettre en évidence, par suite des difficultés d'identification des phénomènes. Les valeurs trouvées sont un peu plus fortes (de 5° à 1°) que celles obtenues à Meudon.

A Cambridge également, A. D. Thackeray, H. A. Brück et W. Moss (*The Observatory*, **64**, 169, 1941; *M.N.R.A.S.* **103**, 258, 1943 et **105**, 17 et 282, 1945) ont comparé les images des protubérances photographiées avec les raies H_α et D_3, dans le but de déterminer le rapport d'intensité H_α/D_3 d'une protubérance à l'autre et d'un point à l'autre d'une même protubérance. Ils trouvent une relation systématique entre la valeur de ce rapport et l'intensité de D_3, liée probablement au self-renversement de H_α sur les protubérances intenses.

De nombreuses mesures ont été faites de divers côtés pour contrôler la validité des lois de Pettit (*Trans. I.A.U.* **6**, 52, 1938). Pour Pan-Puh, qui a mesuré le mouvement de nodules aisément identifiables sur deux séries d'excellents clichés de protubérances obtenus par B. Lyot avec son coronagraphe et sur cinq protubérances enregistrées au spectrohéliographe de Meudon (*Annales Meudon*, **8**, fasc. 4, 1939), aucune des deux lois n'est valable. Ses mesures, sur les graphiques distance-temps, comme d'ailleurs celles de Pettit,

sont aussi bien représentées par des lignes courbes que par des lignes brisées. Pour H. R. Hulme, qui utilise les documents de Pettit (*M.N.R.A.S.* **99**, 634, 1939), la seconde loi n'est pas vérifiée et la première ne s'applique pas aux courants descendants. D'une étude critique analogue complétée par l'observation au spectrohélioscope de Zurich de douze protubérances nouvelles et par la photographie de divers phénomènes au coronagraphe d'Arosa, M. Waldmeier conclut de son côté que, si la première loi se vérifie dans l'ensemble, la seconde ne paraît pas soutenable (*Zeits. Ap.* **15**, 299, 1938; **18**, 241, 1939; **21**, 130 et 286, 1942). C'est aussi l'avis de L. Dezsö, d'après des mesures faites également sur des clichés d'Arosa (*Publ. Eidg. Sternwarte Zürich*, **7**, part. 2/3, 37, 1940). Ces conclusions plutôt négatives, dans l'ensemble, doivent mettre en garde ceux qui seraient tentés d'expliquer par la théorie les mouvements si curieux signalés par Pettit.

Les disparitions brusques de protubérances pendant lesquelles, notamment, s'observent les mouvements ascendants qui viennent d'être examinés, ont fait l'objet de plusieurs études statistiques. R. S. Richardson, qui a fait porter son investigation sur tous les cas observés de 1917 à 1934 au Mount Wilson (*P.A.S.P.* **50**, 299, 1938), aussi bien sur le disque qu'extérieurement au bord, considère que c'est un phénomène plutôt rare. Au contraire, M. Waldmeier, d'après les observations faites à Zurich en 1937 (*Zeits. Ap.* **15**, 299, 1938), trouve que c'est une phase normale dans l'évolution des protubérances. Dans le mémoire cité plus haut (*Annales Meudon*, **6**, fasc. 7, 1948), L. et M. d'Azambuja se rangent à l'avis de Waldmeier. Ils signalent en outre que, deux fois sur trois, le phénomène est suivi d'une réapparition progressive, après quoi la protubérance reprend sensiblement l'aspect qu'elle avait avant de disparaître.

Eruptions chromosphériques. Les caractères essentiels de ces phénomènes ont été décrits dans le volume précédent des *Transactions*, p. 54. Depuis, en dehors de leur observation courante, les auteurs se sont surtout attachés à préciser les particularités de leur spectre. R. G. Giovanelli a cherché à déterminer la largeur de la raie H_α éruptive en déplaçant celle-ci, avec le *line-shifter*, vers le violet, puis vers le rouge, jusqu'à ce que l'éruption ait disparu (*Ap. J.* **91**, 334, 1940). Il trouve que la largeur varie avec l'aire couverte par l'éruption et que les vitesses radiales sont faibles (+3·5 km./sec. en moyenne). M. Waldmeier, indépendamment, a fait aussi par le même procédé des déterminations de la largeur de la raie H_α éruptive, mais pour des éruptions observées au bord (*Zeits. Ap.* **20**, 46, 1940). Il a étudié en outre le comportement de la raie D_3, qui est visible en absorption dans les éruptions d'importance 1, invisible pour une importance 2 et apparaît en émission dans les éruptions cotées 3. M. A. Ellison a, lui aussi, mesuré la largeur de la raie H_α sur les éruptions (*M.N.R.A.S.* **103**, 3, 1943; *The Observatory*, **67**, 181, 1947). Il remarque qu'elle croît très vite au début du phénomène, pour décroître plus lentement ensuite. Les largeurs maxima observées s'échelonnent entre 1·75 A. et 16 A. Comme Giovanelli, il note que les vitesses radiales sont faibles.

R. S. Richardson et R. Minkowski ont photographié le spectre de plusieurs éruptions dans l'intervalle très étendu 3300–11,500 A. (*Ap. J.* **89**, 347, 1939). Ils publient une liste de 21 raies affectées par le phénomène. De son côté, C. W. Allen donne une liste de 116 raies, dans l'intervalle 3933–6678 A. (*M.N.R.A.S.* **100**, 635, 1940). Dans les deux cas, aucun renforcement du spectre continu n'a été observé. Par contre, M. A. Ellison, qui a pu photographier le spectre de l'éruption exceptionnelle du 25 juillet 1946 (*Nature*, **158**, 450, 1946 et *M.N.R.A.S.* **106**, 500, 1946), y a observé un renforcement net du spectre continu, indiquant que l'éruption pouvait être visible en lumière blanche.

L'intensité maxima d'un certain nombre d'éruptions a été déterminée par A. Colacevich et M. Viaro (*Memorie Arcetri*, fasc. 57, 17, 1939), puis par G. Abetti et A. Colacevich (*Memorie Soc. ast. ital.* **13**, 19, 1940). Pour les éruptions observées, cette intensité, déterminée par photométrie photographique, n'a pas dépassé deux fois environ celle du spectre continu. D'autre part, répondant au désir exprimé par la Commission 11 au dernier Congrès de l'U.A.I., H. W. Newton a décrit le photomètre employé à Greenwich pour mesurer l'intensité des éruptions (*M.N.R.A.S.* **99**, 463, 1939).

Des théories sur la nature et le mécanisme des éruptions ont été proposées par K. O. Kiepenheuer (*Zeits. Ap.* **20**, 332, 1941), qui considère la transformation de l'énergie

cinétique d'un élément en rayonnement ultra-violet par l'action du champ magnétique d'un groupe de taches, et par D. S. Evans (*The Observatory*, **67**, 218, 1947), qui assimile les éruptions aux tornades des cyclones terrestres.

Couronne. L'étude de cette partie de l'atmosphère solaire relève à la fois des Commissions 11, 12 et 13. Pour rester en accord avec l'esprit dans lequel la Commission 11 a été formée en 1932, nous nous occuperons exclusivement ici de ce qui concerne les observations de la couronne *en dehors des éclipses*, soit en lumière intégrale, soit à l'aide de ses radiations monochromatiques. C'est ainsi que nous citerons seulement pour mémoire le très intéressant travail de B. Edlén sur l'identification des raies de la couronne avec celles de certains éléments terrestres à un très haut degré d'ionisation.

Le fait le plus marquant, dans l'étude de la structure de la couronne en dehors des éclipses, est la réalisation, par B. Lyot, d'un filtre monochromatique polarisant en spath et quartz permettant d'isoler, avec une sélection de l'ordre de l'angström et une transparence d'environ 40 %, les radiations principales de la couronne et de la chromosphère (*Comptes Rendus Paris*, **212**, 1013, 1941 et *Annales d'Astroph.* **7**, 31, 1944). Pour passer d'une radiation à l'autre, il suffit de modifier la température du filtre. A cet effet, un thermostat, commandé électriquement, entoure l'appareil et permet d'obtenir à volonté, en cinq minutes environ, la radiation voulue. Grâce à une heureuse proportion dans l'épaisseur des lames, les raies verte et rouge de la couronne sont isolées à la même température; une combinaison optique supplémentaire permet d'isoler en même temps H_α; il suffit alors à Lyot d'ajouter à l'instrument un séparateur de radiations, basé sur l'emploi de prismes biréfringents, pour avoir simultanément trois champs monochromatiques avec les longueurs d'onde respectives 6563, 6374 et 5303 A.

Le filtre, fixé au coronagraphe installé à l'Observatoire du Pic du Midi, a permis à l'auteur d'obtenir des résultats très remarquables: les images verte et rouge de la couronne, prises avec des poses relativement courtes, grâce à la grande luminosité de l'instrument et à la perfection de l'isolement, sont beaucoup plus contrastées et riches en détails que celles obtenues en 1931, avec un dispositif de spectrohéliographe et de spectro-enregistreur (*M.N.R.A.S.* **99**, 580, 1939). Elles confirment les différences déjà observées dans la répartition des deux radiations. Elles montrent, de plus, une indépendance générale à peu près complète entre la couronne et les protubérances. Des films obtenus avec l'une ou l'autre radiation, pour lesquels la durée totale des poses a atteint jusqu'à 92 heures, plus de dix fois la durée totale des observations d'éclipses, ont été passés sur l'écran à l'accéléré. Ils révèlent que la couronne semble changer de forme et d'aspect, non pas comme les protubérances par des mouvements relatifs de leurs différentes parties, mais par l'apparition, les variations relatives d'intensité et la disparition des éléments qui la composent. Des arches, des jets et des nuages s'illuminent tour à tour comme les rayons d'une aurore polaire; ils naissent sur place, le long de trajectoires invisibles qui existaient auparavant et dont l'origine et le mode de formation nous échappent. Enfin, Lyot, mettant à profit la haute sélectivité de son filtre, a photographié le disque solaire avec la raie H_α. Ses images ont à peu près l'aspect de spectrohéliogrammes pris avec une dispersion moyenne, mais elles sont beaucoup plus fines, grâce au procédé plus direct employé pour les obtenir.

De son côté, M. Waldmeier, avec le coronagraphe du type Lyot installé à Arosa, a entrepris à partir de 1938, l'étude systématique des propriétés de la couronne accessibles à l'observation en dehors des éclipses. Il cherche d'abord à déterminer, suivant la méthode indiquée par Lyot, chaque fois que l'état du ciel le permet, la distribution de l'intensité des raies coronales autour du disque solaire (*Zeits. Ap.* **19**, 21, 1939; **20**, 172 et 195, 1940; **21**, 85, 1941). Pour cela, il porte radialement, sur un graphique approprié, les intensités estimées à 40″ du bord, pour des angles de position variant régulièrement de 5° en 5° autour du disque. Les contours joignant les points obtenus ont une forme analogue à celle de la couronne. Waldmeier note l'existence de deux forts maxima correspondant à la zone des taches, avec un minimum équatorial et un maximum secondaire vers $\pm 60°$. Les contrastes entre les diverses régions sont plus marqués que ne l'indiquent les isophotes tracées d'après l'observation en lumière intégrale pendant les

éclipses, même si ces isophotes proviennent d'un cliché sous-exposé, montrant bien la couronne intérieure (*Zeits. Ap.* **22**, 18, 1942). Superposant plusieurs graphiques de jours voisins afin d'obtenir des courbes adoucies, l'auteur constate que, pour des époques différentes, les résultats restent bien comparables avec, peut-être, une tendance des maxima principaux à se rapprocher de l'équateur, comme les taches.

Waldmeier note aussi que l'intensité relative des deux raies verte et rouge offre parfois des variations considérables. Elle pourrait être due, selon lui, à la self-absorption dans la raie verte, qui apparaît sur certains de ses clichés, malgré la dispersion plutôt faible de son spectrographe, 30 A. par mm. Notons cependant que A. J. Deutsch, dans une analyse du travail de Waldmeier (*Ap. J.* **101**, 117, 1945) remarque à ce propos que, dans l'hypothèse d'Edlén où la raie verte est due à une transition interdite, elle ne peut être visible en absorption. Waldmeier a étudié ensuite la répartition de l'intensité de la raie verte suivant un rayon solaire. Il trouve (*Zeits. Ap.* **21**, 120 et **22**, 1, 1942) que l'éclat de la raie diminue plus vite que celui du spectre continu. Il a dessiné, d'autre part, des cartes héliographiques de la couronne d'après ses observations (*Zeits. Ap.* **21**, 109, 1942), disposées comme les cartes de Zurich pour la surface ou celles de Meudon pour la chromosphère. Si on admet que les détails coronaux varient peu dans un intervalle de sept jours, l'émission des raies verte et rouge serait plus intense dans la région des taches; mais il y a des régions d'émission qui ne correspondent à aucune tache ni à aucune perturbation chromosphérique.

Plus récemment (*Ast. Mitteil.* No. 146, 1, 1945), Waldmeier a étudié le comportement de la raie jaune 5694 A., découverte par Lyot en 1937. Elle semble n'apparaître qu'au-dessus des groupes de taches importants et actifs; elle peut être alors plus intense que la raie verte. Enfin, il a mesuré la vitesse de rotation de la couronne (*Ast. Mitteil.* No. 147, 1, 1946) par la méthode spectroscopique et par le temps de passage aux bords opposés du Soleil de régions brillantes persistantes. Il trouve une vitesse angulaire analogue à celle de la surface ou de la chromosphère.

Terminologie

Jusqu'à présent, pour nous conformer à l'usage établi—croyons-nous—par G. E. Hale, nous avons toujours appelé *éruption chromosphérique* le phénomène lumineux, de brève durée, apparaissant soudainement dans la chromosphère au voisinage des taches et qui fait l'objet des listes publiées chaque trimestre par le *Quarterly Bulletin on Solar Activity*. Cependant, divers auteurs, notamment H. W. Newton, R. S. Richardson (*P.A.S.P.* **56**, 156, 1944), ont récemment préféré le mot *flare* pour désigner ce phénomène. Leur principal argument est que le mot *éruption* suggère une éjection de matière, alors que l'absence habituelle de grandes vitesses radiales dans les gaz lumineux semble plutôt indiquer qu'ils restent localisés au niveau de la chromosphère. L'argument ne nous paraît fondé qu'en partie. Tous les observateurs, en effet, reconnaissent qu'il y a peu de doute que les petites éruptions, appelées *points brillants* dans le *Quarterly Bulletin*, s'identifient avec des jets protubérantiels, courts, intenses et animés de mouvements rapides, qui constituent bien des éjections. Quant aux phénomènes plus étendus, qui apparaissent souvent surmontés de ces jets protubérantiels, restent-ils confinés dans la chromosphère? Certainement pas dans tous les cas, comme en témoignent l'éruption du 21 février 1942 (p. 114 du présent rapport) et, à un degré plus élevé encore, celle du 25 juillet 1946.

A un autre point de vue, il y a peut-être lieu de rappeler que les premiers observateurs des protubérances ont nommé protubérances métalliques ou *éruptives* les jets intenses dont il vient d'être question et que ce terme a été consacré par l'usage durant de longues années.

Depuis 1925, il est vrai, E. Pettit appelle *protubérances éruptives* des phénomènes tout à fait différents, qui se situent presque toujours loin des régions tachées et qui, bien moins que les précédents, peuvent être considérés comme des éjections. Il s'agit, comme on sait, de protubérances quiescentes de longue durée, auxquelles une soudaine rupture d'équilibre donne un mouvement d'ascension rapide, bientôt suivi d'une disparition complète. Le terme *protubérance ascendante*, proposé par M. Waldmeier, nous paraît plus approprié.

D'autre part, au Congrès de Stockholm, une tentative avait été faite sans résultat bien

net (*Transactions I.A.U.* **6**, 372, 1938), pour fixer les termes les plus propres à définir (*a*) les masses de vapeurs qui, dans la chromosphère, surmontent les facules de la surface; (*b*) les protubérances en projection sur le disque.

En ce qui concerne les premières, il est maintenant connu qu'elles ne sont brillantes, sur les spectrohéliogrammes, qu'avec les raies du Ca^+, la raie H_α de l'hydrogène et les raies de la couche renversante. Elles sont sombres avec les autres raies de la série de Balmer et avec les raies de l'hélium. Si on les nomme *flocculi*, comme on le recommande souvent, il faut donc ajouter *brillants* ou *sombres* suivant les cas. Mais l'expression *flocculi sombres* sert souvent à désigner les protubérances en projection sur le disque. Si on trouve que le terme *plages faculaires*, proposé autrefois par H. Deslandres, n'est pas suffisamment descriptif, on pourrait peut-être adopter *facules chromosphériques*, qui indique bien le caractère du phénomène.

Quant aux projections des protubérances sur le disque, le terme *filament*, proposé lui aussi autrefois par H. Deslandres, et qui a évidemment le défaut, comme d'ailleurs *absorption marking*, d'introduire un second terme pour désigner un seul et même objet, possède au moins l'avantage de bien évoquer l'étroitesse extrême, par rapport à leurs autres dimensions, qui constitue, comme l'on sait, un des caractères les plus remarquables des protubérances.

Suggestions et Propositions

G. Abetti (Arcetri) estime nécessaire que l'on arrive à une définition précise d'une échelle d'intensité des éruptions. Des déterminations ont été faites dans ce but à Arcetri et d'autres sont en cours. Il demande que la terminologie des divers phénomènes chromosphériques soit précisée.

Il suggère que, pour obtenir une plus grande homogénéité dans la centralisation et la publication des données solaires, les Commissions 10 et 11 soient réunies en une seule, qui pourrait s'appeler 'Commission de météorologie solaire' ou 'des perturbations solaires'. Eu égard à l'augmentation des observations mondiales, il serait dès lors possible d'établir un bureau central où toutes les observations, y compris celles de la couronne dans les stations de haute altitude, seraient groupées et distribuées aux institutions intéressées.

W. O. Roberts (Climax) recommande que l'intensité des raies de la couronne soit exprimée dans l'échelle absolue établie par B. Lyot.

Il recommande également que la classification des protubérances soit examinée à nouveau, avec l'idée que la définition des différents types s'appuie sur des facteurs ayant une signification physique permettant de caractériser sans ambiguïté les phénomènes auxquels elle se rapporte.

Il suggère que soit précisée la notion d'intensité minima sur les clichés de protubérances servant à établir la statistique des aires de ces phénomènes.

A. D. Thackeray (Cambridge) recommande d'enregistrer des images de protubérances avec les raies H_α et D_3 de manière à mieux préciser le rapport des intensités H_α/D_3.

Il ressort de ces suggestions et de l'état des questions traitées dans le présent rapport que les travaux de la Commission au prochain Congrès de l'U.A.I. devront porter notamment sur les points suivants:

1. Examen et révision des données solaires publiées dans le *Quarterly Bulletin on Solar Activity*. Recherche d'un indice approprié pour représenter l'activité des protubérances. Classification de ces phénomènes.
2. Utilité de développer l'étude systématique des protubérances avec la raie D_3.
3. Terminologie des phénomènes chromosphériques.
4. Subventions.

Il serait désirable, en outre, que les attributions des Commissions 11, 12 et 13 fussent mieux délimitées en ce qui concerne les questions qui leur sont en partie communes, notamment la couronne et le rayonnement solaire de fréquence radio-électrique.

L. d'Azambuja
Président de la Commission

Janvier 1948

RAPPORT DE LA SOUS-COMMISSION POUR LA CINEMATOGRAPHIE DES PROTUBERANCES

Lors de sa dernière réunion, en 1938, la commission 11 a souligné l'intérêt que présenterait la réalisation de films cinématographiques ininterrompus; ceux-ci montreraient l'évolution des protubérances et des autres phénomènes chromosphériques qui accompagnent les régions actives du Soleil, non seulement pendant une journée, mais pendant tout le passage de ces régions aux bords et sur le disque. Ils révéleraient la succession naturelle de ces phénomènes, leur association et leur répétition en certains points et ils faciliteraient ainsi grandement la compréhension des liens qui les unissent.

Observatoires participants

Quatre observatoires sont actuellement équipés pour la cinématographie des protubérances:

L'observatoire McMath-Hulbert, avec plusieurs spectrohéliographes et spectro-enregistreurs permettant la cinématographie continue, au bord et sur le disque, ainsi que la mesure continue des vitesses radiales.

L'observatoire du Pic du Midi, avec un coronagraphe de 20 cm. d'ouverture et un filtre transmettant une bande de 1·5 A. sur H_α, permettant la cinématographie au bord et sur le disque.

L'observatoire d'Arosa, avec un coronagraphe de 12 cm. d'ouverture pour la cinématographie au bord, suivi, lorsqu'il y a lieu, d'un filtre isolant 17 A. sur H_α, pour augmenter les contrastes.

L'observatoire de Climax, avec un coronagraphe de 14 cm. d'ouverture suivi d'un filtre isolant 5 A. sur H_α, ce filtre augmente beaucoup les contrastes des protubérances au bord, il permet de cinématographier les éruptions sur le disque.

De plus, une caméra est prête à fonctionner à la suite du spectrohéliographe de l'observatoire de Meudon. Un filtre transmettant 0·75 A. sur H_α est en construction pour l'observatoire de Haute-Provence.

La distribution de ces observatoires couvre seulement 115° de longitude, elle ne permet donc pas de réaliser un film continu, mais seulement des films commencés en Europe et terminés aux Etats-Unis. De plus, au Pic du Midi, à Arosa et, dans une certaine mesure, à Climax, les instruments sont utilisés pour des recherches et des travaux divers, principalement sur la couronne; ils ne peuvent donc être consacrés à la cinématographie des protubérances que pendant une partie de la journée et en outre, jusqu'à maintenant, le personnel de ces observatoires a été beaucoup trop restreint pour pouvoir assurer un service continu.

Malgré ces conditions très défavorables, la coopération internationale permettrait: d'accroître la durée maximum d'un film réalisable, de 6^h à 12^h environ, en hiver, et de 12^h à 18^h environ, en été; de combler une partie des lacunes dues au mauvais temps et au fait que les appareils et les observateurs ne sont pas toujours disponibles; de comparer des films obtenus simultanément, avec des appareils différents et, parfois, avec des radiations différentes, de recommander, enfin, l'emploi du dispositif qui aurait donné les meilleurs résultats.

Propositions

La première étape de cette coopération consisterait à associer des films consécutifs ou simultanés obtenus dans des observatoires différents. Ce travail serait facilité par la publication de renseignements relatifs à tous les films qui ont été pris. Nous avons reçu deux propositions à ce sujet:

M. Waldmeier propose de dresser une liste de toutes les photographies de protubérances, contenant les indications suivantes pour chaque film: la date, début et fin de la prise,

intervalle entre deux photos successives, largeur du film employé, diamètre de l'image du Soleil, angle de position de la protubérance, c'est-à-dire du centre de l'image. Ces indications pourraient peut-être être publiées dans le *Quarterly Bulletin on Solar Activity*.

D'autre part, W. O. Roberts nous propose de distribuer aux observateurs qui prennent part à cette coopération, des tableaux sur lesquels ceux-ci inscriraient les renseignements relatifs aux films qu'ils ont obtenus. Chaque ligne correspondrait à un film déterminé et chaque colonne à l'une des indications énumérées, en ajoutant les renseignements suivants:

La longueur d'onde utilisée, la distance du centre de l'image au centre du Soleil exprimée en centièmes du rayon ou l'indication 'limb' ainsi que des remarques sur les conditions météorologiques et l'activité des protubérances.

Il nous semble utile d'ajouter également l'orientation de l'image (angle de position du haut de celle-ci) et, dans le cas assez fréquent où la prise de vues a été interrompue à plusieurs reprises par des nuages, on pourrait ajouter, à l'heure T.U. du début et de la fin, la durée totale du film, déduction faite de ces interruptions.

W. O. Roberts propose que les tableaux, une fois remplis, soient adressés à la sous-commission, celle-ci établirait, avec les données reçues, un tableau complet dont elle enverrait un exemplaire à chacun des observatoires intéressés.

Recommandations

La réalisation d'un film ininterrompu et homogène serait facilitée si les films servant à le composer pouvaient être tournés, dans les divers observatoires, avec les mêmes appareils et dans les mêmes conditions (largeur du film, émulsion, diamètre des images, etc.). Cependant, étant donné la diversité des appareils que les observatoires existants possèdent, le peu d'expérience acquise jusqu'à maintenant, en partie à cause de la difficulté de communiquer pendant cinq années et l'évolution rapide des méthodes, il semble au moins prématuré de tenter une telle unification.

La sous-commission doit, semble-t-il, se borner à exprimer quelques recommandations auxquelles les observateurs tâcheront de se conformer toutes les fois qu'ils le pourront. Ces recommandations devront être discutées à l'Assemblée Générale:

Longueur d'onde. La raie H_α paraît préférable à la raie K, car elle est plus facile à isoler avec les filtres polarisants et elle correspond à une diffusion atmosphérique plus réduite.

Largeur du film. Le film commercial 35 mm. paraît préférable au film 16 mm., malgré son prix plus élevé, car il fournit un champ plus étendu, champ nécessaire dans le cas des protubérances à ascension accélérée et des larges zones d'activité sur le disque.

Qualité de l'émulsion. Les émulsions panchromatiques possédant le grain le plus fin sont les plus intéressantes, pour la même raison, lorsque leur sensibilité est suffisante, car elles permettent de réduire le diamètre de l'image du Soleil et d'augmenter ainsi le champ.

Diamètre de l'image du Soleil. Pour le même motif, il est bon d'adopter le plus petit diamètre permettant d'utiliser la définition fournie par l'instrument. Il semble que, si le grain de l'émulsion est fin, 5 cm. suffiraient. On pourrait envisager également un diamètre plus petit pour la surveillance du Soleil entier; des films positifs convenablement agrandis, montrant les régions actives, pourraient être associés aux autres films pris à plus grande échelle.

Orientation des images. Il serait bon de choisir, pour l'orientation du haut des images, l'une des trois directions suivantes: soit l'angle de position zéro, soit celui du pôle Nord du Soleil, soit celui du centre de l'image rapporté au centre du Soleil. Cette dernière orientation, souvent employée pour les protubérances au bord, convient mal sur le disque.

Nombre d'images par minute. L'enregistrement des phénomènes éruptifs imprévus exige au moins deux ou trois images par minute, d'autre part, une cadence plus rapide entraînerait une consommation de film excessive.

Au sujet des perfectionnements à apporter à la prise de vues, nous avons reçu, de Robert R. McMath et de Orren Mohler, les remarques suivantes qui pourraient également servir de base à des recommandations:

We have found that inclusion of photographic calibration on our motion picture records greatly increases their value. All of our motion pictures now are photographically standardized. We have added a photographic record of the time of each exposure on the film adjacent to the picture. This record supplements and checks our paper tape chronographic record.

Review of the films made in past years at this observatory indicates that a method for simultaneously photographing the disk of the Sun and the neighbouring prominences would be very valuable for the study of flares near the edge of the Sun.

Au Pic du Midi également, depuis l'été 1938, une montre, photographiée sur chaque image, donne l'heure correspondante. Ces enregistrements directs du temps facilitent la comparaison des films et leur assemblage, ils permettent de contrôler, pendant la projection, la régularité de la prise de vues et ses interruptions qui ont pu être nécessitées par le passage de nuages.

Nous souhaitons vivement qu'un nombre plus grand d'observatoires dont certains seraient situés sous d'autres longitudes et dans l'hémisphère Sud puissent participer à la cinématographie des protubérances. L'emploi d'un filtre transmettant une bande étroite (1 A. environ, sur H_α) associé à un coronagraphe ou à une lunette pointée directement sur le Soleil, leur permettrait d'obtenir des images plus nettes et de réaliser des films, même lorsque la transparence atmosphérique est médiocre, non seulement au bord du Soleil, mais sur tout son disque.

B. LYOT
Président de la Sous-Commission

Compte rendu des séances

PRÉSIDENT: L. D'AZAMBUJA.

SECRÉTAIRE: Y. ÖHMAN.

Première séance de la Commission (12 août 1948). Le Président évoque le souvenir de Henri Deslandres, Président d'honneur de la Commission et celui du Père Luis Rodés.

Aucune remarque n'étant faite sur le rapport provisoire de la Commission, celui-ci est adopté.

En ce qui concerne la composition de la Commission, le Président fait remarquer que, sur 14 observatoires qui participent à l'observation des éruptions chromosphériques, 7 seulement sont représentés dans la Commission, qui compte cependant 27 membres. L'attention de la Commission des nominations sera attirée sur ce point.

M. d'Azambuja expose l'état actuel de la publication des cartes synoptiques de la chromosphère et demande à la Commission d'adopter le texte suivant: 'La Commission recommande que la subvention annuelle de 2700 francs-or, accordée par la dernière Assemblée générale de l'U.A.I. à l'Observatoire de Paris-Meudon pour la publication des cartes synoptiques de la chromosphère solaire, soit renouvelée pour la période qui s'étend jusqu'au prochain Congrès de l'Union.'

La proposition est adoptée.

Le Président indique ensuite qu'il lui paraît nécessaire d'introduire quelques modifications dans la présentation des cartes synoptiques, aussi bien pour diminuer le prix de l'impression que pour mieux tenir compte de notre connaissance actuelle des phénomènes solaires. Ces modifications pourraient intervenir après la publication du fascicule se rapportant aux phénomènes de 1944, année du dernier minimum de taches.

M. Abetti a suggéré que, pour obtenir une plus grande homogénéité dans la centralisation et la publication des données solaires, les commissions 10 et 11 soient réunies en une seule. Le Président estime que cette question dépasse la compétence de la seule commission 11. Elle pourra être soumise au Comité spécial en voie de constitution pour réviser les attributions des commissions.

L'ordre du jour appelle l'examen et la révision des données solaires publiées dans le *Quarterly Bulletin on solar activity*.

M. d'Azambuja expose qu'il a relevé, pour l'année 1947, le pourcentage des éruptions observées par heure effective de surveillance du Soleil, dans chacun des observatoires participants. Le résultat est assez décevant. Si le pourcentage est assez voisin de 1 pour plusieurs établissements, ses valeurs extrêmes, 4·6 et 0·04, sont dans un rapport de 100. Il est évident que les différents observateurs n'ont pas la même manière d'apprécier le *seuil* à partir duquel l'intensité observée doit être considérée comme éruptive. Le Président insiste sur la nécessité de préciser ce seuil et de fixer en même temps une échelle d'importances, plus appropriée que l'échelle actuelle.

Au cours de la discussion qui s'engage, M. Abetti estime nécessaire de recourir à une méthode photométrique précise. Déjà, dans ce but, les clichés d'Arcetri sont munis d'une échelle photométrique.

Le Père Romañá propose de déterminer le seuil en s'inspirant de l'importance des *crochets* observés au moment des éruptions sur les enregistrements magnétiques.

M. Link recommande de déterminer l'intensité éruptive par la mesure de la largeur de la raie brillante H_α. Le Président remarque que cette méthode, employée en premier lieu par M. Waldmeier, est probablement une des plus efficaces. Mais la largeur varie avec le temps.

M. Lyot propose de considérer le produit intensité × surface pour éliminer les effets de l'agitation des images. M. Kiepenheuer estime qu'il est nécessaire de spécifier indépendamment les deux facteurs du produit.

M. Ellison décrit les formes les plus habituelles de la courbe représentant les variations, avec le temps, de la largeur de la raie H_α éruptive. Il propose de prendre l'aire totale de cette courbe pour mesure de l'intensité de l'éruption.

M. Mohler remarque que le changement d'intensité est le facteur le plus important au point de vue géophysique. C'est également l'avis de M. Ellison.

La mesure du changement d'intensité avec le temps a d'ailleurs été demandée par la Commission mixte du C.I.U.S. pour l'étude de l'ionosphère à sa récente réunion de Bruxelles.

Finalement, le Président pense que l'emploi combiné du spectrohélioscope et du spectrohéliographe, permettant de recourir à la fois à la mesure de la largeur de la raie et aux méthodes photométriques, donnerait probablement des résultats efficaces. C'est quand ceux-ci seront obtenus que l'observatoire centralisateur proposera un seuil et une échelle d'importances plus appropriés.

Deuxième séance de la Commission (14 août 1948). Revenant sur la question des éruptions, le Président indique que le seuil devra être fixé de telle manière que le nombre des phénomènes figurant dans le *Quarterly Bulletin* soit diminué. Les éruptions au-dessous du seuil seront envoyées néanmoins au centre, et celui-ci en conservera la liste en vue d'une communication éventuelle à ceux qu'elle pourrait intéresser.

M. Nicholson fait remarquer qu'une petite erreur sur le seuil pourra entraîner une différence considérable dans le nombre des éruptions.

M. d'Azambuja demande aux observatoires engagés dans l'observation de ces phénomènes qu'ils envoient leurs résultats au centre sous la forme même où ils sont imprimés dans le Bulletin. Il insiste, en particulier, sur la nécessité d'envoyer sur des feuilles séparées, pour la commodité de leur classement, les listes d'éruptions et le tableau des heures effectives d'observation.

Le Président demande encore qu'un effort soit tenté pour augmenter le nombre des spectrohélioscopes en service. Il remarque, à ce propos, que, sur les 30 spectrohélioscopes

que G. E. Hale avait fait construire en 1930, 7 seulement sont en service actuellement. Il propose de présenter à l'Assemblée générale la recommandation suivante:

'La Commission invite les directeurs des établissements possédant un des spectrohélioscopes standards que G. E. Hale avait fait construire en 1930, et qui ne l'utilisent pas actuellement, à le remettre en service pour la recherche des éruptions chromosphériques ou, éventuellement, à le prêter à d'autres observatoires mieux placés pour les utiliser.'

La recommandation est adoptée par la Commission.

Celle-ci étudie ensuite les moyens d'améliorer les données sur l'intensité de la couronne publiées par le *Quarterly Bulletin*.

Le Président remarque que ces données ne sont pas, actuellement, toujours très comparables.

M. Roberts recommande l'emploi généralisé des mesures photométriques absolues en usage au Pic du Midi. Mais le nombre de jours d'observation dans cette station est encore insuffisant pour qu'on puisse obtenir dès maintenant un bon calibrage. Il faut tenir compte, d'autre part, que le changement d'observateur peut amener une discontinuité dans l'échelle des intensités. Ce changement doit donc être noté.

Une discussion s'engage ensuite, à laquelle prennent part MM. Waldmeier, Kiepenheuer, Lyot. Il s'en dégage notamment l'importance de signaler la distance au bord du Soleil du point de la couronne sur lequel la mesure a porté, la nécessité de prendre en considération la lumière diffusée par l'atmosphère terrestre, l'intérêt d'indiquer la forme, la largeur et la direction de la fente du spectrographe.

Finalement, il est décidé que M. Lyot préparera une note résumant les procédés d'observation employés au Pic et que cette note sera envoyée aux autres observateurs afin qu'un accord intervienne sur une méthode homogène à employer par tous.

On convient, d'autre part, de prendre comme origine des angles de position le pôle nord du Soleil, et non plus le nord astronomique, comme on le faisait dans plusieurs stations.

La Commission aborde alors la question de la publication des données. Les divers membres sont d'accord pour estimer que, tant que la méthode homogène d'observation ne sera pas adoptée et appliquée, il est nécessaire de publier séparément les résultats obtenus dans les diverses stations.

Troisième séance de la Commission (17 août 1948). L'étude de la publication des données sur les intensités coronales continue. Il s'agit maintenant de savoir si ces données seront traduites par des chiffres, comme actuellement, ou par des graphiques qui, à certains égards, seraient plus parlants. Après une discussion à laquelle prennent part le Président, MM. Menzel, Lyot, Rösch, Kiepenheuer, Waldmeier, il est décidé que la publication des tableaux de chiffres, plus précise, continuera, et que, pour chaque date, les intensités des diverses raies observées seront données à la suite. Pour rendre les frais d'impression moins élevés, il est décidé en outre que chaque observatoire participant préparera lui-même des tableaux dactylographiés qui seront ensuite reproduits par clichage dans le Bulletin. Le centre de Meudon établira un projet de tableau standard et le modèle définitif sera adopté après accord entre les intéressés.

Il reste à examiner la forme de publication à adopter pour les données sur le rayonnement solaire de fréquence radioélectrique.

M. Hey critique la méthode de publication employée jusqu'ici pour les observations de ce rayonnement. Le nombre de *bursts* par heure dépend trop du zéro de l'appareil et de l'instant de l'observation. Il propose de définir des intervalles de cinq minutes et de constituer une échelle d'intensité, analogue à celle des éruptions, des phénomènes relevés dans cet intervalle.

Le Président expose qu'une nouvelle Commission de l'U.A.I. étant en voie de constitution pour l'observation des ondes de fréquence radioélectrique, il convient de lui laisser le soin de poursuivre la discussion pour laquelle elle est mieux qualifiée que la Commission 11. Les résultats des observations n'en continueront pas moins à être publiés

dans le *Quarterly Bulletin*. Cette proposition est adoptée et la Commission passe à l'ordre du jour.

Le Président signale que la Commission mixte du C.I.U.S. pour l'étude de l'ionosphère, réunie à Bruxelles en juillet dernier, a émis la résolution suivante: Que les nombres caractéristiques des flocculi du calcium soient de nouveau publiés dans le *Quarterly Bulletin on solar activity* ou, tout au moins, soient rendus accessibles à ceux qui étudient l'ionosphère. M. d'Azambuja ajoute que la méthode d'estimation employée auparavant était très imprécise. On pourrait d'ailleurs l'améliorer simplement en estimant séparément l'importance des groupes de flocculi et en totalisant. Par ailleurs, l'activité des flocculi du calcium, et c'est pourquoi on en a supprimé la publication dans le *Bulletin*, se comporte exactement comme celle des taches avec, toutefois, un retard constant de quelques jours sur celle-ci.

M. Nicholson est d'avis que ce qui importe aux géophysiciens, c'est l'activité de chaque groupe plûtot qu'un indice général. M. Ellison ajoute que les géophysiciens désirent que l'activité des groupes soit caractérisée par le nombre d'éruptions et de filaments actifs que l'on y observe par jour.

Le Président fait remarquer que l'activité individuelle des groupes est signalée chaque jour par les ursigrammes du poste de Pontoise (près Paris) d'après les observations de Meudon, que ces données, transmises immédiatement, sont complétées plus tard par les tableaux d'évolution et les listes des régions actives du *Quarterly Bulletin*.

La Commission est d'avis que, dans ces conditions, il n'apparaît pas nécessaire de reprendre la publication des nombres caractéristiques des flocculi du calcium.

Le Président rappelle la recommandation émise par l'Assemblée restreinte de l'U.A.I., tenue à Copenhague en 1946, invitant la Commission 11 à rechercher un indice caractéristique qui représente mieux l'activité des protubérances que les indices utilisés auparavant. Il propose que cet indice soit, selon une méthode essayée récemment à Meudon, la longueur totale, exprimée en degrés héliocentriques, de tous les filaments visibles sur les spectrohéliogrammes Hα à une date donnée. Ce procédé équivaut à supposer une même hauteur à toutes les protubérances. Ce n'est naturellement pas exact, mais l'erreur commise, d'après des comparaisons précises avec les autres statistiques, est inférieure aux écarts que, pour des raisons diverses, ces autres relevés présentent entre eux. Aucune objection n'étant faite par les membres de la Commission, le Président s'offre à demander à l'observatoire de Kodaikanal, spécialisé dans la statistique des protubérances, de bien vouloir se charger de la détermination du nombre caractéristique nouveau.

M. Kiepenheuer estime qu'il y aurait intérêt à donner deux nombres caractéristiques, l'un se rapportant aux filaments équatoriaux, l'autre aux filaments polaires.

M. d'Azambuja pense qu'il n'y a pas grande difficulté à cela. Il suggère, d'autre part, que l'observatoire de Kodaikanal soit également convié à préparer des ursigrammes analogues à ceux de Meudon, qui pourraient être radio-diffusés par un poste indien. Si le Mont Wilson avait la possibilité de son côté, de préparer aussi des ursigrammes et que ceux-ci fussent transmis par un poste américain, on aurait déjà là la possibilité de fournir des informations quotidiennes rapides et presque sans lacunes. On donnerait aussi satisfaction au vœu émis par la Commission mixte du C.I.U.S. pour l'étude des relations entre les phénomènes solaires et terrestres dans sa séance du 10 août, demandant que l'emploi des ursigrammes sur l'activité solaire soit généralisé.

En conséquence, le Président propose de soumettre à l'Assemblée générale la recommandation suivante: 'La Commission s'associe à la recommandation de la Commission mixte du C.I.U.S. pour l'étude des relations entre les phénomènes solaires et terrestres, relative à l'envoi d'ursigrammes sur l'activité solaire par plusieurs observatoires convenablement répartis en longitude, afin d'éviter les lacunes dues au mauvais temps. Elle attire l'attention sur la nécessité de diffuser ces ursigrammes quotidiens suivant le même code, à des heures voisines, mais ne se recouvrant pas.'

La recommandation est adoptée par la Commission.

MM. Rösch et Lyot proposent que l'observatoire du Pic du Midi soit relié par une voie aussi rapide que possible à un organe centralisateur des observations coronales. Ils

demandent, d'autre part, que les renseignements sur l'activité coronale soient inclus à bref délai, dans les ursigrammes quotidiens. Ces deux propositions sont également adoptées.

Le Président signale un vœu de M. Roberts qui demande que la classification des protubérances soit examinée à nouveau, avec l'idée que la définition des différents types s'appuie sur des facteurs ayant une signification physique permettant de caractériser sans ambiguïté les phénomènes auxquels elle se rapporte.

A ce propos, M. d'Azambuja fait remarquer que, si une telle classification est reprise, elle doit avant tout tenir compte de la forme spatiale des protubérances, maintenant bien connue, et non seulement de leur aspect au bord, comme certaines classifications actuelles.

M. Thackeray a demandé que les observatoires possédant l'équipement nécessaire inscrivent à leur programme de travail la comparaison régulière des images de protubérances données par les raies H_α et D_3, dans le but de préciser le rapport des intensités H_α/D_3. La Commission s'associe au vœu de M. Thackeray.

Le Président appelle l'attention sur une recommandation faite par la Commission mixte de l'ionosphère en juillet dernier à Bruxelles: 'Que, dans la possibilité où les faisceaux corpusculaires émis par le Soleil soient une source de phénomènes ionosphériques ou intéressant la Géophysique, l'attention soit attirée sur l'utilité de la détection de tels faisceaux par l'absorption de la lumière ou des ondes radioélectriques.'

M. d'Azambuja indique que divers auteurs ont cru reconnaître l'existence, sur des tracés microphotométriques, de l'absorption des raies H et K déplacées vers le violet par l'effet Doppler-Fizeau, au moment de fortes éruptions. Mais l'observation est très délicate et doit être confirmée. La Commission ne peut donc que s'associer au vœu de la Commission mixte.

En dernier lieu, l'ordre du jour appelle l'examen des termes servant à désigner certains phénomènes chromosphériques. En fait, il ne s'agit pas de se mettre d'accord sur un terme unique, facile à exprimer en anglais et en français, mais plutôt d'éviter que des termes différents puissent prêter à ambiguïté. C'est ainsi que les expressions *flare* et *éruption chromosphérique* peuvent coexister si on ne trouve pas un meilleur terme pour définir le phénomène qu'elles caractérisent (le mot *flare* n'a pas d'équivalent en français). Mais il n'en est pas de même du mot *flocculi* souvent employé indifféremment pour désigner les nuages chromosphériques qui surmontent les facules et qui sont brillants ou sombres suivant les radiations employées à les enregistrer, et les protubérances en projection sur le disque. Le Président propose de désigner les premiers, soit par *plages faculaires* ou, si le terme paraît peu approprié, par *facules chromosphériques*. En ce qui concerne les protubérances en projection, il recommande le terme *filament* qui caractérise bien l'aspect spatial des phénomènes dont l'épaisseur est extrêmement faible par rapport à leurs autres dimensions, mais qui ne rappelle pas qu'il s'agit de protubérances, ou, en anglais, l'expression *disk prominence*, plus évocatrice de la nature de l'objet.

La Commission est d'accord pour recommander qu'on évite à l'avenir d'utiliser le mot *flocculi*.

Compte rendu de la séance de la Sous-commission de la Commission II, *pour la cinématographie des protubérances*

PRÉSIDENT: M. B. LYOT.

SECRÉTAIRE: M. A. DOLLFUS.

Le président ouvre la séance en rappelant que le but de la sous-commission est de *coordonner l'enregistrement cinématographique du Soleil effectué en différentes stations*, afin de combler les lacunes, d'obtenir un enregistrement ininterrompu du Soleil et de permettre ainsi la synthèse générale des phénomènes chromosphériques. Les longs travaux que nécessite le dépouillement des films obtenus ne sont pas du programme de la sous-commission.

Le président donne ensuite lecture de la liste des observatoires participants qui figure au 'draft report', il la soumet à la discussion.

Monsieur Roberts insiste alors sur les difficultés introduites par l'utilisation des instruments à d'autres recherches et les interruptions des films qui en résultent. Le président signale la même difficulté au Pic du Midi.

Monsieur Roberts a enregistré, à Climax, 15.000 pieds de films, en grande partie non dépouillés.

Monsieur Kiepenheuer indique l'existence, en Allemagne, d'un spectrohéliographe équipé pour la photographie du Soleil en 4 secondes, avec la radiation Hα. Cet appareil pourrait participer à l'étude cinématographique de tout le disque solaire.

Monsieur Ellison pense que le filtre monochromatique de Monsieur Lyot serait approprié à la cinématographie de tout le disque, avec une cadence rapide de une image toutes les 10 secondes, cadence nécessaire à l'enregistrement de mouvements très rapides.

Le président expose ensuite les propositions résumées au 'draft report', relatives à l'établissement d'un catalogue des films déjà obtenus.

Madame d'Azambuja, Messieurs Mohler, Roberts, Kiepenheuer et Nicholson font ressortir l'abondance des films et des images solaires déjà prises, et, par suite, les difficultés matérielles que présente l'établissement des listes.

Le président rappelle que les photographies espacées prises, en particulier, au Wendelstein et au Mont Wilson, pour la surveillance des éruptions, ne peuvent pas être intégrées dans un film continu, il faut au minimum une image par minute pour que les mouvements ne paraissent pas trop discontinus, les listes devraient être limitées aux films de cadence plus rapide.

L'intérêt de la cinématographie solaire est ensuite souligné.

Monsieur d'Azambuja cite l'exemple suivant: Un tiers des protubérances quiescentes naissent près des taches, avec un retard de 20 jours sur celles-ci. Les photographies quotidiennes du Soleil ne permettent pas de distinguer si la matière de ces protubérances, au moment où elles apparaissent, sort de la tache ou se dirige vers elle. Les films permettraient de résoudre des problèmes de ce genre. D'autre part, un certain nombre d'images non utilisées seraient isolées et constitueraient des collections d'images de la chromosphère susceptibles d'être distribuées aux chercheurs qui en feraient la demande. Cette solution remplacerait la publication, qui avait été réclamée, de spectrohéliogrammes dans le *Quarterly Bulletin on Solar Activity*.

Monsieur Kiepenheuer insiste sur l'intérêt financier d'une telle entreprise.

Le président rappelle que les premiers films du Soleil entier, obtenus à l'observatoire McMath par Monsieur Mohler, seront projetés à une séance de l'Union. Il soumet ensuite à la discussion, les conditions des prises de vues: orientation de l'image, diamètre du disque, radiation utilisée, largeur de fente etc.

Le président recommande l'utilisation de films à grain très fin et à grands contrastes; leur faible sensibilité est compensée par la possibilité de réduire le diamètre de l'image et d'augmenter ainsi le champ.

La valeur élevée du contraste permet d'élargir les fentes du spectrohéliographe ou la bande transmise par le filtre monochromatique, sans perdre de détails même pour des objets animés de vitesses radiales. Une largeur de 1·5 A. paraît acceptable.

Pour enregistrer des vitesses radiales très fortes, Monsieur Kiepenheuer propose de prendre des clichés de part et d'autre de la radiation envisagée.

Pour éviter d'avoir des éruptions tout-à-fait noires sur les clichés, Monsieur Ellison propose d'effectuer plusieurs poses successives, à travers divers écrans absorbants. Monsieur Öhman propose, dans le même but, d'utiliser un polariseur et un prisme biréfringent fournissant simultanément deux images de densités différentes, de telle manière que tous les détails soient dans la partie rectiligne de la caractéristique sur l'une d'elles tout au moins. La comparaison des deux images fournirait l'étalonnage photométrique.

Le président insiste sur la nécessité d'imprimer le temps sur chaque image, afin de permettre la comparaison des images simultanées de films différents et le raccordement de ceux-ci.

L'impression du temps au début et à la fin du film peut entraîner des erreurs en cas d'irrégularités de la prise de vue ou d'interruptions pendant le passage de nuages. Cet enregistrement est réalisé à l'Observatoire McMath; au Pic du Midi, une montre est photographiée sur chaque image, en même temps que le Soleil.

Monsieur Kiepenheuer propose d'entrer en relation avec l'observatoire de Tokyo qui possède un spectrohéliographe et qui, par sa situation géographique, permettrait de combler les interruptions communes aux observatoires d'Europe et des États-Unis. La proposition est approuvée.

Le président conclut en rappelant l'intérêt de la cinématographie du Soleil tout entier et en résumant les suggestions qui ont été faites:

Possibilité d'employer le filtre polarisant à la place du spectrohéliographe.

Utilisation d'une bande passante assez large (1·5 A.) afin d'enregistrer les phénomènes animés de mouvements radiaux.

Usage de films à grain fin et à grands contrastes développés avec un révélateur à grain fin.

Prises de paires d'images de densités différentes pour permettre la photométrie des éruptions.

Enregistrement du temps et d'un étalonnage, sur chaque photographie.

12. COMMISSION DE LA RADIATION SOLAIRE ET DE LA SPECTROSCOPIE SOLAIRE

PRÉSIDENT: M. G. ABETTI, *Direttore dell' Osservatorio Astrofisico, Arcetri-Firenze* (3 *R*), *Italia.*

MEMBRES: MM. Abbot, H. D. Babcock, Mme Nováková Bednaróva, MM. Brück, P. Carrasco, Carroll, Chalonge, Chandrasekhar, S. Chapman, Cowling, d'Azambuja, Dingle, Evershed, A. S. King, Lyot, McCrea, Menzel, Migeotte, Milne, Minnaert, Münch-Paniagua, Pannekoek, Pettit, Plaskett, Randers, Righini, Russell, Rutllant, Shane, Mme Moore Sitterly, MM. B. Strömgren, Waldmeier, Wildt, Woolley.

The report is compiled from information supplied by several members, in response to a request for information. Several members replied that they are not now actively concerned with the subjects with which this Commission is dealing. No attempt has been made to review the work done in these subjects in the years since the last General Assembly of 1938.

Daily determinations of the solar constant have been continued by the staff of the Astrophysical Observatory of the Smithsonian Institution at Montezuma (Chile) and at Table Mountain (U.S.). Apparatus and methods are being developed by Abbot and his co-operators for the daily measurement of atmospheric ozone and of its band of absorption, 9–10 μ. Intensity of solar radiation at ground-level has also been measured for some years in several wave-length regions in the ultra-violet, as well as in the visible and near infra-red. Abbot has discussed the variations and their effects on terrestrial temperatures and on precipitation; a revised analysis of solar constant values has also been made by Abbot, who has found a depression of solar constant values associated with terrestrial magnetic storms and other meteorological phenomena.

Measurements of solar radiation with various filters and of sky illumination at various high altitude stations seem desirable, in order to investigate the conditions for suitability for observations of the outer layers of the Sun and particularly of the corona.

Recent contributions to solar spectroscopy have opened new fields of research as well as improving and completing existing data. The principal ones include the explanation of the generation of stellar energy by means of the carbon cycle of nuclear transformations by Bethe; a determination of the amount of hydrogen and of helium in the Sun by Schwarzschild; the extension of the observable solar spectrum to 2200 A. with the aid of rockets by Durand, Oberly and Tousey; discovery and extensive study of radiation emitted by the Sun in the range of frequencies from 60 to 300 Mcyc./sec. and also in the microwave region at 24,000 Mcyc./sec.; observations which appear to show the presence of a general magnetic field in the Sun by Thiessen; a study of chemical compounds in the Sun by Babcock; the extension of high resolution in the spectrum to 2 μ with the PbS photocell by McMath and Mohler; the extension of the photographic solar spectrum to 13,495 A. by Babcock and Moore Sitterly; and a revision of the high dispersion solar spectrum, 2935–3063 A. by Babcock, Moore Sitterly and Coffeen.

Thiessen concluded that the polar intensity of the Sun's field is about 50 gauss and that the polarity is the same as that found by Hale. His null method utilizes visual observations, chiefly on one line in the spectrum. Babcock began work on this subject in 1940, which is not yet completed; the photographic method is used for simultaneous observation of numerous lines in the spectrum produced by a Lummer plate crossed by a grating. The analyser transmits polarized light of one sign for certain lines, of opposite sign for others, and unpolarized light for still others. The sensitivity is adequate but the results are not yet decisive. Better conditions for such observations may be expected with the waning of the present sunspot maximum. McCrea thinks that it would be of great value if the whole of the existing data on the Sun's general magnetic field could be reviewed.

Babcock has extended the early work of Russell on compounds in the Sun, and found bands in sunspots arising from vibrational and electronic states of O_2 and CN well above

the ground-level, as well as numerous extensions to band systems previously known in the Sun. He has listed about 100 band heads identified in spots.

McMath and Mohler report excellent results from the use of a PbS cell in a self-registering spectrograph. Wave-lengths and intensities are given directly from the record. Several elements have been recognized in the region 1·5–2·0 μ by comparison of the solar data with predicted positions of their lines. In the region 12,700 A. their records are in excellent agreement with Babcock's photographic data.

The work of Babcock and Moore Sitterly on the solar spectrum from 6600 to 13,495 A. is in the Press. Wave-lengths and intensities are given for over 7400 lines, of which about one half are atmospheric. With the aid of the Utrecht Atlas and Allen's data, intensities of lines in the spectrum of the solar disk are calibrated in terms of equivalent width. In the sunspot spectrum estimated intensities extend to 11,404 A. The identifications are based on a critical study of laboratory data and include several hundred predicted lines not yet observed in artificial sources. Excitation potentials are given for all classified lines. The sixty-six elements now recognized in solar spectra are listed.

Babcock, Moore Sitterly and Coffeen give a thorough revision of earlier descriptions of the ultra-violet limit of the solar spectrum, as observed from ground-level. Wave-lengths and estimated intensities are listed for 665 solar lines in the region 2935–3063 A. and three-fourths of these are identified. Five hundred additional lines 3063–3153 A. have been measured as a further check on the Revised Rowland data, but these are not published since it is concluded that the labour of remeasuring the rest of the ultra-violet and the visible regions is not justified.

Special attention is called to the additional revised identifications of solar lines now worked out by Moore Sitterly, in the range 3063–6600 A., but not yet published. These lines have now been studied as completely as those in the infra-red and in the 2935–3063 A. region.

Babcock, Russell and myself propose a resolution, to be sponsored jointly by Commissions 12 and 14, to the effect that the Union should consider giving financial aid to the publication of a revised description of the solar spectrum, such revision to contain wave-lengths on the scale of 1928, measured intensities or equivalent widths from Utrecht, and definitive identifications from Moore Sitterly.

Discussion of such a resolution should develop more clearly the best procedure for producing an authoritative statement of existing solar data. The wording above purposely omits the range to be covered. To be justified, such a publication would have to include the visual and most of the high dispersion ultra-violet. Whether a greater range should be included and whether data on sunspot spectra can be sufficiently expressed by statistical relations, now fairly well established, are open questions.

Mrs Moore Sitterly points out that the compilation of atomic energy levels (*Cir. Nat. Bur. St.* 467, Vol. 1, ser. 1, 1948) discussed in the report for Commission 14 has an important bearing on solar problems. For example, the lists of terms known in atomic spectra are being used to predict wave-lengths of important lines beyond 15,000 A. expected to be present in the solar spectrum; observations in this region have recently been reported from the Michigan Observatory. Since precise laboratory wave-lengths are lacking in this region the solar wave-length scale is based on predicted lines of leading multiplets of Fe I. Further identifications can be made by prediction, as has already been done in other regions of the solar spectrum.

With the advent of rocket solar spectrograms the Revised Multiplet Table is inadequate for astrophysical purposes. An Ultra-violet Multiplet Table similar in form to the 1945 Table is being prepared. It will contain the laboratory data shorter than 3000 A. of all spectra of astrophysical interest. No ultra-violet limit of wave-length is being imposed, although the multiplets needed at present for solar work lie between 2200 and 3000 A. All observed ultimate lines of arc and first spark spectra are being listed if they are not in the Revised Multiplet Table. All lines that may be significant in connection with the appearance of forbidden lines in cosmical spectra are likewise being included. In this field, Moore Sitterly has the cordial collaboration of I. S. Bowen, who has

generously furnished such a list to be used as a guide in preparing the new multiplet table.

Preliminary multiplet lists of laboratory data together with estimated solar intensities of lines to be expected in the solar spectrum between 2200 and 3000 A. have been furnished to those engaged in the interpretation of rocket solar spectrograms. These lists will be incorporated into the Ultra-violet Multiplet Table. This Table is now complete for the spectra from H through F and for selected spectra of the elements Na through A. The multiplet lists of the leading spectra of the first long period of the periodic table are also nearly final.

These large and important programmes, developed by Mrs Moore Sitterly, are being co-ordinated in an effort to furnish the astrophysicists with all relevant laboratory data on the analysis of atomic spectra, including unpublished material, which is generously being furnished by many collaborators.

Brück reports that the Irish Government is making a considerable effort to convert the Dunsink Observatory into an efficient modern observatory, where he plans to set up a solar spectroscopic installation.

In a long series of measures made by Evershed of the sodium line D_1 in the Sun and vacuum tube, with the high dispersion liquid prism spectrograph, evidence was obtained of marked variations of wave-lengths of this line, both at the centre of the disk and close to the limb. His recent work seems to indicate that similar variations on a much smaller scale of the wave-lengths of the iron lines in the region between 6280 and 6302 A. are also present at a lower level.

Considerable work has been done at the Observatories of Meudon and of the Pic du Midi under the direction of Lyot on the spectro-photometry of prominences; three hundred lines have been measured between 3300 and 11,000 A. The work will be extended to the faint prominences in order to investigate the relative variations of intensities. The radiation of the solar corona and the profile of its emission lines to various distances from the Sun's limb have been studied with Lyot's methods.

Lyot suggests that the intensity of the Fraunhofer lines be defined by the ratio of the total quantity of light absorbed to that which is contained in a band 1 A. wide of the continuous nearby spectrum. The definition could be extended to the emission lines, as for instance the ones of the prominences and of the corona, adopting the sign + for the emission lines and − for the absorption lines.

The intensity distribution at the extreme limb should present, in the opinion of Minnaert, an interesting subject. The work of Wesselink, Kopal, Wildt, Lindblad, and of Minnaert at the Yerkes Observatory could be compared. It would be worth while to ascertain whether the eclipse method is really useful or not.

This Commission, according to the suggestion of Minnaert, should urge the Union to accelerate the compilation of tables of atomic and molecular transition probabilities, which are so important for spectroscopic work.

Recent laboratory work done in Liège by Swings and Migeotte on molecular bands has received interesting solar applications.

All problems connected with the solar radiation which it is possible to investigate by radio methods are open to discussion, and it is desirable that the members of this Commission who are interested in them should have a joint meeting with members of the Commission for solar and terrestrial relationships.

D. H. Menzel reports the following items which may be useful for discussion in the meetings of Commission 12:

One of the most important contributions in recent years to solar spectroscopy is the photography of the solar ultraviolet from a V-2 rocket. Dr Richard Tousey, of the Naval Research Laboratory, and his collaborators were the first to accomplish this feat. Since then Dr Tousey, as well as other investigators, has obtained several additional spectra.

The spectra are of low dispersion, but the principal features are clearly visible. Most striking, perhaps, is the great intensity of the Mg II doublet at 2800, which appears to be more intense than H and K. These lines, incidentally, show a strong central emission component.

The source of this central emission is probably similar to that giving rise to the cores of H and K. One would expect this intensity to be variable with the number of flocculi.

Additional lines of interest are the resonance line of Mg I, a strong line of Si I, and many lines attributable to the atoms of Fe I and Fe II (*Ap. J.* **109**, 1, 1949).

Among the more profitable lines of investigation, which would require extension of existing theories of the formation of absorption lines, is the interpretation of the spectrum of sunspots. Experimental determinations of the magnitude and rate of variations of magnetic fields of spots and the Sun itself are greatly to be desired. This information is particularly needed by physicists working in the field of cosmic rays.

Dr John W. Evans has recently designed new types of interferometric equipment, which may have a wide application to solar spectroscopy.

GIORGIO ABETTI
President of the Commission

ARCETRI-FIRENZE
Jan. 14, 1948

Compte rendu de la séance

PRÉSIDENT: M. G. ABETTI.

SECRÉTAIRES: MM. M. MIGEOTTE, G. RIGHINI.

Le président ouvre la séance et signale brièvement les différentes questions qui doivent être discutées.

A propos des mesures de la constante solaire, M. Nicolet fait remarquer que la valeur de l'angle d'ouverture des actinomètres ne suffit pas pour définir leurs propriétés géométriques. Il faut aussi considérer 'l'angle limite' et 'l'angle de pente'. En observant cette précaution on peut tenir compte de l'effet d'une source uniforme (source de laboratoire ou lumière du ciel) et d'une source non-uniforme (soleil + ciel) dans le résultat des mesures. Une publication sur ce sujet paraîtra sous peu dans les *Mémoires de l'Institut Météorologique d'Uccle* (Belgique).

M. Link signale qu'il a observé un coefficient de corrélation s'élevant à 0·46 avec une erreur moyenne de 0·05 entre l'éclat de la lune et les variations de la constante solaire. Ceci s'expliquerait par une luminescence de la lune sous l'influence des radiations ultraviolettes du soleil. D'après Abbot, ce serait d'ailleurs l'intensité des radiations ultraviolettes qui serait la plus variable. M. Link fait aussi remarquer qu'une variation de 1% dans la constante solaire produit une variation 30 fois plus grande dans l'éclat de la lune.

Selon M. Brück, des observations photoélectriques d'Uranus ne révèlent aucune diminution d'éclat de la planète. Toutefois, d'après des observations visuelles effectuées à Yale de 1940 à 1946, il y aurait une variation de 0·6 magnitudes.

M. Nicolet fait remarquer que si une corrélation est observée entre la constante solaire et l'éclat d'un astre, il ne faut pas nécessairement en déduire qu'il y a une variation dans la constante solaire; car, dans les deux cas, les variations peuvent provenir de l'atmosphère terrestre.

M. Stratton émet l'opinion qu'il doit exister de grandes variations d'intensité dans le rayonnement ultra-violet solaire ainsi que dans le domaine des ondes de radio.

M. Öhman suggère des mesures de la polarisation circulaire des ondes de radio pendant les éclipses partielles.

M. Menzel fait ensuite la communication suivante:

To explain the variation of ionization in the E and F_1 layers, it is necessary to suppose a variation of 1 to 16 between sunspot minimum and maximum. A similar variation is probably necessary to explain the variation in the F_2 layer but the simpler ionospheric theory does not apply in all details. Hence there is more uncertainty. All three layers show a high correlation between the observed ionization and the sunspot number.

M. Nicolet fait remarquer qu'il ne faut pas confondre l'ultra-violet observable ($\lambda \simeq 3000$ A.) et atteignant le sol avec l'ultra-violet ($\lambda < 1000$ A.) n'atteignant que la haute atmosphère.

M. Kiepenheuer signale que les observations de Hale concernant le champ magnétique solaire ne sont pas confirmées. D'après les dernières mesures de Thiessen, le champ serait certainement, en ce moment, plus petit que 5 gauss. On ne peut dire si le champ est réellement nul ou est périodique.

Des observations de Evershed effectuées avec un prisme liquide semblent montrer que le champ n'existe pas. M. Nicholson donne connaissance d'un rapport de Babcock sur le même sujet. D'après les toutes dernières observations de ce dernier, les mesures n'ont plus permis de déceler un champ magnétique solaire. Stratton pense que les travaux doivent être continués avant de tirer une conclusion définitive.

Mme Moore Sitterly attire l'attention sur la révision des tables de Rowland de 3063 à 6600 A., travail qui n'est pas publié jusqu'à présent. Elle signale aussi la publication des niveaux 'd'énergie atomique' de l'hydrogène au fluor (*Cir. Nat. Bur. St.* 467, vol. 1, sér. 1, 1948). Le travail est actuellement continué au Bureau of Standards (Washington, D.C.). Le volume 1 s'étendra de l'hydrogène au vanadium.

A propos de la publication des tables révisées de Rowland, faut-il introduire des données sur les spectres des taches et y a-t-il lieu actuellement d'étendre le domaine spectral jusque 24000 A., en tenant compte des derniers travaux effectués à l'Université de Michigan? MM. Minnaert, Goldberg, Swings et Nicholson émettent leur avis à ce sujet. A la suite de cette discussion, le président invite M. Swings à rédiger une résolution qui sera soumise au Comité exécutif. Voici le texte adopté par la Commission:

Commission 12 considers that the publication of a revised table of the solar spectrum at the earliest possible time is of the greatest importance to astronomers engaged in solar research and in the investigation of stellar spectra. In order to reduce the delay in publication, Commission 12 recommends that the revised table be limited to the still unpublished spectral range from $\lambda 3063$ to $\lambda 6600$, and that the wave-lengths be given on the scale of 1928. To this purpose, Commission 12 recommends that the I.A.U. provides financial aid for the publication of the revised solar table for an amount of £500 ($2000).

M. Plaskett demande si les intensités des raies dans les tables révisées seront données d'après l'Atlas d'Utrecht. M. Minnaert marque son accord à ce sujet et signale que la Commission 36 doit décider s'il convient d'adopter $\Delta\lambda$ ou $\Delta\lambda/\lambda$ pour les largeurs équivalentes.

M. Menzel signale que les chercheurs engagés dans l'étude des rayons cosmiques sont particulièrement intéressés par les mesures des champs magnétiques du soleil et des taches solaires. Il y a lieu de poursuivre activement des travaux dans ce domaine.

M. Nicholson fait remarquer que la surface d'une tache ou d'un groupe de taches n'a pas de relation avec le champ magnétique. C'est la surface de l'ombre qui est en relation avec l'intensité du champ radial; tandis que celle du champ parallèle dépend de la distance entre les ombres de polarité opposée, d'où une méthode facilement applicable pour juger de l'intensité du champ dans les différentes taches.

M. Kiepenheuer signale qu'il est aussi important de déterminer le champ au voisinage des taches en vue d'une comparaison avec le champ d'excitation de la chromosphère. Toutefois, vu le temps nécessaire pour ces mesures, l'étude ne peut être entreprise que pour des taches sélectionnées.

Pour terminer, M. Minnaert fait connaître les résultats qu'il a récemment obtenus à l'Observatoire Yerkes, concernant l'obscurcissement au bord du disque solaire. Des résultats ont été obtenus par photométrie photographique pour une région du disque comprise entre 90% et 99·5% et pour les longueurs d'onde 5600 et 6250 A.

Problèmes Relatifs au Rayonnement de l'Atmosphère Solaire

Il existe des preuves expérimentales et des raisons théoriques pour le rayonnement assez intense de l'atmosphère solaire dans le domaine inaccessible aux observations terrestres. Je voudrais attirer l'attention sur l'excès de lumière dans la pénombre pendant les éclipses de lune qui peut être en relation avec notre thème.

Il est un fait bien établi qu'il y a un excès de lumière dans la pénombre, variable d'une éclipse à l'autre, excès qui augmente vers le bord de l'ombre, et qui à 5′ du bord, peut atteindre par rapport à la valeur théorique facilement $0^m{\cdot}5$ à $0^m{\cdot}75$. Comme la valeur théorique de l'éclairement dans la pénombre est bien établie et qu'il n'y a aucune explication plausible, je me suis demandé, si ce n'est pas l'atmosphère solaire qui en est la cause. En effet, dans la pénombre, assez près du bord de l'ombre, le disque solaire est beaucoup plus éclipsé que son atmosphère et il peut en résulter l'excès que l'on a constaté. L'éclairement direct optique par l'atmosphère solaire étant trop faible, on peut penser à la luminescence de la surface lunaire sous l'influence des rayons ultraviolets solaires.*

On arrive à interpréter l'excès moyen en admettant que dans la lumière de la pleine lune il y a en moyenne 10% de la composante luminescente. Dans cet ordre d'idées on devrait rencontrer des fluctuations dans la lumière de la lune en dehors de l'éclipse. Les mesures de Rougier† se prêtent très bien à ce genre de recherches. Je les ai employées en corrélation avec les variations simultanées de la constante solaire trouvées par Abbot.‡ On arrive donc au résultat suivant:

$$r = +0{\cdot}44 \pm 0{\cdot}05 \text{ (e.p.)} \quad n = 94.$$

La corrélation paraît donc assez bien établie et donne en quelque sorte la première preuve indirecte des variations de la constante solaire que l'on a en vain cherchée dans les fluctuations de la lumière de Jupiter et de ses satellites et d'Uranus. Il est aussi remarquable que les variations lunaires sont environ 30 fois plus grandes que les variations de la constante solaire. On devrait rapprocher ce fait avec les résultats de Abbot et de Péttit sans parler des résultats ionosphériques qui accusent tous des variations croissantes vers l'extrémité ultraviolette du spectre.

Si l'hypothèse du travail proposé s'affirme, nous aurons la possibilité d'étudier les variations du rayonnement solaire inaccessible aux observations terrestres. On peut songer, en plus des éclipses et de la lumière globale de la lune, à l'intensité résiduelle des raies de Fraunhofer, comme il ressort de la discussion avec MM. Brück, Kiepenheuer, Dufay et autres.

F. Link

Report on Uranus Observations

Brück reports that at Cambridge he has made series of photoelectric observations of Uranus with a view to determine possible variations of the solar constant. The observations extend over an interval of about 5 years, but there are some gaps in the series, and the observations are to be continued at Dunsink.

The reduction of the observations and, in particular, the separation of effects due to possible solar variations from those due to Uranus itself, has not yet been completed.

H. A. Brück

Photographic Measurements of the Solar Limb Darkening

The measurement of the limb darkening is of the greatest importance for establishing a model of the outer layers. Especially the zone very near to the limb should be studied, because this conveys information on the structure of the highest layers, where a great part of the Fraunhofer lines originates.

* F. Link, *C.R.* **223** (1946); *Bull. Soc. Math. Phys. Tchéc.* **72** (1947), n. 65.

† G. Rougier, *Ann. Obs. Strasbourg*, **2** (1933), p. 13.

‡ *Annals of the Smith. Instit.* vol. **6**.

Up to now, the observations belong to two groups:

1. Measurements between 0 and 98% of the radius (Abbot, Moll c.s., Raudenbusch, Chalonge).
2. Measurements between 99·3 and 100%, obtained at total eclipses (Wesselink, Kopal, Lindblad).

It was important to bridge the gap and to study especially the regions near the limb.

A series of photographs of the Sun's disk, taken at the Yerkes Observatory in the summer of 1946, was measured at Utrecht by Miss van den Hoven van Genderen and by Mr van Diggelen. The image had a diameter of 18 cm. The plates had been calibrated, they refer to the wave-lengths $\lambda 6250$ and $\lambda 5600$. Corrections for sky light, chromatic aberration and scintillation were applied. The mean deviation due to scintillation proved of the order of 0·003 R, which corresponds to very good conditions of seeing.

The limb darkening was measured between 90% and 99·5% of the radius, the point at 90% being provisionally taken from Abbot. Well consistent and apparently reliable results were obtained from the different plates.

There is no doubt, that photographic photometry of such sharp photographs must yield quite reliable results even near the extreme limb, and that it would be very useful if other observers could repeat these measurements for different wave-lengths.

% R	90	91	92	93	94	95	96	97	98	99	99_5
$\lambda 5650$	65·3	63·7	61·7	59·7	57·5	55·3	52·6	49·3	44·5	38·6	35·0
$\lambda 6250$	67·9	65·8	63·9	61·8	59·6	57·4	54·7	51·5	47·7	42·6	39·8

M. MINNAERT

13. COMMISSION DES ECLIPSES DE SOLEIL

PRÉSIDENT: Prof. S. A. MITCHELL, *Leander McCormick Observatory, University of Virginia, Charlottesville, Va, U.S.A.*

MEMBRES: MM. Abetti, Allen, Carroll, Clemence, Dunham, Fesenkov, Freundlich, Grönstrand, Horn d'Arturo, A. Hunter, J. Jackson, Lindblad, Link, Lyot, Menzel, Mikhailov, Millman, Minnaert, Smiley, J. Q. Stewart, Stratton, Van Biesbroeck, Woolley.

Since the date of the 1938 Stockholm meeting, there has been vast progress from eclipses both on the observational and the theoretical sides. In the interval there have been five total eclipses: 1940, October 1; 1941, September 21; 1944, January 25; 1945, July 9; and 1947, May 20. In spite of the war and of the ever-present enemy of eclipse observers, clouds, valuable observations were secured from each of the five eclipses.

It is becoming increasingly difficult to draw a line of delimitation between the work of Commission 13 (Eclipses) and of Commission 11 (Chromospheric Phenomena) and Commission 12 (Solar Radiation and the Solar Spectrum). Spectacular developments by the use of coronagraphs at the high-altitude stations in France, in Switzerland and in the United States (Harvard Station at 11,532 ft.) and also by the improved motion-picture techniques developed at the McMath-Hulbert and the Mt Wilson Observatories have made it possible for refined observations of prominences and of the corona to be made outside of a total eclipse. As a splendid example of observations made within and outside the band of totality of an eclipse, may be mentioned the important publication by Waldmeier (*Astron. Mitt. Zürich*, No. 149, 1947) concerning coronagraph observations at Arosa on July 8–10, 1945, or, in other words, on the day of the total eclipse of July 9, and the preceding and following days.

Chromosphere. The most extended observations of the flash spectrum published in the past ten years are those of Mitchell (*Ap. J.* **105**, 1, 1947), and the discussion of these observations by Wildt (loc. cit. p. 36). A total of 3500 spectral lines are recorded between the wave-lengths 3066 and 8863 A. The intensities are given for the Sun and for the chromosphere, the heights above the photosphere in km., and the excitation potentials. The observations are the result of ten eclipse expeditions. Another important contribution is that of Redman (*M.N.* **102**, 134 and 142, 1942) which discussed the observations from the 1940 eclipse. Eclipse observers with their temporary installations are usually at the mercy of great temperature changes which may cause large fluctuations in focus. Redman adopted the excellent plan of protecting the sensitive parts of his spectrograph by placing them vertically in a pit.

The Hydrogen Chromosphere. The prominence of the Balmer and the Paschen series of hydrogen is a manifestation of the overwhelming abundance of hydrogen in the solar atmosphere. The determination of the density gradient of hydrogen is a most important problem for the reason that it should reveal the structure of the bulk of the chromosphere. Heretofore, the chief investigators have been Pannekoek and Minnaert (*Verh. Kon. Akad. Amsterdam*, Vol. **13**, No. 5, 1928) and Cillié and Menzel (*Harvard Obs. Circ.* No. 410, 1935). Both discussions are based on the total intensities of the Balmer lines in the flash spectrum and these intensities are difficult to interpret on account of the self-absorption that may occur in the Balmer lines. The method adopted by Mitchell and Williams (*Ap. J.* **77**, 1933) and by Wildt of utilizing the heights of the Balmer lines estimated from the tips of slitless curved lines turns out to be practically free from interference by the effect of self-absorption. The results attained agree closely with the analysis of the composition of the solar atmosphere of B. Strömgren (*Festschrift für E. Strömgren*, p. 214, 1940).

In the solar chromosphere the last observed member is $n=37$ in the Balmer series and $n=40$ in the Paschen series. Wildt finds the results from both series in good accord. Taking the mean, he finds that in a chromosphere slab at height 500 km. the number per cubic centimetre of positive ions is $2{\cdot}4\times10^{11}$.

Metals in the Chromosphere. Although some metallic lines in the chromosphere like

the H and K lines of Ca II attain greater heights than hydrogen, while other enhanced lines of Sr, Ti, Ba and Fe attain comparable heights, the vast majority of metallic lines are below the 2000 km. level. As was pointed out by Wildt (loc. cit.) and earlier by Mitchell and Williams (*Ap. J.* **77**, 1, 1933), the comparatively small range in the estimated heights has been a handicap in the determination of the density distribution of the metals in the chromosphere.

In consequence of the much greater range in the intensities of the metallic lines, Mitchell, when preparing for the 1947 publication, made re-estimates of his spectra obtained at different eclipses and at the same time made estimates at heights of 400, 600, 800, 1000, 1200, 1500, 2000 km. and on up to the highest levels reached. As explained in the publication, continued attempts were made by him to keep the scale of intensities as constant as possible. Entirely *after* the completion of the estimates, it was interesting to ascertain what the scale of estimates actually was. Consequently, the metallic lines were grouped into multiplets and then arranged according to doublets, triplets and so forth up to septets. (I trust the members of the Commission will pardon its president for enumerating here his findings.) For the sake of brevity, attention will be confined to the lines of doublets and triplets for the twofold reason that they involve the strongest lines and also that the theoretical intensities are more thoroughly determined. In addition to the intensities given in the 1947 publication, the estimates for individual lines at the 400, 600 km. and higher levels were all grouped together, but with diminished weights at the greater heights. Comparisons were made with Russell's important publication (*Ap. J.* **83**, 129, 1936). As the intensities, both observed and theoretical, are relative, the simplest method of procedure is to take the intensity of each line of the multiplet with respect to the total intensity in the multiplet as unity. Then for further simplicity, attention may be confined to the strongest line in each multiplet and its intensity relative to the multiplet as a whole as unity. With 26 doublets and 16 triplets to combine into averages, it was found that the ratio of the scales of the observed relative to the theoretical intensities was 100·4 % for the doublets, and 100·8 % for the triplets, or 100·5 % for the 42 multiplets. The theoretical scale derived from multiplet structure gives the logarithm of the number of 'active atoms' involved. Mitchell's observed scale for the stronger lines of the chromosphere agrees very closely with the logarithm of the square root of the number of active atoms. The agreement with the theoretical scale from multiplet structure is remarkably close. It might be added that scales of intensities are logarithmic and hence are similar to stellar magnitude scales.

In addition to the estimates of intensity made by Mitchell, his 1930 photographs of the flash spectrum have been measured by Mulders with the micro-photometer at the Mount Wilson Observatory. It is therefore planned to derive curves of growth of spectral lines at different heights in the chromosphere. By this means, further information will be derived regarding the relative abundances of the metals and their density distribution.

Wave-Lengths in Emission and Absorption. Comparison by Redman between 328 emission lines with 159 absorption lines near the Sun's limb gives a mean shift in the sense absorption minus emission of $-0{\cdot}0007 \pm 0{\cdot}002$ A.

The Relative Abundance of the Metals. The discussion by Wildt of the relative number of atoms in the chromosphere (loc. cit. p. 74) is in good agreement with the earlier values in the chromosphere found by Menzel and by Mitchell and Williams and these values in turn with the results of Russell (*Ap. J.* **70**, 11, 1929) for the Fraunhofer spectrum. The chromosphere is much richer in hydrogen than the photosphere. Although the metals differ comparatively little from each other in their abundances, Wildt finds that at the 500 km. level, hydrogen is a million times more abundant than neutral iron.

Turbulent Pressure in the Chromosphere. McCrea's theory (*M.N.* **89**, 718, 1929) seemed to have been abundantly verified by various eclipse observers. According to Unsöld (*Physik der Sternatmosphären*, p. 437, 1938) we read that the profiles of the chromosphere lines are mainly determined by turbulence, all of them being equally wide. He concludes that the line profiles measured by Pannekoek and by Minnaert, and also by Menzel (*Publ. Lick Obs.* **7**, 1, 1931) indicate turbulent velocities of the order of 10–15 km./sec.

Mitchell and Williams likewise find turbulent velocities confirmed by the relation between intensity and height. In a most surprising way, the results obtained by Redman, and independently by Wildt, have shown that we must abandon our previous model and that at least the lower parts of the chromosphere are practically in diffusion equilibrium, each gas showing the gradient corresponding to its molecular weight. The opinion expressed by Redman (*M.N.* **104**, 103, 1944) is: 'The present evidence then is that any motion in the solar reversing layer and lower chromosphere which can properly be called "turbulent", i.e. which is common to all material and not Maxwellian in distribution, does not exceed an average velocity of 1 km./sec. in any one co-ordinate.' From the solar curve of growth, K. O. Wright (*Ap. J.* **99**, 249, 1944) finds a turbulent velocity of 0·9 km./sec., while from Menzel and Rubenstein's curve the corresponding value is 0·6 km./sec. Similarly, Struve and Elvey find that turbulence in reversing layers, estimated from curves of growth, must be less than 2 km./sec.

It should be added that it is difficult to reconcile these small turbulent motions with the classical picture of the sun as a 'prairie in flames', the presence of numerous small prominences in continual motion, with the very large hydrogen velocities from flares, and with the newly discovered spicules (Roberts, *Ap. J.* **101**, 136, 1944).

Temperatures in the Chromosphere. All methods of investigating the reversing layer have been in agreement in assigning temperatures of 4000° to 6000°. The presence of He II, 4686 A. in the flash spectrum has been difficult to explain. With temperatures of a million degrees demanded by the spectrum of the corona, it is evident that our ideas of the temperatures in the chromosphere and the corona must be radically revised.

For the chromosphere, there are three different methods of deriving temperatures: (1) excitation temperatures, (2) line profiles, and (3) height gradients. Among the more recent investigators of excitation temperatures are Wildt (loc. cit.), Goldberg (*Ap. J.* **90**, 414, 1939) and Petrie (*J.R.A.S. Canada*, **38**, 137, 1944). The temperatures for hydrogen are about 5000°, for helium the range is from 4300° to 6700° and for the metals the range is from 3000° to 5000°. In other words, all authors are agreed in assigning approximately 5000° as the excitation temperatures. In sharp contrast are the temperatures of 30,000° found by Redman from line profiles. Starting with the height gradients determined by Wildt, Minnaert has calculated the (unpublished) temperatures of 35,000° for H; 60,000° increasing with height to 100,000° for He; and 30,000° increasing to 175,000° for iron and the metals. The temperatures determined from gradients at 2000 km. for hydrogen and the metals are in fair agreement with the kinetic temperatures from line profiles at the same elevations. In contrast, the excitation temperatures are much lower.

Eclipse Spectra from Airplanes. Flying under the auspices of R.C.A.F., Millman (*A.J.* **52**, 157, 1947) secured photographs at the 1945 eclipse. All cameras were on fixed mounts, exposures being made electrically by remote control at intervals of 2–4 sec. Pilots kept the aircraft on the correct course by using an adaptation of the reflector gunsight. Although some vibrations were evident, it is considered that this could have been eliminated had more time been available for mounting the instruments. Satisfactory low-dispersion coronal and chromospheric spectrograms were secured from elevations of 26,000 and 33,000 feet.

Future Chromospheric Observations. It is certain that the chromosphere cannot be in thermodynamic equilibrium. Hence the values of the 'temperature' calculated by applying equilibrium theory to such different properties as excitation, line profiles and density gradients may be expected to differ. The apparent variation in density at different heights in the chromosphere is such as would be produced if higher and higher temperatures were reached at greater and greater distances from the Sun's surface. The only method of solving the dilemma seems to be for future eclipse observers to take up the difficult task of deriving simultaneous observations of line profiles at different heights in the chromosphere.

Several of the more active members of the Commission, who have been interested in spectroscopic problems rather than in direct photography, have independently requested that a statement should be made in the report that after fifty years of photographic

observations of eclipses there is little need of continuing routine spectrographic work on the flash spectrum on the short wave-length side of 7000 A. At the red end, observations could be extended by the use of improved Eastman Z plates, by lead sulphide photoelectric cells and by phosphors. Attention of possible observers should be called to the thinning out of chromospheric lines in this region and also to the presence of strong atmospheric absorption bands.

The Corona. A dozen years ago it used to be said that the solar corona could be observed only for an average of 60 seconds, or 1 minute of time per year, and exclusively at the time of a total eclipse. As a result primarily of the brilliant work of Lyot, it is nowadays possible to photograph the corona in broad daylight and continuously for several hours in succession on many days during the year when the air transparency is high.

The construction of the Lyot coronagraph with its filters and polarizers is described in several journals, including *Ap. J.* **101**, 255, 1945. With the use of a radiation-separator, four images are produced corresponding to different radiations. Three of these are received on a moving film in size 24×36 mm. and they register simultaneously: (1) the prominences photographed in H_α light, (2) the corona in the 6374 A. line in the red, and (3) the corona in the green at 5303 A. The fourth image is used for guiding purposes. Each of the three regions has a spectral width of 2 A. Some of these films were continued for more than 12 hours and cover a total duration of 92 hours of action on the Sun. Spectra taken with concave grating (*Ap. J.* **75**, 1, 1932) showed vast differences in structure between the 5303 and 6374 lines. The Lyot films 'confirm the difference between the green and the red corona and the nearly total independence of the corona and the prominences. On the other hand, they are far from confirming the motions in the corona mentioned by some observers: even when speeded up 2400 times, the corona remains stationary. The arches and jets appear and fade progressively along invisible trajectories, and the corona thus modifies its shape without perceptible motions.'

By the use of his fringe-photometer, Lyot was enabled to compare the intensities of the green and red lines with the intensity of polarized light. Sometimes the two lines have a sharp maximum near the same regions, but far more generally their maxima are at very different position angles. Near the Sun's poles, the intensity may be less than two-millionths of the continuous spectrum of the Sun, while near the equator the brightness may be 40 times greater.

Since 1943, Lyot has been able to measure visually, in 5° steps around the Sun's disk, the intensities of the radiations 5303, 6374 and 5694 (when the activity is great), and these measures are compared with the quantity of polarized light, which in turn is sensibly proportional to the intensity of the continuous spectrum. These measures are continued as regularly as possible from the station at Pic du Midi, and they are utilized as advance predictions for observations on the ionosphere.

As a result of difference in the distribution of the spectral lines around the Sun and their connections with sunspots, Lyot (*M.N.* **99**, 591, 1939) separates these lines into three groups: (1) the yellow line at 5694; (2) the lines of 3388, 5116, 5303, 6702, 7059, 8024, 10,749 and 10,798; and (3) the 6374 and 7892 lines. When his photometric measures are more precise, Lyot believes that it will be possible for him to find differences between the rays of a single group and to classify them in order according to decreasing ionization potentials.

During the 3-day interval at the time of the total eclipse of July 9, 1945, Waldmeier (loc. cit.) was able to come to valuable conclusions derived from his excellent observations. The variations in intensity of the 5303 and 6374 A. lines along the Sun's limb show that the maxima displayed may be classified into three groups: (1) those belonging to the spot zone of the old cycle, (2) those belonging to the new cycle, and (3) those belonging to the zone of activity in high latitudes. The greatest intensity of the 5303 line is equal to 5×10^{-5} A. equivalent breadth of the spectrum at the Sun's equator and it decreases to one-sixth of this value at 2'·74 from the Sun's limb. The intensity of the continuous spectrum of the corona at the point of its greatest intensity at an angular distance 0'·4 from the Sun's limb is equal to 7·8 millionths of the intensity at the Sun's centre. The position of greatest intensity in the coronal spectrum takes place at about the same

elevation above the Sun where the strongest hydrogen lines, or H and K of Ca II, fade off to insignificance.

The Spectrum of the Corona. There are three distinct spectra:

(*a*) The emission spectrum existing close to the Sun's edge consisting of 23 well-determined lines between the wave-lengths 3328 and 10,798 A.

(*b*) A continuous spectrum of intensity JK, in the inner corona.

(*c*) A faint Fraunhofer spectrum of intensity JF in the outer corona. The emission spectrum is superposed on a strong continuous background and it is always very difficult for an observer to decide whether or not he can be sure of a feeble line on his photographs. In *Lick Obs. Bull.* **10**, 1, 1918, Campbell and Moore listed 36 coronal lines between 3328 and 6374 A. Nineteen of these lines have not been confirmed. At the 1936 eclipse, the Japanese astronomers (*Trans. I.A.U.* **6**, 75, 1938) measured several feeble lines and, at the same eclipse, Petrie and Menzel (*Ap. J.* **96**, 395, 1942) measured ten additional lines. The reality of these faint lines must be confirmed (*M.N.* **105**, 323, 1945).

Emission Spectrum of the Corona. In 1941, Edlén astounded the astronomical world by giving identifications for 20 of the 23 known coronal lines; all of the transitions represent 'forbidden' lines. The green line, 5303, is ascribed to Fe XIV and the red line, 6374, to Fe X. Two of the fainter lines, 4359 and 5536 A., are assigned to argon, an element that does not appear in the chromosphere. The stripping of atoms of 10 to 15 electrons, or of half their normal electron envelope, demands a temperature of about one million degrees. Several authors have enumerated the arguments for assuming this colossal temperature. These arguments are:

(1) The high ionization of Fe, Ni, Ca and A.

(2) The width of the emission lines if due to thermal Doppler effect.

(3) The blurring of the Fraunhofer lines in the continuous spectrum of the inner corona assumed to be the effect of the velocities of the scattering atoms.

(4) The absence of the Balmer lines in the emission spectrum explained by the electrons moving too fast to be captured.

(5) Great thermal velocities are required to explain the electron concentration as a function of the distance to the Sun.

In the chromosphere conflicting information regarding temperatures comes from excitation, line profiles and density gradients, while, on the contrary, in the corona all the methods assign the same high temperatures. There have been many plausible guesses at the source of these high temperatures, and the most encouraging explanation so far is that of Woolley and Gascoigne (*M.N.* **106**, 113, 1946).

Regarding the problems of temperature, Bowen and Swings (*Ap. J.* **105**, 92, 1947) state that from the astrophysical standpoint, the presence in the coronal spectrum of lines in the 10th to 15th stages of ionization has raised many difficult questions. Particularly disturbing is the presence of very highly ionized atoms in the corona, while in the photosphere, chromosphere and prominences there are neutral and singly ionized atoms only and with all intermediate stages of ionization seemingly absent from all spectra.

Perhaps the greatest solar problem to-day is to account for the forces which: (1) support prominences in general and produce the amazing prominence motions revealed by the coronagraphs and the spectroheliographs; (2) eject particles from the Sun at velocities around 1000 km./sec. to produce geomagnetic storms; and (3) produce the extended coronal streamers which very strongly give the impression of outward stream motions. Ironically enough, one difficulty will be to explain why the corona is not more extended because the million degree temperature is enough to account for the extension without further force.

Inner and Outer Corona. Grotrian (*Z. f. Ast.* **8**, 124, 1933) gave our present accepted explanation of the corona, namely, that the inner corona exhibits a continuous spectrum without dark lines and with an intensity JK, while the outer corona, of intensity JF, shows the Fraunhofer spectrum. Moore (*P.A.S.P.* **35**, 60, 1923) showed that, even though the Fraunhofer lines were weak, they had the same widths as corresponding lines in the solar spectrum. The colour of the corona is exactly the same as that of the Sun and at all

wave-lengths. The continuous spectrum K is caused by electron scattering and the spectrum F is caused by the scattering from small particles in the neighbourhood of the Sun. According to Öhman (*Pop. Astr. Tidskr.* **27**, 133, 1946), the chief characteristics of the two components of the corona are:

K component	F component
No spectral lines	Fraunhofer lines
Steep decrease in intensity outward	Slow decrease in intensity outward
Same colour as the Sun	Same colour as the Sun
Much stronger near the Sun's equator than near the Sun's poles	Equally bright in polar and equatorial regions

Two methods are possible to separate the K and F components: (1) measurement of line profiles of the Fraunhofer lines in the coronal spectrum, and (2) polarization measurements. From spectra obtained at the 1940 eclipse, Allen (*M.N.* **106**, 137, 1946) follows the spectroscopic method, while Öhman (*Stockholm Obs. Ann.* **15**, No. 2, 1947) discusses the polarization of the corona from observations made at the 1945 eclipse. Another important publication by van de Hulst (*Ap. J.* **105**, 471, 1947), which appeared at about the same time as the other two papers, discusses 'zodiacal light in the corona'.

As an illustration of the difficulty of measuring faint spectral lines, Allen gives measures by three observers of the same spectra. The Fraunhofer lines of the F spectrum gave displacements of +0·13 A., +0·06 A. and −0·06 A., which weighted and combined gave a displacement of $+0{\cdot}084 \pm 0{\cdot}04$ A., equivalent to a radial velocity of 6 km./sec. This is a much smaller value than that of 20 km./sec. derived by Moore (*P.A.S.P.* **35**, 333, 1923; **45**, 147, 1933). It is evident that motions in the outer corona away from the Sun need further confirmation, especially in view of Lyot's observations which show no outward motions.

The Polarization of the Corona. By the use of instruments of four different types, Öhman was able to come to important conclusions concerning the K component of the corona: (1) There is no change in the colour of the corona when proceeding from the Sun's limb outwards. (2) There is no run in polarization with wave-length. (3) The polarization at the poles is considerably smaller than the polarization at the equator. (4) At the equator, the degree of polarization has a maximum value of 45·5% at 0·6 radii from the edge of the Sun and decreases at greater distances from the limb.

Future Coronal Problems. In order to further substantiate Edlén's interpretation of the emission spectrum, it is desirable to secure wave-lengths of additional faint coronal lines. This may be accomplished only if an efficient spectrograph of great light-gathering power is employed.

It is very gratifying to realize that the three most recent publications by Allen, by Öhman and by van de Hulst reach conclusions in substantial agreement. The brightest parts of the inner corona result from the K corona caused by electron scattering. The rays and streamers are always prominent features in all eclipse photographs, and they must consist of concentrations of electrons. The shape of these streamers determines the ellipticity of the corona, whose shape is closely connected with the sunspot cycle (*Hand. der Astroph.* **7**, 396, 1936). The observations by Allen of isophotes of the 1940 eclipse give the ellipticity of the corona in the usual Ludendorff notation as $a+b=0{\cdot}07+0{\cdot}13$.

Particularly important at future eclipses will be photographs taken in the light of the K line, through the use of a monochromatic filter which presumably would tend to remove the Fraunhofer component of the corona or at least reduce it. By this means it would be possible to photograph streamers at greater distances from the Sun. How are these streamers with the plumes and arches shown on eclipse photographs related to the coronagraph photographs in the emission light of 5303 and 6374 A.? The structures in the green and red lines resemble each other in so few details, and in turn they have so few connections with prominences that it will be most important at future eclipses for intensive work to be accomplished by coronagraphs at their own installations, as was done by Waldmeier at the 1945 eclipse.

Although the coronagraphs working outside of an eclipse can give valuable information regarding the brightest parts of the corona, the K corona, the faint outer F corona will remain exclusively an eclipse phenomenon. This corona must be circular in outline and in all probability its intensity is fairly constant though there may be changes in brightness during the sunspot cycle on account of variations in the accumulations of solid particles in the neighbourhood of the Sun.

Further eclipse observations are desirable in order to measure the profiles of the Fraunhofer lines to ascertain whether these lines have widths identical with the corresponding lines in the solar spectrum. Although a most difficult undertaking, it is urgently necessary to redetermine any motions outward in the outer corona. Photographs secured by the Russians at the 1936 eclipse (*M.N.* **104**, 140, 1944) from four widely separated stations, show no outward motions. Allen's 1940 eclipse measures are interpreted by him to indicate no motions. Lyot interprets his own coronagraph observation as confirming no motions.

The publications by Allen and by van de Hulst are in complete agreement in ascribing the Fraunhofer component of the corona to diffraction by solid particles similar to those forming the zodiacal light. It is therefore necessary to emphasize again what was published in the 1938 report of Commission 13, namely, the desirability of observing the zodiacal light at the time of a total eclipse, both by photographs with cameras probably of the Schmidt type and by visual observations. It seems possible that the visual observations by a trained observer will give the more satisfactory results.

Solar Radio Noise. Recent eclipses have added a new field of investigation dealing with the ionosphere, which may be carried out with equal success whether the skies at eclipse time are clear or cloudy. Up to the present these observations have largely been made by radio technicians, but probably in the future more astronomers will become active in the observational programme. The techniques devised in the Second World War and the extensive use of airplanes for eclipse observations should lead to a rapid accumulation of observations, while the million-degree temperature of the corona should provide a sufficiently high temperature for the theorists.

Ionospheric Problems. What are these active areas that may explain the ultra-high-frequency waves from the Sun, in the range of 30–1000 Mcyc.? According to the observations made up to the present time, it is believed that radio noise results from violent disturbances on the Sun that are associated with sunspots. It must be remembered, however, that sunspots are cooler than the photosphere, while in contrast the million-degree corona furnishes the theorists with an important tool of research. Several publications have appeared, including one by Kiepenheuer (*Ann. d. Astrophys.* **9**, 42, 57, 1946). Results from the 1940 eclipse (*M.N.* **103**, 24, 1942) showed evidence of the ultra-violet eclipse in all three regions, E, F1 and F2, but there was no evidence of a particle eclipse. Interpretation led to the conclusion that the radiation producing the ionosphere was not distributed equally over the Sun's surface but was localized in the active areas. In recent years, several partial eclipses have been observed with ionospheric equipment. These partial eclipses may be used for determining the recombination coefficient in the various ionospheric layers and the distribution over the Sun of the ultra-violet source which produces the ionosphere.

Outstanding Solar Problems. The most perplexing problems are those involved with temperatures. In the chromosphere, the excitation temperature is about 5000°, the kinetic temperature determined from line profiles and the ionization temperature determined from He II are about 30,000°, while the temperatures derived from density gradients are still higher. At what distance above the Sun do these discordant temperatures change to the million-degree temperature of the corona? What is the mechanism that can produce the amazing motions exhibited by the prominences? What is the angular relativity displacement at the Sun's edge?

The Relativity Displacement. Practically no additional observational material has come from recent eclipse expeditions. Results from previous expeditions are not in satisfactory accord, with the observed values generally higher than that predicted. At the May 20,

1947 eclipse, Van Biesbroeck was successful with his clever device of placing in front of the lens of his 20-foot telescope and at a 45° angle, a plane-parallel optical plate half-coated in order to bring in an auxiliary star-field 90° from the Sun and at the same zenith distance. At eclipse time the sky was quite favourable, and in August additional plates were taken of the check-field. Unfortunately, the eclipse star-field in 1947 was in a dark lane in the constellation Taurus. Van Biesbroeck writes: 'On the eclipse plates, only 5 stars could be measured within a distance of 4 solar radii. The majority of the 46 others were so far removed that they hardly contribute to the weight of the determination. The faintest star used is 10·0 photovisual magnitude.'

Geodetic Observations at Eclipses. The geodetic problem of Banachiewiez and Bonsdorff (*Observatory*, **66**, 77, 1945) is essentially a Scandinavian project. Therefore, it was fortunate that a total eclipse occurred so near home in July 9, 1945. The success of the research depends on very accurate determination of the times of second and third contacts. The highest accuracy may be attained by photographic observations of the flash spectrum. Quoting from a letter from Lindblad: 'The photometry of the continuous photospheric spectrum gives a photometric determination of the lunar contour and a very accurate connection between this contour and the photosphere at a well-defined instant. The rate of decrease of the intensity at second contact is about 5 mag. per second of arc in the blue and violet and is in fair agreement with theoretical predictions by Wildt and Waldmeier.' The undeniable success of this geodetic scheme in 1945 made it desirable to continue the observations in 1947. Accordingly, Finland sent two expeditions, one to Bocayuva in Brazil, and one to Kpong on the Gold Coast. The Swedish expeditions were located in French Togo and at Araxá in Brazil. Three of the four expeditions had clear skies; the failure was in Araxá, where Öhman had planned polarization observations in addition to the geodetic plans. The Swedish expedition was one out of seven at Araxá that experienced bad luck from clouds. The results from the geodetic observations will be awaited with interest.

Coming Total Eclipses. The total eclipses of the future will in general require long distances of travel away from home.

Date	Duration in minutes	Where visible
1948, Nov. 1	1·9	Central Africa, Madagascar
1950, Sept. 12	0·9	North-eastern Siberia
1952, Feb. 25	3·0	Equatorial Africa, Red Sea, Arabia, Siberia
1954, June 30	2·5	Canada, Scandinavia, Russia
1955, June 20	7·2	Ceylon, Indo-China, Philippines

It would seem desirable to transfer the work of the coronagraphs from Commission 13 to Commission 11 or to Commission 12.

S. A. MITCHELL
President of the Commission

Report of meeting

PRESIDENT: Prof. S. A. MITCHELL.

Views expressed on new problems in coronal spectroscopy were as follows. There is need for extensive laboratory measurements before the identification of coronal lines can be advanced much further. The spectral distribution in the continuous coronal spectrum requires confirmation at forthcoming eclipses, and further search for faint emission lines is recommended.

The suggestion that the outer corona is caused mainly by diffraction of zodiacal light particles is in satisfactory agreement with the latest measurements of the coronal Fraunhofer lines and the polarization. It was pointed out that certain physical quantities in

the corona, the hydrogen to metal ratio, the degree of ionization, the atomic excitation collision cross-section, and the emission of ultra-violet light, can all be determined with reasonable satisfaction. The ultra-violet emission is thought to be mainly in the principal lines of MgX. Theoretical calculations of cross-sections have been made also, and will be available for comparison with observations.

Problems of the corona are profoundly influenced by the realization that the source of most of the solar radio-noise is located in the corona. Reports of solar noise observations were received.

Observations made with the Climax coronagraph show a most suggestive association between the emission of the line 5694 A. and active looped prominences. The 6374 A. line shows velocity displacements of up to 50 km./sec. in these regions.

Attention was drawn to the unsatisfactory state of our knowledge of temperature at different levels in the chromosphere. In this connection there is a call for eclipse observations of darkening at the extreme limb, and also for measurements as high as possible into the corona of both atom density gradients and the width of the lines of Ca^+ and H.

14. COMMISSION DES ETALONS DE LONGUEUR D'ONDE ET DES TABLES DE SPECTRES SOLAIRES

PRÉSIDENT: M. W. F. MEGGERS, *National Bureau of Standards, Washington, D.C., U.S.A.*

SECRÉTAIRE: M. Harrison.

MEMBRES: MM. H. D. Babcock, Barrell, Burns, Edlén, Kiess, Pérard, Mme Moore-Sitterly, M. Swings.

SOUS-COMMISSION DES TABLES D'INTENSITÉS

PRÉSIDENT: M. R. B. King, *Mt Wilson Observatory, Pasadena, Calif.*

MEMBRES: MM. Allen, Bowen, Menzel, Minnaert, J. A. Smit.

I. THE PRIMARY STANDARD

Barrell has given (*Proc. Roy. Soc.* A, **186**, 164, 1946 and *Revue de Métrologie Pratique et Légale*, 2e série, **7**, 33, 1947) a summary of nine directly measured values of the wave-length of the red line of cadmium in terms of the International Metre.

TABLE 1

Values of the Wave-length of the Cadmium Red Line in Terms of the International Metre ($1 A. = 1 \times 10^{-10}$ m.)

Date	Observers	Original value	Corrected value	Differences from mean: 10^{-10} m.	Differences from mean: Parts per million
1892–3	Michelson and Benoît	6438·4722	6438·4691	−0·0005	−0·08
1905–6	Benoît, Fabry and Perot	6438·4696	6438·4703	+0·0007	+0·11
1927	Watanabe and Imaizumi	6438·4685	6438·4682	−0·0014	−0·22
1933	Sears and Barrell	6438·4711	6438·4713	+0·0017	+0·26
1933	Kösters and Lampe	6438·4672	6438·4689	−0·0007	−0·11
1934–5	Sears and Barrell	6438·4709	6438·4709	+0·0013	+0·20
1934–5	Kösters and Lampe	6438·4685	6438·4690	−0·0006	−0·09
1937	Kösters and Lampe	6438·4700	6438·4700	+0·0004	+0·06
1940	Romanova, Varlich, Kartashev and Batarchukova	6438·4677	6438·4687	−0·0009	−0·14
		Mean	6438·4696	±0·0009	±0·14

The values originally reported (column 3) are corrected in column 4 to take account of subsequent conclusions regarding the values to be attributed to the ruled standards of length employed and adjustments to uniform conditions of normal air.

The statistical mean deviation associated with the average value of $6438{\cdot}4696 \times 10^{-10}$ m. derived from the nine experimental determinations amounts to $\pm 0{\cdot}0010 \times 10^{-10}$ m. This mean value of all (corrected) measurements of the cadmium red wave-length is identical with that originally reported by Benoît, Fabry and Perot which was internationally adopted in 1907 as the primary standard for spectroscopic measurements of wave-lengths and the definition of the international angstrom unit.

Alternative sources of the cadmium red line have been discussed by Williams and Gogate (*Proc. Roy. Soc.* A, **167**, 509, 1938) and by Meggers (*Rev. Mod. Phys.* **14**, 59, 1942).

Attention is drawn to the recent production of monochromatic radiation (purer than the cadmium red line) from a single isotope of even mass number, thus eliminating isotope shifts and hyperfine structure. In 1940 Wiens and Alvarez (*Phys. Rev.* **58**, 1005, 1940) first demonstrated that mercury 198 (resulting from the bombardment of gold 197 with neutrons) emitted a sharp green line (5461 A.); but with cyclotrons it is impractical to make sufficient Hg^{198} for permanent lamps (*Phys. Rev.* **70**, 910, 1946). In 1945 many

milligrams of Hg^{198} were made in chain-reacting uranium piles and grams of pure artificial mercury are now in prospect. Lamps containing 5 or 10 mg. of Hg^{198} have been prepared and studied by Meggers (*J. Opt. Soc. Amer.* **38**, 1, 1948) who has measured the wave-lengths relative to the cadmium standard. Preliminary values for the green and yellow lines of Hg^{198} are 5460·753, 5769·598 and 5790·663 A. The Hg^{198} lamps are more intense and convenient than Michelson's cadmium lamp and the order of interference obtainable with Hg^{198} is more than double that of any radiation from natural elements.

Similar results are reported to have been obtained in Germany with the yellow-green line (5650 A.) from krypton sources containing a single isotope Kr^{84} or Kr^{86} cooled in liquid air.

TABLE 2

Red and Infra-red Wave-lengths of the Iron Arc in Air

M. & K. (1924)	M. (1935)	B. (1947)	M. & K. (1924)	M. (1935)	B. (1947)
6750·157	—	·158	7937·172	·166	·164
6945·211	—	·211	7945·882	·878	·873
6978·857	—	·856	7998·980	·972	·971
7068·418	—	·414	8028·356	·341	·346
7090·410	—	·409	8046·084	·073	·073
7130·946	—	·943	8085·207	·200	·198
7164·472	·469	·471	8198·960	·951	·954
7187·341	·341	·339	8207	·767	·766
7207·422	·406	·411	8220·413	·406	·403
7219·690	—	·686	8232	·347	·338
7223·670	—	·671	8239	·130	·129
7239·896	—	·892	8248	·151	·154
7284·843	—	·846	8293	·527	·519
7288·764	—	·760	8327·069	·063	·060
7293·073	—	·064	8331·956	·941	·948
7311·103	—	·102	8339	·431	·426
7320·694	—	·683	8360	·822	·825
7389·423	·425	·421	8365	·642	·643
7401·691	·689	·694	8387·787	·781	·780
7411·184	·178	·175	8439	·603	·605
7418·676	·674	·673	8468·422	·413	·414
7445·778	·776	·774	8514·088	·075	·078
7495·092	·088	·085	8526	·685	·695
7511·047	·045	·041	8582	·267	·266
7531·178	·171	·171	8611	·807	·807
7546·177	—	·170	8621	·612	·610
7568·931	·925	·924	8661·915	·908	·906
7583·801	·796	·796	8674	·751	·753
7586·050	·044	·047	8688·641	·633	·632
7620·538	·538	·537	8757	·192	·191
7653·783	—	·786	8764	·000	·004
7661·230	·223	·222	8793	·376	·380
7664·306	·302	·302	8804	·624	·627
7710·397	·390	·389	8824·238	·227	·226
7748·282	·281	·279	8838	·433	·432
7780·594	·586	·584	8866	·961	·964
7832·233	·224	·223	8999	·561	·562
7912	·866	·867			

II. Secondary Standards

(*a*) *Iron Lines*

As the result of previous reports and actions of the International Astronomical Union there now exist 306 secondary standards among iron lines ranging in wave-length from 2447·708 to 6677·993 A. The number of standards shorter than 3100 A. can be greatly increased, and extended to 2100 A., when another independent and concordant set of values is reported for this range (cf. *Trans. I.A.U.* **6**, 79, 1939).

The Fe I spectrum has been observed by Green (*Phys. Rev.* **55**, 1209, 1939) to 1862·318 A. and ultra-violet standards may be calculated from relative term values in so far as these are fixed by other standards (*Trans. Amer. Phil. Soc.* **34**, Part II, III, 1944).

Vacuum wave-length measurements in the iron spectrum by means of the reflection echelon grating were reported by Williams and Middleton (*Proc. Roy. Soc.* A, **172**, 159, 1939) for 47 lines (3286·7508–5371·4905 A.). The values apply to a low-pressure source (Schüler lamp) and are from 0·002 to 0·006 A. smaller than the adopted secondary standards.

In 1947 Dr Burns measured the wave-lengths (unpublished) of red and infra-red iron lines with interferometers. He employed a 6-ampere arc in air and observed light from a central 3 mm. of a 9 mm. arc gap. His values for wave-lengths greater than 6750 A. appear in column 3 of Table 2 where column 1 shows the values published by Meggers and Kiess (*Sci. Pap. Bur. Stand.* **19**, 273, 1924), and column 2 the values reported by Meggers (*J. Res. Nat. Bur. Stand.* **14**, 33, 1935).

The values in column 1 soon deviate systematically from those in columns 2 and 3, which are in good agreement on the whole. There is no satisfactory explanation of the discrepancies. It appears necessary to await another independent set of observations before recommending the adoption of secondary standards of wave-length for iron lines beyond their present limit in the red.

(*b*) *Neon Standards*

In 1935, eight-figure values of neon wave-lengths, ranging from 5852·4878 to 7032·4127 A., were adopted (*Trans. I.A.U.* **5**, 86, 1935) as secondary standards. Because a Geissler tube containing neon is a reproducible, intense, and convenient source, and because the neon spectrum contains many strong lines in the near infra-red, it may eventually supply useful secondary standards in this portion of the spectrum. In 1934 Meggers and Humphreys reported interference measurements of neon wave-lengths from 4334·125 to 9665·424 A. (*J. Res. Nat. Bur. Stand.* **13**, 293, 1934). The values were determined relative to the cadmium red standard and/or neon orange and red standards. In 1947, Dr Burns measured (unpublished) the longer wave-lengths of neon lines relative

Table 3

Red and Infra-red Wave-lengths of Neon

M. & H. (1935)		B. (1947)		M. & H. (1935)		B. (1947)	
7059·109	(3)	·1081	(5)	8300·3258	(16)	·3244	(24)
7173·9389	(15)	·9376	(30)	8377·6069	(19)	·6055	(29)
7245·1668	(19)	·1664	(38)	8418·4274	(14)	·4259	(20)
7438·8989	(17)	·8972	(32)	8495·3601	(17)	·3585	(29)
7488·8720	(14)	·8706	(21)	8591·2584	(14)	·2583	(22)
7535·7745	(13)	·7732	(23)	8634·6482	(14)	·6466	(23)
7544·046	(4)	·0445	(15)	8654·3834	(13)	·3830	(25)
7943·1802	(10)	·1806	(9)	8780·6222	(12)	·6223	(16)
8082·4582	(8)	·4590	(8)	8783·755	(12)	·7538	(15)
8118·5495	(5)	·5507	(4)	8853·866	(7)	·8670	(7)
8259·380	(2)	·3792	(4)	8865·759	(4)	·7554	(6)
8266·0763	(7)	·0781	(6)				

to neon standards. His values are shown in column 2 of Table 3 where column 1 displays the mean values reported by Meggers and Humphreys. The number of observations is shown in parentheses.

(*c*) *The 'Winmac' Machine*

A new device that may prove important in accelerating the determination of secondary standards of wave-length has been described by the secretary of Commission 14 (George R. Harrison, 'Direct Determination of Wave-Lengths from Fabry-Perot Interferometer Patterns', *J. Opt. Soc. Amer.* **36**, 644, 1946). This is a new type of measuring and computing engine designed to determine wave-lengths and wave-numbers directly from spectrograms that have been made by crossing the dispersion of a Fabry-Perot interferometer with that of a concave diffraction grating. The machine first determines the wave-length of a spectrum line to six-figure accuracy from the grating dispersion, using the method previously used in the M.I.T. automatic comparator (Harrison, *J.O.S.A.* **25**, 6, 1936; Harrison and Molnar, *J.O.S.A.* **30**, 343, 1940). It then converts this wave-length to wave numbers and computes the order of interference corresponding to the wave-length setting of the comparator from the thickness of the etalon separator which has been pre-set into the machine.

The interference pattern of each spectrum line is projected on to a screen in front of the operator with a magnification automatically made proportional to the square root of the order of interference, and falls on a set of parabolic fiducial lines drawn to fit the optical system originally used to project the interference fringes on the slit of the grating spectrograph. The operator moves the screen carrying these parabolic lines up or down until they coincide with the density maxima of the interference pattern. The partial order of interference in the centre of the pattern can then be read to three figures from a dial. By turning the control handle of the machine slightly, the operator then makes a dial-reading of the machine coincide with that of this dial, and other dials then give the wave-length and wave number of the line correct to seven or eight figures, depending on its sharpness. Cams are used to introduce corrections for the dispersion of air and the variation of phase-change with wave-length.

This engine, designated 'Winmac' (Wave-length Interferometric Measuring and Computation), greatly increases the speed and precision of reduction of Fabry-Perot patterns. Repeat readings on sharp lines are found consistent to within a few ten-thousandths of an angstrom, and only a few seconds are needed to determine the wave-length of a line.

Since the first description of the machine appeared, automatic scanning of interference patterns has been developed. A disk, on which is engraved a parabolic slit in polar co-ordinates, rotates between the enlarged image of the interference pattern and two photomultiplier tubes whose circuits alternately pick the centres of gravity of each of the various interference maxima. The pattern is thus scanned radially outward in both directions from the centre by a series of slits that move with velocities that decrease as the dispersion in the pattern diminishes. The width of the slit also varies with the dispersion. A stroboscope lamp is flashed by the maximum-picker as the centre of each pattern is crossed, and this illuminates two rotating dials calibrated in thousandths of an order of interference. Maxima may thus be recorded individually or in groups on each side of the centre. The two rotating dials give the fractional orders on either side of the central image; and an adjustment is provided so that the operator can move the plate slightly until the readings for the two sides are equal, thus insuring symmetrical measurement of patterns. Fifteen fractional-order determinations are thus made per second. The operator sets a pointer on the flickering centre of gravity of the readings, thus obtaining a single average value that feeds through the remainder of the 'Winmac' and gives a corresponding wave-length value.

It is planned to use the 'Winmac' for the measurement of lines distributed fairly uniformly throughout the spectra of complex atoms, which will then be used as working standards for interpolation of wave-lengths of lines photographed with diffraction gratings.

III. Solar Spectrum Tables

(a) *Long-wave Portion*

In the *Carnegie Institution of Washington Publication* No. 579, 1947, H. D. Babcock and C. E. Moore give wave-lengths and intensities for more than 7400 lines in the solar spectrum from 6600 to 13,495 A. Where international standards are lacking (the present limit being 9889 A.) wave-lengths have been interpolated between the Mount Wilson interferometer values, or, beyond this limit (10,604 A.), referred to adopted solar standards in overlapping orders of concave grating spectra. Preliminary values of the wave-lengths selected to establish the scale of the infra-red solar spectrum to its present photographic limit have been published elsewhere (*Ap. J.* **83**, 115, 1936; *Trans. I.A.U.* **6**, 99, 1938). The intensities are calibrated in terms of equivalent width (solar lines only). The change of intensity observed in passing from the spectrum of the solar disk to that of a sunspot is tabulated as far as 11,508 A. Identifications of solar lines are thought to be as definitive as present knowledge permits. Excitation potentials are given for all classified solar lines.

Unblended solar wave-lengths are more homogeneous than the laboratory values of the corresponding lines. For example, strong multiplets in the first spectra of C and of Si are displayed in the solar spectrum more accurately and in greater detail than they are in existing laboratory data. Series of lines in the first spectrum of Mg are found well developed in the solar atmosphere but have not yet been observed in the laboratory.

Table 4

Reference Standards of Wave-length in the Solar Spectrum*

λ in air			λ in air			λ in air		
15° 760 mm.	El.	Int.	15° 760 mm.	El.	Int.	15° 760 mm.	El.	Int.
2995·841	Fe	2	3015·204	Cr	6	3064·379	$\{OH^-$ Co	1
2996·398	Fe	5	3018·143	Fe	3	3064·715	Pt	1
2996·590	Cr	5	3022·749	Mn	3	3066·696	Fe ?	−2
2997·224	—	2 N	3024·804	—	3	3067·783	OH ?	1
2997·980	Pt	2	3029·992	—	3	3068·946	Fe	−1
2998·499	—	1	3030·609	Fe^-	2	3071·431	—	−1
3004·122	Fe	3	3033·107	Fe	2	3082·628	Co	2
3004·632	Fe	3	3033·819	V^+	3	3083·751	Fe	4
3005·054	Cr	4	3042·265	V^+	3	3086·402	$\{$Co OH	1
3005·310	Fe	3	3042·488	Co	3	3089·507	—	−1
3005·970	Fe ?	2	3043·131	V	1	3091·878	—	0
3006·742	—	3	3043·357	Mn	2	3095·080	Zr^+	0
3006·870	Ca	3	3046·048	Fe	1	3098·455	Nd^+ ?	−2
3008·803	Ce^+ ?	−2	3046·505	—	0	3104·169	—	0
3010·182	$\{$Fe ? Fe^+	2	3046·807	Fe	0	3109·624	—	1
3010·630	Fe	1	3048·221	V^+	3	3117·770	OH	1
3011·169	Mn	0	3052·493	—	1	3118·143	$\{$Ti Cr^+	1
3011·279	—	1	3056·112	—	1	3118·255	Co	0
3012·452	Fe	3	3056·342	V	2	3118·829	Ti^+ ?	0
3013·499	—	1	3058·708	—	3	3122·081	Ti^+	0
3013·597	Co	2	3060·347	—	−1	3125·922	Zr^+	0
3013·972	Fe ?	−1	3060·457	V	0	3133·493	Zr^+	0
3014·322	V	1						

* October 1949. A note from H. D. Babcock states that all wave-lengths in Table 4 should be diminished by 0·002 A. See *Ap. J.* **110**, 104, 1949.

TABLE 5

Corrections for Changing Wave-lengths from the Scale of 1922 to the Scale of 1928

Region	Correction to 1922 λ	Region	Correction to 1922 λ
2995–3133 A.	−0·0012 A.	6125–6290 A.	−0·006 A.
3133–3370	(−0·0010)*	6290–6455	−0·007
3370–3705	−0·0006	6455–6630	−0·008
3719–3849	−0·0015	6630	−0·009
3850–3969	−0·0015	6800	−0·010
4000–5600	−0·002	6900	−0·012
5600–5780	(−0·003)*	7000	−0·014
5780–5960	(−0·004)*	7100	−0·016
5960–6125	−0·005		

* Values in parentheses are interpolated.

(*b*) *Short-wave Portion*

In Mt Wilson Observatory Contribution 745 (*Ap. J.* **107**, 287, 1948) H. D. Babcock, C. E. Moore, and M. F. Coffeen give a thorough revision of existing solar data in the region 2935–3063 A., where atmospheric absorption greatly reduces the intensity of the spectrum but high dispersion can still be used at ground stations. By means of overlapping orders the wave-lengths of 67 selected ultra-violet solar lines (see Table 4) were determined in terms of adopted standards in the blue region. With the aid of these ultra-violet reference lines, 1165 wave-lengths, 2935–3153 A., are found; and of these 665, in the range, 2935–3063 A., appear in this contribution. Wave-lengths, intensities, identifications, and low excitation potentials are given. About 75 % of the lines are identified. Nearly one-half of the identified lines are related to singly ionized elements. In the range 2975–3063 A., over which the spectrograms are of best quality, the average number of solar lines per angstrom is 6, and a large proportion of these are blends.

The paper should be helpful in relating the more familiar parts of the solar spectrum to the new observations, made at much lower dispersion, from rockets in flight above nearly all of the effective absorption in the atmosphere.

In Table 5 revised corrections are given for changing wave-lengths expressed on the scale of 1922 to the scale of 1928. This supplements the table given in *Trans. I.A.U.* **4**, 60, 1932.

(*c*) *Tables of Atomic Energy Levels and Application to Solar Spectra*

A critical compilation of *Atomic Energy Levels* as derived from the observation of more than 490 optical spectra of 83 elements is being made at the National Bureau of Standards to replace that of 231 spectra of 69 elements published in 1932 by R. F. Bacher and S. Goudsmit. The data from H through V are now in the Press (*Cir. N.B.S.* 467, 1949). The manuscript is completed for 255 spectra which include nearly all those of light elements through the Ca I isoelectronic sequence. The levels are listed by terms, starting with the ground state zero. A standard notation is suggested, and detailed electron configurations are given. In addition, arrays of observed terms and of predicted terms of the leading isoelectronic sequences, arranged similarly, are included in order to enable the user to grade the analyses, to detect related terms, to ascertain what laboratory observations are needed, etc.

In the far infra-red precise wave-lengths are lacking. The recent observations of the solar spectrum beyond 15,000 A., reported by the solar workers at the University of Michigan, can be interpreted only with the aid of predicted wave-lengths compiled from term lists of spectra whose lines are likely to be present. The solar wave-length scale beyond 15,000 A. is based chiefly on identifications of Fe I lines whose wave-lengths may be calculated from the differences of atomic energy levels, often fixed by the secondary and

tertiary standards of wave-length. Important multiplets are, for example, the combinations of $e\ ^5D$ with $u\ ^5F^\circ$ and $t\ ^5D^\circ$, involving the configurations $3d^6\ 4s\ (a\ ^6D)\ 5s$ and $3d^6\ 4s\ (a\ ^6D)\ 5p$, respectively. Identifications of other elements can be made in a similar manner.

Preliminary multiplet lists of laboratory data and predicted estimates of solar intensities of lines expected to be present in the solar spectrum between 2200 and 3000 A. have been prepared for use in the interpretation of recent rocket solar spectrograms (*Phys. Rev.* **71**, 827, 1947). Because these spectra have a dispersion of approximately 44 A./mm. and low resolution, blending is serious. Consequently, only conspicuous lines whose identity is unquestionable can be used to establish the solar wave-length scale and laboratory wave-lengths suffice. Notable features of the rocket spectra are:

Mg I 2852·120 A.	Mg II 2795·523 A., 2802·698 A.
Si I 2881·595 A.	Fe I 2700–2850 A.
Fe II 2382–2410 A.	

In anticipation of future developments in this field of rocket research, an ultra-violet extension to the Revised Multiplet Table (*Contr. Princeton Univ. Obs.* No. 20, 1945) is being compiled. This is discussed further in the report of Commission 12.

IV. Intensity Tables

Observational and theoretical quantitative data on the intensities (i.e. transition probabilities, or *f*-values) of lines in atomic spectra are extremely meagre and inhomogeneous compared with those available on wave-lengths and term analysis. The basic reason for this situation appears to be that a large part of the spectroscopic data, including intensities, now available to astronomers has been obtained by physicists whose main purpose was the elucidation of the extra-nuclear structure of atoms and ions. After physicists had verified certain general theoretical laws for line intensities by precise measurement of a few typical examples, qualitative intensity estimates were usually sufficient for their purposes. This is not so for the astronomer, who is finding an increasing need for extensive quantitative data on relative and absolute transition probabilities of spectral lines to aid him in the precise determination of abundances, temperatures, and other detailed features of stellar atmospheres. Moreover, at the present time, he is faced with the fact that many physicists have in recent years turned their attention from spectroscopy to other fields. As a consequence, astronomers can expect little additional spectroscopic material, including intensity data, to be supplied by physicists. If the present scanty supply of data is to be materially increased, the initiative in stimulating research in intensities must be assumed by astronomers themselves.

It was against this background that the International Astronomical Union, in 1946, formed a new sub-commission on 'Intensity Tables' under Commission 14. The original membership of the new sub-commission felt that it should have two main objectives:

(*a*) To encourage and co-ordinate quantitative work on the line intensity problems of importance to astrophysics.

(*b*) To collect and compile available intensity data for the purpose of eventual publication in a form useful to astrophysicists.

Transition probabilities, or *f*-values, may be derived from three main sources:

(i) Laboratory investigations.
(ii) Theoretical investigations.
(iii) Astrophysical observations.

The source from which the desired data may be best derived will depend upon the individual case. For example, spectra of atoms in high states of ionization are relatively simple, yet they are very difficult if not impossible to excite in the laboratory under conditions suitable for the measurement of transition probabilities. In such cases theoretical attack may be practicable. On the other hand, many complex spectra of

neutral and singly ionized atoms are so complicated and terms so perturbed as to discourage theoretical approach. Many such spectra, however, are readily obtained in the laboratory in arcs or furnaces under known and controllable conditions of excitation and the transition probabilities of the lines may be measured by well-established methods. In some cases, where laboratory or theoretical attack is impracticable, the spectra of certain stellar atmospheres, when suitably calibrated, may be the best available sources of material for transition probabilities.

The inclusion of intensities from astrophysical sources in the scope of activities of the sub-commission appears natural, but this overlaps certain phases of the programmes of Commissions 12 and 36. This question was taken up by the president of Commission 14 with the presidents of Commissions 12 and 36. It was agreed that the compilation of tables of transition probabilities in atomic spectra logically belongs to the new sub-commission on Intensity Tables of Commission 14.

The quantitative measurement or calculation of transition probabilities is difficult and laborious. Many factors which may introduce systematic errors in the results are involved, and, in comparison with measurement of wave-length, accidental errors are large. Also, on the experimental side, the established methods of excitation are limited in their applicability. Consequently, much work still needs to be done in developing new and improving old methods by which the range and variety of spectra that may be excited under known conditions (e.g. thermodynamic equilibrium) can be extended. Likewise, new methods of recording should be developed in order to speed up the measurement of intensities. Reliable auxiliary data, such as vapour pressures, are badly needed to permit the determination of absolute transition probabilities. At the present time, the existence of such data for elements of particular astrophysical importance is purely a matter of chance.

Considering the magnitude of the problems involved, and the small number of active workers in the field, it must be realized that the accumulation of quantitative intensity data will be slow. It is the hope of the sub-commission that it may be able to stimulate interest in the work from the point of view of astrophysics, to increase the output, and eventually to accomplish its objective of providing comprehensive tables of quantitative line-intensities for the use of astrophysicists.

W. F. MEGGERS
President of the Commission

Report of meeting

PRESIDENT: Dr W. F. MEGGERS.

SECRETARY: Mrs Dr CHARLOTTE MOORE-SITTERLY.

The business meeting of Commission 14 was attended by the following members: Allen, Edlén, Meggers, Menzel, Minnaert, Mrs Moore-Sitterly and Swings, and by guests Miss Adam, Danjon, Goldberg, Mrs Herman, Lyot, Mohler, Miss Oterma.

A visible quantity of an artificial chemical element was exhibited at this meeting of Commission 14 when Dr Meggers presented to Dr Danjon an electrodeless lamp containing 3 mg. of pure Hg^{198} obtained from neutron bombardment of pure Au^{197}. Dr Danjon was requested to deliver to Dr Pérard, Director of the International Bureau of Weights and Measures in Sèvres, France, this gift from the National Bureau of Standards in Washington, D.C. On August 3, Dr Meggers, *en route* to this meeting, presented a similar lamp to Sir C. I. Darwin, Director of the National Physical Laboratory in Teddington, England.

Dr Meggers remarked that the red radiation from cadmium, adopted in 1907 as the primary standard of wave-length, still appears to be the best length standard provided by nature. However, the great improvement in homogeneity of spectral lines emitted by a single even isotope of mercury and the unique advantages of mercury lamps and lines for metrology indicate that Hg^{198} will inevitably replace Cd as a source of the primary

standard. Furthermore, it is now clear that no other chemical element, natural or artificial, can compete with an even isotope of mercury in applications of interferometry to length measurements. It, therefore, seems certain that a wave-length characteristic of Hg^{198} must logically be accepted as the ultimate standard of length. Because this matter belongs primarily to metrology, and because final values of the wave-lengths to be assigned to Hg^{198} lines are not yet available, no recommendations were made. After the International Conference on Weights and Measures has considered this matter and taken final action it will be proper for this Commission to recommend that the I.A.U. adopt a new primary standard of wave-length.

Dr Meggers called attention to new observations of long-wave iron and neon lines by Burns, but since no wave-length can become a secondary standard unless three accordant, independent measurements exist, an extension of our system of standards rests on a third observer. He also stated that Harrison's 'Winmac' machine promises to excel previous measurements in quality as well as in quantity, and emphasized the need of interferometric standards at the extremes of the solar spectrum, that is, shorter than 3700 A. and longer than 9900 A., in which regions tentative standards derived from overlapping spectral orders, or from atomic energy levels, are being used. Mohler suggested that the PbS photo-cell could be applied to extend interferometer measurements beyond the photographic limit in the infra-red.

14. *Report of meeting of Sub-Commission on Tables of Intensities*

PRESIDENT: Dr R. B. KING.

Although Dr King was unable to attend this meeting, he suggested, in a letter, two main topics for discussion by those present:

(1) Notation and nomenclature, including definitions and relationships of such terms as *f*-value, line-strength, transition probability, and intensity.
(2) The need of a critical bibliography of published material on both theoretical and experimental intensities, and on methods used in making quantitative measurements of line intensities.

Meggers called attention to the fact that these topics are treated in some detail in the report of Commission 36 (p. 369) and suggested a division of labour that will avoid duplication. Minnaert stated that a bibliography is not sufficient, the greatest present need being a compilation of existing *f*-values. Goldberg suggested that a list of lines of astrophysical importance be prepared as a guide for further determinations of *f*-values. It was agreed that the main task of this sub-commission will be the preparation of tables of *f*-values of spectral lines.

15. COMMISSION POUR L'ETUDE PHYSIQUE DES COMETES

PRÉSIDENT: M. F. BALDET, *Astronome titulaire de l'Observatoire de Paris, Section d'Astrophysique, Meudon, Seine-et-Oise, France.*

MEMBRES: MM. Bobrovnikoff, P. Bourgeois, Dufay, McKellar, Minkowski, Öhman, S. V. Orlov, Quénisset, Struve, Swings, Van Biesbroeck, Vorontsov-Velyaminov, Vsekhsvyatsky.

Les travaux effectués en physique cométaire depuis le Congrès de l'U.A.I. en 1938, ont apporté une notable contribution à la connaissance de la constitution de ces astres et des phénomènes dont ils sont le siège. Nous allons résumer très brièvement ceux dont nous avons pu avoir connaissance, une partie des publications étrangères ne nous étant pas encore parvenue. Certains répondent directement aux suggestions et recommandations formulées au dernier Congrès.

PHOTOMÉTRIE

La Commission avait mis à l'ordre du jour la photométrie des comètes et l'étude des méthodes pratiques pour la détermination de leurs magnitudes.

Un très important travail a été effectué par l'un des membres: N. T. Bobrovnikoff (*Contr. Perkins Obs.* Nos. 15, 16, 19, 1941, 1942, 1943) qui a réuni 4447 observations photométriques visuelles effectuées sur 45 comètes, par 160 observateurs, depuis celle de Donati (1858 VI) jusqu'à la comète Finsler (1937*f*) et les a discutées et réduites. Les valeurs des magnitudes globales estimées visuellement par divers observateurs, au même moment, diffèrent souvent de une magnitude et parfois davantage. L'auteur a pu déterminer les différentes causes d'erreur, telles que l'ouverture de l'instrument, la méthode de comparaison des étoiles et de la comète, l'effet du fond du ciel, les conditions météorologiques, l'absorption différentielle de la lumière, etc. Les valeurs finalement adoptées pour les magnitudes réduites montrent une amélioration des erreurs moyennes s'élevant à 28%.

La formule photométrique convenant le mieux pour représenter les observations en fonction de la distance r au Soleil et de la distance Δ à la Terre est, en même temps, la plus simple:

$$J = \frac{J_0}{\Delta^2 r^n}.$$

La valeur pondérée de l'exposant n a été trouvée égale à $3{,}32 \pm 0{,}16$ pour l'ensemble des observations. Mais les écarts entre les différentes comètes sont importants: les valeurs de n varient de $-1{\cdot}77$ à $11{\cdot}40$. Des variations périodiques de l'éclat ont été mises en évidence dans 30 comètes avec des périodes comprises entre 12 et 600 jours. L'amplitude de la variation semble liée à la période, et il existe également une corrélation entre l'éclat absolu des comètes et leur période de variation. Il n'a pas été trouvé de diminution progressive de la lumière des comètes due à leur désintégration.

Cette étude d'ensemble a été complétée par une série de 708 observations photométriques de la comète 1942 *g*, avec six instruments différents, en vue de vérifier les résultats des recherches statistiques. L'auteur a pu ainsi démontrer qu'il était possible de faire de la photométrie visuelle avec une exactitude plus grande qu'on ne l'avait espéré jusque là.

S. K. Vsekhsvyatsky et ses collègues, après leur retour à Kiev en 1944, sont revenus aux problèmes de physique cométaire. Ils ont prolongé le Catalogue Général des magnitudes des comètes et ont achevé la détermination des magnitudes absolues de 40 apparitions cométaires entre 1880 et 1900 et de 70 entre 1910 et 1945 qui n'entraient pas dans le Catalogue Général (Notes sous presse dans les *Pub. Obs. Kiev*, no. 2 et *J. Astr.*, par S. K. Vsekhsvyatsky et V. Konopleva). Ils pensent que le Catalogue des magnitudes absolues pour toutes les apparitions observées des comètes (700) sera terminé vers la fin de 1948.

Ils ont achevé une nouvelle étude sur la loi moyenne de variation des magnitudes des

comètes. L'analyse des résultats de N. Bobrovnikoff a montré qu'un exposant de r égal à 4 était la seule valeur bien fondée.

Une théorie de la répartition des éclats dans la tête et la queue des comètes a été donnée par V. Riives (*Publ. Obs. Tartu*, **31**, no. 2, 1946) en partant de la théorie de Wurm sur la photodissociation et la photoionisation des molécules. Il a étudié l'éclat des comètes 1939 *d* et 1940 *c* par une méthode photographique extrafocale. L'erreur probable est inférieure à $\pm 0^m,1$.

W. Becker (*A.N.* **272**, 177, 1942) a décrit une modification à la méthode photographique extrafocale habituelle. Seules les étoiles de comparaison forment leurs images sur une plaque en dehors du foyer.

F. Baldet a poursuivi ses recherches de spectroscopie et de photométrie photographique des comètes et a contrôlé les résultats sur les amas globulaires. Il a construit un microphotomètre photoélectrique spécialement adapté à la mesure de ses clichés. Les résultats seront prochainement publiés.

J. Hunaerts (*Ciel et Terre*, **60**, 44, 1944) a étudié les variations d'éclat de la comète 1942 *g* en corrélation avec l'activité solaire.

F. Link (*Ann. Aph.* **11**, 73, 1948) a repris la discussion des variations lumineuses de la comète Encke entre 1786 et 1947, et a trouvé qu'elle ne montrait pas de fluctuations d'éclat en relation avec le cycle solaire ni de diminution progressive jusqu'en 1905. A cette date, on constate une chute brusque de $1^m,5$ à 2^m environ dans la magnitude réduite. L'exposant n de la loi de variation en r^{-n} dépend de la distance au Soleil, et la comète est d'autant plus faible après le passage au périhélie qu'elle a été plus brillante avant et vice versa.

Travaux généraux

Dans un travail théorique, B. Vorontsov-Velyaminov (*Ap. J.* **104**, 226, 1946) a essayé de déterminer la nature du noyau en employant diverses méthodes. L'application à la comète de Halley, qui a été suffisamment étudiée à ce point de vue, a permis à l'auteur de conclure que son noyau pouvait être regardé comme un amas de blocs météoriques dont les distances mutuelles étaient comparables à leurs dimensions. Le diamètre global du noyau serait de l'ordre de 30 km. et sa masse de $3 \cdot 10^{19}$ gr. Les gaz de la tête et de la queue proviennent de ces blocs météoriques en raison de leur échauffement par le Soleil.

La comète Whipple-Fedtke (1942 *g*) a montré une structure complexe et changeante de la queue rappelant celle de la comète Morehouse (1908 III). De bonnes reproductions d'après les photographies de J. Junkes et A. Zirwes en ont été publiées (*Spec. Astr. Vatic., Ric. Astr.*, **1**, no. 7, 1943).

La théorie des structures cométaires a fait l'objet d'un important travail de R. Coutrez: 'Etudes statistiques sur la Théorie des Comètes' (*Ann. Obs. Belg.* III, 1, sér. 3e, 1944).

S. V. Orlov a développé une nouvelle théorie physique sur la tête des comètes qui lui a permis non seulement d'analyser les observations dont on dispose, mais aussi de prévoir les dimensions et les masses des noyaux cométaires à partir des dimensions de ses enveloppes.

L'étude de S. K. Vsekhsvyatsky des questions relatives à l'origine des comètes a apporté de nouveaux arguments en faveur de la théorie de l'éruption.

K. Wurm a publié un important mémoire, intitulé 'Die Natur der Kometen' (*Hamburger Mitteilungen*, **8**, 1943).

Spectres

L'explication de la luminescence des comètes par un phénomène de fluorescence a été donnée pour la première fois par Schwarzschild et Kron en 1911, puis développée théoriquement par Zanstra et Wurm. Elle a reçu récemment des vérifications décisives en partant des inégalités de répartition des intensités dans les termes de rotation des bandes qui dépendent de l'absorption des raies du spectre solaire et de leurs variations sous l'influence des vitesses radiales de la comète.

La vérification en a été faite principalement par P. Swings (*Lick Obs. Bull.* **19**, 131, 1941) et par McKellar (*Rev. Mod. Phys.* **14**, 179, 1942; et *Ap. J.* **98**, 1, 1943) en admettant que l'émission des bandes de la comète est une pure résonance. Le phénomène est très sensible sur les bandes CN λ 3883, 4216 et CH λ 4315. La répartition des intensités le long des bandes ne correspond à aucune température précise. Cela tient à ce que la notion de température n'a plus beaucoup de signification dans des gaz aussi raréfiés.

J. Dufay (*Ap. J.* **91**, 91, 1940) a confirmé que la bande à λ 4300 était bien due à la molécule CH comme l'avait annoncé M. Nicolet.

Les observations spectrographiques faites dans l'ultraviolet sur la comète Cunningham (1940 *c*) par Swings, Elvey et Babcock (*Ap. J.* **94**, 320, 1941) ont révélé l'existence de raies intenses et fines à λ 3078–3100 qu'ils ont identifiées avec celles de la bande (0·0) de la transition $^2\Sigma^+ \rightarrow {}^2\Pi_{inv}$ de OH et un autre groupe près de λ 3360 pouvant être identifié avec celui donné par les bandes (0·0) et (1·1) de la transition $^3\Pi \rightarrow {}^3\Sigma$ de NH.

Ces radiations sont très intenses et s'étendent loin du noyau. Dans la comète Whipple-Fedtke (1942 *g*), étudiée par Barbier et Chalonge à l'Observatoire de Haute-Provence avec le spectrographe à optique de quartz Arnulf-Lyot ouvert à F/2, les bandes OH s'étendent dans toute la tête. Lorsque la comète se rapproche du Soleil, les bandes de NH deviennent plus intenses que celles de OH.

Le groupe de radiations si caractéristiques situé vers λ 4050, qu'on retrouve dans toutes les comètes près du noyau, et dont l'identification n'avait pu être faite pendant si longtemps, a été reproduit en laboratoire par G. Herzberg (*Ap. J.* **96**, 314, 1942). Il a obtenu des bandes complexes en faisant jaillir une décharge dans un tube sans électrodes parcouru par du méthane. La molécule émettrice serait très vraisemblablement CH_2. Mme R. Herman (*C.R.* **223**, 281, 1946) l'a reproduit en excitant l'hydrogène fortement dilué dans une atmosphère de gaz rare par une décharge entre électrodes de carbone. Elle en a donné les longueurs d'onde et une première classification de 13 bandes du groupe.

La molécule ionisée CH^+ a été identifiée par Swings (*Ap. J.* **95**, 270, 1942) avec les trois radiations $\lambda\lambda$ 4231, 4238 et 4254 qui s'étendent en partie dans la queue. Elles appartiennent à la bande (0·0) de la transition $^1\Pi \rightarrow {}^1\Sigma$. L'auteur a également indiqué la présence probable de la molécule OH^+ et discuté son identification.

J. Hunaerts (*B.A.B.* **9**, 320) a étudié le spectre de OH^+ et l'a comparé au groupe de radiations cométaires situé dans la région λ 3560–3600. Les raies de OH^+ sont masquées dans les comètes par les bandes de CN et CO^+ et perturbées par les nombreuses raies sombres de Fraunhofer du spectre solaire, ce qui rend l'identification difficile, mais la concordance générale est bonne. Il en est de même pour les radiations de OH^+ situées vers λ 4000 et qui se trouvent mêlées aux bandes de CH_2.

La région visuelle du spectre des comètes avait été la moins étudiée. Swings, McKellar et Minkowski (*Ap. J.* **98**, 142, 1943) ont donné une importante liste des radiations relevées dans les comètes pour $\lambda > 4800$, en se basant, en particulier, sur les spectres des comètes 1940 *c* et 1942 *g* obtenus aux grands télescopes de McDonald du Mont Wilson et du Dominion Astr. Obs. La liste s'étend de λ 4838 à 7041. Le groupe à λ 6300 a été identifié par les auteurs avec la bande α du spectre de flamme de l'oxyammoniac attribuée à une molécule polyatomique azote-hydrogène, non ionisée, très probablement NH_2.

P. Swings (*Ap. J.* **95**, 270, 1942) a confirmé la présence de l'isotope C^{13} du carbone dans les comètes. Trois bandes à $\lambda\lambda$ 4706 (3·2), 4723 (2·1) et 4745 (1·0) appartiendraient à la molécule $C^{12}C^{13}$ et une à $C^{13}C^{13}$, λ 4753 (1·0). Cette dernière identification a été contestée par McKellar (*Ap. J.* **99**, 162, 1944) dans le cas de la comète 1942 *g* obtenue avec une forte dispersion.

Bobrovnikoff (*Ap. J.* **99**, 173, 1944) considère comme étant définitivement établie l'existence de la bande isotopique $C^{12}C^{13}$ à λ 4744·26 qu'il a obtenue sur la comète 1940 *c*.

En résumé, en plus des quatre molécules CN, C_2, CO^+ et N_2^+ connues depuis longtemps dans les atmosphères cométaires, on a eu la confirmation, depuis le dernier Congrès, de la molécule CH et la découverte des molécules OH, NH, CH_2, CH^+, NH_2 et très probablement OH^+ auxquelles il faut ajouter la molécule isotopique $C^{12}C^{13}$ et, peut-être, $C^{13}C^{13}$. Il existe encore des groupes de radiations non identifiées.

Grâce à l'emploi de spectrographes suffisamment dispersifs, A. McKellar (*Ap. J.* **99**, 162, 1944) a obtenu, pour la première fois, la résolution de la branche R de la bande λ 3883 du CN de la comète 1942 *g* en ses raies individuelles et Bobrovnikoff (*Ap. J.* **99**, 173, 1944) a photographié trois raies de la même bande dans la comète 1940 *c*. Ces dernières ne présentaient pas de fortes vitesses radiales.

L'étude des bandes rouges du cyanogène par A. S. King et P. Swings (*Ap. J.* **101**, 6, 1945) a montré qu'il y avait peu d'espoir de les retrouver dans les spectres des comètes si elles y sont excitées par fluorescence. En fait, les identifications antérieures obtenues sur les spectres à très faible dispersion dans le domaine voisin de 6000 A., devraient être révisées. Une partie des radiations rouges des comètes paraît due à NH_2. Toutefois, le système rouge de CN pourrait être excité par un processus autre que la fluorescence. P. Swings (*Ann. Astroph.*, à l'impression) a effectivement montré que les bandes infrarouges (2·0) et (3·1) de CN à λ7906 et λ8106, observées récemment dans les comètes sont excitées par un phénomène de dissociation de molécules primaires.

Rapports et Recommandations des Membres de la Commission

P. Swings suggère que: 1° des mesures colorimétriques et des observations spectroscopiques, si possible, soient effectuées régulièrement sur la comète Schwassmann-Wachmann I afin d'élucider ses changements brusques de luminosité. Un tel changement correspond-il à une variation de couleur? Ceci permettrait de différencier entre une éruption de poussières ou de vapeurs même si celles-ci sont polyatomiques et n'ont pas de spectre dans la région observée; 2° qu'un gros effort porte sur l'observation spectroscopique des comètes dans l'infra-rouge proche; 3° que des recherches de laboratoire soient encouragées dans les voies suivantes: spectres de CN^+, C_2^+, NH^+, CH^{++} complètement inconnus, analyse de CH_2 et de NH_2; étude de CH_3 (inconnu); 4° que l'on étudie le spectre de quelques comètes à très grande distance héliocentrique: les molécules polyatomiques devraient y prédominer, les distributions rotationnelles et vibrationnelles d'intensité devraient être du type 'très basse température'. Les phénomènes essentiels apparaîtraient même à très faible dispersion.

Y. Öhman attire l'attention sur la polarisation des comètes. Les bandes brillantes de leurs spectres sont plus ou moins polarisées comme il l'a constaté pour les comètes Jurlof-Achmarof-Hassel (1939 III), Cunningham (1940 *c*) dont le maximum de polarisation atteignit 10%, et la comète de Kock-Paraskevopoulos (1941 *c*) dont le spectre continu avait une polarisation s'élevant à 24%, indiquant la présence de lumière diffusée.

F. Baldet rappelle tout l'intérêt qu'il y aurait à déterminer les magnitudes photographiques des comètes par une méthode simple permettant la comparaison des résultats obtenus en différents lieux. Les résultats récents qu'il a obtenus sur la comète Bester 4 (1947 *k*) à Meudon, comparés à ceux obtenus à l'Observatoire de Haute Provence par M. Bacchus, montrent la nécessité de déterminer des magnitudes monochromatiques portant seulement sur des bandes bien déterminées.

F. Baldet
Président de la Commission

Compte rendu de la séance

Président: Dr F. Baldet.

Secrétaire: Prof. P. Swings.

Le Président rend hommage à la mémoire de MM. Crommelin et Wilk décédés depuis la séance précédente. Il signale les raisons pour lesquelles il se pourrait que son rapport provisoire soit incomplet sur certains points et déclare qu'il recevra avec plaisir toute suggestion de modification ou addition. Sous réserve de telles modifications peu importantes, le rapport est adopté.

Le Dr Minnaert signale que les estimations de brillance des comètes devraient indiquer si la comète a été observée avant ou après le passage au périhélie. En général, une telle indication n'est pas fournie; p. ex. elle ne l'est pas dans le mémoire classique de Holetchek. Cette donnée pourrait être utile, p. ex., dans les discussions de températures de noyaux. Monsieur Minnaert attire ensuite l'attention sur le mémoire de Levin (*Russian Astronomical Journal*, **20**, 48, 1943) dans lequel la loi empirique habituelle de variation de brillance $I = I_0/\Delta^2 r^n$ (n différent pour différentes comètes ou différentes longueurs d'onde) est remplacée par $I = \text{const.} \times e^{-\frac{L\sqrt{r}}{KT_0}}$, où L est la chaleur de désorption, T_0 une constante (environ 350) et K une constante donnée par la théorie cinétique de la matière. Cette loi représente bien les observations pour une valeur de L de l'ordre de celle que fournit la physico-chimie. Une discussion sur les bases physiques de la formule de Levin s'engage, à laquelle prennent part MM. Swings, Fehrenbach, Baldet et Mme R. Herman. Il en résulte que, quelles que soient les objections physiques possibles qu'on puisse soulever contre la théorie de Levin, une loi exponentielle du type indiqué devrait être appliquée à titre d'essai. A ce sujet, M. Swings insiste sur l'importance qu'il y aurait à faire des déterminations de magnitudes monochromatiques de comètes correspondant à des molécules déterminées (CN, C_2, CH, CH_2, NH_2, ...) en fonction de la distance héliocentrique.

Le Dr G. Merton, Secrétaire de la Commission 20, nous informe que cette Commission nous renvoie, pour considération, la recommandation n°. 6 de la page 105 des 'Draft Reports' (voir page 229):

6. Observers are urged to provide more observations of cometary brightness, especially precise observations. There is need for improved methods; experimentation with the application of photoelectric techniques to this field is desirable.

Les informations sur la brillance sont en effet utiles aux calculateurs d'orbites. La Commission prend acte de cette recommandation.

Le Dr Swings expose, en les amplifiant, ses suggestions indiquées dans le rapport. Le Dr Öhman ajoute à sa remarque de la page 158 du rapport, que des observations de polarisation devraient être faites avec une dispersion pas trop faible. Comme on ne peut, en laboratoire, exciter par résonance des vapeurs telles que C_2 ou CN, les observations de comètes pourraient fournir des renseignements utiles aux physiciens.

Au nom du Dr O. Struve et au sien, M. Swings demande que la commission discute s'il ne serait pas opportun et désirable de publier un atlas de spectres cométaires typiques, contenant des spectres à dispersions diverses, avec ou sans fente, de différentes comètes à différentes distances héliocentriques, avant et après leur passage au périhélie. M. Swings expose les raisons pour lesquelles un tel atlas serait utile. La Commission s'associe maintenant à ce vœu. Elle le recommandera au Comité Exécutif en demandant une aide financière pour sa réalisation.

M. Swings signale que des recherches spectroscopiques sur des comètes récentes ont fourni quelques renseignements nouveaux sur les solides et ont mis en évidence l'excitation de certaines bandes par photodissociation.

M. Baldet fait quelques commentaires au sujet de l'origine des gaz cométaires qui pourraient ne pas provenir tous de l'intérieur du noyau mais, peut-être, être capturés par lui dans l'espace parcouru par la comète, surtout dans les régions froides de l'aphélie, ainsi que sur la constitution physique et minéralogique des noyaux. Ceux-ci restent encore la partie la moins connue et la moins accessible à l'observation directe.

M. Swings demande que les recherches chimiques et spectroscopiques sur les gaz occlus dans les météorites soient continuées et étendues. En particulier, on devrait rechercher systématiquement le NH_3, qui n'est pas indiqué dans les listes existantes de gaz occlus dans les météorites, alors que sa présence dans les solides cométaires semble assurée par la présence de NH et NH_2 dans le spectre des comètes.

M. Fehrenbach signale qu'il reste des doutes au sujet de certaines identifications dans le domaine rouge, où NH_2 ne semble pas être la seule molécule participant au spectre. M. Swings est d'accord à ce sujet.

16. COMMISSION POUR LES OBSERVATIONS PHYSIQUES DES PLANETES ET DES SATELLITES

PRÉSIDENT: M. B. LYOT, *Astronome à l'Observatoire de Paris, Section d'Astrophysique, à Meudon, Seine-et-Oise, France.*

MEMBRES: MM. Arend, Armellini, Barabashev, Camichel, Danjon, Delmotte, Delporte, Dunham, Gentili, Hargreaves, Mlle Harwood, MM. Kuiper, Lampland, Luplau-Janssen, Nicholson, Peek, Plakidis, Quénisset, F. E. Ross, E. C. Slipher, Tikhof, Waterfield, Wildt, F. E. Wright, W. H. Wright.

Depuis sa dernière réunion, la commission a été cruellement éprouvée par la perte de son ancien président, de son président et de deux de ses membres les plus actifs.

Le Révérend Père Théodore Phillips, président de 1925 à 1935, est décédé le 13 Mars 1942, à l'age de 76 ans. Il avait dirigé, pendant 35 ans, la section de Jupiter de la B.A.A. et effectué un nombre considérable d'observations. Il nous laisse une œuvre très étendue sur Jupiter et ses courants atmosphèriques, ainsi que des dessins de Mars remarquables par leur beauté et leur précision.

Mentore Maggini qui lui succéda à la présidence est décédé le 8 mai 1941. Il s'était consacré principalement à l'étude de Mars, aux observatoires de Florence et de Catane, en liaison avec William H. Pickering. Il comptait entreprendre une nouvelle étude des planètes par la polarisation.

Eugène Antoniadi est décédé le 10 Février 1944, à l'age de 74 ans. Il avait consacré sa vie à l'étude des planètes dont il réussissait à reproduire les formes, les nuances et les couleurs avec une grande exactitude. Les nombreuses observations qu'il a effectuées avec le réfracteur de 83 cm. de l'Observatoire de Meudon sont résumées par une carte de Mercure, un ouvrage très complet sur Mars et des travaux de synthèse sur les autres planètes.

Gilbert Rougier est décédé le 10 Mars 1947, à l'age de 60 ans. Nous lui devons la construction et la mise au point des premières cellules photoélectriques appliquées à la photométrie astronomique; il est l'auteur d'une étude photométrique de la Lune en fonction de l'angle de phase, étude remarquable par son exactitude et sa précision.

Les questions relatives à la nomenclature lunaire, rattachées à la commission 17 jusqu'en 1938, sont maintenant du domaine de la commission 16. De ce fait, plusieurs membres de la commission 17 ont été nommés membres de notre commission. Nous déplorons la perte de deux d'entre-eux: Le docteur K. Müller décédé le 22 Octobre 1942 et Miss M. A. Blagg décédée le 14 Avril 1944. L'Union Astronomique Internationale leur doît l'ouvrage *Named Lunar Formations* et la carte de la Lune, travaux ardus et importants qui définissent la nomenclature lunaire.

TRAVAUX DE RECHERCHES

Mercure. Aux U.S.A., H. M. Johnson (*J.R.A.S. Canada*, **33**, 210, 1939) reproduit les dessins de 4 observateurs, montrant les principales configurations; par bonnes images, les taches de Mercure lui paraissent plus sombres que celles de Mars. D'après H. Haas (*P.A.S.P.* 25, 1940), elles sont comparables à celles de la Lune vue à l'œil nu et leur déplacement s'effectue dans le plan de l'orbite de Mercure.

Un article de McEven (*J.B.A.A.* **57**, 139, 1947) expose les observations faites par Heath et par lui pendant les élongations occidentale de Septembre 1944 et orientale de Mars 1945. Les dessins paraissent confirmer l'existence des voiles temporaires signalés par Antoniadi, qui afaiblissent ou rendent invisibles des régions habituellement sombres.

Avec une lunette de 38 cm. d'ouverture récemment installée au Pic du Midi, H. Camichel a photographié les principales taches de la planète, en juillet et août 1942, depuis l'élongation du matin jusqu'à la conjonction supérieure. Pendant cette période voisine du périhélie, les images ont été excellentes, nous avons pu dessiner journellement les prin-

cipales configurations de la planète et suivre leur rotation lente. Une tache brillante d'intensité très variable occupait le terminateur, vers le 20e degré de latitude Sud (à paraître dans *L'Astronomie*).

L'ensemble des observations est donc en faveur d'une atmosphère sur Mercure, atmosphère qui paraît cependant peu probable, du point de vue théorique.

Vénus. Nous avons reçu, de l'observatoire d'Athènes, le résumé des observations faites par J. E. Focas, de 1938 à 1945. La phase gibbeuse montrait le maximum de détails, principalement des régions foncées vers lesquelles convergent des bandes sombres, droites ou courbes. L'immobilité des taches sombres pendant plusieurs jours est en faveur d'une rotation lente.

A. Danjon a mis en évidence (*L'Astronomie*, 161, 1943) la rotation lente de Vénus à l'aide d'une nouvelle méthode de réduction qui consiste à superposer des groupes de dessins ramenés à la même phase et à la latitude zéro. Ce procédé atténue considérablement les fluctuations de l'atmosphère de Vénus, il fait apparaître la topographie du sol de la planète et il montre la fixité de ses principales configurations par rapport au terminateur.

La matière dont les nuages de Vénus sont formés est toujours inconnue. R. Wildt avait envisagé les polymères de la formaldehyde, provenant de la réaction photochimique de l'anhydride carbonique sur la vapeur d'eau (*Ap. J.* **92**, 247, 1940), mais les spectres obtenus par W. S. Adams et T. Dunham n'ont pas confirmé cette hypothèse (*Ap. J.* **96**, 312, 1942).

Nous pensons qu'il faudrait plutôt rechercher un constituant liquide, car la polarisation de Vénus, pour les divers angles de phase, est très différente de celle des cristaux et elle est semblable à celle de fines particules sphériques et transparentes.

R. Wildt a calculé la température probable de la surface de Vénus, en tenant compte des coefficients d'absorption de l'anhydride carbonique (*Ap. J.* **91**, 266, 1940). Au point subsolaire, elle serait comprise entre 366 et 408 degrés K. Cette question a été étudiée par A. Adel et C. O. Lampland (*Ap. J.* **93**, 397, 1941).

G. P. Kuiper (*Ap. J.* **106**, 251, 1947) a réalisé un spectrographe infra-rouge ayant pour récepteur les nouvelles cellules au sulfure de plomb, beaucoup plus sensibles que les piles thermoélectriques. Avec cet appareil, il a mis en évidence neuf fortes bandes de l'anhydride carbonique, entre 1·2 et 2·1 microns.

M. Minnaert (*Bull. Astron. Inst. Netherland*, **10**, No. 367, 71, 1946) discute les mesures photométriques de Barabashev, Smejkin et Schoenberg, il montre que la répartition des brillances depuis le limbe jusqu'au terminateur, vers le milieu du croissant, n'est pas en accord avec le principe de réciprocité. Ce fait correspond, soit à des erreurs de mesures dues à la diffusion de la lumière, soit à une différence systématique réelle des nuages, entre le terminateur et le limbe.

Ce fait serait à rapprocher de la différence des polarisations du terminateur et du limbe.

Mars. Les observations visuelles de la surface de Mars ont été extrêmement nombreuses, principalement au voisinage de l'opposition périhélique de 1939 et de celle de 1941 qui fut particulièrement favorable pour les observateurs situés dans l'hémisphère Nord, aussi pourrons nous seulement en dire quelques mots.

Suivant un rapport de J. E. Focas, à Athènes (*Bull. Geographical Service, Greek Army*, Part 3, 1940), le phénomène le plus marquant de 1939 était l'apparition d'une bande très sombre élargissant Mare Cimmerium sur son bord Nord.

En 1941, au Pic du Midi, à l'oculaire et sur les clichés, cette région apparaissait toujours très développée et tachetée de petites îles. La pointe Ouest de Sinus Meridiani s'est montrée double (*L'Astronomie*, 49 et 67, 1943). D'autre part, deux lacs jumeaux dans Chryse et un très petit lac à l'est de Juventae Fons, ont été vus à Meudon, par Baldet et Servajean et photographiés au Pic du Midi (*L'Astronomie*, 241, 1941).

L'existence de la frange sombre bordant la calotte polaire, au début du printemps, a été confirmée par de nombreux observateurs, ainsi que l'assombrissement consécutif habituel de Hellespontus et des régions environnantes.

La fin de l'été Martien a été marquée par de nombreux phénomènes atmosphériques observés par G. Fournier. Un cliché de l'Observatoire Lowell, pris par E. C. Slipher,

tre un système nuageux très brillant, couvrant plus du dixième de la surface de Mars. déplacement vers le Sud-Est a été suivi par les observateurs de la Société Astro- ique de France.

n réfracteur de 60 cm. d'ouverture, installé au Pic du Midi en 1943, nous a montré, oppositions suivantes, de nombreux points noirs dans les mers, près de leurs rives. ollfus a pu détailler, avec cet instrument, la structure tachetée des mers (*L'Astronomie*, 1947) et celle des canaux larges et étroits, doubles ou simples (*Comptes Rendus, Paris*, lars 1948).

ans les observatoires de haute altitude, lorsque les images sont très stables, les sions panchromatiques actuelles permettent d'obtenir des photographies de Mars rieures, à certains égards, aux meilleurs dessins exécutés à l'oculaire, avec les mêmes uments. Les plus importantes séries de tels clichés ont été obtenues en 1939 et aux sitions suivantes, à l'observatoire Lowell, par E. C. Slipher et à l'observatoire du lu Midi, par H. Camichel. Le tirage successif de plusieurs négatifs semblables sur même plaque positive atténue beaucoup le grain et permet de voir des détails faibles ont confondus sur un négatif isolé (*L'Astronomie*, 69, 1943).

s positifs montrent individuellement, mieux que l'observation à l'oculaire, les détails ners (petites taches et chenaux sombres). Sur les régions continentales, des canaux raissent sous des aspects très variés, souvent bien différents des formes trop géo- iques que l'observateur a tendance à dessiner.

P. Kuiper a appliqué, avec succès, ce procédé de tirage composite aux clichés obtenus Barnard, avec la lunette de Lick, en 1909 (*Ap. J.* **105**, 215, 1947) et fait apparaître de nouveaux demi-tons.

Jarry-Desloges et G. Fournier ont publié le fascicule 9 et le fascicule 10 de leurs *rvations des Surfaces Planétaires*. De ces deux volumes très importants, le premier se les observations de Mars faites en 1924, avec des études générales: fusion de la te polaire australe, blancheurs temporaires, changements d'intensité des plages res, des lacs ou marais et des canaux. Le deuxième expose, de la même manière, avaux relatifs aux années 1926 à 1941.

l'observatoire McDonald, G. P. Kuiper vient d'obtenir les premiers résultats positifs a composition de l'atmosphère de Mars: Au mois d'octobre 1947, son spectrographe lule au sulfure de plomb montrait deux bandes infra-rouges de l'anhydride carbonique es près de 1·6 μ., avec une intensité correspondant à 1·8 fois la quantité de CO_2 enue dans l'atmosphère terrestre. En février 1948, Mars étant moins éloigné, les fortes bandes situées près de 2 μ. ont été enregistrées également.

r contre, les tentatives faites pour déceler l'ozone et l'anhydride sulfureux, à l'aide urs fortes bandes d'absorption ultra-violettes, ont donné des résultats négatifs.

algré la présence de CO_2, la température des calottes polaires ne semblait pas assez pour permettre la formation de neige carbonique. G. P. Kuiper a résolu la question vrier 1948: Le spectre de la calotte polaire présente, comme celui de la neige froide, forte absorption à partir de 1·5 μ., tandis que la neige carbonique reste 'blanche' coup plus loin dans l'infra-rouge.

spectre des 'mers' ne montre pas les bandes infra-rouges de la chlorophylle, ce qui lut pas la présence de lichens.

s observations faites avec filtres colorés confirment les conclusions de W. H. Wright lles de F. E. Ross, l'atmosphère de Mars est fortement opaque dans le bleu, à partir 4500, d'autre part elle diffuse de la lumière blanche, vraisemblablement en raison ns cristaux de glace qu'elle tiendrait en suspension, principalement au dessus des ns les plus froides.

téroïdes. Ch. Caillatte (*Bull. Astronomique*, **13**, 21, 1947) a déterminé la forme qu'il attribuer à Eros pour représenter convenablement ses variations d'éclat et leurs gements d'amplitude. L'astéroïde peut être assimilé à un cylindre de longueur égale fois son diamètre, tournant autour d'un axe perpendiculaire à ses génératrices. teur a calculé l'orientation de son plan équatorial. Il a résolu le même problème pour et discuté la possibilité de le résoudre pour d'autres astéroïdes variables.

Jupiter. Bertrand M. Peek (*J.B.A.A.* **49**, 404, 1939) a comparé l'intensité de la Tache louge à son mouvement en longitude, depuis l'année 1891. Ses graphiques mettent en vidence une corrélation très nette entre ces deux phénomènes: Les grandes intensités e la tache correspondent à des accélérations de ce mouvement, elles se produisent, 'autre part, lorsque la tache est dans la Grande Perturbation.

L'auteur explique (*J.B.A.A.* **50**, 4, 1939) les variations de vitesse de la tache par des ariations de son moment d'inertie qui seraient dues à un faible déplacement vertical. on ascension produirait des condensations qui la voileraient et qui se dissiperaient endant la descente. D'après l'auteur et suivant R. Wildt (*Proc. Amer. Phil. Soc.* **81**, o. 2, 1939), la tache, nécessairement solide, serait un bloc très épais, de glace de Bridgman ar exemple, flottant à une grande profondeur, dans une atmosphère très dense qui ourrait être de l'azote. Les changements d'état de la glace réagiraient sur sa température t sur son mouvement vertical.

Pendant les 5 derniers mois de 1940, Peek a observé, au bord Nord de la bande tempérée ud, une tache sombre qui exécutait, en longitude, des oscillations amorties, explicables ar un mécanisme analogue (*M.N.R.A.S.* **101**, 70, 1941).

Une autre tache suivie par les membres de la section de Jupiter de la B.A.A. (*Memoirs*, **5**, part 3, 1944), de novembre 1942 à mars 1943, présentait le même caractère oscillatoire, ais avec une période variable et un mouvement en latitude.

Les clichés pris au Pic du Midi, par H. Camichel, montrent le contour de la Tache louge ovale en 1941, polygonal en 1945 (*L'Astronomie*, 70, 1943 et 160, 1946), tandis u'une tache sombre, allongée Est-Ouest, est restée visible en son milieu.

Les études détaillées des mouvements des taches dans les zônes et dans les bandes de upiter ont été trop nombreuses pour que nous puissions les citer (*Mem. B.A.A.* **35**, arts 3 and 4).

D. P. Bayley (*J.B.A.A.* **55**, 114 et 116, 1945) a montré que la dispersion atmosphérique ltère fortement et en sens opposés, les colorations des deux calottes polaires de Jupiter, rsque cette planète passe au méridien, à une faible hauteur. L'effet du spectre atmo- hérique se fait sentir, non seulement au bord, mais sur toute l'étendue des calottes, raison du fort gradient de leur brillance. Ce phénomène est la cause des variations stématiques de coloration qui ont été observées en Angleterre, avec une période égale celle de la révolution de Jupiter autour du Soleil. Les observations faites en Nouvelle élande, à une latitude plus basse de 18 degrés, ne montraient pas ces changements de loration, les deux calottes étaient gris bleuté.

R. Wildt (*M.N.R.A.S.* **99**, 616, 1939) a recherché les composés chimiques les plus robables pour expliquer les colorations observées sur Jupiter. Dans les conditions de mpérature qui doivent régner à la surface, les solutions de sodium dans l'ammoniac, ui sont les liquides les plus légers connus, ont des couleurs allant du bleu ciel au bleu ncé et aux teintes bronzées.

R. Wildt a discuté la théorie de Kothari qui assigne à Jupiter la constitution des naines lanches (Pritam Sen, *Zeits. Ap.* **16**, 297, 1938). Il estime que l'état dégénéré ne pourrait re atteint qu'au centre de Jupiter (*Ap. J.* **87**, 508, 1938). Si l'on tient compte de la com- essibilité de l'hydrogène qui diminue beaucoup aux très fortes pressions, on trouve une paisseur d'atmosphère plus grande que celle que Peek avait calculée, mais qui reste faible ar rapport au rayon de la planète. D'autre part, l'auteur a pu déduire, du moment d'inertie e Jupiter, des données concernant la répartition des densités à l'intérieur de cette planète.

G. P. Kuiper (*Ap. J.* **106**, 251, 1947) a étudié le spectre de Jupiter jusqu'à 2·5 microns, est, comme dans le proche infra-rouge, très fortement coupé par des bandes appartenant robablement au méthane et à l'ammoniac.

G. Herzberg (*Ap. J.* **87**, 428, 1938) a étudié la possibilité de déceler la présence de grandes antités d'hydrogène ou d'azote moléculaires, par leurs spectres de rotation-vibration. es bandes de H_2 sont très faibles, celles que l'on pourrait observer avec des épaisseurs isonnables sont masquées par celles de la vapeur d'eau et du méthane. Le cas des olécules HD n'est pas plus favorable, à cause de la faible proportion isotopique. Une nde de N_2 située vers 2·16 microns, exigerait une épaisseur de 5 km.

Saturne. Les bandes de la planète ont subi des changements progressifs qui ont été enregistrés sur les clichés des observatoires Lowell et du Pic du Midi. Les photographies de 1941 montraient la bande équatoriale et 6 bandes dans l'hémisphère Sud.

Deux taches blanches ont été photographiées au Pic du Midi: l'une située vers 40° Sud, diffuse le 16 et le 22 septembre 1941, l'autre située vers 15° Sud, petite et brillante le 11 février 1946, plus faible et allongée le 16 février. Cette tache, invisible sur les reproductions (*L'Astronomie*, 161, 1946), a été observée à Meudon, par A. Danjon, le 14 février.

J. E. Focas a observé une tache semblable le 7 février 1947. Il signale, en 1947, une grande activité de la bande tropicale Sud qui présentait des nodosités et qui projetait des filaments dans la zone équatoriale (*L'Astronomie*, 2, 1948).

Au Pic du Midi, 3 divisions ont été observées dans l'anneau B et 2 dans l'anneau A, aucune d'elles ne correspond à la division d'Encke qui paraît être une bande floue (à paraître dans *L'Astronomie*).

Le globe de Saturne est visible à travers la division de Cassini et l'anneau A, sur des clichés de l'Observatoire Lick, cette visibilité est confirmée par les clichés des observatoires Lowell et du Pic du Midi (*L'Astronomie*, 71, 1943).

L'anneau de crêpe apparaît avec une netteté parfaite, sur un cliché du Mont Wilson.

Les spectres infra-rouges obtenus par G. P. Kuiper, jusqu'à 2·5 microns, montrent, sur Saturne, des bandes semblables à celles des spectres de Jupiter, mais avec des intensités relatives différentes (*Ap. J.* **106**, 251, 1947).

Des mesures spectroscopiques très précises, de la vitesse de rotation de Saturne ont été faites par J. H. Moore (*P.A.S.P.* 274, 1939). Elles lui ont permis de mesurer le ralentissement polaire jusqu'à 57° de latitude, où il s'élève à 16 %. Les valeurs trouvées aux basses latitudes s'accordent avec celles qui ont été déduites des taches.

La Lune. Les observations détaillées de régions lunaires ont été très nombreuses, par exemple, le volume 36, Ière partie, des *Mem. B.A.A.*, paru en 1947, donne la description de nombreuses régions intéressantes. Une des plus connues est celle des rainures de Triesnecker. Un dessin de cette région montre un grand nombre de détails. Malheureusement il est très difficile de représenter exactement des configurations aussi complexes, de sorte que l'accord des dessins entre-eux et avec les photographies est, en général, peu satisfaisant du point de vue de la nature des objets, de leurs formes, de leurs dimensions relatives et de leurs positions, si bien que beaucoup de rainures, collines ou craterlets ne peuvent pas être reconnus à l'oculaire ou sur les photographies.

Les dessins du cirque Gassendi fournissent un autre exemple de désaccord (M. Darney, *L'Astronomie*, 19, 1946).

Une coopération étroite entre les grands observatoires bien équipés pour la photographie et les amateurs travaillant visuellement serait très désirable. En effet, les possibilités de la photographie lunaire ont été souvent sous-estimées. Quelques clichés d'une très grande finesse ont été obtenus aux observatoires Lick et du Mont Wilson.

Au Pic du Midi, des clichés pris par M. Gentili, au foyer de 18·25 mètres du réfracteur de 60 cm. d'ouverture et par H. Camichel, en allongeant le foyer à 40 mètres, montrent, avec leur ombre et leur bord éclairé, des craterlets mesurant respectivement 0·8 et 0·6 secondes de diamètre. Les meilleures images contiennent tous les détails visibles dans une lunette de 30 cm. d'ouverture, lorsque les conditions atmosphériques sont parfaites.

De nombreux travaux ont été effectués sur les variations anormales de certaines régions, telles que Linné, Messier, Platon, Grimaldi, Eratosthène, etc. Sauf pour les variations constatées au cours des éclipses de Lune, la plupart des changements observés peuvent être expliqués par le fait que les intensités des différents points de l'objet étudié et de son entourage varient, au cours de la lunaison, suivant des lois différentes. Ces lois dépendent de l'inclinaison de la surface et de ses propriétés photométriques. Dans le cas de l'arène unie de Platon, par exemple, de faibles différences dans les indicatrices de diffusion suffisent pour produire les apparitions et les disparitions des bandes claires, ainsi que leurs changements de contraste.

Aucun changement réel et durable ne paraît avoir encore été observé sur la Lune.

Les propriétés photométriques de la surface lunaire ont été étudiées en divers points, par Arthur L. Bennett (*Ap. J.* **88**, 1, 1938). L'auteur propose de les comparer à celles de substances terrestres.

M. Minnaert (*Ap. J.* **93**, 402, 1941) a montré que le principe de réciprocité de Helmholtz, convenablement appliqué, permet de vérifier les mesures ou de réduire leur nombre.

La question de l'atmosphère lunaire a été remise en cause par Walter H. Haas (*Pop. A.* **55**, 266, 1947) qui a observé, avec ses collaborateurs, 8 ou peut-être 10 points brillants se déplaçant devant la Lune, pendant un temps de l'ordre de la seconde. Leur faible vitesse apparente permet de les attribuer à des météores lunaires. Ces météores nécessitent la présence d'une atmosphère lunaire au moins égale au cent-millième de la nôtre, une telle atmosphère serait facile à déceler.

De Vaucouleurs (*L'Astronomie*, 267, 1947) propose aux amateurs munis d'instruments assez puissants, un programme comportant l'observation de ces objets.

D'autre part, une lueur d'impact météorique paraît avoir été observée à l'extrémité Nord-Ouest de l'arène de Platon, par Francis H. Thornton (*J.B.A.A.* **57**, 153, 1947).

Maurice Darney (*L'Astronomie*, 25 et 158, 1944) définit les 'aires elliptiques' découvertes par Delmotte; il expose le système de Copernic et ceux, moins réguliers, d'Aristarque, Hérodote, Proclus et Tycho.

Eclipses de Lune et lumière cendrée. Les mesures de la radiation thermique de la Lune faites par Edison Pettit (*Ap. J.* **91**, 408, 1940), pendant l'éclipse totale de 1939, confirment les résultats obtenus en 1927. La température de la surface lunaire suit les variations de l'énergie solaire incidente, avec un léger décalage qui correspond à une conductibilité du sol très faible et égale à celle d'une couche pulvérulente de 2·6 cm. d'épaisseur.

Les mesures photométriques effectuées pendant les éclipses de Lune nous apprennent peu de choses sur notre satellite, cependant elles se rattachent aux observations physiques des planètes car elles nous renseignent sur l'aspect de la Terre vue de l'extérieur et elles nous permettent ainsi de la comparer aux autres planètes.

F. Link et V. Guth (*Zeits. Ap.* **18**, 207, 1939 et **20**, 1, 1940; *Annales Ap.* **9**, 227, 1946; *Bull. Astr. Paris*, **13**, 171, 1947) ont déterminé, au cours de 8 éclipses, la distribution de la lumière dans le cône d'ombre de la Terre, en fonction de la distance au centre de l'ombre et de l'azimuth. Ils ont comparé les chiffres trouvés pour la longueur d'onde 0·58 microns, aux valeurs théoriques calculées d'après la distribution connue de l'atmosphère terrestre supposée transparente.

Les parties extérieures montrent un affaiblissement qui correspond à une couche absorbante élevée, plus élevée à l'équateur qu'aux pôles, explicable, en grande partie, par l'ozone. Les parties intérieures manifestent un affaiblissement variable, très important, s'étendant plus loin du centre de l'ombre vers l'équateur que vers les pôles, attribuable à des nuages dont le niveau supérieur est plus élevé à l'équateur. Cet affaiblissement change d'une éclipse à l'autre, suivant les conditions météorologiques et d'un instant à l'autre d'une même éclipse, par suite du passage successif de régions de la Terre différemment nuageuses, au terminateur.

Ces dissymétries ont été confirmées par G. Rougier et J. E. Dubois (*Ciel et Terre*, 217, 1943; *L'Astronomie*, 81 et 173, 1942; 65 et 129, 1943).

Les spectres obtenus par Junior Gauzit et Louis Herman, près du bord de l'ombre, montrent un renforcement des bandes telluriques et trois bandes de Chappuis (*Annales Ap.* **6**, fasc. 3–4, 1943).

Barbier, Chalonge et Vigroux trouvent, dans le cône d'ombre, une absorption qui leur paraît trop forte pour être attribuée à l'ozone.

A l'aide d'observations photométriques de la lumière cendrée, J. E. Dubois (*Ciel et Terre*, 375, 1943; *Bull. Astr. Paris*, **13**, 193, 1947) a calculé l'albédo de la Terre et son indice de coloration. L'albédo varie suivant la saison, il présente deux maxima en janvier et en septembre et deux minima en juin–juillet et en novembre. L'indice de coloration suit des variations parallèles; à son minimum d'éclat la Terre est assez bleue, à son maximum elle est peu colorée.

Les régions océaniques (l'Atlantique qui éclaire la Lune le soir) sont, en général, plus brillantes que les continents (Europe et Afrique qui éclairent la Lune le matin).

L'albédo de la Terre varie avec l'activité du Soleil, il décroît brusquement au moment du minimum. Cet effet est à rapprocher de la loi de Danjon.

Satellites. Antoniadi (*J.R.A.S. Canada*, **33**, 273, 1939) décrit l'aspect des quatre principaux satellites de Jupiter pendant leurs passages et les taches que l'on voit, dans ces conditions, grâce au fond lumineux de Jupiter.

Au Pic du Midi, H. Camichel, M. Gentili et nous-mêmes, avons pu observer régulièrement, des taches sur les 4 principaux satellites de Jupiter, en septembre et octobre 1941, avec un réfracteur de 38 cm. d'ouverture et en décembre 1943, janvier 1944, février et mars 1945, avec un réfracteur de 60 cm. La première série d'observations (*L'Astronomie*, 53, 1943) a montré:

Io avec les pôles sombres et des taches claires le long de l'équateur, Europe avec des pôles clairs et des taches sombres le long de l'équateur, Ganymède avec des taches sombres de part et d'autre de l'équateur et quelques taches claires près des pôles. Callisto avec un aspect analogue à celui de Ganymède, mais des taches moins apparentes.

La deuxième série (à paraître dans *L'Astronomie*) a confirmé la première, elle a montré des taches supplémentaires et permis d'établir, avec plus de détails, les planisphères de ces petits astres.

Sept dessins de Ganymède, faits par Danjon, avec le réfracteur de 48 cm. de Strasbourg, s'accordent avec ceux du Pic du Midi et fournissent, pour les taches principales, des positions peu différentes (*L'Astronomie*, 33, 1944).

H. Camichel a mesuré les diamètres des satellites en comparant ceux-ci a des images de disques artificiels dont il faisait varier le diamètre, l'éclat et la coloration. Il a trouvé, pour les satellites de Jupiter ramenés à la distance 5, en secondes d'arc: Io 0·90, Europe 0·78, Ganymède 1·35 et Callisto 1·26.

Pour les satellites de Saturne ramenés à la distance 9, Titan 0·76, Rhea 0·22, Dione 0·16, les deux dernières valeurs étant de simples indications. Les premières mesures ont été publiées (*Comptes Rendus, Paris*, **219**, 22, 1944).

Tout récemment, G. P. Kuiper a appliqué la même méthode à la mesure des diamètres des satellites de Saturne, avec le réflecteur de 2 mètres de l'observatoire McDonald.

G. P. Kuiper (*Ap. J.* **100**, 378, 1944) a obtenu des spectres des 10 plus gros satellites, dans le rouge et l'infra-rouge. Les principales bandes du méthane apparaissent avec intensité sur Titan; elles sont faibles et douteuses sur Triton et invisibles sur les autres satellites.

Un nouveau satellite d'Uranus vient d'être découvert à l'observatoire McDonald, aux deux tiers de la distance du premier et plus faible de deux magnitudes.

Suggestions et Propositions

1. *Nomenclature lunaire*

H. Percy Wilkins propose l'adoption, par l'U.A.I., de 22 noms nouveaux dont il donne la liste. Il estime ceux-ci nécessaires pour désigner une partie des très nombreuses formations représentées sur sa nouvelle carte à grande échelle.

Les formations auxquelles il désire attribuer ces noms sont, en général, petites ou observables près du limbe, dans des conditions médiocres. La plupart d'entre elles sont déjà désignées par des lettres et ces désignations ont été adoptées, par l'U.A.I., comme définitives.

G. Delmotte propose, conformément à l'opinion que Sir Frank Dyson avait exprimée, pour les formations qui ne sont pas encore désignées, de ne donner des noms qu'aux plus importantes, telles que le grand affaissement rectangulaire situé au Sud du Mur Droit, qui contient les cratères Hell et Lexell et pour lequel E. Antoniadi avait proposé, en 1942, le nom de Henri Deslandres. On pourrait retenir également le nom de Frank Dyson proposé par H. Percy Wilkins ou encore ceux de R. Jarry-Desloges ou William H. Pickering.

2. *Observations de la Lune*

G. Delmotte propose que l'U.A.I. coordonne les efforts des sections sélénologiques, créées dans les associations astronomiques. Il faudrait, pour cela, établir un catalogue d'objets douteux à surveiller, catalogue formé, par exemple, en groupant les suggestions des diverses associations. Ce catalogue serait révisable, augmenté des faits nouveaux, diminué des faits acquis et fourni à chacune des associations.

Celles-ci communiqueraient à l'Union les travaux de leurs membres, après un premier examen. L'Union devrait ensuite concentrer les résultats, les discuter et les publier.

Pour éviter les différences considérables qui existent entre les dessins d'observateurs différents et qui empêchent, le plus souvent, l'identification des détails, les observateurs devraient travailler uniquement sur des gabarits qui leur seraient fournis et qui auraient été tracés à grande échelle (au moins 2 à 3 mètres pour le diamètre lunaire), d'après des agrandissements de photographies prises dans des conditions appropriées.

G. Delmotte propose, d'autre part: Un programme photographique d'ensemble qui reprendrait méthodiquement, avec des moyens modernes (émulsions, instruments, etc.), les œuvres de Loewy et Puiseux, Pickering, etc., les clichés étant obtenus sous cinq éclairages différents.

Des clichés de détails se rapportant, de préférence, aux régions signalées pour l'observation visuelle en commun et des clichés pris avec d'autres radiations, infra-rouge ou ultra-violette.

Les clichés seraient diffusés largement, uniquement par tirages photographiques (contact sur films à grain fin, agrandissement sur papier brillant et glacé).

3. *Nomenclature Martienne*

G. Fournier regrette l'absence d'une nomenclature précise et unanime: Les observateurs ont ajouté, à la nomenclature de Schiaparelli, un certain nombre d'objets nouveaux, d'autre part, à des objets déjà nommés sont substitués, parfois sans nécessité apparente, des vocables nouveaux et quelques désignations consacrées par l'usage ont été transposées et changées d'objet. Le moment semble venu d'opérer une révision d'ensemble, suivant des règles précises, en tenant compte, avant tout, du caractère d'instabilité de la topographie de la planète.

Il conviendrait, tout d'abord, de faire table rase de toutes les désignations d'objets de durée éphémère et de dimensions minuscules qui encombrent les cartes et dont les identifications sont incertaines; des lettres provisoires pourraient leur être attribuées.

Pour les autres objets, il faudrait examiner les noms figurant sur les cartes de Schiaparelli, Cerulli, Molesworth, Jarry-Desloges et Fournier, Antoniadi et choisir, dans chaque cas, le nom le plus ancien ou, en cas d'égalité, le mieux approprié.

Une telle révision pourrait être confiée, par la commission 16 de l'U.A.I., à un organisme spécialisé déjà existant, avec mission d'établir un projet. Ce projet serait soumis à l'approbation de l'Union dont la commission 16 serait seule habilitée à introduire les modifications jugées ultérieurement nécessaires.

4. *Observations de Jupiter*

C. Luplau Janssen, ayant observé, à l'Observatoire Urania, dans la zône équatoriale de Jupiter, des taches sombres qui ne suivent pas le système I, attire l'attention des observateurs sur toutes les formations de cette zône et sur l'importance que présente l'étude de leur période de rotation.

Les latitudes des bandes Joviennes varient avec une période qui semble coïncider avec celle de la révolution de Jupiter autour du Soleil. Ces variations sont peut-être attribuables à des erreurs d'observation dues à la faible hauteur de la planète pendant la moitié de sa révolution autour du Soleil.

C. Luplau Janssen recommande aux observateurs de l'hémisphère austral de mesurer, au micromètre, les latitudes des bandes, pendant les années prochaines et, en général, lorsque la planète se trouve au Sud de l'équateur.

B. Lyot
Président de la commission

Compte rendu de la séance

PRÉSIDENT: M. B. LYOT.

SECRÉTAIRE: M. LUPLAU-JANSSEN.

Réunion du vendredi 13 août à 11.30. Le Président rend hommage aux membres que la commission 16 a perdus depuis le dernier congrès: Le Rév. T. E. R. Phillips, Messieurs M. Maggini, E. M. Antoniadi et G. Rougier.

A ces noms s'ajoutent ceux du Dr K. Muller et de Miss M. A. Blagg, auteurs des travaux de l'Union concernant la nomenclature lunaire.

Le président résume les travaux qui ont été effectués pendant les dix dernières années et déjà exposés brièvement dans le draft report. Il ouvre la discussion à ce sujet.

M. Luplau-Janssen attire l'attention sur les observations de trainées lumineuses devant la partie non éclairée du globe lunaire, lesquelles sont résumées dans le draft report.

Le président exprime l'opinion que, si l'atmosphère lunaire atteignait 1/100 000 de la nôtre, valeur estimée nécessaire à l'observation de météores, on devrait pouvoir la déceler en observant, avec un coronagraphe, la limite de l'ombre portée par la Lune dans cette atmosphère, dans le prolongement des cornes du croissant. M. Dollfus signale que la lumière diffusée par l'atmosphère lunaire pourrait être reconnue grâce à sa très forte polarisation.

M. Danjon rappelle que, vers la conjonction, la longueur des cornes du croissant diminue et tend vers zéro pour une phase de 173°. Le président estime que ce fait contraire à l'existence d'une atmosphère importante, faciliterait l'observation d'une atmosphère très faible. Messieurs Brunner-Hagger et Whipple suggèrent la recherche de phénomènes lumineux analogues à nos aurores polaires, mais M. Danjon craint que la lumière cendrée ne masque le phénomène. Selon M. Link il n'y aurait pas de concentration aurorale vers les pôles, en raison de la faible valeur du champ magnétique lunaire prévue par la théorie de Blackett et selon le président, la lumière diffusée par l'atmosphère serait plus intense que celle des aurores.

La photométrie des planètes inférieures est un point important sur lequel M. Danjon expose les travaux non encore publiés, qu'il a effectués depuis 1935. Sur Mercure, les mesures antérieures faites par Müller à Potsdam, à l'aurore ou au crepuscule, ne sont pas assez précises en raison de la forte absorption atmosphérique ($\Delta m = 1$ magnitude). Les nouvelles observations au nombre de 200 environ ont été effectuées de jour, près du méridien, en comparant directement la planète à une image quasi ponctuelle du Soleil affaiblie par un coin photométrique. La correction d'absorption différentielle est alors inférieure au dixième de magnitude, l'écart des mesures est 0·01 m.

L'indice de couleur, déterminé à l'aide de filtres rouges et verts trichromes de Wratton, est très voisin de celui de la Lune; la courbe de lumière déterminée entre les phases 2° et 125° est identique à celle de la Lune tracée par Rougier. L'albédo, étalonné sur des étoiles, est voisin de 0·04, inférieur à celui de la Lune.

Sur Vénus, la courbe de lumière, déterminée jusqu'à 172°, au moyen de 300 observations environ est tout à fait différente, elle est rectiligne au-dessus de 80°; extrapolée jusqu'à 180°, elle fournit, pour l'anneau lumineux la magnitude zéro; l'albédo est 0·72. Une erreur est à signaler, à ce propos, dans le *Handbuch der Astrophysik* (article de Graff).

Ces résultats pourraient servir de base à une théorie de la diffusion dans l'atmosphère de Vénus. La formule classique de Müller ne permet pas de les représenter, il faut ajouter un terme très important du second dégré.

Sur Mars, les mesures ne peuvent être effectuées que jusqu'à 45°, de plus les valeurs sont dispersées par l'effet de la phase, de la rotation, de l'inclinaison de l'axe et de la saison.

Monsieur Wildt rappelle l'importance de la photométrie des planètes pour l'étude des variations de la constante solaire. Toutefois les librations et les taches sont des causes d'imprécision.

Le président souligne l'intérêt de la méthode de Monsieur Danjon pour comparer directement le Soleil aux étoiles brillantes et déterminer, avec une excellente précision, les variations de la constante solaire dans différentes régions du spectre visible.

Il soumet ensuite, à la discussion, les propositions qui sont résumées dans le Rapport.

Au sujet de la nomenclature lunaire, en accord avec Monsieur Delmotte, la Commission est d'avis de continuer à désigner les objets d'importance secondaire par des lettres et de ne donner des noms qu'à des formations importantes. Elle adopte la proposition de Monsieur Antoniadi.

Monsieur Danjon estime que le projet de Monsieur Delmotte occasionnerait des dépenses que l'U.A.I. ne pourrait pas prendre à sa charge, la préparation des gabarits par exemple, devrait être faite par les associations astronomiques, en attendant l'établissement d'un projet plus détaillé, par ces associations.

Le président regrette l'absence de Monsieur Fournier qui aurait pu apporter des précisions sur son projet de révision de la nomenclature martienne. Monsieur Fournier serait qualifié pour établir la liste des objets à renommer.

A la suite de cette discussion, la Commission adopte les résolutions suivantes:

1. La Commission décide de ne donner des nouveaux noms qu'à des formations lunaires inportantes parmi celles qui n'ont pas encore été désignées.

Elle propose de donner le nom de Deslandres à la grande dépression rectangulaire située au sud du mur droit et qui contient les cratères Hell et Lexell.

2. La Commission recommande aux observateurs de la Lune de travailler uniquement sur des gabarits tracés au moyen de photographies à très grande échelle prises dans des conditions d'éclairement appropriées.

Elle recommande aux sections lunaires des associations astronomiques de s'entendre directement entre elles et avec les observatoires bien équipés pour obtenir de telles photographies.

3. La Commission recommande aux observateurs qui étudient les colorations des planètes, d'utiliser des dispositifs corrigeant la dispersion atmosphérique, lorsque les observations sont faites à une faible hauteur.

17. COMMISSION DU MOUVEMENT ET DE LA FIGURE DE LA LUNE

PRÉSIDENT: M. LE PROFESSEUR T. BANACHIEWICZ, *Directeur de l'Observatoire de Cracovie, ul. Copernic 27, Cracovie, Pologne.*

MEMBRES: MM. Bonsdorff, Brouwer, Comrie, Guth, Kozieł, Lindblad, Meyer, Sadler, Sundman, Volta, Worssell, Yakovkin.

YALE UNIVERSITY OBSERVATORY, DIRK BROUWER, *November* 13, 1947

The discussions of observations of occultations have been published annually in the *Astronomical Journal*. The publication, dealing with the observations in the year 1942, which appeared in *A. J.* **51**, 144–5 (1945), concludes the series of annual discussions made at the Yale Observatory. Beginning with the observations in the year 1943, the British Nautical Almanac Office has assumed the responsibility for the reduction and discussion of occultations of stars by the Moon.

A discussion of the Moon's motion based upon about 5000 occultations in the eleven years, 1932–42, and about 1000 Washington meridian circle observations in the years 1933–44 was made by D. Brouwer and C. B. Watts, *A. J.* **52**, 169–76 (1947). Both series were reduced to the FK 3 system and corrections for limb error were applied, based upon Hayn's charts. In the case of the occultations the tables by Watts, *A. J.* **48**, 170 (1940), were used for a partial elimination of the systematic limb effect from the lunation solutions. The meridian circle observations were corrected individually.

An analysis of each of the two series of observations separately was made by least squares. Terms having the periods of the tropical, nodical and anomalistic months were introduced in addition to a constant and, in the longitude only, a term varying linearly with the time. For the occultations the means by lunations were used, for the meridian data the individual observations. The substitution of the solutions yields residuals that show:

(1) Excellent agreement between meridian circle observations and occultations, especially in the longitude.

(2) The lack of uniformity of the Earth's rotation during the ten years 1933·0–1943·0 produced a maximum deviation of only 0″·3 in the Moon's observed mean longitude.

(3) The well-known annual term in the occultation results in longitude has practically disappeared from the final results by lunation; it appears that the three different periods were present in the original residuals.

A complete interpretation of the coefficients of the periodic terms found in the solutions cannot be made on the basis of the available data. Appreciable differences between the coefficients from east and west limb of the meridian observations and occultations indicate that, to some extent at least, the periodic terms must arise from residual limb effects.

U.S. NAVAL OBSERVATORY, C. B. WATTS, *November* 17, 1947

At the U.S. Naval Observatory, Washington, C. B. Watts has undertaken to make a new survey of the Moon's marginal zone with the purpose of deriving an improved set of corrections for those classes of measures that involve the Moon's limb. The work will be based on photographs made at Washington and at the Yale Southern Station at Johannesburg. A photo-electric measuring engine is being constructed with which it is expected that the photographs can be measured automatically.

H.M. NAUTICAL ALMANAC OFFICE, LONDON, D. H. SADLER, *December* 22, 1947

(*a*) Since the I.A.U. meeting in Stockholm the Nautical Almanac Office has continued with its routine programme of prediction of occultations for about sixty stations. Throughout the war predictions were sent to every station with which communication was possible.

The occultation reduction elements were omitted from the *Nautical Almanac*, 1942, but were issued in the U.S.A. through the courtesy of the American Section of the I.A.U. It was then decided that the number of observed occultations did not warrant the continued pre-computation of the occultation reduction elements and these have been consequently dropped from the *Nautical Almanac* from 1943 onwards. From that year the Nautical Almanac Office has undertaken to reduce observations of occultations of all stars included in the *N.Z.C.* From the same year the Office has also taken over from Prof. Brouwer the compilation and discussion of the occultation observations in relation to the position of the Moon. The discussion for 1943 is in process of publication in the *Astronomical Journal* and it is hoped that the wartime arrears of reduction will shortly be made up.

(*b*) I would like to suggest that if an opportunity arises the following subjects might be discussed by the Commission in Zürich:

(i) The limitations to be adopted for the prediction of occultations so as to ensure a balance between the amount of work involved and the restriction of observations to those which can be made only in good conditions.

(ii) The topography of the limb of the Moon, especially in regard to the work now in progress by Mr C. B. Watts in Washington.

(iii) The value of **k** (the ratio of the Moon's diameter to that of the Earth) to be adopted for occultations.

(*c*) We have no motions for submission to the General Assembly.

CRACOW UNIVERSITY OBSERVATORY, *Director:* T. BANACHIEWICZ

According to the *Engelh. Obs. Public.* **21**, 4 (1939) the determination of the libration constants from 200 heliometer observations is a huge computational problem; e.g. the solution by least squares of 400 equations with eight unknowns forms but one-fiftieth of the whole work. T. Banachiewicz examined the problem both from the fundamental and from the technical standpoint, and a new method which resulted from this study was applied—with some further developments—by K. Kozieł to Hartwig's Dorpat observations of 1884–85. Owing to certain observational particularities this Dorpat set was especially difficult to deal with. The new method of reduction uses throughout the Cracovian calculus. Some points of it are here reported on.

One of the first points to clear away was the puzzling libration term in the Moon's radius. Yakovkin found in 1934 from the discussion of his Kasan 1916–26 heliometer observations that the radius R of the Moon, corrected for the limb's irregularities after Hayn, shows an increase $b = +0''{\cdot}048$ ($\pm 0''{\cdot}006$ m.e.) for every degree of the libration in latitude. To test this result T. Banachiewicz investigated the great series of 235 observations of Hartwig, as reduced recently by Naumann, and found $b = +0''{\cdot}054$ ($\pm 0''{\cdot}006$) and $b = +0''{\cdot}029$ ($\pm 0''{\cdot}005$), respectively without and with Hayn's inequalities, in this way confirming qualitatively the existence of the term. The observed latitudes of Mösting A do not show, however, any corresponding changes, so that, contrary to some opinions, the mountains near the Moon's south pole taken alone could not explain the effect. The explanation of it may be as follows. In the usual (defective) method of determining R from the heliometer observations, R is based principally on the high-latitude regions of the Moon. Hence the apparent changes of R are a function of the particular slopes of these regions. Unfortunately, Hayn's photographs, owing to their lack of an absolute scale, give only relative heights which are self-influenced by the marginal elevations of a regular character, and cannot lead therefore to the true dimensions of the Moon. A confirmation of this view is afforded by the investigations of K. Kozieł. When treating the Dorpat observations in the ordinary way, he obtained $b = +0''{\cdot}040$ ($\pm 0''{\cdot}014$), like Yakovkin, but the new method gave him $b = -0''{\cdot}011$ ($\pm 0''{\cdot}010$), and the puzzle disappeared.

The heliometric observations of the Moon's libration lead to the values of λ, β, h (3 co-ordinates of Mösting A), I (inclination of the Moon's equator) the mechanical ellipticity f and the Moon's mean angular radius R. Every measured distance of

Mösting A brings in reality an observation-equation for these six unknowns. Instead of solving these equations directly, which was too long for the Gaussian algorithm of least squares, the usual method consisted of determining from every full observation-set three intermediary quantities, dL, dB and dR. Then dL and dB were expressed in terms of $d\lambda$, $d\beta$, dh, dI and df, and gave the observation-equations for these five unknowns. A discussion was needed for determining the relative weights of the dL and dB equations. These equations, however, obtained from the same measured distances, are not independent, and the ordinary rules of least squares, when applied to them, cannot give results of unambiguous mathematical significance. Moreover, by the distinct solution of reduced normal equations for dR, important relations between R and other unknowns, as yielded by the intercomparison of the east and west limb's distances, were lost, to the great detriment of the value of the whole solution. The correct procedure is very simple. Form, as usually, the normal equations for dL, dB and dR; consider the corresponding Cracovian square-root equations; put into them the expressions of dL and dB as functions of the five unknowns. Solve then the equations with six unknowns obtained in such a way, considering them as independent observation-equations of weight unity. The result is shown to be an exact least-squares solution of the whole material. This method gives also directly the *a posteriori* mean error of every measured distance, the important quantity which remained unknown in the usual method of solution.

To investigate the Yakovkin term, K. Kozieł introduced yet a seventh unknown b, and obtained in this way, as already said, b equal to zero. The doubtlessly positive value of b in the former method of reduction would indicate—if the trend of the marginal lunar zones might be extrapolated—that the axis of the Moon's elongation be directed not towards the centre, but to the southern hemisphere of the Earth.

As regards the accuracy of the solution, K. Kozieł obtained from the thirty-six Dorpat observations the following mean errors of the unknowns: $d\lambda \pm 11''{\cdot}5$, $d\beta \pm 17''{\cdot}0$, $dh \pm 0''{\cdot}56$, $dI + 22''{\cdot}6$, $df \pm 0{\cdot}051$. These mean errors are remarkably small as compared with the mean errors of the unknowns yielded by the usual method; e.g. a (greater) set of fifty-one observations, made by an experienced observer with a similar heliometer, yielded, *Engelh. Obs. Publ.* **23**, 11 (1945), the mean errors of the same unknowns respectively $\pm 32''$, $\pm 27''$, $\pm 1''{\cdot}1$, $\pm 37''$, $\pm 0{\cdot}09$. It appears, therefore, that the mathematically exact method of determination of all unknowns at one sweep marks a decisive progress. The mean error of one measured distance is 'with Hayn' $\pm 0''{\cdot}614$. K. Kozieł has solved all equations using two assumptions: 'without' Hayn and 'with' Hayn, and has obtained, for the first time in the literature, all unknowns agreeing with themselves in two systems within their mean errors. The above mean errors were obtained with the initial value $f=0{\cdot}73$. On my proposition K. Kozieł made the calculations also with $f=0{\cdot}50$, and discovered that there exists still another solution for all unknowns with the initial value f lying on the other side of the critical value $f=0{\cdot}662$. In this second solution $f=0{\cdot}60 \pm 0{\cdot}05_5$; the mean error of one measured distance becomes $\pm 0''{\cdot}575$, being therefore somewhat less than in the first solution $f=0{\cdot}71$. It remains for future investigations to decide on which side of the critical value 0·662 lies the mechanical ellipticity f. The assumption often made by modern writers on the authority of Hayn that f lies in the vicinity of 0·7 appears, according to K. Kozieł, to be deprived of a sufficient basis.

In his thorough dissertation (printed in *Acta Astronomica*) K. Kozieł has taken into account a new reduction of the measured position angles: for the convergency of hour circles. It consists of two parts, and amounts up to about 3′ in the Dorpat series, made in moderate declinations of the moon.

The great increase of the accuracy, equivalent to a three-fold or greater extension of the available observations, as well as clarifying of results obtained, when calculating the observations with the help of the Cracovian method, adds new arguments for the fresh reduction and investigation of the whole material of heliometer measures. One might then hope to obtain among other things a better insight into the problem of the arbitrary libration of the Moon, as well as to decide the new problem, which of the two solutions for f corresponds to the truth. These vast problems demand international co-operation,

and Dr Kozieł would desire a resolution of the Committee in this respect, as well as a subvention of the I.A.U. for this work.

As regards the photographic observations of the figure of the lunar disk, provision must be taken to secure in the future not only the position angles, but also the exact value of the scale, in order to avoid systematic level-errors, like those producing the Yakovkin term.

Publications of the Libration Constants

Since the Stockholm meeting of the I.A.U. there have appeared two important publications: (i) 'Selenographische Koordinaten' by Hans Naumann (*Veröff. der Sternw. zu Leipzig*, Heft VII, 1939), and (ii) 'The Rotation and the Figure of the Moon', in two parts, by A. A. Yakovkin (*Publ. Obs. Engelh*, **21**, 1939, and **23**, 1945, in Russian). The results are summarized as follows:

	Leipzig publication Observer Hartwig, 1890–1915–(1922)	*Kasan publication* Observer Yakovkin, 1916–1931
λ	$-5^\circ\,10'\,0'' \pm 11''$	$-5^\circ\,10'\,25'' \pm 10''$
β	$-3\;\;10\;\;56 \pm 9$	$-3\;\;10\;\;26 \pm 8$
h	$15\;\;34{\cdot}2 \pm 0{\cdot}41$	$15\;\;34{\cdot}06 \pm 0{\cdot}4$
I	$1\;\;31\;\;29 \pm 12$	$1\;\;31\;\;44 \pm 12$
f	$0{\cdot}71 \pm 0{\cdot}033$	$0{\cdot}68 \pm 0{\cdot}02$
	157 (from 235) observations, each consisting of 10–15 distances. Heliom. 184 mm. apert., 2·7 m. focal length.	251 observations, each consisting of 7–8 measured distances. Heliom. 106 mm. apert., 1·7 m. focal length.

All the mean errors given in the Leipzig publication are here multiplied by 4/3, owing to an erroneous formula used there.

The agreement of both values of f does not warrant this quantity, because of the possibility of the second solution for f, both authors having departed from the value of f in the same region; on f depend (feebly) all unknowns.

Yakovkin makes an attempt to determine the arbitrary libration in longitude by harmonic analysis based on the assumed value of the period, corresponding to $f=0{\cdot}72$. He obtains the amplitude $31'' \pm 12''$.

Naumann utilised only 59% of the observations of Hayn, who observed till 1922. The incomplete observations that he left out as inaccessible to treatment by the usual method of reduction, could be utilized by using the Cracovian method. The great value of his publication would be, according to Dr Kozieł, still much enhanced if it contained more particulars, and especially the moments of individual observations, enabling the reader to introduce some delicate corrections. Experience having shown that the same sets of observations are being reduced again and again, it is highly desirable that the libration-observations be published as fully as possible, giving all observed moments, and even the habits of the observer, especially relative to the position of the measured crater in the field of the eye-piece.

Yakovkin reduced his 1916–22 observations to Brown's radius of the Moon by applying to Hansen's radius the correction $1''{\cdot}50$, this being the difference between the two radii on January 1, 1923. A variable correction, from $1''{\cdot}42$ for the horizontal parallax 54′ till $1''{\cdot}64$ for the horizontal parallax 62′ would fit better.

Mme Chandon published (*C.R. Paris*, juin 1941) a renewed investigation of forty plates already discussed in the memoir of Puiseux (*Ann. Obs. Paris, Mém.* **32**, 1925). She had regard to the rough error indicated in *Rocz. Astr. Obs. Krak.* **5**, 168 (1928), but the results are incomparable in accuracy to the heliometer measures. The memoir of Puiseux remains to be revised. Meanwhile four of these plates were used by Th. Weimer, *C.R. Paris*, **226**, 559 (1948), in an attempt to determine the elongation of the Moon from the magnitude of the parallactic displacements of the craters.

Prof. Sundman prepared a memoir 'The Motion of the Sun and the Moon at the Solar eclipse of July 9, 1945'.

Yakovkin gave a semigraphical, successive-approximations method for predicting occultations, *Russian Astr. Journ.* **24**, 223 (1947). The same author constructed a machine for this purpose, ibid., 228 (1947).

A. Strzałkowski calculated the Moon's limb irregularities (to be published in *Acta Astronomica*) for the solar eclipse of May 20, 1947. This eclipse was indicated in 1928 by T. Banachiewicz as suitable for the geodetic linking of Africa and South America, e.g. in the *C.R Comm. Géod. Balt.* (séance à Berlin), pp. 161–4.

Some contrivances for the photo-electronic, physical registration of the occultations, even of faint stars, are being devised now at the Cracow Observatory.

F. Koebcke gives, in *Poznań Reprint*, **11** (1947), Cracovian formulae adapted to the method of Comrie, as well as that of Davidson, for computing the selenographic co-ordinates P and D of the point of the Moon's limb where the occultation takes place.

The close constancy of the selenographic longitude of Mösting A during the last 100 years, as deduced from the heliometer observations, shows that the duration of one rotation of the Moon equals the length of one revolution around the Earth within about $\frac{1}{10}$ sec. This quantity amounts to only one-ninetieth of its upper limit deduced by Bessel from the unchanged appearance of the Moon from ancient to modern times.

T. BANACHIEWICZ
President of the Commission

For the report of the meetings, which was received with considerable delay, see page 430.

18. COMMISSION DES LONGITUDES PAR TELEGRAPHIE SANS FIL

PRÉSIDENT: M. P. TARDI, 19 *rue Auber, Paris-9, France.*

MEMBRES: MM. R. Baillaud, Buchar, de Lemos, Demetrescu, Mme Dubois, MM. Esclangon, Fayet, Guyot, de Graaff Hunter, Jeffers, Spencer Jones, Jouaust, R.P. Lejay, MM. Madwar, Michkovitch, Moreau, Nörlund, Pavlov, Peisino, Plakidis, Silva, Sollenberger, R. M. Stewart, Stoyko, Ping-Jan Tsiang, Watts, Witkowski.

I. OPÉRATION DES LONGITUDES MONDIALES DE 1933

A. *État actuel de la publication*

Les modalités de la publication ont été décidées lors de l'Assemblée Générale de Stockholm en 1938.

Il est rappelé que le nombre des stations ayant participé à l'opération n'est pas moindre que *soixante-et-onze*. Le rassemblement des renseignements a été très long et a duré jusqu'à la fin de 1937, soit quatre ans après la fin des mesures.

Il avait été décidé de publier à frais répartis par moitié entre l'U.A.I. et l'U.G.G.I. un volume par station donnant des renseignements et des *tableaux* très complets relatifs aux observations astronomiques, aux réceptions radiotélégraphiques et à la marche des garde-temps utilisés. On devait en outre publier un fascicule introductif et un volume de conclusions.

En fait seules les quatre premières stations ont été publiées par volumes séparés. Il avait été décidé rapidement de grouper les résultats par 5 ou 6 stations et la publication devait finalement comprendre *vingt* volumes, répartis comme suit:

Liste des Fascicules

1. Fascicule introductif
2. Adelaïde
3. Alger
4. Belgrade
5. Ber Rechid
6. Bucarest (Inst. Géog. Milit.)
Bucarest (Obs. astr.)
Buenos-Aires
Canton
7. Cap de Bonne Espérance
Coïmbra
Córdoba
Dehra-Dun
Evanston
Gdynia
8. Greenwich
9. Hambourg (Berg.)
Hambourg (Obs. Nav.)
Heidelberg
Helwan
Honolulu-Niu
10. Izana
Kharkov
Kitab
Kodaïkanal
Ksara
11. Lembang
Leningrad
Lick (Mt Hamilton)
Liège
Lisbonne
12. Madrid
Manille
Melbourne
Milan
Mogadiscio
Montevideo
Moscou (Inst. géod.)
13. Nankin
Neuchâtel
Ottawa (Dom. Obs.)
Ottawa (Geod. Survey)
14. Paris

15. Phu Lien, Pino Torinese, Potsdam, Poulkovo, Poznań, Prague

16. Rajburi, Riga, Rio de Janeiro, San Diego, San Fernando, Sofia, Strasbourg

17. Tachkent, Tacubaya, Tananarive, Tokio (Astr. Obs.), Tsing Tao

18. Uccle, Vancouver, Varsovie (Inst. Astr.), Varsovie (Observ.), Vienne (Obs.), Voksenaasen (Oslo)

19. Washington (Obs. Nav.), Wellington, Zacatecas, Zi Ka Wei, Zurich

20. Conclusions (en voie de rédaction)

En fait seuls les volumes de 1 à 13 ont été effectivement publiés, le volume 13 (Nankin, Neuchâtel, Ottawa) étant sorti au début de l'année 1948 des presses de la Librairie Hermann à Paris.

Le volume 20, de beaucoup le plus important, qui est relatif aux *Conclusions Générales* est actuellement rédigé. Il a été mis à peu près complètement au point avant sa mort par le regretté Armand Lambert. Les derniers détails de rédaction ont été assurés par Mme Dubois. Le fascicule comporte également une importante étude de M. Stoyko sur la propagation des ondes radiotélégraphiques.

Les causes de ce retard dans la publication sont multiples:

Le décès du Général G. Perrier et surtout celui d'Armand Lambert suffiraient à l'expliquer partiellement, même dans une période normale. Et chacun sait que la période envisagée est loin d'avoir été normale. Non seulement la période de guerre proprement dite (4 volumes ont parû de 1939 à 1942). Mais plus peut-être encore la période d'après-guerre qui a vu croître les prix d'impression dans de très considérables proportions, en laissant une très grande incertitude sur les ressources de l'U.A.I. et de l'U.G.G.I. et sur la possibilité pour ces organismes de poursuivre l'effort financier qui avait été entrepris en des jours meilleurs.

B. *Financement de la publication des volumes de 1 à 13*

Les volumes de 1 à 12 ont été entièrement réglés à l'éditeur, la somme totale se monte à 242·534 frs.

Ces dépenses ont été couvertes de la façon suivante:

Recettes	1ère subvention U.A.I. (1937)	50·997 frs.	123·271 frs.
	2ème subvention U.A.I. (1939)	72·274 frs.	
	subvention U.G.G.I.	42·387 frs.	
	subvention cotisation de la France	76·876 frs.	
		242·534 frs.	

Il résulte de cet état que l'U.A.I. a versé pour le moment 123·271 − 42·387 = 80·884 frs. de plus que l'U.G.G.I.

La facture de la maison Hermann relative au volume 13 se monte à 240·127 frs.

Mais par ailleurs l'U.N.E.S.C.O. vient d'allouer à l'U.G.G.I. pour cette publication une subvention de 500 dollars soit environ 108·000 frs.

La dépense correspondante au vol. 13 sera donc réglée comme suit:

Subvention U.N.E.S.C.O.	108·000 frs.
Solde U.G.G.I.*	80·884 frs.
	188·884 frs.
Reste à régler par l'U.A.I.	25·621 frs.
Reste à régler par l'U.G.G.I.	25·622 frs.
	240·127 frs.

L'expédition à l'étranger des volumes non encore mis en distribution représentera une somme assez élevée que l'on peut estimer à 15·000 frs., soit 7·500 frs. pour chacune des deux Unions.

Il restera, en outre, à assurer les frais relatifs à l'achèvement de la publication, d'après les décisions qui seront prises à ce sujet.

C. *Achèvement de la publication*

La plupart des astronomes qui ont été consultés sont d'avis que, dans les circonstances actuelles, il doit être considéré comme matériellement impossible de continuer la publication sous la forme luxueuse sous laquelle elle avait été entreprise.

L'effort financier correspondant serait tout à fait disproportionné avec l'importance des résultats publiés.

Quinze années se sont écoulées maintenant depuis que les observations ont été faites. Qui se soucie encore du détail des observations effectueés en chacun des observatoires ayant participé à l'opération?

Les seules parties qui doivent à tout prix être publiées sont:

(*a*) l'exposé général des méthodes suivies pour les calculs et pour les réductions. Cet exposé figure dans le volume No. 1, et on en trouve des applications détaillées dans les douze volumes suivants;

(*b*) les *résultats finaux*, les *conclusions* et les *études* consécutives telles que celles relatives à la propagation des ondes radiotélégraphiques.

Il convient cependant que chacun des Observatoires dont les résultats n'auront pas été publiés (ils sont au nombre de 30) soit mis en possession d'un exemplaire des calculs qui ont été effectués par les soins de l'Observatoire de Paris sur leurs propres observations. Mais nous proposons qu'il en soit envoyé à chacun une simple copie dactylographiée (ou manuscrite), l'original restant à l'Observatoire de Paris à la disposition de quiconque serait désireux de le consulter.

En fixant à 3·000 frs. le prix de chacune des copies à établir, on arrive ainsi à une dépense de 90·000 frs., toujours à couvrir par moitié par chacune des deux Unions.

Le dernier volume (Conclusions) serait donné à la composition à la librairie Hermann de façon à paraître dans la même collection (même format et même couverture) que les 13 volumes déjà parus. — Il semble que l'on puisse chiffrer à 180·000 frs. le prix de l'impression de ce volume (90·000 frs. par Union).

D. *Total des dépenses restant à couvrir par l'Union Astronomique*

Règlement du tome 13	25·500 frs.
Frais généraux d'expédition	7·500 frs.
Copie des résultats pour 30 Observatoires	45·000 frs.
Volume des Conclusions	90·000 frs.
	168·000 frs.

Soit aux tarifs actuels des changes 800 dollars.

* Pour égaler les versements déjà faits par l'U.A.I.

Il est à remarquer que tout ou partie de cette somme pourrait être couverte par une subvention demandée à l'U.N.E.S.C.O., cette subvention pouvant être demandée soit par l'U.A.I., soit par l'U.G.G.I.

Il serait entendu qu'une subvention octroyée par l'U.N.E.S.C.O. quelle que soit celle des deux Unions à qui elle est accordée, viendrait en défalcation de la somme générale à débourser pour l'ensemble des deux Unions, — ainsi qu'il a été fait pour la subvention de 500 dollars accordée en 1948 au titre de l'U.G.G.I.

II. Communications reçues par le Président

La seule communication reçue par le Président émane de l'U.S. Naval Observatory de Washington (lettre du 12 Nov. 1947). — Il concerne l'emploi du Photographic Zenith Tube, instrument utilisé, comme on le sait, à la fois pour la détermination de la latitude et pour celle de l'heure locale.

Ce Rapport ayant été communiqué simultanément à la Commission de Variation des Latitudes ne sera pas autrement analysé ici.

III. Projet d'Ordre du Jour pour la Réunion de Zurich

1. Composition de la Commission—Décès—Membres nouveaux.
2. Mise en discussion du Rapport du Président concernant l'opération de 1933. Propositions et demande de crédits à présenter à l'Union.
3. Communications présentées par Mme Dubois et M. Stoyko résumant l'essentiel des conclusions contenues dans le dernier volume à paraître prochainement de l'Opération de 1933.*
4. Y-a-t-il lieu d'envisager dans un avenir plus ou moins proche une réédition des Opérations mondiales de 1926 et 1933?
5. Répartition actuelle, dans le temps et dans l'espace, des diverses émissions radiotélégraphiques de signaux horaires. Schémas des transmissions. Désiderata des opérateurs de terrain (qui peuvent être différents de ceux du Bureau International de l'Heure chargé de contrôler les émissions).
6. Progrès récents réalisés dans les instruments. Emploi du Photographic Zenith Tube. Astrolabe à micromètre impersonnel. Théodolite astronomique T4 de Wild.
7. Emploi comparé des micromètres impersonnels avec entraînement à main ou à moteur.
8. Détermination des différences de longitude en campagne. Importance pour la mesure de la composante E.-W. de la déviation relative de la verticale.
9. Questions diverses soulevées par des Membres de la Commission et qui n'ont pu être inscrites à temps sur le présent Ordre du jour.

P. Tardi
Président de la Commission

Compte rendu de la séance

Président: M. P. Tardi.

Secrétaire: M. N. Stoyko.

La Commission a tenu séance le jeudi 12 août à $10^h.30$.

Les Membres de la Commission présents à cette séance étaient MM. Tardi, Guyot, Jeffers, Spencer Jones, Madwar, Moreau, Nörlund, Silva, Sollenberger, Stewart, Stoyko, Watts et Witkowski.

* Un résumé de ces deux communications sera remis au préalable à chaque Membre de la Commission.

1. Le Président met en discussion les conclusions de son Rapport en ce qui concerne la publication des résultats de l'opération des Longitudes mondiales de 1933 (voir plus haut).

Après un échange de vues auquel prennent part plusieurs membres ces conclusions sont mises aux voix et adoptées. En conséquence il est décidé:

(*a*) Que la publication très complète des résultats, telle qu'elle avait été entreprise, ne sera pas continuée à cause des frais trop considérables qu'elle entraînerait;

(*b*) que le volume 13 (Nankin, Neuchâtel, Ottawa) récemment sorti des presses sera mis en distribution dès que possible;

(*c*) qu'il sera procédé à l'impression du volume des Conclusions et Résultats qui comportera de 70 à 80 pages;

(*d*) qu'une révision sera faite de la répartition des 12 premiers volumes qui a subi de grandes irrégularités du fait de la guerre mondiale—afin d'éviter des frais d'envois excessifs; cette répartition sera faite par l'intermédiaire du Service des échanges internationaux;

(*e*) qu'une subvention estimée à 800 *dollars* sera demandée au Comité exécutif pour assurer l'exécution de ces mesures, cette somme ayant été calculée pour que la charge totale soit répartie par moitié entre l'Union Astronomique internationale et l'Association internationale de Géodésie.

2. La Commission décide que toutes les questions relatives aux signaux horaires radiotélégraphiques seront discutées au cours de la réunion de la Commission de l'Heure (no. 31).

3. Après un échange de vues auquel prennent part en particulier Sir Harold Spencer Jones, M. Guyot, M. Gougenheim et M. Nörlund, il est décidé qu'il n'y a pas lieu d'envisager *pour l'instant* le renouvellement d'une détermination mondiale des longitudes. Les méthodes de détermination des Longitudes sont actuellement en pleine évolution et l'on peut escompter que l'on aboutira très prochainement à une augmentation très sensible de la précision.

Il y aura lieu dans un avenir relativement proche de procéder à une nouvelle détermination d'ensemble comportant quelques stations judicieusement réparties sur le Globe et particulièrement bien équipées. D'autres stations moins bien équipées seront invitées à participer à l'opération — mais une discrimination devra être faite au cours de la discussion finale en tenant compte de la précision variée des observations.

Il est souhaité que cette opération future suscite comme la précédente de nombreuses recherches dans des domaines variés et contribue à amener un important progrès dans le problème de la détermination des Longitudes.

4. Sur la proposition de son Président la Commission décide de demander au Comité exécutif de l'Union sa transformation en une *Commission de détermination des positions géographiques*, étant entendu qu'elle continuera à s'occuper comme par le passé du problème des différences de longitude.

Cette nouvelle Commission devra travailler en liaison avec la Commission de l'Heure et celle de l'Astronomie méridienne — et plus particulièrement avec les organisations correspondantes de l'Association internationale de Géodésie.

Il est demandé au Comité exécutif de procéder, compte tenu de l'extension des attributions de cette nouvelle Commission, à une refonte de la composition de ses membres après consultation des différents comités nationaux.

19. COMMISSION DE LA VARIATION DES LATITUDES

PRÉSIDENT: SIR HAROLD SPENCER JONES, *Astronomer Royal, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.*

DIRECTEUR DU BUREAU: M. CARNERA.

MEMBRES: MM. Baldini, Buchar, H. E. Burton, H. Castro, Cecchini, Dodwell, Lambert, Markowitz, Michkovitch, Moreau, A. J. Orlov, Peres, Sollenberger, Stoyko, M. F. Subbotin, E. L. Williams.

A. REPORT OF THE DIRECTOR OF THE CENTRAL BUREAU FROM 1938 TO THE END OF 1947

When, in May 1922 after the First World War, the I.A.U. and the I.G.G.U. met for the first time it was decided that the systematic study of the motion of the pole should be continued. This study had been commenced over 23 years earlier by the International Geodetical Association and had been continued without interruption during the war, thanks to the keenness of the observers and the work of the Swiss and Dutch geodesists and astronomers, who had undertaken to maintain the necessary contacts between the observing stations and the Potsdam Central Office. The Second World War, which broke out barely two decades later, had more serious consequences for this study. The generous and worthy offer of our Swiss colleagues to be intermediaries between the belligerent countries and to help in the exchange of data between the observing stations and the Central Bureau passed unheeded. The Italian Foreign Minister at the time refused to allow the observing books to be transmitted. We had hoped that, when hostilities were over and communications had been re-established, we should be able to obtain, although late, the complete series of observations. But, unfortunately, the war proved to have had serious consequences for our work. The station of Carloforte, after having had its observing activity increasingly hampered, was compelled, in the face of increasing danger, to dismantle the instruments and suspend all activity in the spring of 1943. From Batavia came the even more sad news of the complete destruction of the station. During 1940 the Adelaide Observatory had to suspend its activities. So, of the eight stations on which the latitude service was based in 1940, and which were giving yearly about 11,000 values for the latitude, three were missing, two of which were amongst the most active, while for other reasons the work of some of the other stations was more or less seriously hampered at various times. We also lament the loss of some of our best supporters who, directly or indirectly, had greatly helped our work and whose loss leaves a gap which cannot be filled. It will suffice to recall the names of Kimura, Schlesinger, Aguilar, Schumann, Bianchi, Yamasaki, Kawasaki, to realize what a gap has been caused in these recent years in the small circle of students of this problem; this gap will be particularly felt by the writer, who was fortunate in having, from his early years, the above-mentioned astronomers as colleagues. I should like to pay tribute to their memory.

It would not be right if, at this point, after having recalled the sad part, I did not mention the valuable help received from the Allied Military Government, which made it possible to re-establish relations with the President of the Commission, Sir H. Spencer Jones and the Vice-President of the I.G.G.U., Dr W. Lambert, and to obtain not only the observation books from the stations but also financial help to enable us to continue our work and to fill the gap in our knowledge of the motion of the pole caused by the delay in the receipt of the observations since 1940. We are also very grateful to the American, Colonel Washburn, who, as a head of the liaison office between M.A.G. in Rome and the Ministry of Education, managed to arrange that the work at our station of Carloforte should be started again.

To all those who helped us and co-operated with us, and especially to the three above-mentioned, I express my warm and heart-felt thanks.

I. *Observational Work at the Stations of the International Latitude Service*

Since January 1938, the date which ended my last report presented to the I.A.U. at Stockholm in August 1938, the following observers have taken duties in the international latitude stations:

At Mizusawa:

M. Yamasaki and S. Kawasaki until the end of 1942.
Tadahiko Hattori, from January 1943 to May 1944 and then from October 1944 to date.
Shigetsugu Takagi, from January 1943 to September 1944.
Tetsuro Ikeda, from June 1944 to date, acting director of the station.
Susumu Goto in August and September 1944.

At Kitab:

L. Schtschirgezky from the beginning to end of 1941.
W. Obraszow from the beginning of 1940 to the end of 1941.
E. Schaposhnikowa from the beginning of 1942 to the period of the last observation book received (March 1946).
M. Korotaeva from May 1942 to March 1946.
G. Lange intermittently from the beginning of 1944.

At Carloforte:

G. Righini from the beginning of the period until December 1939.
M. Mattana from the beginning of the period until June 1941.
T. Nicolini from July to October 1941 and June to October 1946.
A. Colacevich from January to the end of April 1940.
N. Missana-Rudari from July 1941 to April 1943.
M. Castellano from October 1941 to December 1941 and from June 1946 to date.

At Gaithersburg:

E. L. Williams for the whole period.

At Ukiah:

H. G. Wrocklage from the beginning until the end of August 1946.
L. F. Canvette from December 1946 to date.

At Adelaide:

R. V. Burton from the beginning until August 1940 when observations ceased.

At La Plata:

V. Manganiello from the beginning until October 1942.
T. Agabios, from September 1942 until the end of June 1943.
R. Lassalle from July 1944 until the end.

At Batavia:

E. A. Scharpff from beginning to March 1940, the last month for which we received observations.
Schulte in the first months of 1938.
Poldervaart from December 1938 to the first month of 1939.
Ch. M. Kalkmann from February to December 1939.
K. Gsoellpointner from March to December 1939.
Poels the first three months of 1940.

All the stations, unfortunately, were subject during these years to more or less prolonged interruptions for different reasons, with the exception of Mizusawa and perhaps also Kitab. From this last station we have not received any observation books since April 1946. It is to be hoped that the work of observation has continued and that soon, with the support of the authorities and bodies which are trying to re-establish cultural exchanges with the U.S.S.R. we may be able to receive the observations since March 1946. Russian Science has made an important contribution to the work of the International Latitude Service since 1899, first with the station of Tschardjui and then later of Kitab. The Kitab observations would be particularly valuable for the months in 1946 during which we have not at our disposal either the observations of Carloforte or those of Ukiah.* But the station that was particularly missed during these years was Carloforte; the lack of suitable and willing staff, which already was much felt during 1939 when three months of valuable observations were lost by incapacity or apathy in installing and adjusting the zenith telescope after the overhaul and repair done by the Officine Galileo of Florence, was fully manifest in the following year 1940, when during August, without any reason, the observations were completely stopped, and it was not possible to start them again until the beginning of July 1941.

In June 1938 the large zenith telescope which had been in use for 39 years and was in need of complete overhaul in every part, had to be exchanged with another one of the same make of a somewhat smaller dimension, which was obtained on loan from the Astronomical Observatory of the Palermo University. This instrument was in use from June 1938 until the end of March 1939. The recommencement of regular observations, entrusted in the second half of 1941 to conscientious staff, was soon hampered by the war, which in the spring of 1943 had assumed such violence as to necessitate the closing down of the Observatory. Later on, at the end of hostilities, every effort was made for an early resumption of work, but the assurances and promises of the ministries in Rome, and even the intervention of Colonel Washburn, met with so many obstacles that not until the spring of 1946 was it possible to begin the repairs at the station and the reinstallation of the instruments, enabling the observations to be recommenced. Even now, at the time of writing, the staff necessary for the regular functioning of the station has not been allocated.

For the station of Gaithersburg we deplore an instrumental fault in the micrometer which at the beginning was unnoticed (movement of the micrometer head with respect to the screw itself). This fault developed later to such an extent as to render suspect the observations of the last three months of 1941, compelling us to reject completely the results obtained in December 1941. Once the fault was repaired it was noticed that the displacement of the position of the movable wire with respect to the readings had necessarily affected the determinations of the progressive errors of the screw and it was necessary to reduce the observations without taking these errors into account.

In the second half of 1946 Mr H. G. Wrocklage, observer at Ukiah, who had spent many years at the station and had attained an exceptional standard of observing, had a sudden illness which interrupted the observations for three months (September to November 1946). From December 1946 the regular work was taken up in a commendable manner by Mr Canvette. We have already referred to the destruction of the Batavia Observatory. We deplore what has happened, which has deprived our research of such an important contribution. It is hoped that the archives of the station have not been lost and that the details of the observations since March 1940 (the date of the latest observations to reach us) will be available, and that in the near future we shall see the station reopened.

From Adelaide we received, at the end of the war, the observation books which extend up to August 1940, when observations were stopped, the telescope being then returned to Mizusawa, the period of loan having expired. The renewal of the loan and the resumption of observations is under consideration. It is hoped that this will prove possible, because

* [The Kitab observation books from March 1946 to September 1947 have been received since the report was written. H. S. J.]

the combination of the observations at Adelaide with those at La Plata adds greatly to the weight with which the polar motion is determined. The station of La Plata, thanks to the great interest of their observers and particularly of Ing. V. Manganiello, and of the directors Aguilar, Manganiello and Wallbrecher, has continued observations for the whole period except for a few months in 1947, when it was necessary to interrupt them for a complete overhaul of the instrument. Now Director Wallbrecher is considering the installation of a photographic instrument.

As far as Mizusawa is concerned we have nothing to say except to mention the loss of the founder of the station, Prof. Kimura, who directed the observatory with great ability until his death, and of his collaborators S. Kawasaki (from April 1922) and M. Yamasaki (from April 1924).

The actual work of observation achieved by the different stations during the nine years is summarized in the following Table in which we give the total number of pairs of stars observed in each year at the individual stations:

TABLE I

	1938	1939	1940	1941	1942	1943	1944	1945	1946	Total
Mizusawa	1,166	1,464	1,510	1,205	1,373	1,220	1,208	1,178	1,339	11,663
Kitab	1,298	1,325	1,677	1,315	1,310	1,909	2,077	1,549	315**	12,775
Carloforte	1,699	872*	597†	875‖	1,322	197¶	—	—	910††	6,472
Gaithersburg	1,313	1,307	1,253	1,433	1,232	1,440	1,370	1,053	1,558	11,959
Ukiah	1,336	1,468	1,205	1,188	1,145	1,221	1,454	1,541	1,221	11,779
Adelaide	1,280	1,501	530‡	—	—	—	—	—	—	3,311
La Plata	1,582	1,125	890	1,058	841	521	1,045	253‡‡	—‡‡	7,315
Batavia	1,937	1,962	267§	—	—	—	—	—	—	4,166
	11,611	11,024	7,929	7,074	7,223	6,508	7,154	5,574	5,343	69,440

* Of low weight because the three months April, May and June are completely missing and the remaining months are of poor quality.

† Only the first eight months and exceptionally poor even during months of the most favourable weather.

‡ Only the first eight months of the year.

‖ Only the second half of the year.

§ Only the first three months of the year.

¶ Only the first three months of the year.

** Only the first three months: presumably the work has been carried on but the observations have not been received.

†† Only from June to December.

‡‡ Only the months of January and February. The note-books of observations for other months up to March 1947 have reached us in the form of microfilms, but they have not been computed on account of difficulties in utilizing these copies. Thanks to the kind interest shown by the Director of the Military Geographical Institute of Florence we shall shortly have copies sufficiently clear and we shall proceed with the computation of these observations.

The values of the monthly mean latitudes obtained from the two groups of observations at the different stations are to be found in the following Tables where the number of pairs used for the mean are stated. Tables II and III contain the results of the northern stations and Tables IV and V those of the southern stations; for both groups we have separated the evening observations from the morning. The latitudes were calculated in the usual manner, keeping unchanged for the whole of 1940 the values already adopted for the levels, for the scale of the micrometer screws and for the progressive and periodical errors. After 1940, while keeping the same values for the levels and the errors of the micrometer screws, we adopted slightly different values for the screw-values based on the results of the definitive reductions of the observations in the years 1935–40. The mean positions and proper motions of the stars used up to the end of 1940 were based on a communication by Prof. Kimura, before the Albany *General Catalogue* had been received. When I started the definitive calculations the data received from Kimura were compared with the *General Catalogue*; while there was on the whole very good agreement,

TABLE II
Evening

Epoch	Group	Mizusawa		Kitab		Carloforte		Gaithersburg		Ukiah	
		ϕ	Obs.	ϕ	Obs.	ϕ	Obs.	ϕ	Obs.	ϕ	Obs.
		″		″		″		″		″	
1938·06	IV	3·775	27	1·825	38	8·817	99	13·334	34	12·240	28
·14	V	·444	58	·615	22	·733	76	·247	45	·135	36
·23	VI	·508	57	·764	47	·876	91	·354	67	·386	25
·31	VII	·410	46	·599	68	·779	78	·350	71	·298	52
·39	VIII	·266	62	·593	82	·756	99	·253	38	·217	76
·47	IX	·165	9	·400	65	·670	95	·159	64	·044	72
·55	X	·180	49	·603	81	9·026	124	·225	52	·134	84
·64	XI	·328	38	·794	93	·235	81	·431	111	·172	84
·72	XII	·438	69	·861	100	·156	68	·478	46	·170	75
·80	I	·550	73	·823	59	·120	43	·433	80	·152	54
·88	II	·438	59	·733	29	8·863	52	·107	55	11·959	48
·97	III	·762	43	·687	20	9·017	20	·395	45	12·203	46
1939·06	IV	3·638	57	1·711	12	8·885	22	13·408	24	12·230	50
·14	V	·472	54	·659	53	·696	44	·102	47	·076	41
·22	VI	·574	85	·739	65	·852	22	·364	68	·342	52
·31	VII	·421	108	·615	50	—	—	·280	65	·261	60
·39	VIII	·307	62	·621	73	—	—	·223	83	·153	60
·47	IX	·190	55	·404	78	—	—	·224	51	·021	72
·56	X	·200	69	·622	62	·907	109	·298	66	·161	83
·64	XI	·334	46	·725	84	9·145	69	·428	42	·179	78
·73	XII	·377	49	·838	57	·178	38	·434	63	·161	71
·80	I	·475	64	·760	68	·316	70	·482	82	·141	78
·89	II	·284	65	·667	46	8·952	70	·167	68	11·977	72
·97	III	·638	65	·866	53	9·182	37	·395	50	12·152	23
1940·06	IV	3·630	76	1·788	29	9·018	31	13·336	45	12·113	35
·14	V	·564	52	·710	47	8·708	71	·067	31	·075	34
·22	VI	·619	52	·834	79	·870	59	·297	55	·274	42
·31	VII	·488	77	·744	68	·718	46	·319	57	·275	48
·39	VIII	·344	99	·639	99	·608	35	·274	51	·180	54
·47	IX	·161	85	·409	94	·655	36	·231	50	·060	72
·56	X	·145	41	·760	74	·825	38	·276	61	·135	70
·64	XI	·540	45	·864	100	9·057	34	·471	49	·201	59
·73	XII	·411	85	·779	92	—	—	·479	90	·187	66
·80	I	·453	98	·747	86	—	—	·418	65	·183	45
·89	II	·463	38	·740	52	—	—	·179	42	11·963	62
·97	III	·625	52	·812	47	—	—	·488	49	12·243	30
1941·07	IV	3·557	50	1·793	28	—	—	13·220	38	12·147	41
·14	V	·399	35	·727	83	—	—	·148	58	·006	41
·22	VI	·614	50	·811	46	—	—	·367	53	·245	48
·30	VII	·468	72	·727	46	—	—	·237	80	·224	40
·39	VIII	·358	69	·699	55	—	—	·173	72	·142	48
·47	IX	·265	46	·577	61	—	—	·220	85	·132	60
·56	X	·308	13	·623	108	8·774	78	·221	60	·100	72
·64	XI	·304	34	·756	104	·948	110	·423	62	·244	72
·71	XII	·351	39	·827	90	·976	92	·430	102	·225	59
·79	I	·380	82	·784	26	9·087	62	·378	58	·231	53
·88	II	·272	62	·785	18	8·924	86	·240	70	·015	42
·96	III	·531	57	·892	9	·933	41	(·627)	26	·264	36
1942·07	IV	3·406	41	2·078	11	8·905	28	13·364	26	12·141	24
·14	V	·368	39	1·607	25	·788	33	·215	44	11·995	48
·22	VI	·504	65	·961	18	9·034	53	·332	49	12·153	36
·30	VII	·411	78	·708	51	8·916	55	·217	68	·161	36
·39	VIII	·419	91	·706	87	·861	51	·149	63	·035	41
·47	IX	·313	83	·632	34	·839	63	·123	83	·037	48

TABLE II (*continued*)

Evening

Epoch	Group	Mizusawa φ	Obs.	Kitab φ	Obs.	Carloforte φ	Obs.	Gaithersburg φ	Obs.	Ukiah φ	Obs.
		″		″		″		″		″	
1942·56	X	3·375	50	2·582	66	8·825	122	13·140	58	12·022	78
·64	XI	·521	78	·792	98	·935	45	·280	60	·160	72
·71	XII	·504	50	·785	92	·960	89	·387	59	·220	60
·79	I	·533	60	·666	76	·995	61	·343	66	·247	60
·88	II	·403	42	·458	86	·846	45	·202	37	·080	47
·96	III	·510	49	·848	44	9·071	53	·571	28	·345	36
1943·06	IV	3·389	63	1·773	80	8·940	37	13·439	41	12·274	48
·14	V	·282	31	·526	41	·843	34	·301	51	·084	40
·23	VI	·424	71	·790	44	9·051	40	·473	89	·255	54
·31	VII	·400	72	·733	70	—	—	·303	70	·129	36
·39	VIII	·288	61	·640	88	—	—	·234	58	11·976	60
·47	IX	·225	54	·684	135	—	—	·158	58	·903	66
·56	X	·343	58	·711	106	—	—	·103	56	·929	64
·64	XI	·466	53	·852	124	—	—	·226	75	12·028	72
·72	XII	·521	22	·892	110	—	—	·275	74	·099	71
·80	I	·592	92	·818	89	—	—	·159	70	·171	48
·90	II	·247	27	·713	80	—	—	·070	64	·071	37
·98	III	·515	35	·872	38	—	—	·309	38	·469	24
1944·06	IV	3·522	42	1·731	53	—	—	13·287	66	12·327	42
·14	V	·347	34	·499	101	—	—	·247	54	·144	36
·23	VI	·505	43	·706	76	—	—	·440	59	·329	71
·31	VII	·326	46	·670	95	—	—	·338	56	·184	48
·39	VIII	·243	71	·721	99	—	—	·281	69	·065	54
·48	IX	·076	48	·692	112	—	—	·263	81	·003	60
·56	X	·222	50	·795	138	—	—	·190	45	11·873	84
·64	XI	·380	65	2·005	110	—	—	·234	90	·926	96
·72	XII	·609	64	·082	107	—	—	·144	39	·963	84
·81	I	·637	97	1·948	98	—	—	·025	80	12·026	60
·89	II	·442	61	·684	68	—	—	12·984	41	11·845	60
·98	III	·711	33	·928	30	—	—	13·292	32	12·331	50
1945·06	IV	3·587	65	1·772	51	—	—	13·148	36	12·382	53
·14	V	·540	39	·556	54	—	—	·144	42	·200	54
·22	VI	·573	51	·683	60	—	—	·388	48	·446	48
·31	VII	·307	89	·553	69	—	—	·381	71	·360	72
·39	VIII	·231	72	·486	80	—	—	·396	65	·206	56
·47	IX	·046	46	·491	107	—	—	·291	46	·121	84
·55	X	·046	48	·680	77	—	—	·264	37	·030	102
·64	XI	·167	53	·868	106	—	—	·257	58	·064	89
·72	XII	·325	22	2·041	80	—	—	·299	23	·013	81
·80	I	·470	47	·158	60	—	—	·185	66	11·948	80
·90	II	·442	65	1·692	20	—	—	12·945	33	·695	30
·97	III	·661	27	2·090	44	—	—	13·028	28	12·032	45
1946·06	IV	3·777	47	2·054	48	—	—	13·170	65	12·231	69
·14	V	·626	55	1·737	64	—	—	12·984	70	·077	70
·22	VI	·719	59	·830	58	—	—	13·246	68	·268	51
·30	VII	·497	92	—	—	—	—	·303	42	·357	84
·39	VIII	·312	53	—	—	—	—	·255	49	·217	72
·48	IX	·159	69	—	—	8·685	54	·287	35	·248	84
·56	X	·015	50	—	—	·869	120	·312	57	·174	88
·64	IX	·160	64	—	—	9·038	57	·423	76	·231	48
·72	XII	·242	53	—	—	·246	84	·503	95	—	—
·81	I	·297	72	—	—	·251	63	·426	72	—	—
·89	II	·255	51	—	—	·116	41	·125	70	—	—
·97	III	·486	38	—	—	·340	48	·359	28	·161	65

TABLE III

Morning

Epoch	Group	Mizusawa		Kitab		Carloforte		Gaithersburg		Ukiah	
		ϕ	Obs.	ϕ	Obs.	ϕ	Obs.	ϕ	Obs.	ϕ	Obs.
		"		"		"		"		"	
1938·07	V	3·568	25	1·612	34	8·687	78	13·193	20	12·155	26
·14	VI	·635	54	·807	18	·901	63	·394	32	·359	35
·23	VII	·497	65	·718	46	·740	83	·360	65	·363	24
·31	VIII	·392	44	·586	65	·847	61	·314	70	·245	48
·39	IX	·182	49	·370	49	·678	90	·174	43	·126	77
·47	X	·222	15	·508	64	·753	80	·289	64	·149	72
·56	XI	·355	39	·685	77	9·157	114	·447	37	·228	84
·64	XII	·362	51	·726	81	·265	71	·519	98	·238	78
·73	I	·420	61	·735	71	·271	49	·392	38	·154	77
·80	II	·402	89	·708	48	8·879	40	·156	81	11·958	53
·88	III	·631	49	·925	23	9·046	38	·460	26	12·182	47
·98	IV	·698	35	·858	18	8·736	6	·223	31	·158	35
1939·06	V	3·485	52	1·766	12	8·740	9	13·054	12	12·034	46
·14	VI	·657	56	·901	47	·870	29	·349	41	·328	42
·22	VII	·507	81	·669	62	·844	26	·352	62	·332	47
·31	VIII	·388	83	·658	45	—	—	·307	59	·210	60
·40	IX	·194	46	·283	73	—	—	·275	62	·041	60
·47	X	·294	43	·554	71	—	—	·305	28	·140	72
·56	XI	·360	56	·670	55	9·037	102	·461	56	·252	86
·64	XII	·382	43	·723	73	·202	57	·485	44	·190	78
·73	I	·502	50	·737	54	·267	31	·506	48	·143	72
·80	II	·339	59	·722	46	8·979	62	·216	75	11·942	77
·89	III	·533	67	·814	34	9·343	53	·453	64	12·215	71
·97	IV	·550	49	·844	52	·111	22	·335	47	·120	19
1940·06	V	3·459	73	1·700	19	8·757	19	13·071	41	12·013	30
·14	VI	·688	47	·902	32	·988	42	·311	28	·261	32
·22	VII	·584	50	·800	71	·787	43	·291	58	·252	42
·31	VIII	·470	56	·689	73	·677	42	·285	55	·256	48
·39	IX	·264	82	·407	88	·619	20	·072	51	·127	54
·47	X	·268	72	·611	93	·846	22	·349	44	·199	70
·56	XI	·349	21	·736	74	·953	89	·450	60	·293	66
·64	XII	·591	34	·755	97	9·095	20	·557	44	·234	60
·73	I	·394	80	·626	82	—	—	·510	81	·187	66
·80	II	·260	92	·700	86	—	—	·185	64	11·967	39
·89	III	·534	40	·799	48	—	—	·550	41	12·219	51
·97	IV	·541	63	·847	47	—	—	·480	41	·149	30
1941·07	V	3·411	45	1·815	23	—	—	13·246	31	11·954	38
·14	VI	·685	33	·900	80	—	—	·293	47	12·277	32
·22	VII	·501	57	·790	45	—	—	·273	57	·077	41
·30	VIII	·518	66	·762	39	—	—	·214	89	·195	37
·39	IX	·369	59	·636	56	—	—	·154	73	·211	48
·47	X	·381	60	·631	67	—	—	·195	66	·354	59
·56	XI	·314	11	·692	102	8·907	72	·376	61	·333	72
·64	XII	·418	25	·802	94	·957	101	·486	65	·234	67
·71	I	·419	42	·721	83	9·059	68	·457	91	·203	60
·79	II	·286	83	·683	23	8·882	63	·201	61	·000	52
·88	III	·379	71	·811	18	9·014	76	·434	54	·370	40
·96	IV	·437	54	·902	11	8·980	26	(·186)	30	·064	30
1942·07	V	3·395	44	1·545	10	8·811	18	13·141	38	12·068	23
·14	VI	·600	38	·989	21	·974	16	·436	44	·246	42
·22	VII	·499	56	·744	18	·928	35	·147	32	·101	36
·30	VIII	·462	82	·639	36	·884	40	·192	72	·090	30
·39	IX	·318	64	·607	78	·851	49	·163	68	·068	42
·47	X	·407	68	·588	25	·917	57	·176	71	·073	48

TABLE III (*continued*)

Morning

Epoch	Group	Mizusawa φ	Mizusawa Obs.	Kitab φ	Kitab Obs.	Carloforte φ	Carloforte Obs.	Gaithersburg φ	Gaithersburg Obs.	Ukiah φ	Ukiah Obs.
		"		"		"		"		"	
1942·56	XI	3·482	36	1·731	72	8·963	115	13·273	56	12·129	78
·64	XII	·542	57	·744	97	·944	105	·345	47	·218	72
·71	I	·535	51	·610	90	·988	83	·440	55	·226	60
·79	II	·377	51	·434	61	·820	62	·273	54	·076	60
·88	III	·547	53	·798	71	9·117	39	·472	39	·341	35
·96	IV	·430	47	·776	43	8·922	25	·465	15	·321	33
1943·06	V	3·348	49	1·567	72	8·933	23	13·356	40	12·113	48
·14	VI	·459	29	2·154	29	·953	26	·501	43	·273	42
·23	VII	·406	65	1·759	27	9·002	37	·381	35	·147	54
·31	VIII	·344	80	·704	60	—	—	·248	65	·038	35
·39	IX	·274	62	·640	80	—	—	·300	37	11·958	60
·47	X	·382	42	·669	126	—	—	·204	55	·964	66
·56	XI	·487	38	·804	101	—	—	·258	50	·988	60
·64	XII	·448	62	·830	121	—	—	·292	73	12·058	71
·72	I	·586	20	·841	95	—	—	·195	85	·130	66
·80	II	·363	74	·627	89	—	—	·111	56	11·981	39
·90	III	·636	31	·816	74	—	—	·320	61	12·313	36
·98	IV	·517	29	·829	30	—	—	·188	45	·289	24
1944·06	V	3·271	45	1·538	54	—	—	13·220	57	12·176	36
·14	VI	·350	32	·711	83	—	—	·347	40	·394	36
·23	VII	·367	30	·641	70	—	—	·371	54	·276	63
·32	VIII	·289	41	·580	82	—	—	·341	43	·196	48
·39	IX	·130	64	·552	92	—	—	·317	45	·038	53
·48	X	·167	37	·727	106	—	—	·279	80	·001	60
·56	XI	·338	40	·890	125	—	—	·314	43	11·967	81
·64	XII	·388	57	2·010	113	—	—	·261	111	12·024	96
·72	I	·465	52	2·004	86	—	—	·149	33	·029	84
·81	II	·464	69	1·748	92	—	—	12·918	78	11·848	53
·89	III	·801	54	·986	59	—	—	13·184	42	12·206	58
·98	IV	·647	34	·810	28	—	—	·059	32	·258	41
1945·06	V	3·488	59	1·621	52	—	—	13·123	30	12·206	47
·14	VI	·631	34	·797	48	—	—	·301	32	·478	53
·22	VII	·467	62	·600	59	—	—	·295	46	·438	48
·31	VIII	·393	78	·449	65	—	—	·346	54	·331	72
·40	IX	·142	65	·491	60	—	—	·368	57	·182	53
·48	X	·122	37	·453	102	—	—	·438	39	·098	84
·55	XI	·355	30	·726	70	—	—	·464	17	·107	102
·64	XII	·245	42	·883	107	—	—	·265	52	·133	80
·72	I	·400	18	2·013	68	—	—	·280	23	·029	75
·81	II	·351	33	1·832	60	—	—	12·989	84	11·711	62
·89	III	·700	65	2·233	15	—	—	13·172	38	12·005	27
·97	IV	·596	31	2·035	35	—	—	·212	28	·091	44
1946·06	V	3·658	45	1·772	38	—	—	12·984	65	12·044	63
·14	VI	·719	37	·818	53	—	—	13·186	45	·297	60
·22	VII	·681	61	·670	54	—	—	·216	71	·358	41
·31	VIII	·500	73	—	—	—	—	·255	51	·295	82
·39	IX	·269	52	—	—	—	—	·286	68	·270	66
·48	X	·220	65	—	—	8·745	54	·334	54	·215	85
·56	XI	·142	35	—	—	·954	113	·422	79	·306	88
·64	XII	·210	56	—	—	9·107	59	·562	92	·296	48
·72	I	·105	56	—	—	·107	82	·377	106	—	—
·81	II	·106	65	—	—	·085	60	·212	79	—	—
·89	III	·526	50	—	—	·395	37	·484	86	—	—
·97	IV	·488	41	—	—	·246	38	·267	35	·129	57

TABLE IV

Evening

Epoch	Group	Adelaide φ	Adelaide Obs.	La Plata φ	La Plata Obs.	Batavia φ	Batavia Obs.
		"		"		"	
1938·06	IV	36·547	40	31·781	74	38·167	64
·14	V	·692	59	·887	75	·434	29
·23	VI	·776	76	·848	54	·535	68
·30	VII	37·091	43	32·127	48	·830	87
·39	VIII	·026	67	31·825	91	·951	59
·47	IX	36·984	36	·795	65	·747	73
·55	X	·767	28	·629	86	·236	119
·64	XI	·724	32	·539	78	·387	108
·72	XII	·895	90	·838	94	·690	111
·81	I	·657	70	·675	80	·166	91
·88	II	·344	67	·592	64	·070	63
·97	III	·677	73	·985	64	·367	71
1939·06	IV	36·539	104	31·870	57	38·103	49
·14	V	·682	76	·967	69	·324	73
·22	VI	·626	80	·884	71	·458	85
·30	VII	37·124	60	32·240	90	·599	62
·39	VIII	36·997	69	31·920	41	·815	86
·47	IX	·988	75	·810	47	·750	82
·55	X	·943	66	·606	40	·250	78
·64	XI	·760	27	·495	34	·444	57
·73	XII	·953	88	·773	33	·754	91
·81	I	·735	69	·463	54	·252	101
·88	II	·473	35	·579	44	·262	91
·97	III	·673	37	·924	61	·593	66
1940·05	IV	36·579	55	31·826	36	37·966	37
·15	V	·719	41	·918	82	38·033	49
·22	VI	·591	28	·897	52	·095	39
·30	VII	·958	26	32·226	51	—	—
·40	VIII	·982	37	31·882	32	—	—
·47	IX	·929	35	·729	31	—	—
·56	X	·763	15	·620	44	—	—
·62	XI	·793	10	·520	47	—	—
·72	XII	—	—	·801	31	—	—
·82	I	—	—	·587	39	—	—
·88	II	—	—	·431	34	—	—
·97	III	—	—	·842	54	—	—
1941·05	IV	—	—	31·773	70	—	—
·15	V	—	—	·857	44	—	—
·23	VI	—	—	·912	43	—	—
·32	VII	—	—	32·167	42	—	—
·39	VIII	—	—	·953	38	—	—
·47	IX	—	—	·783	52	—	—
·56	X	—	—	·771	31	—	—
·65	XI	—	—	·509	50	—	—
·72	XII	—	—	·816	61	—	—
·81	I	—	—	·575	76	—	—
·89	II	—	—	·421	62	—	—
·98	III	—	—	·801	68	—	—

Epoch	Group	La Plata φ	La Plata Obs.
		"	
1942·05	IV	31·708	53
·15	V	·913	49
·21	VI	·849	43
·31	VII	32·228	50
·39	VIII	·033	32
·47	IX	31·967	28
·56	X	·960	29
·64	XI	·667	29
·72	XII	32·010	48
·80	I	31·717	52
·89	II	·451	67
·97	III	·739	34
1943·07	IV	31·608	28
·15	V	·791	58
·22	VI	·661	37
·31	VII	32·033	29
·39	VIII	31·890	29
·45	IX	·750	6
·55	X	·829	32
·64	XI	·780	21
·73	XII	·919	27
·80	I	32·104	32
·91	II	31·588	23
·95	III	32·010	1
1944·06	IV	31·696	28
·14	V	·623	12
·22	VI	·708	98
·31	VII	32·026	73
·38	VIII	31·793	48
·50	IX	·774	27
·55	X	·615	18
·66	XI	·635	42
·71	XII	·928	65
·81	I	·909	33
·89	II	·685	77
·99	III	32·039	53
1945·07	IV	31·853	60
·14	V	·944	81

TABLE V

Morning

Epoch	Group	Adelaide φ	Adelaide Obs.	La Plata φ	La Plata Obs.	Batavia φ	Batavia Obs.
		"		"		"	
1938·06	V	36·612	38	31·935	50	38·421	59
·14	VI	·633	63	·871	61	·491	42
·23	VII	37·126	72	32·256	39	·731	77
·30	VIII	36·921	33	31·970	36	·934	94
·39	IX	·904	48	·788	76	·839	71
·47	X	·908	32	·667	60	·268	77
·55	XI	·703	27	·523	71	·456	97
·64	XII	·929	34	·719	55	·774	124
·72	I	·741	75	·645	83	·246	129
·81	II	·452	59	·533	64	·213	103
·88	III	·709	52	·925	54	·543	47
·97	IV	·544	66	·950	60	·103	82
1939·06	V	36·640	100	31·994	51	38·380	45
·14	VI	·616	78	·928	46	·333	72
·22	VII	37·005	99	32·249	61	·615	95
·30	VIII	36·930	59	31·990	66	·757	86
·37	IX	·926	47	·877	29	·649	94
·47	X	·846	64	·721	30	·219	111
·55	XI	·724	45	·442	23	·525	73
·64	XII	·975	32	·734	21	·754	77
·73	I	·729	75	·569	25	·364	107
·81	II	·522	59	·252	35	·289	104
·88	III	·756	32	·888	48	·636	101
·97	IV	·575	25	·932	39	·210	75
1940·05	V	36·571	53	31·888	33	38·023	23
·15	VI	·676	40	·892	47	37·833	58
·22	VII	·880	27	32·266	40	38·430	61
·30	VIII	·772	24	32·016	35	—	—
·40	IX	·805	46	31·948	15	—	—
·47	X	·845	40	·646	22	—	—
·56	XI	·969	9	·617	39	—	—
·62	XII	37·002	18	·683	28	—	—
·72	I	—	—	·533	16	—	—
·82	II	—	—	·400	13	—	—
·88	III	—	—	·842	15	—	—
·97	IV	—	—	·831	54	—	—
1941·05	V	—	—	31·835	48	—	—
·15	VI	—	—	·685	32	—	—
·24	VII	—	—	32·231	24	—	—
·32	VIII	—	—	31·983	29	—	—
·39	IX	—	—	·951	30	—	—
·47	X	—	—	·770	27	—	—
·56	XI	—	—	·578	24	—	—
·65	XII	—	—	·737	35	—	—
·73	I	—	—	·509	46	—	—
·81	II	—	—	·379	54	—	—
·89	III	—	—	·864	34	—	—
·97	IV	—	—	·723	38	—	—

Epoch	Group	La Plata φ	La Plata Obs.
		"	
1942·05	V	31·788	36
·15	VI	·837	40
·21	VII	32·205	21
·32	VIII	·009	22
·39	IX	·109	15
·47	X	31·816	17
·55	XI	·860	13
·64	XII	·978	15
·72	I	·791	28
·80	II	·541	33
·89	III	·780	68
·97	IV	·623	17
1943·07	V	31·721	26
·15	VI	·642	36
·21	VII	·941	18
·31	VIII	·851	14
·40	IX	·857	18
—	X	—	—
·58	XI	·753	15
·63	XII	·970	12
·74	I	·855	14
·79	II	·511	31
·93	III	32·075	14
—	IV	—	—
1944·07	V	31·726	9
·15	VI	·624	9
·23	VII	32·085	94
·32	VIII	31·794	57
·38	IX	·783	42
·49	X	·587	24
·54	XI	·563	10
·65	XII	·887	41
·70	I	·785	43
·81	II	·684	29
·89	III	32·079	65
·99	IV	31·958	48
1945·06	V	31·966	39
·15	VI	·765	73

TABLE VI

North—Evening

Epoch	Group	Mizusawa φ″	Mizusawa Obs.	Kitab φ″	Kitab Obs.	Carloforte φ″	Carloforte Obs.	Gaithersburg φ″	Gaithersburg Obs.	Ukiah φ″	Ukiah Obs.
1935·06	IV	3·657	42	1·897	5	8·915	42	13·494	54	12·236	56
·14	V	·345	59	·709	47	·890	40	·159	61	·034	26
·23	VI	·547	63	·812	31	·977	80	·340	61	·272	59
·30	VII	·373	79	·782	50	·912	90	·231	50	·138	70
·39	VIII	·292	78	·673	74	·834	75	·199	94	·083	67
·47	IX	·163	42	·487	70	·645	133	·044	68	11·957	55
·56	X	·284	53	·759	52	·808	156	·159	64	12·019	94
·64	XI	·499	59	·839	89	·940	149	·355	36	·232	96
·72	XII	·503	42	·831	63	·945	74	·474	68	·240	78
·80	I	·567	87	·788	62	·941	31	·573	69	·232	72
·89	II	·567	73	·653	48	·850	29	·224	53	·120	60
·97	III	·734	39	·896	49	9·032	26	·596	42	·338	39
	Totals		716		640		925		720		772

North—Morning

Epoch	Group	Mizusawa φ″	Mizusawa Obs.	Kitab φ″	Kitab Obs.	Carloforte φ″	Carloforte Obs.	Gaithersburg φ″	Gaithersburg Obs.	Ukiah φ″	Ukiah Obs.
1936·06	V	3·380	43	1·646	5	8·831	31	13·246	34	12·081	48
·14	VI	·645	48	·934	45	9·018	42	·257	44	·306	21
·23	VII	·451	78	·803	28	8·928	76	·285	46	·171	55
·30	VIII	·390	77	·721	48	·858	69	·150	53	·122	70
·39	IX	·244	69	·572	60	·677	53	·167	82	11·998	59
·47	X	·275	32	·669	63	·827	126	·206	71	12·094	54
·56	XI	·434	28	·917	59	·964	124	·373	40	·229	96
·64	XII	·539	40	·812	96	·951	136	·539	23	·235	96
·72	I	·511	34	·765	59	·976	66	·576	60	·278	77
·81	II	·423	69	·733	54	·794	19	·215	53	·057	71
·90	III	·616	76	·826	44	9·028	13	·526	42	·365	56
·97	IV	·634	47	·929	40	8·945	19	·526	30	·267	36
	Totals		641		601		774		578		739

South—Evening

Epoch	Group	Adelaide φ″	Adelaide Obs.	La Plata φ″	La Plata Obs.
1935·06	IV	36·647	84	31·722	122
·14	V	·785	92	·816	114
·23	VI	·726	63	·717	132
·30	VII	37·053	32	32·069	111
·39	VIII	36·895	56	31·925	86
·47	IX	·914	28	·863	95
·56	X	·894	40	·785	99
·64	XI	·710	85	·633	78
·73	XII	·868	44	·920	81
·81	I	·664	75	·745	76
·89	II	·461	69	·558	88
·97	III	·699	55	·831	78
	Totals		723		1160

South—Morning

Epoch	Group	Adelaide φ″	Adelaide Obs.	La Plata φ″	La Plata Obs.
1935·06	V	36·743	82	31·804	111
·14	VI	·661	95	·773	94
·23	VII	37·052	70	32·104	117
·30	VIII	36·859	23	31·887	98
·39	IX	·860	47	·847	62
·48	X	·843	18	·754	68
·56	XI	·731	38	·709	85
·64	XII	·886	76	·878	45
·73	I	·713	42	·800	64
·81	II	·420	72	·626	60
·89	III	·713	61	·909	70
·97	IV	·653	57	·745	68
			709		928

in two instances I found a sensible difference; in the declination and proper motions of star 1 of the pair 51 (group IX) and of star 1 of the pair 65 (group XI). The first leads to a difference of $+0''{\cdot}48$ in the mean declination of the pair and a change of this amount in the latitudes derived from it; and in consequence a difference of about $+0''{\cdot}08$ to the mean latitude obtained from that group, from the epoch 1940 when we adopted the data of the *General Catalogue* in the calculation of the ephemerides. The second discrepancy results in a decrease in the value for the latitude obtained with the pair of about $0''{\cdot}085$ also from 1940, and in a decrease of $0''{\cdot}014$ for the mean latitude of the group. The values which we give for 1940 are referred to the declinations of the previous years, but not the values for the years 1941–46; this gives rise to the difference between the values of z obtained for the groups IX and XI in the first years and the last years.

It may be recalled that following a decision taken at Stockholm by our Commission the Central Bureau was entrusted with the final calculation of the observations made during 1935 at the International stations, because from the beginning of that year the present programme of observation, slightly different from that of the previous years, was adopted. In order that the results for that year should be on a uniform basis with those of the following years, all the observations taken in 1935 have been recomputed. The results are summarized in Table VI in a similar manner to those for the years 1938–46.

Using the values of the mean latitude adopted in the previous years for each of the different stations, the instantaneous co-ordinates x and y of the North Pole of rotation and the z term were calculated for the mean epoch of the observation of each group, for the morning and evening observations separately. This separation is necessary, because the z term depends on effects of a diverse nature and, in particular, on the corrections to the adopted declinations of the stars. This effect has a magnitude greater than all the others and a value which is characteristic of each group, as is seen by comparing, in Table VII, the value of z derived from the morning observations in any month with the value derived from the evening observations in the following month, the same group of stars being observed. In Table VII are given the values found for the co-ordinates x and y of the pole from morning and evening observations, together with the mean values; also the values of z from morning and evening observations, together with the mean values for the same group but in consecutive months.

It may be remembered that when it was possible to use the results from Adelaide and La Plata to supplement those of the northern stations, the instantaneous co-ordinates of the pole were derived not only in the customary manner but also by taking into account the southern observations, so obtaining results which have greater weight. The advantage of including the results of the southern observations becomes more apparent the smaller the polar motion, as the magnitude of the residual errors of observation then approximates more nearly to the amplitude of displacements of the instantaneous pole from the mean pole. It would be very advantageous if the co-operation of the two southern stations were permanent. But, as we have already stated, the observations at Adelaide were discontinued in 1940 and the inclusion of the observations from La Plata only would be of little, if any, value. However, as the calculations were made for 1935 and subsequently for the years 1938 and 1939 in this manner, i.e. taking into account all the seven stations, we give in Table VIII the values for 1935, obtained from the northern stations only, and in Table IX those for the same years 1935, 1938 and 1939, obtained from all the seven stations.

The agreement between the two values of the co-ordinates X and Y, obtained from the evening and morning groups is generally satisfactory, but it is apparent how noticeably the agreement is affected by lack of or extreme poorness in observations at times at some stations, which by their geographical position affect noticeably the determination of one or other of the co-ordinates.

Thus it is clear that the X values become less accordant when there is a noticeable decrease in the number of observations at Carloforte, as is usually the case in the winter months, or, worse still, when the observations are missing altogether, while the lack of

TABLE VII

Northern Stations

Epoch	Group	X			Y			Z		
		E.	M.	Mean	E.	M.	Mean	E.	M.	Mean
		″	″	″	″	″	″	″	″	″
1937·97	III–IV	—	—	—	—	—	—	—	+·029	—
1938·06	IV–V	−·215	−·206	−·210	−·044	+·014	−·015	+·097	−·063	+·063
·14	V–VI	−·114	−·145	−·129	+·057	+·048	+·052	−·081	+·107	−·072
·23	VI–VII	−·116	−·170	−·143	+·092	+·106	+·099	+·061	−·021	+·084
·31	VII–VIII	−·114	−·067	−·090	+·148	+·128	+·138	−·032	−·044	−·026
·39	VIII–IX	−·055	−·065	−·060	+·134	+·178	+·156	−·105	−·219	−·074
·47	IX–X	−·039	−·024	−·031	+·145	+·168	+·156	−·235	−·142	−·227
·56	X–XI	+·129	+·120	+·124	+·119	+·142	+·130	−·098	+·046	−·120
·64	XI–XII	+·195	+·180	+·187	+·095	+·154	+·129	+·058	+·087	+·052
·72	XII–I	+·126	+·149	+·137	+·062	+·062	+·062	+·094	+·064	+·090
·80	I–II	+·054	+·013	+·033	+·025	−·037	−·006	+·092	−·095	+·078
·88	II–III	−·016	−·004	−·010	−·071	−·012	−·041	−·094	+·133	−·094
·97	III–IV	−·116	−·206	−·161	+·014	−·090	−·038	+·101	+·034	+·117
1939·06	IV–V	−·101	−·086	−·094	+·062	−·082	−·010	+·054	−·096	+·044
·14	V–VI	−·118	−·125	−·122	−·017	+·003	−·007	−·114	+·106	−·105
·22	VI–VII	−·120	−·101	−·111	+·085	+·118	+·102	+·054	+·018	+·080
·31	VII–VIII	−·052	+·023	−·015	+·115	+·104	+·110	−·034	−·024	−·008
·39	VIII–IX	+·038	−·019	+·010	+·096	+·222	+·159	−·086	−·231	−·055
·47	IX–X	+·037	+·040	+·039	+·163	+·144	+·154	−·206	−·089	−·218
·56	X–XI	+·093	+·084	+·089	+·151	+·170	+·161	−·099	+·020	−·094
·64	XI–XII	+·160	+·180	+·170	+·128	+·137	+·133	+·021	+·054	+·020
·73	XII–I	+·181	+·167	+·174	+·078	+·094	+·086	+·061	+·094	+·057
·80	I–II	+·202	+·123	+·163	+·084	−·003	+·041	+·097	−·090	+·095
·89	II–III	+·114	+·172	+·143	+·022	+·061	+·042	−·121	+·136	−·105
·97	III–IV	+·069	+·075	+·072	−·016	−·012	−·014	+·121	+·066	+·128
1940·06	IV–V	−·007	−·067	−·037	−·016	−·054	−·035	+·056	−·118	+·061
·14	V–VI	−·150	−·113	−·132	−·070	−·036	−·053	−·088	+·098	−·103
·22	VI–VII	−·109	−·131	−·120	+·003	+·017	+·010	+·063	+·028	+·081
·31	VII–VIII	−·129	−·146	−·138	+·076	+·082	+·079	−·008	−·042	+·010
·39	VIII–IX	−·109	−·107	−·108	+·109	+·120	+·114	−·111	−·225	−·077
·47	IX–X	−·011	+·031	+·010	+·183	+·164	+·174	−·226	−·075	−·225
·56	X–XI	+·101	+·048	+·074	+·109	+·161	+·135	−·102	+·028	−·089
·64	XI–XII	+·053	+·039	+·046	+·051	+·109	+·080	+·101	+·119	+·064
·73	XII–I	+·158	+·096	+·127	+·109	+·174	+·142	+·073	+·024	+·096
·80	I–II	+·089	+·161	+·125	+·088	+·021	+·055	+·049	−·106	+·037
·89	II–III	+·055	+·111	+·083	−·048	+·102	+·027	−·062	+·127	−·084
·97	III–IV	+·026	+·128	+·077	+·061	+·044	+·053	+·131	+·113	+·129
1941·07	IV–V	−·023	+·134	+·055	−·031	−·019	−·025	+·015	−·011	+·064
·14	V–VI	+·059	−·030	+·015	+·044	−·059	−·008	−·079	+·106	−·045
·22	VI–VII	−·021	+·027	+·003	−·029	+·009	−·010	+·092	+·025	+·099
·30	VII–VIII	−·024	−·037	−·031	−·001	+·004	+·002	−·004	+·005	+·010
·39	VIII–IX	+·031	−·017	+·007	+·037	+·048	+·042	−·065	−·094	−·030
·47	IX–X	+·046	−·013	+·016	+·119	+·062	+·090	−·112	−·080	−·103
·56	X–XI	−·007	+·046	+·019	+·082	+·141	+·112	−·118	−·026	−·099
·64	XI–XII	+·077	+·037	+·057	+·144	+·128	+·136	+·005	+·060	−·010
·71	XII–I	+·067	+·068	+·067	+·106	+·142	+·124	+·032	+·057	+·046
·79	I–II	+·096	+·061	+·079	+·081	+·055	+·068	+·034	−·101	+·046
·88	II–III	+·114	+·073	+·093	+·023	+·118	+·071	−·082	+·054	−·091
·96	III–IV	−·002	+·047	+·023	+·015	+·003	+·009	+·080	+·035	+·067
1942·07	IV–V	+·072	−·040	+·016	−·029	+·048	+·009	+·053	−·129	+·044
·14	V–VI	−·003	−·011	−·007	+·042	−·002	+·020	−·128	+·128	−·129
·22	VI–VII	+·017	−·016	+·001	−·025	−·033	−·029	+·073	−·037	+·100
·30	VII–VIII	+·006	−·024	−·009	+·040	+·022	+·031	−·041	−·068	−·039
·39	VIII–XI	+·002	+·022	+·012	−·015	+·056	+·020	−·088	−·123	−·078

TABLE VII (*continued*)

Northern Stations

Epoch	Group	*X*			*Y*			*Z*		
		E.	M.	Mean	E.	M.	Mean	E.	M.	Mean
		″	″	″	″	″	″	″	″	″
1942·47	IX–X	+·025	+·011	+·018	+·028	+·043	+·035	−·135	−·092	−·129
·56	X–XI	−·008	+·014	+·003	+·029	+·024	+·027	−·134	−·008	−·113
·64	XI–XII	−·015	−·033	−·024	+·006	+·052	+·029	+·016	+·037	+·004
·71	XII–I	−·006	−·017	−·012	+·064	+·129	+·096	+·047	+·035	+·042
·79	I–II	−·001	+·027	+·013	+·085	+·134	+·109	+·034	−·128	+·035
·88	II–III	−·034	+·033	·000	+·096	+·105	+·102	−·125	+·128	−·126
·96	III–IV	+·045	−·002	+·022	+·135	+·139	+·137	+·141	+·057	+·135
1943·06	IV–V	+·033	+·053	+·043	+·132	+·136	+·134	+·037	−·065	+·047
·14	V–VI	+·082	+·062	+·072	+·140	+·012	+·076	−·103	+·142	−·084
·23	VI–VII	+·137	+·077	+·107	+·061	+·076	+·068	+·022	+·011	+·082
·31	VII–VIII	+·084	+·113	+·098	+·054	+·037	+·045	−·009	−·060	+·001
·39	VIII–IX	+·122	+·172	+·147	+·049	+·072	+·060	−·106	−·093	−·083
·47	IX–X	+·186	+·077	+·132	+·010	+·005	+·007	−·136	−·094	−·114
·56	X–XI	+·094	+·101	+·098	−·041	−·043	−·042	−·121	−·007	−·107
·65	XI–XII	+·112	+·129	+·120	−·053	−·012	−·032	+·005	+·026	−·001
·72	XII–I	+·096	−·020	+·038	−·046	−·063	−·054	+·055	+·027	+·040
·81	I–II	−·066	+·019	−·023	−·059	−·002	−·030	+·016	−·137	+·021
·90	II–III	+·090	−·076	+·007	+·009	+·020	+·014	−·121	+·095	−·129
·98	III–IV	−·091	−·042	−·067	+·106	−·003	+·051	+·079	+·037	+·087
1944·06	IV–V	−·071	+·004	−·033	+·070	+·137	+·103	+·038	−·119	+·037
·14	V–VI	−·042	+·027	−·007	+·131	+·158	+·144	−·118	+·034	−·118
·23	VI–VII	−·010	+·030	+·010	+·153	+·154	+·153	+·073	−·004	+·053
·31	VII–VIII	+·091	+·061	+·076	+·120	+·163	+·141	−·024	−·060	−·014
·39	VIII–IX	+·190	+·192	+·191	+·075	+·164	+·119	−·055	−·094	−·057
·48	IX–X	+·293	+·263	+·278	+·105	+·075	+·090	−·108	−·076	−·101
·56	X–XI	+·274	+·274	+·274	−·024	−·020	−·022	−·091	+·016	−·083
·64	XI–XII	+·292	+·266	+·279	−·105	−·075	−·090	+·034	+·062	+·025
·72	XII–I	+·139	+·164	+·151	−·209	−·128	−·168	+·076	+·038	+·069
·81	I–II	−·027	−·012	−·019	−·195	−·166	−·180	+·006	−·158	+·022
·89	II–III	−·004	−·105	−·055	−·118	−·151	−·134	−·166	+·102	−·162
·98	III–IV	−·126	−·179	−·152	−·076	−·080	−·078	+·110	+·106	+·106
1945·06	IV–V	−·169	−·138	−·153	+·009	+·030	+·019	+·030	−·079	+·068
·14	V–VI	−·196	−·152	−·174	+·043	+·064	+·053	−·089	+·109	−·084
·22	VI–VII	−·129	−·146	−·137	+·137	+·159	+·148	+·079	+·002	+·094
·31	VII–VIII	−·007	−·124	−·066	+·223	+·216	+·219	−·027	−·068	−·012
·40	VIII–IX	+·065	+·120	+·092	+·230	+·235	+·232	−·085	−·110	−·076
·48	IX–X	+·170	+·172	+·171	+·219	+·254	+·236	−·158	−·120	−·134
·55	X–XI	+·283	+·186	+·234	+·124	+·115	+·119	−·112	+·027	−·116
·64	XI–XII	+·310	+·248	+·279	+·038	+·033	+·036	−·020	+·012	+·003
·72	XII–I	+·343	+·267	+·305	−·059	−·071	−·065	+·073	+·071	+·042
·81	I–II	+·292	+·187	+·239	−·189	−·177	−·183	+·093	−·146	+·082
·89	II–III	+·037	+·163	+·100	−·172	−·262	−·217	−·210	+·162	−·173
·97	III–IV	+·045	+·104	+·074	−·239	−·135	−·187	+·070	+·100	+·116
1946·06	IV–V	−·067	−·162	−·114	−·165	−·151	−·158	+·145	−·066	+·122
·14	V–VI	−·174	−·179	−·176	−·122	−·050	−·086	−·078	+·065	−·072
·22	VI–VII	−·136	−·247	−·192	−·042	+·034	−·004	+·083	+·024	+·074
·31	VII–VIII	−·231	−·204	−·217	+·191	+·142	+·166	−·070	−·076	−·023
·39	VIII–IX	−·113	−·155	−·134	+·203	+·275	+·239	−·156	−·186	−·116
·48	IX–X	−·055	−·047	−·051	+·289	+·231	+·260	−·196	−·134	−·191
·56	X–XI	+·140	+·095	+·117	+·273	+·302	+·287	−·204	−·083	−·169
·64	XI–XII	+·156	+·171	+·163	+·229	+·281	+·255	−·059	+·013	−·071
·72	XII–I	+·263	+·263	+·263	+·163	+·163	+·163	+·044	−·088	+·029
·81	I–II	+·263	+·278	+·270	+·084	+·060	+·077	+·048	−·146	−·020
·89	II–III	+·246	+·234	+·240	−·067	−·042	−·054	−·102	+·198	−·124
·97	III–IV	+·290	+·167	+·228	+·047	−·059	−·006	+·067	+·090	+·132

TABLE VIII

Northern Stations

Epoch	Group	X			Y			Z		
		E.	M.	Mean	E.	M.	Mean	E.	M.	Mean
		″	″	″	″	″	″	″	″	″
1935·06	IV–V	−·064	−·007	−·036	+·029	+·059	+·044	+·122	−·089	+·106
·14	V–VI	+·049	−·055	−·003	+·006	−·043	−·019	−·098	+·116	−·094
·23	VI–VII	−·027	+·011	−·008	+·041	+·026	+·034	+·068	+·005	+·092
·30	VII–VIII	+·037	−·008	+·015	+·026	+·010	+·018	−·038	−·074	−·016
·39	VIII–IX	+·035	−·009	+·013	+·058	+·073	+·066	−·110	−·194	−·092
·47	IX–X	−·003	+·036	+·017	+·069	+·069	+·069	−·267	−·113	−·230
·56	X–XI	+·049	+·045	+·047	+·004	+·038	+·021	−·119	+·059	−·116
·64	XI–XII	−·007	−·001	−·004	+·041	+·101	+·071	+·051	+·091	+·055
·72	XII–I	+·005	+·010	+·008	+·084	+·147	+·116	+·075	+·095	+·083
·80	I–II	−·023	−·025	−·024	+·092	+·004	+·048	+·085	−·079	+·090
·89	II–III	−·053	−·034	−·044	+·030	+·104	+·067	−·054	+·150	−·066
·97	III–IV	−·059	−·041	−·050	+·068	+·043	+·056	+·200	+·141	+·175

observations at Kitab brings a greater uncertainty to the determination of Y. From this it is clear that it is desirable that the work should proceed everywhere with the greatest regularity and without interruption. The interruptions, apart from upsetting the homogeneity and continuity of the results, also cause doubts and uncertainties. I wonder whether, in view of all the difficulties experienced in Italy in maintaining the service at Carloforte, it would not be advisable to revert to the original system prior to 1914 when all the stations were directly controlled by the old International Geodetic Association.

It has been already pointed out that the values of Z derived from the observations in each group represent to a great extent the effect of the errors in the adopted declinations and consequently they give, with a change of sign, the corrections to the mean of the declinations of each group. It follows that the values of Z obtained in successive years should agree; the agreement is, in fact, satisfactory when it is remembered that the individual values are subject to errors of observation and that in Z are included also the effects of real or apparent latitude variations, which can be separated only with difficulty.

In Table X are summarized the values obtained in each year from 1935 to 1946, after applying the corrections to the values for the years previous to 1940 to the groups IX and XII, as already mentioned, in order to reduce all the results to the positions of the *General Catalogue*. In the last line the mean value for each group is given. The mean error of a single value, derived from the scatter about the mean values, is $\pm 0''{\cdot}028$; that of the mean group corrections is $\pm 0''{\cdot}008$.

The values of X and Y from Tables VII, VIII and IX were plotted and smooth curves drawn to pass as nearly as possible through the plotted points. From these curves the co-ordinates X and Y of the instantaneous pole were read off at every tenth of a year and are given in Table XI. With these values the curves showing the polar motion are to be found in the diagrams.

II. *Final Reductions of the Observations for the Period* 1935–40

The end of 1940 completed the first period of 6 years, which includes five Chandlerian periods and six yearly periods, from the time when the reduction of the observations taken at the International Latitude Stations was entrusted to us. The reduction in the work of the Office caused by the war enabled me to investigate the observational data so far collected in order to determine improved values of the polar motion to supersede the provisional values which are published year by year.

TABLE IX

Northern and Southern Stations

Epoch	Group	X E.	X M.	X Mean	Y E.	Y M.	Y Mean	Z_b E.	Z_b M.	Z_b Mean	Z_a E.	Z_a M.	Z_a Mean
		″	″	″	″	″	″	″	″	″	″	″	″
1935·06	IV–V	−·063	−·025	−·044	+·030	+·043	+·037	+·120	−·087	+·120	+·106	+·020	+·106
·14	V–VI	+·037	−·044	−·004	−·004	−·033	−·019	−·097	+·113	−·092	+·004	+·081	+·012
·23	VI–VII	−·023	−·001	−·012	+·045	+·015	+·030	+·068	+·005	+·091	+·072	−·280	+·077
·30	VII–VIII	+·026	−·007	+·010	+·016	+·011	+·014	−·037	−·074	−·016	−·260	−·075	−·270
·39	VIII–IX	+·012	−·018	−·003	+·039	+·066	+·053	−·108	−·191	−·091	−·112	−·062	−·094
·47	IX–X	−·005	+·032	+·014	+·068	+·066	+·067	−·264	−·111	−·228	−·095	−·001	−·079
·56	X–XI	+·063	+·035	+·049	+·016	+·030	+·024	−·120	+·059	−·116	−·034	+·081	−·018
·64	XI–XII	−·004	−·020	−·012	+·043	+·085	+·064	+·050	+·092	+·055	+·099	−·092	+·090
·72	XII–I	−·022	−·042	−·032	+·062	+·103	+·083	+·076	+·099	+·084	−·102	+·029	−·097
·80	I–II	−·050	−·050	−·050	+·069	−·017	+·026	+·087	−·075	+·093	+·083	+·273	+·056
·89	II–III	−·060	−·083	−·071	+·026	+·062	+·044	−·052	+·153	−·064	+·282	−·026	+·278
·97	III–IV	−·081	−·053	−·067	+·050	+·034	+·042	+·200	+·140	+·177	+·021	+·092	−·003
1937·96	—	—	—	—	—	—	—	—	+·033	—	—	+·109	—
1938·06	IV–V	−·187	−·215	−·201	−·021	+·007	−·007	+·093	−·062	+·063	+·116	·000	+·112
·14	V–VI	−·133	−·161	−·147	+·042	+·034	+·038	−·078	+·110	−·070	+·009	+·029	+·004
·23	VI–VII	−·119	−·176	−·147	+·089	+·101	+·095	+·065	+·026	+·087	−·036	−·423	−·003
·31	VII–VIII	−·128	−·088	−·108	+·135	+·110	+·122	−·026	−·038	·000	−·326	−·165	−·374
·39	VIII–IX	−·034	−·071	−·052	+·150	+·172	+·161	−·102	−·212	−·070	−·148	−·069	−·156
·47	IX–X	−·030	−·013	−·021	+·152	+·177	+·164	−·232	−·137	−·222	−·107	−·007	−·088
·56	X–XI	+·098	+·093	+·095	+·094	+·119	+·106	−·091	+·052	−·114	+·102	+·189	+·047
·64	XI–XII	+·163	+·141	+·152	+·069	+·121	+·095	+·063	+·095	+·057	+·182	−·020	+·185
·72	XII–I	+·093	+·129	+·111	+·035	+·040	+·037	+·098	+·068	+·097	−·053	+·115	−·036
·80	I–II	+·040	+·013	+·026	+·013	−·037	−·012	+·094	−·096	+·081	+·138	+·314	+·126
·88	II–III	−·039	−·032	−·035	−·083	−·036	−·059	−·094	+·135	−·095	+·339	−·021	+·326
·97	III–IV	−·142	−·201	−·171	+·022	−·085	−·032	+·103	+·031	+·119	−·053	+·041	−·037
1939·06	IV–V	−·148	−·101	−·125	+·023	−·094	−·036	+·059	−·098	+·045	+·078	−·019	+·060
·14	V–VI	−·130	−·147	−·139	−·028	−·015	−·022	−·113	+·107	−·106	−·035	+·013	−·027
·22	VI–VII	−·154	−·147	−·151	+·055	+·079	+·067	+·059	+·025	+·083	+·023	−·350	+·018
·31	VII–VIII	−·106	−·038	−·072	+·093	+·079	+·086	−·042	−·032	−·009	−·403	−·175	−·377
·39	VIII–IX	+·015	−·084	−·035	+·086	+·196	+·141	−·089	−·241	−·061	−·165	−·133	−·170
·47	IX–X	−·042	−·052	−·047	+·131	+·104	+·118	−·209	−·095	−·225	−·111	+·007	−·122
·56	X–XI	+·036	+·012	+·024	+·127	+·135	+·131	−·094	+·026	−·094	+·023	+·221	+·015
·64	XI–XII	+·147	+·147	+·147	+·112	+·114	+·113	+·026	+·060	+·026	+·179	−·049	+·200
·73	XII–I	+·157	+·138	+·148	+·058	+·070	+·064	+·066	+·100	+·063	−·074	+·135	−·062
·80	I–II	+·188	+·152	+·170	+·074	+·022	+·048	+·103	−·089	+·102	+·126	+·342	+·131
·89	II–III	+·068	+·098	+·083	−·016	−·001	−·009	−·117	+·144	−·103	+·282	−·011	+·312
·97	III–IV	+·019	+·002	+·011	−·059	−·073	−·066	+·124	+·072	+·134	+·009	+·054	−·001

TABLE X

Group...	IV	V	VI	VII	VIII	IX	X	IX	XII	I	II	III
Year	″	″	″	″	″	″	″	″	″	″	″	″
1935	+·106*	−·094	+·092	−·016	−·092	−·150†	−·116	+·041†	+·083	+·090	−·066	+·175
1936	+·122	−·096	+·090	+·032	−·050	−·103	−·093	+·042	+·079	+·127	−·201	+·154
1937	+·092	−·075	+·058	−·014	−·103	−·161	−·142	−·005	+·051	+·084	−·106	+·152
1938	+·063	−·072	+·084	−·026	−·074	−·147	−·120	+·038	+·090	+·078	−·094	+·117
1939	+·044	−·105	+·080	−·008	−·055	−·138	−·094	+·006	+·057	+·095	−·105	+·128
1940	+·061	−·103	+·081	+·010	−·077	−·145	−·089	+·050	+·096	+·037	−·084	+·129
1941	+·064	−·045	+·099	+·010	−·030	−·103	−·099	−·010	+·046	+·046	−·091	+·067
1942	+·044	−·129	+·100	−·039	−·078	−·129	−·113	+·004	+·042	+·035	−·126	+·135
1943	+·047	−·084	+·082	+·001	−·083	−·114	−·107	−·001	+·040	+·021	−·129	+·087
1944	+·037	−·118	+·053	−·014	−·057	−·101	−·083	+·011	+·069	+·022	−·162	+·106
1945	+·068	−·084	+·094	−·012	−·076	−·134	−·116	−·013	+·042	+·082	−·173	+·116
1946†	+·122*	−·072	+·074	−·023	−·116	−·191	−·169	−·085	+·029	−·020	−·124	+·132
1946*	+·090	—	—	—	—	—	—	—	—	—	—	—
Mean	+·071	−·090	+·081	−·008	−·074	−·135	−·112	+·007	+·060	+·058	−·122	+·125

* Half-weights should be given to the two values for 1935 and 1946, as the first is obtained from the observations for the month of January only and the second for December only.

† The corresponding values for the years 1935–40 have been corrected in order to bring the proper motions to the values given by the G.C.

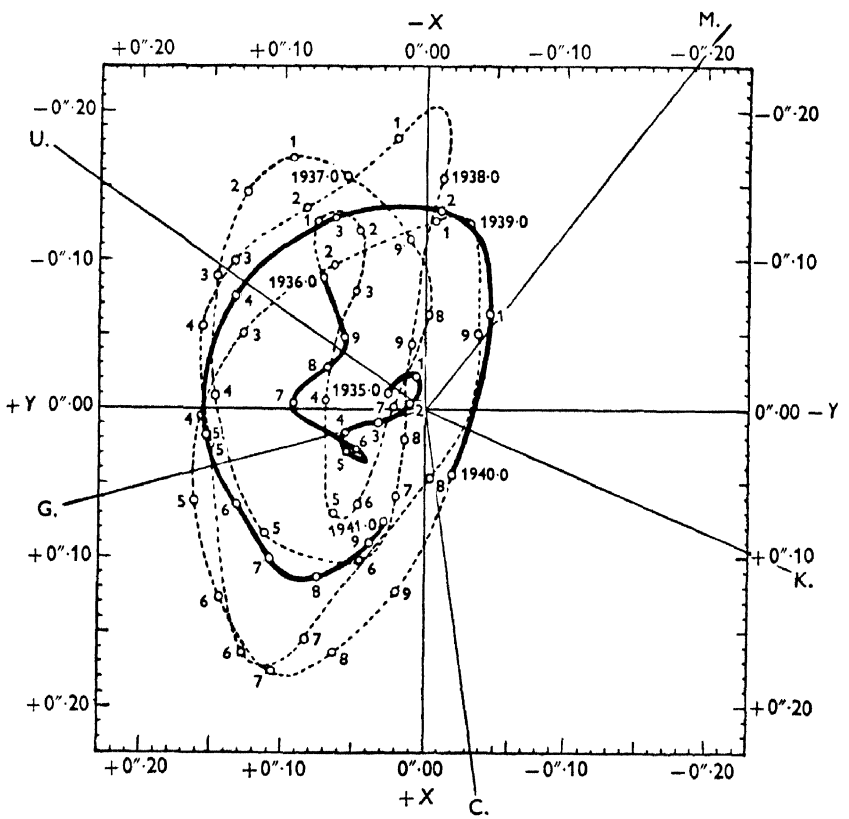


Fig. 1.

TABLE XI

Epoch	X	Y	Epoch	X	Y
	″	″		″	″
1938·0	−·156	−·012	1943·0	+·030	+·146
·1	−·183	+·020	·1	+·056	+·112
·2	−·135	+·084	·2	+·087	+·070
·3	−·100	+·136	·3	+·118	+·055
·4	−·056	+·158	·4	+·145	+·036
·5	+·024	+·153	·5	+·129	−·005
·6	+·162	+·128	·6	+·104	−·037
·7	+·154	+·084	·7	+·063	−·056
·8	+·046	−·002	·8	+·007	−·033
·9	−·048	−·038	·9	−·049	+·012
1939·0	−·120	−·031	1944·0	−·066	+·058
·1	−·126	−·006	·1	−·026	+·125
·2	−·097	+·063	·2	+·004	+·156
·3	−·051	+·127	·3	+·060	+·144
·4	+·004	+·156	·4	+·210	+·116
·5	+·062	+·162	·5	+·268	+·084
·6	+·127	+·143	·6	+·272	−·060
·7	+·176	+·107	·7	+·182	−·150
·8	+·165	+·065	·8	−·010	−·180
·9	+·123	+·019	·9	−·084	−·130
1940·0	+·044	−·020	1945·0	−·144	−·062
·1	−·064	−·046	·1	−·173	+·012
·2	−·134	−·012	·2	−·152	+·135
·3	−·129	+·063	·3	−·060	+·211
·4	−·076	+·132	·4	+·092	+·237
·5	+·018	+·153	·5	+·191	+·228
·6	+·064	+·131	·6	+·280	+·065
·7	+·100	+·108	·7	+·305	−·038
·8	+·114	+·075	·8	+·252	−·178
·9	+·091	+·038	·9	+·115	−·215
1941·0	+·070	+·016	1946·0	+·012	−·176
·1	+·038	−·013	·1	−·144	−·105
·2	+·003	−·012	·2	−·191	−·004
·3	−·013	+·006	·3	−·217	+·166
·4	−·004	+·069	·4	−·140	+·234
·5	+·021	+·093	·5	−·020	+·288
·6	+·040	+·124	·6	+·134	+·278
·7	+·066	+·121	·7	+·265	+·195
·8	+·082	+·081	·8	+·292	+·092
·9	+·074	+·047	·9	+·246	−·040
1942·0	+·023	+·018	1947·0	(+·214)	(−·078)
·1	+·007	+·006			
·2	−·004	+·001			
·3	+·001	+·016			
·4	+·009	+·027			
·5	+·009	+·028			
·6	−·007	+·034			
·7	−·008	+·076			
·8	+·002	+·103			
·9	+·014	+·120			

Northern Stations

Epoch	X	Y
	″	″
1935·0	−·012	+·025
·1	−·023	+·007
·2	−·004	+·010
·3	+·009	+·032
·4	+·017	+·056
·5	+·028	+·053
·6	+·030	+·049
·7	−·003	+·092
·8	−·028	+·068
·9	−·049	+·057
6·0	−·088	+·071

Northern and Southern Stations

Epoch	X	Y
	″	″
1935·0	−·036	+·026
·1	−·043	+·005
·2	−·021	+·008
·3	−·001	+·030
·4	+·008	+·050
·5	+·028	+·050
·6	+·021	+·042
·7	−·028	+·064
·8	−·054	+·041
·9	−·067	+·037
1936·0	−·105	+·060
1938·0	−·188	−·019
·1	−·185	+·013
·2	−·142	+·072
·3	−·109	+·125
·4	−·052	+·163
·5	+·021	+·150
·6	+·132	+·099
·7	+·126	+·056
·8	+·033	−·013
·9	−·068	−·061
1939·0	−·150	−·034
·1	−·152	−·017
·2	−·134	+·032
·3	−·086	+·100
·4	−·023	+·135
·5	+·045	+·146
·6	+·118	+·132
·7	+·148	+·080
·8	+·133	+·020
·9	+·074	−·030
1940·0	(−·025)	(−·087)

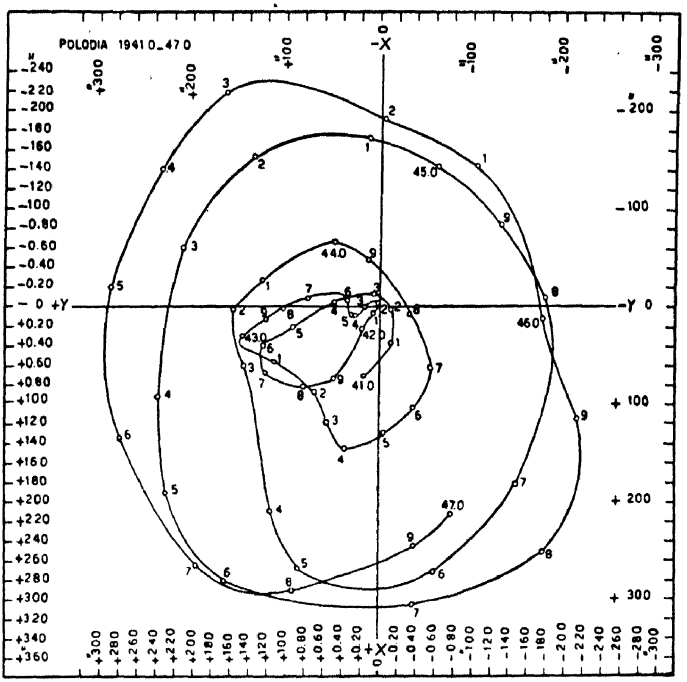
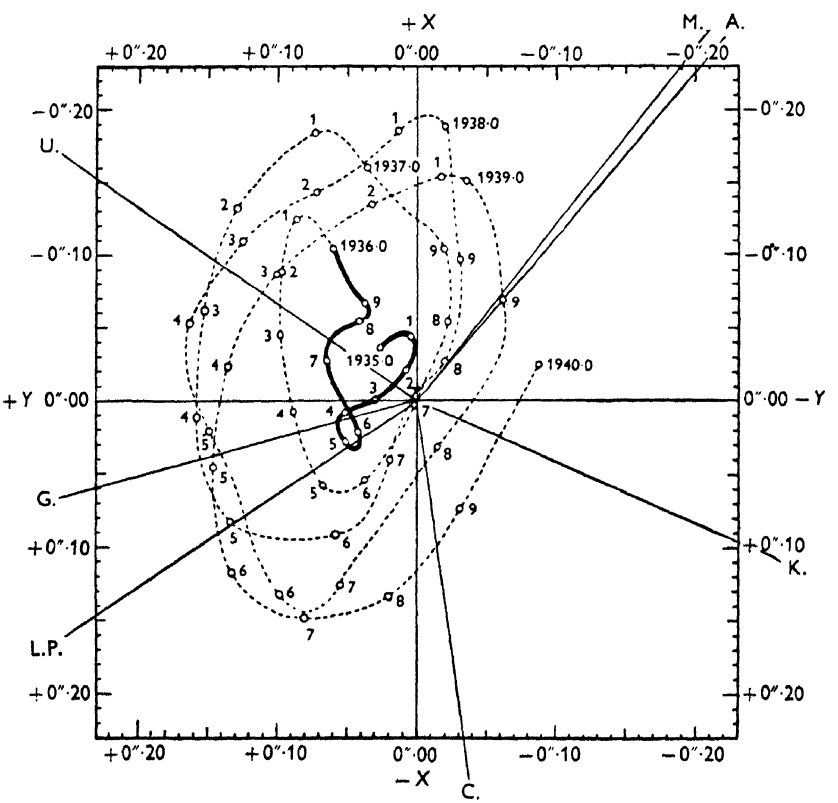

POLODIA 1941.0_47.0
-X
+X
+Y
-Y
45.0
44.0
46.0
43.0
42.0
41.0
47.0

Fig. 2.


+X
-X
+Y
-Y
M.
A.
U.
G.
L.P.
K.
C.
1935·0
1936·0
1937·0
1938·0
1939·0
1940·0
+0″·20
+0″·10
0″·00
−0″·10
−0″·20

First of all we had to investigate the instrumental constants in order to ensure that the values of the latitude variation were free from systematic errors of an instrumental nature. The large mass of observations obtained at the several stations had to be analysed in order to determine the value of one revolution of the micrometer screw of each instrument and its variations with temperature and time. The conclusions have been published in the *Memorie dell' Accademia Nazionale dei Lincei di Roma.** At almost all the stations special observations were made for this purpose, limited in the earlier period to the observations of certain polar stars at their maximum elongation, and then later supplemented by the observation of a pair of stars, as suggested by Prof. Kimura.

The first of these methods offers a means of obtaining simultaneously the screw-value as well as material for the investigation of periodic and progressive errors of the screws, but has many inconveniences for the determination of the screw value. The second is really efficient only when the declinations of the stars are very accurately known and when the observations are continued systematically throughout the whole period, to co-ordinate the results obtained in the different epochs. A long time (about half an hour) is required for the observation of a circumpolar star across the whole field of view of the telescope near its elongation; to observe at intervals of two-tenths of a revolution throughout this time is a considerable strain on the observer; in addition, the position in which the telescope is set will introduce flexure effects. The uncertainties which are thus introduced could perhaps be eliminated if the observations of each star were equally distributed not only between the two instrumental positions but also between the two elongations; this would necessitate repeating the work at intervals of several months and giving preference to observations which are taken when the temperatures are almost identical; but we cannot be certain that nothing will have intervened in the meantime to alter the scale-value of the micrometer. Sufficient attention has not been paid to these factors and the inconsistent results obtained make one suspect the existence of systematic differences due to flexure and personal errors, though no reliable conclusions can be drawn. I believe that if one cannot afford a period long enough for observing, with all possible precautions, a fundamental star very near to the pole, this method of determining the screw-value should not be recommended, as the accuracy of the results obtainable is not proportionate to the work entailed.

The results show, without any doubt, that the method of observing pairs of stars is much more efficient, but for this it is essential: (1) that the declinations and proper motions of the stars should be known with a great accuracy; (2) that the difference in the declinations should be sufficiently large, so that the effects of accidental errors of observation as well as of errors on the adopted declinations are minimized; (3) that the observations of the same pair of stars should be repeated on many evenings in different instrumental positions so as to eliminate personal and instrumental errors and to obtain material for estimating the order of magnitude of the accidental error of measurement, and later for judging whether the differences between the results from individual pairs are to be attributed to errors in the declinations or to accidental errors of measurement; (4) that observations should be made of many pairs in the hope of balancing out the effects of errors of the adopted declinations; (5) that a number of pairs should be observed at different periods of the year when the temperatures will be different (for instance in the northern hemisphere with observations taken in the morning in the month of April after the latitude observations, and in July in the evening before the latitude observations) in order to determine the effect of temperature on the screw-value. I shall not give details of the results obtained at individual stations but merely mention that the proposal made at the meeting in Paris in 1935 by Prof. Kimura that the stations should observe a large number of star pairs has been followed in practice only at the stations of Batavia, Adelaide, La Plata, Mizusawa and Kitab (perhaps because with a larger staff they could more easily attend to this extra work).

* *Memorie Classe Scienze fisische, matematiche e naturali dell' Accademia Nazionale dei Lincei*, vol. 1, fasc. 4, Sezione 1. Roma, 1947.

Unfortunately, the method of making the observations has been interpreted differently at different stations. The stars given by Kimura present a serious difficulty, as the pairs do not follow each other in such a way that they can be observed in succession; if one particular pair is observed, it is necessary to miss the next pair and sometimes two or three others; moreover, at certain times as many as 14 pairs occur in a period of two hours, but there are other periods during which only three or four are to be found. At Batavia it was thought that all the 92 pairs should be observed, and that it would have been sufficient to do this once or twice every year. At other stations, a selection was made of certain pairs, and the measures of these pairs were repeated many times during each year. The choice of the pairs having been made according to different criteria, the pairs observed at the different stations were not the same. This gave rise to some difficulty when it was desired to intercompare the results obtained. Since it can be assumed that the effect of errors in the declinations will be less the larger the number of different pairs observed, the number of pairs should not be too small; on the other hand, each pair should be observed for a sufficient number of times to enable corrections to the declinations to be derived. At the same time, it is important not to overload the observers. Experience gained in recent years at the different stations shows that 40 pairs will be sufficient. It is desirable that all the stations should concentrate on these pairs and preferably on those which have already been observed sufficiently to derive reliable corrections to the declinations, so that the results can be reduced to the mean of all the pairs. These corrections are found in the Table on pp. 280–1 of my above-mentioned work. I must also mention another trouble which came to light in the course of this investigation. From time to time there occur sudden and apparently inexplicable changes in the micrometer screw-value, without any note in the observing book of any adjustment of focus having been made. While, for instance, for Batavia every small fact which might possibly affect the observations is noted, for Kitab there is no note to account for a change of screw-value of over 0″·055 corresponding to a displacement of the plane of the wire system of the order of about 2 mm. We must also add that these variations are exactly confirmed by the results of the subsequent investigations.

TABLE XII

Year	Adelaide	Mean error	La Plata	Mean error
	″	″	″	″
1935	+·00468	±·00204	−·00628	±·00114
1936	+·01230	±·00293	−·00676	±·00130
1937	+·00982	±·00261	−·00891	±·00140
1938	+·00814	±·00201	−·00444	±·00141*
			+·00419	±·00053†
1939	+·01013	±·09215	+·00052	±·00136
Mean	+·01009	±·00120	−·00686	±·00068‡
			+·00177	±·00111§

* Value obtained from the first eight months of the year 1938.
† Values obtained from the four last months of this year.
‡ Mean obtained from the period for the years 1935–37 and the eight months of the year 1938.
§ Mean of the last months of 1938 and the year 1939.

Having completed this first study and having determined the micrometer screw-values and their variations, both with temperature and through the six-year period, all the latitude variations were re-computed. It is clear that if there had not been any errors in the declinations adopted for the latitude pairs and if the adopted screw-values at the different stations were correct, the mean of the monthly latitudes (and particularly those derived only from the nights when all the six pairs of each group were observed) should give identical results. If this does not happen, differences must arise from errors of the adopted declinations or screw-values. If we consider the results obtained in a particular month for a particular group, observed by the five northern stations, we have six unknowns

for the six corrections of declinations and five for the corrections of the five micrometer screw-values; i.e. a total of 11 unknowns, with 30 equations of condition; it is clear that it is possible to determine these 11 unknowns. A rigorous solution would have involved very heavy computations, made more difficult by the small differences between the coefficients for the correction of the micrometer screw-values at the various stations for any given pair. A method of successive approximations was therefore adopted. Particulars need not be given; but as an illustration of the results, those obtained for the two stations of the southern parallel at Adelaide and La Plata are quoted. Taking the micrometer screw-values found on p. 215 (for Adelaide) and on p. 231 (for La Plata) of my quoted work, I found, after three successive approximations, that for the years 1935–39 the value of the screw-values required the corrections given in Table XII on p. 200.

A glance at these corrections and at their mean errors shows that the differences between the yearly means are not necessarily real differences; we must subdivide the whole interval into limited periods within which the corrections oscillate within the limits of the expected errors. For Adelaide two periods are enough: the one consisting of the year 1935 and the other of the years 1936–39. For La Plata, the following five periods are used: (1) 1935–36; (2) 1937; (3) 1938, January to end of August; (4) 1938, September to December; (5) 1939–40. The following values of the screw-values were used:

Adelaide	1935	$R = 39{\cdot}9481 - 0{\cdot}00120\,(t° - 15°{\cdot}0)$
	1936–39	$R = 39{\cdot}9535 - 0{\cdot}00120\,(t° - 15°{\cdot}0)$
La Plata	1935–36	$R = 39{\cdot}7644 - 0{\cdot}00117\,(t° - 15°{\cdot}0)$
	1937	$R = 39{\cdot}7620 - 0{\cdot}00117\,(t° - 15°{\cdot}0)$
	1938 to end of August	$R = 39{\cdot}7665 - 0{\cdot}00117\,(t° - 15°{\cdot}0)$
	1938 Sept.–Dec.	$R = 39{\cdot}7751 - 0{\cdot}00117\,(t° - 15°{\cdot}0)$
	1939–40	$R = 39{\cdot}7710 - 0{\cdot}00117\,(t° - 15°{\cdot}0)$

Along with the determination of the corrections to the screw-values we have determined the declination correction for each star pair, required to reduce the latitude derived from that pair to the mean value for the whole group. It must be remembered that these corrections are not the whole corrections, as each group needs a declination correction to reduce the groups to the same basis. This error of the mean declinations of each group, however, affects the correction for the screw-values. It may happen, therefore, that for two groups of stars, observed on the same night, two different corrections for the screw-value may be required, and that such systematic differences will recur from year to year, because they have their origin in a residual error of the declinations of the two groups.

It is unnecessary in this report to give particulars of these investigations, which require detailed description, supported by all the numerical results, and which will have to be published separately. It is sufficient to mention that these computations have been completed and that, using the derived values, the definitive reduction of all the observations obtained from the beginning of 1935 to the end of 1940 has been undertaken and completed.

For the eight stations we have derived for each pair and for each group the values of the mean monthly latitudes and for each group also the mean latitudes for each night. The computation of the instantaneous co-ordinates of the pole and the detailed study of the residual term, due to phenomena of local or general character, is still to be done. It may be of interest to mention a result already obtained. Because of the uniformity of distribution through the year of the observations at La Plata and because the observations during six years, which include six yearly cycles and five Chandlerian cycles, were all made by one observer, I have analysed the mean latitudes according to the hour angle $\theta_{\mathfrak{C}}$ of the Moon at the mean time of observation, giving to the individual values a weight proportional to the number of pairs used. The values ϕ of the latitude for the different lunar hour-angles are given in Table XIII, where the number of pairs and the relative weight is also given for each value. In the fifth column are given the residuals of each value from the mean. In the sixth are given the values computed from the

following formula omitting the terms in $3\theta_{\mathbb{C}}$ for the reason given below and in the seventh are the corresponding residuals v'.

$$f = 31''\cdot814 + 0''\cdot0016 \cos\theta_{\mathbb{C}} - 0''\cdot0059 \sin\theta_{\mathbb{C}} + 0''\cdot0156 \cos 2\theta_{\mathbb{C}} - 0''\cdot0047 \sin 2\theta_{\mathbb{C}} + [+0''\cdot0010 \cos 3\theta_{\mathbb{C}} + 0''\cdot0033 \sin 3\theta_{\mathbb{C}} + \ldots].$$

Inspection of the residuals v shows how the latitude values vary periodically, and that the main term must be half the lunar day. By analysing them, the formula given above was derived. The sum of the squares of the residuals v is 6783, and of the residuals v' is only 3120, i.e. less than half. When the calculation is repeated with the inclusion of the terms in $3\theta_{\mathbb{C}}$, the sum of the squares of the residuals is 3037. This reduction is far too small to enable us to attribute any reality to those terms. This result, while confirming the results obtained years ago by Stetson, proves that in the latitude determinations we must take into account a short-period variation, of a maximum amplitude of three to four hundredths of a second, which might be caused by the sum of the effects of different phenomena due to the Moon, such as the deviation of the vertical produced by solid tides and refraction phenomena related to atmospheric tides. Even this brief description is sufficient to show how much interest this type of research can have not only for astronomy but also for geodesy and geophysics, and how necessary it is that, as soon as possible, the service should be intensified in order to secure a wider collection of observations, which should be of the highest accuracy.

TABLE XIII

Moon's hour angle	Seconds of lat.	No. of pairs	P	v	f	v'
0^h	31″·808	350	1·2	− 6	31″·831	−23
1	833	372	1·2	+19	825	+ 8
2	833	469	1·6	+19	816	+17
3	811	385	1·3	− 3	806	+ 5
4	794	442	1·5	−20	798	− 4
5	781	399	1·3	−33	793	−12
6	794	469	1·6	−20	793	+ 1
7	789	407	1·4	−25	797	− 8
8	821	452	1·5	+ 7	805	+16
9	802	345	1·1	−12	813	−11
10	834	406	1·3	+20	822	+12
11	834	379	1·3	+20	827	+ 7
12	819	353	1·2	+ 5	828	− 9
13	812	323	1·1	− 2	825	−13
14	825	370	1·2	+11	819	+ 6
15	821	335	1·1	+ 7	812	+ 9
16	799	374	1·2	−15	806	− 7
17	814	416	1·4	0	803	+11
18	804	350	1·2	−10	804	0
19	792	435	1·4	−22	809	−17
20	830	395	1·3	+16	816	+14
21	834	390	1·3	+20	824	+10
22	816	301	1·0	+ 2	830	−14
23	843	347	1·2	+29	833	+10

The attempt to correlate the latitudes with lunar declinations did not give any conclusive results. Probably there are many effects which are so small that they are masked by other larger effects. I hope to revert to this particular research when all the computations have been completed. It will then be possible to eliminate the effect of the motion of the pole from the derived latitudes and therefore it should be easier to identify the

lunar effects; it will then be possible to obtain the corresponding values also for the other stations.

I hope that I have given a clear idea of the actual state of the work of the definitive reductions of the observations for the six years, 1935–40. The delay in completing this work has been due in part to the necessity for overtaking the arrears of computation of the observations obtained during the war years and in part to the fact that insufficient staff has been available to permit the work to be hastened.

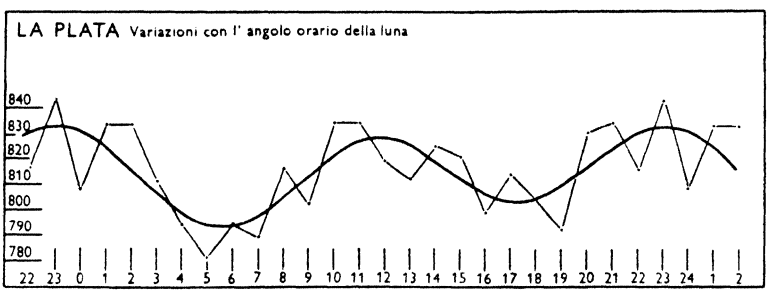


Fig. 4.

III. *Research carried out in Italy for the Study of the Problems of Latitude Variation*

I feel that it is my duty, before concluding this report, to draw the attention of the Commission to some researches which have been carried out in Italy, although they do not come under the Central Bureau.

When in 1943 war operations compelled observations at Carloforte to be suspended, it was decided, in agreement with the President of the Italian Geodetic Commission, and with the approval of the Ministry, to take advantage of a programme of work already in hand by Prof. Cecchini, Director of the Observatory of Pino Torinese, to undertake latitude determinations at the Observatory, using the same methods as at the International Stations, and to continue them until such time as work could be resumed at Carloforte. While Dr Missana, the observer from Carloforte, using a zenith telescope put at his disposal by the Observatory of Capodimonte, observed the two latitude groups, each of six pairs of stars, Prof. Cecchini, assisted by Dr A. Fresa and Dr Tedeschini, observed the same stars with a Bamberg transit instrument as well as the preceding and following groups of the general programme. In this way not only was a mutual check of the results obtained, but the uninterrupted period of night observations lasting eight hours provides data for complementary researches of great interest. This work was continued until the end of 1946 so that there are available seven months of simultaneous observations. These observations can also be used for the study of the movement of the pole during the period in which the collaboration of Carloforte was lacking.

The results of these two long series of observations are only partly available at present, but the full results should be ready within a few months.

In connection with series of latitude observations, intended for investigation of local phenomena, I must also mention those recently started by Prof. Peisino at Teramo. The observations are made with a small zenith telescope and the programme is similar to that adopted at the International stations.

A research of great interest is in progress at Naples by Dr Nicolini, who, after having made a great contribution as an observer at the station of Carloforte, has now devoted himself to the study of latitude variation phenomena, analysing from different viewpoints the large number of observations which have been so far gathered, with the purpose of separating, as far as possible, the two principal movements of the pole, the yearly movement and the Chandler movement. He has already published two papers, one in

the *Rendiconti* and one in the *Memorie dell' Accademia Nazionale dei Lincei*; he has prepared a summary of his conclusions which is included in this Report. Apart from the variable amplitudes and periods shown both by the annual cycle and the Chandlerian cycle, there is also shown a displacement of the path of the pole with respect to the mean pole. This displacement, while showing at times a relative regularity of motion, has at other times sudden variations which coincide with changes of programme. It seems reasonable to believe that, while the regular displacements are to be attributed to the imperfect knowledge of the proper motions in declination of the observed stars, the sudden displacements are due to the lack of a proper connection between the different programmes of observation. This draws attention to an inconvenience which has not been sufficiently emphasized. Although we have nearly a half century of accurate observations for the determination of the motion of the pole, we still lack a homogeneous system of declinations.

In the case of the stars included in the first programme of observation at the northern stations (from 1899 to the beginning of 1906) we have, in addition to the investigation of Prof. Fr. Cohn (*Ableitung der Declinationen und Eigenbewegungen der Sterne für den Internationalen Breitendienst*), the direct determinations made with the meridian circle of the Bonn Observatory by Dr Mönnichmeyer (*Beobachtungen der Internationalen Polhöhensterne*, Bonn, 1904). But there is no direct link with the following programmes. It is true that an effort was made always to keep in a new programme a number of pairs belonging to the old programme, but a liaison between the mean systems of declinations was missing. A determination of the declinations of the stars used at the latitude stations would be of great value and might help to enlighten some parts of the problem, though it is difficult to say whether the consequences of these missing links could entirely be overcome; it might then be necessary to recompute all the observational material. In my view the declinations ought to be observed not only with meridian circles but also with vertical circles, such as those of Pulkova, Odessa, Munich, Babelsberg, Belgrade, etc. and possibly making use also of instruments in the prime vertical. The Observatory of Capodimonte intends, as soon as it obtains permission from the Ministry to reorganize its staff, to start these determinations with the Repsold Meridian Circle and eventually to use also a transit instrument in the prime vertical, for which an application has already been made; but it is hoped that the Capodimonte Observatory will not be the only one and that other observatories which possess suitable instruments will collaborate, so that reliable declinations can be determined. If only four observatories would collaborate with a degree of accuracy similar to that of Mönnichmeyer's work we should secure proper motions of greater reliability and obtain better agreement between the latitudes deduced from the different pairs than is possible using the positions of the Boss *General Catalogue* which, though good, are not good enough for the purpose.

From this research by Nicolini it seems to me that the interpretation to be given to the Chandlerian period of the polar motion is still an open question, particularly if we think of the variability of the amplitude as well as of the duration of the period. It appears necessary, rather than desirable, to continue the observations without interruption; while studying means of making them more reliable and numerous, the present liaison system between the stations must be continued, so as to limit as much as possible the sources of uncertainty, among which we must give full weight to the insufficient knowledge of declinations.

IV. *Future Work*

From what has been said, it is clear that if the war has noticeably hampered the normal prosecution of research, these years have not, however, been entirely fruitless. I would dare to say that it is clearer to-day how the study of the movement of the pole of terrestrial rotation is to be considered as a problem of great interest to astronomers, geodesists and geophysicists. In order to clarify many still obscure points, a full and complete collaboration from all sides is indispensable. The astronomical observations ought to be perfected to such an extent as to obtain a much higher degree of accuracy. This to me seems

unattainable unless we could increase the focal lengths, eliminate the use of levels, and increase the stability of the instruments. All this seems to have been achieved with the photographic instrument in use at the Naval Observatory at Washington, but with a noticeable increase of work, as to the night observing has been added the measurement of the plates. The proposal to equip a number of stations with similar instruments would certainly, if achieved, give a noticeable advantage, as residual errors due to refraction and personal errors in setting would be eliminated. But if we want to obtain from these new instruments the fullest advantages, we should never depart from the condition presented by the present latitude stations that they should be placed on the same parallel, so as to be able always to observe the same stars. A decision which would enable us to create in the northern hemisphere a group of at least three stations equipped with similar instruments, with at least two stations in the southern hemisphere, would be indeed welcome. For instance, if we wanted to keep the present station of the Naval Observatory, I believe it would not be difficult to find in Europe suitable localities (in Italy for instance, Catanzaro in Calabria, a town of over 40,000 inhabitants) and probably even in the western regions of the United States, north of San Francisco. Personally, I consider it indispensable to retain the stations where they are at present, and as they are at present.

There is no doubt, though, that to eliminate the inconvenience of the discontinuity presented by the station of Carloforte where, for climatic reasons, there are several months of great activity, with other months (in the late autumn and early spring) with very few possibilities of observations, it would be desirable to obtain the co-operation of another observatory placed not far from the Greenwich meridian, in a favourable climatic position, as for instance at Lisbon, prepared to make an efficient contribution by means of regular and systematic observations. Perhaps a recommendation from the I.A.U. to this effect, proposed by our Commission, might result in an understanding with that Observatory and obtain its co-operation.

But our researches do not concern only astronomy, which might well be contented with a less exhaustive study of the problem, but also other fields from which it would be desirable to receive some co-operation. For instance, there is no doubt that it would be very useful to have experiments and observations with the aim of verifying at different places on the Earth the effects produced by the actions of the Moon upon the direction of the local vertical and upon the atmospheric tides, to see to what extent they can cause systematic variations in the refraction; in general, it would be important to know with accuracy every event of meteorological, seismic, hydrological and volcanic nature which might show noticeable perturbations in the state of disposition of masses of the Earth. It is not appropriate for me to draw a programme of such wide co-operation, particularly in view of the difficult conditions under which scientific research is working in almost all countries of the world. It will be enough for the present to have remarked upon it and to leave to the future the task of providing for it.

V. *Financing of the Central Office*

Up to the beginning of the war it had been possible to provide for the needs of the Central Bureau with the remittances sent regularly every year by the I.A.U., the International Union for Geodesy and Geophysics together with the grant from the Consiglio Nazionale delle Ricerche and from the Ministry of Public Instruction. When, later on, difficulties first arose in transferring money from one country to another, they were overcome by a method of compensation. The Consiglio Nazionale delle Ricerche in Rome was credited with the money due to Italy by the I.A.U. and the I.U.G.G. The Consiglio Nazionale delle Ricerche paid to us the amounts due. So the useless double transfer of funds was avoided; this system was carried on also during the war. To be precise I should say that the I.A.U. should have paid the sum of 1350 francs (gold) to the Observatory of Arcetri for the publication of the *Immagini spettroscopiche del bordo solare*, and 2250 francs (gold) to our Central Bureau; since the total sum was in excess of the Italian

subscription, the amounts of money given to Arcetri and to Naples were proportionally reduced. When in 1943 and 1944 our office at Naples was cut off and could not receive any financial grant either from the Ministry or from the Consiglio Nazionale delle Ricerche, we had to turn to the generous and keen interest of the President of our Commission, Sir Harold Spencer Jones, and to the Vice-President of the International Union of Geodesy and Geophysics, Dr Walter D. Lambert. We received from the first a sum of £200 sterling granted to us by the Royal Society of London, and from the second an amount of 245.06 dollars, on behalf of the International Association of Geodesy. Similarly thanks to the interest of the President, Sir Harold Spencer Jones, we received during the year 1946 the sum of £200 sterling from each of the two international unions. It was thanks to these grants that we were able to carry on our work; because while the devaluations of the lira reduced it to one-fortieth of its pre-war value, the grant from the Consiglio Nazionale delle Ricerche was still the same and the grant of the Ministry was only double the original. We therefore had to meet practically all the expenses with the grants which reached us from the Unions. I had hoped that the situation would improve during 1947 but instead it deteriorated. It is true that the Unions fixed an annual grant of 2500 francs (gold) each and that the International Astronomical Union at the beginning of 1947 gave instructions to the Consiglio Nazionale delle Ricerche to pay me the amount of 2250 francs (gold) corresponding to the contribution due from Italy to the Union. But so far we have not yet received payment of the residue and nothing has reached us from the International Association of Geodesy, so that, for the whole of the year 1947, the Central Bureau, apart from the partial grant of the International Astronomical Union, has received only the 25,000 lire from the Consiglio Nazionale delle Ricerche (the same sum was granted to us before the war) and 40,000 lire from the Ministry (which is double what had been granted to us in 1942–43) and therefore a total of 210,386.80 lire, which covers only a small part of our real expenses.

It is to be hoped that we shall succeed in obtaining in the very near future the payment of the grant fixed by the Unions for the year 1947–48, payments which are facilitated by the Consiglio Nazionale delle Ricerche of Rome which is disposed to follow the system which proved so practicable in the past, that is to say in paying to us on behalf of the Union the grants and being credited with the subscriptions. But apart from this it is also absolutely necessary that the Consiglio Nazionale delle Ricerche adjust their contribution to the present value of the lira. If this is not done so as to secure our financial position for 1948, it will be impossible for us to continue our work. We have already made an application for this. So far we have met with no success. If it is wished that the Central Bureau should remain entrusted to Italy, which has contributed so powerfully to the study of the problems of the variation of latitude since the time of the researches of Fergola and of A. Nobile, it is necessary that the representatives of Astronomy and Geodesy in the Consiglio Nazionale delle Ricerche and the Italian Geodetical Commission at the Ministry manage to persuade and remind those who still, to-day, contribute practically the same sums as before the war, that the actual value of the lira is only one-fortieth of the pre-war value.

LUIGI CARNERA
Director

APPENDIX. *Observed Characteristics of the Polar Movement.* By T. NICOLINI

As 45 years of definitive results of the International Latitude Service and 12 years of provisional results reduced by Prof. L. Carnera are now available, it is possible to examine in a relatively simple way the fundamental characteristics of the observed polar movement. The summary here sketched presents some features of interest which are not fully in accord with what is generally accepted.

The present analysis is based on analogy with beating wave-forms. The two ascertained components of the polar motion have periods of 1·00 and nearly 1·20 years, so that the

oscillations in X and Y, as well as the resultant total motion, have variations in amplitude with 'beat period' of about 6 years.

The period of a single revolution of the pole will be subject to an oscillation, as is clear from the first diagram in the figures. It follows from theory that when the crests of that oscillation are contained in the interval 1·00–1·20 years, the annual component is predominant; when this interval contains the troughs of the oscillation, Chandler's component is predominant.

The straightforward application is evident from the diagram, based on the times of transits of the polar path through $+X$. The wave-form shows, about 1923 and 1939, discontinuities in which the amplitude ratio of the two components is reversed: the predominant term is the annual within this time interval, the Chandlerian out of it. These clear indications, like the 'beat period' (which is the simple period of the figured wave-form), must be kept in mind when analysing the data of the International Latitude Service, in order to get a proper disentanglement and determination of the two components of the motion.

A detailed discussion is given in 'Contributi Astronomici' (*Capodimonte*, ser. II, vol. III, No. 8). This paper gives sixteen successive determinations of the annual term. When these have been subtracted from the total polar motion, the residual component is Chandler's motion. The regularity of this component in X and Y is so striking that it must be concluded that only the annual and Chandler's periodicities have physical reality. In contrast to the annual terms, Chandler's term shows striking variations in amplitude; there are five intervals within each of which the amplitude may be considered fairly constant. In Table I are given the mean annual terms in the five intervals of determination which are closest to those now mentioned for that of Chandler.

TABLE I

Annual terms in five intervals, by tenths of year (unit o″·01)

Fractions of year ...		·0	·1	·2	·3	·4	·5	·6	·7	·8	·9	Bary-centres
1890·7–907·6	X	−1·5	−5·9	−8·1	−7·2	− 3·3	+ 2·5	+ 7·3	+ 9·0	+ 7·4	+3·6	+0·4
	Y	−4·1	−1·3	+2·3	+5·5	+ 7·6	+ 7·3	+ 5·2	+ 0·9	− 2·2	−4·9	+1·6
1907·7–16·6	X	−1·1	−5·4	−6·3	−3·4	+ 2·2	+ 7·6	+11·8	+11·3	+ 8·2	+4·0	+2·9
	Y	−5·8	−2·8	+2·5	+7·8	+10·8	+11·3	+ 7·4	+ 2·6	− 2·9	−6·1	+2·5
16·7–22·6	X	+2·2	−2·3	−3·2	+0·2	+ 5·5	+10·4	+14·2	+14·3	+11·4	+7·1	+6·0
	Y	−5·9	−2·5	+3·0	+7·2	+ 9·4	+ 8·9	+ 5·3	− 0·5	− 5·3	−6·9	+1·3
22·7–39·6	X	−4·8	−8·7	−9·4	−7·3	− 3·6	+ 0·8	+ 6·8	+ 8·9	+ 5·5	+1·3	−1·0
	Y	−6·2	−4·1	+1·7	+7·2	+10·7	+11·2	+ 8·8	+ 2·8	− 3·0	−5·9	+2·3
39·7–46·6	X	−1·0	−4·1	−5·4	−3·4	− 3·4	+ 8·9	+12·4	+12·2	+ 8·1	+3·1	+3·4
	Y	−0·6	+1·3	+4·9	+9·4	+12·0	+12·3	+ 7·6	+ 2·0	− 0·4	−2·1	+4·6

TABLE II

Chandler's term in five intervals, by tenths of cycle, commencing with the troughs of the X oscillation (units o″·01)

Fractions of cycle...			·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
(I)	1890·0–907·8	X	−14·9	−10·9	− 4·3	+ 5·5	+11·5	+12·9	+10·7	+ 3·7	− 5·7	−12·2
		Y	− 0·8	+ 8·8	+13·7	+12·6	+ 6·7	− 1·3	− 7·8	−13·3	−13·4	− 7·7
(II)	1907·8–17·3	X	−19·6	−16·0	− 7·4	+ 8·0	+16·6	+20·0	+16·7	+ 5·0	− 6·1	−16·2
		Y	− 0·5	+12·6	+19·9	+19·8	+10·8	− 2·0	−13·6	−20·1	−20·6	−13·6
(III)	17·3–23·2	X	−13·8	− 9·2	− 4·4	+ 4·0	+ 9·4	+11·6	+ 9·2	+ 3·4	− 3·8	− 9·2
		Y	+ 1·0	+ 8·6	+12·2	+11·0	+ 6·0	− 0·6	− 8·6	−11·0	−10·2	− 3·8
(IV)	23·2–42·7	X	− 7·3	− 5·3	− 2·7	+ 0·5	+ 3·8	+ 6·8	+ 6·6	+ 3·2	− 0·7	− 4·9
		Y	+ 0·4	+ 3·5	+ 5·7	+ 6·2	+ 4·7	+ 1·4	− 3·2	− 6·0	− 5·8	− 3·8
(V)	42·7–46·3	X	−11·3	− 7·3	− 1·3	+ 6·7	+13·3	+16·7	+14·7	+ 4·3	− 4·7	−10·7
		Y	+ 3·0	+ 8·3	+12·3	+11·7	+ 3·7	− 4·7	−12·3	−16·3	−14·0	− 6·7

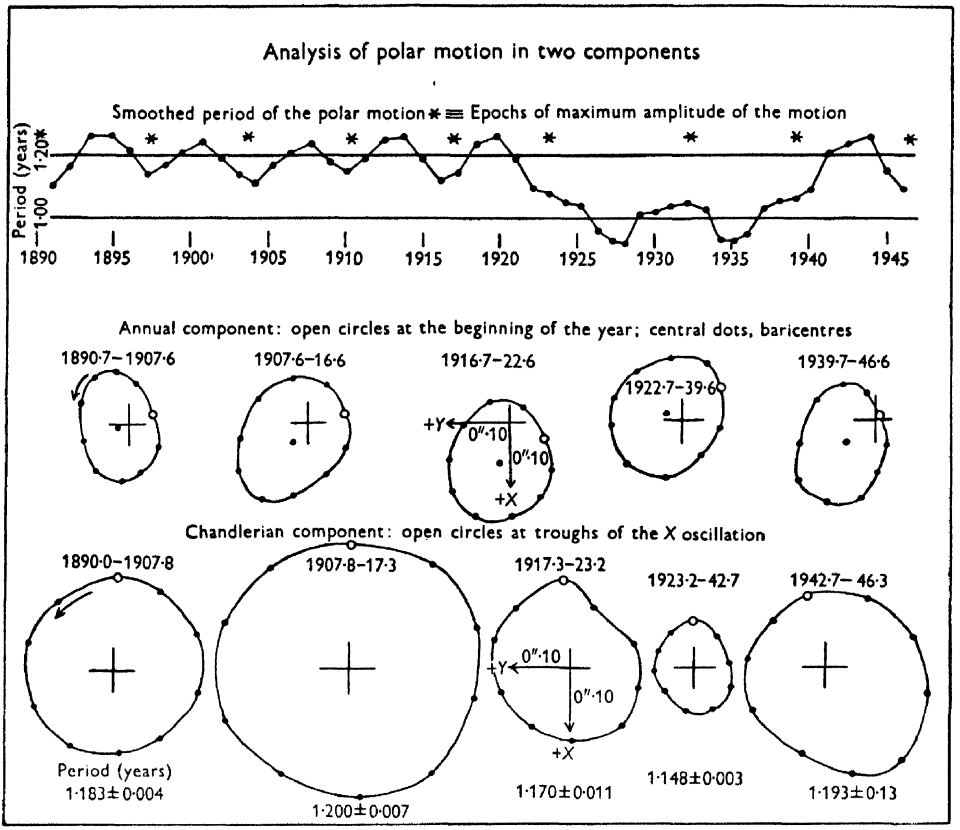


Fig. 5.

The shifting of the barycentres in reference to the 'mean pole' (assumed origin of X and Y) is an apparent motion, a 'programme shifting' due to errors in proper motions and changes in the observing programme. For instance, since 1940 the declinations from the Albany *General Catalogue* have been used; the previous values were modified by as much as $+0''{\cdot}96$ and $-0''{\cdot}16$; in addition the observations at the Carloforte Station (nearly on the X axis) have had a long period of interruption. Consequently, the shifting of the barycentre in the last interval is not surprising. The results referring to Chandler's term are synthesized in Table II and are shown, under the annual ones, in the figure. It is of interest to note that the period is variable in correspondence with the amplitude variation.

The transits of Chandler's motion through the points of maximum co-ordinates $+X$ and $-X$, give a time series whose dates are all determined with about the same precision. As our series begins at 1890·0, and this epoch coincides with a well-established transit through $-X$, i.e. with a trough of the X oscillation, we will consider here the whole series of these troughs. This series has been accurately smoothed by considering the epochs corresponding to all the crests and troughs of Chandler's oscillations in X and Y. The best results are so obtained, and they are given in Table III, with the first differences P, which correspond to the successive single values of Chandler's period. Some more details are given in the published paper, particularly in Table VII.

These results may be used to get both mean periods and their precision. In regard to the M.S.E. of a value P, it appears possible without serious difficulty to make a general

estimate (from differences, considered as accidental, between tabulated P and mean values in the five large intervals), which gives 0·054 years. On account of the presumably equal precision of all the epochs, each of the five intervals is to be considered as affected by the same M.S.E., and then we get the M.S.E. of the mean periods. The final results are synthesized in Table IV.

TABLE III

Transits of Chandler's component pole through points of maximum co-ordinate $-X$, and successive periods

Epochs	P	Epochs	P	Epochs	P	Epochs	P	Epochs	P
1890·00	1·09	1901·88	1·19	1913·78	1·17	1925·64	0·93	1936·91	1·10
91·09	1·21	3·07	1·15	14·95	1·23	26·57	1·17	38·01	1·18
92·30	1·24	4·22	1·21	16·18	1·16	27·74	1·12	39·19	1·22
93·54	1·16	5·43	1·12	17·34	1·18	28·86	1·09	40·41	1·16
94·70	1·13	6·55	1·19	18·52	1·26	29·95	1·15	41·57	1·13
95·83	1·25	7·74	1·18	19·78	1·21	31·10	1·11	42·70	1·16
97·08	1·24	8·92	1·26	20·99	1·09	32·21	1·19	43·86	1·22
98·32	1·20	10·18	1·12	22·08	1·11	33·40	1·14	45·08	1·20
99·52	1·19	11·30	1·21	23·19	1·18	34·54	1·23	46·28	1·19
1900·71	1·17	12·51	1·27	24·37	1·27	35·77	1·14	(47·47)	—

TABLE IV

Amplitude and mean periods of Chandler's component motion in five intervals

Intervals:		I 1890·7–1907·8	II 1907·8–17·3	III 1917·3–23·2	IV 1923·2–42·7	V 1942·7–46·3
Nos. of periods:		15	8	5	17	3
Amplitude:	$A=$	0″·282	0″·420	0″·242	0″·132	0″·292
Periods (years):	$P=$	1·183	1·200	1·170	1·148	1·193
M.S.E.		±·004	±·007	±·011	±·003	±·013

The variations of period appear to be significant; moreover, they appear nearly proportional to the corresponding amplitude variations, according to the relation

$$P = 0{\cdot}185A + 1{\cdot}128$$

(P in years, A in 0″·01 units). It might be thought that the variations of period are apparent, and due to some unforeseen effect of the changes of programme on Chandler's term. But the reliability of the results can hardly be challenged, for though a change of programme may shift the annual term it should not modify that of Chandler. In the effective motion, the 'beat period' is clearly seen; it is the time interval between successive epochs of maximum amplitude of the total polar movement (or between crests, or troughs, in the first diagram), and it gives immediately Chandler's period. So, after the maximum amplitude at about 1917, come those of 1923, of 1931, and of 1939; the 'beat period' is clearly lengthened, and this interference effect shows in the simplest way that Chandler's period has decreased. This same fact is also evident in the diagram given by Sir H. Spencer Jones in 'Observations made with the Cookson floating Zenith Telescope, 1927–36' (*Royal Observatory, Greenwich*), which are independent of the international programme. The reality of variations in the period is checked also by the analysis of the second differences; reference may be made to the respective diagram in the paper in 'Contributi' (*Capodimonte*).

The variation of the mean period, particularly the small value during the fourth interval, shows that the analogy (proposed by G. U. Yule) of the 'bombarded pendulum', in which there is a natural period of oscillation, while the periodicity is disturbed by changes of phase, is not appropriate. It would seem preferable here to make the analogy with an uncompensated pendulum, or with one of variable length.

Another conclusion from the above may be mentioned, which provides a warning with regard to changes in the plan of the I.L.S. Up to the present the continuity of programme of the stations on the same parallel has kept the wandering of the 'mean pole' sufficiently under check. Every change of programme should be carefully studied in advance otherwise this check could become rather confused, and a valuable series of data could get impaired.

B 1. Abstracts of Papers by Members of the Staff of the U.S. Naval Observatory

1. 'Lunar effects on clock corrections.' By Paul Sollenberger and G. M. Clemence. *A.J.* **48**, 78, 1939. The analysis of five years of clock corrections determined by the PZT shows the normal tidal effect in longitude.

2. 'Effect of the Moon on the determination of latitude at Washington.' By Wm. Markowitz and S. M. Bestul. *A.J.* **49**, 81, 1941. The analysis of 24 years of latitude observations with the PZT shows the normal tidal effect in latitude.

3. 'The free polar motion, 1916·0–1940·0.' By Wm. Markowitz. *A.J.* **50**, 17, 1942. The motion was determined from the PZT and the Cookson telescope observations of Greenwich. The motion was regular up to 1923 but not thereafter. The average amplitude and period were 0″·104 and 422 days. Increase in period is correlated with increase in amplitude. The pole of figure did not show a secular change.

4. 'Redeterminations of latitude and longitude.' By Wm. Markowitz. *Trans. Amer. Geophys. Union*, **26**, 197, 1945. Apparent continental shifts are traced to systematic errors. The indicated westward shifts of Greenland found by Jelstrup are ascribed to a systematic correction of about 4^s that the earlier lunar methods of longitude determinations require. An indicated change of 1^s in the longitude of South America is ascribed to errors in the early cable determinations. An indicated change of −0″·7 in the latitude of three U.S. Coast and Geodetic Survey stations is eliminated when modern proper motions are used.

5. 'Declinations and proper motions of 64 stars observed with the photographic zenith tube.' By Paul Sollenberger. *A.J.* **51**, 145, 1945. The relative declinations and proper motions were derived from the PZT observations. The tabulated values are on the FK3 system.

6. 'Magnitude effects in proper motions.' By Wm. Markowitz. *A.J.* **51**, 153, 1945. A comparison of the PZT and transit circle proper motions in declination shows a magnitude effect in the latter. Additional data, which confirm this, show that the effect varies with different declination zones.

7. 'Variation of latitude at the U.S. Naval Observatory, 1938 to 1945.' By Paul Sollenberger. The annual results have been published as a continuation of the results of preceding years in the *A.J.* numbers: 1110, 1130, 1141, 1144, 1147, 1150, 1154 and 1159. The 1946 results are in the Press.

B 2. Report on the U.S. Naval Observatory Photographic Zenith Tube No. 2

Photographic zenith tube No. 2, being constructed by the Material Department of the Observatory, is to be located at the U.S. Naval Base, Guantanamo Bay, Cuba. The objective has been accepted from the makers, the Perkin-Elmer Corporation.

Drawings of the instrument are being prepared and will be available soon. Those desiring copies may write to the Observatory. The Observatory has been designated by the I.A.U. as an information centre on matters concerning the PZT.

The new station is in nearly the same longitude as Washington while its latitude is +20°. By operating the two stations additional information regarding the variation of latitude and longitude will be obtained. The weather conditions at the two stations being independent, the accuracy of the time service will be increased.

The general principles of the design of F. E. Ross are followed except that the automatic

reversal and the synchronous motor-plate drive, which have been incorporated in PZT No. 1, are now part of the instrument. The instrument rests on rails set in a hollow concrete foundation instead of having massive iron castings for the lower part of the tube. The various parts of the instrument may readily be disassembled and set up again at another site where a foundation has been cast. A brief comparison of the two instruments follows:

	PZT No. 1	PZT No. 2
Aperture	8 in.	8 in.
Focal length	203 in.	149 in.
Half-field in arc	10′	17′
Height, main part	140 in.	54 in.
Weight, largest section	700 lb.	250 lb.
Exposure, each image	20 sec.	20 sec.

A study of the Washington observations indicates that the accuracy of the PZT is limited largely by variations in refraction through the night; it is not operated like the usual photographic instrument in which all the stars on the plate are taken simultaneously. It appears, therefore, that a reduced focal length will not materially reduce the accuracy, whereas important advantages will accrue because of the larger field and increased speed. The operation of the new PZT will serve as a test.

B 3. Photographic Zenith Tube for the Royal Observatory, Greenwich

Observations with the Cookson floating zenith telescope were terminated in 1940 and will not be resumed. A photographic zenith telescope is under construction and will be placed at the new site of the Observatory at Herstmonceux, Sussex. The design differs in many respects from the Washington design. The principal differences are as follows:

(i) The aperture is 10 in., focal length 135 in.
(ii) A plain ball-bearing is used for constraint of the rotary, in place of the conical bearing, in order to reduce friction and to facilitate construction.
(iii) An autocollimation method is used as a criterion of the angle of reversal of the rotary.
(iv) As a fixed axis of rotation is not required for (iii), a definite constraint in the horizontal plane is not needed. The two working orientations are each defined by a pair of stops instead of by a single stop.
(v) Adjustments to the objective are provided for squaring-on and for coincidence of the nodal plane and photographic plate.
(vi) Automatic reversal is accomplished by means of a system of wires which exert a pure torque on the rotary and therefore no tilting torque on the tube. The system is such that unidirectional rotation of the driving shaft is converted into reciprocating rotation of the rotary.
(vii) The plate carriage is annular and the plate-holder mount is circular so that symmetry of diffraction pattern is secured. The carriage constraints are external to the aperture.
(viii) Relative motion of the carriage and rotary is made to approximate to pure translation by means of a compensating system of flexed rods which constrain the carriage in the horizontal plane to which the motion is restricted by means of three balls that roll between horizontal planes.
(ix) Uniformity of rate in the relative translation of carriage and rotary is obtained by a specially designed system comprising a differential roller and metallic tapes.
(x) The time-scale is produced photographically by means of a clock-controlled lamp, giving flashes of very short duration. An independent chronograph is not required.
(xi) The height of the mercury surface is accurately adjustable and, as criterion of adjustment for constancy of scale-value, an optical null method has been introduced for use in conjunction with a suspended silica rod.

C. General

Vol. VIII of the *Results of the International Latitude Service,* containing the definite discussion of the observations at the International Latitude Stations from 1922·7 to 1935·0 by Dr H. Kimura was published in 1940. As the volume was printed in Japan, copies were not available until after the conclusion of the war; with the assistance of the U.S. Coast and Geodetic Survey, the stock of copies was brought to America and distributed from there.

Arrangements have been made, through the International Council of Scientific Unions, for grants in aid of the work of the Central Bureau of the International Latitude Service to be paid by U.N.E.S.C.O. through the International Astronomical Union and the International Union for Geodesy and Geophysics. These grants are paid with arrangements by which U.N.E.S.C.O. accepts financial responsibility for certain permanent scientific services of international character, the scientific direction of the work remaining with the Unions themselves. A separate grant has also been made towards the cost of publication of vol. IX of the *Results of the International Latitude Service.*

H. Spencer Jones
President of the Commission

Report of meetings

President: Sir Harold Spencer Jones.

Secretary: Paul Sollenberger.

Sessions: August 20, at 10.30 a.m.; August 21, at 11.30 a.m.

The President opened the meeting with a brief review of the conduct of the latitude work during the war. Mizusawa and Kitab continued work without interruption throughout the war, but observations at Carloforte were stopped. The President arranged for the collection of observing books from the American and Russian stations, and sent them to Prof. Carnera. The books from Japan were received after the end of the war through the U.S. Coast and Geodetic Survey. U.N.E.S.C.O. has accepted the latitude work as a project which it will support through the International Astronomical and Geodetic Unions. The report of Carnera appears in the Report of the Commission.

In view of the fact that Prof. Carnera is about to retire the President recommended that the work of the Central Bureau be continued in Italy under the direction of Prof. Cecchini at Turin. A resolution to this effect was approved, as was also a resolution thanking Prof. Carnera for carrying on the work during the difficult period of the war.

It was stated that arrangements have been made to resume work at Carloforte in spite of some difficulties. Prof. Cassinis had been very helpful in making the necessary arrangements through the National Research Council in Italy.

The President pointed out the importance of continuing latitude observations at the two stations on the same parallel in the southern hemisphere, particularly in the northern winter when northern observations are less complete. Observations were made at Adelaide, with a zenith telescope loaned by Mizusawa, for 7 years till the end of 1940, when the telescope was returned to Japan. La Plata is now the only remaining southern station. It is considered important that observations be resumed at Adelaide. That observatory has been closed, and the site of the new University Observatory is not suitable for latitude variation observations. A suitable site has been found near the old observatory, however, but a telescope and funds are required. An experienced observer is available.

The President has requested the Minister of the Interior of the Commonwealth Government to provide the necessary funds to enable observations to be resumed for a period of 7 years. A favourable response is looked for, but it was believed that a resolution by the Union, stressing the importance of the project, would be helpful. Such a resolution

was adopted. At the end of the 7-year period it is expected that the development of the photographic zenith tube will require a review of the international latitude variation programme.

The President stated that in 1944 the Batavia station had been destroyed, and that the observing books have disappeared. The zenith tube is intact at the Bosscha Observatory.

Prof. Carnera is undertaking the reduction of the latitude results from 1935·0 to the end of the present year. The questions as to money grant and form of publication were discussed. In particular, there was a question as to the possibility of abridging the publication. The President favoured publication in the same form as before, as also did Dr Lambert and Prof. Cecchini. The President thought that the nations which were carrying on the latitude work should have the greatest voice in the manner of publication. M. Tardi said that the Association of Geodesy had not contributed to the recent volume. He thought that only 30 to 100 persons were interested in all the details, and thought that, instead of printing 1000 copies, a smaller number should be produced by some other process. It was pointed out that part of the cost of publication of the results computed in Japan had been borne by that government, but that Italy would probably be unable to do likewise. The President believed that unforeseen uses for the complete work might arise, and advocated full publication. He hoped that the Association of Geodesy would contribute. Dr Lambert hoped that U.N.E.S.C.O. would help, but had no definite information.

The President proposed a grant of 8000 gold francs towards the cost of publication of the results from 1935·0 to the end of the present year. This was to be in addition to the 4000 gold francs voted at Copenhagen, but not yet spent. The Commission approved the proposed grant. It was also agreed that the annual grant of 3000 gold francs for carrying on the work of the Central Bureau would be continued.

The President asked for a special grant of 1000 gold francs for moving the archives, records, calculating machines and other equipment of the Central Bureau from Capodimonte to Turin. This was approved.

A letter from Prof. Hagihara was read, urging that the latitude results should be published promptly. The President thought that the delays in recent years had not been due to the Central Bureau, but were caused by delays in forwarding the observing books to that agency. A resolution was adopted urging that the observing stations should forward the observing books to the Central Bureau promptly.

The President summarized a communication from Prof. Hagihara. At Mizusawa two entirely different types of telescope, one photographic and one visual, were used. The latitudes determined by these two instruments during a four-year period were closely similar. The following data were given:

Systematic difference (photo-visual)		−0″035
Mean closing errors:	Photo	−0″251
	Visual	−0″221

It was further noted that the variation of closing errors from year to year, as obtained with the two instruments, was closely similar. This indicated that the variations were not due to the instruments themselves, a result contrary to the conclusion of F. E. Ross. The variation in atmospheric conditions from evening to morning are therefore considered a more probable cause of the variation in closing error. Prof. Cecchini said that fifteen years ago he had noted a close correlation between closing errors and atmospheric conditions. The results communicated by Prof. Hagihara showed that the annual component of the latitude variation was relatively uniform in amplitude, while the amplitude of the Chandlerian component varied widely. Similar results have been found by Nicolini (*vide* pp. 206–10). It was also noted that the length of period and amplitude of the Chandlerian component increased and decreased together.

Prof. Orlov proposed that the effect of the variation in the position of the mean pole should be removed from the published latitudes. He proposed that corrections for this

purpose should be derived for application to the published latitudes for 1900–35, and that the effect of variation in the position of the mean pole should be excluded from the results in the future. The President asked how the polar movement was to be computed, and Prof. Orlov replied that it was to be by the method of successive approximations. He said he had already done this for his own work, and furnished a paper to illustrate. The President pointed out that the application of such corrections would cause delay in the work of the Central Bureau, and therefore suggested that it should be left to that Bureau to decide whether corrections should be made. Prof. Orlov also proposed that the latitude of 39° 8′ should be kept for the location of latitude instruments, but that the existing instruments should be replaced with larger telescopes, such as the Pulkova instrument of 135 mm. aperture.

The President said that there had been no proposal to change the latitude from 39° 8′. He expressed the opinion that any decision about a change in the instruments should be delayed pending more experience in the use of photographic zenith tubes. He thanked Prof. Orlov for drawing attention to these matters.

In further discussion of the matter the President said that the fluctuations of the mean pole shown by the Greenwich observations and by the results derived from the international observations showed some fluctuating differences. He believed that the question required research. Further, he stated that Greenwich results showed that the fluctuation of the mean pole depended on the amplitude of the polar motion. Prof. Orlov did not agree with this conclusion. He advocated the application of corrections for the mean polar motion, even for periods of only one year.

Prof. Cecchini presented a resolution expressing the great interest of the International Astronomical Union in the observations for the variation of latitude, made with the large zenith telescope of l'Instituto Geografico e Cadastral de Lisbonne. The resolution was adopted.

Dr Lambert presented a proposal to refer all latitude values to the same pole. The matter was discussed very briefly. It was felt to be a matter requiring careful study, and it was therefore postponed for consideration at the next meeting of the Union. In the meantime the Central Bureau will be able to study the matter.

Mr Sollenberger said that Dr Beals was planning to install a photographic zenith tube at Ottawa. He had expressed a desire that the Union should adopt a resolution supporting such projects, as an assistance to him in obtaining the necessary funds. A suitable resolution was approved by the Commission.

20. COMMISSION DES POSITIONS ET DES MOUVEMENTS DES PETITES PLANETES, DES COMETES ET DES SATELLITES

PRÉSIDENT D'HONNEUR: M. LEUSCHNER.

PRÉSIDENT: M. DELPORTE, *Directeur honoraire de l'Observatoire Royal de Belgique, 151 Groeselenberg, Uccle, Belgique.*

VICE-PRÉSIDENT: M. D. BROUWER, *Director of the Yale University Observatory, New Haven, Conn., U.S.A.*

MEMBRES: MM. S. Arend, Asplind, Banachiewicz, Belyawsky, R. Carrasco, Comrie, Cox, Crawford, Cunningham, Eckert, Fayet, Grandón, Guth, Heinrich, Herget, Hertz, Itzigsohn, Mme Samoilova-Jakhontova, MM. Jeffers, Spencer Jones, Kamieński, Kepiński, Mme Laugier, Mme Levy McDonald, MM. E. L. Martin, Mauderli, Maxwell, Merton, Michkovitch, Nechvíle, Sadler, Schaumasse, G. A. Shajn, Sharpless, Silva, Van Biesbroeck, van den Bos, Mlle Vinter Hansen, MM. Volta, Whipple.

SOUS-COMMISSION POUR L'ÉTUDE DES COMÈTES PÉRIODIQUES

PRÉSIDENTE: MLLE VINTER HANSEN.

MEMBRES: MM. M. Davidson, Fayet, Guth, Kepiński, Matkevich, Van Biesbroeck.

NOTE SUR L'ACTIVITÉ DU PRÉSIDENT E. DELPORTE, PENDANT LA PÉRIODE 1938–47

Après le Congrès de l'U.A.I. Stockholm 1938, M. Delporte, Président de la Commission, s'est mis en rapport avec les membres de la dite Commission élus à Stockholm et avec les membres de pays non adhérents à l'Union et dont la cooptation proposée au meeting de Stockholm avait été acquise par vote. Le déclenchement des hostilités en 1939 a rompu les contacts entre les états. La Belgique encore neutre, a pu servir d'intermédiaire entre le Rechen-Institut de Berlin et la France, l'Angleterre et l'Afrique du Sud pour l'acheminement des éphémérides pour 1940 (*Kleine Planeten*).

Au 10 mai 1940, la Belgique envahie à son tour n'a plus su continuer le rôle d'intermédiaire. Les correspondances avec le Rechen-Institut de Berlin et le Bureau central des Télégrammes astronomiques de Copenhague ont elles-mêmes été coupées pour le reste de l'année 1940 mais ont pu reprendre ensuite, souvent avec des retards très importants. Je tiens à signaler que le Directeur et les membres du Rechen-Institut ont, dans la mesure où cela leur était possible, fait tous leurs efforts pour la continuation des services de petites planètes, intervenant même pour que la fourniture de plaques photographiques soit effectuée.

Les volumes d'éphémérides (*Kleine Planeten*) ont été publiées régulièrement jusqu'en 1944. Le volume contenant les éphémérides pour 1945 a été calculé mais les exemplaires ont été détruits à l'imprimerie même, à la suite de combats de la fin de guerre.

Pendant la période 1938–47, la Commission 20 a perdu plusieurs de ses membres et notamment: le Prof. G. Stracke, décédé en 1943, et dont l'activité au service des petites planètes a été si importante; le Prof. K. Boda, successeur du Prof. Brendel au bureau de calcul de Frankfort; M. le Prof. Neujmin, l'actif observateur de l'Observatoire de Siméis, qui a eu l'amertume de voir d'abord anéantir l'établissement si renommé par ses travaux; M. de la Villemarqué S.J. qui a continué, jusqu'à la fin de sa vie, ses beaux travaux de perturbations et d'orbites; M. Crommelin, le grand spécialiste des calculs d'orbites cométaires et d'objets spéciaux (astéroïdes); M. le Prof. E. Strömgren, directeur du bureau des télégrammes; MM. Numerof, Komendantof et Giacobini.

Malgré l'absence d'éphémérides, l'Observatoire d'Uccle pendant le second semestre de 1945 a continué ses prises de clichés en ayant en vue principalement l'observation des planètes trouvées à Uccle. A cet effet le calcul d'éphémérides de celles de ces planètes arrivant en opposition à ce moment, a été effectué. Un calcul identique a été fait pour

l'année 1946 sous la direction de M. Arend par les calculateurs du service: MM. Sanders et Roland. L'Observatoire de Belgrade, à qui nous avons demandé s'il ne possédait pas les *Kleine Planeten* 1945, nous a envoyé les éphémérides d'un certain nombre de planètes arrivant en opposition au cours du dernier trimestre de 1945, ce qui a facilité l'identification d'astéroïdes trouvés sur nos plaques.

L'Observatoire d'Uccle a calculé les éphémérides d'une vingtaine de planètes brillantes pour chacune des années 1946, 1947, et 1948, éphémérides destinées à figurer dans l'annuaire Flammarion de la Société astronomique de France. Le manuscrit du *Kleine Planeten* 1946, remis par M. le Prof. Kopff, a pu être reproduit à un nombre restreint d'exemplaires par la photographie, par le service américain. Le problème du calcul des éphémérides pour l'ensemble des planètes pour 1947 a été posé à la réunion restreinte de l'Union Astronomique Internationale, tenue à Copenhague en mars 1946.

Deux exemplaires des *Kleine Planeten* 1945 avaient pu être retrouvés et se trouvaient à l'Institut théorique d'Astronomie de l'Académie des Sciences de Leningrad, qui en a mis un exemplaire à la disposition du Nautical Almanac Office de Londres.

Grâce à l'obligeance de M. Sadler, Superintendent du Nautical Almanac Office, l'Observatoire d'Uccle a pu se servir de cet exemplaire pour établir une liste d'éléments d'orbites des planètes pour lesquelles ces éléments différaient de ceux des *Kleine Planeten* des années précédentes.

Les correspondances échangées avec le Rechen-Institut, qui s'était fixé à Heidelberg, ayant conclu à l'impossibilité pour ce bureau de se charger du calcul d'éphémérides pour 1947, le travail a été partagé entre un certain nombre d'observatoires européens qui reçurent les éléments de calcul de l'Observatoire d'Uccle qui les avait préparés et qui devait centraliser les résultats.

L'Institut d'Astronomie théorique de l'Académie des Sciences de l'U.R.S.S. s'est chargé du calcul d'un certain nombre d'astéroïdes (1° semestre 216, 2° semestre 219). Pour le 1er semestre, le Président de la Commission 20 a sollicité les concours d'observatoires européens.

Les observatoires d'Alger, Barcelone, Belgrade, Madrid, Nice, San Fernando, Tortosa, Türku et Uccle ont répondu à cet appel.

M. le Prof. Cunningham a réuni en 1 fascicule le résultat de ces travaux, auxquels il a joint les éphémérides d'un petit nombre de planètes calculées à Berkeley.

Les observatoires d'Alger, Belgrade, Nice, Türku et Uccle ont également calculé un nombre restreint d'éphémérides pour le 2° semestre 1947. La plus grande partie des éphémérides du second semestre ont été calculées en Amérique au moyen des machines Watson.

C'est grâce aux efforts combinés de M. le Dir. Eckert et de M. le Prof. Cunningham que cette partie importante du travail a pu être menée à bien en un temps assez court. Les observateurs ont donc pu disposer en 1947 de l'entièreté des éphémérides des planètes arrivant en opposition.

D'autre part, le Japon étant coupé encore de relations postales, M. le Prof. Y. Hagihara, Président de l'une des Commissions du Conseil National de recherches de ce pays, a fait calculer les éphémérides de 186 astéroïdes par les soins de cette Commission. Le calcul a été basé sur les éléments d'orbites contenues dans le volume *Kleine Planeten* 1941 qui était le plus récent en main des observateurs.

L'envoi des documents publiés pour 1947 a été fait au Japon pour permettre aux observateurs l'identification des objets observés, et qui ne se seraient pas trouvés dans la liste de M. Hagihara.

Pour l'année 1948 des dispositions ont été prises pour que le travail complet des éphémérides soit assuré par l'Institut d'Astronomie théorique de Leningrad avec le concours du Rechen-Institut. Néanmoins les observatoires d'Alger et de Belgrade, qui avaient déjà commencé leurs calculs, ont fourni déjà un certain nombre d'éphémérides.

E. DELPORTE
Président de la Commission

In March 1947, President Delporte asked to be relieved of some of his duties and requested the Vice-President to take charge of various activities in connection with the work of the Commission, including the preparation of this Report. In September 1947 the following circular was sent to all members of the Commission:

I. Publication of observations. For some time the need has been felt for a rapid means of publication such as existed in the Rechen-Institut Circulars before the war. After ample consideration it was decided to issue Minor Planet Circulars under the auspices of the International Astronomical Union. Dr Paul Herget accepted the responsibility for this service. An announcement concerning this step was recently made by the President and the Secretary of the International Astronomical Union.

It should be understood that this has no effect upon the work of the Bureau of Astronomical Telegrams which will remain at Copenhagen.

II. Publication of Ephemerides. For the year 1947 the calculation and publication of ephemerides had to be improvised because of insufficient time for adequate preparation.

A volume to be published under the auspices of the Union and containing all of the ephemerides for this year is now being prepared by Dr Paul Herget in cooperation with the U.S. Naval Observatory. This volume is intended primarily for reference purposes: it will appear too late to be of any use in furnishing search ephemerides.

For the year 1948 all of the ephemerides of numbered minor planets will be furnished by the Leningrad Institute. This Institute had originally undertaken a smaller programme but expanded its programme at the request of the President of the Union.

The Rechen-Institut, now at Heidelberg under the direction of Prof. Kopff, has offered to contribute ephemerides of the more recently discovered asteroids for which the Rechen-Institut has data not generally available, as well as ephemerides of asteroids for which it possesses perturbation tables in manuscript form.

It is hoped that for the year 1949 numerous ephemerides based upon improved orbits may be introduced. In this connexion it would be most helpful if members of Commission 20 would communicate what contributions they intend to make. Especially useful would be a listing of those minor planets for which ephemerides based upon perturbed co-ordinates could be contributed. This subject is closely related to that discussed in section IV.

III. Organization of observations. On Harvard Announcement Card No. 781 a tentative plan formulated by Prof. Leuschner for dealing with the organization of the observations of asteroids was communicated. The purpose of this plan was to obtain observations of asteroids for which additional observations are urgently needed in order to secure their orbits, and to avoid unnecessary duplication. An attempt has been made to carry out such a programme, but its effectiveness has suffered on account of the fact that many ephemerides for the current year were necessarily of poor quality. A programme of this type cannot be successfully introduced at once. It is necessary to have all ephemerides available well before the beginning of each calendar year, and the ephemerides should be of improved accuracy.

Suggestions concerning this matter will be welcome.

IV. Need for orbit and perturbation calculations. The minor planets that will need particular attention are those that have been observed in fewer than four oppositions. Numerical integrations for a large number of these minor planets, with the aid of high speed calculating machines, are planned by Dr Herget in Cincinnati and possibly elsewhere. The task of making differential orbit corrections by comparing these perturbed orbits with observations cannot be performed so readily by these machines. It is therefore proposed that a co-operative plan be formulated in which the onerous routine calculations would be performed by the automatic machines and provided to the computers who wish to complete the computation of the differential corrections. At least some of the perturbations should be available some time between January and March of 1948. Members of the commission are requested to communicate to what extent they would wish to participate in undertaking a share of this work. It is believed that in this manner useful contributions can be made in numerous centres of research, and that this type of co-operation may grow to a successful international undertaking of considerable scope.

It has been emphasized in previous years by Leuschner that increased activity in the field of providing general perturbations is particularly desirable. On the other hand, in order to obtain accurate osculating elements to be used as the basis of general perturbations, it is necessary to link at least four oppositions by means of special perturbations. Much of this preparatory work remains to be done in the near future.

In response to the request for reports from members, numerous communications have been received. These are summarized by countries. It was found necessary to omit extensive bibliographies, and reduce the extent of detailed tabulations. In view of the impossibility of obtaining reports from all members at a sufficiently early date, the President of the Commission has on previous meetings omitted these reports from the Draft Reports. Since this year the reports contain information on work in progress that may be particularly useful in the discussions at Zürich, it appeared desirable to have these available in advance. It was evidently impossible to achieve completeness. Reports that may be received later will be presented at a meeting of the Commission.

Argentine Republic

B. H. Dawson at La Plata and J. Bobone at Córdoba have contributed extensive series of observations of comets, published in the *Astronomical Journal*. The latter has also made observations of minor planets and of Jupiter's sixth satellite.

Captain Guillermo O. Wallbrecher, director of the La Plata Observatory, has expressed the intention of the observatory to take an active part in a programme of observation of minor planets.

Belgium

A report by E. Delporte and S. Arend on the activity of the Observatoire Royal de Belgique for the period July 1938 to 15 December 1947 reads in part:

L'astrographe double de Zeiss, de 400 mm. de diamètre et 2 mètres de longueur focale a été consacré pendant toute la période à la recherche et l'observation des petites planètes et à l'observation de comètes. La difficulté de se procurer des plaques pendant la guerre et dans la période qui a suivi celle-ci, a fait que l'emploi simultané des 2 chambres a été très rare.

La méthode d'observation à double pose (barre-point), sans modification de centre, a été moins employée. On lui a substitué très souvent la méthode à doubles poses (barre-point) mais avec décalage du centre pour la 2e pose. Cette méthode donne des plaques plus chargées puisque chaque étoile a deux images, mais pour les mesures précises elle a l'avantage que les secondes poses (point) ont la même durée pour les étoiles et l'astéroïde; les images sont donc mieux comparables.

La méthode Trépied-Metcalf a été beaucoup plus employée en raison de la moins grande sensibilité des émulsions photographiques dont on a pu disposer et qui obligeait donc à concentrer la pose sur un objet faible en tenant compte de son mouvement par les déplacements micrométriques.

Le rendement en nombre d'objets mesurables a donc été moindre pour cette raison.

Deux autres causes ont grandement influencé le rendement du service, c'est d'abord le fait que les conditions du ciel ont été très mauvaises; le trouble de l'atmosphère allant en augmentant jusqu'à la fin de la periode (1947); d'autre part les opérations de guerre ont contrecarré l'observation, soit qu'il s'agisse des tirs contre avions ou contre engins V1 ou V2 obligeant à fermer les coupoles, soit en raison des restrictions dans l'éclairage commandées par l'occupant.

Pendant la plus grande partie de l'année 1940, le personnel a été plus réduit, M. Arend étant absent pour raisons militaires. Les autres années le service d'observation a comporté trois observateurs: MM. E. Delporte, S. Arend, F. Rigaux.

Relevé statistique: 1938 *Juillet*—1947 *Décembre*

Nombre de centres, 795
Nombre total de positions, 1697
Planètes nouvelles découvertes, 101
Planètes anciennes observées, 822
Nombre de positions approchées, 867:
Planètes connues, 788; Planètes nouvelles, 79
Nombre de positions précises, 830:
Planètes connues, 688; Planètes nouvelles, 142.

Résultats: 1938–47. Planètes numérotées au profit de l'observatoire d'Uccle et dénominations:

E. Delporte	1937	UC 1433 Geremtina
	1936	FD_1 1434 Margot
	1936	RA 1476
	1938	QA 1486 Marilyn
	1938	QB 1493 Sigrid
	1941	SI 1543
	1942	XB 1560
P. Bourgeois	1929	CZ 1547
S. Arend	1943	EQ 1563 Noël
F. Rigaux	1937	RC 1458 Mineura
	1941	SA 1555 Dejan

En plus les planètes découvertes à Uccle:

E. Delporte 1938 CB 1463 a été numérotée au profit de l'Observatoire de Türku qui en avait la priorité de découverte,

de même S. Arend 1935 CD a été numérotée au profit de l'Observatoire d'Heidelberg à la suite de la redécouverte 1938 WB. Elle a reçu le nom 'Arenda'.

Calculations of orbits of planets discovered at Uccle in which S. Arend, J. Biezemans, J. Hunaerts, F. Rigaux, and P. Sanders participated, have been published in the *Bulletin Astronomique de l'Observatoire Royal de Belgique*, Vols. **2** and **3**.

J. Delvosal and J. Warzée published photographic observations of Eros with the Carte du Ciel instrument.

Numerous articles on subjects related to minor planets by members of the observatory staff appeared, principally in *B.A.B.* and in *Ciel et Terre*. Among these may be listed: J. F. Cox et H. Jehle, 'Éléments canoniques des petites planètes nos. 1 à 1183', *B.A.B.* **3**, 248–65, 1944; P. Bourgeois et J. F. Cox, 'Probabilité de la découverte et nombre de petites planètes', *A.N.* **265**, 1–20 (nos. 6338–9), 1938; various articles by S. Arend on the method of reduction of astronomical photographs; two articles by S. Arend et P. Sanders, 'Application du calcul des matrices à l'amélioration de l'orbite de l'astéroïde 1938 QB = 1493', *B.A.B.* **3**, 60–4, 1939; 'Application du calcul des Cracoviens à l'amélioration des orbites', *B.A.B.* **3**, 101–4, 1940.

Czechoslovakia

Dr V. Nechvíle, of the National Observatory at Prague, reports:

Before the war, eleven accurate positions of the comet 1939*d* Jurlov-Achmarov-Hassel were obtained with the double Zeiss astrographic equatorial of the Stefánik Observatory at Prague, with the collaboration of Prof. E. Buchar. During and after the war 42 accurate astrographic positions of the planet Eros, obtained during the opposition 1930–31, were newly reduced on the basis of the new and definitive positions of the reference stars, given in the Catalogue by Dr H. Spencer Jones and P. J. Melotte in the *Memoirs of the Royal Astronomical Society*, Vol. LXV, part IV, 1937. Both publications are in the Press in the *Annales de l'Observatoire National de Prague.*

Denmark

Julie M. Vinter Hansen reports on the activities at the University Observatory at Copenhagen:

Comets. Preliminary orbits and ephemerides for numerous comets have been computed, particularly by the late Mr Jens P. Möller, in connection with the activities of the I.A.U. Bureau of Astronomical Telegrams.

Elis Strömgren and H. Q. Rasmusen published a paper 'On the original orbits of comets 1925 I, 1920 III, and 1897 I' (*Publikationer og Mindre Meddelelser fra Københavns Observatorium*, No. 114).

Definitive orbits for comets 1929 I and 1941 VII were computed by H. Q. Rasmusen and P. Naur, respectively (*Pub. Kopenhagen Obs.* Nos. 128 and 141).

Unpublished investigations are: by H. Q. Rasmusen on the prediction for the return of comet Olbers (finished) and by J. M. Vinter Hansen on periodic comet Comas Solá (in progress).

Minor Planets. Observations of the brighter minor planets at the Copenhagen Observatory, principally by J. M. Vinter Hansen and J. P. Möller, were continued (*Pub. Kopenhagen Obs.* Nos. 117 and 123). While at the Lick Observatory and at Berkeley, California, Miss Vinter Hansen's activities included 'Observations of Eros and of 51 Nemausa' (*Lick Obs. Bull.* Nos. 512, 516) and, with A. O. Leuschner, 'The calculation of ephemerides of Watson Asteroids for 1942' (*Lick Obs. Bull.* No. 509).

Prof. Bengt Strömgren reports on an investigation of the motion of 51 Nemausa:

The aim of the investigation is to derive, ultimately, systematic corrections of the fundamental system in the equator zone. This asteroid, which at opposition is always close to the equator, is suitable for such a study. Most of the computational work involved has been carried out by Mr Ole Möller, part of it by Messrs Ole Hesselberg, Erik Sinding, and Peter Naur.

Using preliminary improved elements derived from observations 1927–39 the motion has been calculated 1927–47 taking account of the perturbations by all the major planets. The observations of the asteroid in this period are being re-reduced and compared with the resulting ephemeris using improved positions of the comparison stars. The positions of 120 comparison stars have been determined by Dr Anders Reiz from meridian observations made by him at the Lund Observatory. The improved elements resulting from this discussion will presumably be available within a year, and will then form the basis of a repeated numerical integration of the equations of motion. From a comparison of the resulting ephemeris with observations of high accuracy in a well-defined system it will be possible to derive the required systematic corrections in the equatorial zone. It is planned to base the final solution on twelve oppositions of high-accuracy observations. It will be possible, however, to derive rather accurate preliminary values already from three accurately determined oppositions.

Tables published in *Pub. Kopenhagen Obs.* are:

H. Q. Rasmusen, *Äquatoriale Uranus- und Neptun-Koordinaten für den Zeitraum* 1800–1903, *bezogen auf das Äquinoktium* 1950·0 (No. 121).

Jens P. Möller, *Tafeln zur Reduktion gemessener Differenzen in Rektaszension und Deklination auf Differenzen der mittleren Örter bezogen auf das Äquinoktium des Jahresanfangs* (No. 123).

France

M. G. Fayet, directeur de l'Observatoire de Nice reports:

Sauf pendant 1944 et 1945, où l'on a dû interrompre, faute de plaques et aussi d'éphémérides, le grand astrographe double, que possède notre observatoire, a été utilisé, depuis 1935, à la recherche photographique des astéroïdes. Ce service a toujours été confié à Madame Laugier et à M. Patry.

Voici le résumé des résultats obtenus:

Obsr	Nombre de clichés	Nombre d'astéroïdes	Planètes nouvelles ou non identifiées
	I—1937–43		
Mme Laugier	654	1108	121
M. Patry	363	981	39
	II—1946–fin oct. 1947		
Mme Laugier	118	143	5
M. Patry	77	163	15

D'autre part, Mme Laugier a calculé 42 orbites et M. Patry 12.

En 1946, mes deux collaborateurs ont calculé et adressé à M. Delporte, une centaine d'éphémérides pour l'opposition de 1947.

En appliquant la méthode qu'il a exposée dans le *Journal des Observateurs* (Vol. **29**, Nos. 5–6), M. Patry a entrepris une recherche systématique en vue d'identifier les petites planètes insuffisamment observées pour qu'il soit possible d'en déterminer l'orbite. Parmi les 416 objets examinés jusqu'à présent, M. Patry a réussi à établir 56 identités parmi lesquelles il convient de citer particulièrement celles qui intéressent les astéroïdes 459, 650, et 750 perdus depuis longtemps.

Enfin je vous signalerai que j'ai achevé, depuis déjà plusieurs années, un mémoire assez étendu consacré à l'*étude générale des proximités dans le système solaire*, mais qui n'a pu encore être imprimé faute de crédits. J'espère toutefois qu'il pourra paraître, dans un avenir assez proche, dans le prochain volume des *Annales du Bureau des Longitudes*.

M. A. Schaumasse, astronome, Observatoire de Nice reports:

Jusqu'en juillet 1942 j'ai pu continuer à l'équatorial coudé de 40 cm. de l'Observatoire de Nice, mes travaux sur les recherches de comètes, l'observation des petites planètes et les calculs d'orbites et d'éphémérides.

Mon activité a été interrompue jusqu'en 1947, les objectifs des instruments ayant été enlevés, mais depuis le mois de mai Monsieur Fayet vient de me charger du chercheur de comètes de 25 cm. d'ouverture de Zeiss, qui après quelques modifications, va sans doute me permettre de recommencer mes recherches.

A report received from L. Boyer, Observatoire d'Alger, Bouzaréah, reads in part:

Pendant la période 1938–47 le service des petites planètes et comètes a eu une activité réduite et à certaines époques complètement arrêtée par suite de la guerre.

Observations. L'instrument employé est l'Equatorial Photographique de la Carte du Ciel. Les observations sont faites par la méthode Trépied-Metcalf.

J'ai pris environ 1200 clichés et obtenu les positions de 1150 planètes et de 100 comètes, ainsi que 5 positions de Pluton.

Cinq planètes nouvelles ont été découvertes; une seule a pu être suivie assez longtemps pour être numérotée: 1511.

Sur la demande de divers calculateurs des séries d'observations s'étendant sur un intervalle de 4 à 6 mois ont été faites: notamment pour 1 Céres, 2 Pallas, 3 Juno, 4 Vesta, 433 Eros, et 1036 Ganymed.

En 1946–47 13 comètes differentes ont été observées. Elles sont suivies le plus longtemps possible.

Travaux de calcul: 1° Positions précises de planètes et de comètes: 950 environ.

2° Calcul d'orbites des planètes découvertes à Alger.

3° Calcul des perturbations par Jupiter et Saturne et amélioration des éléments de quelques planètes découvertes à Alger, en particulier de 1177, 1301, 1339, 1377.

4° Continuation du calcul des perturbations de 173 Ino par toutes les grosses planètes. Ce travail entrepris par M. P. Caubet, astronome à Toulouse, a été poursuivi ici. Les éléments de

cette planète ont été améliorés pour la dernière fois avec des observations de 1924. Depuis cette date jusqu'en 1944 les observations, à chaque opposition, sont représentées d'une façon très satisfaisante. Pour les observations des 16 oppositions qui ont eu lieu pendant cette période, les moyennes des valeurs absolues des écarts entre les observations et le calcul sont de $0^s{\cdot}05$ en α et de $0''{\cdot}6$ en δ. Actuellement je continue les calculs de façon à combler le retard et à publier une année à l'avance les éléments de cette planète pour l'opposition à venir, comme cela était fait avant la guerre.

Les résultats des calculs qui précèdent sont ou seront publiés au *Journal des Observateurs*. Les positions des comètes et de quelques planètes sont publiées aux Circulaires de l'U.A.I.

5° Contribution au calcul des éphémérides pour les années 1947 et 1948 avec la collaboration de M. Reiss.

6° D'autre part M. A. Schmitt et M^me^ Schmitt-Bancilhon ont obtenu visuellement à l'Equatorial Coudé environ 200 positions de comètes. M. A. Schmitt a calculé les orbites et les éphémérides de 3 comètes.

Remarques. L'Observatoire d'Alger a demandé à collaborer aux observations systématiques de certaines petites planètes (Cir. U.A.I. No. 1071). Aucun plan d'observation n'est parvenu à ce jour.

Les circulaires de l'U.A.I. parviennent à Alger 10 à 15 jours après leur départ de Copenhague. Par suite de ce retard il est parfois impossible d'utiliser les éphémérides publiées par ces circulaires. Il y aurait interêt à les expédier parfois par avion.

Great Britain

Mr D. H. Sadler, Superintendent of H.M. Nautical Almanac Office, reports:

The second volume of Planetary Co-ordinates referred to the equinox of 1950·0, covering the years 1940–60 (and including spherical co-ordinates of Uranus and Neptune for 1800–1900) was published in September 1939. It followed closely the plan of the first volume, with minor improvements, such as the use of a smaller interval of tabulation for Saturn and the retention of an extra figure in the attractions on the Sun. Owing to the war, distribution was much restricted. The type, plates and stock were destroyed in November 1940; a reprint was unfortunately impossible until after the war, but it was possible to meet the most urgent requirements by loan copies. A photographic reprint has now been issued.

It is proposed to issue a similar volume covering the years 1960–80 in about 1955.

Dr J. G. Porter, Director of the Computing Section of the British Astronomical Association, reports:

The work of the Computing Section in connection with Minor Planets, Comets and Satellites since the last I.A.U. meeting has been as follows:

Minor Planets. An ephemeris of Vesta from Leveau's tables was prepared by B. F. Bawtree up to the year 1943, but was discontinued after that date.

Comets. Regular predictions of the return of all periodic comets have been made and published annually in the *Handbook of the British Astronomical Association*. Work is now in progress on the comets due to return in 1949 and 1950. Investigations have been made as to the degree of accuracy of predictions based on Crommelin's tables (*Memoirs R.A.S.* **64**, 149); and methods of correcting a Cowell or Encke scheme for observations are also being tried.

Satellites. No predictions of mutual eclipses, etc., of Jupiter's satellites were possible. Predictions of phenomena for Saturn's satellites in 1948 will appear shortly, and this work is being continued. Mutual phenomena of Jupiter's satellites in 1949 are being investigated.

Dr G. Merton, University Observatory, Oxford, reports:

The only observations of position of sufficient accuracy for orbit determinations, made in the British Isles, are those of comets by Dr W. H. Steavenson at Cambridge (30-inch reflector) and those from photographs, obtained with small cameras of relatively short focus, which are measured when required by Dr G. Merton at Oxford, where two such cameras are now mounted

and in use on photometric work. Since such observations of position are generally not of the high order of accuracy required for definitive computations of orbits, they are not made except for checking or computing preliminary orbits.

Occasional computations of cometary orbits have been made in this country chiefly by Dr Martin Davidson, and the regular work on periodic comets (reported under the Sub-Commission for periodic comets) is carried on by members of the Computing Section of the B.A.A.; and recently Dr G. Merton has returned to join in both types of work. Generally speaking the calculation of preliminary orbits, and of improved orbits, cannot at present be usefully undertaken here because reliable observations are not received sufficiently quickly. In fact recently the first-class elements for orbits which Dr L. E. Cunningham computes, and which are telegraphed from the United States, are usually received through the I.A.U. Bureau before the three accurate observations necessary for an orbit determination become available. Ephemerides are, however, computed as needed and published in the B.A.A. Circulars and elsewhere.

The inclusion in the annual Council Notes of the Royal Astronomical Society of information on Minor Planets was discontinued after the death of Dr A. C. D. Crommelin, and that for comets has not been so complete as before. In the Council Notes for 1947, however, an attempt has been made to bring the information on cometary orbits up to date, and details of 70 orbits are given there.

Italy

Prof. E. L. Martin, Direttore dell' Osservatorio Astronomico, Trieste, reports that owing to damage suffered during the war, the observatory has no instruments that can be utilized for observations of minor planets, comets, and satellites. The director and the observatory staff are anxious to take an active part in the calculation of ephemerides and in the differential correction of orbits. For the present, the scarcity of competent personnel and of calculating machines will limit the extent to which such contributions can be made.

Poland

Prof. M. Kamieński, Cracow, reports that he is continuing his work on the motion of periodic comet Wolf I, a summary of which appeared in *Monthly Notices R.A.S.* **106**, 267–73, 1946. In connection with investigations on the motion of Halley's comet (see recommendation no. 7), investigations have been in progress on the co-ordinates of the principal planets in the remote past. These include: Tables of the Sun for the Period from 10,000 to 4000 B.C., by M. Kamieński; and Tables of Uranus and Neptune from 4000 B.C. to 3000 A.D., by M. Kamieński and R. Walter. These publications are in print in *Bulletins of the Polish Academy of Sciences.*

Prof. F. Kepiński, Warsaw, reports that he is continuing his work on the periodic comet 1906 IV. An account of work done during the war was published in *Publications of the Polytechnic Astronomical Institute* at Warsaw, No. 23. In this same number he published an account of the cruel effects of the war on the Institute and its staff.

South Africa

Dr W. H. van den Bos, Union Astronomer, Johannesburg, reports that the Union Observatory tries to cover the southern half of the ecliptic every year for minor planets, and observes all comets in the southern hemisphere as far as possible. The regular programme was interrupted in 1940 when Mr C. Jackson, who concentrated on minor planets, and Mr E. L. Johnson, who concentrated on comets, left the Observatory on account of military service. After the war Mr Jackson became observer in charge at the Yale (now Yale-Columbia) Southern Station in Johannesburg. Mr Johnson has since early in 1946 been in charge of the observing of both minor planets and comets. Observations from 1938 to early in 1941 were published in *Union Observatory Circular*, Nos. 101–4. During the war years some work was carried on by Dr van den Bos, Mr J. A. Bruwer and Dr H. van

Gent. The observations during this period will appear in *U.O. Circular*, No. 105, now in print. Van Gent's observations of minor planets in 1940 were published in *B.A.N.* **9**, 1942.

Spain

A report has been received from Prof. R. Carrasco, Director del Observatorio Astronómico de Madrid. The civil war caused total suspension of the work, and partial suspension afterward. The astrograph of the Madrid Observatory and its building were damaged, and were out of operation until 1946. During the world war difficulties similar to those in other countries were experienced, especially caused by lack of ephemerides, photographic plates, etc. These difficulties have now been overcome, and the work is normal. Active co-operation with the San Fernando Observatory will stimulate work in Spain in the field of minor planets, comets and satellites. The observatories took an active part in the calculation of ephemerides for the year 1947. A total of 144 ephemerides were computed: 51 at the Observatorio de Fabra (Barcelona), 22 at San Fernando, 15 at Ebro, and 56 at Madrid.

The number of positions of minor planets and comets obtained during the period 1938 July to 1947 July are

	Minor Planets		Comets	
	1938–44	1946–47	1938–44	1946–47
Fabra	283	67	36	6
San Fernando	12	52	2	1
Madrid	—	58	82	21

A large part of these observations was published in the R.I. circulars, I.A.U. circulars and, for Madrid, in the *Boletin Astr. del Obs. de Madrid*, Vols. **2** and **3**.

A definitive orbit of comet Carrasco (1931 V) was published by R. Carrasco, *Bol. Astr. del Obs. Madrid*, **3**, No. 5.

Articles by Ortez Farnaguera on a comparative study of different methods of orbit calculation with calculating machines and by Febrer on a statistical study of the distribution of asteroids are in print.

Switzerland

A report has been received from Prof. S. Mauderli, Astronomisches Institut der Universität Bern.

Since 1939 orbit determinations have been made for the minor planets 1531, 1551, 1554 and 1556. Accurate special perturbations by Jupiter in the elements have been continued for 1009 Sirene, 1134 Kepler, 1308 Halleria, 1313 Berna, and 1435 Garlena. For Sirene occasional perturbations by Mars have been included. Dr Max Schürer took charge of the work on minor planets on April 1, 1946, when Professor Mauderli retired; Schürer has contributed numerous orbit corrections by approximate methods.

During the war, Mauderli maintained an extensive exchange of observations and circulars between the Observatories at Algiers, Cape of Good Hope, Córdoba, Johannesburg, La Plata and Nice with the Astronomisches Rechen-Institut. This exchange included the mailing of R.I. circulars Nos. 2103–2567 to these observatories, and in return of communications of observations to the Rechen-Institut.

United States of America

At the University of California, Berkeley, Dr Sophia Levy McDonald, of the mathematics department, has continued her development of general perturbations and the determinations of mean elements of minor planets of the Hecuba group on the basis of the Berkeley Tables. A summary of the highly satisfactory results on a total of 35 planets of

the group was reported by her at the December, 1947, meeting of the American Astronomical Society at Columbus, Ohio. A manuscript on the results of the individual planets is ready for publication.

Research Surveys for 1091 planets were published by Leuschner late in 1935 as Vol. **19** of the *Publications of the Lick Observatory*, and embody all available material published to June 30, 1929. Afterwards, these surveys were extended to include material published since that date, and surveys have been completed for additional planets up to and including planet 1489. This continuation is in manuscript and contains all available material published to June 30, 1938. It was carried out with the aid of the Works Progress Administration of the United States Government with Dr Katherine Prescott Tinker as supervisor of workers made available by that agency. No provision has yet been made for the publication and further continuation.

In a report received from H. M. Jeffers, covering the activity at the Lick Observatory, it is stated that a certain amount of the observing time with all the major instruments is available for the observation of comets and minor planets. The bulk of this work is carried on by means of the Crossley 36-inch reflector, and the 20-inch Carnegie astrograph. The principal observers are, on the Crossley, Dr H. M. Jeffers, and on the 20-inch astrograph, Dr C. D. Shane. The observational work on the comets and planets is to a large degree co-ordinated with investigations being carried on at Berkeley, principally by Dr L. E. Cunningham. An attempt is made to obtain observations of currently visible comets each month, and more often than this if the positions are needed. The minor planets that are observed are mainly those of special interest for one reason or another. (It has not been found practicable to devote much of the 20-inch time to the routine observation of the known minor planets.) Satellites are observed occasionally, for one reason or another. During the years 1942–45 few comet and minor planet observations were made, since during these years several members of the Observatory staff were away.

General observational programmes of minor planets and comets have been in progress at the Yerkes and McDonald Observatories, principally by Van Biesbroeck; at the United States Naval Observatory, Washington, D.C., in recent years principally by Sharpless and Reuning; and at the Lowell Observatory, Flagstaff, Arizona, principally by Giclas. Most of the observations obtained have been published in the *Astronomical Journal*.

Miscellaneous investigations of the motions of minor planets and comets have been pursued, particularly at the University of California, Berkeley, at the Cincinnati Observatory and at the United States Naval Observatory. Cunningham's numerous preliminary orbits and ephemerides of newly discovered comets, and his calculation and distribution of ephemerides of minor planets in the early months of 1947 were most significant contributions. In the latter part of 1947, an installation of punch-card calculating machines was made at the Cincinnati Observatory. With this equipment Herget intends to make extensive studies of the motions of minor planets. Since the work has only recently been started, no details are as yet available. Herget made significant contributions by undertaking the publication of minor planet circulars and by editing a compilation of all the minor planet ephemerides for the year 1947.

At the United States Naval Observatory, G. M. Clemence has initiated a programme of observation of thirteen minor planets which were selected by G. W. Hill, *Coll. Math. Works*, **1**, 105–7, as particularly suitable for an accurate determination of Jupiter's mass. The periods of the principal terms of long period for these planets range from 61 to 121 years. By 1955, for all but two of these planets a complete period of the principal inequality will have elapsed since discovery. The current series of observations is intended to serve for the determination of accurate osculating elements which may be used as the basis of the computations of the perturbations.

As reported to Commission 4 by G. M. Clemence, work on the improvement of the orbits of the first four minor planets is in progress at the United States Nautical Almanac Office, at the Cincinnati Observatory, and at the Yale Observatory with the purpose of obtaining orbits that may be used for the calculation of precise ephemerides.

The Yale programme of observations of 16 selected minor planets for deriving systematic corrections to fundamental star catalogues has been continued, the series of observations to end in the summer of 1948. In 1938 G. van Herk at the Observatory at Leiden, Netherlands, began a series of observations with the 13-inch photographic refractor in support of this programme. Leiden observations for the years 1938–44 were published in the *Bulletin of the Astronomical Institutes of the Netherlands*, Vols. **9** and **10**. Plates for this programme obtained at the Allegheny Observatory, at the Yale-Columbia Southern Station, and at the Yale Observatory are being measured at the Yale Observatory. Since 1941 this work has been carried out by G. Land and assistants. The computational work for the programme at the Thomas J. Watson Astronomical Computing Bureau at Columbia University came to a complete standstill in 1941. It was resumed in 1947 at the Watson Scientific Computing Laboratory, New York, through the co-operation of its director, W. J. Eckert. This includes both the plate reductions and the numerical integrations of the orbits.

At the Mount Wilson Observatory, Nicholson's photographic survey of the region around Jupiter led to the discovery of two new satellites in 1938, the motions of which were well established by a series of photographic observations with the 60-inch and 100-inch reflectors in subsequent years. Other important contributions to the study of the motions of faint satellites were made by Van Biesbroeck and by Sharpless. With the Yale telescope at Johannesburg H. L. Alden made an extensive series of observations (1939–42) of the satellite of Neptune and obtained an improved value of the ratio between the mass of the satellite and the primary, $m_s/(m_p+m_s) = \cdot00128 \pm \cdot00023$ (*Astr. Journal*, **50**, 110, 1943).

At the United States Naval Observatory, F. H. Hollander has undertaken the measurement of Saturn's satellites on photographic plates taken at the Allegheny Observatory and at the Yale-Columbia Southern Station. The principal immediate purpose of this work is the determination of the mass of Saturn.

At the Yale Observatory an investigation of the motions of Jupiter's Galilean satellites has been undertaken. A collection of eclipses since the middle of the seventeenth century has been made by J. Ashbrook. Various phases of the theory have been examined by Brouwer. It is hoped that a discussion of the eclipse material will throw new light upon the discordances found by the late Prof. W. de Sitter between the mean motions obtained from observations since 1890 and the average mean motions during the past three centuries.

The Watson Scientific Computing Laboratory at New York, with W. J. Eckert, director, has already demonstrated the capacity of its equipment and staff by the rapid calculation of ephemerides of 783 minor planets for 1947. With powerful additional equipment the Laboratory will be even better prepared to undertake important computational projects in the future. Several projects dealing with motions of minor planets, in addition to the Yale programme, are being considered.

Union of Soviet Socialist Republics

A report received from G. Shajn covers the activity at the Crimean Astrophysical Observatory at Simeis. The observations of minor planets were interrupted in September, 1941, two weeks before the invasion by German troops. The observatory was ruined, but is being rebuilt. Two 120 mm. cameras were preserved, and observation of minor planets was resumed in August, 1947. It is hoped that the observational work in this field can be developed to the same level as before the war.

For many years Prof. Shajn has not personally participated in this work and for this reason he wishes to resign from the membership of Commission 20. In the near future it will be cleared up who, from the staff of the observatory, will be engaged in the work so successfully carried on by the late Dr G. Neujmin before the war.

Although no report was received from the Institute for Theoretical Astronomy at Leningrad, reference should be made to the significant contributions by this Institute.

Recent publications show an intensive activity in the field of perturbation calculation and orbit correction of minor planets, both by special and general perturbations. The Institute issued printed ephemerides for 435 minor planets for the year 1947, and undertook the calculation of the ephemerides of all numbered minor planets that will be in opposition during the year 1948.

YUGOSLAVIA

A report has been received from Prof. V. V. Michkovitch, Secretary General of the Serbian Academy of Sciences.

A list of all insufficiently observed minor planets for which there are no orbits has been prepared by Prof. Michkovitch with the co-operation of others at the University Observatory at Belgrade. The list contains about 3600 observed objects, and furnishes: date of observation, observed position, daily motion if determined, apparent magnitude, and approximate date of opposition. For some objects approximate node and inclination have been computed. This compilation, which was begun before the war, has been completed, and it is hoped that it can be made available to astronomers and observatories as a publication by the Serbian Academy of Sciences. It is expected that this publication will be useful for the identification of minor planets even if all the records of the Rechen-Institut have been preserved.

The Astronomical Division of the Mathematical Institute of the Serbian Academy of Sciences has decided to initiate research on problems concerning minor planets, and contemplates taking an active part in the work of this Commission.

Communications were also invited from Prof. A. Kopff at Heidelberg, Germany, and from Prof. Y. Hagihara, Tokyo, Japan.

GERMANY

Prof. A. Kopff, director of the Astronomisches Rechen-Institut at Heidelberg and director of the Königstuhl Observatory, writes:

Observations. The Königstuhl Observatory intends to observe minor planets in the same way as before the war; at the moment it is not possible to obtain special plates for astronomical purposes so that the programme had to be nearly stopped.

Calculations. The Astronomisches Rechen-Institut in Heidelberg intends to do as much work on minor planets as possible. A special list of minor planets for which the perturbations and corrections of elements will be calculated in future has already been sent to Dr Brouwer and Dr Herget. Ephemerides for 1948 are being calculated for this programme. In the future ephemerides will be calculated according to a special plan. We also wish to extend this programme and to take part in the co-operative plan for the correction of elements of planets in connection with the work by high-speed calculating machines.

For all planets discovered at Heidelberg or elsewhere in Germany we wish to calculate the first orbits and ephemerides necessary to secure these bodies.

Publications. The observations and results of calculation will be published as quickly as possible by our publications here. But we also wish to send this material to all other authorities which need it. All ephemerides for 1948 are published in the *Veröffentlichungen* of the Observatory. The publication (first part) is now being printed.

JAPAN

Prof. Y. Hagihara, Director of the Tokyo Astronomical Observatory, Mitaka near Tokyo, reports that in 1946 he was appointed chairman of a research commission for asteroids and comets, created on his recommendation by the Japanese National Research Council. Under the auspices of this commission, several hundred ephemerides of minor planets for the year 1947 were computed. These were mostly on the basis of elements furnished in *Kleine Planeten* 1941. Perturbations were computed and included for only

a small number. These ephemerides were received by Dr Herget about the middle of 1947. For the year 1948 ephemeris calculations of about 300 minor planets have been made. The results were ready for mailing in November 1947. Approximate Jupiter perturbations are included for 49 minor planets (for 153 Hilda approximate Saturn perturbations are also included); approximate general perturbations are included for 40 minor planets. The remaining ephemerides were computed without perturbations, but improved elements were used for 1232 Cortusu and empirical corrections to the mean anomalies in 63 cases.

For the year 1949 Prof. Hagihara proposes to compute ephemerides for the same minor planets, increasing the number of orbits for which perturbations are to be taken into account, but this cannot be accomplished for more than about 100 minor planets. He stresses his desire to participate in co-operative work in orbit and ephemeris computations and in observations.

Work on comets in Japan has concerned principally the calculation of perturbed orbits of periodic comets that are expected to be observable in 1948 and 1949.

Several papers of theoretical content were published by Prof. Hagihara, including: 'A Proof of Poisson's Theorem on the Invariability of the Major Axes of Planetary Orbits', *Jap. J. Astr. Geophys.* **21**, 9–27, 1944; 'On the General Theory of Libration', ibid. 29–43, 1944.

With the help of two assistants Hagihara is computing the perturbations of Thule over a complete period of its libration. This work is similar to that on Hilda by K. Hirayama and K. Akiyama (*Jap. J. Astr. Geophys.* **15**, 137–48, 1937), which is being extended by Akiyama to its complete period of libration. For this purpose the Tokyo Observatory has completed the calculation of Jupiter's heliocentric positions with a ten-day interval from 1961·0 to 2060·0, based on Hill's tables.

The research commission encourages observations of asteroids and comets. The 8-inch Brashear camera at the Tokyo Observatory and the 12-inch Cooke telescope of the Kwasan Observatory are being used for this purpose, although it is difficult to obtain photographic plates. The Azabu Observatory was completely destroyed during the war. The larger Mitaka Observatory lost its main building with books and measuring equipment. The larger instruments of the Tokyo Observatory are not in working order.

Recommendations

The following recommendations have been received:

1. The interval of minor planet ephemerides in the annual volumes shall be changed to 10 days beginning with the ephemerides for the year 1950, the number of ephemeris dates remaining six.

For comet ephemerides the recommended intervals remain 2, 4 or 8 days, depending upon the motion. An interval of 10 days is acceptable for comet ephemerides computed so many years in advance that national ephemerides giving the solar co-ordinates for every day are not yet available.

2. The variation shall be published as a fraction, $d\delta/d\alpha$, so that the numerator and the denominator indicate the ephemeris correction in each co-ordinate corresponding to an advance of the object in its orbit by the amount of motion during one ephemeris interval. The quotient would be the variation as it had been given in the past. The advantage is that an estimate of the error in the mean anomaly may be converted directly into an ephemeris correction.

3. It is recommended that all observations be published to the full accuracy with which they have been measured and reduced. Accurate observations are to be encouraged especially for minor planets that have been observed in fewer than four oppositions and for the minor planets the motions of which are so accurately known that approximate positions cannot add significantly to the knowledge of the orbit.

4. Permanent numbers shall as a rule be assigned to new planets after they have been observed in two oppositions, and after a satisfactory orbit based upon accurate special perturbations has been obtained. In the case of planets that approach the earth within

the orbit of Mars a permanent number may be assigned after a single opposition, provided that the planet was well observed and that a satisfactory orbit was obtained.

5. Each annual volume of minor planet ephemerides shall contain an appendix giving the basis of all elements. The first year in which new elements are introduced it shall state the number and the extent in time of the observations upon which the orbit is based, the kind of perturbations employed, the range of the residuals, and a reference to the publication of the orbit correction. If the data have not been published, the name of the institution or computer responsible for the orbit shall be given. In succeeding years it shall give the year of the annual ephemeris volume in which this information was published, together with references to new relevant information that has become available.

6. Observers are urged to provide more observations of cometary brightness, especially precise observations. There is need for improved methods; experimentation with the application of photoelectric techniques to this field is desirable.

7. It is desirable to extend the investigation by Cowell and Crommelin of the motion of Halley's comet as far back into the past as possible.

Recommendations 1 to 6 were prepared by a group of American members. Recommendation 7 is made by Kamieński who adds the following comments:

The orbit of this comet was investigated only to 240 B.C. It is feasible to extend this work, at least approximately, for 2000 years or more. The computed apparitions of the comet may then be compared with the records found in S. Lubienietski's work.

In addition to the consideration of these recommendations, the principal business for the meetings of the Commission is that of bringing more definite order to various phases of the work on minor planets that require international co-operation. The following items will deserve particular attention:

(*a*) Division of the work of computing ephemerides.

(*b*) Arrangements for the publication of annual volumes of ephemerides.

(*c*) Arrangements for the prompt distribution of the results of observations.

(*d*) Arrangements for assigning temporary designations and permanent numbers to newly discovered minor planets.

(*e*) Arrangements for improving the planning of observations, possibly along lines suggested by Leuschner in Harvard Announcement Card, No. 781.

(*f*) Plans for the recovery of minor planets that have not been observed in recent years, especially those that have been observed in fewer than four oppositions.

(*g*) Division of the work of improving the quality of ephemerides by deriving adequate orbit corrections, with and without special or general perturbations.

(*h*) In connection with recommendation No. 3, consideration of the question whether some provision can be made to guide observers in deciding whether accurate or approximate positions are desired for specific minor planets.

January 8, 1948

DIRK BROUWER
Vice-President of the Commission

REPORT FROM THE SUB-COMMISSION ON SHORT-PERIOD COMETS

The activities of the Sub-Commission have proceeded along the same lines as those outlined in *Transactions of the I.A.U.* **6**, 387, although greatly hampered by the sad death of its president Dr A. C. D. Crommelin and by the war. At the Copenhagen meeting in March 1946, Miss J. M. Vinter Hansen of the Copenhagen Observatory was entrusted with acting as president of the Sub-Commission.

The main work of the Sub-Commission is to arrange for the calculation of orbits and ephemerides of short-period comets so as to avoid—as far as possible—the duplication of work. This—never an easy task—has been made further difficult by the present uncertain mail conditions; it has often been impossible for the President to get in touch with some of the astronomers who previous to the war had announced their intention of computing a definitive orbit for a short-period comet. In the following table of short-period comets

for which reservations are known to the President more than one computer have therefore sometimes been listed, the name in brackets denoting the computer who primarily has made no reservation through our Sub-Committee but has come nobly to our rescue when it seemed probable that no prediction for the next apparition of a comet would be forthcoming from the listed computer. We are greatly indebted in this respect to several astronomers, particularly to the computers in the Comet Section of the British Astronomical Association and to Dr Leland E. Cunningham of the Students' Observatory, Berkeley, who have often published search-ephemerides which led to the recovery of a comet that might otherwise have been lost. A question mark after the name of a listed computer means that either no results to our knowledge have materialized or that it has been impossible to contact the computer.

Name of comet	Period (years)	Last apparition observed	Next apparition	Computer
1. Encke	3·3	1947	1951	Matkievicz
2. Grigg-Skellerup	4·9	1947	1952	Cripps
3. Tuttle-Giacobini	5·–	1907	?	Stephens (?)
4. Tempel 2	5·2	1946	1951	Ramensky
5. Neujmin 2	5·4	1926	1953 (?)	Poulkovo Observatory
6. Schwassmann-Wachmann 3	5·4 (?)	1930	1952 (?)	Parfenow (?), (Cripps)
7. du Toit (1945 c)	5·5	1945	1949	Cunningham
8. du Toit-Neujmin-Delporte	5·5	1941	1952	Naur
9. Tempel 1	6·0 (?)	1879	?	v. Schrutka-Rechtenstamm
10. Pons-Winnecke	6·1	1945	1951	Guth (?), Porter
11. Kopff	6·2	1945	1951	Kepiński
12. Forbes	6·4	1942	1948	Makarow (?), (Cripps)
13. Schwassmann-Wachmann 2	6·5	1948	1954	Rasmusen
14. Reinmuth 2	6·6	1947	1954	Rabe
15. Giacobini-Zinner	6·6	1946	1953	Cripps, Cunningham
16. d'Arrest	6·6	1943	1950	Recht
17. Daniel	6·8	1943	1950	Hirose (?), (Cripps)
18. Finlay	6·9	1926	1953	Cimino (?)
19. Borrelly	6·9	1932	1953	Cunningham
20. Brooks 2	6·9	1946	1953	Cunningham, Cripps
21. Holmes	7·–	1906	?	Koebcke
22. Reinmuth 1	7·2	1935	1950	Kanda (?)
23. Faye	7·3	1947	1955	Zseverzsev (?), (Cunningham)
24. Whipple	7·4	1947	1954	Cunningham
25. Wolf 2	7·5	1924	1954	Kanda (?)
26. Jackson-Neujmin	8·–	1936	1952	Poulkovo Observatory, Cunningham
27. Oterma (1942 VII)	8·0	Observed every year		Oterma, Herget
28. Schaumasse	8·2	1943	1952	Kanda (?) (B.A.A.)
29. Wolf 1	8·3	1942	1950	Kamieński
30. Comas Solá	8·5	1944	1952	Vinter Hansen
31. Swift	8·9 (?)	1889	?	Stephens (?)
32. Väisälä	10·–	1939	1949	Oterma
33. Gale	11·0	1938	1949	Cunningham, Cripps
34. Tuttle 1	13·6	1939	1953	B.A.A.
35. Schwassmann-Wachmann 1	16·3	Observed every year		Behrens, Cunningham, Herget
36. Neujmin 1	17·7	1931	1948	Poulkovo Observatory, (Cunningham)
37. Stephen-Oterma	38	1942	1980	Oterma
38. Westphal	61·7	1913	1975	Koebcke
39. Olbers	69·6	1887	1956	Rasmusen
40. Pons-Brooks	71·6	1884	1956	Herget
41. Halley	76·0	1910	1986	Bobone
42. Herschel-Rigollet	156·–	1939	2095	Maxwell + Kaster, Rigollet

The comet Pons-Coggia-Winnecke-Forbes on which Dr Crommelin did such a splendid work needs a computer. Its next apparition is due in 1956.

Astronomers who may wish to compute definitive orbits for short-period comets are urgently requested to consult the president of the Sub-Commission before starting work.

From a few members of the Sub-Commission reports have been received, the most extensive being that of Dr G. Merton. As it contains some valuable suggestions it is quoted here in full:

Since the last Report British work on comets has sustained a very severe loss in the death of Dr A. C. D. Crommelin, then President of this Sub-Commission. The predictions for the returns of periodic comets have always constituted one of the most important sections of work in the British Astronomical Association's annual *Handbook*, for which the Director of the Computing Section has been responsible. The death in 1939 of Dr Crommelin, who so greatly contributed to these predictions, left many problems unsolved, and a tribute must be paid to Dr J. G. Porter, appointed Director of that Section in 1940, for the able and energetic leadership he then brought to the whole organization of the work. In the midst of the duties of a professional career outside astronomy, and working under the great difficulties and anxieties of the war period he was able, with the assistance of a few amateur computers similarly overburdened by war-time duties, to continue the predictions in each annual *Handbook*. Recently Dr G. Merton, working in close collaboration with Dr Porter, has taken over the responsibility for organizing the work on these predictions.

As our first purpose must be to prevent the periodic comets from becoming lost, the B.A.A. aims to give predictions close enough to ensure the comets being recovered, that is to give T within, say, one day. When more accurate orbits are available from other computers these are used but, unfortunately, in many cases those who carry out the more thorough investigations do not complete, or do not communicate, their predictions in sufficient time for their inclusion in the *Handbook*. It has to be remembered that the *Handbook* has to go to press in August of the year previous to that for which the ephemerides are required; in some cases this means two years or more before the predicted perihelion. Some unnecessary duplication of effort has thus resulted, and steps to avoid this in future should be considered.

Of the perturbation methods that have been used in the B.A.A. work, the modified Cowell-Crommelin method of integrating the perturbed rectangular co-ordinates, and Encke's method, have yielded most of the best results. Their employment is limited, however, by the small number of our computers who can borrow, or afford to buy, the calculating machines necessary. The perturbation of elements method employing Crommelin's tables (*Mem. R.A.S.* **64**, 149–207) is designed for logarithmic calculation but has not always proved successful because of the manner in which it was employed. Investigations are proceeding on the techniques to be adopted to reach a higher standard of accuracy in future predictions. One important need is for computers who are able to undertake the preliminary correction of orbits. Another is that other workers who are carrying on accurate investigations of orbits should communicate their results to the B.A.A. workers in advance of publication, especially their revised starting orbits for the prediction computations, in order that the use of inferior starting orbits may be avoided.

In the case of the orbits of periodic comets observed for the first time, attention is still rarely given by their computers to the need for indicating the range of uncertainty in the elements, particularly in the period. Experience has shown that the probable error in the mean motion deduced from a least squares' solution is not a good indication of the range of values for the period which the observations will tolerate, or of the reliability of a prediction based on the solution found. It is worth repeating the remark in Prof. Leuschner's report to the I.A.U. meeting at Rome in 1922 (*Trans. I.A.U.* 1, 57, item 6) that an orbit deduced from three first-class normal places will prove more valuable for predicting a finding ephemeris at the next return than the usual so-called definitive orbit, provided the extreme range of possible period and eccentricity is determined. It is now suggested that, if a 'definitive' determination is made, the residuals of the normal places should be expressed to show the effect of small changes in the mean motion adopted, and from them also the sum of the squares of the residuals for different assumed values of the mean motion. This will enable an estimate of the

range of uncertainty in the prediction to be made. Examples of this will be found in the cases of the periodic comets Grigg-Skjellerup (*Mem. R.A.S.* **64**, 94–6) and Schaumasse (*M.N.* **87**, 566–7), and it will be noted that although this demands that the computer shall make his solution in a certain way, it does not involve any great amount of extra work. It is also desirable in stating the elements that the corrections to them for a small change in the adopted mean motion should be given, in order to facilitate correction when an improved value is obtained as the result of re-observation at a subsequent apparition. It is admitted that none of these processes is accurate for any but small changes in the mean motion, since the differential factors on which the solutions depend themselves change with the alteration of the assumed elements. Nevertheless, this does not destroy their value for the purposes we have mentioned.

Work on the revision of orbits is sometimes delayed because the observations are not published for a long time, and it is not known what material is available. It is therefore suggested that observers of periodic comets should be requested to send to the I.A.U. Bureau (and the Chairman of this Sub-Commission), *immediately* after the apparition of each comet, a list of the dates of their observations and their nature, that is whether of accurate position or of physical details. Those investigating the orbits and physical changes of these comets could then be put into correspondence with the observers and obtain from them, in advance of publication, the extracts giving the essential data required.

The comparative lack of cometary observations from the southern hemisphere, especially when the object is faint, sometimes affects the work. It seems highly desirable that means should be found to ensure at least the minimum of essential observations when a comet in southern declination is out of reach of northern observatories, even if no extended programme of cometary observations is considered justified by the better equipped southern observatories. At some returns a comet does not come within reach of a northern observatory and the only hope of recovering it lies in searches by southern observatories, e.g. in the case of Encke in 1944 and Schwassmann-Wachmann (3) in 1946. It will have been noted that the record of observation at every return since 1819 of Encke's comet was broken in 1944 when no observation was recorded. Yet during the whole of October that year, a few weeks after perihelion, the comet was over 50° from the Sun and, though faint, could probably have been recorded if searches with a suitable instrument had been made in the southern hemisphere. If it is considered impracticable to deflect larger instruments from their programmes to this occasional work, thought might be given to the possibility of providing on loan to amateurs in the south two or three Schmidt cameras of moderate size to meet this need.

Dr Van Biesbroeck has sent the following interesting remarks:

At present two periodic comets with small eccentricity have been followed through aphelion and are therefore observable like an asteroid at each successive opposition. They are 1925 II (Schwassmann-Wachmann) and 1942 VII (Oterma). In the latter object the brightness changes normally with the distances, while the first one behaves in the most erratic way as far as light-intensity is concerned. Sometimes it has changed between magnitudes 9th and 18th in the course of a few days; sometimes it hardly changes for several months. Upon investigation there is no indication of deviations from normal motion connected with this unusual behaviour.

Further, the attention is drawn to Prof. Kamieński's proposal, found elsewhere in the general report of Commission 20, that the computation of the orbit of comet Halley should be carried as far back as possible and even extended, approximately, two or more millennia back.

JULIE M. VINTER HANSEN
President of the Sub-Commission

ACTING PRESIDENT: Dr D. BROUWER.

SECRETARIES: Dr S. AREND, Dr G. MERTON.

The appointments of the Vice-President, Dr D. Brouwer, to take the chair during this meeting, and of the secretaries, Dr S. Arend and Dr G. Merton, were agreed by the members of the Commission present.

The chairman read greetings to the members and best wishes for the success of the meeting received from the President, Prof. E. Delporte, who was unable to be present. Both the Chairman and the new President of the Sub-Commission on periodic comets, Miss J. M. Vinter Hansen, referred to the serious loss the Commission had sustained in the death of Dr A. C. D. Crommelin, the late President of the Sub-Commission.

Dealing with the report of the Sub-Commission on periodic comets, Miss Vinter Hansen said she had little to add to the printed report. The task of the Sub-Commission was to arrange for the computation of the orbits of periodic comets so as to avoid duplication of work. This has not always been possible as will be seen from the list (p. 230). It was partly due to the bad communications that existed during the war. Moreover, it had been difficult, she said, to do anything about it because it is also our work to see that ephemerides appear in good time, and, as we have not always been able to rely on those who have promised predictions, we have sometimes been very grateful to others who, although unannounced, have provided us with orbits.

It was remarked that the list was not complete, and it was suggested that it would be useful if a list of periodic comets for which computers were needed could also be published.

The suggestion was made by Mr Merton that the name of the periodic comet Pons-Coggia-Winnecke-Forbes was very cumbersome and that the present occasion offered a fitting opportunity to honour the name of the past President of the Sub-Commission, who had done so much for cometary astronomy, by naming the comet 'Crommelin's comet'. This was not a new idea as, when Dr Crommelin had submitted to the late Prof. Kobold his proofs of the identification, Kobold had not only accepted them but had from that time always referred to this comet in the *Astronomische Nachrichten* and elsewhere as 'der Crommelinischer Komet'. After a short discussion the following resolution was unanimously agreed:

Resolution 1. The Commission recommends that the periodic comet Pons-Coggia-Winnecke-Forbes should in future be called Crommelin's comet.

The announcement by Prof. F. Kepiński that he would continue his investigations of the periodic comet Kopff was welcomed. The records of his computations, he said, had been lost in the war, but he had saved the accurate ephemerides for the 1939 and 1945 apparitions. These he had compared with observations. A note of these results (residuals about 0'·5 in 1945) was presented by him for members to see.

Prof. A. A. Mikhailov referred to the work on periodic comets being done in the U.S.S.R., and mentioned in particular the work on the motion of Encke's comet that was begun at the end of 1944 at the Institute for Theoretical Astronomy of the Academy of Science of the U.S.S.R. This is a continuation of the well-known investigation by Matkevitch, and is being carried out under his supervision. While the Institute will carry forward this study it also intends to undertake the study of the motions of some other periodic comets.

Mr Merton drew attention to the need of preventing confusion in the naming of comets now that it frequently happened that one observer discovered several. He suggested that numbering after the name of a discoverer should be used only to clarify the identity of the comet and not to denote the number of comets discovered by any one observer. The following resolution which, it was pointed out, conformed to previous custom, was then carried:

Resolution 2. The Commission recommends that the addition of numbers after the names of comets should be made only for the purpose of distinguishing between cases of periodic

comets bearing the same name (or combination of names) as a previous comet, and that other periodic comets, and all 'non-periodic' comets, should be distinguished simply by the year and letter (or year and Roman numeral) in conjunction with the name of the discoverer. For example, the du Toit Comets, in their order of discovery are thus designated: 1941 VII P/du Toit-Neujmin-Delporte, 1944 III P/du Toit (1), 1945*c* P/du Toit (2), 1945*d* du Toit, and 1945*g* du Toit (where P/ indicates a periodic comet).

Attention was drawn to the importance of having immediate notification by telegram of the recovery of periodic comets on their returns, and of having early information after the apparition of the observational data which would be available. It was agreed that the observer should notify the I.A.U. Bureau through the appropriate official channels, immediately upon securing the recovery observation. This would be unnecessary in the case of comets under more or less continuous observation such as Schwassmann-Wachmann (1) and Oterma, which were not given annual letter designations.

It was also agreed that observers should be requested to notify the President of the Sub-Commission, after the apparition of every periodic comet, of the extent and nature of their observations of it (positional and physical), without waiting to complete the reductions. Computers and others requiring the use of the observational material could then ascertain from the President of the Sub-Commission what would be available to them and, if necessary, could request advance copies of this information.

The Commission then considered the recommendations listed in the Draft Report. The first proposal was passed in amended form as follows:

Resolution 3. The Commission recommends that, beginning with the ephemerides for the year 1950, the interval of minor planet ephemerides shall be changed to 10 days, chosen to conform with the rule for the standard 40-day dates, the number of ephemeris dates remaining six.

The second part of the original proposal, advocating 8-, 4-, or 2-day ephemerides for comets, was not agreed. The desirability of achieving uniformity with the preceding resolution concerning minor planets was urged, and Dr Comrie suggested for discussion that the intervals might be made 10, 5, or 2 days. Dr Jeffers, seconded by Miss Vinter Hansen, objected to the suggestion of these intervals as compared with the 8-, 4-, or 2-day basis on the general ground that an ephemeris with a 5-day interval does not lend itself to rapid and convenient subdivision. Observers frequently find it desirable to reduce the published ephemeris intervals of comets by interpolation to halves, in order to be able to obtain the position and rate of motion from the ephemeris without having to consider higher differences.

It was agreed, however, that cases for which a 5-day ephemeris would be troublesome from this point of view did not occur very frequently. These objections would be met if the computers would in such cases give ephemerides for shorter intervals than has been their previous practice.

Dr F. L. Whipple urged that it was important to avoid the confusion that would result if the choice of one of these systems were left optional. After some further discussion the following resolution was passed:

Resolution 4. The Commission recommends that the interval normally employed in comet ephemerides should, from the beginning of the year 1950, be 10 days or 5 days, the dates being chosen to fit the standard 40-day dates. But that in all cases in which a high rate of motion or a rapid change of motion occurs, such as is likely to make the interpolation of position or of the instantaneous rates of motion troublesome to the observer, the computer should give the ephemeris for 2-day or 1-day intervals.

The attention of Commission 4 was drawn to Resolutions 3 and 4 with the suggestion that it would be of value if the national ephemerides distinguished in some way the standard 10-day dates in the tables of solar co-ordinates.

The Commission considered and approved the next proposals in the Draft Report, subject to a few slight modifications. The resolutions were carried in the following terms:

Resolution 5. The Commission recommends that, in ephemerides of minor planets, the variation shall be given in two ways, the one in the form which has been customary, and the other in the form of the ratio $\Delta\delta\ (1^\circ)/\Delta\alpha\ (1^\circ)$, the numerator and the denominator denoting the changes in the declination and in the right ascension, respectively, for an alteration of $+1^\circ$ in the mean anomaly.

Resolution 6. The Commission recommends that all observations should be published to the full accuracy to which they have been measured and reduced. And further, that the ephemerides of planets for which accurate observations are desired should be marked to indicate the fact to observers who, in such cases, should not be content to obtain approximate positions only.

Resolution 7. The Commission recommends that permanent numbers shall, as a rule, be assigned to a new minor planet after it has been observed in two oppositions and a satisfactory orbit has been obtained. In the case of a planet that approaches the Earth within the orbit of Mars, a permanent number may be assigned after a single opposition provided that the planet was well observed and that a satisfactory orbit was obtained.

Resolution 8. The Commission recommends that each annual volume of minor planet ephemerides shall contain an appendix giving the basis of each set of elements. The first year in which new elements are introduced it shall state the number and the extent in time of the observations upon which the orbit is based, the kind of perturbations employed, the range of residuals, and a reference to the publication of the orbit correction. If the data have not been published, the name of the institution or computer responsible for the orbit shall be given. In succeeding years it shall give the year of the annual ephemeris volume in which this information was published, together with references to new relevant information that has become available.

Consideration was then given to the sixth proposal of the Draft Report requesting more observations of cometary brightness. After discussion it was decided that this matter should first be referred to Commission 15. Subsequently the Commission unanimously voted the following resolution:

Resolution 9. The Commission recommends that observers should be urged to provide more observations of cometary brightness, especially more reliable determinations of it. Further, the details of the methods used should be reported in the final publication of the observations.

The chairman then asked Prof. A. A. Mikhailov to report on the work on minor planets which was being done in the U.S.S.R. His report gave the following information:

Until 1941, the Institute for Theoretical Astronomy of the Academy of Science of the U.S.S.R. (formerly Leningrad Astronomical Institute) performed the following work:

(1) Investigation of the motions of the planets near Jupiter (Trojan planets and planets of the Hilda and Hecuba types), about 100 planets in all. Numerical integrations of the equations of motion, taking into account the attractions by Jupiter and Saturn, were performed. For the majority of these planets the orbital elements were corrected, using several (4 to 8) oppositions. The results of this work were published in Bulletins of the Institute and in the Russian Astronomical Journal.

(2) For the planets of the Minerva type (mean daily motion near 750″) the perturbations were computed by the method of Bohlin. For 40 planets tables of perturbations were computed. For 20 of these the elements were improved, using several oppositions, and the mean elements determined. These results were published in nos. 53 and 55 of the Bulletin of the Institute.

(3) For all of the above-mentioned planets, ephemerides in which perturbations by Jupiter and Saturn had been taken into account were computed annually.

The work which almost stopped during the war was resumed in 1945. For 1946 ephemerides of 219 bright planets (not fainter than 12·5) were computed, 55 with perturbations and 164 without perturbations. These ephemerides were computed and distributed in mimeographed form to all Soviet and certain foreign observatories.

For 1947, 435 ephemerides were computed. Of these, 175 were with perturbations. These ephemerides were published in two parts, in April and in June.

In a letter of August 29, 1946, the President of the International Astronomical Union, Sir Harold Spencer Jones, asked the Institute for Theoretical Astronomy to undertake the computation of search ephemerides of all minor planets. Accordingly, the Institute undertook the computation of ephemerides of all numbered minor planets, beginning with the year 1948.

The ephemerides of 677 minor planets whose oppositions occurred during the first six months of 1948 were published by the Institute at the end of 1947. The ephemerides of the remaining 556 planets with oppositions during the second half of 1948 were distributed in July, 1948. This second part also contains the elements of all 1563 numbered minor planets.

The number of minor planets that have oppositions in 1948 is 1233. For 276 of these, ephemerides were computed with perturbations (numerical integration was used for 96 planets, Bohlin's method for 50 planets, and Brendel's method for 138).

The following institutions participated in the computation of the ephemerides for 1948: the Sternberg Astronomical Institute in Moscow, the Institute of Mathematics and Physics of the Latvian Academy of Science, the Kiev Observatory, the Odessa Observatory, and schools of astronomy of the Universities of Kazan, Kharkov and Rostov, and of the Kherson Pedagogical Institute.

For 1949 for the first time the ephemerides of minor planets will be published in one volume for the whole year. This issue will contain the ephemerides of 1199 planets that will have oppositions in 1949. The computation of all unperturbed ephemerides was performed with the aid of punched-card machines. The number of planets for which perturbations are taken into account has been increased only slightly as compared with that in 1948. All these computations are based on the elements published in the circular *Ephemerides of minor planets for* 1948, *Part two*. The computations have been completed, the manuscript went to press in June, 1948, and it is hoped that the volume will be published in November, 1948.

Plans for future work include:

(1) The publication of ephemerides as early as possible. The ephemeris computations for 1950 are being carried out on the same basis as those for 1949. The work is almost finished; the manuscript will go to press in November, and will be printed during the first half of 1949. The volume will be distributed promptly.

(2) Simultaneously with the computation of ephemerides for 1950, numerical integrations in rectangular co-ordinates are being performed for 375 planets of the Hecuba type. Perturbations by Jupiter only are taken into account. This work, which is being done with punched-card machines, has just been started. The results will be available for the first time for the computation of the ephemerides for 1951.

(3) At the end of 1948 it is proposed to begin the systematic improvement of the elements of the orbits of planets for which there are observations in at least four oppositions during recent years.

(4) It is planned to continue the systematic study of the motions of planets with unusual orbits: 887 Alinda, 944 Hidalgo, 1221 Amor, and some others.

(5) The ephemerides of the planets Ceres, Pallas and Juno are computed by the method of numerical integration with perturbations by Jupiter and Saturn. The ephemeris of Vesta is computed with the tables of Leveau. It would be possible to compute these ephemerides for a long period of time.

The chairman expressed appreciation of the great amount of work done by the Institute for Theoretical Astronomy of the Academy of Science of the U.S.S.R. He regretted that, notwithstanding the excellent efforts of this Institute, there had been a considerable

amount of duplication of calculation on account of unavoidable delays in receiving ephemerides from Leningrad. For 1949 there would again be duplicate publication of ephemerides. He reminded the members of the Commission that the arrangement made in 1946 was on a temporary basis, and suggested that, beginning with the ephemerides for 1950, it might be possible to return to the original plan whereby there would be truly international co-operation and a single publication of ephemerides of minor planets under the auspices of the International Astronomical Union.

The chairman stated that so many minor planets are urgently in need of perturbation calculations and orbit corrections that rapid improvement in the average quality of the ephemerides will be possible only if the work can be shared by all the institutions interested in contributing. He then outlined how the work might be divided between the Institute for Theoretical Astronomy of the U.S.S.R., the Rechen-Institut at Heidelberg, and other centres elsewhere, all working in collaboration in a general scheme.

In the first part of the publication of the ephemerides computed by the Rechen-Institut for 1948 (*Veröff. d. Badischen Landessternwarte zu Heidelberg* (*Königstuhl*), Band **15**, No. 4, p. 42) a list is appended of 631 minor planets, or about 40% of the total number, for which the Rechen-Institut has adequate data for the calculation of ephemerides. It would be unnecessary, he said, to duplicate work on any of these planets elsewhere as long as so much remains to be done on the remaining 60% of the numbered planets. This remainder might well be divided about equally between the Institute for Theoretical Astronomy of the U.S.S.R. and institutions elsewhere. Among work by the latter, he referred to a large project undertaken by Dr P. Herget at the Minor Planet Centre at Cincinnati in co-operation with other institutions. This concerns especially numerical integrations and orbit corrections of minor planets observed in only two or three oppositions and also some other planets that have shown very large deviations from their ephemerides in recent years.

Mr Mikhailov agreed that it would be possible to avoid duplication of publication after 1950, but that in the U.S.S.R. the ephemeris material up to then was either already in the press or in the process of completion. Following some further discussion, the chairman remarked that he wished it recorded that he (Brouwer) had made repeated efforts during the past two years to achieve a proper division of the work. Would the Institute for Theoretical Astronomy, he asked, now be prepared to transmit a selected list of those minor planets for which it had adequate data and for which it could furnish ephemerides for the ephemeris volumes to be published by the I.A.U. for 1950 and subsequent years? Mr Mikhailov replied that he thought it would.

The Commission approved unanimously the outline of the future plan of work presented by the chairman, and after some discussion the following three resolutions were passed unanimously:

Resolution 10. The Commission recommends that the Minor Planet Centre at Cincinnati be maintained, that it continue the publication of the Minor Planet Circulars, and that, beginning with the ephemerides for the year 1950, the Centre publish the annual volumes of ephemerides under the auspices of the International Astronomical Union.

Resolution 11. The Commission recommends that an annual grant of one thousand dollars be given to the Minor Planet Centre for the publication of its circulars and ephemerides.

Resolution 12. The Commission recommends that the Minor Planet Centre at Cincinnati be authorized to assign provisional designations and permanent numbers to minor planets and to approve and assign the names proposed for them by their respective discoverers.

With regard to the responsibilities of the Minor Planet Centre stated in Resolution 12, the chairman proposed and the Commission approved that there would be a small committee to assist Dr P. Herget, in charge of the Centre, in the decisions.

Attention was drawn by Mr Merton to the lack of observations of faint comets by

observatories in the southern hemisphere, and the delays in their communication. He moved the following resolution, supported by Miss Vinter Hansen, and this was agreed:

Resolution 13. The Commission draws attention to the lack of observations of faint comets by observatories in the southern hemisphere, and recommends that steps be taken by observatories suitably equipped to obtain, especially in the case of periodic comets, at any rate the essential minimum of observations of position and magnitude when the comets are out of reach of active observatories in the northern hemisphere, and to communicate such observations without delay to the I.A.U. Bureau.

Prof. Th. Banachiewicz spoke in favour of the proposal made in the Draft Report by Prof. M. Kamieński, that the orbit of Halley's comet should be traced backward as far as possible and comparison made with S. Lubienietski's work. The Commission recognized the desirability of this work and expressed the view that the undertaking should be encouraged.

Prof. G. Fayet informed the meeting of the work being carried on at Nice by M. Patry in the identification of minor planets with provisional designations for which the number of published observations has been insufficient for the determination of an orbit. Out of 400 cases in the period 1900–30 M. Patry has been able to find 70 identifications. After the chairman had pointed out the great value of this work, the Commission unanimously passed the following resolution:

Resolution 14. The Commission expresses the wish that the research undertaken by the observatory at Nice, in identifying those minor planets discovered after 1900 for which only two observations were obtained, be continued.

The chairman referred to the Research Surveys of minor planets, carried on under Prof. A. O. Leuschner, and to their great value. He proposed a resolution, warmly supported by Prof. G. Fayet and Prof. A. Kopff, which was carried as follows:

Resolution 15. The Commission reaffirms its high opinion of the usefulness of the *Research Surveys of Minor Planets* prepared and published under the direction of its honorary president, Prof. A. O. Leuschner, and recommends that they be continued. It expresses the hope that ways and means may be found for this purpose.

Turning then to the subject of planning of observations, the chairman referred to the minor planet work at the Union Observatory, done in recent years by Mr E. L. Johnson. The limiting magnitude is 14. In order to be able to cover the sky it was desirable to limit the observations there to declinations south of $-15°$ during the months March to September. This would enable them to obtain two positions, or more, for planets requiring this attention. Dr G. Meyer and M. A. Schmitt of Algiers stated that they could co-operate with the Union Observatory to secure adequate coverage of the sky, and that the equipment at Algiers could reach a limiting magnitude 16. Mr Kopff said that a division of the sky according to declination might be acceptable for the southern sky, but that attempts by the Rechen-Institut to arrange this for the northern sky had not proved successful. It was decided that a quarterly publication in the Minor Planet Circulars of lists of minor planets that were in urgent need of observation would be most useful. The Minor Planet Centre could further give individual attention to special minor planets.

The chairman also reported two recommendations by Mr Johnson: that planets differing 3 minutes of time or more in right ascension from their ephemeris positions should be followed more closely, with two or more observations; and further, that if a planet searched for was not found, this fact should be reported. He thought that these were good suggestions.

As to the planning of computations, the chairman stated that the programme for the immediate future should be: (*a*) the orbit correction, with or without perturbations, of all planets differing 3 minutes of time or more of right ascension from their ephemerides, and (*b*) the orbit correction, with or without perturbations, of all planets observed in

2 or 3 oppositions. For planets observed in only one opposition, it would as a rule be impossible to improve the orbital elements. He suggested that all astronomers interested in taking part in the project should communicate with him or Dr Herget concerning the work they might wish to undertake, and give a list of the planets in which they were interested.

The subject of the magnitudes of minor planets was discussed briefly, Mr Kopff pointing out that he had found as much as two magnitudes difference between the two systems used.

The chairman also reported that Mr Whipple, not present at this session, had hoped to speak on the purpose and direction of future work on minor planets.

It was decided that two committees be appointed by the chairman to study each of these two problems, and to report to the Commission at the next meeting of the Union.

The Commission had such a crowded agenda that there was no time left during any of its four sessions to have scientific papers presented to it. Among the papers considered, read by title, were: a communication by Prof. W. W. Heinrich on a suitable transformation found by him for the treatment of proximity and collision problems in planetary motion, and a communication by T. Ura and T. Takenouchi on numerical integration. The latter had been received by the chairman from Prof. Y. Hagihara. Dr E. Sevin had asked time to speak on the prediction of trans-Uranian planets. He subsequently presented this subject at a time not scheduled for a session of the Commission.

22. COMMISSION DES METEORES, DE LA LUMIERE ZODIACALE ET DES PROBLEMES ANALOGUES

PRESIDENT: M. F. L. WHIPPLE, *Harvard College Observatory, Cambridge* 38, *Mass., U.S.A.*

MEMBERS: MM. Astapovich, Bečvář, Bosler, Chant, M. Davidson, Dobson, N. Donitch, Dufay, Elvey, J. W. Evans, Fedynsky, Fesenkov, Mme Flammarion, MM. Gatterer, Guth, Harang, Housman, Kaplan, Kopal, LaPaz, Leonard, Link, McIntosh, Millman, Nielsen, Nininger, Olivier, Öpik, Porter, Prentice, V. M. Slipher, Störmer, Vandekerkhove, Watson.

SOUS-COMMISSION DE LA LUMIÈRE ZODIACALE ET DE LA LUMIÈRE DU CIEL NOCTURNE

PRÉSIDENT: M. DUFAY.

MEMBRES: MM. Horace W. Babcock, Bousfield, Cabannes, Cap, S. Chapman, Dauvillier, N. Donitch, Elvey, Fesenkov, Gauzit, Harang, Housman, Link, V. M. Slipher, Störmer, Struve, Swings, Vegard.

The scope of this Report is to cover briefly the progress in the study of meteors and meteorites since the 1938 meeting of Commission 22. The Sub-Commission on the Zodiacal Light has been expanded to include also the Light of the Night Sky and is now presided over by M. Jean Dufay. The ever-increasing scientific interest in the problems of nocturnal radiations and the fascinating difficulties of interpretation promise an exciting future for research in these two observationally related fields. On the other hand, the present intensive interest in the earth's upper atmosphere and in ionospheric research makes interpretation in any one field of research in Commission 22 even more dependent upon knowledge of results in the other fields. Hence it appears essential that Commission 22 and its sub-commission keep in close *rapport* and that a considerable overlapping of membership be maintained.

Progress in the application of radar and other electronic techniques to the observation of meteor ionization trails has recently become of outstanding importance. The contributions of many workers, particularly the British J. S. Hey and G. S. Stewart,* E. Appleton and R. Naismith,† and others are revolutionizing the methods of meteor observation; Hey, Parsons and Stewart‡ and A. C. B. Lovell report the actual measurement of meteor velocities electronically! Intensive work in this field is being conducted in Canada by P. M. Millman and his colleagues, in Russia by B. Levin and his colleagues and by at least four active groups in the United States. It appears that Commission 22 must pay special attention to this new technique of observation.

The extremely active meteor shower from the Giacobini-Zinner comet on the night of October 9, 1946, aroused world-wide interest. Its accurate prediction coupled with extensive observations by all known techniques marks this shower as the most important event in meteor history during at least this century. Any attempt to describe the phenomenon or to list observers and observational results would extend this Report unduly; also the facts are so generally known that recapitulation appears superfluous.

1. *Meteor Organizations.* A certain disruption of activity among some meteor organizations has occurred during recent years. Among these organizations listed in the 1938 volume of the *I.A.U. Transactions*, those from the following countries have become inactive or have failed to reply to correspondence: Belgium, Esthonia, France, Hungary, Italy, Spain and the U.S.S.R. Active groups in these countries and other unlisted active meteor organizations are requested to notify Commission 22 of their address, officers and general scope of activity.

* J. S. Hey and G. S. Stewart. *Proc. Phys. Soc. Lond.* **59**, 858–83, 1947.

† E. Appleton and R. Naismith. *Proc. Phys. Soc. Lond.* **59**, 461–72, 1947.

‡ J. S. Hey, S. J. Parsons and G. S. Stewart, *M.N.R.A.S.* **107**, 176–83, 1947.

The Society for Research on Meteorites has changed its name to The Meteoritical Society. Its president is now A. S. King of Mount Wilson Observatory, Pasadena, California, U.S.A. An Institute of Meteoritics, with L. LaPaz as Director, has been established at the University of New Mexico, Albuquerque, New Mexico, U.S.A.

2. *Visual Observations.* Meteor astronomy lost one of its keenest observers in the death of E. Loreta of Bologna, Italy. Activity in the visual observation of meteors or in the analysis of visual observations has been resumed or maintained in Canada by P. M. Millman, in Czechoslovakia by A. Bečvář and V. Guth, in Denmark by A. V. Nielsen, in Germany by C. Hoffmeister, in Great Britain by J. G. Porter and J. P. M. Prentice, in Japan by the Meteor Section of the Oriental Astronomical Society with K. Komaki, in New Zealand by the Meteor Section of the New Zealand Astronomical Society under the strong impetus of R. A. McIntosh, in the United States by the American Meteor Society and C. P. Olivier and in the U.S.S.R. by I. S. Astapovich, A. Bakharev, B. Levin, S. V. Orlov and K. A. Voroshiloff. Recently a group of observers under S. van den Bergh has commenced meteor observations in the Netherlands.

Of great interest are the observations and analysis of meteors observed via the rocking mirror method by E. Öpik,* who concludes that a large percentage of visual meteors possess hyperbolic velocities and occur at lower heights than shower meteors of nearly comparable geocentric velocities. On the other hand, J. G. Porter,† from a lengthy analysis of British meteor observations, concludes that his data do not indicate hyperbolic velocities nor a marked seasonal effect in height. R. A. McIntosh,‡ from all visual trajectories, finds a seasonal effect in height and confirms the relatively greater height for the shower meteors. H. C. Plummer§ finds an increase in meteor height with number. An independent analysis of visual meteor observations has been conducted by B. Levin|| who finds no evidence for hyperbolic velocities. A valuable catalogue of southern meteor radiants has been published by R. A. McIntosh.

3. *Telescopic Meteors.* Observations have been made by J. D. Williams, R. Brandt and others, while analyses of frequencies have been made by F. G. Watson, J. D. Williams¶ and C. Hoffmeister. Through the visual and telescopic ranges the numbers appear to vary inversely as the luminosity or somewhat more slowly.

4. *Photography.* Meteor photography has been conducted largely in Canada by P. M. Millman, in Czechoslovakia under the direction of A. Bečvář, in the U.S.S.R., and at Harvard in the United States. Numerous observers over the world were successful in photographing meteors from comet Giacobini-Zinner.

Analyses of single meteor trails have been made by S. Arend and J. Hunaerts, P. F. Sitnikov, K. P. Stanjukowitsch, N. N. Sytinskaya and F. G. Watson. Trails are great circles within a few minutes of arc.

Harvard results, by F. L. Whipple** and recently Z. Kopal, L. Jacchia, and Miss F. Wright, from two-camera photography with rotating shutters, show that the Taurid stream is associated with Encke's comet, that the Geminid orbit is extremely small, and that few, if any, hyperbolic orbits exist among the bright meteors while 'asteroidal-type' orbits are fairly frequent. Measures of daily motions and cosmic spread of radiants have been made for the Taurid, Geminid and Perseid showers. Small but measurable meteor decelerations make possible the calculation of upper-atmospheric densities which show a marked seasonal effect. A very large photographic programme is being planned, utilizing a 'super-Schmidt' type of camera designed by J. G. Baker and to be made by the Perkin-Elmer Corporation in the U.S.A.

* E. Öpik. *Pub. Tartu Obs.* **30**, No. 5, 1940; ibid. No. 6, 1941.
† J. G. Porter. *M.N.R.A.S.* **103**, 134–53, 1943; ibid. **104**, 257–72, 1944.
‡ R. A. McIntosh. *M.N.R.A.S.* **100**, 510–28, 1940; *Jour. R.A.S. Can.* **37**, 305–15, 1943.
§ H. C. Plummer. *M.N.R.A.S.* **101**, 76–83, 1941.
|| B. Levin. *Ast. Jour. U.S.S.R.* **23**, No. 2, 1946.
¶ J. D. Williams. *Ap. J.* **92**, 424–33, 1940.
** F. L. Whipple. *Proc. Am. Phil. Soc.* **79**, 499–548, 1938; ibid. **83**, 711–45, 1940; ibid. **91**, 189–200, 1947; *Rev. Mod. Phys.* **15**, 246–64, 1943.

A number of meteor spectra have been obtained by P. M. Millman* especially, and by A. Bacharev and by C. O. Lampland. An unusually bright high-dispersion and high-excitation spectrum obtained by A. N. Vyssotsky† deserves special attention. Millman concludes tentatively that the state of ionization and excitation in meteor spectra is closely related to the geocentric velocity and that all meteors in a single shower have similar spectra. Shower meteors appear to arise from stones. Colours have been obtained by Ch. Hetzler and by N. N. Sytinskaya.

It appears that the detailed character of meteorite orbits should be determined with great precision within a few years by photographic and electronic techniques—and to surprisingly faint magnitudes.

5. *Methodology.* Reduction methods for visual and photographic meteors have been investigated by I. S. Astapovich, A. Bečvář, V. Guth, H. Inouze, A. S. Jagolin, V. Maitre, R. A. McIntosh, J. P. M. Prentice, E. F. Reilly, and K. P. Stanjukowitsch, while useful tables have been prepared by V. Guth, A. V. Nielsen‡ and E. Willis. A number of writers have criticized E. Öpik's use of harmonic mean heights. Methods for calculating orbits have been published by B. de Jekhowaky and C. C. Wylie. The methods used at Harvard for photographic-meteor reductions will be published soon.

A photometer for observing meteor trains has been devised by N. Sytinskaya.

6. *Fireballs and Trains.* Research on the trajectories and velocities of fireballs is very active in Europe, U.S.S.R. and the United States. C. C. Wylie§ has studied additional fireballs with low heliocentric velocities and deduces asteroid-type orbits for these objects. A similar result is reached by N. N. Sytinskaya.‖ In this connection, C. Hoffmeister,¶ in a general survey of the orbital data, divides meteor orbits into ecliptical (short-period asteroidal), cometary, and hyperbolic groups. A. V. Nielsen contests a short-period orbit for the Pultusk meteor.

Important studies of meteor trains observed in Tadjikstan have been made by V. V. Fedynsky,** while C. P. Olivier†† has published two analyses involving nearly 1500 long-enduring trains. Olivier finds average velocities of the order of 200 km./hr.

7. *Meteorites.* The work in Meteoritics has become so great and the literature so rich that no short competent survey is possible. Especially noteworthy is the activity incited by The Meteoritical Society. In the U.S.S.R. numerous papers have appeared in *Meteoritics*, the official publication of the Meteorite Committee of the Academy of Sciences of the U.S.S.R. Among the active workers in this field have been H. H. Nininger, L. LaPaz and J. D. Buddhue in the U.S.A. and L. A. Kulik, P. L. Dravert and P. N. Chirvinsky in the U.S.S.R.

It is hoped that V. G. Fesenkov and A. E. Krinov will soon report fully on the crater-forming fall of February 12, 1947, north-east of Vladivostok. Evidence for ancient meteor craters in geological strata has been presented by J. D. Boon and C. C. Albriton and supported by R. A. Daly.‡‡

A geographical system of co-ordinate numbers for Meteorites has been devised by F. C. Leonard and applied by him in a comprehensive catalogue of 1347 meteorite falls of the world, the first publication of the Institute of Meteoritics of the University of New Mexico, U.S.A. Several papers on meteorite statistics have been published by F. C. Leonard§§ and B. Slalin and by L. LaPaz. Valuable catalogues of Meteorites have

* P. M. Millman. *Jour. R.A.S. Can.* **34**, 117–29, 1940; ibid. **34**, 469–79, 1940. *H.A.C.* No. 782, 1946.

† A. N. Vyssotsky. *Ap. J.* **91**, 264–66, 1940.

‡ A. V. Nielsen. *Medd. Ole Rømer Obs.* No. 12, 1938.

§ C. C. Wylie. *Pop. Ast.* **48**, 41–2, 1940; ibid. **48**, 306, 1940.

‖ N. N. Sytinskaya. *Meteoritics*, **2**, 103, 1941; ibid. **2**, 110, 1941.

¶ C. Hoffmeister. *Pop. Ast.* **55**, 492–97, 1947.

** V. V. Fedynsky. *Ast. Jour. U.S.S.R.* **21**, 291–305, 1944.

†† C. P. Olivier. *Proc. Am. Phil. Soc.* **85**, 93–135, 1942; ibid. **91**, 315–27, 1947.

‡‡ R. A. Daly. *Jour. Geol.* **55**, 125–45, 1947.

§§ F. C. Leonard. Various papers. *Pop. Ast. and Contr. Soc. Met.* 1941–6.

been published by M. H. Hey,* I. S. Astapovich and especially by A. L. Coulson† of India.

The physical and metallurgical structure of Meteorites has been studied intensively by Lord Rayleigh, J. D. Buddhue, U. Dehlinger, E. A. Owen, S. W. J. Smith and J. Young, R. M. Leard, and by H. Brown and C. Patterson. The volume by S. H. Perry‡ of the U.S. Smithsonian Institute is especially valuable. Harrison Brown (in the Press) has proved that meteorites must have cooled under a pressure of the order of 10^5 atmospheres, hence are fragments of a broken planet comparable to Mars in mass.

Isotopic abundances in meteorites have been studied by R. D. Evans, B. F. Murphy and A. O. Nier, G. E. Valley and H. H. Anderson,§ and by H. Brown and M. G. Inghram. No anomalies with respect to terrestrial substances appear.

F. A. Paneth|| and colleagues have had to increase the estimates of maximum meteorite ages by the helium method to nearly 7×10^9 years after allowing for the effect of thorium. C. Bauer has shown that small helium content is associated with massive meteorite falls and that cosmic rays may play an important role in the production of helium in small meteorites. Hence the helium ages may represent only upper limits.

Spectrographic measures of meteorites in the laboratory have been made by W. W. A. Johnson and D. P. Norman,¶ and laboratory spectrophotometric measures by E. L. Krinow.

Meteoritic dust has been collected by H. H. Nininger and H. E. Landsberg and its consequences considered theoretically by J. Kaplan and A. R. Khan.

The origin of tektites has been discussed by H. O. Beyer, K. Himpel, J. Kaspar, L. LaPaz and W. C. Rufus.

8. *Theory.* The physical theory of the meteoric process has been further investigated by E. Öpik, J. Hoppe and B. Levin. Certain aspects of the problem have been studied by M. Khan, C. Hoffmeister, C. C. Wylie, T. Gustafson, A. Hadding and F. Link**. It is apparent that many experimental data essential to an exact solution of this problem are still lacking. In addition, certain meteoritic data for visual and photographic meteors are highly uncertain. Nevertheless, the general confirmation by V-2 rocket firings of the atmospheric densities, determined from photographic meteors at Harvard, shows that the present theory is qualitatively correct.

A general theory of Jupiter perturbations on orbits with aphelia within Jupiter's orbit has been developed by D. Brouwer. This method generalizes the special case of the Taurid meteors and Encke's comet studied by F. L. Whipple.

9. *Treatises.* I. S. Astapovich and V. V. Fedynsky have published a book in the Russian language entitled *Meteors* (126 pp., 73 illus., Academy of Science of the Soviet-Union, Moscow, 1941) and F. G. Watson a book in English, *Between the Planets* (214 pp., 106 illus., Blakiston Co., Philadelphia, Pa., U.S.A., 1941). Both books are written for the highly intelligent layman. Watson's book also considers comets and asteroids.

The following suggestions have been presented for consideration by the Commission:

(1) That more simultaneous electronic and visual or photographic observations are needed. Detailed interpretation of the electronic observations is still handicapped by this lack. (E. Öpik and others.)

(2) That emphasis in visual observing programmes be directed toward the determination of meteoric magnitudes, frequencies and radiants rather than the determination of heights and velocities. Comprehensive statistical correlations of visual with photographic or electronic observations are now of the greatest importance. (F. L. Whipple.)

* M. H. Hey. *Pub. British Museum*, 1940 (136 pp.).

† A. L. Coulson. *Mem. Geol. Survey India*, Vol. **75**, 1947.

‡ S. H. Perry. *U.S. Nat. Mus. Smithsonian Institution, Bull.* No. 184, 1944 (206 pp.).

§ G. E. Valley and H. H. Anderson. *Phys. Rev.* **59**, 113–14, 1941.

|| W. J. Arrol, R. B. Jacobi and F. A. Paneth. *Nature, Lond.*, **149**, 235–8, 1942.

¶ W. W. A. Johnson and D. P. Norman. *Ap. J.* **97**, 46–50, 1943.

** F. Link, *Pub. Obs. Nat. Prague*, No. 18, 1947 (25 pp.).

(3) That suitable star-charts for visual observations be made more available. (P. M. Millman and others.)

(4) That new efforts be made to induce governmental agencies such as Naval or Weather organizations to gather and publish data on fireballs and meteor trains. (C. P. Olivier.)

(5) That the preparation of an appendix to the v. Niessl-Hoffmeister catalogue be considered. (A. V. Nielsen.)

(6) That astronomers make special effort to encourage specialists in physical research to apply new research methods in laboratory studies of meteorites; and that such studies should cover systematically all representative classes of meteorites. (F. L. Whipple.)

(7) It is recommended that simultaneous observation of meteors by electronic (radar) and visual or photographic means be extended because this Commission is convinced that the continuation and extension of such research is now essential to the proper advance of meteoric astronomy and of researches related to it.

F. L. WHIPPLE
President of the Commission

Report of meetings

PRESIDENT: M. F. L. WHIPPLE.

SECRETARY: M. J. KAPLAN.

The report of the Commission, prepared by the President and printed in the Draft Reports, was unanimously accepted by the members of the Commission.

A special session of the Commission, to discuss reorganization of the Commission to include research on fundamental problems of the Earth's upper atmosphere, was called by the President at a time later in the programme.

The six recommendations of the Commission, published in the Draft Reports, were passed, with minor modifications, by the Commission. The resolutions as approved by the Commission are as follows:

(1) It is recommended that simultaneous observations of meteors by electronic (radar) and visual or photographic means be extended, because this Commission is convinced that the continuation and extension of electronic (radar) observations is now essential to the proper advance of meteoric astronomy and of researches related to it. (Proposed by E. Öpik and others.)

(2) It is recommended that suitable star-charts for visual observations be made more available, and that a committee consisting of Millman (chairman), Bečvář, Olivier and Prentice be named to study the form and publication of these star-charts. (Proposed by P. M. Millman and others.)

(3) That astronomers make special effort to encourage specialists in physical research to apply new research methods in laboratory studies of meteorites; and that such studies should cover systematically all representative classes of meteorites. (Proposed by the President.)

(4) That emphasis in visual observing programmes be directed towards the determination of meteoric magnitudes, frequencies and radiants, rather than the determination of heights and velocities. Comprehensive statistical correlations of visual with photographic or electronic observations are now of the greatest importance. (Proposed by the President.)

(5) That new effort be made to induce government agencies such as Naval and Weather organizations, and Variable Star Associations, to gather and publish data on fireballs and meteor trains. (Proposed by C. P. Olivier.)

(6) That the preparation of an appendix to the von Niessl-Hoffmeister Catalogue be considered. (Proposed by A. V. Nielsen.)

Resolutions 1, 2 and 3 were presented to the General Assembly and were later approved by that body.

Notes on the resolutions:

(3) Mr Federer offered to print and distribute star-charts for meteor observers. The Gnomic Star Chart Atlas by M. Guth at Prague has been completed and a copy was shown to the Commission.

(4) M. Dufay pointed out that in France meteorological observers now carry out the recommendation. He suggested that variable star associations be included. He also offered to write out instructions to observers and to send them to Mr Olivier. M. Naef pointed out that Mr Thomas in Vienna issues instructions for meteor observations and M. Baldet stated that there are detailed observations of meteors and fireballs in North Africa and the Sahara.

The chairman presented a recommendation from Mr LaPaz, that a thorough investigation be made of all phases of the recent meteorite fall near Vladivostok. The Commission voted to table this resolution until the astronomers of the U.S.S.R. could be consulted.

Report on the meeting of the Sub-commission on Zodiacal Light and Light of the Night Sky

PRESIDENT: M. J. DUFAY.

SECRETARY: M. J. KAPLAN.

The chairman called first on Dr Whipple, who presented a proposed outline of the work of Commission 22 in order to take into account the great advances and increased interest in these problems. Dr Whipple's outline follows (attached to the minutes by vote of the Commission):

Observations (related results in parentheses and detailed below):

A. Meteors (and meteor trains):
   1. Visual (*a*, *d*, *f*).
   2. Photographic (*a*, *d*, *e*?, *f*) (spectra included).
   3. Radar (*a*, *b*?, *d*, *e*, *f*, *g*?).
   4. Meteorites (*a*, *c*).

B. Night Sky Light:
   1. Night sky (*b*, *d*, *e*, *f*, *g*).
   2. Twilight sky (*b*, *d*, *e*, *f*, *g*).
   3. Aurorae (*b*, *d*, *e*, *f*, *g*).
   4. Zodiacal (*a*, +?).
   5. Gegenschein (*a*, +?).

C. Other Methods:
   1. Fraunhofer Corona (*a*, +?).
   2. Ozone measures (*d*, *e*, *f*, *g*).
   3. Searchlight work (*d*, *f*).
   4. Rocket research (*c*, *d*, *e*, *f*, ++ ...).
   5. Other geophysical methods, such as propagation of sound, noctilucent clouds, etc.

Results concerning

(*a*) Nature and origin of small bodies in the solar system (bearing on comets, asteroids and interstellar dust).
(*b*) Nature of interplanetary (and interstellar) gas.
(*c*) Cosmic rays.
(*d*) Atmosphere of the Earth (density, temperature, pressure).
(*e*) Atmospheric composition (including dissociation, ionization, etc.).
(*f*) Atmospheric variations with day, season, latitude (also with solar variations).
(*g*) Ultra-violet solar radiation.

Following the discussion Dr Swings presented a paper on suggestions for spectroscopic investigation of the night sky, twilight and aurorae. This paper is attached to the Minutes, by vote of the Commission.

A scientific session was held on August 16, at 20.15. The following papers were presented:

J. Kaplan: 'Production of Night-Sky Radiation in the Laboratory.'

A. Colacevich: 'A New and Extremely Rapid Camera Optical System.'

J. Dufay: 'Spectres crépusculaires.'

M. Nicolet: 'Structure de la Haute Atmosphère déduite de l'Etude des Mécanismes de Dissociation et d'Ionisation.'

Tcheng Mao Lin: 'Polarisation de la Lumière zodiacale.'

F. L. Whipple: 'Seasonal Variations in the Density of the Upper Atmosphere as Determined from Observations of Meteors.'

SUGGESTIONS FOR SPECTROSCOPIC INVESTIGATIONS OF THE NIGHT SKY, TWILIGHT AND AURORAE

By P. Swings

The present memorandum contains suggestions for investigations which would provide important information to upper atmosphere physicists. The main emphasis is placed on the desirable observations, although laboratory and theoretical investigations will also be suggested.

General Principles

(1) The simultaneous investigation and discussion of the spectra of the night sky, twilight and aurorae are extremely fruitful. The aurorae present over the night sky the advantage of a higher brightness and of an easier determination of the height of emission (by triangulation or possibly by radar). They also offer a wide range of conditions of height (hence of atmospheric temperature and density) and of density or energy of exciting particles. Moreover, the excitation mechanisms of the night sky, twilight and aurorae are different, although the ultimate source of excitation is, in all cases, the Sun. On account of the differences in excitation mechanisms, the spectra of the three sources reveal different atoms or molecules, or different transitions of the same atom or molecule, or different relative intensities, hence rendering comparisons fruitful. There are phenomena which are essentially common to two or three sources, such as the intensity variations of the red [O I] line (twilight and various types of (and heights in) aurorae), the behaviour of the N_2^+ bands (twilight and sunlit aurorae), the selective emission of $\lambda 6560$ (night sky and twilight).

(2) In all three sources an increase in spectral resolution will provide interesting new results. Better wave-lengths and profiles will thus be obtained, facilitating the discussion of the identifications and excitation mechanisms. Additional emission features will also be found.

(3) There is a great need for extending the observed spectral ranges of the three sources. In the case of the night sky, only the region $\lambda < 5000$ may be considered as satisfactorily covered, although an increase in resolution in this region would still be fruitful. The observational night sky data for $\lambda > 5000$ are rather poor, although their need is quite apparent (as will be shown later). Little or nothing is known of the twilight spectrum in the ultra-violet and infra-red regions (especially the latter). The spectroscopic information on aurorae is not sufficient in the ultra-violet, poor in the visual region and entirely absent in the infra-red.

As a first step an extension of the observations toward the red and infra-red would be most profitable. The corresponding spectrographs should of course be as fast as possible, and each emission should be studied with the highest possible resolution. In the case of the aurorae (and possibly also of other sources), the spectrograph should be equipped to render a quick change of dispersion possible, in order to take advantage of occasional higher intensities of certain emissions. For this purpose it seems that a spectrograph equipped with a plane grating (or a mosaic of gratings) and a set of cameras would be the most advantageous.

(4) There is a lack of accurate spectrophotometric data in all three sources. This will be illustrated later on.

(5) The close co-operation of observers, theoreticians and laboratory physicists is required. Obviously the investigation of the night sky, twilight and aurorae must proceed in the light of the information provided by the optical study of the lower layers of the atmosphere (sp. of setting sun, of the ozone layer, of the eclipsed disk of the moon), or by any other physical method (ionospheric observations, meteors, observations from 'V 2's', noctilucent clouds, etc.).

(6) For the identifications, synthetic spectra of low temperature rotational distribution should be prepared for all molecules. In all cases where a fluorescence excitation by solar radiation is envisaged, the synthetic spectra should take into account the presence of absorption lines in the solar spectrum. Such synthetic spectra may differ considerably from the spectra of ordinary laboratory discharges.

Desirable Observational Data on the Night-sky Spectrum

(*a*) Obtain additional data on the bands of the first positive system of N_2 present in the night sky:

(i) Investigate the infra-red region for structure of the intense λ10440 emission of N_2, and for check on absence of the [N I] doublet near λ10400.

(ii) Determine the relative intensities of the (0, 0) and (1, 0) bands. (Check that (1, 0) at λ8910 is absent or very weak relative to (0, 0) at λ10440.) This is essential for the discussion of the main excitation mechanism.

(iii) Study the structure of λ6560 with higher resolution; this is essential for the identification of the emission which shows a conspicuous twilight effect, and would reveal the distribution of the N_2 molecules as a function of height, if the identification is ascertained and if the fluorescence mechanism of the twilight emission is proved. See next section on twilight.

(*b*) Obtain additional quantitative data on relative intensities of the Vegard-Kaplan bands and, especially, on the distribution of the N_2 molecules on the vibrational levels of the excited electronic state $A^3\Sigma$. This was partly done by Cabannes and Dufay, and should be repeated with more refined photometry and theory. The vibrational distribution on $A^3\Sigma$ would reveal whether the Vegard-Kaplan system is emitted solely as a result of the first positive system (in which case the $v=0$ level should have the highest population), or mainly through another mechanism, such as direct conversion of D (N_2) into excitation energy on the $A^3\Sigma$, v level; or through a combination of various mechanisms.

The Vegard-Kaplan bands constitute the main emission in the blue-violet region, and their interpretation is essential for the understanding of the night sky phenomena.

(*c*) Examine the ultra-violet region with higher resolution, in order to decide definitely whether or not the Lyman system of N_2 and the Schumann-Runge system of O_2 are present. This is important for ascertaining the excitation mechanism, since the Lyman system of N_2 requires an appreciably higher energy than the well-identified features. However, it should be noted that the desired increase in resolution will not be an easy matter and will require powerful instruments; at the present time the ultra-violet spectrograms obtained in France by D. Barbier may be considered as the best. On their basis, one would rather consider that the Lyman and Schumann-Runge systems are absent, but this should be confirmed once and for all.

(*d*) Emission of H_2O in the red and infra-red, and other molecular or atomic emissions to the red of λ5000. Nothing definite may be said at present (except for the [O I] and Na-lines); new observations are needed; see paragraph (*a*) above.

(*e*) Investigation of the real physical nature of the apparently continuous emission. The question of this continuum is still far from settled. Is it a real continuum, or the superposition of weak bands and extensions of bands? The latter view is advocated by Barbier. It could be settled by increasing the resolution in the blue-violet region and by improving the accuracy of the photometry.

(*f*) The most important problem is that of the determination of the heights of emission of the different radiations. In such work great care should be taken to apply properly all necessary corrections, especially those due to scattering and absorption. The discrete emission patches should be studied in detail. Interesting information could perhaps be obtained by photoelectric observations from a night-fired 'V 2'.

(*g*) The study of the variations with magnetic latitude, magnetic activity, season, course of the night, solar phenomena, ionospheric activity should be continued.

(*h*) The night-sky spectrum should be examined after auroral displays or after any other manifestation of solar activity, for two essential reasons:

(i) excited metastable states of long life (such as ^2D of N I) may persist for quite some time at great heights (as appears in an observation by Götz);

(ii) the upper layers may have been perturbed (in temperature or distribution) and remain perturbed for some time.

Desirable Observational Data on the Twilight Spectrum

(*a*) Profile and photometry of the N_2^+ emission at twilight. A rotational intensity distribution obtained with sufficient resolution (about 1 A.) would enable one to decide as to the excitation mechanism of the N_2^+ flash. By precise photometry of the intensity of the N_2^+ flash at twilight and dawn, as a function of the solar depression (similar to the intensity measurements of the red [O I] line and of the yellow Na-line by Elvey and others) the distribution of N_2^+ with height may be obtained, if the fluorescence hypothesis is found to be valid.

(*b*) The twilight effect of Na should be re-examined with refined photometric techniques in order to discuss an hypothesis recently advanced by Vegard according to which the Na-emission results from absorption of ultra-violet radiation. The resonance hypothesis is instead accepted generally. An investigation of the ultra-violet spectrum of the twilight would reveal how the second principal line of Na, at λ3303, behaves; this information would be valuable for a discussion of the Na-problem.

(*c*) The structure of the λ6560 band at twilight should be examined, and compared with that of the emission around this wave-length in the night sky. If the λ6560 emission is a band of the first positive system of N_2, excited by fluorescence, the effect of the solar absorption lines (e.g. of the strong absorption at Hα) should be revealed, while the night-sky emission should not be affected by solar absorption lines. This is important as already stated above.

(*d*) Nothing is known of the twilight spectrum in the infra-red or the extreme red. Yet important data may be expected from such a study. Here are three examples. Are N_2 bands other than λ6560 (especially the 0, 0 transition) enhanced at twilight? Is there any emission of potassium lines (λ7699–λ7664) similar to sodium? Is there any O I-emission near λ8440 or λ7990 excited by ultra-violet radiation (Spitzer's suggestion)?

If photographic methods are found to be impractical, photoelectric measurements with fairly narrow filters or in connection with a dispersing system would be satisfactory.

(*e*) The investigation of the ultra-violet spectrum should be further pursued, in order to check definitely on the possible presence of λ3303 Na, λ3064 OH and λ3565 OH^+.

(*f*) Interferometric determinations of the width of the red [O I] line for different solar depressions would provide important data on the kinetic temperature at various heights.

Desirable Observational Data on the Spectra of Aurorae

(*a*) An increase in resolution all over the spectrum would provide important data: on O_2^+ and on additional bands of N_2 (first positive) in the red region; on the system of NO in the violet region; on additional N_2^+ transitions and Vegard-Kaplan bands all over the spectrum. New molecular systems will most likely also be discovered. The hypothetical atomic identifications will be more easily and thoroughly discussed.

(*b*) Practically nothing is known of the infra-red region. The intensity distribution among the infra-red N_2-bands would be of great interest for comparison with night sky and twilight.

(*c*) An accurate profile should be obtained for the (0, 0) band of N_2^+ in sunlit aurorae. Such a profile—which should be compared with that of N_2^+ at twilight and in ordinary low-altitude aurorae—would reveal the relative importances of collisional and resonance excitation in sunlit aurorae.

(*d*) Additional data should be gathered on the H^-, He I and He II emissions in aurorae, including photometric determinations of the Balmer decrement at different heights.

(*e*) It is essential to have interferometric determinations of width made for the [O I] lines at different heights, with a resolving power higher than was used by Vegard. Such determinations would provide badly needed data on the kinetic temperatures of the atoms at different heights.

(*f*) New measurements of rotational temperatures, based on different molecules (N_2^+ and N_2 at least), in different transitions (especially first and second positive systems of N_2) should be made at various well-determined heights. These determinations could then be compared with the 'atomic' temperatures derived interferometrically, with the theoretical temperatures estimated by various methods, and with the 'ionospheric' temperatures.

(*g*) Further spectroscopic comparisons (especially quantitative intensity ratios of the different bands) should be made for the different types of aurorae at different heights.

(*h*) The intensity ratio $\frac{\text{2nd positive of } N_2}{\text{1st positive of } N_2}$ should be determined at various heights in different types of aurorae. The behaviour of this ratio with height should provide unequivocal information on the energy variation of the exciting particles with height and with type of aurorae.

(*i*) The intensity decrements in the N_2^+ sequences should be better measured, so that comparisons between various types and heights of aurora (including the sunlit aurorae) and also comparisons with twilight may be made. Barbier's suggestion of reabsorption effects in high-altitude aurorae should be scrutinized. As suggested by Barbier, it may be useful to take absorption spectra of bright stars through an auroral display.

Distribution of the Elements in the Upper Atmosphere

(*a*) The de-excitation phenomena should be investigated by measurement of the speeds of the intensity changes of specific forbidden emissions (red [O I]; green [O I]; ultra-violet [N I]; green [N I]; Vegard-Kaplan bands) at well-determined heights, in aurorae of various brightnesses and types. A careful discussion of such measurements would give valuable data on de-excitation processes at different heights.

(*b*) The data obtained in (*a*), combined with quantitative twilight observations and new theoretical data, would provide the distribution in height of:

N_2 (from twilight effect on λ6560);
O (from twilight effect on the red line of [O I]);
N_2^+ (from twilight effect on N_2^+).

Photometric measurements in aurorae of well-defined geometry would provide other similar information of value.

(*c*) An accurate determination of the relative populations on the excited levels at different heights in aurorae of various types would provide a sound basis for the determination of the excitation processes in aurorae.

Desirable Laboratory Investigations

Any laboratory investigation on the spectra of N_2, N_2^+, O_2, O_2^+, NO, NO^+, and other atmospheric constituents is useful, especially typical being the valuable work by J. Kaplan on the afterglow. Among other things the Herzberg system of O_2 (vibrational classification

still in doubt), and Barbier's hypothetical system (carrier unknown) should be the object of laboratory work. Renewed effort should be devoted to the discovery of the forbidden intercombination system of NO. Various energies of dissociation and ionization remain hypothetical, the most important case being the heat of dissociation of N_2. Predissociation effects in N_2 should be further studied.

For the interpretation of aurorae, new experiments should be performed on the excitation of N_2, O_2, ... by hydrogen atoms, in conditions simulating the upper atmosphere as closely as possible.

Desirable Theoretical Investigations

There is a wide variety of pending theoretical problems which are important for upper-atmosphere physics. Outstanding are the following:

(*a*) Since the variations of atmospheric temperature and density are well known, up to about 120 km., the general problem of the dissociation of O_2 should be re-examined in detail.

(*b*) The distribution of N_2 and N should be investigated, as soon as certain laboratory data which are still lacking become available.

(*c*) Our knowledge of the temperature distribution is very unsatisfactory above 100 km. New observations suggested earlier in this memorandum should help considerably.

(*d*) Work on the de-excitation phenomena is desirable.

Once the observational data indicated in this memorandum are available it is likely that the compositions, densities and temperatures will be known at all heights, as well as the mechanisms responsible for the excitation of the night sky, twilight and aurorae.

23. COMMISSION DE LA CARTE DU CIEL

PRÉSIDENT D'HONNEUR: M. ESCLANGON.

PRÉSIDENT: M. J. BAILLAUD, 148 *Boulevard du Montparnasse, Paris-14, France.*

MEMBRES: MM. Ali, Benitez, Bok, Bratu, W. E. Cook, Couderc, Curlewis, Danjon, Delporte, Favaro, Greaves, Hertzsprung, J. Jackson, Järnefelt, Spencer Jones, Knox-Shaw, Lindblad, Luyten, Meyer, Nissen, Oort, Paloque, Plaskett, Russell, Smart, Spigl, Stein, van Rhijn, Warzee, H. W. Wood.

La longue période écoulée depuis la dernière assemblée générale de l'Union Astronomique Internationale aurait dû marquer dans l'entreprise de la Carte du Ciel l'achèvement de l'œuvre décidée par l'ancien Comité Permanent et une reprise des travaux dans des voies nouvelles ouvertes par le développement de la Science. Dans sa réunion de 1938 la Commission avait examiné comment l'œuvre pourrait se continuer. Nous nous étions alors engagés à apporter à la réunion qui aurait dû se tenir en 1941 des projets précis, conformes aux échanges de vues qui avaient alors eu lieu. Les événements qui ont bouleversé le monde nous en ont empêchés. Ils ont imposé à trop d'entre nous de tout autres soucis que le développement désintéressé d'une œuvre scientifique de longue haleine, et ils ont empêché toute liaison suivie entre le président de la Commission et ses collègues. Nous n'avons pu jusqu'à présent recueillir sur le travail accompli dans les divers observatoires que des renseignements trop insuffisants pour rendre justice à tous. Nous nous excusons auprès de nos collègues et nous les prions de considérer le rapport actuel comme un rapport préliminaire que nous espérons compléter avant la réunion de Zürich.

Le rapport de 1938 reposait sur une enquête étendue auprès des observatoires attachés à la Carte du Ciel et auprès des astronomes s'intéressant à l'entreprise. Dans le rapport actuel nous nous bornerons à compléter les indications qui ont alors été données sur la réalisation du programme du Comité Permanent et à proposer aux membres de la Commission les sujets sur lesquels nous désirerions que portassent à Zürich les échanges de vues et les discussions.

1. RÉALISATION DU PROGRAMME DU COMITÉ PERMANENT

Zones:

+90° à +65°. *Greenwich.* Carte et Catalogue publiés.

+64° à +55°. *Vatican.* La Carte est toujours en cours d'exécution; 150 feuilles environ ont été publiées en héliogravure; les suivantes sont reproduites sur carton au chloro-bromure. Le Catalogue est terminé et publié.

+54° à +47°. *Catane.* La Carte n'a pas été entreprise. Le Catalogue a été terminé en 1942; il est publié.

+46° à +40°. *Helsingfors.* Carte: clichés obtenus; reproduction non faite. Le Catalogue est terminé et publié.

+39° à +32°. *Potsdam, Uccle, Hyderabad, Oxford, Paris.* Cette zone avait été primitivement attribuée à l'Observatoire de Potsdam; elle a été abandonnée par cet observatoire peu après la guerre de 1914. A ce moment, sept volumes du catalogue avaient été publiés; ils donnaient les listes de coordonnées rectangulaires de 407 clichés, mais ces clichés sont très irrégulièrement répartis et aucune zone n'est complète. Le travail a dû être entièrement repris.

Carte: L'Observatoire d'Uccle s'est chargé de la publication de la carte par héliogravure. Le tirage des planches qui avait été interrompu par la fermeture de l'atelier Schutzenberger a pu être repris à Bruxelles même et sera terminé dans le courant de l'été 1948.

Catalogue: Grâce à l'influence de H. H. Turner, alors président de la Commission 23, le Catalogue fut pris en charge entre les deux assemblées générales de 1925 et de 1928 par les observatoires d'Hyderabad (zones +39° à +36°) et d'Oxford (zones +35° à +32°). A la mort de H. H. Turner l'Observatoire d'Oxford, pressé par d'autres travaux abandonna les deux zones +34° et +35°. Celles-ci furent reprises en 1938 par les Observatoires

d'Uccle et de Paris, Uccle se chargeant de la prise des clichés et Paris des mesures et des calculs. A la date actuelle, Hyderabad a terminé la publication des catalogues des 4 zones +36° à +39°. L'Observatoire d'Oxford, dont la vie a été profondément troublée par la guerre, n'a pas achevé la mise en œuvre de ses deux zones +32° et +33°. Peu de choses reste à faire, mais la publication du catalogue n'est pas encore entreprise. L'Observatoire d'Uccle a envoyé à l'Observatoire de Paris pour y être mesurés, 203 clichés des zones +34° et +35°, sur les 320 qu'elles contiennent. Paris a mesuré plus de la moitié de ces clichés.

+31° à +25°. *Oxford.* La Carte n'a pas été entreprise. Le Catalogue est terminé et publié.

+24° à +18°. *Paris.* La Carte et le Catalogue sont terminés et publiés.

+17° à +11°. *Bordeaux.* La Carte et le Catalogue sont terminés et publiés.

+11° à +5°. *Toulouse.* La Carte est terminée et publiée. Le Catalogue est terminé; la zone +10° est en cours d'impression; les autres sont publiées.

+4° à −2°. *Alger.* La Carte et le Catalogue sont terminés et publiés.

−3° à −9°. *San Fernando.* La Carte et le Catalogue sont terminés et publiés.

−10° à −16°. *Tacubaya.* La guerre a empêché la continuation de la Carte. 382 champs seulement sur 720 ont été reproduits par héliogravure. Le Catalogue a pu être continué. Dix fascicules nouveaux des zones −16° à −12° ont été publiés.

−17° à −23°. *Santiago di Chili, Hyderabad.* Cette zone avait été primitivement attribuée à Santiago. En 1909 elle fut partagée entre Santiago et Hyderabad, Hyderabad se chargeant des zones −17° à −20°. Le Catalogue de ces quatre zones fut terminé en 1922; Hyderabad entreprit alors celui des trois autres zones −21° à −23°. Le catalogue de la zone entière est terminé et publié. La Carte n'a pas été entreprise.

−24° à −31°. *Córdoba.* Cette zone avait été assignée en 1891 à l'Observatoire de La Plata qui ne put pas commencer le travail. Elle a été reprise en 1900 par l'Observatoire de Córdoba. Carte: tous les champs ont été photographiés; la zone −25° seulement a été reproduite par héliogravure. Catalogue: terminé et publié.

−32° à −40°. *Perth.* Cette zone primitivement attribuée à l'Observatoire de Rio de Janeiro a été prise en charge par l'Observatoire de Perth à la suite de la réunion de 1900 du Comité Permanent. La Carte n'a pas été entreprise. Catalogue: tous les clichés ont été obtenus à Perth. Le catalogue des zones −32° à −37° a été dressé et publié par l'Observatoire de Perth. La mesure des clichés des trois zones −38° à −40° a été faite à l'Observatoire d'Edimbourg. Un seul fascicule a été publié; il contient le catalogue des heures 0 à 6 de la zone −40°. Les manuscrits des catalogues des trois zones mises en œuvre à Edimbourg sont terminés et prêts pour l'impression.

−41° à −51°. *Le Cap.* Carte: tous les clichés ont été pris avec une seule pose; la reproduction n'a pas été faite. Catalogue: terminé et publié.

−52° à −64°. *Sydney.* Carte: 952 champs ont été photographiés. La reproduction des clichés n'a pas été faite. Catalogue: tous les champs ont été photographiés. Vingt-cinq volumes, sur les 52 que doit comprendre le Catalogue, ont été publiés. Douze volumes sont prêts à être envoyés à l'impression.

−65° à −90°. *Melbourne.* L'Observatoire de Melbourne ayant été désaffecté en vue du transfert de ses instruments au Commonwealth Observatory (Canberra), il y a eu peu de changements dans l'état du travail depuis 1938. Carte: tous les clichés étaient alors pris; leur reproduction n'avait pas été entreprise. Catalogue: les volumes I, II, et III, contenant les coordonnées rectangulaires des étoiles des zones −65° à −70°, ont été publiés. Les volumes IV et V (zones −71° à −75°) sont prêts pour l'impression. Les trois volumes restants sont très avancés; il ne reste que 12 clichés à mesurer. Le Comité National Australien d'Astronomie étudie comment le travail déjà considérable accompli à Melbourne pourra être mené à bonne fin par une coopération entre les observatoires de Sydney et de Perth.

II. Programme de Travail pour la Réunion de la Commission à Zurich

Carte

Le programme du Comité Permanent relatif à la Carte comprenait deux séries de clichés se contrôlant mutuellement. L'une portait une seule pose qui devait être de 40 minutes, l'autre trois poses de 30 minutes donnant trois images disposées aux sommets d'un triangle équilatéral. Cette série à trois poses devait être reproduite par héliogravure sur cuivre; des tirages sur papier devaient être distribués aux observatoires. Ces deux séries étaient imbriquées l'une dans l'autre de telle manière que le point du ciel qui formait son image dans un coin du cliché d'une série se trouvait photographié au centre d'un cliché de l'autre série. Toute la voûte céleste aurait donc été assez bien représentée, malgré le peu d'étendue du champ de bonne définition de l'objectif des équatoriaux de la Carte du Ciel.

Malheureusement, dans la plupart des observatoires, une seule série de clichés a été faite. Comme les clichés donnés par les équatoriaux de la Carte du Ciel ne donnent des images vraiment satisfaisantes que dans un cercle de un degré de rayon, les surfaces célestes photographiées aux bords et dans les coins des clichés sont sacrifiées. De ce seul fait, le quart du ciel environ se trouve défavorisé dans la Carte, telle qu'elle a été réalisée jusqu'à présent. A cette perte, qui affecte certainement toutes les zones, il faut ajouter celle qui provient des clichés défectueux, parfois nombreux.

Ces diverses considérations obligent à conclure que si l'œuvre qui a été accomplie pour réaliser la Carte du Ciel est très notable, le programme du Comité Permanent est loin d'avoir été rempli et que ce qui a été fait est sujet à des critiques graves.

Quoiqu'un grand nombre d'observatoires aient renoncé à satisfaire aux recommandations du Comité Permanent, il ne faudrait pas croire que le but initial de l'entreprise, celui de transmettre aux siècles à venir une image du ciel actuel, soit maintenant sans intérêt. L'enquête faite en 1938 montre au contraire que ce but est toujours considéré comme très important. Si quelques observatoires s'en sont détournés, c'est parce que le programme de 1896 impliquait la reproduction des clichés par héliogravure à une échelle double des clichés originaux; cela entraînait des dépenses trop élevées et mettait entre les mains des astronomes des documents dont ils tiraient un trop faible parti. Il existe déjà dans quelques observatoires des séries de clichés donnant l'image entière du ciel; nous pensons en particulier aux Cartes de Franklin Adams et aux magnifiques collections de Harvard College Observatory. Ces collections ont, sans aucun doute, rendu plus de services que ce qui a paru de la Carte du Ciel. Il faudra décider si elles suffisent pour remplir le but du Comité Permanent. Excellentes comme instrument journalier de travail, sont-elles à même d'être utilisées dans les siècles à venir? Nous souhaitons que les astronomes qui les ont utilisées nous donnent leur avis sur ce point.

Si l'on estime que, malgré l'existence de ces collections, il convient d'en établir une qui soit spécialement destinée à conserver une image du ciel et à servir de référence immuable, la Commission devra rechercher quelles sont les dispositions qu'elle peut préconiser dans l'état de la science et de la technique pour réaliser cette conservation.

Parmi les solutions qu'on peut donner à ce problème, en dehors de celle adoptée en 1896, citons les deux suivantes:

(*a*) Reproduction des clichés par héliogravure à l'échelle même des clichés originaux, ce qui diminuerait de quatre fois le prix de la reproduction et mettrait entre les mains des astronomes des documents plus faciles à mettre sur une machine de mesures.

(*b*) Reproduction des clichés originaux sur des plaques diapositives conservées dans des conditions aussi bonnes que possible et qui elles-mêmes seraient reproduites à nouveau lorsque leur état le demanderait. L'expérience acquise depuis la généralisation des plaques au gélatino-bromure laisse penser que des plaques bien traitées peuvent se conserver au moins une cinquantaine d'années. Ce ne serait donc que tous les 50 ans qu'on aurait besoin de recommencer le tirage. On ne distribuerait pas à tous les observatoires des

reproductions des clichés, mais des contretypes sur verre pourraient être envoyés aux observatoires qui le demanderaient.

L'un ou l'autre de ces procédés pourrait être appliqué à des photographies stellaires prises avec l'astrographe normal de la Carte du Ciel par chacun des observatoires attachés à l'entreprise, ou avec un instrument nouveau ayant un champ de bonne définition plus étendu et dont des exemplaires seraient installés dans des stations bien choisies.

Les diapositives sur verre se prêtent beaucoup mieux aux mesures et à la comparaison avec d'autres images de champs stellaires que les planches de cuivre héliogravées. Le second mode de conservation de l'image du ciel nous paraît être le plus avantageux. Mais il y aurait lieu de définir un mode opératoire qui rende aussi faibles que possible les déplacements inévitables d'images qui se produisent dans la reproduction.

En proposant l'établissement de la Carte du Ciel, les astronomes de la fin du siècle dernier considéraient que des astres de la 14ème magnitude étaient à la limite de ceux qu'il était intéressant d'étudier. Nous pensons maintenant qu'il faudrait aller sensiblement plus loin pour que l'image du ciel soit vraiment utile. Les membres de la Commission devront faire connaître leur opinion sur la magnitude limite à atteindre, compte tenu de la nécessité de se borner à un programme réalisable conduisant à des clichés de dimension maniable, propres aux mesures et sur lesquels les images stellaires ne soient pas tellement proches les unes des autres qu'on ne puisse les isoler.

Catalogue

La tâche la plus urgente qui incombe à la Commission est d'assurer l'achèvement du Catalogue. Il ne reste en retard que les anciennes zones de Potsdam de $+32°$ à $+35°$, une partie des zones de Tacubaya $-10°$ à $-16°$, la publication des zones de Perth–Edimbourg $-38°$, $-39°$, $-40°$, enfin, les zones de Sydney et de Melbourne. Pour toutes ces zones la plus grande partie du travail a été faite. Le retard n'est imputable qu'aux perturbations que la guerre a apportées aux travaux des observatoires intéressés. La Commission devra examiner à Zürich quelles sont actuellement les perspectives d'achèvement de ces zones, et rechercher quelles dispositions elle pourrait prendre pour aider les observatoires en retard. Il est possible que le calcul des éléments des clichés soit une des causes de retard. Certains observatoires libérés d'autres charges, pourraient y participer. Dans la plupart des Catalogues photographiques les éléments de chaque cliché accompagnent la liste des coordonnées rectangulaires des étoiles. L'impression des volumes ne peut ainsi commencer que lorsque tous les calculs sont terminés. Du temps serait gagné pour la publication si les éléments étaient rassemblés à la fin du volume, ou même publiés dans un fascicule séparé. On pourrait de cette manière commencer le travail d'impression dès que les coordonnées rectangulaires seraient obtenues.

Mouvements Propres

Un très grand nombre d'observatoires attachés à la Carte du Ciel ont entrepris la détermination des mouvements propres des étoiles de leurs zones. La méthode de comparaison des positions stellaires anciennes et nouvelles varie d'un observatoire à un autre. Ce peut être la comparaison aux coordonnées rectangulaires mesurées sur les clichés anciens et faisant l'objet du Catalogue Photographique, des coordonnées rectangulaires des images sur les clichés nouveaux. Ce peut être aussi la comparaison différentielle des positions des étoiles sur les deux séries de clichés, soit à l'aide de comparateurs dans lesquels les deux clichés sont placés sur des porte-plaques différents, soit en accolant les plaques l'une à l'autre dans une machine de mesures ordinaire, soit en imprimant sur un même cliché des répliques des deux clichés à comparer.

Dans sa réunion de Zürich, la Commission devrait pouvoir formuler des recommandations sur le meilleur procédé à adopter, selon que l'on prend en considération avant tout la recherche de la précision, ou bien celle de l'économie de temps et d'argent. Nous prions ceux des membres de la Commission qui ont déjà commencé l'étude systématique des

mouvements propres de leurs zones et qui ne pourraient pas venir à Zürich de nous envoyer avant cette réunion une note qui nous fasse connaître leur opinion sur les points suivants: méthode employée; avantages et inconvénients reconnus à cette méthode; précision atteinte; durée du travail jugée nécessaire pour la mesure des différences de coordonnées de 100 étoiles d'un même cliché; méthode employée pour transformer les mouvements propres relatifs donnés par les mesures en mouvements propres absolus. Ce dernier point est un des plus importants. Le but à atteindre n'est pas de rechercher les mouvements rapides de certaines étoiles pour lesquelles les autres étoiles du cliché pourraient être considérées comme étoiles de fond, immobiles, mais de rechercher les mouvements de toutes les étoiles et, en particulier, de mettre en évidence les mouvements d'ensemble.

Nous ne devons pas perdre de vue que la valeur des résultats tirés de la Carte du Ciel reposera principalement sur leur homogénéité étendue au ciel entier. Nous devons prendre toutes les mesures possibles pour conserver cette homogénéité.

Magnitude

La détermination des magnitudes est une partie très importante du Catalogue Photographique. La Commission aura à décider quel procédé il convient de recommander aux observatoires participants pour ramener à l'échelle internationale les nombres qui donnent dans les divers catalogues une évaluation de la magnitude.

Travaux divers

Les divers catalogues photographiques sont rapportés à des systèmes de fondamentales différents et souvent mal définis. Il importerait que les observatoires attachés à la Carte du Ciel fournissent les données nécessaires pour rapporter les positions stellaires tirées de leurs catalogues au même système de fondamentales.

Le Professeur J. H. Oort nous suggère d'entreprendre le recensement des clichés stellaires qui existent dans les divers observatoires. Il serait utile que ce recensement s'étendit non seulement aux collections de la Carte du Ciel, mais aux collections d'autres origines.

M. le Dr Warzée suggère qu'on entreprenne la détermination pour tout le ciel des nombres d'étoiles des diverses magnitudes jusqu'à la 14ème ou la 15ème. Les clichés de la Carte du Ciel portent en principe les images des étoiles jusqu'à la 14,5. Mieux que tout autres ils se prêteraient semble-t-il au recensement proposé par le Dr Warzée.

Jules Baillaud
Président de la Commission

Compte-rendu des séances de la Commission tenues les 12 et 14 août 1948

Président: M. Jules Baillaud.

Secrétaire: M. Paul Couderc.

La Commission de la Carte du Ciel a tenu deux séances les 12 et 14 août 1948. En ouvrant la première séance, M. Jules Baillaud, président, salue la mémoire des membres de la Commission décédés depuis la réunion de 1938: Sir Frank W. Dyson, le Prof. Frank Schlesinger, le Prof. G. Bratu, le Dr J. M. Baldwin, les Prof. A. Bemporad, R. Furuhjelm, G. Rougier, Don Luis Herrero. Il rappelle plus particulièrement ceux qui ont consacré toute leur activité scientifique à la Carte du Ciel, le Prof. A. Bemporad, qui fut directeur de l'Observatoire de Catane, et le Prof. R. Furuhjelm, qui fut directeur de l'Observatoire d'Helsingfors. Tous deux ont accompli dans leurs observatoires respectifs une tâche considérable, si bien que les Catalogues Photographiques de Catane et d'Helsingfors se

classent parmi les plus complets que nous ayons. Ils ont droit à la reconnaissance des astronomes.

Le Président présente ensuite ses souhaits de bienvenue aux membres nouveaux, directeurs ou chefs de service d'observatoires où se poursuit l'œuvre de la Carte du Ciel: le Dr Akbar Ali, d'Hyderabad; M. W. Benitez, de San Fernando; le Prof. G. Järnefelt, d'Helsingfors; les Drs J. Warzée, d'Uccle; H. S. Spigl, de Perth; H. W. Wood, de Sydney; Paul Couderc, de Paris.

La plupart des observatoires attachés à la Carte du Ciel ont été dans l'impossibilité au cours de ces dix dernières années de faire avancer les problèmes qui avaient été examinés par la Commission en 1938. Tout en ne perdant pas de vue l'ensemble du travail à accomplir, le Président propose à la Commission d'étudier tout d'abord les questions pour lesquelles des décisions pourraient être effectivement prises; puis, si le temps le permet, d'échanger quelques idées sur celles qui devraient être mises au point avant la prochaine réunion.

Catalogue. La tâche fondamentale que la Commission a à assurer est l'achèvement du Catalogue Photographique, ce qui comprend l'amélioration des catalogues déjà publiés pour les mettre à même de rendre tous les services que l'astronomie actuelle doit pouvoir en tirer. Depuis 1938 des progrès sensibles ont été atteints dans quelques zones. La zone de Catane est maintenant complètement publiée. Ceci est dû en très grande partie à l'activité et au dévouement du Prof. G. Favaro, à qui on doît la plus grande partie des mesures et des réductions de ce catalogue. L'Observatoire d'Hyderabad a terminé la publication des zones dévolues primitivement à l'Observatoire de Potsdam et dont il s'était chargé, les zones $+36°$ à $+39°$. Hyderabad avait déjà publié le Catalogue des zones $-17°$ à $-23°$. Le Président adresse ses félicitations au Prof. G. Favaro et à l'Observatoire d'Hyderabad. Quelques progrès ont été aussi accomplis à Tacubaya, à Sydney, à Melbourne.

Pour la zone de Melbourne, l'achèvement du travail est rendu difficile par la désaffectation de l'Observatoire de Melbourne et le transfert de ses services à Canberra. M. Vonwiller, puis le R.P. O'Connell, au nom du Comité National australien d'Astronomie, exposent la situation particulière des observatoires du Commonwealth Australien, en ce qui concerne l'achèvement du Catalogue Photographique. Le Dr H. W. Wood, directeur de l'Observatoire de Sydney (New South Wales), accepterait de prendre en charge, en plus des zones de Sydney, celles de Melbourne, s'il pouvait recevoir une aide matérielle correspondant au travail supplémentaire qu'il aura à assurer. Le Dr O'Connell annonce à la Commission que le Dr R. v. d. R. Woolley, directeur de l'Observatoire du Commonwealth, Canberra, est disposé à prêter à l'Observatoire de Sydney deux assistants pour deux ans. Par contre on ne peut pas compter que les Etats australiens pourront fournir les fonds nécessaires à l'impression du Catalogue. Il serait souhaitable que l'Union contribuât aux dépenses de cette impression.

Le président de la Commission remercie le Comité National australien de l'intérêt qu'il montre à la Carte du Ciel, et il remercie les Drs Wood et R. v. d. R. Woolley des dispositions qu'ils acceptent de prendre pour assurer l'achèvement des Catalogues des zones australiennes. Il lui paraît prématuré de demander à l'Union une aide financière pour l'impression des Catalogues qui ne sont pas terminés mais il ne doute pas que la Commission n'appuiera fermement en 1951, auprès de l'Union, une demande de crédits déposée par le Comité National australien lorsque les manuscrits des catalogues seront prêts à être imprimés. Le R.P. O'Connell indiquant qu'une démarche de l'Union auprès des gouvernements intéressés faciliterait beaucoup les négociations, la Commission soumet à l'Assemblée générale de l'U.A.I. la résolution suivante:

L'Assemblée Générale de l'Union Astronomique Internationale et la Commission de la Carte du Ciel attirent l'attention des Gouvernements du Commonwealth Australien et des Etats intéressés sur l'importance qui s'attache à l'achèvement des zones du Catalogue Photographique du Ciel confiées aux Observatoires Australiens; elles leur demandent d'en favoriser l'exécution en programme d'urgence. Les dernières lacunes du Catalogue Photographique nuisent à

l'utilisation globale de cet instrument scientifique précieux qui a déjà demandé tant d'efforts internationaux; elles sont d'autant plus regrettables que l'essentiel du travail a déjà été fourni.

L'U.A.I. serait reconnaissante à M. H. W. Wood, Government Astronomer, Sydney, New South Wales, d'accepter la direction de l'achèvement des Catalogues des zones australiennes, et à M. le Dr R. v. d. R. Woolley, Directeur de l'Observatoire du Commonwealth, Canberra, de lui fournir les assistants nécessaires.

La Commission de la Carte du Ciel s'engage à demander l'aide financière de l'U.A.I. pour la publication des derniers volumes de ces Catalogues lorsque les manuscrits seront prêts pour l'impression.

Impression des Catalogues. L'Assemblée Générale de 1938 de l'U.A.I. avait accordé à la Commission les fonds nécessaires, dans les conditions financières qui régnaient alors, pour imprimer les catalogues préparés par les observatoires d'Edimbourg (Zones $-38°$, $-39°$ et $-40°$), d'Oxford (Zones $+32°$ et $+33°$) et d'Hyderabad (Zones $+36°$ et $+37°$). L'Observatoire d'Hyderabad, seul, a pu terminer l'impression de ses zones. Les Observatoires d'Oxford et d'Edimbourg en ont été empêchés par les conséquences de la guerre. Dans les conditions actuelles du marché du travail, les fonds qui avaient été mis en 1938 à la disposition de la Commission et qui restent disponibles sont tout à fait insuffisants pour permettre l'impression des Catalogues en souffrance. Il résulte d'une enquête faite par le président de la Commission que les prix de cette impression seraient les mêmes, en Angleterre, en Hollande et en France, et qu'ils seraient réduits de près de moitié si les catalogues étaient imprimés par photozincographie au lieu de l'être par typographie. On obtiendrait de plus une réduction de prix sensible si la publication, au lieu d'être faite dans le format qui a été adopté jusqu'ici en France et en Grande-Bretagne pour les Catalogues photographiques, était faite dans le format 21×27 cm., qui est un format standard pour les presses employées en photozincographie.

Comme contrepartie de l'avantage considérable qu'offre le procédé photomécanique pour la réduction du prix de l'impression, on trouve l'inconvénient d'une charge sensiblement plus lourde pour les éditeurs responsables de la publication, qui sont obligés de fournir à l'imprimeur un manuscrit dactylographié dans la forme même où la reproduction doit être faite, sans qu'aucune correction d'épreuves soit possible. Les Observatoires d'Edimbourg et d'Oxford ne disposant pas du personnel nécessaire pour ce travail, leurs directeurs W. M. H. Greaves et H. H. Plaskett ne peuvent pas en accepter la charge.

M. Jules Baillaud, dégagé de tout devoir professionel, offre de prendre la direction et la responsabilité de cette impression.

Le Directeur H. H. Plaskett regrette d'avoir à signaler que les difficultés dues à la guerre ont empêché l'Observatoire d'Oxford de terminer les calculs des catalogues des zones $+32°$ et $+33°$. Il reste peu à faire, mais l'Observatoire d'Oxford manque des moyens de toute nature pour les mener à bien. Le Dr Heckmann (Hambourg) pense que l'Observatoire de Potsdam assumerait volontiers cette tâche. M. le Directeur Kienle (Potsdam) a confirmé ultérieurement cette proposition.

M. Jules Baillaud est chargé d'assurer la bonne marche de ce transfert. Pour permettre l'impression des 5 volumes d'Edimbourg et d'Oxford dont les manuscrits sont terminés ou pourront l'être dans très peu de temps, la Commission présentera à l'Assemblée générale de l'Union la demande de subvention suivante:

La Commission de la Carte du Ciel, désireuse de voir se terminer la publication du Catalogue Photographique, demande à l'Union Astronomique Internationale de mettre à sa disposition, en plus des fonds qui lui ont déjà été attribués et qui ne sont pas encore dépensés, une somme de 21.000 francs-or, pour couvrir les frais d'impression des 5 volumes du Catalogue appartenant aux zones laissées en souffrance par les Observatoires de Potsdam et de Rio de Janeiro, et dont les manuscrits préparés par les Observatoires d'Oxford et d'Edimbourg pourraient être imprimés d'ici 1951.

Amélioration des données du Catalogue Photographique. Les données du Catalogue Photographique doivent être améliorées en ce qui concerne les positions et en ce qui

concerne les magnitudes. En ce qui concerne les positions, le Prof. van Biesbroeck a signalé au président de la Commission la grande importance qui s'attache à l'utilisation des étoiles faibles du Catalogue Photographique comme étoiles de repère pour la réduction des clichés stellaires obtenus avec des instruments à champs peu étendus. Mais les positions de ces étoiles tirées du Catalogue Photographique ne sont pas toujours assez précises. Il y aurait intérêt à reprendre le calcul des éléments des clichés publiés dans ces Catalogues. A l'appui de cette remarque de M. van Biesbroeck, le Dr Heckmann fait connaître à la Commission qu'il a été calculé à nouveau à l'Observatoire de Hambourg un grand nombre d'éléments des clichés de Paris et de Bordeaux et que l'amélioration des positions obtenues est frappante; l'erreur probable des positions stellaires conclues est réduite de moitié. A la suite d'un échange de vues sur ce sujet, la Commission adopte la résolution suivante:

Afin de permettre l'utilisation des étoiles faibles du Catalogue Photographique comme étoiles de repère dans la réduction des clichés stellaires à champ peu étendu, il importe que le Catalogue ait toute la précision possible. Pour la plupart des volumes, cette précision est limitée par un défaut d'exactitude des *éléments* des clichés, dû à l'insuffisance des positions adoptées pour les étoiles de repère.

La Commission recommande donc aux observatoires qui ont participé à l'exécution du Catalogue Photographique de reprendre la détermination des éléments des clichés après avoir amélioré les positions des étoiles de repère en utilisant par exemple les positions photographiques obtenues soit à Yale Observatory, soit dans les observatoires attachés à l'*A.G.* 2 (voir Commission 8, 'Draft Reports', p. 45).

La Commission rappelle à ces mêmes observatoires la nécessité déjà mise en lumière dans la réunion de 1909 du Comité Permanent, de rapporter à un système fondamental bien défini les éléments du Catalogue Photographique. Elle les invite à entreprendre les études nécessaires pour rattacher le catalogue de leur zone au système du FK 3.

En ce qui concerne *les magnitudes* la Commission discute et adopte la résolution suivante:

La Commission recommande instamment aux observatoires qui ont contribué au Catalogue Photographique de fournir aux astronomes les données nécessaires pour transformer les magnitudes attribuées aux étoiles dans leurs catalogues en magnitudes internationales.

Carte du Ciel. Le plan dressé en 1892 et en 1896 pour conserver une image matérielle du ciel actuel n'a été rempli que pour la moitié environ de la voûte céleste. Le but que se proposaient les promoteurs de l'Entreprise de la Carte du Ciel reste cependant toujours digne d'être atteint. Mais, pour y réussir, ce serait faire un travail vain que de dépenser encore beaucoup de temps et d'argent pour appliquer un programme établi avec les moyens dont on disposait il y a 50 ans, et insuffisant pour les besoins actuels de la Science. A la suite d'un court échange de vues, la Commission prend la résolution suivante:

La Commission de la Carte du Ciel est d'avis qu'il convient toujours de chercher à atteindre le but primordial de l'Entreprise, qui était de transmettre aux siècles à venir une image précise et matérielle du ciel actuel.

Tout en proclamant la grande valeur des documents déjà obtenus pour la Carte du Ciel, elle reconnaît que les recommandations faites en 1892 et 1896 par l'ancien Comité Permanent ne sont plus en accord ni avec les besoins de l'astronomie, ni avec les moyens dont elle dispose actuellement. Elle met à l'ordre du jour de ses travaux l'étude des moyens à mettre en œuvre pour réaliser une nouvelle Carte portant des images d'étoiles beaucoup plus faibles que les étoiles limite de la Carte de 1896. Elle donne mission à son président de provoquer les recherches et les discussions nécessaires pour présenter à l'assemblée générale de l'Union en 1951 un projet définissant le type d'instrument à adopter, la magnitude limite à atteindre, et le procédé à la fois le plus pratique et le plus sûr pour assurer la permanence de l'image du ciel ainsi obtenue.

Mouvements propres. Aucun programme de travail impératif ne paraît pouvoir être proposé aux observatoires participant à la Carte du Ciel pour l'utilisation de leurs documents en vue de la détermination des mouvements propres, les moyens dont ils disposent étant trop divers, et aucun procédé de mesure ne pouvant prétendre à une supériorité

bien nette sur un autre. La Commission estime cependant qu'elle doit faire les recommandations suivantes:

La Commission recommande aux observatoires attachés à la Carte du Ciel d'utiliser les documents qu'ils possèdent pour la recherche des mouvements propres. Elle juge désirable qu'ils emploient pour la mesure des mouvements propres une méthode différentielle et qu'ils se mettent à même d'obtenir ensuite des mouvements propres absolus.

Les avantages principaux de la Carte du Ciel étant l'homogénéité et la continuité sur la voûte céleste, il importe de maintenir ces caractères dans la détection des mouvements propres. Si les observatoires ne pouvaient pas explorer tous les champs de leurs zones, ils devraient tout au moins étudier des champs répartis de telle manière que les résultats puissent être considérés comme une image fidèle de la zone entière.

La Commission rappelle qu'il ne s'agit plus simplement de mettre en évidence les mouvements les plus grands, mais qu'on doit chercher à atteindre ceux de toutes les étoiles figurées sur les clichés. Elle recommande de conduire le travail de telle manière qu'entre les clichés anciens et les clichés nouveaux — qui seront comparés par un procédé différentiel — il y ait pour tous le même intervalle de temps, qui devrait être d'au moins quarante ans. Enfin elle signale l'intérêt qu'il y aurait, dans le but d'atteindre des étoiles plus faibles, de ne pas se borner à l'utilisation des clichés pris pour le Catalogue Photographique, mais de tirer parti, autant que cela sera possible, des clichés à longues poses formant la série de la Carte du Ciel.

Recensement des collections de clichés. Le Prof. J. H. Oort, appuyé par le Prof. H. N. Russell, a signalé au président de la Commission de la Carte du Ciel l'intérêt qu'il y aurait à ce qu'il soit effectué un recensement des séries importantes de clichés stellaires qui existent dans les divers observatoires. La Commission de la Carte du Ciel serait bien désignée pour tenir à la disposition des astronomes qui auraient à les utiliser les résultats d'un tel recensement.

Le Président de la Commission se mettra en rapport avec les directeurs d'observatoires pour réaliser ce recensement.

24. COMMISSION DES PARALLAXES STELLAIRES ET DES MOUVEMENTS PROPRES

PRÉSIDENT: M. J. JACKSON, *H.M. Astronomer at the Cape of Good Hope, Royal Observatory, Cape Town, South Africa.*

MEMBRES: MM. W. S. Adams, Alden, Cecchini, Finsen, Hertzsprung, Mlle Hoffleit, MM. A. Hunter, C. Jackson, Lindblad, Luyten, Mitchell, W. W. Morgan, Nechvíle, Russell, Shapley, Smart, Stearns, Van de Kamp, van Rhijn, Voûte, Vyssotsky, Wagman.

TRIGONOMETRIC PARALLAXES

The determination of stellar parallaxes photographically using occulting shutters initiated by Schlesinger at Yerkes in 1903 and taken up vigorously at a number of observatories in the northern hemisphere about 1913 and in the southern hemisphere about 1925 has resulted in the determination of more than 9000 parallaxes relating to more than 5000 stars.

The position at the end of 1947 compared with that at the end of 1934 (as shown in *I.A.U. Transactions*, Vol. 5, 149) is approximately as follows, although for want of official figures some of the data are only estimates.

		Parallaxes determined to	
Observatory	Commenced	1934	1947
Allegheny	1914	1302	1660
Bosscha	—	150	(150)
Cape	1926	620	1525
Dearborn	1913	193	(193)
Greenwich	1913	583	(760)
McCormick	1914	1160	1808
Mount Wilson	1913	394	550
Sproul	1912	340	400
Stockholm	1933	—	46
Uppsala	1894	17	(50)
Van Vleck	1925	94	203
Yale	1925	1174	1550
Yerkes	1903	373	402
	Total	6400	(9297)

In addition there must be plates available for several hundred additional stars.

The increase in the number of trigonometrical parallaxes since the publication of the Yale *General Catalogue* (2nd edition, 1935) is nearly 50%, and I have therefore raised the question of a new edition or supplement. Members of the Commission are agreed that such a compilation is most desirable and there is a general agreement that the second edition is on such a good basis that a new edition could be satisfactorily based on the earlier one. I think most astronomers consider that the system of probable errors adopted by Schlesinger in forming the Catalogue reflects the actual errors better than those published by most of the observers. Although it may be that later lists with observations extending over more epochs than the earlier ones, and often depending on more plates, have truer probable errors there is much to be said for leaving the system unchanged.

The work of preparing a new catalogue or supplement will be very considerable and on a suggestion that Miss Jenkins who collaborated with Prof. Schlesinger would be most suitable to carry out the work I wrote to Prof. Brouwer who answered:

Upon receipt of your letter of November 6 Miss Jenkins made at once a survey of the new parallax material that could be considered ready for publication in an appendix to the *General Catalogue of Parallaxes*. She made counts in six half-hour stretches of right ascension,

$0^h\ 0^m$ to $0^h\ 30^m$, $4^h\ 0^m$ to $4^h\ 30^m$, etc. By multiplying the numbers by eight she arrived at the following numbers:

New stars with trigonometrical parallaxes	1008
Old stars with revised trigonometrical parallaxes	824
First trigonometrical parallax of stars for which spectroscopic or dynamical parallaxes were published in the *General Catalogue*	344
New stars with spectroscopic parallaxes	464
Revised spectroscopic parallaxes	736
Total	3376

Allowing for some overlapping in these five groups it would appear that an appendix prepared at this time would have approximately 3000 entries. This is a good deal more than either Miss Jenkins or I would have guessed before this count was made, and we are inclined to believe that the time has come for preparing such an appendix, which Miss Jenkins would be quite willing to undertake. She would propose to follow the same system as was used in the *General Catalogue*, without going to a revision of the system of weights and systematic corrections.

Prof. Brouwer added that he had considered a supplement rather than a new edition on grounds of economy of time and money.

Members might like to have the distribution of stars in the 2nd edition of the Yale *General Catalogue* according to probable error of the trigonometric parallax. This is

Up to $\pm''\cdot006$	939
$\pm''\cdot007$ and $\pm''\cdot008$	1032
$\pm''\cdot009$ and $\pm''\cdot010$	1353
$\pm''\cdot011$ and $\pm''\cdot012$	480
$\pm''\cdot013$ and $\pm''\cdot014$	107
$\pm''\cdot015$ and $\pm''\cdot016$	22
$\pm''\cdot028$	1
	3934

Although it will be seen from the figures given above that there has so far not been a great falling off in the work there has been a growing feeling that the bulk of the work of determining parallaxes trigonometrically has already been completed. From letters received there is a decided disinclination to undertake new heavy observing programmes of a general nature, although it is admitted that there is still a lot of work which can be profitably carried out. The position is something like this. All the brighter stars (down to magnitude 5·5), except some early-type stars, have been observed. In addition a very considerable number of selected fainter stars have been observed. These are for the most part stars for which a considerable parallax might be expected on account of large proper motion. But other stars have been included for other reasons, e.g. large dynamical or spectroscopic parallax. Recent additions to the working lists of several observatories contain an increasing proportion of faint stars for which Luyten has determined a proper motion exceeding $0''\cdot5$. (The Cape working list contains about 360 stars of which a third are faint stars from Luyten's list, a third are stars being re-observed because the parallax already found exceeds $0''\cdot100$ and the other third a miscellaneous collection.)

There is general regret that after Van Maanen's death the determination of the parallaxes of very faint stars with the Mount Wilson reflectors has been dropped. There is certainly important work to be done by at least one large reflector in determining the parallax of stars too faint for observation with refractors. The practical limit with photographic refractors is not much fainter than 14·0 and certainly stars fainter than 15·0 are out of the question.

From letters received the stars most in need of observation at present are

(1) Faint (and very faint) stars of large (or very large) proper motion.

(2) Stars with definitely dwarf characteristics (M type and white dwarfs).

(3) Stars for which existing determinations are discordant.

There is of course a large overlap between (1) and (2). Amongst the M-type stars at present attracting considerable attention are the dwarfs discovered by Vyssotsky and others at McCormick Observatory from their spectra, before their proper motion was known. A few have very small motion (*Ap. J.* **97**, 381, 1943; and **104**, 234, 1946). Included in (3) are a number of bright stars. There are also

(4) Important stars with early determinations from scanty material. Rather more than two thirds of the stars in the *Yale Catalogue* (2nd edition) for which a trigonometric parallax was available depended on observations at a single observatory. The position has probably slightly improved since 1934, but certainly more than half of the stars will have been observed at one observatory only.

More special stars for which observations are requested are

(5) Stars which may not conform to the normal position in the Russell-Hertzsprung diagram.

(6) Wide binaries, especially those with white dwarf components.

(7) Red giants with dynamical parallaxes for which the trigonometric and spectroscopic parallaxes disagree.

(8) Stars in regions of obscuring matter, e.g. Taurus and Orion.

(9) Dwarf variables of the T Tauri and SS Cygni types.

(10) Individual stars specially named and probably already being carefully investigated, ξ Bootis, α and Prox. Centauri.

A number of observers are replacing stars of large parallax on their observing programmes. Such observations are intended not merely to improve the parallax determinations but to investigate possible displacements not due to parallax or proper motion. In the case of visual binaries there is the determination of mass ratios while for other stars there is the discovery of invisible companions. We know too few mass ratios accurately, but their determination is difficult because we are usually unable to wait long enough for them to be disentangled from other unknowns. For the discovery of unseen companions ignorance of the period greatly enhances the difficulty of the problem and in the case of spectroscopic binaries for which a period is known the fact that the two components may be luminous produces further difficulties both by reducing the minute quantities to be measured and by uncertainty in their interpretation when observed. In the case of spectroscopic binaries with periods of the order of a year the size of the orbit will be comparable with the parallax but the displacement to be measured may be greatly reduced by smaller mass of the companion and (or) fusion of images. The number of favourable cases for observation is very small. See especially orbits deduced by Alden in the *Astronomical Journal* and as an example of the work involved when the period is unknown his orbit of δ Aquilæ (*A.J.* **45**, 193, 1936; and *A.J.* **51**, 59, 1944).

When we seek for companions of planetary size, say 0·01 or 0·001 of the mass of the Sun we can, with a yearly period, only expect displacements of about 0·01 or 0·001 of the parallax and with periods of 10 years these ratios are only about five times greater. If α Centauri had a planetary system similar to our own its Jupiter would produce an orbit 0″·004 in size with a period of 12 years on which would be superposed other orbits of a half and a third the size with periods of 29 and 165 years.

Observations of this kind are therefore for the most part confined to stars with a parallax exceeding 0″·100 or 0″·150. It is not necessary to take plates at the time of maximum parallactic displacement. As indicated above, the longer the period the larger the displacement, so that it will not usually be necessary to take plates at very short intervals. But to get the necessary accuracy very large numbers of plates are required (Van de Kamp reports 1200 plates for Barnard's star). Stars for these special investigations must be carefully selected. The Yale (Johannesburg) plan of taking plates at intervals of 7 and 14 years after the epoch of parallax determination should show up stars for which results may be expected in a reasonable time.

During the past 12 years a number of papers have appeared in the *Astronomical Journal* giving determinations of mass ratios and orbits deduced from parallax plates. Some of the

latter appear to be real but in nearly all cases further confirmation is desirable. It is sometimes hardly realized how difficult the problem is of finding orbital motion of the order of a few hundredths of a second of arc. With a proper motion at our disposal we can close almost any set of residuals to give an apparent period the same in both co-ordinates and closely related to the interval covered by the observations. We still want more and more accuracy in our parallax observations and for orbit work on parallax plates with so many variables at our disposal it is clear that long series of observations of the highest accuracy are essential.

When we consider that there are still many important stars requiring a second parallax determination, many faint stars still to be observed and any amount of the highest quality work in investigating orbital motion we can conclude that there is still ample scope for the parallax telescopes even although a number of them have been continuously engaged in this work for more than 30 years.

Attention may be drawn to a series of articles at the beginning of Vol. **51** of the *Astronomical Journal* (also Vol. **52**, 37) and to papers by Van de Kamp in the same *Journal* dealing with frames of reference for observations of fast moving stars extending over a long interval of time. (Vol. **52**, 226, 1947.)

At one time it was considered unnecessary to preserve parallax plates after measurement. In view of the possibility that the plates may be wanted in connection with orbital motion, proper motion or magnitude, etc. it seems desirable not to destroy them if they can be stored.

In 1939 I circularized members of the Commission with regard to the details given in published lists of parallaxes. There was a difference of opinion about changing the standard equinox from 1900.0 to 1950.0, but those who favoured the earlier equinox were more definite in their views and the result has justified them. It was generally agreed by observers that it was better to give for faint stars a magnitude estimated from the exposure time rather than perpetuate a magnitude seriously in error, e.g. Wolf 629 has been given as a star of photographic magnitude 11 or 11·7, 34^s preceding Wolf 630, while it is more nearly a star of magnitude 14, only $3^s{\cdot}4$ preceding Wolf 630. Prof. Schlesinger stated that it was most useful in preparing a general catalogue to have the DM numbers of stars given in the lists.

One of the desiderata of the present time is more information of the physical characteristics of stars for which the parallax has been determined. Many observers are undertaking the determination of proper motion in both co-ordinates and extending this work to the comparison stars and other stars suitably exposed on the plates. It is most desirable to get accurate magnitudes in at least two colours, and there is a wide field for work of this kind especially for the fainter stars. Also we want spectroscopic observations for accurate spectral classification, absolute magnitude and radial velocity. For much of this work the parallax telescopes are not the most suitable instruments and the co-operation of other observers is specially desirable. Useful work of this kind for stars of large proper motion has resulted from Luyten's co-operation with Harvard, Córdoba, and Arizona.

Spectroscopic Parallaxes

The coating of mirrors with aluminium instead of silver should make it possible to utilize additional lines, in the violet end of the spectrum, for the determination of absolute magnitudes.

At Mount Wilson about 5000 spectroscopic parallaxes have been determined although no additional results have been published since 1935. Some of the McCormick M-type dwarfs have been observed.

With the 13-inch Boyden telescope at Bloemfontein in conjunction with an objective prism giving a dispersion of 45A. to the mm. Harvard Observatory hopes to determine the absolute magnitudes of all stars brighter than visual magnitude 6·6, later than A 5 in type and south of declination $-20°$. Results have been published for 300 M-type stars (some in northern hemisphere) and 365 K-type stars (*HC* 448, 449). Results for several

hundred F-type stars should be ready shortly, while many plates have been taken. Some plates show stars to apparent magnitude 7·5.

At Yerkes an extensive programme for the observation of northern B-type stars has been undertaken. Approximately 700 of the brightest have been observed and it is planned to observe all stars brighter than magnitude 6·5. Spectroscopic absolute magnitudes and parallaxes for 75 O9–B5 super-giants and 52 B stars with interstellar lines are ready for publication. *Stockholm Annals*, Vol. **13**, No. 9 (1941), contains spectrophotometric determinations of stellar luminosities for stars in the Hyades and Praesepe down to photographic magnitude 13·5. Further work of the same type is being done in the Lacerta region, Selected Areas and open clusters.

Dynamical Parallaxes

No further lists of dynamical parallaxes have been published. These must depend on double star observations.

Proper Motion

In the last 10 years a great deal has been accomplished in the determination of proper motions by photography. Most important for parallax observers is the discovery of stars of large proper motion. In this field the work of Luyten carried out on plates taken with the 24-inch Bruce refractor of Harvard Observatory has been outstanding as it covers the whole of the southern sky and extends to stars fainter than the 16th magnitude. In all rather more than 100,000 stars have been found to show appreciable motion. The positions and motions for 28,535 stars south of $-50°$ have been published, those for 25,000 stars between declinations $-35°$ and $-50°$ have been determined, while work is in progress on 20,000 stars between $-20°$ and $-35°$. The cream of the results has been published in four special catalogues, *Minnesota Publications*, Vol. **3**, 1–4, in which are listed 904 stars with motions exceeding $0''·5$ annually, 1147 stars with motions between $0''·3$ and $0''·5$ and 832 pairs with common proper motion. The northern sky has not been so systematically surveyed as the southern in this respect although a considerable portion of it was covered by Wolf and Ross. It is most desirable that this be completed.

Proper motions for all stars down to about the ninth magnitude should result from a comparison of positions determined from photographic plates with earlier positions based on observations with the meridian circle. Most of the work for the northern hemisphere has been completed but not published. The largest portion at present available is for the zones $-30°$ to $+30°$ undertaken at Yale. The results have been published for all except* zones $-2°$ to $+20°$ and refer to some 85,000 stars. The zones $-30°$ to $-40°$ are ready for printing at the Cape; the proper motions of some 40,000 stars between $-40°$ and $-52°$ have been published, the second volume referring to stars fainter than 9·0 on the C.P.D. scale. South of $-52°$ photography is well in hand and the zone $-56°$ to $-60°$ is being measured at Greenwich.

Poulkovo Publications, Series II, Vol. **55**, contains the proper motions of about 18,000 stars in 74 of the 91 Kapteyn Selected Areas between Dec. $+15°$ and the north pole. The photographic work was commenced by Kostinsky in 1911 and completed by Deutsch in 1938. Stars down to magnitude 15·0 are included. The instrument used was a normal Astrographic Telescope and two separate determinations were made with time intervals of about 20 years. The probable error of the proper motion in each co-ordinate is about $\pm 0''·0046$. This work can be used in conjunction with the rather more extended work on all the 115 northern areas done at the Radcliffe Observatory, Oxford, with a larger telescope but a shorter time interval.

More than 30 years have elapsed since the first plates were taken for parallax and it is now possible to get accurate proper motions by repeating the earlier series. In particular when the parallax star has had its proper motion well determined in a fundamental

* Further results have now been published.

system, then the relative proper motions of all stars measured with it can be made absolute on that system. In 1937 McCormick published the proper motions of 17,900 faint stars reduced to the G.C. system. A second catalogue* is in preparation which will give the proper motions and photovisual magnitudes of 11,300 stars between the 8th and 12th magnitude with spectral classification for 7600 of them. These are contained in 441 regions distributed uniformly between Dec. $-20°$ and the north pole. The proper motions are on the FK3 system, to which system the 17,900 stars previously measured will be reduced. The whole mass of proper motions has been discussed in combination with the Cape motions between $-40°$ and $-52°$ declination with gratifying results as to agreement of constants derived from different classes of stars (*A.J.* No. 1167, Jan. 1948).

Other observatories have not yet undertaken such extensive proper motion work. With some it is due to shortage of staff or preoccupation with parallax and orbital motion, with others to the shortness of the time interval. In due course we may expect further proper motions in which early parallax plates are used for the first epoch.

It has been found possible at McCormick to get fairly reliable proper motions by comparing the positions of stars on plates with the measured positions on plates of the *Astrographic Catalogue*.

Some special lists of proper motions may be mentioned:

(1) The relative motions of 2920 stars of the Pleiades based on work done at Leiden during the past 20 years utilizing plates from fifteen observatories is in the printer's hands.

(2) Van Maanen has published proper motions of stars in the Pleiades, the double cluster in Perseus and M67.

(3) Plates for the determination of the proper motion of Cepheid variables have been taken at Mount Wilson and proper motions have been determined at Mount Wilson (Van Maanen and R. E. Wilson) and at McCormick (Mitchell).

(4) First-epoch plates have been taken for 438 long-period variables at McCormick Observatory but it is not intended to take second-epoch plates till photometric and spectroscopic data are available for the comparison stars.

(5) First-epoch plates are being taken at Stockholm for regions in Lacerta, Taurus and the north galactic pole.

I think it will be most useful to have a general discussion of parallax work at the I.A.U. meeting. Points which may be considered are:

(*a*) Continuation of the work.
(*b*) Faint stars.
(*c*) Selection of new stars for observation.
(*d*) Repetition of stars not sufficiently observed.
(*e*) Discordant results.
(*f*) Selection of stars for intensive examination.
(*g*) Utilization of plates taken early in the parallax programmes for proper motion, double stars, etc.
(*h*) Accurate magnitudes and spectroscopic observation of parallax stars.

It will be much easier to decide on stars to be observed under (*c*) to (*f*) after a new general catalogue is available.

The heaviest work in parallax determination for all stars except the faint ones is the measurement of the plates. As twenty or more plates centred on the same part of the sky have to be measured for each parallax the possibility of automatic measurement might be explored by some one with the necessary technical knowledge.

J. JACKSON
President of the Commission

* Now published.

Report of meeting

PRESIDENT: Dr J. JACKSON.

SECRETARY: Prof. A. N. VYSSOTSKY.

The President mentioned a few alterations required in the Draft Report as a result of additional publications and later information. Prof. Cecchini had moved from Milan to Turin and the reduction of both the trigonometric parallaxes and the spectroscopic parallaxes was still incomplete. Mrs Burbidge stated that parallax determinations had been undertaken with the former Radcliffe refractor, now at University of London Observatory, the preliminary programme containing 66 test stars.

The second proper motion catalogue from McCormick Observatory and a further volume of the Yale *A.G.* Catalogues with proper motions had been published. Still another Yale Catalogue was in the hands of the publishers. Dr Nechvíle reported that he was continuing his work on proper motions at Prague.

A discussion took place on a third edition of the Yale *General Catalogue of Parallaxes.* There was much new material available and only twenty copies of the second edition remained. It was therefore necessary to prepare a new edition instead of a supplement. Prof. Schilt strongly urged that the new catalogue should contain in detail the relative parallaxes and probable errors of the different observations without alteration so that they might be available for statistical investigations in the future without the need to take out the systematic corrections applied in the second edition. Prof. Mitchell thought that for general use it would be essential to have all the observations reduced to a system. It was agreed that the best plan would be to publish both the original relative parallax and a weighted mean parallax based on all the relative parallaxes reduced to some system—possibly the system of the second edition. An introduction would give details of the system.

Prof. Brouwer described how the work had been carried on at Yale by Miss Jenkins after the second edition had been published. The Yale Observatory could undertake the preparation of a new edition. In deciding the exact form of the catalogue it would be important for Miss Jenkins to be assisted by members of the Commission. Yale Observatory could undertake the preparation of the typed manuscript, but the cost of publication would be heavy. It was therefore resolved that an application be made to the Executive Committee for the sum of $1500 towards the cost of printing and binding the volume.

Prof. Schilt made a short statement on a communication by Profs. Luyten, van de Kamp and himself in which special emphasis was laid on the need for continuing observations especially of very faint stars, for which a large reflector was required, and of stars which might not conform to the Russell-Hertzsprung diagram. Copies of this report were available for distribution.*

Report of second meeting. August 16, 1948

The representatives of the different observatories made a report on the work being done by them. Although there was some falling off in parallax observations it was agreed that there was still much useful work to be done. The observation of very faint stars could only be done by large reflectors which were not required for the observation of bright stars. Amongst classes of stars which should be observed without reference to proper motion or other physical characteristics were the very bright stars of O and B types and stars fainter than magnitude 5·5 of types F8 and G0. Prof. Schilt drew attention to the discordances which exist between the parallaxes determined at different observatories. He did not think these could be explained by accidental errors, but thought they could easily arise from the use of different sets of comparison stars and he urged that this be investigated by examination of the stars used and possibly remeasurement with different comparison stars. Some observers, while agreeing that the discordances required explanation, thought that the labour of measuring plates was so great that remeasurement of a large number of plates could not be undertaken without a large sacrifice of other work.

* See *Pop. Astr.* LVI, 421, 1948.

25. COMMISSION DE PHOTOMETRIE STELLAIRE

PRÉSIDENT: M. E. HERTZSPRUNG, *Villavej* 6, *Tølløse, Denmark.*

MEMBRES: MM. Baade, Dufay, Mme Payne Gaposchkin, MM. S. Gaposchkin, Greaves, Hall, Kron, Kuiper, Malmquist, Mees, Nikonov, Öhman, Oosterhoff, Redman, Roach, Rybka, Schilt, Seares, Shapley, Stebbins, Šternberk, Stoy, Vanderlinden, van Rhijn, Wesselink.

SOUS-COMMISSION DES ETALONS DE GRANDEUR STELLAIRE

PRÉSIDENT: M. GREAVES.

MEMBRES: MM. Hertzsprung, Oosterhoff, Seares, Shapley, Stoy, Wesselink.

SOUS-COMMISSION DES SÉQUENCES DE MAGNITUDES

PRÉSIDENTE: MME PAYNE GAPOSCHKIN.

MEMBRES: MM. Vyssotsky, Wallenquist.

Since the last report of our Commission, now 10 years ago, there has been important progress in the development of photometric methods, notably the increase in sensitivity of the photoelectric cell. This improvement opens a wide field of useful work even with smaller instruments in the hands of skilled observers. As the cell can only deal with one object at a time, it is desirable that an increased number of instruments be adapted for this kind of work.

The photographic method, which is now antiquated in every case where the highest accuracy is required, will still maintain itself when the problem is to obtain approximate information about a large number of stars within a reasonable time and for the photometry of the very faintest stars which can be reached.

General photoelectric photometry should, of course, be effectuated in two colours, preferably selected in such a way that close similarity with ordinary photographic and photovisual magnitudes is achieved. Attention should be paid to the possibility of adding white dwarfs to standards of faint stars, among which there will otherwise, owing to selective extinction in space, be a natural lack of stars with small index of colour. Also from this point of view an examination of white dwarfs on constancy of brightness is wanted.

That the photoelectric cell, in spite of its high accuracy and the simplicity in the reduction of the measures, has so far rarely been used for general photometry, where comparison of stars far from each other in the sky is needed, has its reason in the necessity of a more precise knowledge of the differential extinction than is ordinarily available. The first thing to do, therefore, will be to establish a considerable number of fundamental stars of selected brightness and colour (avoiding double stars) evenly distributed all over the sky in the fashion adopted for the visual Potsdam photometry.

I see it as a preliminary task of this Commission to agree about recommendations in this line.

E. HERTZSPRUNG
President of the Commission

REPORT OF THE SUB-COMMISSION ON SEQUENCES OF MAGNITUDES

This sub-commission was established in recognition of the need for reliable standard magnitude sequences for investigations of stellar distribution, variable stars, galaxies, faint asteroids, and proper motion stars. (*Trans. I.A.U.* **6**, 341, 1938.)

The existing sequences for variable stars constitute an enormous body of material. Unfortunately, however, very few of these sequences have been adequately investigated as to the system of magnitudes, i.e. as to zero point, scale, and colour equation.

Another large body of material is found in the Mt Wilson magnitudes in the Selected Areas north of $-15°$. These are well established as to system, but they do not afford means for other investigators to determine their individual colour equations.

It is very difficult to recommend an ideal method of standardizing sequences. Direct comparison with the North Polar Cap is not entirely satisfactory in cases of sequences remote from the pole, as systematic errors affecting the scale are introduced. (Weaver, *Ap. J.* **106**, 366, 1947; Wirtanen and Vyssotsky, *Ap. J.* **101**, 141, 1945; Bergstrand, *Trans. I.A.U.* **5**, 157, 1935). While the half-filter method seems to be much more promising as regards scales, it has been relatively little tried and it does not fix the zero point. The colour equation of any sequence can be determined either by direct comparison with the North Polar Cap or by a determination of effective wave-length with a coarse grating. Probably the most reliable method of determining scale and colour is by means of photoelectric photometry, although we cannot at present hope that very many sequences of faint stars can be established in this way.

In order to make progress toward establishing more nearly adequate sequences with well determined zero point, scale and colour equation, the sub-commission makes the following recommendations:

1. That well-determined sequences, photographic and photovisual, be established in several declination zones. The Harvard Standard Regions at $+15°$ (C regions) are being actively investigated at Harvard; those at $-45°$ (E regions), by Dr R. H. Stoy of the Cape Observatory. The D regions ($-15°$) should receive similar study.
2. That these sequences be determined by more than one observatory, and that they be observed by photoelectric photometry as well as by photographic methods.
3. That the individual observers, when publishing sequences, include wherever possible either the colours or the spectra of the sequence stars.

It is realized that these recommendations involve a great amount of effort, but until satisfactory standard sequences are available it will be impossible to bring uniformity into the enormous existing mass of heterogeneous material.

CECILIA PAYNE GAPOSCHKIN
Chairman of the Sub-commission

ADDENDUM I

Report of the Sub-Commission on Standards of Stellar Magnitude

The task entrusted to the Sub-Commission was to report on the memorandum by Prof. E. Hertzsprung (*Trans. I.A.U.* **6**, 407, 1938) advocating that photographic magnitudes should be abandoned as standards as soon as possible and should be replaced by a system of monochromatic magnitudes to be obtained by spectral photometry of the region between H_δ and H_ϵ.

The advantages of monochromatic magnitudes over heterochromatic ones are well known. Monochromatic magnitudes are capable of precise definition in simple physical terms and most astronomers would agree that it is ideally desirable to set up a standard sequence or sequences of monochromatic magnitudes. But the Sub-Commission are at present concerned with a situation in which any recommendation as to the immediate future activities of astronomers must be guided by certain practical considerations. Stoy points out that 'many of the most important problems of the structure of our own Galaxy and of the extra-galactic nebulae depend on a knowledge of the brightness of the faintest stars which can be reached with our telescopes. To observe such stars the fastest plates, sensitive to a wide spectral range, must be used, while the work must be done with in-focus images. Since these magnitudes have ultimately to be compared with those of brighter stars, the latter have also to be observed in a similar manner. This leads us back

to ordinary magnitudes of the type now in use.' A similar view is expressed by Seares who comments that 'there will always be stars so faint, that a wide spectral interval—e.g. the Pg region—must be used to observe them at all. To meet these needs the North Polar Sequence standards should be retained.'

Stoy makes the further comment that 'ordinary magnitudes are convenient parameters to express a rather indefinite function of the energy output of a star integrated over a limited spectral range when the star is being regarded as a member of the general stellar population. When we regard a star as an individual physical body we want to know something very much more specific, viz. the intensity distribution of the stellar radiation from end to end of the spectrum. It is possible to determine the magnitudes of several hundred thousand stars; on account of the vast labour involved it is possible to investigate the continuous spectrum of a few thousand selected stars only.' This view is shared by Greaves who considers that monochromatic magnitudes should refer to the continuous spectrum alone and thinks that while the establishment of sequences of such magnitudes is desirable it is primarily a matter for Commission 36, the aim being to obtain detailed knowledge of a limited number of stars and so to contribute to the astrophysical study of stars as individuals.

Oosterhoff considers that even if it be granted that the existing photographic standards be replaced by monochromatic ones the latter should be of the highest possible accuracy and it would be inadvisable to attempt to establish monochromatic sequences by the existing methods of photographic spectrophotometry. He remarks that 'in view of the difficulties met in photographic photometry on the one hand and the recent developments of photoelectric photometry on the other, it does not seem wise to determine a standard sequence with the aid of inferior methods. At this moment photoelectric magnitudes are usually far from being "monochromatic", but spectra are already being registered photoelectrically at the telescope, and the method would yield directly the "monochromatic" magnitudes required. A large telescope and a refined equipment would however be needed.' Hertzsprung expresses agreement with this view and Wesselink also thinks that the photoelectric cell should replace the photographic plate for the problem of determining standard magnitudes in a sequence of stars. He points out that photoelectric magnitudes are not sensitive to variations in focal setting and that whereas photographic magnitudes are complicated by the existence of a photographic analogue to the Purkinje effect there is no corresponding source of trouble in photoelectric work. Stoy refers to the development of photoelectric methods, but remarks that there is one field in which it appears that photographic methods will hold their own, viz. the determination of magnitudes where large numbers of stars can be observed together.

Shapley writes 'that the development of a photometry in a limited region of the spectrum would be a nice addition to what we have at the present time. But it will be a long time before we can safely or intelligently abandon the existing visual, photovisual, and, especially, the photographic magnitudes. The idea is good. Some years ago we experimented with the setting up of a series of monochromatic magnitudes. If they are done cleanly enough, and numerously enough, they can take the place of a lot of spectroscopy, absolute magnitude work, as well as standard photometry. But technically we are far from able to run through a good set of narrow magnitude standards for general use. In fact, as you may know, we have great difficulty in astronomy in getting anyone to work systematically on the basic photometry we all feel we need.'

Wesselink agrees with Hertzsprung that standard magnitudes should be nearly monochromatic, but criticizes Hertzsprung's contention that ordinary photographic magnitudes do not fulfil this requirement because of the marked variation of effective wave-length with colour. His criticism is briefly as follows:

Denote the energy distribution function by $i(\lambda)$ and the sensitivity function (ignoring any effect analogous to the Purkinje phenomenon) by $\phi(\lambda)$. The brightness is then

$$I = \int_0^\infty i(\lambda) . \phi(\lambda) . d\lambda.$$

If we now put $$i(\lambda) = i(\lambda_0) + (\lambda - \lambda_0)\,\psi(\lambda),$$

we get $$I = i_0 \int_0^\infty \phi(\lambda).d\lambda + \int_0^\infty (\lambda - \lambda_0)\,\psi(\lambda).\phi(\lambda).d\lambda,$$

where $$i_0 = i(\lambda_0).$$

If the second derivative of $i(\lambda)$ be considered negligible then

$$\psi(\lambda) = i'(\lambda_0) = i_0'$$

and we can make the second integral in the expression for I vanish by defining λ_0 so that

$$\int_0^\infty (\lambda - \lambda_0)\,\phi(\lambda) = 0.$$

We then have $$I = i_0 \int_0^\infty \phi(\lambda).d\lambda,$$

so that I is proportional to i_0 and the heterochromatic magnitudes are thus identical with monochromatic magnitudes at wave-length λ_0. In practice (if all absorption lines are smoothed out) the second derivative $i''(\lambda)$ can be ignored and the magnitudes are accordingly essentially monochromatic. But the wave-length λ_0 is not the effective wave-length which may be defined as the weighted mean of λ with weight $i(\lambda)\,\phi(\lambda)$. λ_{eff} varies from star to star in virtue of the *first* derivative $i'(\lambda)$, but the magnitudes only cease to be essentially monochromatic if the second derivative cannot be safely ignored.

If Wesselink's argument be accepted then it would seem that since photographic (and other heterochromatic) magnitudes are essentially monochromatic they could be referred to standard monochromatic magnitudes at the appropriate wave-length. This would mean that although heterochromatic measures involving a considerable wave-length range are necessary for the faintest stars, the fundamental standard sequences could be monochromatic. To this argument Greaves raises the objection that the effect of spectral lines is being ignored. Two stars may have the same monochromatic magnitude at wave-length λ_0 and yet their heterochromatic magnitudes, referred to the same wave-length, may be different if the distribution of spectral lines is different for the two stars. He therefore considers that as long as certain problems demand the measurement of photographic magnitudes for faint stars, the standard sequences on which the measures must be based must also be photographic.

From the above it will be seen that as regards the answer to the immediate question referred to them the members of the Sub-Commission are unanimous in considering that at the present time the Commission should not attempt to replace the existing photographic standards of magnitude by the monochromatic standards envisaged by Prof. Hertzsprung. But this does not mean that the Sub-Commission regards the present standards as entirely satisfactory; the opinion of its members is rather that the time has not yet come for making specific recommendations for their replacement. By presenting his memorandum to the Commission Prof. Hertzsprung has done good service in stimulating discussion on matters which are fundamental to the whole subject of stellar photometry, and it is hoped that further discussion will take place at the Zürich meeting. The concluding portion of this report is intended to serve as a basis for such discussion.

It will probably be generally agreed that photographic magnitudes do not provide entirely satisfactory standards. In addition to the difficulties inherent to any system of heterochromatic magnitudes they suffer from the existence of the photographic Purkinje effect, which means that the sensitivity factors $\phi(\lambda)$ are not functions of λ alone but involve the brightness itself. Further, the factors $\phi(\lambda)$ involve the transmissive properties of the atmosphere and the optical train used as well as the characteristics of the photographic emulsion. To make photographic (or any other heterochromatic) magnitudes strictly self-consistent it would be necessary for each observer to work at a definite altitude as well as employing a definite instrument working under definite conditions; for photo-

graphic magnitudes these definite conditions would include the use of a definite emulsion and a definite exposure time. Each such set of observations would define a separate system of magnitudes and the relationships between the various systems would involve colour. This means that if each separate system of photographic magnitudes is to be reduced to any common standard the magnitude measures must be accompanied by measures of colour, a fact which has been pointed out by Seares and others and which has been stressed by Stoy who remarks that 'magnitudes are a function of two independent variables, the total energy received from a star and the spectral distribution of this energy. In the ideal case of a star radiating like a black body of temperature T the magnitude would be a function of its surface area and of T. Actual stars do not radiate exactly as black bodies, but if we are comparing star with star, we can assume that the great majority have energy distributions which can be specified by a parameter similar to T (for exceptional objects like planetary nebulae, Wolf-Rayet stars, etc., magnitudes can have no precise meaning).'

It is to be feared that some astronomers still do not realize the desirability for accompanying measures of magnitude by measures 'of a parameter similar to T'. Indeed it is somewhat doubtful if this will be enough if magnitudes are to have 'precise meaning'. It is too little realized that any measure of heterochromatic magnitude is a composite measure of the energy received in the continuous spectrum of a star and of the strengths of the spectral lines, and that the contribution of the latter to the total brightness can amount to something of the order of half a magnitude. This means that if two stars have the same surface area and if their outputs of continuous radiation are the same it still can happen that the magnitudes can be substantially different (e.g. as between supergiants and main sequence stars). It is possible that a third parameter, expressing average line intensity, is required; it could be obtained perhaps by magnitude operations using a filter which isolates the higher members of the Balmer series.

But, on the other hand, in spite of the undoubted difficulties which beset the use of heterochromatic magnitudes in general and of photographic magnitudes in particular there remains the fact that for the elucidation of some of the most important problems in astronomy we require measures of brightness of the faintest objects accessible to observation and for these measures there is no practicable alternative to photographic magnitudes, since we cannot afford to lose light by restricting the range of wave-length used. But it is important that observers should realize the inherent difficulties. It is especially important that it should be realized that every instrument, working under prescribed conditions, will, if high accuracy is the aim, define its own magnitude system and that this system will differ from other systems by a colour term and, possibly, by an additional term involving average line intensity. A consequence of this is that when high accuracy is contemplated, plates taken with a given instrument cannot be calibrated for scale by exposing them to sequences which have been 'standardized' with different instruments working under different conditions. It would seem obvious that magnitudes in one individual system cannot be standardized by using magnitudes appertaining to other and different systems, but this does not seem to have been always appreciated. Of course, if the highest accuracy is not the aim, the differences between two systems obtained under broadly similar conditions can be ignored and the technique becomes easier.

With regard to monochromatic magnitudes this term appears to have been used by different people in different senses. By monochromatic magnitudes some astronomers mean magnitudes appertaining to the continuous spectrum alone; the determination of such would require the employment of the technique of spectrophotometry using an adequate dispersion. Monochromatic magnitudes in this sense could only be practicably measured for a limited number of bright stars; they would form a welcome addition to astrophysical data and are a matter for the attention of Commission 36 rather than Commission 25. But from Prof. Hertzsprung's memorandum it appears that he contemplates magnitudes restricted to a comparatively narrow range of wave-length but integrating all the spectral lines in that range. For some wave-length ranges the contribution

made by the lines to the total magnitude would be greater than for photographic magnitudes and for others it would be less. It should be noticed that two such monochromatic systems, centred at the same wave-length, but employing different wave-length ranges, will not necessarily be identical magnitude systems since the line contributions may be different; similarly a heterochromatic system may be essentially monochromatic at wave-length λ_0 in Wesselink's sense, but the magnitudes may not be identical with those of a monochromatic system at wave-length λ_0. This is an argument against any attempt to lay down monochromatic standards on which the photographic magnitudes of the fainter stars are to be based. But, of course, it is not to be implied that monochromatic magnitudes of this kind would not have their uses. One use has already been suggested; magnitudes obtained by employing a filter restricting transmission to the higher members of the Balmer series may provide, when compared with other magnitudes, a measure of average line intensity (in this way we could get a numerical measure of the *c* characteristic).

It is clear that there is plenty of scope for useful and stimulating discussion, but most astronomers will probably agree that this is not a matter on which Commission 25 should attempt to issue anything in the nature of a directive. The disadvantages of the present magnitude system are already obvious to many, and attempts to remove them may safely be left to individual enterprise. On the other hand, many astronomers are anxious to obtain answers to the problems which require a photometric approach (e.g. problems of galactic structure) and will push ahead employing the existing photographic technique which has been shown to be quite effective for many purposes. The best service that the Commission can perform at present is to stimulate discussion and research on the one hand, and, on the other, to emphasize that the study of some very important problems can be advanced by systematic work on established lines.

W. M. H. GREAVES
Chairman of the Sub-Commission

ADDENDUM II

At the request of the Chairman, Prof. Redman gave some details of a large photometric programme being followed under the direction of Dr Stoy at the Cape. The work started when it was decided to measure accurate magnitudes in conjunction with a positional programme, viz. the photographic repetition of the A.G. zones. This original programme is still being continued (photovisual and photographic magnitudes between about 7 and $10^m{\cdot}5$ *pv*), but during its early stages it was discovered that the available standard stars in the southern sky were entirely unsatisfactory, so that another large programme was commenced, devoted to standardizing the magnitudes of stars in the E regions at $-45°$ declination, over the range of brightness just mentioned. Using the twin photometric cameras (4-component Ross-type lenses, 35 in. focal length, 5 in. aperture stopped to 3 in.) at first at the Cape and later at Pretoria, extensive intercomparisons of the E regions have resulted in a self-consistent system of magnitudes (*pg* and *pv*) with a mean error per star of about $0^m{\cdot}02$ or $0^m{\cdot}03$. The scale of the magnitudes has been checked by measures using the Fabry method. It is of the highest importance that the magnitudes should be reduced to the accepted international photographic and photovisual systems, and thus the outstanding problem at present is to provide an accurate link with the N.P.S. Extensive intercomparisons have been made between the E regions on the one hand and the Pleiades, Hyades, Praesepe, and the Eros comparison stars on the other, but the results have not so far been entirely satisfactory. Now the Cape cameras have been moved to Cambridge, England, where it is intended to intercompare the Kapteyn areas at $+15°$ declination with the region around the North Pole with the highest possible accuracy. Subsequently the cameras will be returned to the Cape, where the E regions will be photographed against the $+15°$ Kapteyn areas. The aim is to continue this work until systematic differences between the E region magnitudes and those at the North Pole do not exceed about $0^m{\cdot}02$ in scale, zero, or colour characteristics, over the range $7^m{\cdot}0$ to $10^m{\cdot}5$ *pv*.

PRESIDENT: Prof. E. HERTZSPRUNG.

SECRETARY: Prof. H. L. VANDERLINDEN.

Prof. W. M. H. Greaves reads his report of the Sub-Commission on Standards of stellar magnitudes. He considers first the points of view expressed by different authors (Stoy, Oosterhoff, Wesselink, etc.) and lays stress on the actual fundamental basis of stellar photometry.

The Commission recommends that the report by Prof. Greaves be included in the printed report of the Commission.

Dr Redman reports on the photometric work of Stoy on the determination of standards of photographic and photovisual magnitudes in the region of $-45°$ declination and the reduction of those magnitudes to the international scale of the North Polar sequence; the mean error aimed at is of the order of $\pm 0{\cdot}01$ or $0{\cdot}02$ magnitude.

An abstract of Dr Redman's report will be added to the report of the Commission.

26. COMMISSION DES ETOILES DOUBLES

PRÉSIDENT D'HONNEUR: M. AITKEN.

PRÉSIDENT: M. W. H. VAN DEN BOS, *Union Astronomer, Union Observatory, Johannesburg, South Africa.*

MEMBRES: M. Baize, Mme Bonnet-Sainturier, MM. B. H. Dawson, Finsen, Hertzsprung, Jeffers, Kuiper, Luyten, P. Muller, Rossiter, Russell, Strand, van Biesbroeck, Voûte, Wallenquist, Woolley, Zagar.

The effect which the war has had on the progress of Astronomy in general, and of Double Star Astronomy in particular, cannot yet be reliably estimated, but we can already say that it is severe and will be felt for many years to come. Its least serious (because, we may hope, only temporary) aspect is the delay in the publication of observations. This effect may be mitigated if observers will communicate their unpublished results and forward reprints of their publications to the two central offices: Lick Observatory for declinations $+90°$ to $-30°$, Union Observatory for $-19°$ to $-90°$. If this be done, information supplied by these offices could include unpublished results.

The completion of the systematic surveys at Lick, Bloemfontein and Johannesburg seems to have made the discovery of new pairs amongst the stars down to the ninth Durchmusterung magnitude largely a matter of the past, unless a considerable improvement in our powers of detection should be achieved. For the fainter stars, a continuation of the visual work of Espin, Jonckheere and others with instruments of greater optical power as well as inspection of photographic plates obtained with long focus instruments would doubtless result in the addition of large numbers of faint pairs. The question is: how would this benefit the progress of our branch of Astronomy, when we are not even in a position to provide adequate, systematic measurement of the pairs already known? It would seem a wiser policy to test for duplicity (repeatedly, when desirable) a limited number of stars selected for special reasons, such as large parallax or proper motion, variable stars when near minimum light, etc. If we should desire some knowledge of the occurrence of double stars among the stars fainter than the ninth magnitude, some Selected Areas plan would seem to be indicated, in order to keep the number of new discoveries within manageable proportions.

With regard to routine measurement of known pairs, the position is not satisfactory. The small number of powerful instruments which are wholly or in part devoted to this task have to carry too great a responsibility. When one keeps a Card Catalogue up to date, one knows how much remains to be done. It is not very satisfying to find that a pair such as ADS 8739 was not measured between 1902 and 1924, nor does a pair such as ADS 4472 give evidence of careful planning of our observing programmes.

We still have to rely mainly on visual measurement with the micrometer in one of its various forms. While the usual micrometer, if used with care and skill under adequate atmospheric conditions, still seems to give the best results as far as position angles are concerned, modern forms of the double-image micrometer and the comparison-image micrometer appear to give better distances, with the additional advantage that they can be used for determining magnitude differences. With suitable precautions, both interferometric and photographic measurement can reach a much higher accuracy than visual, but both are of limited applicability.

Orbit computation leaves nothing to be desired. Whenever a double star has been adequately measured—and not infrequently long before this stage has been reached—one or more orbits are certain to appear.

Our observations of position need to be supplemented by accurate data on parallax, mass ratio, magnitudes, spectral types, radial velocities, etc., of great importance for theoretical investigations. More attention is now being paid to this aspect, but much remains to be done here, notably for faint objects of special interest, such as pairs with degenerate components.

W. H. VAN DEN BOS
President of the Commission

Report of meeting. Friday, August 13, 1948. 11.30 a.m.

PRESIDENT: Dr W. H. VAN DEN BOS.

SECRETARY: Mr P. MULLER.

The President opened the meeting, Mr P. Muller acting as Secretary.

The President remarked that, as an overlap of one degree between the domains covered by the northern and southern central offices is sufficient, it might lighten the burden of the northern office if Dr Jeffers considered shifting his southern limit from $-30°$ to $-20°$.

Dr Jeffers gave information on the present state of the northern Card Catalogue at Lick Observatory, received from Dr Aitken a few years ago. As none of those present desired to discuss further points of the Draft Report, the President proceeded to read a letter from Prof. Hagihara, that the astronomers at Tokyo intend to take up the measurement of double stars as soon as the 26-inch refractor is back in operation.

The President invited those present to send letters of greeting to Messrs R. G. Aitken (Honorary President), H. N. Russell, G. van Biesbroeck and J. Voûte. These were circulated and signed.

The desirability of a publication of General Catalogues for the northern and southern domains, to bring the ADS and SDS up to date since 1927, was next discussed. The general opinion was that such publications, in a not too distant future, were highly desirable.

Dr Jeffers remarked that a large number of observations made in recent years had not yet become available at Lick and the President confirmed that the same applied to the southern central office.

Dr Jeffers invited opinions on the most desirable form of such a General Catalogue. The President pointed out that this was not an urgent matter at the present stage and could be dealt with more efficiently by correspondence when the time to prepare manuscripts approached.

The President invited a discussion on the future and aims of Double Star Astronomy. He mentioned that a number of experienced astronomers had voiced their concern that few young men appear to enter this field, to replace those retiring from active work. He himself agreed that this was the case, but was not particularly worried, as he believed that unjustified neglect of any branch of astronomy was bound to correct itself in the long run. Dr Mitchell said that the same situation was found in parallax observation and that he ascribed it to the rigours of the observational work. The President remarked that the case is relatively more serious for double stars, as these have to be kept under observation, whereas a parallax is known, once it has been sufficiently well determined. Nevertheless, he hoped that double star observation would always be in the hands of astronomers who took a genuine interest in the subject, as the results obtained by those who perform it as a routine duty tend to be of small value.

Dr Baize wished to see the technique of measurement improved. According to his comparisons, the filar micrometer is satisfactory for position angles, but surpassed by modern forms of the double image micrometer in the measurement of distances.

Prof. Zagar mentioned the great need for accurate determination of differences of magnitude and radial velocities, as referred to in the Draft Report, and emphasized the importance of continued statistical studies of double stars.

Mr Muller stated that, using his double image micrometer as a photometer, he is obtaining magnitude differences with a mean error of about $0^m{\cdot}04$.

Prof. R. E. Wilson said that astronomers working in other branches needed the results of double star observers and that at Mount Wilson spectra of both components of about 200 pairs have been obtained. This permits them to be placed on a Russell diagram. Mr Muller mentioned that a similar result was obtained from his measurements of magnitude differences in two colours, red and green, for a number of bright stars.

There being no further discussion, the President closed the meeting at 12.15 p.m.

27. COMMISSION DES ETOILES VARIABLES

PRÉSIDENT: M. A. DANJON, *Directeur de l'Observatoire de Paris, Paris-14, France.*

MEMBRES: MM. J. Ashbrook, Banachiewicz, Blazhko, Brun, Campbell, de Kock, Einbu, Gadomski, S. Gaposchkin, Mlle Harwood, MM. Hertzsprung, Huffer, Jacchia, Joy, Kopal, Kordylewski, Kron, Kukarkin, Lacchini, Lindley, McLaughlin, Martynov, J. E. Merrill, P. W. Merrill, Mitchell, A. V. Nielsen, Oosterhoff, Parenago, Pearce, Peltier, Pierce, Russell, Ryves, Shapley, Steavenson, Stebbins, Stein, Tsesevich, Vandekerkhove, Van Hoof, Wesselink, F. Bradshaw Wood.

SOUS-COMMISSION POUR LA DÉNOMINATION DES ETOILES VARIABLES

PRÉSIDENT: M. DANJON.

MEMBRES: Mme Payne Gaposchkin, MM. Kukarkin, Oosterhoff.

Nomenclature. Le Comité Exécutif réuni à Copenhague en mars 1946 a pris différentes décisions intéressant la Commission 27 (voir *Circulaire* VI, 2). La sous-commission chargée de la désignation des étoiles variables a publié les 42e et 43e listes, contenant respectivement 123 et 1051 variables dénommées. Ces listes avaient été préparées par Boris W. Kukarkin et Paul P. Parenago. Les règles adoptées sont énumérées dans l'Introduction de la 43e liste.

On demande la publication prochaine du 3e volume de la Bibliographie de Prager. A. Brun suggère qu'il soit rédigé en anglais. La Commission 27 devra examiner également les conditions de publication du catalogue quinquennal. Il y aura lieu, enfin, de préparer la publication de la liste des observations inédites, dont Grouiller avait été chargé en 1938 et que sa mort a suspendue.

Ashbrook demande un supplément aux *Tabellen zur Nomenklatur der V. St.* publiées par Prager en 1927, donnant les désignations successives de chacune des variables découvertes depuis 20 ans. Ces tables pourraient être imprimées à la suite du 3e volume de G. u. L.

E. Hertzsprung suggère qu'on utilise les combinaisons de lettres non encore employées (par ex. BA), au moins pour les variables remarquables présentant un intérêt spécial.

Alfred H. Joy et P. Th. Oosterhoff proposent chacun un changement de nomenclature pour les étoiles dites 'variables d'amas' (cluster type): 'Such a large number of these short-period stars have been found in our own galaxy that they can no longer be considered as characteristic of the clusters. My own preference would be to call such stars RR Lyrae stars, whether in our own galaxy or in the clusters.' (Joy.) 'Bailey's subclasses *a*, *b* and *c* depend on the shape of the light-curve. As the change between the classes *a* and *b* is a gradual one, which sometimes makes it impossible to assign a variable to either of these subclasses, I suggest that in the future only subclasses *a* and *c* will be maintained. The new subclass *a* would then cover the former subclasses *a* and *b*.' (Oosterhoff.)

Cartes, séquences, positions. Le P. Stein rappelle la publication du volume 9 de l'*Atlas Stellarum Variabilium* (43 cartes, 46 variables, 3280 étoiles de comparaison).

Mitchell a achevé la révision des séquences pour les 450 cartes de la A.A.V.S.O. (Publ. of Leander McCormick Obs. **6** et **9**–5).

A. Brun n'estime pas suffisante la précision de 1s et 0'·1 recommandée par Guthnick en 1938 pour les positions des variables nouvelles qui ne figurent dans aucun catalogue. Il demande 'la publication de petites cartes donnant le champ stellaire dans un rayon de 3 à 4' autour de la variable... au moins pour celles qui paraissent présenter des caractéristiques intéressantes'. Il demande que des séquences soient préparées pour toutes les novoïdes.

R.P. de Kock signale les difficultés que rencontrent les observateurs d'étoiles variables dans l'hémisphère sud: 'Observers in the Southern Hemisphere are handicapped by

having to prepare charts by hand. In a number of cases the sequences of comparison stars do not extend to the minimum magnitude of the variable star. For example, the following stars U Cen, R Lup, R Cae. Magnitudes in several sequences require revision. R Hor is a case in point.' Hertzsprung insiste également sur la recherche des variables australes.

Observations. L. Campbell a établi un rapport sur l'activité des associations d'observateurs d'étoiles variables. Bien que le nombre des observations ait sensiblement baissé pendant la guerre, aucune des variables régulièrement suivies depuis 30 ou 40 ans n'a été complètement négligée. Il serait désirable de développer le programme des observations, et, pour cela, de fournir aux observateurs de nouvelles cartes et séquences. On appelle de nouveau l'attention sur la liste de 100 étoiles établie en 1938: une trentaine d'entre elles seulement sont régulièrement observées. Si importante que soit l'observation photographique, l'observation visuelle doit etre assidûment poursuivie; c'est grâce à elle qu'on a pu, par exemple, noter, depuis 1896, 360 maxima de l'étoile SS Cyg.

La A.A.V.S.O. a recueilli sa millionnième observation. L'Association scandinave, présidée par Axel V. Nielsen depuis la mort du regretté E. Strömgren, a poursuivi son œuvre pendant la guerre. L'Association française, atteinte par la mort de Grouiller, a repris son activité et ses publications, Bigay centralisant les observations à l'Observatoire de Lyon.

La liste de 100 variables intéressantes établie par L. Campbell a donné lieu à diverses remarques: 'That list is rather long; at any rate, it contains a few stars which are too difficult for amateur observers, and, according to my point of view, a few other stars which have to be enclosed may be pointed out', écrit Axel V. Nielsen, qui propose de préparer une publication donnant des cartes et des séquences pour toutes les variables dont l'observation systématique est désirable. De son coté, A. Brun estime que 'cette liste devrait être augmentée de toutes les étoiles présentant le caractère de novoïdes (types SS Cyg, Z Cam, Z And, V Sge) ainsi que de celles particulièrement énigmatiques, des types RR Tau et R Crb'.

S. Gaposchkin donne les renseignements suivants sur l'état d'avancement de la révision des variables galactiques brillantes entreprise à Harvard College Observatory: 'A working programme was drawn up which included over 1500 variables. For each star an average of 1000 observations could be obtained. The work was financed by the Milton Fund of Harvard University. We employed several assistants. We have already published the results for eleven of the 54 fields in very concise form; 24 fields are ready for publication and the last 19 are being completed at present.'

Shapley signale des différences entre les Céphéides des deux nuages de Magellan et de la Galaxie (fréquence des périodes, périodes pour lesquelles se présentent deux maxima). La comparaison est facile entre les deux Nuages, une même séquence pouvant être employée pour chacun d'eux. Au contraire, la comparaison entre les Nuages et la Galaxie est difficile en raison de la multiplicité et de l'hétérogénéité des séquences galactiques. 'The prolonged study of the variable stars in the Magellanic Clouds brings out a need for international co-operation.... It would be of high value in the study of cepheid phenomena if very precise light curves on an accurate magnitude system could be obtained for the cepheid variables of the Milky Way, especially for those with periods less than three days, between 8 and 12 days, and in the neighbourhood of 16 days period-length. Precision in the magnitude scale is important. Accuracy in the zero point is less significant.'

Miss Margaret Harwood continue l'étude des variables du nuage de Scutum, suivant le plan établi en 1930. En 1940, la variabilité de 392 étoiles avait été reconnue, dont 120 appartenant au nuage lui-même. Depuis lors, plus de 900 autres variables ont été découvertes sur les plaques obtenues à la station australe de Harvard Observatory. 'What is needed most now are more larger scale plates suitable for obtaining sequences of faint magnitudes in all parts of the Cloud on the same scale as those of Krieger's area A. This is the only Krieger area which contains stars fainter than 16·0 on the international scale.'

A. van Hoof a découvert une soixantaine de variables dans Canis Major et Puppis.

Wesselink appelle l'attention sur les variables brillantes (n'atteignant pas 11 à leur minimum) qui échappent aux méthodes habituelles de recherche à l'aide du blink-microscope parce que leurs images sont surexposées. Il recommande l'emploi de la chambre de Schmidt, qui peut donner l'image d'un grand nombre de variables brillantes dans un champ étendu.

Le P. Stein annonce la publication, par le P. Zirwes, d'une partie des 30,000 observations laissées par le P. Esch, ainsi que la publication d'un grand nombre d'observations visuelles qu'il a faites lui-même.

Mouvements propres. Mitchell a terminé la mesure des mouvements propres de 125 céphéides (err. prob. $\pm 0''{\cdot}0022$ par an) en collaboration avec R. E. Wilson et A. van Maanen (Mount Wilson Obs.). Les vitesses radiales ont été publiées par Joy (*Ap. J.* Vol. **86**). Une première série de clichés portant les images de 450 variables à longue période a été obtenue au Leander McCormick Observatory il y a une vingtaine d'années; la seconde série n'a pas encore été obtenue.

Variables à éclipses. Sous l'impulsion de H. N. Russell, un groupement pour l'étude des variables à éclipses (Panel on Eclipsing Variables) s'est constitué au Princeton University Observatory, avec H. N. Russell lui-même comme président, Z. Kopal comme secrétaire exécutif.

Russell en définit ainsi l'objet: 'All of the members of the Panel are effectively engaged in some form of research connected with eclipsing binaries—photometric or spectroscopic observation; specific theory of the properties of such systems and the determination of these elements; or general astrophysical theory bearing on these properties, and are in active correspondence regarding the progress of these studies....Up to the present time (Sept. 1947) definitive elements have been derived for two systems, and are in process of determination for two more difficult cases, and many others are to follow.' Kopal ajoute: 'We sincerely hope that our Panel, which has so far been a purely American affair, will be internationalized at the next Meeting of the I.A.U., as a subcommittee of Commission 27 or in some other affiliation.'

Tous les membres du groupe de Princeton insistent sur la nécessité urgente d'observer dans les prochaines années les minima de toutes les variables à éclipses présentant un intérêt particulier et notamment celles dont la période est sujette à des variations. Il est aussi utile, actuellement, de déterminer le plus grand nombre possible d'époques de minima, que de chercher à déterminer des courbes de lumière complètes. D'autre part, la détermination des éléments et des propriétés physiques des binaires à éclipses requiert des mesures photométriques de haute précision. A cet égard, le rapide développement des méthodes photométriques photoélectriques au cours de la guerre met à la disposition des astronomes des moyens nouveaux. Kopal souhaite qu'un Bulletin soit créé par la Commission 27 pour faire connaître aux spécialistes les progrès de l'optique (interference filters), de l'électronique (photoelectric photometry) et de la photographie.

Gerald E. Kron (Lick Obs.) insiste de son côté sur l'intérêt de la photométrie photoélectrique, combinée avec la spectroscopie, pour l'étude des variables à éclipses: 'It has been found possible to derive darkening coefficients with reasonable precision. We are working on the possibility of observing the effects of gravity darkening, and the effects of polar flattening in rapidly rotating stars. We are also working on the problem of explaining asymmetry in the light-curve of some eclipsing variables. A detailed study of AR Lacertae leads us to the conclusion that one of the two components of this star has dark spots upon its surface.'

Russell, J. E. Merrill et N. L. Pierce, formulent, en termes presque identiques, les propositions de résolution suivantes, qu'il y aurait lieu de faire ratifier par l'Assemblée Générale. Certaines d'entre elles figurent déjà dans les Rapports précédents, mais il semble qu'elles aient échappé à l'attention des observateurs, qui devraient être instamment priés de s'y conformer dans l'avenir.

1° Les époques des minima des variables à éclipses doivent être publiées individuellement, en Temps Moyen de Greenwich, c'est-à-dire, en faisant commencer le jour à midi moyen de Greenwich. Ces époques seront héliocentriques, et exprimées en jours et

fractions décimales du jour. En aucun cas, la publication ne pourra être limitée à celle d'une époque normale. Si l'on veut donner les résidus des observations par rapport à une éphéméride, on fournira le résidu correspondant à chaque minimum observé, ainsi que la formule numérique ayant servi au calcul de l'éphéméride.

2° Pour remédier autant que possible au manque d'observations pendant les dernières années, il est recommandé de déterminer, au cours des deux ou trois années à venir, les minima de toutes les variables à éclipses intéressantes, non seulement de celles qui offrent un mouvement de la ligne des apsides, mais encore de celles dont la période semble présenter des fluctuations. Les observations visuelles peuvent rendre ici de grands services.

3° L'étude détaillée des systèmes binaires à éclipses les plus intéressants exigeant la connaissance de leurs variations spectrales, il est recommandé de mener autant que possible simultanément les observations photométriques et les observations spectrographiques. Les unes et les autres devront être concentrées sur le plus court intervalle de temps possible. La même recommandation s'applique aussi à l'étude des céphéides brillantes, pour lesquelles on peut obtenir des spectrogrammes à grande dispersion.

J. E. Merrill écrit: 'Photostatic copies of extended tables for solution for orbital elements by the Russell method are available at Princeton for loan to other observatories.... The entire project (tables, general geometrical and physical theory, detailed examples of solutions, nomographs and instructions for their use) will be published part-by-part as a Contribution from the Princeton University Observatory, with the tables appearing as the first section, we hope by autumn of 1948.'

De son côté, F. Link annonce que la Société Astronomique Tchécoslovaque de Prague tient à la disposition des calculateurs des tables pour la détermination des éléments par la méthode de Harting-Ellsworth.

La seconde édition de *A Finding List for Observers of Eclipsing Binaries* (Contr. from the Princeton Univ. Obs., No. 22), publiée par Newton L. Pierce, contient les données relatives à 546 étoiles dont la déclinaison n'est pas inférieure à $-30°$, et qui, au minimum, sont plus brillantes que la magnitude 13.

A. van Hoof mentionne diverses recherches sur la détermination des éléments orbitaux ou les propriétés physiques des composantes, notamment, sur la détermination de l'assombrissement au bord, et sur le calcul de k à partir des courbes de lumière pour deux couleurs différentes. S. Gaposchkin, qui recherche les variables à éclipses sur les clichés de Harvard Observatory, écrit: 'This work has made it clear that colorimetry, for finding the "monochromatic" properties of eclipsing variables, should be applied in the same broad and accurate way as has been done in the general field of spectrophotometry.'

Plusieurs membres de la Commission appellent l'attention sur l'utilité d'une coopération ou d'un échange rapide d'informations, soit pour faciliter la recherche et l'étude des variables à éclipses, soit pour éviter les doubles emplois. E. Hertzsprung écrit à propos de la recherche des variables dans l'hémisphère sud: 'Le nombre des clichés nécessaires est d'environ 300 au minimum. Afin de pouvoir décider entre les valeurs de la période réciproque qui diffèrent d'un entier, il faut nécessairement ou disposer d'observations faites à des angles horaires différents, ou combiner des observations avec des observations faites en un observatoire complémentaire situé à une autre longitude....Un intérêt spécial s'attache aux étoiles qui présentent une excentricité sensible.'

Recommandant l'étude photoélectrique des variables, P. Th. Oosterhoff suggère 'that a communication centre be created, where every one can obtain all the information about the variables which are being observed or which have been put on an observing programme, this in order to avoid unnecessary duplication of work.' Enfin, Z. Kopal souhaite la création, en plus du Bulletin d'informations mentionné plus haut, 'of appropriate channels through which the information on variable star observing programmes at various observatories could be effectively disseminated.'

A. DANJON
Président de la Commission

PRESIDENT: M. DANJON.

SECRETARY: M. OOSTERHOFF.

The Commission has approved the rules for the naming of variable stars, which had been provisionally adopted by the Sub-Commission for the naming of variable stars. These rules, which were published in the introduction of the 43rd name-list, are:

(1) Periodic variables of which type, period and light curve are known should be named.
(2) Non-periodic variables of which the type has been well established should be named.
(3) Variables of which the type seems to be obvious, although no further details are given, should be named.
(4) The selection of stars, satisfying the above rules, must be made on the basis of strict, critical discussion of all data.

M. Hertzsprung's suggestion that letter combinations, which have not been used so far (e.g. BA), should be used for variables of special interest, was rejected.

The Commission has decided to request the General Assembly to have printed and distributed the 44th name-list of variable stars, the manuscript of which has been prepared by M. Kukarkin and M. Parenago. This list contains the naming of 266 new variables. An annual grant of $250 would probably cover the expenses.

At the meeting of the Commission M. Kukarkin distributed among its members the new catalogue and ephemerides of variable stars, which has been prepared by M. Kukarkin and M. Parenago at the request of the I.A.U. It contains data for 10,912 variable stars. It will be distributed to all regular observatories and to every astronomer who asks for it. The Commission highly appreciates the large amount of work which the Russian astronomers have done in order to continue the publication of the former Prager catalogue, and the fact that this catalogue will be distributed free of charge. The catalogue will now be issued once every 5 years. As the introduction, the list of Russian authors and the remarks have been given in Russian language and characters, the Commission has decided to ask the General Assembly for a single grant of $250 in order that the pages involved may be translated, printed and distributed separately.

Suggestions by MM. Mergentaler, Wesselink and others about the form of this catalogue in the future (e.g. to give also approximate galactic co-ordinates; to indicate the variables included for the first time) will be duly taken into account by the authors.

M. Kukarkin reported that he and his Russian colleagues intend to publish in 6 or 8 years' time a complete bibliography of all variable stars. This publication, which probably will consist of five volumes, each of about 500 pages, will be in the Russian language.

M. Kienle reported that M. Schneller and M. Hoffmeister have practically finished the manuscript of the still missing third volume of Prager's bibliography and that it could be published within about 2 years. This publication would do no more than fill in the existing gap felt by nearly all workers in the field of variable stars.

The Commission is of the opinion that both these publications will be of high value and are much needed. Many members, however, fear that the first-mentioned general bibliography will practically be inaccessible for many astronomers on account of the language. In this connection M. Kukarkin promised that its form would be as international as possible.

M. Banachiewicz reported about plans of the Cracow Observatory to publish a lexicon on variable stars in which selected data will be collected mostly in numerical form.

The Commission decided to request the Bureau of the I.A.U. to publish the list of unpublished observations of variable stars, which has been prepared by the late M. Grouiller and the value of which has already been emphasized at the Stockholm meetings. According to M. Brun the manuscript of this list is ready for publication at the Observatory of Lyon.

The proposal made by M. Joy that cluster-type or RR Lyrae-type variables should be called RR Lyrae stars, whether they occur in clusters or in our galaxy, was adopted. The Commission also decided to use a new sub-classification *a* for RR Lyrae stars instead of Bailey's subclasses *a* and *b*.

A recommendation by M. Brun that small charts should be published of newly discovered variables, which do not occur in any meridian or positional catalogue, was adopted.

M. de Kock and M. L. Campbell asked for charts of variable stars in the Southern Hemisphere for which sequences already exist. M. Shapley suggested that a draughtsman be engaged for this task. As the number of variables, for which such charts should be made, is somewhat over one hundred, the Commission recommended that a single grant of $250 be put at the disposal of the President of the Commission in order that these charts be made for the benefit of amateur astronomers.

At the request of several members, the Commission desires to emphasize the value of visual observations of certain classes of variable stars. In order to stimulate these observations M. L. Campbell will be requested to make some revisions in his list of 100 interesting variables, which has been composed for the benefit of amateurs.

At the request of M. Ryves the Commission will ask the different associations of variable star observers to increase their efforts for a more intense co-operation, which could already be obtained by a regular interchange of information about the stars which are being observed. In this manner more continuous records of certain variables could be obtained. It is agreed that the Commission will be more active in these matters in the future.

The Commission recommended that an annual grant of 1000 gold francs shall be put at the disposal of M. Banachiewicz for the publication of the ephemerides of eclipsing binaries on the condition that the dates will be expressed exclusively in the Julian Day.

Of the remarks about work in progress at different observatories, not published in the report, mention is here made of those by M. Shapley and M. Fracastoro.

M. Shapley reported on various researches in progress or recently completed at the Harvard Observatory. The 'Milton Bureau' variables (1500 brighter than 10·5 *pg* at maximum) are being published in three volumes of the *Harvard Annals*. His own continued work on the variables in the Magellanic Clouds shows:

(1) Several giant β Lyrae eclipsing stars of absolute photographic magnitude $-2{\cdot}0$. They are found in both Clouds and are definitely Cloud members.

(2) No RR Lyrae stars ($P < 1$ day) that are definitely members of either Cloud, although several are in the foreground.

(3) For Cepheids very little change in *average* light curve throughout the period range from 1·5 days to 30 days, except for some double maxima near 10 days and the larger than average amplitudes for periods greater than 12 days.

(4) A peculiar and important difference in the frequency of periods of Cepheids in the Small Cloud as compared with the Large Cloud and the galactic system: few periods, out of the 200 determined for the Large Cloud, are less than 2·5 days, while more than half of the 600 now measured for the Small Cloud are less than 2·5 days.

M. Fracastoro reported about his spectro-photometric observations of ζ Aurigae during the last minimum (1947–48), asking for information about results obtained at different longitudes. He will gladly communicate provisional results.

The Commission approved and supported the three following recommendations formulated by M. Russell, M. Merrill and M. Pierce:

(1) The epochs of minimum of eclipsing binaries should be published individually in Greenwich mean time, the day beginning at Greenwich mean noon. These epochs should be heliocentric and be expressed in days and decimal fractions of days. Publication should never be limited to that of a normal epoch. If residuals of observations with respect to a certain ephemeris are given, the residuals for each observed minimum as well as the numerical formula employed should be published.

(2) In order to compensate for the considerable lack of observations during the last few years it is recommended that epochs of minimum should be determined in the next 2 or 3 years for all interesting eclipsing binaries. Variables with a rotation of the line of apsides as well as variables with varying periods are of special interest in this connection. Visual observations could be of great help here.

(3) As a knowledge of the spectral changes is of great importance for a detailed study of the most interesting eclipsing binaries, it is recommended that photometric and spectrographic observations be made simultaneously as far as possible. Both types of observations should be concentrated in the shortest possible interval.

The same recommendation is made with regard to the bright Cepheids for which spectrograms of high dispersion can be obtained.

At the suggestion of M. O'Connell the Commission desired to emphasize the importance of spectrographic observations of variable stars in the Southern Hemisphere.

The Commission approved the formation of a new commission (no. 42) on photometric double stars. The members of the Panel on Eclipsing Variables, which was formed some years ago at the Princeton Observatory under the presidency of M. Russell, will also be members of this new commission together with a number of newly selected members mostly from other countries.

The Commission has decided that a number of proposals and recommendations with regard to eclipsing binaries, given in the Report, shall be transferred to this new commission for a final decision.

The Commission recommends that if the rough position of a variable is indicated by a number of six figures, as has been done among others by Harvard astronomers, the epoch 1900 for the right ascension and declination be used.

M. Brun reports that he has drawn maps of the northern sky, which reach magnitude 7·5. For all stars photovisual magnitudes have been indicated. The scale is 1 cm./degree. Variables and double stars have been marked, together with bright and dark nebulae. Extra-galactic nebulae as faint as magnitude 12 have also been indicated. Printed copies of these maps can be obtained for the price of 20 Swiss francs when at least 50 sets are ordered all together.

28. COMMISSION DES NEBULEUSES EXTRAGALACTIQUES

PRÉSIDENT: M. E. P. HUBBLE, *Mount Wilson Observatory, Pasadena 4, Cal., U.S.A.*

MEMBRES: MM. Baade, Carpenter, Erro, Holmberg, Humason, Lemaître, Lindblad, Lundmark, McVittie, Madwar, N. U. Mayall, Paraskevopoulos, Randers, Reynolds, Seyfert, H. Shapley, V. M. Slipher.

No report has been received.

Report of meetings

PRESIDENT: Dr E. P. HUBBLE.

SECRETARY: Dr C. K. SEYFERT.

The Commission on Extra-Galactic Nebulae held three meetings to discuss informally the principal observational and theoretical problems of the extra-galactic nebulae. One resolution was drafted and adopted pointing out the desirability of having Dr C. O. Lampland's valuable nebulae photographs published.

(1) Hubble described the atlas of photographs of extra-galactic nebulae he is preparing and which should be ready for distribution in about a year's time. The atlas will include photographs of about 200 representative nebulae of all types, mostly brighter than 13·0 mag. selected from the Shapley-Ames Catalogue.

(2) The problem of the determination of the masses of extra-galactic nebulae was reviewed by Hubble. The three main sources of obtaining masses, from clusters of nebulae (virial theorem), spectrographic rotations, and from velocities of pairs of nebulae give masses differing by at least a factor of 10 for nebulae of the same absolute magnitude. Intergalactic matter within the great clusters of nebulae cannot definitely be ruled out as a contributing factor to explain at least part of this discrepancy.

(3) Seyfert described the extremely wide planetary-like emission bands found in the nuclei of several spirals. In collaboration with Minkowski a search is now being made to determine whether or not similar objects show abnormally wide absorption lines in order to compare the stellar velocities in the nucleus with the velocities of the gas.

(4) Stebbins described the results of an investigation of photoelectric colours of faint elliptical nebulae which he and Whitford have recently obtained. A linear relation is found between international colour index and red shift for four clusters of nebulae, the most distant of which (Bootes) has a red shift corresponding to a velocity of 39,000 km./sec. (18·2 mag. *pg*) and a distance of about 7×10^7 ps. For the Bootes group the measured colour is +1·36 mag. or 0·52 mag. redder than nearby nebulae of similar type (elliptical). On the basis of the six-colour photometry of M 32 one would expect that the red shift alone would make the nebulae in Bootes only 0·22 mag. redder than similar nearby systems. The resulting colour excess of 0·30 mag. for this group (and correspondingly smaller excesses for nearer groups) has had as yet no adequate explanation.

(5) A discussion initiated by McVittie and others brought out the desirability of closer co-operation between astronomers who are obtaining observations of extra-galactic nebulae and astronomers who are using these observations to construct models of the universe. In particular, the theorists desire that the observers include in their publications their original uncorrected observations together with details of their reductions to the adopted system.

(6) Shapley pointed out the fact that the Magellanic Clouds contain objects which definitely appear to be globular clusters, and that several of these objects are resolvable with the 60-inch reflector. However, a thorough search has not revealed a single cluster-type Cepheid variable that can definitely be associated with either Cloud, although such stars would be within the range of the Harvard reflector.

(7) The methods involved in establishing the distance scale for the nebulae were reviewed and the uncertainties involved in each successive state were discussed at some length.

(8) The problem of the pronounced discrepancy between the total absolute magnitude of the globular clusters in the Milky Way, the Magellanic Clouds and M 31, was discussed —but still remains unexplained.

(9) It was reported that Humason is now preparing a catalogue of the spectra and radial velocities of 500 extra-galactic nebulae. His spectra and those of Mayall indicate that 90% of the late type spirals show (O II) emission (λ3727), whereas only about 20% of the early elliptical nebulae show similar emissions.

These and related subjects were discussed at length to the profit of both observational and theoretical astronomers working in the field.

29. COMMISSION DES SPECTRES STELLAIRES

PRÉSIDENT: M. O. STRUVE, *Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.*

MEMBRES: MM. W. S. Adams, E. A. Baker, Barbier, Beals, Beer, Cecchini, Cesco, Chalonge, Colacevich, Dunham, Edwards, Erro, Fehrenbach, Mme Payne-Gaposchkin, MM. Gratton, Greaves, Gregory, Herzberg, Hiltner, F. S. Hogg, Hynek, Joy, Keenan, Kharadze, Lacroute, O. J. Lee, Lindblad, Mme Davis Locanthi, MM. McKellar, McLaughlin, Mme Walton Mayall, MM. N. U. Mayall, Melnikov, P. W. Merrill, Milne, Minkowski, W. W. Morgan, Nassau, Petrie, Redman, Russell, Sahade, Sanford, G. A. Shajn, Stratton, Swings, Thackeray, Vorontsov-Velyaminov, Vyssotsky, Weaver, R. C. Williams, O. C. Wilson.

SOUS-COMMISSION DES NOVAE

PRÉSIDENT: M. STRATTON.

MEMBRES: MM. Baade, C. Bertaud, Cecchini, Mme Payne-Gaposchkin, MM. Gratton, McLaughlin, P. W. Merrill, Minkowski, Struve, Swings, Zwicky.

SOUS-COMMISSION DES BANDES MOLÉCULAIRES DANS LES SPECTRES STELLAIRES

PRÉSIDENT: M. MCKELLAR.

MEMBRES: MM. Adel, Fehrenbach, Herzberg, Keenan, Sanford, Swings.

I. THE FUNDAMENTAL PROBLEMS

The Commission on Stellar Spectra records great progress in its field of investigation. We have reached the stage where a concerted attack can be made on two problems of fundamental importance which consciously or unconsciously have been the principal aim of stellar spectroscopists. The first is the problem of the abundances of the chemical elements in their relation to the question of nuclear transformations and the origin of the elements. The other is the problem of the origin of the stars and of their subsequent evolution.

Our knowledge of the abundances of the elements in the solar reversing layer, originally due to Russell, has been further increased through the work of Wildt, Chandrasekhar, and others who have solved the problem of the continuous absorption coefficient; of B. Strömgren, who applied the apparatus of modern physics to the construction of theoretical line-profiles and determined from them the important ratio of hydrogen to metal abundances; and of Chalonge and Barbier, as well as Chandrasekhar and Münch, who made use of the absorption coefficient of H^- to explain the energy distributions of the continuous spectra of all but the hotter stars.

The determination of abundances in the stars seemed almost within our grasp 20 years ago when Russell and Adams published their classical paper on the spectra of several bright stars observed with the Mount Wilson Coudé spectrograph. The discovery in 1934 of the peculiar features of the stellar 'curves of growth', and especially of the unexpected phenomenon of turbulence, retarded progress, so that at the Stockholm meeting neither Commission 29 nor Commission 36 (Spectrophotometry) felt inclined to discuss this problem. The intervening ten years have seen a gratifying change. The work of Unsöld on τ Sco gave us the abundances in a normal early B star and demonstrated the unexpectedly high values for He and Ne. Unsöld's recent work on the abundances in the solar reversing layer shows an amazing similarity to τ Sco (and to the meteorites) despite the fact that τ Sco is located within the great obscuring clouds of Ophiuchus, and that it belongs to the Scorpius-Centaurus cluster. Aller made important progress in the study of curves of growth of O, B, and A stars; K. O. Wright found remarkable differences in

the curves of growth of several F stars, which depend upon excitation potential (especially for Fe I) and upon stage of ionization; and Struve suggested that the turbulent velocity may increase with the height in the atmospheres of some F-type supergiants. There is a strong suggestion, especially in some unpublished work of Schwarzschild and perhaps also in that of K. O. Wright, that in these supergiants the turbulent elements are not small as compared with the extent of the layer, and also that the distribution of velocities may not be Maxwellian. The most recent advance is that of Greenstein who found that normal F stars, including members of the main sequence, giants, and supergiants, have remarkably similar abundances (within less than a factor of two). But a 'metallic-line' A star can only be explained by assuming a vastly different distribution of some of the elements.

While the painstaking analysis of individual line profiles and the elucidation of the features of the curves of growth are required for detailed studies, much progress can be made by relatively crude methods. Popper's and Bidelman's discoveries of faint stars of early type without H lines are reminiscent of the earlier work at Mount Wilson and Yerkes on υ Sgr and at Lick on R CrB. Such cases can be explained, at present, only by assuming an abnormally low abundance of H. Not many years ago our only suspicion of differences in abundance came from the C and N differentiation of the W stars.

It is tempting to seek in the cases of small hydrogen abundance a manifestation of the process of nuclear transformation of H into He. But at present we cannot draw such a conclusion. Not only is it dangerous to generalize for the entire star results pertaining to only a very thin outer fringe, but we must be prepared to find evidence of other physical processes, such as stratification, rotation, radiation pressure, etc., and of differences in composition resulting from regional differences in the original medium. There are indications of such effects: the low abundance of H in the nebula surrounding the B-type component of α Sco may be the result of radiation pressure, and the peculiar line intensities of some A-type stars may be related to their magnetic fields (H. W. Babcock).

Future work will probably be directed along several different lines. There must be further work on the curve of growth in order to dispose of questions relating to the properties of the turbulent motions. The best conclusion now is to regard these motions as arising in something like a vast field of prominences (Menzel, Struve). It is possible that the forces which operate in these prominences are selective (Shajn) and that this may produce an apparent anomaly of chemical composition in the supergiants and shell stars. Even more promising should be studies of individual line-profiles with instruments of higher resolving power than are available to-day. The interpretation of these profiles by the method of Strömgren should greatly reduce the present uncertainty.

The abundances of the isotopes of C, among others, are of special interest according to recent work at Victoria by McKellar, at McDonald by Herzberg, and at Saint Michel by Fehrenbach. The causes of these differences are still obscure but McKellar and Fermi have suggested that they may have some connection with the fact that in the Bethe cycle C^{13} would be used up more rapidly than C^{12}, so that if the original abundance of C^{13} was abnormally large the cycle would gradually bring about equilibrium at $C^{12}/C^{13} \sim 90$. Progress has been slow because few contemporary stellar spectroscopists are sufficiently acquainted with the theory and even the practice of molecular spectroscopy. The Commission calls attention to this fact and expresses the hope that several astrophysicists in different countries will undertake this field of study. This is especially important because relatively few pure physicists are now working in spectroscopy.

Another promising start could be made with instruments of moderate dispersion to determine whether there are any spectroscopic differences in stars of the same type depending upon differences in origin or physical characteristics. For example, the location of the main sequence in the HR diagram determines the theoretical abundance of H. It would be important to compare the spectra of stars of the same type in clusters having different HR diagrams. The work of Trumpler and of others has given us a beginning. With a dispersion of 50 A./mm. considerable progress should be possible (this suggestion is in part due to a conversation with Baade and Merrill). The remarkable weakness of

the absorption lines of the B-type Pleiades, quite aside from their systematically large velocities of rotation, is of interest in this connection. Special attention should also be directed to the pronounced correlation between spectroscopic characteristics of stars belonging to Baade's populations I and II, and their motions.

The problem of regional differences in the spectra of the stars is intimately connected with that of their origin and evolution. In this field the principal advance was made by Joy, who recently announced the discovery of some forty peculiar bright-line stars in and near the dark absorbing clouds of Taurus. This remarkable discovery is the culmination of the long and painstaking process of recording innumerable small features of peculiar bright-line stars principally by Merrill, Sanford, Joy, and others at Mount Wilson, by Swings and Struve at McDonald, by McLaughlin at Michigan, Neubauer at Lick, etc. It is the first clear-cut connection between peculiar spectroscopic features and location in or near a cosmic dust cloud. As Greenstein and Aller have pointed out, only faint, small stars show this connection. Ordinary stars of early and intermediate spectral classes have normal spectra. If the evolution of a real star resembles that described in the theoretical work of Spitzer and Whipple, then we may well wonder whether such an object as the intrinsically faint emission-line star which may be responsible for the relatively large reflection nebula B10 of Taurus may not be an embryonic star, and whether the interaction between the particles of the cloud and the radiation of the star may not produce the emission lines of the latter and (perhaps through a process of fluorescence) the abnormally large surface brightness of the former.

II. THE PHYSICAL PROPERTIES OF STELLAR ATMOSPHERES

The most significant advance in this field during the years covered by this report was the discovery in 1946, by H. W. Babcock, at Mount Wilson, of magnetic fields up to about 10,000 Gauss, in a number of stars belonging to the peculiar group of strontium-europium objects of classes A and F. A sequence to Hale's work on the magnetic field of the sun, this new result opens a large area for observational and theoretical study. It is intimately connected with the problem of stellar rotation and with that of the peculiar sequences among the A stars. The spectra of physical variables have been exhaustively investigated at Mount Wilson. Among the many conclusions of this work we record Merrill's opinion that the H emission lines of long-period variables may originate *below* the conventional level of the photosphere (because the metallic absorption lines which cut into these emission lines at their first appearance may be stronger than would be inferred from lines which fall in the ordinary continuous spectrum). The spectra of Cepheid variables with high dispersion are under investigation by Adams and Schwarzschild, as well as by Swings and his collaborators. Earlier results by Pannekoek, Walraven and Van Albada in Amsterdam (from Victoria plates) and by Struve at McDonald suggest that some lines may originate in a shell-type layer (partly supported against gravity), and that the line profiles and radial velocities do not necessarily record the true velocity of the deeper pulsating layers. In this connection the simultaneous existence of two displaced H lines near the phase of median increasing brightness of RR Lyrae is of interest, and the undisplaced emission lines (Struve, Sanford) may be caused by the interaction of the two colliding layers. This process (which has been discussed for nebulae by Oort and Burgers) may be of great importance in stellar spectroscopy.

At Victoria, Petrie has nearly completed the measurement of Δm in some 100 spectroscopic binaries with two spectra. The results are of great value in connection with studies of the mass-luminosity relation. The spectra of peculiar stars, especially those with emission lines, have given a wealth of new information. It is instructive to realize that sometimes the same observational phenomenon—in this case the presence of emission lines—may be produced by entirely different causes—turbulence or collisional processes in relatively deep atmospheric layers of some Cepheids and perhaps of the long-period variables; fluorescence in extended nebulous envelopes of some 'symbiotic stellar spectra' (a term suggested by Merrill for such stars as Z And, AX Per, etc.). The identification

problem of the emission lines, especially of the forbidden lines, and the interpretation of their intensities has been advanced especially by Swings, Bowen and others. The former suggests that a search be made for forbidden lines in the near infra-red region (e.g. [Fe I] 8347·55).

Studies of peculiar emission-line objects at Mount Wilson and McDonald have already been mentioned. The excitation of emission through fluorescence is fairly well understood, largely through the work of Bowen, Swings, Thackeray, Merrill and others. The study of Be stars and their spectroscopic variations has been continued by McLaughlin at Michigan and by Gregory in London. Heard at Toronto has made a comprehensive study of the peculiar shell-star HD 218393. Merrill is working on the third section of his catalogue of Be stars and he requests observers to send him notes on discoveries and observations of Be and Ae stars; lists of references would also be welcome. Dufay at Lyon and Miss Hase in the U.S.S.R. have investigated the spectrum of γ Cas. Especially impressive is the progress made in the study of W stars, by Swings and Hiltner at McDonald, by O. C. Wilson at Mount Wilson and by Aller at Lick and Indiana. Some of the surprising results of this work are the large percentage of spectroscopic binaries, the systematic displacements of different emission lines, the absence of Wilson's expected time lag between light minimum and velocity curve, and especially Kopal's and Mrs Shapley's conclusion that the emitting shell of a W star is nearly opaque to the radiation of the B-type companion eclipsed by it. The spectra of several P Cygni stars were investigated by Beals at Victoria. A most amazing case of an object with several rapidly changing expanding shells producing several simultaneous violet-displaced absorption components has been the subject of an unpublished investigation by Minkowski.

Studies of other peculiar stars include those of Keenan and Hynek on the perplexing variations of the O I lines in VV Cephei; and of Popper, Bidelman, Greenstein, Thackeray, Keenan, Swings and Larson-Leander on the equally surprising changes in the absorption spectrum of ρ Cas. The eclipsing binaries have led to the discovery of gaseous streams in close systems (Joy, Struve, S. Gaposchkin) and to the conclusion that the bright Ca II lines are usually produced in rather small 'tidal bulges' of late-type components of binaries (Joy, Hiltner) which must not be too close to one another (W UMa stars do not have such emission lines). Emission lines of Ca II in *d*K and *d*M stars have been the subject of studies by Joy at Mount Wilson, Popper at McDonald, and Gratton at Merate.

Spectra of high dispersion have given a wealth of information on peculiar line-duplicities (Adams); asymmetries (Adams, Greenstein) and identifications (Miss Davis, Swensson, Swings and Struve). Among the most noteworthy advances during the past 10 years was the study by Wellmann at Berlin-Babelsberg and especially by O. C. Wilson at Mount Wilson of the structure of a giant atmosphere from high-dispersion plates of ζ Aurigae during its partial eclipses. On Mount Wilson Coudé plates of M-type supergiants Spitzer found interesting differences in the central intensities of strong Fe I lines which depend upon excitation potential and also, in the case of one multiplet, upon a peculiar process of fluorescence. The latter phenomenon is related to that investigated earlier by Thackeray in long-period variables. The central intensities in the absorption lines of early-type stars (Unsöld, Greenstein, Miss Underhill) are also best explained as the result of fluorescence, though there appear to be interesting differences between B-type supergiants and main-sequence stars.

The Stark effect of the He I lines has been the subject of several discussions. Miss Douglas and Foster stressed the peculiar fact that the measured stellar λ of the forbidden (2P–4F) line, λ 4470, is almost identical with the predicted λ for zero field strength at which the theoretical intensity should be nil (this was first noticed by Struve). They proposed a fascinating explanation in terms of a peculiar cycle; observational results by W. Petrie and Miss Underhill at first seemed to confirm the existence of such a cycle. But experience from the study of the He I cycles in shell spectra (Wurm, Struve) would rather tend to throw doubt upon the operation of a powerful cycle in stars of the main sequence where physical factors (such as dilution of radiation) are probably not conducive to the formation and maintenance of the cycle. An important advance was made by

Mrs Kiess-Krogdahl, who followed up an idea of Chandrasekhar and showed that the theory of microscopic inter-ionic fields in an ionized stellar atmosphere differs markedly from that of a uniform, large-scale field, such as was considered by Foster. The new theory reduces the discrepancy between theory and observation, but perhaps does not completely remove it. The existence of the Foster-Douglas cycle should be further investigated.

Collisional broadening of spectral lines, hardly recognized ten years ago, has become a commonplace phenomenon. Unsöld, Lindholm, Mrs Kiess-Krogdahl, and several others have made theoretical and observational studies of this phenomenon.

Notable progress has been made, especially by Kuiper, in the study of the spectra of white dwarfs, sub-giants and other special groups. The long-neglected group of spectrum variables has been investigated by Deutsch for the determination of the periods and by Swings and Struve and also by Tai, for their physical properties. Ordinary changes of ionization are not sufficient to explain the observed variations of line intensities, and we are again faced with the necessity of attributing unusual abundances to certain elements (for example, to the rare earths).

The work of Chalonge, Barbier and other French investigators on the continuous spectra of the stars, and especially on the Balmer discontinuity, has already been commented upon. The identification problem in absorption spectra, though well advanced, is by no means solved. Swings calls attention to the urgent need of laboratory investigations of some doubly ionized metals, especially Ni III, Cr III, Mn III, Ti III, and of some doubly ionized rare earths, especially Eu III, Gd III, Dy III (under way at Liége). It is probable that the large number of unidentified lines, especially in some peculiar A stars, could be greatly reduced if these spectra were known.

III. SPECTRAL CLASSIFICATION

When the I.A.U. was founded this problem was the only one which came within the scope of Commission 29. Since that time the name of the Commission has been changed several times depending upon whether the principal task was to deal with the technical problem of classification or with the physical interpretation of the spectra. The aims of the classifier are often far removed from those of the astrophysicist: he may have little or no concern with the physical properties of the stars and desire information only concerning their luminosities and distances. It may be desirable, now or in the future, to discuss whether a separate commission should be organized to deal with classification problems alone. But while many persons engaged in spectral classification could probably get along quite well without the astrophysical interpretations, the astrophysicist cannot get along without the help of his colleague who is interested in classification. Hence, for the immediate future the Commission believes that the present arrangement should be continued and that later, if there should be a sufficient desire for more detached deliberation of classification problems, a sub-committee be formed for this purpose.

One of the earlier reports of this Commission expressed the hope that a set of reproductions of typical stellar spectra be prepared in order to standardize the Henry Draper system of classification. This has now been accomplished through the publication of the Morgan-Keenan-Kellmann *Atlas*, of which a new and greatly enlarged edition is in preparation. It should be noted that several members of this Commission have complained that the *Atlas* is not available at many of even the most important observatories.

Because of Dr Morgan's experience in problems of spectral classification I have asked him to prepare a brief statement concerning some of the outstanding problems:

It does not appear that there will be a marked increase in accuracy in the determination of spectral types in the near future; progress is more likely to take place in the application of methods already developed to general problems of stellar astronomy. Among many promising lines of inquiry the following may be noted especially:

1. The segregation of groups of stars of similar absolute magnitude for investigations of galactic structure. The development of Schmidt objective prism cameras of the type now in

use at Cleveland and Tonanzintla has made possible large-scale extensions of the spectroscopic parallax methods formerly used on slit spectrograms. It is now possible to identify supergiants of all spectral types to photographic magnitude 10 or 11 on objective prism spectrograms having a dispersion of around 300 A./mm. in the blue region. This makes possible additional investigations of certain features of our system at distances of the order of that to the galactic centre. It would also be a simple observational problem to prepare a catalogue of all B stars brighter than the twelfth magnitude and within a few degrees of the galactic equator. The importance of such a catalogue—especially when combined with photoelectric colour determinations—cannot be over-emphasized.

2. A survey for the discovery of stars of special astrophysical interest; for example, the spectrum variables of class A can be recognized by certain spectral peculiarities visible with very low dispersion.

3. When slit spectrograms are used having a dispersion in the photographic region of 60–130 A./mm., it is possible to derive fairly accurate absolute magnitudes and parallaxes for non-peculiar stars of all types. The most difficult to discuss at present are probably stars of classes B9–A3, while the most accurate absolute magnitudes can be derived for the B0–B3 stars and those of classes G5–K0 having absolute magnitudes fainter than zero. It can be stated safely that at present there are hundreds of thousands of stars within the reach of accurate spectroscopic parallax methods; the only things that are needed to bring in this rich harvest are the time to obtain the plates and to make the necessary observations and reductions. A programme having for its object the determination of absolute magnitudes and parallaxes of all stars brighter than the tenth magnitude by objective prism methods is perfectly feasible at present; the whole programme could be completed within a few years if embarked on by a carefully organized group of observers.

Alfred H. Joy of Mount Wilson writes that in order that the Harvard system of stellar classification may be made more accessible to various observers, the time seems opportune to propose a set of standard stars which, after due consideration by experienced observers, might eventually be adopted by the International Astronomical Union. It would be a great advantage if the existing system of classification which has been approved by the Union and is extensively used throughout the world, could be maintained in its essential features without change until such time as a more comprehensive system based on physical parameters can be devised. Dr Joy has, therefore, prepared a list of stars which represent the Harvard system in its simplest form, and he will send a copy to those who request it. He would be glad to have criticisms from the members of the Commission as to its usefulness and suggestions as to the suitability of the individual stars.

A. N. Vyssotsky recommends the adoption of ten standard areas in each of which fifty or more stars between magnitudes 8 and 11 *pg.* should be classified as to luminosity and temperature according to W. W. Morgan's criteria. These should be used to establish a sound statistical basis for the system of classification of any instrument or observer dealing with faint stars. The following suggested list of areas may serve as a basis for discussion.

Designation	R.A.	Decl.	Long.	Lat.
S.A. 8	1h 00	+60°	92°	− 2°
S.A. 22	2 38	+45	111	−13
S.A. 94	2 52	+ 0	144	−48
S.A. 122	6 13	−15	190	−13
S.A. 98	6 48	− 0	181	+ 2
S.A. 33	13 50	+45	57	+67
S.A. 134	18 10	−15	343	0
S.A. 111	19 35	+ 0	6	−12
22 Cyg.	19 52	+38	41	+ 4
S.A. 41	21 50	+45	61	− 8

Note that the first and the next to last of these areas are rich in B stars. Furthermore, the selection allows a comparison with the Bergedorf, Potsdam, and H.D.E. systems.

A communication from A. Schwassmann dated August 7, 1938, which had arrived too late for the Stockholm meeting, recommends the preparation of a 'Spektrale Himmelskarte', providing for stellar spectra what the Franklin-Adams charts provide for direct images. A Schmidt camera of 60 cm. aperture and 1·2 m. focal length, with a linear dispersion of 2 mm. between Hβ and Hε would register spectra of stars to phot. mag. 13·5 in one hour, over a field of 50 square degrees. The Commission will wish to consider this recommendation. Perhaps one of the existing Schmidt telescopes could undertake this task.

Actual progress in the classification of stellar spectra has been most encouraging. Morgan and Bidelman's principal contribution has been the accurate classification of many bright stars, especially those of class B, which are complete to mag. 6·5 and are now being extended to mag. 9·0. The continuation of the HD extensions by Mrs Mayall and their publication are being eagerly awaited. Vyssotsky has completed 37,100 faint stars in the A.G. zones $-2°$ to $+10°$; $+10°$ to $+20°$; and $+30°$ to $+50°$; and some 10,000 stars of known p.m. He has discovered 270 new *d*M stars. Extensive work is in progress at Saltsjöbaden and Uppsala. (A summary of these investigations with bibliography, by Lindblad, appeared in *Ap. J.* **104**, 325, 1946.) Lindblad reports that special attention is being devoted to the study of 'racial' differences among stellar spectra. Ramberg is concerned with the stars in Cepheus and Lacerta, Elvius with those in selected areas, Larsson-Leander with open clusters, Setterberg has completed a study of CN and CH in late-type stars, and Brahde one of T CrB. Zonn of Warsaw has investigated at Saltsjöbaden the spectra of δ Cep, η Aql and ο Cet, while Miss Iwanowska of Torun has made a study of the spectra of high-velocity stars. The Dearborn Observatory has completed its survey of red stars. Classification work at Case School by Nassau, McCuskey and others has only recently been started. The advantages of the 36-inch Schmidt telescope with objective prism are so great that we may well look forward to an unprecedented increase of our knowledge of the spectra of faint stars from this source. Even more recent is the objective prism work inaugurated by Erro, Haro, Rivera and others with the new Tonanzintla (Mexico) Schmidt telescope. The Palomar 18-inch Schmidt was used by Humason and Zwicky for a search of faint blue stars.

We have no direct information concerning the classification work by Schwassmann in Germany. According to Dutch sources Vol. **3** of the *Bergedorf Spektraldurchmusterung* (zone $+30°$) was ready for publication before the end of the war. This volume was received at the Yerkes Observatory while the report was in the Press. This Commission records its interest in the continuation of the valuable *Spektraldurchmusterung*.

The classification of O and B stars with a slit-spectrograph of average dispersion by Petrie at Victoria has led him to suggest (*a*) that the classification by means of estimated line ratios be abandoned, (*b*) that a sequence of standard stars be established separately for giants and for dwarfs, for rotating and for non-rotating stars, which have been investigated at one or more observatories for line-intensity, and (*c*) that the classification of other, fainter stars be based upon direct comparisons with these sequences. Swings has remarked that several W stars are now known to possess lines of carbon and nitrogen with similar intensities so that the classification of these objects may have to be revised.

IV. INSTRUMENTS AND OPPORTUNITIES FOR RESEARCH

In the field of instrumentation we have witnessed an extension into the extreme infrared region by means of lead-sulfide photoconductive cells (Kuiper, Whitford, McMath, Adel, Mohler) and into the region of radio-frequencies ('cosmic static'). The near ultraviolet has been thoroughly explored with aluminized mirrors, gratings and quartz prisms. Rocket spectroscopy has given us a knowledge of the solar spectrum to about λ 2200. In the ordinary photographic region, which now extends from λ 3000 to about λ 10,000 there has been a tendency to use more powerful spectrographs, and some of the most successful consist entirely of mirror systems with gratings as dispersing units. The enormous increase in the efficiency of diffraction gratings ruled by Wood at Johns Hopkins and by H. D. Babcock at Mount Wilson has created a revolution in spectrograph design.

Equally important was the invention of fast photographic emulsions in the red and near infra-red regions (especially by the Eastman Co.). Swings has remarked that still further progress may be expected by means of the evaporographic technique. The nearer infra-red has been explored by photographic means, especially at the Perkins Observatory.

The non-reflecting coatings of lenses and prisms have not only increased the efficiency of many spectrographs of more conventional design, but have helped still further to eliminate scattered light—an advantage which in some instances has led observers to prefer *good* prisms to *good* gratings. An interesting development was the tendency at Mount Wilson to concentrate an increasing amount of observing at the Coudé focus. Plans are under way, for at least one large telescope of the future, to eliminate altogether the usual type of Cassegrain spectrograph, and to work only at the Coudé and the prime foci. Perhaps equally spectacular was the development of fast nebular spectrographs—some of them using solid-block Schmidt cameras—especially at the Lick (N. U. Mayall) and Mount Wilson (Humason) Observatories. These instruments quite regularly record the spectra of objects which cannot be seen on the slit, so that for successful operation the guiding must be done on a field star. For purposes of spectral classification several large Schmidt telescopes have been built, the most successful to date being the 36–24-inch instrument at Case Institute of Technology in Cleveland. The completion of the Palomar Mountain 200-inch reflector and 72–48-inch Schmidt telescope will undoubtedly lead to new and startling developments in stellar spectroscopy. Modern electronic methods have had a small, but encouraging amount of application. Thus, it is customary to use electronic amplifiers for the recording of infra-red spectra. An unusual photoelectric guiding device at the Coudé focus of the Mount Wilson 100-inch (H. W. Babcock) has brought realization to a century-old dream of the astronomer: to let a machine do the work of the observer in the dome. Some physicists (Dieke) have expressed the opinion that direct photoelectric recording of spectra has now reached such a stage of perfection that it should be used for many, if not all, astrophysical observations. Attempts in this direction, ten or more years ago, were not too encouraging. But technical developments during the war have been so great that a new effort should be made to eliminate the photographic procedure in the study of line contours and equivalent widths. The difficulty of compensating for 'variable seeing' can probably be overcome by means of differential measurements in two wave-lengths. Hiltner and Code have started such an instrument for high-resolution scanning. Along the more conventional lines the inauguration of spectroscopic work at Córdoba, by Gaviola, Sahade and others was of the utmost importance since it represented the first step toward equalization of effort in the southern and northern hemispheres. But, as some members of this Commission have stressed, there is still a deplorable lack of spectrographic results from the southern regions. In this connection Dunham, in collaboration with the Fund for Astrophysical Research, has prepared a plan for a 70-inch telescope-spectrograph which would operate in the Coudé form and for which some of the mirrors and disks are already in existence. Dunham proposes that this instrument be mounted somewhere in South Africa for the purpose of photographing spectra of southern stars, without interrupting the programmes of other, more universal, telescopes. This Commission records its interest in this project and urges that astronomers interested in the spectra of southern stars communicate with Dr Dunham in order to solve the remaining financial problems—perhaps on a collaborative basis.

On the debit side of this Report we must record the wanton destruction by the German armies of the Simeis reflector with its spectrographic equipment and of the entire equipment at Pulkovo. Perhaps equally disastrous, though understandable as a just retribution, was the dismantling of the Berlin-Babelsberg Observatory after the war, which removed an active institution from research in stellar spectroscopy and which, to date, has not brought about a revival of observational work in stellar spectroscopy in Russia. These, and other losses caused by the war, are far more important than is evident on the surface. They have still further reduced interest in and understanding of stellar spectroscopy among the astronomers of several countries in Europe. This Commission is seriously concerned over this situation. It wishes to bring to the attention of all members of the

I.A.U. that without a thorough appreciation and understanding of stellar spectroscopy there can be no real progress in many other, apparently unrelated, fields of astronomy, such as the study of variable stars, of proper motions, of visual binaries, etc. The Commission considers it important to combat the defeatist attitude of many astronomers in war-torn countries to abandon efforts in stellar spectroscopy, and in consequence to lose interest in its results, because of the realization that only wealthy nations can afford the large telescopes required for this type of work. In an attempt to further this purpose the Commission recommends:

1. That the I.A.U. adopt a programme for the proposed international observatory that would include equipment for stellar spectroscopy with slit and slitless instruments.

2. That members of Commission 29 make full use of the offer extended to them as the result of previous correspondence from the directors or astronomers of the Mount Wilson, Lick, Victoria, Perkins and McDonald Observatories to secure from these institutions prints (or glass reproductions), microphotometer tracings and other material suitable for original research. Requests for such material (which should be accompanied by a detailed outline of the proposed investigation and should be intended for *immediate* use) may be addressed to the directors of these observatories, to the spectroscopist members of Commission 29, or to the chairman of this Commission. Although it may not be possible to fill all requests, there is a large amount of material available which can be investigated without having access to the telescopes.

3. That foreign astronomers visiting the large observatories should not necessarily take the view that it is useless for them to spend their limited time in stellar spectroscopy because after their return home they would be unable to continue work in this field, and that consequently they should devote themselves exclusively to work requiring inexpensive instrumental facilities. A reasonable fraction of these visitors should, on the contrary, establish close ties with stellar spectroscopists in those countries where the necessary equipment exists and arrange some sort of co-operative work with them that could last after their return home. In another branch of astronomy and in another era the work of Kapteyn has demonstrated how much may be accomplished in this manner.

4. That stellar spectroscopists in the larger institutions be encouraged to publish material which they have not had the time to discuss. An example of this is the Hiltner-Williams Atlas of tracings from McDonald Observatory Coudé spectrograms. This Atlas contains a wealth of information on curves of growth, abundances of elements, etc., which has not yet been utilized. Stratton's *Atlas* of Nova Herculis, 1934, is another example. Plans are now under way, at Merrill's suggestion, to publish for limited distribution occasional issues, perhaps as an appendix to the *Astrophysical Journal* and probably by a cheap off-set process, which will contain extensive tabular material and other bulky data not suitable for the regular issues of a journal. This Commission welcomes the plan and recommends that observers make available to others, by its means, tabular and other data which may be only incompletely digested. For example, it would be appropriate to publish in this form a list of equivalent widths in an unusual spectrum like αCVn, or in a Cepheid variable. Authors would hesitate to print incomplete studies in the regular issues of a scientific journal. In some cases the distribution of half-tones or even of photographic reproductions of unusual spectra, such as Novae, shell-stars, spectrum variables like ρ Cas, etc. would furnish material for those who now lack it and would at the same time solve the problem of several large observatories which are now unable to keep up with the discussion of the plate material in their files.

V. REPORT OF SUB-COMMITTEE ON NOVAE

In a Symposium held in Paris in 1939 under the presidency of H. N. Russell and with the support of the Singer-Polignac Foundation the problems of Novae and Supernovae were fully discussed (see *Actualités Scientifiques et Industrielles*, Nos. 901, 902, 903; Hermann: Paris, 1941). The present report will confine itself to later publications and to still outstanding problems.

Novae. Recent observations of earlier Novae have included photographs of *Nova Herculis* 1934 taken at Mount Wilson in red and blue light ten years after the outburst. They show an expanding elliptical shell with condensations at the ends of the major axis. The sight-line velocities of the red and violet maxima have changed but little in ten years, but the expanding shell is now large enough to show that different spectral lines are not equally strong over the whole shell. The lines [O III], 4959, 5007 are strongly present over the shell and in the condensations at the ends of the major axis, but are weak at the ends of the minor axis, where the lines [N II] 6548, 6584 are strong.

A recent photograph (1944) taken at Mount Wilson of *Nova Persei* 1901 suggests strongly that the irregular condensations expanding from the Nova are part of an elliptic shell of which for some unexplained reason only a portion is visible.

The later spectrograms of *Nova Herculis* 1934, including such lines as those of [Fe VI], [Fe VII], suggest resemblances to the stars surrounded by shells examined by Struve and Swings (*Ap. J.* **91–8**). The problem of shells, both stationary and expanding but simultaneously present, is akin to that of successive shells surrounding the central star of a Nova.

Of the Novae which have appeared since 1939 the most interesting is *T Coronae Borealis*, which had an outburst in 1946, resembling in many details the previous recorded outburst in 1866. On this second occasion we have had the unusual opportunity of watching spectral changes in the star for some years preceding the outburst. The rapid fading, without changes of velocity, of a high-velocity absorption spectrum caught at the Yerkes Observatory just after the outburst suggests the blowing out and dispersal of an existing shell already surrounding the star.

Another interesting object was *Nova Cygni* 1942, a slow Nova which in its spectral changes at the deep drop in brightness closely followed *Nova Herculis* 1934. (For a possible explanation of the phenomena accompanying the deep minima in slow novae see ter Haar, *M.N.R.A.S.* **104**, 283, 1947.)

For a comparative study of a number of Novae reference may be made to Bertaud (*Ann. de l'Obs. de Paris, Section d'Astrophysique à Meudon*, **9**, 1, 1945) and Cecchini and Gratton (*Publ. d. R. Assoc. Astr. de Milano*, 1939), but above all to a series of papers on the general problems of Novae by McLaughlin (in particular *Publ. Obs. University of Michigan*, **8**, No. 12, 1942). He has discussed the relations existing between the time, the absolute magnitudes at maximum, the light curves, spectral sequences, and the velocity of outflow of atoms and also the resemblances and differences between fast and slow Novae.

In this necessarily very brief summary of the fresh material of the last few years much has been omitted. Two points remain to be added: (1) a list of further observational data urgently required; and (2) a list of problems for discussion at the meeting in 1948.

(1) (*a*) Infra-red spectra of Novae at different stages, especially to aid in a search for molecular bands. Infra-red spectra of *Nova Puppis* 1942 were secured at the McDonald Observatory, but only for the immediate post-maximum stage.

(*b*) Further spectrophotometric study of (i) the continuous spectrum, with an attempt to separate when possible the radiation from the central star and that from a surrounding envelope; (ii) the changing relative intensity of band emission and the continuous background; (iii) the absorption and emission components in composite bands; (iv) changes of equivalent widths of spectral lines with time; and (v) marked departures from black-body curves in the continuous spectrum.

(*c*) Relations between variations in the light curve and the various items discussed in (*b*).

(*d*) Possible evidence for magnetic fields in the star or the shells.

(*e*) Pre-maximum spectra.

(2) (*a*) Spectral nomenclature. The separate details to be allowed for in the case of each component spectrum should include the following: (i) the stage of Nova development at which it is strongest; (ii) spectral type; (iii) nature of absorption lines (sharp, diffuse or very diffuse); (iv) at later stages the source of the spectrum: star or shell.

(*b*) The physical relations between successive shells.
(*c*) The cause of the slowing down of the first pre-maximum spectrum.
(*d*) The possibility of measuring the brightness of the central star at different stages.
(*e*) The chemical abundance of elements.
(*f*) The evaluation of the total mass ejected by successive shells.
(*g*) The different distribution of different elements.
(*h*) The occurrence of condensations in pairs, generally equally displaced from the central star, in opposite directions.
(*i*) The asymmetry of the expanding envelope.
(*j*) The question of securing an atlas of the spectra of a series of Novae at different stages.

Supernovae. Supernovae are now subdivided into two classes (Minkowski, *P.A.S.P.* **55**, 1941). Class I have the continuous spectrum very weak in the ultra-violet. There are a number of very wide emission bands, as yet unidentified (save for the possible presence of [O I] 6300, 6363 as comparatively narrow bands at a late stage. To the violet of λ 5000 the bands shift gradually towards the red, while to the red of λ 5000 they appear and disappear much as bands do for ordinary novae: the spectra are closely comparable at the same time after maximum (Minkowski, *Ap. J.* **59**, 156, 1938). Class II show a strong extension into the ultra-violet for a week after maximum. Subsequently, absorptions and broad emission bands develop. Hydrogen and the usual forbidden lines are weak or missing, but the spectrum resembles that of a nova in the transition stage and may be built up by superposing a series of wide overlapping emission bands (Payne-Gaposchkin and Whipple). These are probably very bright and highly excited Novae of the ordinary type: there is reason to identify the Crab Nebula with a Nova of this type occurring some 900 years ago. *Nova Cassiopeiae* 1572 and *Nova Ophiuchi* 1604 may have been class I supernovae in our galaxy.

Points to be discussed are the following: (*a*) the spectra of class I stars; (*b*) the stellar changes likely to accompany an outburst of the order of that of a supernova; (*c*) the possible relation to white dwarfs.

F. J. M. STRATTON
Chairman of the Sub-committee

VI. REPORT OF THE SUB-COMMITTEE ON MOLECULAR BANDS IN STELLAR SPECTRA

In preparing this report, the question arose as to the form which would be most useful. It was decided not to attempt to provide a bibliography of recent and current articles on molecular spectra, it being believed that the recent troubled conditions of the world have now subsided sufficiently to allow investigators to gain access to most, if not all, the important publications. Also, a complete bibliography would have made the report too long. It was decided that a useful means of encouraging and promoting the study of molecules in stellar atmospheres would be to list a number of problems in this field which are considered to be of importance at the present time. Accordingly, such a list is given below. To keep the report within reasonable length, only a limited number of problems can be described and those briefly. It is felt that a contribution to the solution of any one of them will be of definite value. The suggested problems have come from correspondence between the members of the sub-committee, a comprehensive and valuable memorandum by P. Swings being the first step in this process. Also, worthwhile suggestions have been received from H. D. Babcock, P. W. Merrill and R. F. Sanford of the Mount Wilson Observatory.

Observational Problems

1. One of the problems requiring attention is the establishment of a physically significant sequence of the stars of type S. Their spectra are characterized by the occurrence of ZrO bands and the present sub-classification is ordered only upon the intensity of these bands. Whether this gives a true temperature scale has not been demonstrated and should be examined. The problem, complicated by some ambiguity in the distinction of type S from type M stars, must, on account of the faintness and redness of the stars, be done using relatively low dispersion. Probably the red and perhaps the infra-red region should be included in the study. It is emphasized that the whole relationship of class S to class M must be better understood before a completely satisfactory classification can be set up. Among the items that should be carefully studied are:

(*a*) Intensity of ZrO bands.
(*b*) Intensity of TiO bands.
(*c*) The excitation temperature indicated by the atomic line spectrum.
(*d*) The apparent abundance of various elements, especially Y, Zr and Ba.

2. It is suggested that observers be encouraged to make spectrographic observations as far as practicable into the infra-red for late-type stars. Both, photographic techniques, and those employing the new sensitive lead sulphide cells, could be used. In this region vibration-rotation bands of various molecules might be sought in the spectra of the coolest stars. As a low-dispersion application, extensive objective-prism surveys using Schmidt-type telescopes and infra-red sensitive plates would supply useful information on the distribution of the faint cool stars.

3. A late M-type star and perhaps also a representative star of each of types S, R and N should be studied with the highest practicable dispersion and in the greatest possible detail, as was recently done for β Pegasi by Dorothy N. Davis (*Ap. J.* **106**, 28, 1947). Also, a detailed intercomparison, if necessary with more moderate but not low dispersion, should be made of the spectra of several stars of each of these types.

4. Observers of late-type stars should keep a close watch for the possible occurrence of bands due to polyatomic molecules, for example CH_2 (λ 4051).

5. Observers of Novae should be alert to discover possible bands such as those of C_2 and CH^+ as well as those of CN which have been noted previously. Occurrences of molecular bands in the spectra of novae are of much interest in connection with the behaviour of molecules in stellar atmospheres (e.g. questions of the photo-dissociation of molecules, see e.g. Swings and Struve, *Ap. J.* **96**, 268–9, 1942).

6. A detailed study of the ultra-violet spectra of late-type stars under high dispersion would doubtless yield new and valuable information on molecular absorption features. For example, G. Herzberg has noted that on his recent plates of α Boo, the 0, 0 and 1, 1 NH bands show up much more clearly than in the previously published photographs which were secured in the pioneering work in this region. A specific problem is posed by the presence of unidentified bands in Se and Me spectra with heads near $\lambda\lambda$ 3571 and 3680 reported by P. W. Merrill.

7. The relative abundances in stellar atmospheres, of the isotopes of the elements is a question of much interest and of possible importance in connection with problems of energy generation, origin of the elements and stellar evolution. Measurements on molecular bands appear to be the only feasible method of attacking this subject. Data on the C^{12} to C^{13} ratio have been provided by a number of recent investigations. The most promising cases for study would appear to be the TiO and ZrO bands in M and S-type spectra. A careful study of these bands on high-dispersion spectrograms should enable valuable conclusions to be reached regarding the occurrence and possibly relative abundances of the isotopes of Ti, Zr and O.

8. It is worth while to emphasize that, in the study of molecules in stellar atmospheres, the normal solar and sunspot spectra offer valuable material for comparison. In connection with paragraph 2 above, H. D. Babcock and C. E. Moore in Carnegie Institution of Washington Publication, No. 579 (in the Press), on the *Infra-red Solar Spectrum*, give a

list of about 30 identified band heads between λ 6600 and λ 13495. With reference to paragraph 6, H. D. Babcock, C. E. Moore and M. F. Coffeen in a forthcoming Mount Wilson contribution have revised the earlier data in the region λ 2935 to λ 3063 in the solar spectrum. Here, as well as having newly identified some OH and NH absorptions, they found several bands of unknown origin.

Experimental Work in the Laboratory

1. The experimental determination of the relative transition probabilities of the various bands within the systems occurring in stellar spectra would be of great value. The band-systems include the violet and red CN bands, the Swan system of C_2, the three systems of CH, the three TiO systems and the ZrO systems. Possibly the best method would be the use of an electric furnace to produce the bands in absorption, employing the general techniques used by R. B. King and A. S. King to obtain *f*-values of atomic transitions (*Ap. J.* **87**, 24, 1938). Some work at present being done by R. B. King at the Mount Wilson Observatory will probably yield *f*-values for the C_2 Swan bands.

2. A problem related to the above, namely determination of the absolute *f*-value of a molecular electronic transition (band-system as a whole) is also of interest, as applied to individual systems occurring in stellar spectra. Results could be applied to intensity measurements in stellar spectra to evaluate the relative numbers of absorbing molecules of different kinds. An *f*-value has been deduced for the violet CN bands by J. U. White (*J. Chem. Phys.* **8**, 79 and 459, 1940), whose method, or variations of it, might be applied to other molecules of astrophysical interest. The great need for studies of this type is illustrated by the discrepancies pointed out by H. D. Babcock (*Ap. J.* **102**, 165, 1945) between different estimates of molecular abundances in the solar atmosphere.

3. Strong unidentified bands in the spectra of some N-type stars have been studied by R. F. Sanford, by C. D. Shane and recently by A. McKellar (*J. Roy. Astr. Soc. Canada*, **41**, 147, 1947). Among possible carrier molecules suggested by the latter were TiH and FeH. G. Herzberg and J. G. Phillips have, during 1947, tried a variety of sources in an attempt to produce in the laboratory the spectrum of TiH, but without as yet any success. Further laboratory work on possible molecules is desirable. It is believed the blue-green bands have the distinction of being the strongest absorption features in stellar spectra as yet unidentified.

4. Detailed study of the band systems of TiO and ZrO as produced in the laboratory should yield data of value to astrophysicists. One particular aspect requiring attention is the isotope effect. Also, wave-lengths for the lines of many more bands of TiO than the three heretofore analysed should be measured and possibly certain details of the vibrational assignments checked. (See P. W. Merrill, *Spectra of Long Period Variable Stars*, University of Chicago Press, 1940, ch. v.)

Three general remarks which apply not only to TiO and ZrO may be interposed at this point:

(*a*) Existing laboratory data on bands in the red and infra-red are very scanty, and it is in these regions that much new observational material on stellar spectra is being gathered.

(*b*) Most laboratory data relate to emission whereas the astrophysicist is more interested in absorption spectra.

(*c*) Physicists usually only measure the lines of enough bands to make possible the evaluation of the molecular constants. Measurements of all the intense bands of a system, admittedly a laborious process, would nevertheless be appreciated by astrophysicists.

It is hoped these remarks may be given consideration by spectroscopists doing work on bands in the laboratory.

5. Any laboratory investigation leading to more trustworthy and accurate values of the heats of dissociation of diatomic molecules involving astrophysically abundant elements is of great importance in making possible a more satisfactory calculation of the dissociation equilibrium in stellar atmospheres.

Calculation from Theory

1. It is very desirable that theoretical calculations of the relative intensities of the bands of the Swan system of C_2, and also of the bands of the systems of CN, TiO and ZrO be carried out. These should be as accurate as possible, using theory at least as refined as that given by E. Hutchisson for the anharmonic oscillator (*Phys. Rev.* **37**, 45, 1931) in conjunction with the best values of the molecular constants. Such calculations would be a valuable check on and adjunct to the experimental determinations. When results such as these are available, reliable determinations of vibrational temperatures in stellar atmospheres can be found, independently of any possible curve-of-growth effect, from bands of similar intensity. Also information on the extent to which thermodynamic equilibrium obtains might be deduced. New relative transition probabilities based on the theory of the harmonic oscillator have been calculated for the violet CN and the Swan C_2 systems by W. Buscombe and A. McKellar (*Publ. Dom. Ap. Obs.* **7**, No. 23, in the Press), in connection with measurements of band intensities in R-type spectra.

2. Theoretical calculations of the absolute f-values of whole band systems of astrophysical interest are also of value, as indicated in paragraph 2 under experimental work. The agreement between theoretical and experimental values would allow an estimation of the accuracy of the f-values and possibly, too, of the theory.

3. Questions of the sources of opacity in stellar atmospheres, particularly in late-type stars, have recently become important. The significance of the role played by H^- ions in solar-type stars has directed attention to negative ions. Certain molecules such as O_2 can apparently form negative ions. Any calculations yielding results on the magnitude of the electron affinities of astrophysically abundant molecules or estimates of the effective absorptions of the ions would be received with the greatest interest.

Compilation of Molecular Data

1. A project, the results of which would prove of great value to astrophysicists interested in molecular bands, would be a compilation of an extensive table of molecular constants, etc. for all band systems of astronomical importance. Such a project could be a relatively long-term one. As well as the wave-lengths of the bands and their intensities, the various vibrational and rotational constants, the heats of dissociation, etc. should be given. Such a project might prove an interesting undertaking for some qualified person who need not necessarily have access to observational or laboratory equipment.

2. As a companion to the above, a photographic atlas of band spectra of astrophysical interest, reproduced in such a way that reasonably accurate wave-lengths could be read off easily, would be of much help to those studying the spectra of late-type stars. Such an atlas could best be prepared where both the laboratory facilities are available and, also, observational work on late-type stars is under way. The most suitable choice for this would appear to be the Mount Wilson Observatory, where laboratory spectra of most such molecular bands have already undoubtedly been photographed.

Both the above-mentioned projects might appropriately be done under the auspices of Commission 29. It is recommended therefore that the early preparation of the *Atlas* and *Tables* be encouraged and that, if necessary, some financial support be given by the International Astronomical Union.

Andrew McKellar
Chairman of the Sub-committee

VII. RECOMMENDATION CONCERNING A SUB-COMMITTEE ON VARIABLE STARS

Several members of this Commission (Merrill, Swings) have independently suggested that a sub-committee (originally proposed at the Stockholm meeting) be formed, consisting of members of this Commission and of Commission 27 (Variable Stars), in order

to bring about prompt and effective collaboration between photometric and spectrographic observers. Commission 29 welcomes the spectacular development of accurate photoelectric methods and directs attention to several recent projects of collaboration (RR Lyrae: Leiden, photoelectric; McDonald, spectrographic). It wishes also to emphasize the great importance of maintaining accurate ephemerides of many eclipsing variables and of continuing the light curves of long-period and of irregular variables. These latter tasks can still be handled best by many observers with visual or simple photographic instruments.

OTTO STRUVE
President of the Commission

Report of meetings

PRESIDENT: Prof. OTTO STRUVE.

SECRETARY: Prof. LIVIO GRATTON.

First meeting (August 12, 1948. 9.30 a.m.)

1. *List of stars for standard spectral types.* The desirability that a list of standard stars for spectral types be made available as soon as possible, together with reproductions of standard spectra, was pointed out by Struve, Mrs Mayall, Swings and others. A committee was formed for discussing a preliminary list prepared by Joy and for adopting a definitive list. On the President's suggestion the following persons will be members of this informal committee: Vyssotsky (Chairman), Joy, Mrs Mayall, Morgan, Nassau, Schalén.

STANDARD STARS FOR SPECTRAL TYPE

This list was originally composed by A. H. Joy of the Mount Wilson Observatory and presented to Commission 29, which passed a resolution that the list should be published after it had been discussed in detail by a small group appointed by the President of the Commission. The outcome of this discussion presents a compromise as to the choice of stars included. In general there is good agreement between the estimates made at Mount Wilson and Yerkes, with the exception, perhaps, of the dwarf M branch, where the Mount Wilson system was adopted for the present list.

The list is primarily intended for the use of observers with large instruments. To make it usable for smaller instruments, visual doubles were avoided as far as possible, or marked as VD when they were included. Similarly, a few spectroscopic binaries were marked as SB. It is assumed that an observer will wish to set up his own series of standard photographs taken with his particular instrument.

This list is subject to further revision if the need arises.

The following abbreviations have been used: VD = visual double; SB = spectroscopic binary; P = period; d = distance; Δm = difference in magnitudes; Y = Morgan, Keenan and Kellman, *Atlas of Stellar Spectra.*

WOLF-RAYET STARS

Spectral type	Star	Boss	Vis. mag.	α 1950 h. m.	δ ° ′	Remarks
WN5	HD 187282	...	10·0	19 46·2	+18 4	...
WN5	HD 211564	...	11·1	22 14·7	+55 21	...
WN6	HD 191765	...	7·8	20 8·4	+36 1	...
WN6	HD 192163	...	7·4	20 10·3	+38 12	...
WN7	HD 151932	...	6·6	16 48·8	−45 46	...
WN7	HD 92740	...	6·5	10 39·3	−59 25	...
WN8	HD 177230	...	11·1	19 1·3	− 4 24	...
WN8	HD 96548	...	7·8	11 4·3	−65 14	...

WOLF-RAYET STARS (*continued*)

Spectral type	Star	Boss	Vis. mag.	α 1950 h. m.	δ ° ′	Remarks
WC6	HD 16523	...	10·0	2 35·2	+56 28	...
WC6	HD 165763	...	7·8	18 5·5	−21 16	...
WC7	HD 192103	...	7·9	20 10·0	+36 3	...
WC7	HD 119078	...	9·4	13 39·5	−67 9	...
WC8	HD 184738	...	10·0	19 32·8	+30 24	...
WC8	HD 164270	...	8·8	17 58·4	−32 43	...

GIANTS

O5	9 Sgr	4560	5·9	18 0·8	−24 22	...
O6	HD 190864	...	8·2	20 3·8	+35 28	...
O7	9 Sge	5073	6·3	19 50·1	+18 33	...
O8	λ^1 Ori	1357 A	3·7	5 32·4	+ 9 54	VD: $d=4''$, $\Delta m=1^m\cdot9$
B0	υ Ori	1340	4·6	5 29·5	− 7 20	...
B0	κ Ori	1435	2·2	5 45·4	− 9 41	...
B1	β CMa	1609	2·0	6 20·5	−17 56	...
B2	12 Lac	5856	5·2	22 39·2	+39 58	...
B3	GC 6632	1295	5·6	5 21·1	− 0 12	...
B5	18 Peg	5653	6·0	21 57·6	+ 6 29	...
B5	δ Per	838	3·1	3 39·4	+47 38	...
B8	β Tau	1304	1·8	5 23·1	+28 34	...
B9	γ Lyr	4824	3·3	18 57·1	+32 37	...
A0	GC 27939	5160	6·2	20 5·8	−10 13	Two spectra: rad. vel. var.
A0	δ Cyg	5048	3·0	19 43·4	+45 0	...
A2	β Ser	4009	3·7	15 43·9	+15 35	...
A2	λ UMa	2729	3·5	10 14·1	+43 10	...
A3	δ Her	4376	3·2	17 13·0	+24 54	...
A5	β Tri	482	3·1	2 6·6	+34 45	SB: $P=31^d$
A5	α Oph	4459	2·1	17 32·6	+12 36	...
A7	γ Boo	3722	3·0	14 30·1	+38 32	...
F0	ζ Leo	2730	3·7	10 13·9	+23 40	...
F2	β Cas	12	2·4	0 6·5	+58 52	...
F2	20 Peg	5658	5·7	21 58·7	+12 53	...
F5	ι Vir	3660	4·2	14 13·4	− 5 46	Y: F6
F5	25 Mon	1999	5·2	7 34·8	− 4 0	...
F8	1 Com	3142	6·6	11 59·2	+22 22	...
G2	η Peg	5865	3·1	22 40·7	+29 58	SB: $P=818^d$
G5	γ Hya	3449	3·3	13 16·2	−22 55	...
G8	ϵ Oph	4147	3·3	16 15·7	− 4 34	...
G8	κ Cyg	4923	4·0	19 15·9	+53 17	...
K0	η Cyg	5103	4·0	19 54·4	+34 57	...
K0	ν Oph	4536	3·5	17 56·3	− 9 46	...
K2	κ Oph	4315	3·4	16 55·3	+ 9 27	...
K5	GC 33081	6118	5·9	23 48·0	−14 41	...
K5	γ Dra	4541	2·4	17 55·4	+51 30	...
M0	β And	259	2·4	1 6·9	+35 21	...
M1	7 Cet	33	4·7	0 12·1	−19 13	...
M1	75 Cyg	5567	5·4	21 38·2	+43 3	...
M2	α Cet	691	2·8	2 59·7	+ 3 54	...
M2	χ Peg	31	4·9	0 12·0	+19 56	...
M3	μ Gem	1604	3·2	6 19·9	+22 32	...
M4	GC 265	30	5·4	0 11·9	− 8 4	Y: M3
M5	56 Leo	2915	6·0	10 53·4	+ 6 27	...
M6	45 Ari	660	5·9	2 53·0	+18 8	...
R0 ($C1_3$)	HD 182040	...	7·0	19 20·4	−10 48	...
R4 ($C2_3$)	HD 16115	...	8·3	2 32·7	− 9 40	...

GIANTS (*continued*)

Spectral type	Star	Boss	Vis. mag.	α 1950 h. m.	δ ° ′	Remarks
R6 ($C4_4$)	HD 52434	...	7·5	6 58·5	− 3 11	...
R8 ($C5_3$)	HD 25408	...	7·9	4 1·5	+61 40	...
N0 ($C6_2$)	19 Psc	6102	5·3	23 43·8	+ 3 13	...
N2 ($C7_3$)	U Hya	2827	5–6	10 35·1	−13 7	...
N6e ($C7_4$)	R Lep	...	6–10	4 57·3	−14 53	...
Se (S2e)	V Cnc	...	7–13	8 18·8	+17 26	...
Se (S3e)	R Gem	...	6–14	7 4·4	+22 47	...
Se (S3e)	R Cyg	...	6–14	19 35·5	+50 5	...
Se (S4e)	R And	...	6–15	0 21·4	+38 18	...
S (S4)	HD 35155	...	7·0	5 19·9	− 8 43	...

NOTE. Second spectra of carbon stars are as given by Keenan and Morgan (*Ap. J.* **94**, 501), and those of ZrO stars are due to Dorothy N. Davis (*P.A.S.P.* **46**, 267).

MAIN SEQUENCE

O6	θ' Ori C	1363	5·4	5 32·8	− 5 25	...
O6	λ Cep	5719	5·2	22 9·8	+59 10	...
O9	ι Ori	1366 br.	2·9	5 33·0	− 5 56	SB: P=29^d
B0	ζ Oph	4225	2·7	16 34·4	−10 28	...
B1	η Ori	1301	3·4	5 22·0	− 2 26	SB: P=8^d; VD: d=1″, Δm=1^m·0
B2	ν Sco	4117	4·3	16 9·1	−19 20	VD: d=1″, Δm= 2^m·5
B2	GC 28228	5210	5·8	20 16·4	+40 35	VD: d=3″, Δm=2^m·2
B3	μ Aur	1204	3·3	5 3·0	+41 10	...
B3	GC 23058	4345	5·6	17 3·0	− 0 50	...
B5	κ Hya	2600	5·0	9 37·9	−14 6	...
B8	β Lib	3890	2·7	15 14·3	− 9 12	...
B9	α Peg	5944	2·6	23 2·3	+14 56	...
A0	30 Mon	2237	4·0	8 23·2	− 3 45	...
A2	ζ Vir	3508	3·4	13 32·1	− 0 20	Y: A3
A5	β Ari	428	2·7	1 51·9	+20 34	SB: P=107^d
A7	α Aql	5062	0·9	19 48·3	+ 8 44	...
A8	53 Her	4300	5·4	16 51·1	+31 47	Y: F2
F0	μ Cap	5623	5·2	21 50·6	−13 47	...
F2	σ Boo	3729	4·5	14 32·5	+29 58	...
F5	γ Ser	4055	3·9	15 54·1	+15 49	Y: F6 IV
F5	ι Peg	5688	4·0	22 4·7	+25 6	...
F8	β Vir	3105	3·8	11 48·1	+ 2 3	...
G0	δ Tri	514	5·4	2 14·0	+34 0	SB: P=10^d
G0	λ Ser	4010	4·4	15 44·0	+ 7 31	Y: G2
G2	72 Her	4403	5·4	17 18·8	+32 32	...
G5	κ Cet	752	5·0	3 16·7	+ 3 11	...
G8	τ Cet	391	3·7	1 41·7	−16 12	...
G8	GC 95	6	6·2	0 4·0	+28 45	...
K0	54 Psc	133	6·1	0 36·8	+20 59	...
K2	ϵ Eri	814	3·8	3 30·6	− 9 38	...
K4	GC 32089	...	7·6	22 59·3	− 4 7	...
K6	61 Cyg A	5433	5·6	21 4·7	+38 30	Y: K5
M0	61 Cyg B	5434	6·3	21 4·7	+38 30	...
M0	C 1412	...	9·7	11 25·9	+ 7 50	Sf of two stars
M1	BD+42° 2296	...	9·1	12 19·4	+42 26	...
M1	BD−21° 1051	...	8·3	5 0·3	−21 20	...
M2	BD+36° 2147	2935	7·6	11 0·6	+36 18	...
M3	BD+4° 4048	...	9·2	19 14·5	+ 5 6	...

MAIN SEQUENCE (*continued*)

Spectral type	Star	Boss	Vis. mag.	α 1950 h. m.	δ 1950 ° ′	Remarks
M4	GC 25648 A	...	8·9	18 42·2	+59 33	VD: $d=17''$, $\Delta m=0^m\cdot8$
M4	BD+5° 1168	...	10·0	7 24·7	+ 5 30	...
M5	BD−12° 4523	...	10·0	16 27·5	−12 32	...
M5	BD+4° 3561	...	9·5	17 55·4	+ 4 24	...
M6e	20 C 600	...	13·5	10 54·2	+ 7 20	...

SUPER-GIANTS

O9	HD 188209	5083	5·5	19 50·5	+46 54	...
O9	16 Sgr	4613	6·0	18 12·2	−20 24	Two spectra; rad. vel. var.
B0	ϵ Ori	1370	1·8	5 33·7	− 1 14	...
B1	ζ Per	894	2·9	3 51·0	+31 44	...
B2	χ^2 Ori	1507	4·7	6 0·9	+20 8	...
B3	9 Gem	1578	6·3	6 13·9	+23 46	...
B3	55 Cyg	5361	4·9	20 47·2	+45 56	...
B5	67 Oph	4548	3·9	17 58·1	+ 2 56	...
B8	β Ori	1250	0·3	5 12·1	− 8 15	SB: $P=22^d$
A0	η Leo	2694	3·6	10 4·6	+17 0	...
A2	α Cyg	5320	1·3	20 39·7	+45 6	...
A5	ϕ Cas	298	5·3	1 16·9	+57 58	...
A7	97 Pup	1968	4·8	7 27·7	−22 55	...
A8	GC 24543	...	7·3	17 59·5	−22 54	...
F0	α Lep	1347	2·7	5 30·5	−17 51	...
F2	π Sgr	4874	3·0	19 6·8	−21 6	...
F3	10 Pup	2082	5·7	7 50·0	−14 43	...
F4	ν Aql	4962	4·9	19 24·0	+ 0 14	...
F5	α Per	772	1·9	3 20·7	+49 41	...
F8	γ Cyg	5229	2·3	20 20·4	+40 6	...
G0	β Aqr	5527	3·1	21 28·9	− 5 48	...
G0	GC 30534	5612	7·2	21 46·2	+38 43	...
G1	α Aqr	5676	3·2	22 3·2	− 0 34	...
G2	11 Pup	2099	4·4	7 54·7	−22 45	...
G3	ω Gem	1806	5·2	6 59·4	+24 17	...
G3	GC 32063	5931	5·5	22 58·0	+56 41	...
G4	ζ Cap	5507	3·9	21 23·8	−22 38	...
G5	9 Peg	5590	4·5	21 42·1	+17 7	...
G8	ϵ Gem	1717	3·2	6 40·9	+25 11	...
K0	56 Peg	5954	5·0	23 4·7	+25 12	Y: G8, H+K in emission
K1	ζ Cep	5714	3·6	22 9·1	+57 57	...
K2	56 Ori	1458	5·0	5 49·8	+ 1 51	...
K3	10 Ori	1181	4·7	4 56·0	+ 1 38	...
K4	γ Aql	5047	2·8	19 43·9	+10 29	...
K5	3 Cet	6182	5·2	0 1·9	−10 47	...
M1	α Sco	4193	1·2	16 26·3	−26 19	...
M2	α Ori	1468	0·9	5 52·5	+ 7 24	...
M3	π Aur	1479	4·6	5 56·2	+45 56	...
M5	α Her	4373	3·6	17 12·4	+14 27	VD: $d=5''$, $\Delta m=2^m\cdot0$

NOTE. According to the Yerkes observers, the last two stars are not of the highest luminosity among super-giants; the following variables are examples of M type stars of highest luminosity:

M3–M4	SU Per	...	7–9	2 18·6	+56 23	...
M5–M6	RS Cnc	...	5–7	9 7·6	+31 10	...
M5–M6	Y Lyn	...	7–8	7 24·6	+46 5	...

2. *Classification of white dwarfs and sub-dwarfs.* The president read a letter by Dr Luyten on the spectral classification of stars below the main sequence. After a discussion by Swings, Gratton, Vyssotsky and others, the Commission recommended that a summary of Dr Luyten's letter be prepared by Gratton and Vyssotsky and included in the Report.

After calling attention to the necessity of a more logical system of classification of stars below the main sequence, Dr Luyten pointed out that the designation of very dense stars as dwarfs or intermediate stars as sub-dwarfs is inadequate, because in some cases these stars might be more luminous than main sequence stars of later spectral types. Therefore, he suggested that the prefix 'sd' should be dropped. Instead of that he proposed to denote the bona fide white dwarfs and degenerate stars by using the letter D followed by a symbol of spectral class, such as DA; if the spectrum is virtually continuous, the spectral type should be designated as DC. For intermediate (sub-dwarfs) stars he proposes to postpone the final decision.

3. *Sub-committee on the spectra of variable stars.* After a suggestion by Gratton, Swings and Stratton, the following resolution was adopted:

Commission 29 recommends to the Executive Committee that a Sub-Commission on the spectra of all variable stars be created; that Commission 27 (Var. Stars) furnish two or three of its members and Commission 29 (Stellar Spectra) an equal number.

4. *Report of the President of the Sub-committee of Novae.* In addition to the Draft Report, Stratton read an important paper by McLaughlin containing an outline of a classification of the spectra of Novae. As the paper is too long for publication in the Report, it is recommended that McLaughlin's ideas be considered in preparing a scheme of a classification of the spectra of Novae spectra; this should be especially considered in the preparation of an Atlas of representative spectra of Novae. The following persons were designated to co-operate in the preparation of a new Atlas: Stratton (acting as Chairman), Bertaud, McLaughlin. Stratton, Bertaud and Gratton will prepare during the meeting a scheme of classification which could serve as a basis for the Atlas and would include the essentials of the suggestions contained in McLaughlin's letter (see § 13) Stratton then read a letter by Dr Baade of which the following is a summary as prepared by Gratton and Stratton.

Dr Baade's letter contained the important suggestion that the well-known features of the complex nebular lines in Nova Aq 1 1918 arise from rings instead of from shells or jets. Baade calculates from the observations a complete system of rings parallel to the equator and symmetrically placed north and south; the inclination of the polar axis of the rotating star being at 15° to the line of sight. Although it is not easy to understand the physical relationship between these rings and the rotational state of the star, Baade's idea is very interesting and may have application to the interpretation of the spectral features of Novae.

Finally, the Sub-Commission recommended that those observers who are not continuously working on Novae and possess valuable observational material should lend it to other workers in this field. It was mentioned that copies of the *Atlas* of the Spectrum of Nova Her 1934 are still available.

5. *Standard areas for spectral classification.* A. N. Vyssotsky recommended the adoption of ten standard areas in which a number of stars should be classified as to luminosity and temperature. Miss M. E. Walther and Nassau remarked that some of these areas have been taken care of, while the others might not be suitable. Vyssotsky replied that the list is flexible and may be modified. The Commission recommended that the list is to be adopted as printed in the Draft Report.

6. *Researches on stellar spectra in Japan.* The following is a summary of a letter by Dr Hagihara, read by the President of the Commission.

Dr Hagihara quoted some interesting results by Japanese astronomers concerning mainly the chemical composition and structure of stellar atmospheres. These relate to the branching of the spectral sequence at types M–S (Fujita); to the abundance of C and N in some later type stars; to the computation of model atmospheres (Miyamoto); to

Unsöld's theory of convective equilibrium taking into account the ionization (Hitotuyanagi); and to the theory of the atmospheres of Be stars. Finally, colour observations of Nova Pup 1942 by Tonita and Haruhata are also mentioned.

At 11.30 a.m. the meeting was adjourned.

Second meeting (August 14, 1948. 9.15 a.m.)

7. *Molecular spectra.* Dr Swings underlined the importance of work in the field of molecular spectra. The need of a compilation of molecular data was especially felt; an atlas containing the spectra of molecules of astrophysical interest would be extremely useful. Dr Swings suggested that the Atlas might possibly be prepared at the Vatican Observatory in collaboration with other institutions.

Dr Rosen stated that a compilation of all existing molecular data is being prepared by the International Chemical Union (Tables of Constants) and that it would be important to organize a collaboration between the Astronomical and Chemical Unions in order to save effort and avoid duplication of work. The needs of both organizations are closely related to each other. Moreover, it is difficult to decide on the kinds of molecules which are or may become in the future of astrophysical interest. Following a suggestion of the International Chemical Union, it may be possible to publish the table as a part of the 'Tables of Constants'. Father Junkes pointed out some difficulties concerning the preparation of the Atlas at the Vatican Observatory but gave assurance of interest on behalf of that institution. Accordingly the following informal committee was appointed for the compilation of molecular data and the preparation of the Atlas: McKellar, Junkes (or Gatterer), Herzberg, R. B. King, R. W. B. Pearse, Rosen, Swings.

The following recommendation was then adopted: 'Commission 29 recommends that a compilation and an atlas of laboratory molecular spectra of astrophysical interest be prepared and published as soon as possible.'

8. *General report.* Commission 29 voted that the Draft Report be adopted as printed, without further discussion.

9. *Photography of the sky with large-field telescopes and objective prisms.* Vyssotsky pointed out the importance of Schwassmann's plan for the complete photography of the whole sky with large field telescopes and objective prisms. After a short discussion by Struve, Gratton and Nassau, the Commission adopted the following resolution:

Commission 29 recommends that Prof. Schwassmann's plan to photograph the whole sky with large Schmidt telescopes equipped with an objective prism be followed as far as possible. If several observatories co-operate in this plan, periodic reports and exchange of information will be necessary. The President of Commission 29 will serve as an intermediary for that purpose.

The following table was prepared from information available at the meeting:

Observatory	Person in charge	Region covered	Dispersion	Limiting magnitude
McCormick	Vyssotsky	+90° to −15°	300 A./mm.	12
Bergedorf	Wachmann	North sel. areas	,,	13
Potsdam	?	South sel. areas	,,	12
Case	Nassau	Selected regions	280 A./mm.	12·5
Tonanzintla	Erro	?	,,	12·5
Harvard	Mayall	+20° to −90°	400 A./mm.	11·5
Palomar	Zwicky	?	?	12·5
Vatican	—	—	—	—
Stockholm	—	—	—	—

10. *Mrs Mayall's report on spectral classification.* The work of the Henry Draper Extension is being continued at Harvard and the next volume will be published in the early fall of this year. It will contain all of Miss Cannon's unpublished spectrum classifications, supplemented by a few of mine, about 85,000 stars in all. My current programme

is a large Milky Way region extending south from Monoceros. I am continuing my Sagittarius nova patrol programme, and have a spectrum plate taken about once a month during the observing season on each of three selected centres in the Sagittarius-Scorpius cloud. I am also having spectrum plates taken to cover the whole southern sky, from $+20°$ to $-90°$, limiting magnitude about 11·5.

11. Mrs Burbidge suggests investigations of all Be stars which show some changes for the purpose of studying magnetic fields.

12. Mlle Bloch reports on recent observations of Nova Ser 1948 and Nova Cygni 1948 at l'Observatoire St Michel. A sudden change in the spectrum of Nova Ser 1948 on June 16 is especially interesting; unfortunately, Mlle Bloch's observations at that time have large gaps; hence it would be very important to know whether other observers possess spectra of the Nova at about that time.

13. Fehrenbach reports on a method of measuring radial velocities by means of an objective prism; his results are very promising and the method constitutes a great improvement over previous ones.

14. *A scheme of classification of the spectra of Novae.* The lack of a uniform and generally understood nomenclature of the systems of lines and the stages of development of the spectrum of a Nova is a very great difficulty that is encountered by all stellar spectroscopists working on that field. This is probably due to the fact that each star has been studied in detail by a different investigator, and the manner of presentation of the results has been therefore different in each case. Now several good records of the spectra of different Novae are available and enough is known about the normal sequence of stages to justify an attempt at a general classification.

In attempting a classification of the spectra of Novae, it has to be borne in mind that often these spectra are very complex in the sense that at the same time several sets or *systems* of lines are present both in absorption and emission, which are distinguished from each other by a common radial velocity, excitation potential, etc. These systems differ somewhat in different Novae, but they have, nevertheless, some common features which permit one to recognize them and justify the use of the same designation. It is suggested that Roman numerals be used to indicate the systems of lines, leaving the general letter Q followed by a number for the designation of the more or less complex spectrum which results from the superposition of several systems of lines and is characteristic of each stage of development. The following systems seem to be normal in ordinary Novae:

Premaximum	Absorption I	Emission I
Principal	Absorption II	Emission II
Diffuse Enhanced	Absorption III	Emission III
Orion	Absorption IV	Emission IV
Nitrogen III (λ4640)	Absorption V	Emission V
η Carinae (forbidden Fe II)	—	Emission VI
Nebular	—	Emission VII
Wolf-Rayet	—	Emission VIII

Systems I and II often closely resemble spectra of normal stars (usually super-giants); in these cases the spectral type may be added in parentheses, for instance II (F 5) is a fair and short description of the principal spectrum of N Her 1934. Absorption III consists of a few rather broad lines of hydrogen and ionized metals, and absorption IV (usually indicated as 'Orion spectrum') consists of lines of N II, O II, C II, He I, etc. These absorption systems are often multiple, consisting of several components of different radial velocities. For distinguishing between components of different radial velocities the use of subscript Arabic numerals is suggested, such as III_1, III_2, ...; at different times the various components can be identified mainly on the basis of their history. Absorption and emission V are especially characterized by their connection with the well-known band at λ4640. Emissions VI, VII and VIII are sufficiently described by their name.

As far as the spectrum on the whole is concerned, the following classification is proposed:

Q 0. This should be the spectrum, at present practically unknown, of a Nova before its outburst.

Q 1. The spectrum before maximum, consisting of absorption I and emission I.

Q 2. The spectrum at maximum, or better, immediately after maximum, consisting of absorption and emission II.

Q 3. The 'diffuse enhanced absorption' stage; a complex spectrum consisting of absorptions and emissions II and III (the latter being often multiple).

Q 4. The 'Orion absorption' stage. The spectrum consists mainly of absorptions and emissions II and IV, but absorption and emission III are also present.

Q 5. Two alternative classes, Q 5w and Q 5f; the first is characteristic of fast Novae and the second of slow Novae, although this rule might have exceptions.

Q 5w consists of emissions and absorptions II, IV and V; sometimes emission and absorption III are faintly present.

Q 5f is the 'eta Carinae' stage of slow Novae, characterized by emission VI, but emissions and absorptions II and IV and sometimes III are also present.

Q 6w and Q 6f are long transition stages in which emissions V and VII or respectively VI and VII are present at the same time, with different intensity.

Q 7. The 'nebular stage' consisting practically only of emission VII.

Q 8. The 'Wolf-Rayet' stage. The stellar spectrum consists of emission VIII on a weak continuum; emission VII is also present, but belongs clearly to the nebula.

Q 9. The 'final' stage consisting of emission VII (very faint) for the nebula and a stellar spectrum which in many cases is practically continuous. It cannot be decided at present if spectrum Q 9 is identical with spectrum Q 0.

The following items may be added to this general description:

(1) In almost all cases 'transition' stages are defined which often last long; they may be indicated, using two numbers. For instance, Q 1–2 will be the transition stage from Q 1 to Q 2.

(2) In all stages there are peculiarities which cannot be indicated with the preceding short description; especially important is the presence of molecular bands in some Novae.

(3) Attention should be paid to the presence of forbidden lines of O I, N II, etc., in the early stages. A short note may be added in this respect.

(4) In some cases there have been observed 'regressions' from a later stage to an early one, although in a 'normal' Nova the stages as indicated are more or less in chronological order.

(5) The development of some Novae (especially the so-called 'recurrent' Novae like TCrB, RS Oph, T Pyx, etc.) usually does not follow closely the sequence previously described. No suggestions are offered for a classification in these cases.

It is obvious that future work might suggest alterations to the preceding scheme; but it is felt that the present outline may be used advantageously for the preparation of an Atlas of the spectra of Novae.

30. COMMISSION DES VITESSES RADIALES STELLAIRES

PRESIDENT: M. J. A. PEARCE, *Dominion Astrophysicist, Dominion Astrophysical Observatory, Victoria, B.C., Canada.*

MEMBERS: MM. Albitzky, Bok, Edmondson, Hiltner, F. S. Hogg, Joy, McLaughlin, P. W. Merrill, J. H. Moore, Neubauer, Petrie, Popper, Redman, Sanford, G. A. Shajn, Struve, R. E. Wilson.

SUB-COMMISSION ON STANDARD VELOCITY STARS

CHAIRMAN: M. SANFORD.

MEMBERS: MM. J. H. Moore, Pearce.

SUB-COMMISSION ON CO-OPERATION IN RADIAL VELOCITY OBSERVATIONS

CHAIRMAN: M. MOORE.

MEMBERS: MM. F. S. Hogg, Joy, McLaughlin, Pearce, G. A. Shajn, Struve.

SUB-COMMISSION ON WAVE-LENGTHS

CHAIRMAN: M. PETRIE.

MEMBERS: MM. Adams, Albitzky, Neubauer, Struve, R. E. Wilson.

Since the last meeting of the Union, this Commission has lost two valued members, Dr W. E. Harper and Dr J. S. Plaskett, a past-President of this Commission. Both Harper and Plaskett made extensive contributions in the field of stellar radial velocities.

The recent war seriously hindered research at all observatories, many of the institutions carrying on with reduced staffs and greatly diminished resources. The most serious blow to the work of this Commission was the destruction of the Pulkova and Simeis Observatories. The sympathy of the Commission is extended to our Russian colleagues for the loss of their splendid equipment and the destruction of their accumulated photographs. The hope is expressed that their important spectroscopic researches, so tragically interrupted, may soon be resumed.

SURVEY OF RADIAL VELOCITY WORK

During the past decade, radial velocity programmes have been energetically conducted and gratifying progress may be reported. The velocities of 3000 stars have been published and a considerable number of additional velocities await publication. This progress is due, in part, to several recent technical improvements; all large reflectors have been aluminized, and the optics of most spectrographs have been coated with non-reflecting fluoride films. Improved photographic emulsions have been further sensitized by baking or by mercury vapour sensitization. Fast Schmidt Camera spectrographs are in use at the Mount Wilson and McDonald Observatories permitting spectra of the 12th magnitude stars to be secured with reasonably short exposures. A substantial reduction in the labour of measuring spectrograms represents an important advance. Petrie, at Victoria, has introduced the projection comparator which reduces the time of measurement and reduction to one-half its former value, and at the Lick Observatory Johnson has constructed an experimental model of an automatic measuring machine.

Extensive programmes recently completed at Mount Wilson include:

(*a*) approximately 1000 F–M stars of 6th–9th visual magnitudes in Boss's *Preliminary General Catalogue*. The radial velocities of all stars with $\mu > 0''.1$ per annum have now been determined;

(*b*) the velocities of 400 M type giants by R. E. Wilson;

(*c*) the velocities of 180 dwarf stars with $\mu > 0''.35$ per annum by Joy, including stars of the lowest luminosity thus far observed for radial velocity;
(*d*) the velocities of over 280 R- and N-type stars by Sanford;
(*e*) the velocities of 204 stars in the region of the Taurus cluster by R. E. Wilson.

Among the current programmes at this Observatory may be mentioned:
(*a*) the observation of some 300 stars in the Kapteyn areas for which velocities have not been determined;
(*b*) a programme of the separate components of 200 visual binaries being observed by Joy and R. E. Wilson;
(*c*) the investigations of the O–B3 stars in 32 galactic open clusters by Sanford.

At the Lick Observatory, Moore and Paddock have completed their programme of 820 F–G-type stars of photographic magnitude 8·5–8·6, distributed fairly uniformly over the sky north of declination $-30°$. Neubauer has published the velocities of 433 O–B5 stars in the declination zone $0°$ to $-23°$; the great majority of the 3000 spectrograms were taken with a dispersion of 75 A./mm., although for some 80 stars fainter than magnitude 9·4, a dispersion of 150 A./mm. was employed. The current observations of some 200 faint O–B5 stars in the declination zone $0°$ to $+20°$ are well advanced. Trumpler's extensive investigation of some 670 stars in 80 open clusters, north of declination $-35°$, is now practically complete and his results are awaited with great interest.

At the David Dunlap Observatory, during the years 1935–42 the velocities of 874 stars brighter than photographic magnitude 7·59 in and near the Kapteyn areas in the northern hemisphere were determined. A second programme recently completed comprised 681 A–M-type stars brighter than magnitude 8·0, selected from Schlesinger's *Bright Star Catalogue*. Current programmes at this institution include:
(*a*) the observation of 1043 G–M-type stars brighter than magnitude 9·0, selected from the *Yale Zone Catalogue*;
(*b*) a programme of 105 stars brighter than magnitude 7·6 in the northern Kapteyn areas between RA 9^h and 18^h.

During the years 1938–41, two series of radial velocity observations were carried on at the Simeis Observatory by Shajn and Albitzky:
(*a*) a programme of 200 F5–K5-type stars between the magnitudes 6·5–7·5, for which a camera having a dispersion of 74 A./mm. at Hγ was employed;
(*b*) the observation of 100 bright A0–F2 stars whose spectra were photographed with a dispersion of 36 A./mm. at Hγ.

The results are in part being prepared for publication, but it will be some years before spectrographic work, interrupted by the war, is resumed.

At the McDonald and Yerkes Observatories, the 82-inch reflector and the 40-inch refractor have been used principally for spectrographic studies of spectrum and eclipsing variables, peculiar stars, and interesting binary systems. A number of important radial velocity contributions have been made: Seyfert and Popper determined the velocities of 268 faint class B stars, between photographic magnitudes 9·0–11·0. Two plates of each star were obtained with a II-prism spectrograph equipped with an *f*/2 Schmidt Camera of 180 mm. focal length, the resulting dispersion being 76 A./mm. at Hγ. The spectra were photographed on films, not generally preferred for radial velocity work. A systematic correction of $-2{\cdot}1 \pm 0{\cdot}8$ km./sec. to their velocities was deduced from 58 observations of 23 brighter B-type stars. The velocities of such faint and distant stars are very important for studies of galactic rotation and it is hoped that this programme will be continued.

The radial velocities of some 158 stars of large proper motion were determined by Popper, Munch and Luyten. Struve and Smith published the velocities of 71 stars of the Pleiades cluster, and 20 O- and B-type stars in and near the galactic cluster N.G.C. 6231 were observed by Struve.

The radial velocities of 708 10th magnitude K-type stars, contained in the McCormick Proper Motion Catalogues have been determined by Edmondson. The majority of the observations were made at the McDonald Observatory and the remainder at Mount Wilson. The linear dispersions of the spectrographs employed were 152 A./mm. and 120 A./mm.

at Hγ respectively. The preliminary analysis shows interesting results: a large and well-determined velocity dispersion was found, and 6% of the stars have peculiar motions exceeding 63 km./sec., all directed towards galactic longitudes between 120° and 0°. The observations of the 400 10th magnitude A-type stars are two-thirds complete. The dispersion used to photograph the spectra of these stars is 324 A./mm. at Hγ. The radial velocities of these faint stars of known proper motion will make important contributions to our knowledge of the motions of these stars.

At the Dominion Astrophysical Observatory extensive radial velocity work is in progress. The most important of these is a programme of 800 stars of spectral types B 5 and earlier, north of declination +10° and between visual magnitudes 7·5 and 9·5, being observed by Pearce and Petrie. In addition to accurate radial velocities, it is important that these stars be classified as precisely as possible and that reliable luminosities be derived. For these reasons a dispersion of 51 A./mm. at Hγ is used and the spectra are made sufficiently wide (0·2 mm.) so that the photometry of important faint lines and the interstellar *K* line may be carried out. Relatively fine-grain emulsions are used. The exposures are necessarily long and progress consequently slow, but to date observing is about two-thirds completed. In the course of this programme a number of massive binary systems have been discovered and their orbits have been investigated. An auxiliary programme of 95 O to B 5 stars between visual magnitudes 5·5 and 7·5 has been completed. These stars have been observed in order to strengthen previous results. The plates have been measured and the results await publication.

Some 300 spectra of 70 members of the Pleiades cluster have been obtained by Pearce. He has determined radial velocities for the B-type members and will now measure the spectra of the A to G stars using the recently revised wave-length standards. The dispersion employed for the brighter members is 20 A./mm. and 30 A./mm. at Hγ and for the fainter stars it is 51 A./mm. The mean radial velocity from the fifteen brightest members is $+7{\cdot}8 \pm 0{\cdot}2$ km./sec.

The bright members of the Ursa Major Cluster have been observed with high dispersion (11 A./mm. at Hγ) by Petrie. The radial velocities of 19 stars have been determined and the results await publication.

The programme of stars near the galactic pole is mentioned elsewhere. Other studies include lists of selected visual binaries and some galactic clusters being observed by Petrie. In addition, a number of spectroscopic binaries are being followed for orbit determinations.

Galactic Pole Programmes

For the past three seasons, Petrie has been engaged upon a programme of 250 A–F 5-type stars, visual magnitudes between 6·5–9·5, in the region of the North Galactic pole. Three plates of each star are being secured with a dispersion of 51 A./mm., and the observations are 50% complete. A similar programme is being undertaken by Weaver at the Lick Observatory, who is observing 277 stars selected from Malmquist's list (*Lund Medd.* **4**, No. 37), brighter than photographic magnitude 12·1 and bluer than C.I. 0·45. He plans to obtain three to four plates of each star, and the linear dispersion of his spectrograph is 75 A./mm.

These programmes are undertaken to provide accurate data for the analysis of motions perpendicular to the galactic plane.

Objective Prism Radial Velocities

The comprehensive programme of determining the radial velocities of the 10th magnitude stars in selected fields along the entire Milky Way, attempted at Harvard (*H.A.* **101**), has unfortunately been abandoned. Bok reports that the results of their two-year research are affected by unexplained systematic errors. Pending the construction of specialized equipment suggested by Baker, this worth-while programme has been discontinued. At the Simeis Observatory Shajn and Albitzky, using a 120 mm. prismatic camera,

succeeded in obtaining satisfactory results for stars brighter than the 8th magnitude. By taking six plates per star and carefully correcting for field distortion, probable errors could be reduced to ± 8 km./sec.

The ingenious suggestion of Prof. R. W. Wood of securing objective prism spectra by means of a 'bi-prism grating' was tested out by MacRae and Bok (*Publ. A.A.S.* **10**, 60, 1940), who mounted a 6-inch 'bi-prism grating' over a 16-inch objective. The dispersion of the combination was 100 A./mm. at $H\gamma$, and exposures of 2 hours were necessary to obtain spectra of the 9th magnitude stars; the radial velocities had probable errors of ± 10 km./sec. The principal objection to this method is the great difficulty of constructing a first-order mosaic grating yielding spectra of excellent quality.

At the new Observatoire de Haute Provence, Fehrenbach has suggested the use of a new type of prism designed to reduce field corrections (*Annales d'Astroph.* **10**, 306, 1947). The results for the few stars obtained are very promising. The use of a Wernicke prism to eliminate distortion is proposed by Treanor (*The Observatory*, **68**, 94, 1948); he further suggests that an undispersed star image superimposed upon the spectrum would be a better calibration mark than the usual neodymium chloride line. Results obtained by these two new methods, tested on large-scale programmes of several hundred stars, are awaited with great interest.

The importance of expediting the radial velocities of the faint stars justifies the continuation of research to find a satisfactory objective-prism method of obtaining velocities with probable errors reduced to the limit set by statistical studies.

Spectroscopic Binaries

Spectroscopic binaries have been energetically observed at all observatories engaged in radial velocity work, but especially at the McDonald Observatory by Struve and his collaborators. It is not possible here fully to review the progress in this field, but mention should be made of Struve's researches on binaries accompanied by gaseous shells or streams, Hiltner's studies of Wolf-Rayet systems, and Petrie's extensive spectrophotometric determinations of light ratios. Many stars have been re-observed in order to study possible changes in their elements; observations of eclipsing variables as faint as the 9th magnitude have been undertaken at the Mount Wilson and McDonald Observatories, and at Victoria. As a general rule orbital elements are computed for all double-lined class B binaries discovered at the Lick and the Dominion Astrophysical Observatories.

The rapid accumulation of information on binary systems has made the publication of a new catalogue highly desirable. This has been undertaken by Moore and Neubauer, whose *Fifth Catalogue of Spectroscopic Binaries* containing the orbital elements of 475 systems published prior to January 1, 1947, is now in the press. The thanks of the Commission are here recorded and extended to these members for their work.

Catalogue of Radial Velocities

During the 16 years since the publication of the Lick General Catalogue, the number of radial velocities has increased from 6723 to approximately 12,000. With the completion of current programmes, within 3 years it is estimated that velocities will have been determined for at least 14,000 stars. The publication of a New General Catalogue so that these velocities may be available to students of stellar motions should not long be delayed. Discussions should be initiated at once, so that the best form of the catalogue may be agreed upon, and an editor selected to undertake this important task.

Radial Velocities of the Southern Stars

Unquestionably the most pressing need for additional radial velocities is in the southern hemisphere, where for one-quarter of the galaxy few observations exist for stars fainter than the 6th magnitude. The urgent need for these velocities has long been recognized and has been clearly manifested in all studies of stellar motions.

A resolution of this Commission, adopted by the General Assembly at the 1932 meeting, materially assisted in the establishing of the Radcliffe Observatory at Pretoria. One of the principal programmes planned with its 6-foot reflector was the determination of the radial velocities of the early-type stars, but unfortunately, for our work, that institution is still without spectrographic equipment. The present meeting would seem to be an appropriate time for this Commission to urge the International Astronomical Union to use every possible influence in expediting the delivery of spectrographic equipment to the Radcliffe Observatory, in order that spectrographic observations in the southern hemisphere, discontinued nearly two decades ago, may be resumed.

Reports of Sub-Committees

The following reports indicate that considerable progress has been made in these fields. The results accomplished are largely due to the personal efforts of the Chairmen of these sub-committees to whom the President desires to express the thanks of the Commission.

Agenda

The following subjects are proposed for the consideration of the Commission:

(*a*) discussion on and disposal of the reports of the three sub-committees;
(*b*) considerations of the format of a new General Catalogue of Stellar Radial Velocities;
(*c*) the desirability of publishing a sixth catalogue of spectroscopic binary stars;
(*d*) considerations of the best means of having spectrographic observations secured by observatories in the southern hemisphere;
(*e*) discussion of other subjects arising out of the Report;
(*f*) reorganization of the Commission.

J. A. Pearce
President of the Commission

REPORT OF SUB-COMMISSION ON STANDARD VELOCITY STARS

It seems best for ease of reference to republish the list of stars for standards of radial velocity which appeared in these *Transactions* (**3**, 171, 1928). In doing so the final values of the velocities as given in *Publ. of the Lick Observatory*, **18**, 1932, the co-ordinates for 1950, and the types as revised at Mount Wilson are given in Table I.

The other star list for standards of radial velocity, which was published in these *Transactions* (**5**, 191, 1935), was intended for use with low-dispersion instruments for which the stars in the first-mentioned list might be too bright. These velocities have been strengthened by numerous additional spectrograms obtained at the Mount Wilson Observatory either with a prismatic dispersion of 35 A./mm. at Hγ or of 10 A./mm. with the Coudé grating spectrograph at the 100-inch telescope. A study of all the velocities which have been obtained led to the rejection of eight stars which appear in the earlier list because of a suspicion of variability. It is recommended that the remainder (Table II) now be used instead of the list in **5**, 191, 1935.

Table I

Revision of Recommended Standard Velocity Stars
(*Trans. I.A.U.* **3**, 171, 1928)

HD	Name	Mag.	Type	α (1950) h. m.	δ (1950) ° ′	V (km./sec.)	No. obs.
3712...	α Cas	2·47	G7	0 37·7	+56 16	− 3·8±0·1	41
4128...	β Cet	2·24	G6	0 41·1	−18 16	+13·1±0·1	70
12929...	α Ari	2·23	K1	2 4·3	+23 14	−14·3±0·1	130
18884...	α Cet	2·82	M2	2 59·7	+ 3 54	−25·7±0·1	27

TABLE I (*continued*)

HD	Name	Mag.	Type	α (1950) h. m.	δ (1950) ° ′	V (km./sec.)	No. obs.
20902...	α Per	1·90	cF4	3 20·7	+49 41	− 2·4±0·1	245
29139...	α Tau	1·06	K5	4 33·0	+16 25	+54·1±0·0	168
36079...	β Lep	2·96	G1	5 26·1	−20 48	−13·5±0·1	42
36673...	α Lep	2·69	cF3	5 30·5	−17 51	+24·7±0·2	19
45348...	α Car	−0·86	cF0	6 22·8	−52 40	+20·5±0·0	114
62509...	β Gem	1·21	G8	7 42·3	+28 9	+ 3·3±0·0	171
81797...	α Hya	2·16	K5	9 25·1	− 8 26	− 4·4±0·0	68
84441...	ε Leo	3·12	cG3	9 43·0	+24 0	+ 5·1±0·1	50
87737...	η Leo	3·58	cA0p	10 4·6	+17 0	+ 2·2±0·2	22
102870...	β Vir	3·80	F8	11 48·1	+ 2 3	+ 5·0±0·1	22
108903...	γ Cru	1·61	M4	12 28·4	−56 50	+21·3±0·1	28
109379...	β Crv	2·84	G4	12 31·8	−23 7	− 7·7±0·1	50
124897...	α Boo	0·24	K0	14 13·4	+19 27	− 5·1±0·0	494
146051...	δ Oph	3·03	M0	16 11·7	− 3 34	−19·8±0·2	29
150798...	α Tri	1·88	K4	16 43·4	−68 56	− 3·7±0·1	27
156014*...	α^1 Her	3·48	M5	17 12·4	+14 27	−32·5±0·1	24
168454...	δ Sgr	2·84	K2	18 17·8	−29 51	−20·0±0·0	43
172167...	α Lyr	0·14	A1s	18 35·2	+38 44	−13·8±0·1	219
186791...	γ Aql	2·80	K4	19 43·9	+10 29	− 2·0±0·1	56
204867...	β Aqr	3·07	cG1	21 28·9	− 5 48	+ 6·7±0·1	44
206778...	ε Peg	2·54	cK0	21 41·7	+ 9 39	+ 5·2±0·3	74
222368*...	ι Psc	4·28	F5	23 37·4	+ 5 21	+ 5·2±0·2	17

* Suspected to have slightly variable velocity.

TABLE II

Revision of Recommended Standard Velocity Stars

(*Trans. I.A.U.* **5**, 191, 1935)

HD	Name		Mag.	Type	α (1950) h. m.	δ (1950) ° ′	V (km./sec.)	No. obs.
3765...	Lal.	1045	7·5	K5	0 38·1	+39 55	− 62·7±0·4	7
8779...	Boss	320	6·5	K0	1 23·9	− 0 39	− 5·9±0·7	6
9138...	μ Psc		5·1	K4	1 27·6	+ 5 53	+ 35·1±0·5	16
26162...	Boss	952	5·7	K1	4 6·2	+19 29	+ 23·8±0·6	18
29587...	Groom	864	7·3	G2	4 38·1	+42 2	+112·1±0·3	7
35410...	Boss	1300	5·2	K0	5 21·9	− 0 56	+ 20·6±0·4	12
44131...	Boss	1599	5·2	M1	6 17·5	− 2 55	+ 46·7±0·2	16
65583...	Lal.	15565	6·9	G7	7 57·4	+29 22	+ 13·0±0·4	7
66141...	Boss	2130	4·5	K3	7 59·7	+ 2 28	+ 70·7±0·3	14
89449...	Boss	2741	5·0	F5	10 17·0	+19 44	+ 5·9±0·4	10
92588...	Boss	2846	6·4	K1	10 38·9	− 1 29	+ 43·5±0·4	10
103095...	Boss	3112	6·5	G5	11 50·1	+38 5	− 98·8±0·4	15
107328...	Boss	3213	5·1	K1	12 17·8	+ 3 35	+ 35·5±0·1	11
114762...	Cin.	1695	7·7	F7	13 9·9	+17 47	+ 50·2±0·5	6
123782...	Boss	3631	5·4	M2	14 6·4	+49 42	− 13·0±0·4	16
144579...	Groom	2305	6·8	G8	16 3·2	+39 17	− 59·2±0·4	9
145001...	κ^1 Her		5·3	G4	16 5·8	+17 11	− 9·5±0·3	6
184467...	Groom	2875	6·7	K5	19 30·3	+58 29	+ 12·8±0·5	7
187691...	o Aql		5·2	F8	19 48·6	+10 17	− 0·4±0·5	13
212943...	Boss	5790	4·9	K0	22 25·3	+ 4 27	+ 53·9±0·3	13
213014...	Lal.	43876	7·5	G8	22 25·8	+17 0	− 39·7±0·6	8

R. F. SANFORD,
J. H. MOORE,
J. A. PEARCE.

REPORT OF SUB-COMMISSION ON CO-OPERATION IN RADIAL VELOCITY OBSERVATIONS

In order to prevent needless duplication of effort in the observation of the radial velocities of spectroscopic binaries, light variables, etc., where an extensive series of spectrograms of each object is required, your Sub-Committee prepared a list of such stars under observation on January 1, 1935, copies of which were distributed to the seven observatories interested in radial velocity work. A revision of this list containing 289 stars being observed at nine observatories was published in *Trans. I.A.U.* **6**, 259, 1938. Experience with this method of co-operation appears to justify its continuance and the Sub-Committee, therefore, has prepared a new list on the basis of data furnished by seven observatories now engaged in radial velocity determinations.

The accompanying table lists the spectroscopic binaries, light variables and other special stars under spectroscopic observation on January 1, 1948 at the six observatories indicated in column 6 by the following abbreviations:

D = David Dunlap	W = Mount Wilson
L = Lick	Y Md = Yerkes and McDonald
M = Michigan	V = Victoria

For the Yerkes and McDonald Observatories the observer who is studying the star is indicated in parentheses, by H = Hiltner, J = Jose, P = Popper and S = Struve; for the Lick by Hg = Herbig, Ne = Neubauer, Tr = Trumpler and We = Weaver; and at Victoria by McK = McKellar, Pt = Petrie and Wr = Wright. In the final column a brief notation is given of the purpose for which the star is being observed, O = orbital elements; O red = redetermination of orbital elements; sp var = spectral variation; sh per var = short period variation in velocity or spectrum or both; irreg vel var = irregular velocity variation; atm ecl effects = atmospheric eclipse effects in spectrum; etc. Additional data concerning the star or purpose for which observations are being obtained are given in the notes following the table and indicated by an asterisk (*).

The list contains the data for 252 stars of which only seven are under observation at more than one observatory. For 164, orbital elements are being determined, of which number, 63 are eclipsing variables. The other 88 stars, many of which are known intrinsic light variables, are being studied for spectral or velocity variations or both.

It is believed that the information contained in the final column increases considerably the value of such a list, not only to spectroscopists who may find it desirable to co-operate in the observation of certain stars, but also to photometric observers of eclipsing variables, when knowledge that a spectroscopic orbit will be available may influence their choice of object or prevent them from needlessly obtaining a series of radial velocity observations.

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A. H. Joy,
D. B. McLaughlin,
J. A. Pearce,
G. A. Shajn,
O. Struve,
J. H. Moore, *Chairman.*

Variable Velocity Stars under Observation

Stars	α 1950 h. m.	δ ° ′	Mag.†	Sp	Observatory	Purpose
TW And	0 00·7	+32 34	Ecl	dF0+G0	Y Md (S, H)	O
225093	00·8	+72 53	7·5	A2	D	O
2019	22·0	+31 06	6·8	B9	D	O
TU Cas	23·6	+51 00	Var	F8v	W	vel curve
k Cass	30·1	+62 39	4·2	B0	D	sh per var?
3264	33·4	+48 17	7·4	B2	D	O

† Mag. Magnitudes are visual, except those printed in heavy type, which are photographic.

VARIABLE VELOCITY STARS UNDER OBSERVATION (*continued*)

Stars	α 1950 h. m.	δ ° ′	Mag.	Sp	Observatory	Purpose
δ And	36·6	+30 35	3·5	K4	L	O
3881	39·1	+59 39	7·4	A6	D	O
64 Psc	46·3	+16 40	5·2	F6	L	O
BM Cas	51·7	+63 48	Ecl	cA5	Y Md (P)	O
γ Cas	53·7	+60 28	Var	B0nne	M	sp var
σ Psc	1 00·1	+31 32	5·5	B9	L (e)	*
ο Psc	11·0	+24 19	4·6	G7	L	O
*+57° 252	16·5	+58 00	9·7	B2	L (Tr)	O
47 And	20·8	+37 28	5·5	A3	Y Md (J)	O
8634	22·8	+23 15	6·1	F5	V (Wr)	O
8862	25·2	+43 47	6·6	B9	D	O
XX Cas	26·2	+60 42	Ecl	B4n+B6	Y Md (H)	O
9021	27·5	+70 00	6·0	F5	V (Wr)	O
AX Per	33·2	+54 00	Var	M+pec	D	sp var
10588	41·0	+31 58	6·4	G5	D	O
α UMi	48·6	+89 02	Var	cF7	L	long per O
ζ Cet	49·0	−10 35	3·9	K0	L	O
ξ Psc	51·0	+ 2 56	4·8	G7	L	O
β Ari	51·9	+20 34	2·7	A3	L (We)	O red*
XZ And	53·8	+41 52	Ecl	A0	Y Md (H)	O
60 And	2 10·1	+44 00	5·1	K5	L	O
65 Cet	10·3	+ 8 37	4·5	G4	L	O
*+56° 587	18·7	+56 54	9·6	B2	L (Tr)	O dbl ls
14688	19·8	+16 39	6·8	A1s	D	O
15138	24·5	+50 20	6·3	F2	D	O
*+60° 497	28·2	+61 23	9·0	O8	L (Tr)	O
*+60° 501	28·8	+61 15	9·8	O9	L (Tr)	O
*+60° 502	28·9	+61 14	7·8	O7	L (Tr)	irreg vel var
*+59° 552	47·2	+60 13	7·1	O8	L (Tr)	O (triple)
SU Cas	47·5	+68 41	Var	F2–F9	D	sp var
γ Per	3 01·1	+53 19	3·1	G0+A2	M	O
β Per	04·9	+40 46	Ecl	B8	M	O (triple)
RS Ari	11·5	+27 40	Ecl	F9+G5	Y Md (H)	O
ζ Eri	13·4	− 9 00	4·9	A3	L	O
20336	15·5	+65 28	4·8	B3ek	M	sp var
ο Tau	22·1	+ 8 51	3·8	K1	L	O
23626	44·6	+32 03	6·2	F6	D	O
23862	46·2	+24 00	5·2	var pec	M	sp var
X Per	52·2	+30 54	Var	B0nne	M	sp var
RW Tau	4 00·8	+28 00	Ecl	B9 (K0e)	WY Md (H) V (Pt)	O
*+50° 940	11·2	+51 07	8·9	cB9	L (Tr)	O
52 Per	11·5	+40 22	4·9	cG3	L	O
27483	18·0	+13 45	6·1	F4	D, V (Wr)	O
29104	32·7	+19 47	6·6	F8	D	O
B 1074	33·2	+41 10	4·5	K0+A3	M, W	O
R Lep	67·3	−14 53	Var	N6o	W	vel curve
ϵ Aur	58·4	+43 44	Ecl	F5p	M	O
ζ Aur	59·0	+41 00	Ecl	K5+B1	M	atm ecl effects
BF Aur	5 01·5	+41 13	Ecl	A0	D	O
η Aur	03·0	+41 10	3·3	B3	D	sh per var?
RW Aur	04·6	+30 20	Var	G0	W	vel curve
ρ Ori	10·7	+ 2 48	4·6	K3	L	O
UV Aur	18·5	+32 28	Var	Nep	W	vel curve
35189	20·8	+16 39	6·1	A1s	D	O
35439	22·1	+ 1 48	4·7	B3ne	M	sp var
114 Tau	24·6	+21 54	4·8	B3	D	sh per var?

Stars	α 1950 h. m.	δ ° ′	Mag.	Sp	Observatory	Purpose
FO Ori	5 25·5	+ 3 34	Ecl	—	Y Md (S)	O
δ Ori	29·5	− 0 20	Ecl	B1nk	Y Md (S)	O
36484	30·2	+32 46	6·5	A2	D	O
VV Ori	31·0	− 1 11	Ecl	B2	Y Md (S)	O
ι Ori	33·0	− 5 56	2·9	O8sk	L (We)	O red*
*+34° 1103	33·0	+34 07	8·5	B2	L (Tr)	O
*+34° 1107	33·1	+34 06	9·2	B2	L (Tr)	O
T Ori	33·3	− 5 30	Var	A3e	L (Hg)	vel curve
ζ Tau	34·7	+21 07	3·0	B3e	M	O sp var
σ Ori	36·2	− 2 38	3·8	B0	D	sh per var?
37366	36·2	+30 52	7·5	B3	D	O
B 1399	38·3	− 1 09	5·0	B3	L (We)	O red*
40372	55·8	+ 1 50	6·1	A5	D	O
60 Ori	56·2	+ 0 33	5·2	A0	L	O
AZ Aur	57·7	+39 39	Var	Ne	W	vel curve
μ Ori	59·6	+ 9 39	4·2	A2	Y Md (P)	var vel sys
CQ Aqr	6 00·6	+31 19	Ecl	—	D	O
41335	01·8	− 6 42	5·1	B2e	M	sp var
*+24° 1123	06·0	+24 22	7·8	B4	L (Tr)	var vel doubtful
WY Gem	08·9	+23 14	Var	M3ep	D	sp var
η Gem	12·2	+22 32	Var	M3	M	O
SV Mon	18·8	+ 6 30	Var	F8–K5	D	sp var
44458	19·1	−11 45	5·5	B2ne	M	sp var
BN Mon	19·3	+ 7 22	Var	N	W	vel curve
T Mon	22·5	+ 7 07	Var	cG4v	W	vel curve
45194	23·8	+13 08	6·6	F8	D	O
10 Mon	25·5	− 4 44	5·0	B3	D	sh per var?
β′ Mon	26·4	− 7 00	4·7	B3ne	M	sp and vel var
*+4° 1299	29·4	+ 4 55	8·5	B1	L (Tr)	O dbl ls
RW Mon	32·0	+ 8 52	Ecl	A0	D	O
SV Cam	35·1	+82 19	Ecl	dG3+dG5	Y Md (H)	O
47415	36·5	+24 39	6·5	F8	D	O
*+9° 1332	37·8	+ 9 51	7·8	B5	L (Tr)	O dbl ls
42 Cam	45·7	+67 38	5·0	B3	D	sh per var?
RX Gem	46·9	+33 18	Ecl	A2	V (Pt)	O red
SS Cam	7 10·3	+73 25	Ecl	gG1+dF5	Y Md (H)	O
*−10° 1933	12·1	−10 14	6·0	O9	L (Tr)	long per vel var
27 CMa	12·2	−26 16	4·7	B5	Y Md (S)	vel curve
*τ CMa	16·6	−24 52	4·4	O9	L (Tr)	O red
RY Gem	24·6	+15 45	Ecl	A2+K	V (McK)	O red
65 Gem	26·7	+28 01	5·1	K1	L	O
U Mon	28·4	− 9 40	Var	G5–K2	D	sp var
B 1985	31·5	−14 24	5·1	K5, B	M	long per vel var?
13 Pup	41·8	−28 50	4·1	cA2ep	L (Ne)	vel curve
63630	48·4	+46 05	6·5	A5	D	O
63887	51·8	+71 50	7·5	A0	D	O
XY Pup	8 07·2	−11 50	Ecl	A3	Y Md (H)	O
TW Cnc	26·9	+12 37	Ecl	G5	Y Md (P)	O
RZ Cnc	36·0	+31 58	Ecl	K0+K4	Y Md (H)	O
TX Cnc	37·2	+19 11	Ecl	—	Y Md (S, P)	O
S Cnc	41·0	+19 13	Ecl	A0 (G5)*	W	O
12 Hya	44·0	−13 22	4·4	G4	L	O
T Cnc	53·8	+20 22	Var	N3	W	vel curve
ξ Cnc	9 06·5	+22 15	5·2	G9	L	O
τ UMa	06·8	+63 43	4·7	cF6	L	O
RS Cnc	07·6	+31 10	Var	M6	W	vel curve
81995	27·4	+44 59	7·1	A5	D	O
82191	28·4	+27 37	6·6	A0	D	O
82780	32·2	+40 11	6·6	F2	D	O

VARIABLE VELOCITY STARS UNDER OBSERVATION (*continued*)

Stars	α 1950 h. m.	δ ° ′	Mag.	Sp	Observatory	Purpose
10 Leo	9 34·6	+ 7 04	5·1	G9	L	O
RT Leo	42·6	+20 09	Ecl	—	Y Md (H)	O
4 Sex	47·9	+ 4 35	6·2	F5	Y Md (P)	O
η Leo	10 04·6	+17 00	3·6	A0p	D	sp var
88815	13·8	+73 19	6·5	F0	V (Wr)	O
μ UMa	19·4	+41 45	3·2	K5	L	O
V Hya	49·2	−21 00	Var	N6	W	vel curve
α UMa	11 00·6	+62 01	2·0	G7	L	vis bin, sh per var
97334	09·8	+36 05	6·9	G0	D	sp var
100018	28·1	+41 34	7·0	F2	V (Pt)	O
105702	12 07·5	+ 6 05	6·0	F0	D	sp var
110533	38·4	+83 55	7·2	F7	V (McK)	O
110628	40·8	+26 24	7·0	F0	D	sp var
ξ^2 UMa	13 23·2	+55 15	4·0	A5n	D	sh per var?
W Vir	23·5	− 3 06	Var	cG0p	W	vel curve
BF Vir	45·3	− 0 21	Ecl	A0	D	O
BH Vir	55·9	− 1 26	Ecl	G0	Y Md (H)	O
UW Boo	14 19·2	+47 19	Ecl	F	D	O
131511	51·1	+19 21	6·0	K0	V (Wr)	O
β CrB	15 25·8	+29 17	3·7	A7s	L (Ne)	sh per var?
TW Dra	33·1	+64 01	Ecl	A6+K2	Y Md (S)	O
B 4008	43·5	− 1 39	5·4	B8	L (We)	O red*
V CrB	47·8	+39 44	Var	N3e	W	vel curve
T CrB	57·4	+26 04	Var	—	W	vel curve
RR Her	16 02·8	+50 38	Var	Nep	W	vel curve
SW Oph	13·8	− 6 51	Ecl	A0	Y Md (H)	O
V Oph	23·9	−12 19	Var	N3e	W	vel curve
*−41° 11037	50·7	−41 46	8·5	O9	L (Tr)	O
*−41° 11042	50·8	−41 46	8·5	O9	L (Tr)	O dbl ls
TT Her	52·2	+16 55	Ecl	A5	Y Md (S)	O
154528	58·3	+77 44	6·7	A0	D	O
WZ Oph	17 04·2	+ 7 50	Ecl	G0+G0	Y Md (H)	O
μ^1 and μ^2 Dra	04·3	+54 32	5·1	F6	L	sh per var?
158013	22·5	+57 02	6·6	A2	D	O
157978–9	23·9	+ 7 38	6·0	G0+A0	M	O (triple)
*−32° 12935	31·4	−32 33	5·7	O7	L (Tr)	O red dbl ls
Y Oph	50·0	− 6 08	Var	F8–G7	D	sp var
Z Her	55·8	+55 01	Ecl	F2+F2	Y Md (H)	O
164898	59·7	+45 21	7·4	A0	D	O
*−24° 13831	18 01·5	−24 22	8·3	B0	L (Tr)	O dbl ls
ζ Sct	20·9	− 8 58	4·8	K0	L	O
AW Her	23·4	+18 16	Ecl	K2+G4	Y Md (H)	O
B 4667	24·7	+ 0 10	5·3	G0+A2	M	O (triple)
V 451 Oph	26·8	+10 51	Ecl	A0	D	O
AC Her	28·2	+21 50	Var	G6ev	W	vel curve
170829	28·6	+20 48	6·6	G8	D	O
172187	35·2	+43 10	6·3	A5	D	O
B 356 Sgr	44·9	−20 20	Ecl	A0	Y Md (P)	O
DI Her	51·4	+24 13	Ecl	B5	V (McK)	O
δ′ Lyrae	52·0	+36 54	5·5	B3	V (McK)	O red
B 4797	52·6	+22 34	4·6	G0+A3	M	O
FF Aql	56·0	+17 18	Var	F5	W, D	vel curve, sp var
V 337 Aql	19 01·5	− 2 08	Ecl	B3n	D	O
TT Aql	05·7	+ 1 13	Var	G5–K0	D	sp var
η Lyr	12·1	+39 04	4·5	B3	D	sh per var?
180316	13·0	−27 51	6·7	B5	D	O
RS Vul	15·5	+22 21	Ecl	B8+B9	Y Md (H)	O

Stars	α 1950 h. m.	δ ° ′	Mag.	Sp	Observatory	Purpose
26 Aql	19 17·9	− 5 31	5·1	K0	L	O
υ Sgr	18·8	−16 04	4·6	B8p	M	sp var
RR Lyr	23·7	+42 42	Var	A5v	Y Md (S), W	var vel curve
TT Lyr	25·9	+41 36	Ecl	A	D	O
183794	28·7	− 2 13	6·7	B8	D	O
β^1 Cyg	28·7	+27 52	3·2	K0+A0	M	slow vel var
U Vul	34·4	+20 13	Var	cG4v	W	vel curve
φ Cyg	37·4	+30 02	4·8	K0	L	O
BR Cyg	39·4	+46 40	Ecl	—	D	O
SVS 873 Cyg	40·3	+31 11	Ecl	B8	L (Hg)	O
SU Cyg	42·8	+29 09	Var	F2p	D	sp var
δ Sge	45·2	+18 24	3·8	Ma+A0	M	O sp var?
CI Cyg	48·4	+35 33	Var	Ocp	D	sp var
SV Vul	49·5	+27 19	Var	K1v	W	vel curve
V 505 Sgr	50·3	−14 44	Ecl	A2	Y Md (P)	O
S Sge	53·7	+16 30	Var	cG3v	L	vel curve, long per O
120073	20 00·6	+ 5 36	7·9	A0p	D	sp var
KR Cyg	07·0	+30 24	Ecl	—	Y Md (H)	O
191610	07·6	+36 42	4·8	B3nne	M	sp var
KU Cyg	11·1	+47 15	Ecl	cF2	Y Md (P)	O
31 Cyg	12·1	+46 35	4·0	K0+B8	M	O
32 Cyg	14·0	+47 34	4·2	K0+A3	M, V (W)	O red
*+37° 3860	14·7	+37 28	8·2	B0	L (Tr)	2 per var ampl
*+37° 3862	14·7	+37 28	9·2	B1	L (Tr)	O (triple)
RW Cap	15·1	−17 50	Ecl	A3+A4	Y Md (H)	O
35 Cyg	16·7	+34 50	5·2	cF5	L	O
MY Cyg	18·1	+33 46	Ecl	A	D	O
U Cyg	18·1	+47 44	Var	Nep	W	vel curve
*+38° 4063	22·0	+38 21	9·0	F5	L (Tr)	O
Bε Vul	23·7	+27 12	Ecl	—	D	O
195987	31·1	+41 43	7·0	G5	V (Wr)	O
196133	32·0	+45 00	6·6	A2	D	O
GO Cyg	35·4	+35 16	Ecl	B9n+A0	Y Md (H)	O
AE Aqr	37·6	− 1 03	Var	G8e	W	vel curve
X Cyg	41·4	+35 24	Var	F8–K0	D	sp var
E Cyg	44·2	+33 47	2·6	K0	L	O
VW Cep	45·5	+75 24	Ecl	G5	Y Md (P)	O
198287–8	46·1	+39 06	7·0	cA7se	W	vel curve
199140	52·2	+28 20	Var	B1	V (Pt)	sh per var
RR Vul	52·6	+27 44	Ecl	A	Y Md (H)	O
S Equ	54·7	+ 4 53	Ecl	B9	V (Pt)	O
CG Cyg	56·2	+34 58	Ecl	F2	D	O
200120	58·1	+47 20	4·9	B3ne	M	sp var
ξ Cyg	21 03·1	+43 44	3·9	cK5	L	O
201032	03·2	+63 11	7·3	A5	D	O
DT Cyg	04·4	+30 59	Var	F5	W	vel curve
203338–9	17·9	+58 24	5·6	M1+B(e)	M	sh per vel var?
203467	18·3	+64 40	5·2	B3nek	M	sp var
205114–5	29·8	+52 24	6·2	K0+A3	M	vel var?
EE Peg	37·6	+ 8 57	Ecl	A0	D	O
AI Cep	44·7	+56 42	Ecl	—	D	O
*+61° 2213	52·0	+62 21	9·1	B3	L (Tr)	O dbl ls
*+61° 2217	52·5	+62 21	7·1	B2	L (Tr)	O
VV Cep	55·3	+63 23	Ecl	M2ep+B	M	O sp var
208835	55·9	+46 37	7·4	B8	D	O
UZ Cyg	57·2	+44 07	Ecl	A3+K1	Y Md (S)	O
RT Lac	59·5	+43 39	Ecl	G9+K1	Y Md (H)	O
AR Lac	22 06·6	+45 30	Ecl	K0+G5	D, W, Y Md (H)	O
212076	19·1	+11 57	4·9	B3e	M	sp var

VARIABLE VELOCITY STARS UNDER OBSERVATION (*continued*)

Stars	α 1950 h. m.	δ ° ′	Mag.	Sp	Observatory	Purpose
π Aqr	22 22·8	+ 1 07	4·6	B1wnek	M	sp var
XZ Cep	30·9	+66 54	Ecl	B5	V (Pt)	O
214168	33·7	+39 22	5·8	B3nek	M	sp var
W Cep	34·5	+58 09	Var	Mp	D	sp var
214946	38·9	+44 45	7·1	A2	D	O
WY Cep	44·7	+67 28	Ecl	A7	D	O
*+57° 2607	44·9	+57 49	8·9	O9	L (Tr)	O dbl ls
217050	54·8	+48 25	5·2	B3nek	M	sp var
β Psc	23 01·4	+ 3 33	4·6	B5e	M	sp var
SZ Psc	10·8	+ 2 24	Ecl	G5	D	O
94 Aqr	16·5	−13 44	5·3	G4	L	O
AR Cas	27·7	+58 16	Ecl	B3	V (Pt)	O red
Z And	31·3	+48 32	Var	Oop	D	sp var
R Aqr	41·2	−15 34	Var	M+Be	D	sp var
ρ Cas	51·9	+57 14	Var	Var	M	sp and vel var

* NOTES

σ Psc	Test for variation in line intensity with position in orbit.
+57° 252	In cluster NGC 457.
β Ari	Test for variation in line intensity with position in orbit.
+56° 587	In cluster χ Per.
+60° 497	In cluster IC 1805.
+60° 501	In cluster IC 1805.
+60° 502	In cluster IC 1805 ADS 1920.
+59° 552	In cluster IC 1805 IC 1848 ADS 2161.
RW Tau	Spectrum K0e at minimum.
+50° 940	In cluster NGC 1528.
ι Ori	Test for variation in line intensity with position in orbit.
+34° 1103	In cluster M 36.
+34° 1107	In cluster M 36 ADS 4194 A.
B 1399	Test for variation in line intensity with position in orbit.
+24° 1123	In cluster M 35.
+ 4° 1299	In cluster NGC 2244.
−10° 1933	In cluster NGC 2353.
+ 9° 1332	In cluster NGC 2264 ADS 5316.
τ CMa	In cluster NGC 2362 ADS 5977.
S Cnc	Spectrum G5 at minimum.
B 4008	Test for variation in line intensity with position in orbit.
−41° 11037	In cluster NGC 6231.
−41° 11042	In cluster NGC 6231.
−32° 12935	In cluster NGC 6383.
−24° 13831	In cluster NGC 6530.
+37° 3860	In cluster IC 4996 ADS 13626 B.
+37° 3862	In cluster IC 4996 ADS 13626 C.
+38° 4063	In cluster NGC 6913.
+61° 2213	In cluster NGC 7160 ADS 18420 A.
+61° 2217	In cluster NGC 7160 ADS 15434 B.
+57° 2607	In cluster NGC 7380.

REPORT OF SUB-COMMISSION ON WAVE-LENGTHS

1. The determination of satisfactory wave-lengths for radial-velocity determinations remains, and will remain for some time, one of the important concerns of the Commission. Discussions in previous reports have made it clear that it is unwise to suggest the general adoption, at different observatories, of a set of effective wave-lengths. For spectral types

later than A0 nearly all the principal features used in general radial-velocity work are blends of two or more lines and the effective wave-length of the blend depends upon the purity and dispersion employed. Recent studies at Victoria on spectral types from A0 to K8 have confirmed this conclusion reached by other investigators. It may be possible to recommend standards for general adoption for the less complex O and B spectra, although even here several of the important features are blends and it is not certain that satisfactory values can be suggested for all dispersions without further study and comparison. The question is now under investigation and it should be possible to make more definite statements in the near future.

2. In view of the above it is suggested, therefore, that attention be centred upon the means used to determine effective wave-lengths. Methods employed should ensure that the radial velocities for all spectral types, and determined with any given spectrograph, shall refer to a common zero point which is based upon independent dynamical results. To this end the following procedure is proposed:

(*a*) For solar-type stars, defined for this purpose to embrace the range F5 to K8, the adopted wave-lengths shall reproduce the velocities of members of the solar system as computed from their orbital elements, and shall also reproduce the adopted radial velocities of the brighter Standard Velocity Stars observed with high dispersion.

(*b*) For other spectral types (O, B, A0–F2, M) the adopted wave-lengths shall reproduce the radial velocities computed from the space motion of moving clusters. Preference is to be given to the clusters for which a reliable space motion can be calculated from proper motions and trigonometrical parallaxes. For others the adopted cluster motion is to be based upon radial-velocity determinations of solar-type members using wave-lengths found as in (*a*), above.

(*c*) In addition to the clusters certain visual binaries may serve as control objects. Those selected are to have one component a solar-type star and the velocity is to be determined from it using wave-lengths verified as in (*a*) above. In selecting binaries wide pairs are to be preferred so that the relative radial velocities of the components may be ignored. Every precaution is to be taken to make sure that the pair constitute a physical system.

It is not recommended that wave-lengths be adjusted arbitrarily to force *exact* agreement with the standards used as control velocities. To do so would incorporate into the wave-lengths instrumental errors and those due to measurement. There is also the danger that such a procedure may mask real velocity differences between members of clusters and other interesting effects such as the gravitational shift. An alternative, and more fundamental, method is to employ the standard velocities as checks and controls upon the adopted effective wave-lengths (*J. Roy. Ast. Soc. Can.* **40**, 325, 1946). These wave-lengths are to be predicted from studies of high-dispersion stellar and laboratory spectra, bearing in mind the degree of blending introduced by the particular spectrograph being used.

3. In order to implement the above proposals the Sub-Committee notes the need for work as follows:

(*a*) Radial velocities should be determined and adopted for suitable control objects to be used as standards for spectra other than solar-type. The Ursa Major,* Taurus, Pleiades, and Coma clusters may be regarded as reasonably well known, but clusters containing O and B stars should be studied to determine reliable values for adopted cluster motions. Suitable visual binaries should also be proposed.

(*b*) Detailed studies are required for a number of representative stellar spectra using the highest possible dispersion. All lines should be listed, and accurate wave-lengths and careful intensity estimates should be provided. It appears that relative intensities on a visual scale are sufficient. The Revised Rowland Table and the recent valuable Coudé studies from the Mount Wilson and McDonald Observatories

* Some of the stars of this cluster exhibit radial-velocity residuals not yet fully explained.

are essential to an understanding of the blended features which must be used in general radial-velocity work with relatively low dispersion. The need for such information is felt most keenly for stars of types A0 and earlier.

(*c*) Studies of the mechanism of blending should be encouraged as discussed in the previous Report. The purely instrumental effects should be distinguished from physical causes. In solar-type spectra the blended wave-length may be found by weighting the separate components roughly according to their Rowland Intensities. The subject is more obscure for the early-type stars where the influences of rotational broadening and Stark effect complicate the problem. Attention may be drawn specifically to the helium triplets λλ4026, 4471 in the B stars, and the blends of hydrogen and ionized helium at λλ4101, 4340 in the O stars, since these lines generally have high weight in radial-velocity determinations.

4. It is highly desirable that published lists of radial velocities be accompanied by a tabulation of the wave-lengths used or that the system be described in sufficient detail. Dr Adams reports that for spectral types between A5 and M he employs the solar wave-lengths of the Revised Rowland Table for measures of Coudé spectra.

At Victoria the entire wave-length system has been studied anew and revised values have been adopted for spectral types from A0 to K8 inclusive, while the O and B spectra are now under investigation. The revised wave-lengths will be published in full, the following having appeared:

(i) F4 to K8—High Dispersion. *J. Roy. Ast. Soc. Can.* **40**, 325, 1946.
(ii) F4 to K8—Moderate Dispersion. Ibid. **40**, 325, 1946.
(iii) A0 to F2—High Dispersion. Ibid. **41**, 311, 1947.

W. S. ADAMS, V. ALBITZKY, F. J. NEUBAUER, O. STRUVE, R. E. WILSON, R. M. PETRIE.

Report of meetings

PRESIDENT: Dr J. A. PEARCE.

SECRETARY: Dr R. E. WILSON.

Two meetings of the Commission were held, Dr J. A. Pearce presiding, and Dr Ralph E. Wilson acting as secretary. The Draft Report (received too late for publication) was adopted with some minor amendments.

A fifth Catalogue of the orbital elements of 475 spectroscopic binary systems deduced prior to January 1, 1947 has been compiled by Moore and Neubauer and is now in the press. The thanks of the Commission were extended to the authors for their work.

The need for a New General Catalogue of Stellar Radial Velocities is generally recognized. Since the publication of the Lick Observatory Catalogue of 1932, the number of stellar radial velocities has increased from 6700 to 12,000, and it is estimated that approximately 14,000 radial velocities will have been determined by 1950. The Commission is pleased to announce that Dr Ralph E. Wilson has consented to edit a New General Catalogue of Stellar Radial Velocities, to contain all velocities determined before January 1, 1950. This Catalogue will be published by the Mount Wilson Observatory.

The Commission again emphasizes the urgent need for spectrographic observations in the Southern Hemisphere, where for one-third of the Galaxy no radial velocities have been determined for stars fainter than the 6th magnitude. The asymmetrical distribution of velocities militates against advancement in many fields, and this deplorable condition will be further accentuated unless spectrographic observations are immediately resumed and energetically carried out in the Southern Hemisphere. The Commission hopes that the Radcliffe Observatory will undertake this important work at the earliest possible date, and appeals to the President to exert every possible influence of the International Astronomical Union in expediting the construction of a spectrograph for the Radcliffe Observatory.

31. COMMISSION DE L'HEURE

PRÉSIDENT: M. N. E. NØRLUND, *Directeur de l'Institut Géodésique de Danemark, Copenhague.*

VICE-PRÉSIDENT: M. JOUAUST.

DIRECTEUR DU BUREAU: M. DANJON.

MEMBRES: MM. R. Baillaud, Banachiewicz, Carnera, Fayet, Guyot, Lejay, Mikhailov, Moreau, Pavlov, L. Picart, Shcheglov, Silva, H. M. Smith, Sollenberger, R. M. Stewart, Stoyko, Tinoco, Verbaandert, Wentworth, Zverev.

La sixième Assemblée Générale de l'Union Astronomique Internationale adopta, d'après la proposition de la Commission de l'Heure, la résolution suivante:

La Commission approuve la proposition britannique transmise par le Comité exécutif de l'U.A.I. d'adopter à partir du 1er janvier 1940 les positions d'étoiles du système FK 3 pour les déterminations d'heure et leur utilisation en vue de l'émission des signaux horaires.

Le Bureau International de l'Heure tiendra compte de cette proposition à partir du 1er janvier 1940.

Par conséquent, le B.I.H. et tous les services qui s'occupent de l'heure, ont adopté à partir du 1er janvier 1940 les positions d'étoiles du système FK 3 en remplacement de celui d'Eichelberger qui avait été utilisé depuis 1926.

Les travaux du Bureau International de l'Heure se développent considérablement. De 11 enregistrements journaliers de signaux horaires en 1927, on est arrivé à 38 en 1939. Actuellement on atteint déjà 60 réceptions par jour. En 1947, le nombre des émissions enregistrées est égal à 13821.

Durant la période de 1938 à 1947 le Bureau International de l'Heure a fonctionné sans interruption. Le Bulletin Horaire a paru régulièrement pendant cette période. Il a donné les heures demi-définitives de toutes les émissions reçues au Bureau International de l'Heure.

La publication de l'heure définitive a été retardée à cause de l'interruption des communications postales pendant la guerre 1939–45. Le Bulletin Horaire a publié les heures définitives pour 1938 en utilisant les résultats de 18 observatoires et pour 1939 et 1940 (mars–décembre 1940 est sous presse) en utilisant les résultats de 20 observatoires. On a publié aussi l'heure définitive pour 1946 en utilisant les résultats de 14 observatoires. Pour chaque jour on publie l'heure définitive de plus de 100 émissions horaires.

Il reste à publier l'heure définitive pour la période de 1941 à 1945, dont le calcul s'avance grâce aux subventions de l'Union Astronomique Internationale et de l'Union Géodésique et Géophysique Internationale.

Le Bureau International de l'Heure commande 4 fois par jour une émission de signaux horaires scientifiques sur différentes longueurs d'onde.

Certains perfectionnements ont été réalisés au Bureau International de l'Heure. Il dispose actuellement de 3 horloges à quartz et 2 horloges à diapason; 5 chronographes enregistreurs à cylindre pour la comparaison des pendules, la réception des signaux horaires et la comparaison des fréquences; un ensemble nouveau pour l'émission des signaux horaires; un ensemble pour la comparaison des fréquences, etc.

Les appareils pour l'émission et la réception des signaux, ainsi que pour la comparaison des pendules et des fréquences sont installés dans une nouvelle salle.

M. Edmond Guyot fait remarquer qu'il serait désirable d'améliorer encore l'heure définitive en prenant certaines précautions. Lors de la réunion de Stockholm en 1938, M. René Baillaud avait proposé que les stations collaborant avec le B.I.H. enregistrent toutes le même signal horaire ou certains signaux choisis spécialement. Cette proposition mériterait d'être reprise. D'autre part, il faudrait que toutes les stations utilisent les signaux de la même manière.

Actuellement, bien des observatoires installent des horloges à quartz qui tendent à remplacer les horloges à gravité. Il serait intéressant d'entendre l'opinion de ceux qui ont eu l'occasion d'observer à la fois des horloges à quartz et des horloges à gravité.

D'après ces considérations l'ordre du jour sera le suivant:

1. Rapport du Président de la Commission sur les comptes des dix dernières années.
2. Rapport du Directeur du B.I.H. sur l'activité du Bureau.
3. Enregistrement des signaux rythmés.
4. Garde-temps.
5. Demande au Comité exécutif de la subvention nécessaire au fonctionnement du B.I.H. jusqu'à la prochaine Assemblée générale.
6. Questions diverses.

N. E. NØRLUND
Président de la Commission

TIME SERVICE

ROYAL OBSERVATORY (GREENWICH), 1939–47

The period since the last General Assembly of the I.A.U. has been one of rapid development in the time service of the Royal Observatory, Greenwich. In 1939, the principle of combining the results from a number of Shortt free pendulum clocks to form a 'Mean Clock' was still further expanded, and the astronomical observations of clock error were referred directly to a mean comprising up to seven standard clocks. Reception of American short-wave time signals was commenced on a limited scale, and a simple type of electronic relay was designed and installed in the fundamental circuits. Concurrently with this technical progress, attention was directed to the protection of vital equipment and the establishment of a reserve time service.

In 1940, arrangements were made for the emission of the 1000 and 1800 rhythmic time signals on short waves as well as by the usual G.B.R. transmitter on a frequency of 16 kcyc./sec. More regular comparisons were made with the American short-wave time signals, and also with the long-wave N.S.S. time signals, which were restarted in June. Considerable modifications in computing methods were introduced, and some general progress made in the circuits and equipment. In accordance with the I.A.U. recommendation the FK3 star places were adopted for time determinations.

A time-service installation capable of independent operation was completed at Abinger, and owing to the interference caused by the night air raids on London, work at Greenwich was closed down in November. In order to provide a second reserve station, some equipment was transferred to the Royal Observatory at Edinburgh, and this station was fully equipped for time-service duties in December.

Although the two stations, Abinger and Edinburgh, were designed for independent operation in case of emergency, during 1941 methods were developed for the normal operation of the time service by mutual co-operation. Observations at both stations were utilized, and clock intercomparisons effected by comparing the reception times of the G.B.R. 1000 rhythmic time signals. Dual operation was subsequently further facilitated by the provision of a direct line link. For prediction work, therefore, observations at both stations were referred to a mean of the best clocks irrespective of their location, and actual control of the rhythmic time signals was possible from whichever station had, at that time, the most stable line conditions to Rugby.

It was becoming increasingly apparent that certain radio and radar developments then taking place would soon be demanding a far higher standard of accuracy in the time signals—particularly for checking precision frequency standards over periods of 24 hours. As no immediate improvements were possible in the astronomical observing equipment, the number of observations was greatly increased in order to reduce the probable error of prediction. Reception and measurement techniques were improved, and all possible efforts were made to obtain the highest precision from the available equipment. Electronic

development was accelerated and reception erratics on the 16 kcyc./sec. signals reduced to under half a millisecond. The 'Mean Clock' during 1942 was formed by combining the best results from nine Shortt clocks at Abinger and Edinburgh, and two quartz clocks at the National Physical Laboratory.

In the course of attempts to attain still higher precision, it soon became clear that great scientific advantages were being gained by the system of dual operation. The co-operation of the National Physical Laboratory made figures available from a third station, and quantitative estimation of reception erratics was possible. In order to meet the requirement of checking frequency standards over twenty-four hour periods, great care was taken to keep the rate defined by 1000 G.B.R. signals on successive days as near as possible to its true value, and if the observations showed an accumulating error, return to 'right time' was made by a sudden jump in the signals. Such discontinuities were introduced, as required, on predetermined days, and their magnitude—40 msec.—rendered them immediately apparent to users of precision frequency standards, while still ensuring that the maximum time error would not be inconvenient to navigation.

In July 1942, a service of British short-wave time signals, similar to the experimental transmissions during 1940, was introduced on a permanent basis, and new aerials were installed at Abinger to permit adequate checking of the transmissions. In August a very considerable advance was made possible by the co-operation of the Post Office Radio Branch, where a number of high-precision quartz clocks were in operation. These clocks were compared daily with the G.B.R. time signals, and the results communicated by telephone. The greatly improved long-term stability of these clocks ensured their early incorporation in the 'Mean Clock', and within a few months they entirely displaced the Shortt clocks for long-term work. A radical change was thus effected in comparison and computing methods, and by 1943, the interval between 1000 G.B.R. signals radiated on successive days defined a twenty-four hour interval with a maximum error of plus or minus 4 msec., despite the limitations imposed by the transit observations liable to probable errors which were from 20 to 30 msec.

In 1944, three quartz clocks of Post Office design and manufacture were installed at the Observatory stations, and used for day-to-day prediction, and, with phaseable phonic motors fitted with rhythmic contacts, for the control of the G.B.R. signals from February 26, 1944. As the clocks were mains operated, interruptions were frequent, and long-term prediction was still based on the Radio Branch clocks. The tape chronographs, previously employed for clock comparisons, and for time-signal measurement, were not sufficiently accurate for use with quartz clocks, and were replaced with decimal counter chronometers. These instruments are designed to give an immediate indication, on decade dials, of the time interval to five places of decimals of a second, between two electrical pulses, and they now form an essential part of the time-service installation. Regular reception of the American standard frequency transmissions from WWV were commenced, and with the decimal counter chronometers, a very high accuracy of comparison with the superimposed time signals was attained. The most serious obstacle to further progress was the comparatively large probable error of the astronomical observations, and it was decided to construct a Photographic Zenith Tube. A preliminary examination of the project showed, however, that a lengthy programme of research and investigation would be required if the new instrument were not to become out of date within a few years of its installation. Laboratory work on the vital features of the design was accordingly commenced, and is still in progress.

The dual operation by Abinger and Edinburgh continued throughout 1945, and erratics in the radiated times of the G.B.R. time signals were still further reduced by the introduction of a short pre-signal test transmission, which permitted more accurate determination of the lag introduced by the land lines to the transmitter. Investigations on the form of the G.B.R. radio time signals were carried out, and improved long-wave time-signal receivers were designed in the Electronics Laboratory of the Time Department, and additional ancillary electronic equipment installed. In October 1945, a low-power radio transmitter was installed at Abinger, for the daily transmission of a standard

2 Mcyc./sec. signal to permit direct-rate intercomparisons between the quartz clocks at the various stations. These transmissions have gradually become of much wider application and, with the increased power now available, are used by many research establishments and commercial firms.

In January 1946, the time-service work at Edinburgh was finally closed down, and the equipment transferred to Greenwich. Work was also commenced at Abinger on the installation of twelve quartz clocks, all of Post Office design, and operated on floating batteries. These were finally completed, and fitted with rotary beat-counters providing constant automatic comparisons between the standards, in October 1947. Six similar clocks are now in full operation at Greenwich. New phonic motors have been designed in co-operation with Messrs Muirhead, and in the very near future the pendulum clocks will be relieved of their one remaining task of operating the contacts for the B.B.C. and hourly signals. All the quartz standards are rated to mean time, and sidereal time is obtained for transit purposes from geared phonic motors. From August to December 1946, a longitude programme was carried out in co-operation with Mount Stromlo Observatory, Australia, which showed that the longitude previously adopted placed the latter observatory 0·103 sec. too far to the East. This programme coincided with the recommencement of transit observations at Greenwich.

Measurement and comparison technique is being further developed, and new computing methods have recently been introduced to ensure that the best possible use is made of the data from the 12 clocks at Abinger, 6 at Greenwich, 9 at the Post Office Radio Branch Laboratories, and other standards at co-operating establishments. The normal schedule of work now includes regular reception and measurement of radio time signals from France, Russia and America. The Electronics Laboratory is engaged on the design and manufacture of further frequency measuring equipment, improved time-signal receivers, and experimental investigation on quartz crystal circuits. The Optics and Instrument Laboratory is proceeding with investigations and tests in connection with the design of the photographic zenith tube, and of an entirely new form of horizontal transit instrument and other allied problems.

A Bamberg transit instrument, on loan from the Royal Observatory, Edinburgh, has been thoroughly overhauled and modified, and brought into use at Abinger. A considerable reduction in observational errors has been achieved, and, following completion of experimental work in the laboratory, a motor-drive micrometer is now under construction in the workshop.

Proposal for Submission to Commission 31

Technical developments in the field of radio and electronics have led to increasing demand for higher accuracy in the determination of frequency. Since frequency is expressed in terms of cycles per second, the reciprocal unit of time must be determined to an order of accuracy comparable with that required for establishing primary standards of frequency. The present demand is for a precision of better than one part in 100,000,000, and the astronomer is therefore required to maintain a time service which establishes the length of the day correct to less than 0·001 sec.

At present the accepted standard of time is based on the period of rotation of the earth, but the length of the day, as now defined, varies slightly in consequence of the polar motion which causes variations of longitude as well as of latitude. These departures from the mean day may be as much as $\pm 0{\cdot}0003$ sec. and are therefore not negligible. As a temporary expedient, therefore, an attempt has been made since 1 January 1947, to minimize the effects of these variations upon the time service maintained by the Royal Observatory, Greenwich. From figures supplied by the U.S. Naval Observatory regarding the current latitude variation of Washington, it is possible to compute an approximate value of the corresponding longitude variation of Greenwich. By applying these corrections to the time observations which are then smoothed by comparison with standard quartz clocks, it is possible to obtain a more uniform time system.

The performance of modern quartz clocks is, in fact, reaching a standard which may permit a continuous check on the rate of rotation of the earth. It becomes the more desirable, therefore, that the day should be so defined as to free it from all variations due to known causes. The simplest means of nullifying the effects arising from changes of longitude due to the polar motion is to define 0^h Local Sidereal Time no longer as the instant at which the vernal equinox crosses the actual meridian of the observer, but as that instant at which it crosses his 'mean' meridian; this meridian being determined by the position on the earth of the mean poles.

It is therefore recommended that the various technical considerations involved should be referred to the delegates of the Commission de l'Heure at the Zürich meeting of the I.A.U. in August 1948, with a view to the preparation of more detailed proposals for submission to a future meeting.

Reception of Long-wave Time Signals

An examination of the published results of reception times of the Rugby G.B.R. radio time signals indicates that large variations are apparently experienced at some observatories. This may be partly due to variations in radio propagation, but it is thought that variable lags in receiving and measuring equipment may be contributing appreciably to the variations.

It is perhaps not sufficiently realized that owing to the low radio frequency of the Rugby transmitter—16 kcyc./sec.—the signal dots rise slowly to the maximum value, and it is therefore essential to ensure that the recorder is operated at the same predetermined point on the build-up curve at each reception. This involves adjusting the gain of the receiver to obtain the same maximum signal voltage on each occasion, and then arranging for the recording pulse to be 'triggered' when the voltage reaches a pre-set value.

A highly selective receiver will also introduce further 'flattening' of the build-up curve, and thus alter the effective lag of the set. Variations in tuning, or failure to tune accurately, may thus give rise to substantial errors of measurement.

By careful design, the risk of such errors becoming appreciable may be greatly reduced, and with care in adjustment and tuning, reception erratics may be reduced to almost negligible proportions.

During the war period, the British time service utilized standard quartz clocks at a number of different institutions, and intercomparisons were effected by comparing the reception times at each station of the G.B.R. 1000 radio time signal. The results obtained permitted a quantitative estimate of reception erratics at each station to be made, and it was found possible to reduce the probable error of a single reception, which included the effects of clock erratics and variable propagation, to about 0·3 msec.

It is suggested that this matter is worthy of consideration at the forthcoming meeting of the Commission de l'Heure at the Zürich meeting of the I.A.U., and relevant information from participating observatories would be appreciated.

H. M. Smith

Time Observations from 1938 to 1947

	Greenwich	Abinger S.T.	Abinger Bamberg	Edinburgh	Total of each year
1938	128	—	—	—	128
1939	135	—	—	—	135
1940	117	48	—	—	165
1941	—	141	—	62	203
1942	—	165	—	157	322
1943	—	191	—	130	321
1944	—	124	—	127	251
1945	—	97	—	116	213
1946	58	130	—	8	196
1947	218	94	88	—	400
	656	990	88	600	2334

Le Bureau International de l'Heure

Rapport de M. A. Danjon, *Directeur*

La période 1938–47 a marqué un progrès très important dans les services du Bureau International de l'Heure. Le nombre des réceptions des signaux horaires qui a été 7500 en moyenne, pour la période 1935–37, a augmenté considérablement, sauf pendant la période 1944–45, comme on peut voir d'après le tableau ci-dessous:

Année ...	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	Σ
Réc. Sig.	9320	10221	11009	11674	9585	7835	5915	6673	8848	13859	94939
Obs. Ast.	287	287	290	259	266	207	221	240	204	280	2541

Dans le même tableau, on donne le nombre des observations astronomiques de l'heure pour chaque année.

Durant la période de 1938 à 1947, le Bureau International de l'Heure a fonctionné sans interruption. Le *Bulletin Horaire* a paru régulièrement pendant cette période. Il a donné les heurs demi-définitives de toutes les émissions reçues au Bureau International de l'Heure.

La publication de l'heure définitive a été retardée par l'interruption des communications postales pendant la guerre 1939–45. Le *Bulletin Horaire* a publié les heures définitives pour 1938, en utilisant les résultats de 18 observatoires et, pour 1939 et 1940, en utilisant les résultats de 20 observatoires. On a publié aussi l'heure définitive, pour 1946, en utilisant les résultats de 14 observatoires. Pour chaque jour, on publie l'heure définitive de plus de 100 émissions horaires.

On a terminé le calcul de l'heure définitive pour l'année 1941 et pour les 6 premiers mois de 1947. La publication a été retardée par des difficultés d'impression. Le calcul de l'année 1942 sera bientôt fini.

Il reste donc à calculer l'heure définitive en retard pour la période de 1943 à 1945 et à la publier pour la période de 1941 à 1945 et pour 1947.

Le Bureau International de l'Heure commande 4 fois par jour une émission de signaux horaires automatiques et une émission de signaux horaires scientifiques sur différentes longueurs d'ondes.

Certains perfectionnements ont été réalisés au Bureau International de l'Heure. En 1940, on a introduit l'enregistrement des signaux par les chronographes Belin à gros cylindres (1 seconde = 500 mm.) tournant soit à la période de 1 seconde de temps moyen (signaux américains et signaux automatiques), soit à la période de 60/61 seconde de temps moyen (signaux rythmés).

De plus, on utilise, pour la comparaison des divers garde-temps, l'enregistrement continu sur un chronographe Belin, à petit cylindre (1 seconde = 250 mm.); la feuille paraffinée est changée tous les trois jours.

On dispose, actuellement, en plus de 7 pendules à pression et à température constantes, de 3 horloges à quartz et 2 horloges à diapason, appartenant à l'Observatoire de Paris et qui sont comparées continuellement avec les 7 horloges à quartz du Laboratoire National de Radioélectricité de Bagneux.

On dispose, entre autres, de 5 chronographes enregistreurs à cylindre pour la comparaison des pendules, la réception des signaux horaires et la comparaison des fréquences; un ensemble nouveau pour l'émission des signaux horaires; deux ensembles pour la comparaison des fréquences, etc.

Les appareils pour l'émission et la réception des signaux horaires, ainsi que pour la comparaison des pendules et des fréquences sont installés dans une nouvelle salle.

Dans les salles spécialement aménagées à cet effet, se trouvent les horloges à quartz et à diapason, ainsi qu'une pendule à pression et à température constantes pour la commande des signaux rythmés.

Les observations astronomiques ont été faites régulièrement en utilisant deux lunettes de passage: Gauthier no. 381 (ouverture 75 mm.) et Bouty (ouverture 102 mm.).

En 1947, pour améliorer la détermination de l'heure, on a commencé les observations

astronomiques avec une lunette de M. Danjon. De plus, une lunette zénithale de M. Couder est en construction à l'Observatoire de Paris, ainsi qu'un astrolabe à prisme impersonnel de M. Danjon.

Pendant la période de 1938–47, on a étudié la propagation des ondes radioélectriques; les variations des longitudes; la régularité des garde-temps en fonction de différents phénomènes, comme les tremblements de terre, l'attraction luni-solaire; les irrégularités de rotation de la terre, etc.

FINANCES

1er janvier 1938–31 décembre 1947

RECETTES		Frcs.
Actif au 1er janvier 1938		1 136,50
Subvention de l'Union Astronomique Internationale en 1938		86 521,10
Subvention de l'Union Géodésique et Géophysique Internationale en 1938		38 442,30
Subvention de l'Union Astronomique Internationale en 1939		88 032,20
Subvention de l'Union Géodésique et Géophysique Internationale en 1939		46 699,30
4. v. 1940	Subvention de l'Union Astronomique Internationale	57 929,25
11. vi. 1941	Cotisation de la France pour 1940 versée par l'Académie des Sciences	24 124,14
5. vii. 1941	Arriéré de cotisations antérieures versées par l'Académie des Sciences	16 979,63
4. xi. 1941	Subvention de l'Union Astronomique versée par M. Oort	39 025,23
28. i. 1942	Subvention de l'Union Astronomique versée par M. Oort	29 268,80
24. vi. 1942	Cotisation de la France pour 1941 versée par l'Académie des Sciences	24 124,90
20. i. 1943	Cotisation de la France pour 1942 versée par l'Académie des Sciences	33 171,70
18. v. 1943	Cotisation de la France pour 1943 versée par l'Académie des Sciences	33 171,00
6. iv. 1944	Cotisation de la France pour 1944 versée par l'Académie des Sciences	33 172,00
1. vi. 1944	Subvention de l'Union Astronomique versée par M. Oort	12,216,00
3. vii. 1945	Cotisation de la France pour 1945 versée par l'Académie des Sciences	33 172,00
Subvention de l'Union Astronomique Internationale en 1946 (2400$)		284 880,00
Subvention de l'Union Géodésique Internationale en 1946 (150£)		71 840,00
Subvention de l'Union Astronomique Internationale en 1947 (8800$)		1 044 320,00
Subvention de l'Union Géodésique Internationale en 1947 (4400$)		522 160,00
		2 520 386,05

PAYEMENTS		Frcs.
Dépenses de l'exercice 1938		123 437,40
,,	,, 1939	92 293,05
,,	,, 1940	74 855,15
,,	,, 1941	74 446,10
,,	,, 1942	73 613,00
,,	,, 1943	56 490,60
,,	,, 1944	44 187,00
,,	,, 1945	50 195,00
,,	,, 1946	128 985,00
,,	,, 1947	504 036,00
Actif au 1er janvier	1948	1 297 847,75
		2 520 386,05

Compte rendu de la réunion tenue le 12 août 1948, à Zürich

PRÉSIDENT: M. N. E. NØRLUND.

SECRÉTAIRE: M. N. STOYKO.

PRÉSENTS: MM. F. Baeschlin, W. H. van den Bos, G. M. Clemence, R. T. Cullen, A. Danjon, A. Gougenheim, W. M. H. Greaves, E. Guyot, H. Jeffers, Sir Harold Spencer Jones, F. Kepiński, W. D. Lambert, M. R. Madwar, Maître, Mathias, F. Moreau, Persin, A. J. Robertson, G. Silva, H. M. Smith, P. Sollenberger, P. Tardi, G. Tiercy, J. Tinoco, C. B. Watts.

Le Président rend hommage à la mémoire des membres de la Commission qui sont décédés depuis 1938: le Général G. Perrier, A. Lambert, E. Bianchi, N. Dneprovsky, F. W. Dyson, T. Niethammer, R. A. Sampson.

Les comptes financiers du Bureau International de l'Heure (B.I.H.) ont été examinés par le Président de la Commission qui estime que les dépenses ont été faites conformément au règlement. Les comptes financiers—qui sont joints à ce compte rendu—sont approuvés.

A Atlantic City, en 1947, le Comité International pour les Télécommunications (C.I.T.) a décidé de créer une commission (No. 3) pour les emissions de fréquences étalons et de signaux horaires. A sa réunion, tenue à Stockholm en 1948, cette commission a décidé de travailler en collaboration avec la C.I.H.

Le Directeur du B.I.H., M. A. Danjon, lit le rapport sur l'activité du B.I.H. au cours de la période 1938–47.

M. Tardi, Secrétaire général de l'Union Géodésique Internationale, demande une copie du rapport du B.I.H. qu'il présentera à Oslo à l'Assemblée de l'Union Géodésique et Géophysique Internationale.

M. Persin, représentant du C.I.T., déclare que la commission No. 3 créée par ce Comité avec l'agrément du Comité Consultatif International des Radiocommunications (C.C.I.R.) ne peut résoudre la question des signaux horaires sans liaison étroite avec la C.I.H. M. Persin demande que la C.I.H. délègue l'un de ses membres à la réunion que tiendra le C.I.T. en septembre 1948. M. A. Danjon est élu représentant de la C.I.H. près du C.C.I.R.

M. Sollenberger décrit l'activité de la station WWV du Bureau of Standards. Ce Bureau fait des émissions continues de fréquences et de signaux horaires sur diverses longueurs d'ondes. On compte installer deux stations supplémentaires pour ces émissions: l'une de ces stations sera installée en Europe Occidentale, la seconde dans la région du Pacifique. Le Bureau of Standards possède des horloges à quartz qui sont comparées—14 fois par jour—aux horloges du Naval Observatory de Washington.

M. W. D. Lambert déclare que le Coast and Geodetic Survey utilise les signaux émis par WWV. Les corrections définitives pour 3 et 15 h. T.U. de ces signaux sont publiées dans le *Bulletin du B.I.H.*

M. Smith a constaté que les signaux du WWV sont plus réguliers que ceux du NSS. Il pense qu'il est préférable d'utiliser les signaux horaires émis par WWV plutôt que la fréquence émise par ce poste, car la réception de la fréquence dépend des conditions ionosphériques. Cette thèse est appuyée par M. Sollenberger. MM. Danjon et Stoyko mentionnent, à ce sujet, les travaux de M. B. Decaux.

M. Persin ajoute que l'on envisage, pour améliorer la réception des fréquences, d'augmenter le nombre de stations d'émission de fréquences. On discute actuellement la question d'emplacement de ces stations. Grâce à cela, la précision de réception de fréquence sera considérablement augmentée.

M. E. Guyot dit que l'Observatoire de Neuchâtel va acquérir 7 horloges à quartz et fera des émissions de fréquences par l'intermédiaire des stations suisses.

Sir Harold Spencer Jones estime que la précision des horloges modernes et de la détermination astronomique de l'heure exige maintenant que l'on tienne compte du déplacement du pôle. A Greenwich, on a égard à ce déplacement en utilisant aussi les observations faites au zenith telescope de Washington.

M. Smith signale que si l'on ne tient pas compte du déplacement du pôle, on trouve la période de 14 mois dans la marche des pendules, avec une amplitude qui peut atteindre $0^s.020$ ou même $0^s.030$.

M. Stoyko ajoute qu'on tient compte du déplacement du pôle dans le calcul des heures définitives du B.I.H.

M. Sollenberger dit que l'Observatoire Naval de Washington envisage l'établissement d'une station astronomique près de l'équateur, ceci afin de diminuer l'influence du déplacement du pôle. A Greenwich, cette influence est grande à cause de la latitude.

M. Stoyko fait remarquer que les corrections provisoires du déplacement du pôle sont suffisamment bonnes pour l'étude des fréquences, mais qu'elles sont insuffisantes pour les déterminations des longitudes.

M. le Président lit une proposition relative à une nouvelle définition du temps. Il estime que cette proposition doit être également soumise à la Commission 4. M. Danjon pense qu'il faut mentionner dans cette définition que la seconde correspond au temps newtonien. Il subsiste une difficulté par suite du terme qui correspond à l'irrégularité de la rotation de la Terre.

M. W. D. Lambert pense que la question est encore plus complexe; elle se rapporte, dit-il, à la question générale de la définition des constantes astronomiques.

M. F. Moreau émet le vœu suivant: 'Que les observateurs veuillent bien mentionner, en publiant leurs résultats, si les déterminations astronomiques de l'heure ont été faites dans les deux positions de la lunette et s'il a été tenu compte de l'inégalité et des irrégularités des tourillons.'

Ce vœu est adopté par la commission.

M. le Président lit le vœu suivant adopté par l'U.R.S.I. (Union Radio-Scientifique Internationale) en son assemblée générale tenue en octobre 1946: 'L'U.R.S.I. attire l'attention de l'U.A.I. sur l'importance des mesures précises de la vitesse de propagation des ondes longues et demande aux observatoires astronomiques de collaborer avec les radioélectriciens en vue d'organiser en commun des mesures aussi précises que possible. En particulier, il serait désirable d'organiser des expériences de chaque côté de l'Atlantique permettant de mesurer des différences de temps de parcours dans les deux sens.' Prennent part à la discussion de ce vœu: MM. Danjon, Smith, Sollenberger et Stoyko. M. Sollenberger dit que si la commission émet un vœu favorable au rétablissement de la station NSS sur ondes longues, le fonctionnement de cette station sera probablement rétabli. Ce vœu est adopté.

M. Danjon demande une subvention annuelle de $8800 pour le fonctionnement du B.I.H., la moitié de cette subvention étant payée par l'U.A.I. La proposition est adoptée sous réserve que l'U.N.E.S.C.O. accorde son aide.

M. Baeschlin demande: (1) Que les émissions de signaux horaires soient telles qu'elles permettent de déterminer les marches des pendules avec une grande précision sans devoir recourir aux résultats publiés par le B.I.H. Après discussion, ce vœu est adopté. On souhaite que lorsqu'on est amené à faire une forte correction à l'émission des signaux horaires, cette brusque correction soit faite à des jours convenus. (2) Que le B.I.H. publie, comme autrefois, les résultats des comparaisons mutuelles des pendules. Ce vœu est adopté.

32. COMMISSION DES 'SELECTED AREAS'

PRÉSIDENT: M. P. J. VAN RHIJN, *Astronomical Laboratory 'Kapteyn', Groningen, Netherlands.*

MEMBRES: MM. W. S. Adams, Alden, Baade, E. A. Baker, A. N. Deutsch, Mme Payne Gaposchkin, MM. Knox-Shaw, Oort, Seares, Shapley.

The following lines give a summary of the work of Kapteyn's Plan of Selected Areas from January 1938 up to September 1947.

1. DURCHMUSTERUNG

Two surveys of the Selected Areas of the Systematic Plan are available: [1] and [5].*

HARVARD, GRONINGEN

The Durchmusterung of the areas of the Special Plan will be printed in the near future.

2. PHOTOGRAPHIC AND VISUAL OR PHOTOVISUAL MAGNITUDES, COLOUR INDICES AND EFFECTIVE WAVE-LENGTHS

The investigations [2] to [4] and [6], [7], [10], [12] to [14] had been completed before the publication of the previous Report in 1938.

MOUNT WILSON: PHOTOVISUAL MAGNITUDES, NORTHERN AREAS

All the available photographs for determining photovisual magnitudes in 42 Selected Areas between declination $+75°$ and $-15°$ have been completely reduced. Publication has been deferred because the long-exposure plates for some of the areas proved unsatisfactory owing to peculiarities of gradation. Meanwhile standards have been supplied on request to numerous observers. It now seems desirable to print the results as they stand, and it is hoped that this may be done within the coming year.

HARVARD: PHOTOVISUAL MAGNITUDES, NORTHERN AREAS

The determination of the photovisual magnitudes in the northern Selected Areas at the Harvard Observatory, see [3], has been discontinued. The plates of some of the more interesting areas in the zone at $+60°$ declination have been measured and the results have been discussed in *Astrophysical Journal*, **90**, 249, 1939.

MCCORMICK OBSERVATORY: PHOTOVISUAL MAGNITUDES, NORTHERN AREAS

Plates have been taken for the determination of photovisual magnitudes in 52 Selected Areas down to the magnitude 13. It is doubtful whether the project will be finished.

PERKINS OBSERVATORY

The red magnitudes of the stars brighter than $15^{m}{\cdot}18$ in a square $15' \times 15'$ of Selected Area 108 have been determined at the Perkins Observatory by J. J. Nassau and J. A. Hynek, see [17]. The probable error is $\leqq \pm 0^{m}{\cdot}05$.

POTSDAM: PHOTOGRAPHIC MAGNITUDES, NORTHERN AREAS

Plates have been taken at the Potsdam Observatory for the determination of the photographic magnitudes in the areas at declination $+15°$ and in the Special Areas 2 to 7, 24 and 25. No report has been received about the progress of this work.

* [1] means No. 1 of the list of Publications in section 11. This notation is continued in the following pages.

Harvard, Groningen: Photographic magnitudes, northern areas

Photographic magnitudes of the stars in the northern Selected Areas brighter than 13·0 are being determined at the Kapteyn Laboratory on plates taken at the Harvard Observatory. The field is $3°{\cdot}5 \times 3°{\cdot}5$. The spectral classes of the same stars are being determined at the Hamburg Observatory. The results for areas 1 to 43 have been published, see [40]. The manuscript for the areas 44 to 67 is ready for the printer. The magnitudes of the zones of declination $+15°$ and $0°$ are being determined at present.

Harvard: Southern areas

The photographic magnitudes of the S.A. at declinations $-15°$, $-45°$ and $-60°$ have been published, see [12]. The photographic and red magnitudes of standard stars in the S.A. 140 to 206 also have been published, see [14]. The work will not be continued.

Leiden: Photographic magnitudes, southern areas

The main purpose of the programme is to obtain photographic magnitudes which are reliable in scale and zero point. The plates are taken with the Rockefeller twin-astrograph at the Leiden station at Johannesburg (aperture 40 cm., focal length 229 cm.).

The programme will be carried out in separate parts. The first part, which is being undertaken now, consists in the determination of magnitudes for stars brighter than about $10^{m}{\cdot}5$ in the 91 areas with negative declination. The field to be measured is 16 square degrees. The scale is found by means of an objective grating and will be checked by means of a neutral filter and perhaps photoelectric measurements. The zero point will be determined by means of many intercomparisons of southern areas and a comparison of some of the southern fields with northern fields for which the international magnitudes are known.

Plates of the southern areas have also been taken with 10^{m} exposures, one telescope with the objective grating, the other with the full aperture. By means of these plates the scale can be extended to the 14th photographic magnitude. This second part of the programme will, however, not be undertaken until the first part is completed.

Potsdam: Photographic magnitudes, southern areas

It was announced in the former report that the photographic magnitudes of the stars in the southern hemisphere, the spectra of which have been classified (see section 7), would be determined at the Potsdam Observatory. This work has been discontinued.

Abastumani Astrophysical Observatory: Colours in the northern areas

The colours of the stars of magnitude 11 to 13 in Selected Areas 1 to 67 will be determined at the Abastumani Astrophysical Observatory by E. K. Kharadze. The field is $2° \times 2°$; the mean error of the colour indices is $\pm 0^{m}{\cdot}08$.

Results for some fields have been published in *Bulletins of Abastumani Astrophysical Observatory*, Nos. 6, 7 and 8. I cannot give the details of these publications because they have not arrived in this country. The results for the areas 1 to 43 are completed. Some results for part of the fields are given in *The Observatory*, **65**, 220, 1944.

Hamburger Sternwarte in Bergedorf

The colour indices of the stars in the Areas 26, 35 and 40 have been determined by Martin Christopher Clasen, see [15]. The plates have been taken with the Bergedorfer 60 cm. refractor. The limiting magnitude is approximately 11 to 12.

Ghent Astronomical Institute

The effective wave-lengths of the stars in the Selected Areas 40 and 41 have been determined by A. Velghe at the Ghent Astronomical Institute, see [16]. The plates have been taken by H. L. Vanderlinden with the 24-inch reflector at the Yerkes Observatory. The limiting photographic magnitude is 14 to 15.

Lund Observatory—Observatoire de Haute-Provence: Northern areas

The colours of the red stars in the northern Selected Areas at galactic latitude of approximately 20° will be investigated by Mr Reiz of the Lund Observatory. The plates will be taken with the 81 cm. Couder telescope of the Observatoire de Haute Provence and will be measured at the Lund Observatory. The limiting magnitude is approximately 16 photographic and the field is the same as that of the *Bergedorfer Spektral Durchmusterung*. Some trial plates have been taken of Selected Area 26.

3. VARIABLE STARS

Hamburg

Thirty-five variables in Selected Area 41 have been observed by A. A. Wachmann in a field of 34 square degrees, see [9]. Wachmann also investigated Selected Area 64 for variable stars; the results will be published in the near future. The work is being extended to some other areas.

Radcliffe Observatory: Northern areas

Twenty-six variable stars have been found on the plates used at the Radcliffe Observatory for the determination of the proper motion, see [8] and [22].

Edinburgh: Areas at +75° declination

E. A. Baker investigates the variables rising above the 14th magnitude at maximum in some northern areas. Results for areas 2, 3 and 4 have been published, see [11], and those for areas 5 to 7 are ready for publication. The work on this subject has now been suspended.

Harvard: Northern areas

Throughout the war the Harvard Observatory has continued to take plates with the 3-inch Ross camera on the northern Selected Areas. The plates will provide a very useful background material for the study of variable stars in and around the Selected Areas to a limiting magnitude of 13·5 to 14·0. There are no immediate plans for the measurement of these plates.

Sternberg Astronomical Institute of the University of Moscow

Systematic observations of variable stars have been made in Selected Areas 1, 2, 3, 8, 9, 10, 19, 24, 25, 38, 39, 65, 66, 88 and 89. No report has been received about the progress of this work since 1938.

4. PROPER MOTIONS

The relative photographic proper motions in the northern areas have been determined at the Radcliffe and Yerkes Observatories, see [18] and [22]. The absolute proper motions in the northern areas have been derived from meridian positions by C. H. Hins, see [23].

Poulkovo: Areas at declination +75° to +15°

A. N. Deutsch and E. J. Perepelkin have measured the proper motions of 3189 stars in the areas at +75° and +60° declination and in the area 28, see [24]. The plates have been taken with the 33 cm. astrographic telescope (focal length 346 cm.). The probable error of the proper motions is ±0″·0065. The measured area is the same as in the Durchmusterung of *Harvard Annals*, **101**; outside this area only the fundamental stars are measured, see [23]. The proper motions in 74 areas between the pole and declination +15° have been measured by A. N. Deutsch, see [27]. The telescope used is again the 33 cm. astrographic telescope and the field of each area is the same as in *Harvard Annals*, **101**. The probable error of the proper motions is ±0″·0046. The limiting magnitude is 14 to 15 photographic.

Cambridge (England): Northern areas

Areas of the systematic plan at declination 0° to +60° and the special areas 8, 9, 10, 12, 18, 20 and 24 were photographed in 1930 with the Sheepshanks telescope (aperture 30 cm., focal length 590 cm.). The limiting magnitude is about 15; the field to be measured is 90′ × 90′. The areas will be re-photographed after the lapse of a suitable interval.

Dearborn: Areas at the equator

The proper motions of the stars in the equatorial zone will be determined within the next few years by means of plates taken with the 47 cm. refractor (focal length 703 cm.). The time interval is about 20 years.

Bonn: Northern areas

The areas of the northern hemisphere between 0° and +75° declination were photographed with the 30 cm. refractor (focal length 513 cm.) by F. Küstner some 50 years ago. Two exposures were made on each plate: one of 60 min. and one of 1 or 2 min. The measurable field is 85′ × 85′ and the limiting magnitude 15. The refractor was damaged in the war; after it has been repaired second-epoch plates will be taken for the determination of the proper motions. A reduction of the proper motions to an absolute system will be performed by means of plates taken with the telescope used for the repetition of the *Astronomische Gesellschaft Catalogue*.

Algiers, Groningen: Northern areas

Approximately sixty plates have been taken at the Algiers Observatory for the determination of the proper motions in some areas of the equator. The early plates are the regular plates of the *Carte du Ciel* catalogue. At least half of each plate is covered by the 3°·5 × 3°·5 field of the *Bergedorfer Spektral Durchmusterung*. The plates have been measured at the Kapteyn Laboratory. The reduction is progressing slowly.

Mount Wilson: Northern areas

A. van Maanen and H. C. Willis have determined the large proper motions of 122 stars in 42 Selected Areas, see [20]. The lower limit of completeness is 0″·050 annually; the limiting magnitude 18 photographic. P. Th. Oosterhoff has extended the investigation to another 651 stars in 97 Selected Areas, see [25]. The areas 1 to 139 have been investigated.

Radcliffe, Groningen: Northern special areas

The proper motions of the stars in the special Selected Areas 2, 5, 9 and 24 have been determined at the Kapteyn Astronomical Laboratory by B. Hiemstra by means of plates taken at the Radcliffe Observatory with the 60 cm. photographic refractor (focal length 690 cm.), see [26]. These areas show a black part surrounded by rich parts of the Milky Way. The distance and absorption of the clouds have been computed.

Yerkes Observatory: Areas between declination $+90°$ and $-15°$

Most of the areas between the north pole and the declination $-15°$ have been photographed by Ross at the Yerkes Observatory with the 10-inch Ross telescope from 1928 to 1932. The limiting magnitude is 16 to 17; the measurable field has a diameter of 4 to 5 degrees. The plates might be used later for finding the stars of large proper motion (*Publications American Astronomical Society*, **9**, 98, 1937).

Proper Motions in the Southern Selected Areas: Yale-Columbia southern station

Dr D. Brouwer and Dr J. Schilt report as follows:

Between March 1927 and December 1928 plates were taken of the areas 116 to 205 of the systematic plan and nos. 13, 14, 21, 22, 27, 29, 30, 31, 36, 37, 38, 39, 40, 41, 43 and 44 of the special plan with the large Yale telescope (aperture 66 cm., focal length 1100 cm.). Two exposures of 10 min. were taken on each plate and two plates on each area. In 1934 a more extensive programme was begun with the intention of securing proper motions on an absolute basis. Five overlapping plates whose centres are separated by $0°{\cdot}5$, of which the central one coincides with the centre of the Selected Area, are taken with one exposure of not less than 20 min.; all areas of the systematic plan and of the special plan enumerated above are included. These plates are taken with a grating placed in front of the 26-inch lens giving a difference of about 5 magnitudes between the central image and the first-order spectrum. Two plates centred on the same region have also been taken with the Ross camera of 5-inch aperture (scale 1 mm. = 100″), using plates covering 120 square degrees. A grating with a magnitude interval of 3·5 is placed in front of the camera lens. These exposures are also 20 min. The camera plates will be reduced by means of all the stars of the *General Catalogue* that appear on them. The gratings permit the inclusion of stars differing greatly in magnitude without the introduction of magnitude equation (see *Transactions International Astronomical Union*, **5**, 207, 1936).

The camera plates show stars fainter than the twelfth photographic magnitude and the plates with the large telescope stars considerably fainter than the fifteenth.

The plates of the series started in 1934 have been taken between February 1934 and April 1936. At least part of the plates of the 1927 and 1934 series will be repeated in the near future and the proper motions will be determined.

Meanwhile, it has been decided that a new lens for the catalogue camera in Johannesburg will be constructed having the same focal length as the present camera (scale 1 mm. = 100″) but an aperture of 8 inches instead of the 5 inches of the present camera. The disadvantage of the present camera lens is the colour magnification error described in *Astronomical Journal*, **47**, 88. It is hoped that the new lens will be free from this error.

In the near future three first-epoch series of plates will be taken of the Selected Areas south of declination $-20°$ (as stated below, the Lick Observatory takes care of the areas at declinations north of $-20°$):

1. With the 66 cm. refractor two plates of each area. The size of the plates is 25×30 cm. if the images near the corners of these plates appear to be measurable; otherwise the size will be $16{\cdot}5 \times 21{\cdot}5$ cm. The limiting magnitude will be approximately 15–16. A grating

will be used for the determination of the magnitude error; the grating constant (magnitude difference between the central image and first-order spectrum) will probably be three magnitudes.

With the catalogue camera (new lens) two series of plates will be taken.

2. Two plates of each area, size of the plates 42 × 42 cm.; limiting magnitude 9.

3. Two plates of each area; size of the plates 20 × 25 cm.; limiting magnitude approximately 12 to 13.

In both cases a grating will be used; no decision has as yet been taken about the grating constant. The number of exposures on each plate of the series 2 and 3 remains a matter for consideration.

We have decided to take a new series of plates with the 66 cm. refractor because the interval of five magnitudes used in the 1934 series is rather too large for a satisfactory determination of the magnitude error. Otherwise the purpose of three series of plates of the new plan is the same as that contemplated by Schlesinger with the two series of plates that constituted the 1934 programme. This purpose is to obtain absolute photographic positions and proper motions of stars within a wide range of magnitudes by means of an echelon of exposures ranging from the faintest stars to stars of such brightness that they may be referred directly to the fundamental system. Exposure times and limiting magnitudes for each series will depend upon the speed of plates that will be available. The first-order diffraction images will of course be used for the determination of the magnitude error.

Probably a new set of plates will be taken to match the 1927 series and proper motions will be determined at Groningen by means of these plates. The proper motions will not be on an absolute system, and will not be free from magnitude errors, but these requirements are not essential in certain investigations dealing with the dispersion in proper motions. On the other hand, a repetition of the three new series of plates will make it possible to eliminate the magnitude errors in the proper motions. No definite time is planned for this repetition. An interval as short as 10 years between the two new epochs would be sufficient to yield significant results, again in combination with the 1926 series.

Lick Observatory: Areas from declination −15° to the north pole

The whole sky north of declination −20° will be photographed in the near future with the new Lick astrograph (aperture 50 cm., focal length 360 cm.) with the purpose of finding the proper motions of faint stars relatively to extragalactic nebulae. The proper motions of the latter being zero, we get a system of absolute proper motions in fields containing a sufficient number of extragalactic nebulae. The proper motions of the bright stars will be determined, referred to the same system and free from magnitude error by means of grating exposures and other means. The proper motions of the stars in the Selected Areas which are not too far from the centre of a plate of the nebular programme can be measured on these plates. If on the other hand this distance is too large for a satisfactory determination of the proper motions, special plates will be taken with the corresponding Selected Area in the centre of the plate. The Lick plates, therefore, are intended to yield the absolute proper motions of bright and faint stars in the Selected Areas between declination −15° and the north pole.

5. TRIGONOMETRIC PARALLAXES

Yerkes: Areas at declination +45°

The trigonometric parallaxes of the stars in the areas at declination +45° have been published by O. J. Lee, see [18]. The limiting magnitude is 13 to 14 photographic.

6. STANDARDS OF POSITION

LEIDEN, BONN, BABELSBERG, PARIS, STRASBOURG: NORTHERN AREAS

The right ascensions and declinations of approximately ten stars in each area of the northern hemisphere, excepting the polar area, have been determined at the Babelsberg, Bonn, Paris, Leiden and Strasbourg Observatories, see [28], [30], [31]. Final mean places have been derived by C. H. Hins, see [23].

The stars in the polar area have been observed at Babelsberg, Bonn and Leiden, see [32] and [33].

PERTH AND LA PLATA: SOUTHERN AREAS

The positions of the standard stars in the southern areas have been determined by H. A. Martinez, see [29]. The observations at the Perth Observatory have been discontinued.

SOUTHERN AREAS

The positions of the brighter stars in the entire southern hemisphere will be determined jointly by the Yale Observatory (declination 0° to −30°) and the Cape Observatory (declination −30° to −90°). The stars of the Selected Areas occurring in this investigation will serve as standards of position for these areas.

7. SPECTRAL CLASSIFICATION

MOUNT WILSON: NORTHERN AREAS

M. L. Humason classified approximately 35 stars in each area north of and including the equator. The limiting magnitude is 12 to 13, see [36].

HAMBURG: NORTHERN AREAS

The third volume of the *Bergedorfer Spektral Durchmusterung* containing the zone of declination +30° has been published in 1947. The spectral classes of the stars in the zones +15° and 0° have been observed by A. Schwassmann. The results will be published as soon as the photographic magnitudes to be determined at the Groningen Laboratory are available.

HAMBURG: SPECIAL AREA 16

The spectral classes in the Special Area 16 were observed by A. A. Wachmann. The photographic magnitudes and the magnitudes at $\lambda = 5840$ are being determined at present.

MCCORMICK OBSERVATORY

Miss B. A. Mater has completed the classification of *A.G.* catalogue stars in the zones +10° to +20° and +30° to +50° declination. In the course of this work she has tabulated 1171 stars which are found also in the +45° zone of the *Bergedorfer Spektral Durchmusterung* [40]. The discussion of this material will be completed in 1947.

The spectral classes of the stars in the Selected Areas 5, 8, 11, 19, 23, 33, 38, 123, 124, 126, 127, 129, 133, 137, 139 were classified at the McCormick Observatory, the purpose being a comparison* with the Bergedorf [40] and Potsdam spectra [38]. The limiting magnitude of the McCormick material is about 12 photographic. The systematic differences as well as the mean accidental differences between both Bergedorf and McCormick as well as between Bergedorf and Potsdam are given. A comparison has been made between the Mount Wilson spectra [36] and the Bergedorf spectra which both pertain to stars in Selected Areas.

* 'Intercomparison of Various Spectral Classifications of Faint Stars', by A. N. Vyssotsky, *Astrophysical Journal*, **93**, 425, 1941.

POTSDAM: SOUTHERN AREAS

The spectral classes for the areas in declinations $-75°$, $-60°$, $-45°$, $-30°$ and $-15°$ have been published by F. Becker and H. Brück. The limiting magnitude is 12 photographic; the fields vary from 40 to 24 square degrees, see [35], [38] and [39]. The supplementary publication [39] contains the photographic magnitudes of the areas in the zones $-75°$ and $-60°$; they could not be determined satisfactorily in the former publication [35]. The spectral classes were determined anew.

8. ABSOLUTE MAGNITUDES AND INTENSITY MEASURES OF FRAUNHOFER LINES

MOUNT WILSON: NORTHERN AREAS

The spectroscopic absolute magnitudes of about 250 A to M stars brighter than the 8th magnitude in the areas 1 to 139 have been published by W. S. Adams and his collaborators, see [42]. The absolute magnitudes of all F to M stars and some A stars observed for radial velocity will be determined in the near future.

BONN: SOUTHERN AREAS

Spectral intensity measures and spectroscopic absolute magnitudes of stars in the southern areas have been published, see [41], [43], [44] and [45].

DAVID DUNLAP OBSERVATORY: NORTHERN AREAS

The absolute magnitudes of the stars in the areas between the north pole and declination $+15°$ are being determined at the David Dunlap Observatory. The same stars are observed as in the radial velocity programme; see section 9.

STOCKHOLM: NORTHERN AREAS

Mr Elvius has undertaken a photometric and spectrophotometric investigation of 14 Selected Areas situated about the Milky Way in the Cygnus and Cepheus region. The numbers of the areas are 1, 2, 6, 7, 15, 16, 17, 18, 19, 20, 40, 41, 42, 43. They are distributed over the declinations $+45°$ to the pole. The field is usually one square degree. Spectra are observed with an objective prism to the photographic magnitude 13·5. All spectra are recorded in a microphotometer. The methods developed for spectrophotometric determination of spectral type and absolute magnitude are applied.

The photographic magnitudes are measured in the spectra as monochromatic magnitudes at $\lambda = 4215$ for B to F stars and at $\lambda = 4360$ for G to M stars. The Mount Wilson and Bergedorf magnitudes are used for standardization using known reductions from monochromatic magnitudes to the international scale. The reduced monochromatic magnitudes agree well with the Mount Wilson scale. The mean error of a single measured image is $0^m{\cdot}05$. Photovisual magnitudes are measured on plates taken with the visual 50 cm. refractor and the 40 cm. astrographic telescope. The mean error of a single image is $0^m{\cdot}05$. The photovisual work has been started recently and is completed only for area 40.

A comparison between spectral class and colour for giants and dwarfs in the late spectral types shows that the segregation of giants and dwarfs is satisfactory. The spectral classes agree with Bergedorf; the separation into giants and dwarfs shows large deviations from the Bergedorf catalogue. It seems that actual microphotometric measurements are necessary for this purpose. A preliminary account of the work has been published, see [46]. A future enlargement of the work to a greater number of areas is intended and Mr Elvius has taken a considerable number of plates for this enlarged scheme from declination $+45°$ to the pole.

9. RADIAL VELOCITIES

Mount Wilson: Northern areas and declination $-15°$

The radial velocities of 467 stars in the northern areas and in the zone declination $-15°$ are being observed at the Mount Wilson Observatory. A list of the stars is found in *Transactions of the International Astronomical Union*, **5**, 215, 1936. The stars of the list have not been selected on the basis of either large or small proper motion with the exception of the stars given in the quoted *Transactions*, p. 210.

The radial velocities of 168 stars of the list have been published, 112 stars are completed but unpublished and 187 stars are unfinished. For most of the stars the plates have been taken but on account of the war not all of the plates have been measured and reduced.

David Dunlap Observatory: Northern areas

The radial velocities of stars in the northern Selected Areas between the north pole and declination $+15°$ brighter than the photographic magnitude 7·59 have been observed at the David Dunlap Observatory. The field of each area is $6° \times 6°$. See [47] and [49].

The work is being extended to an $8° \times 8°$ field for a limited number of areas.

McDonald Observatory: Northern areas

The radial velocities, spectral types, magnitudes and colour indices of approximately 40 B-type stars between the photographic magnitudes 9 and 11 in some northern and southern Selected Areas have been determined by C. K. Seyfert and D. M. Popper, see [48].

10. INVESTIGATIONS WHOLLY OR PARTIALLY BASED ON OBSERVATIONAL MATERIAL OF THE SELECTED AREAS

A summary is given of the investigations published since the Stockholm meeting in 1938:

1. 'A study of proper motions of 3189 stars in Kapteyn's areas in zones $+75°$ and $+60°$ and in area 28 of zone $+45°$', by A. N. Deutsch, *Bulletin de l'Observatoire Central à Poulkovo*, **15**, No. 5, 1937. Although published in 1937 this publication and the next one have not been included in the Stockholm report.

The paper contains an investigation of the solar apex and the vertex of star-streaming. The proper motions are determined at the Poulkovo Observatory. The result is for the apex: R.A. $= 280°$, D $= +22°$; and the vertex: R.A. $= 91°$, D $= -2°$. Further, the mean secular parallaxes of different groups of stars are computed.

2. 'Proper motions of faint stars in Kapteyn's area 80 relative to anagalactic nebula N.G.C. 4262', by A. N. Deutsch, *Bulletin de l'Observatoire Central à Poulkovo*, **15**, No. 5, 1937. The relative proper motions derived at the Poulkovo Observatory are reduced to absolute values by means of measurements of the anagalactic nebula N.G.C. 4262, the proper motion of which is supposed to be zero. The result is compared with the reduction to absolute proper motions derived from Hins's catalogue (*Annalen Leiden*, deel **15**, vierde stuk, 1934). The differences may probably be explained by accidental errors. Further mean parallaxes, space velocities and absolute magnitudes are derived for the stars of area 80.

3. 'Dark clouds in Kapteyn's Special Areas 2, 5, 9 and 24 and the proper motions of the stars in these regions', by B. Hiemstra, *Publications of the Kapteyn Astronomical Laboratory at Groningen*, No. 48, 1938.

The proper motions of the stars of the areas 2, 5, 9 and 24 have been measured on 16×16 cm. photographic plates taken at the Radcliffe Observatory with the 60 cm. refractor. The probable error of a proper motion is $\pm 0''{\cdot}005$; the limiting photographic

magnitude is between 14 and 15. All areas show a dark region surrounded by rich parts. The dark regions are ascribed to clouds, the distance and absorption of which have been determined. The results are:

Areas	Cloud Distance	Absorption
2	600 to 1200 parsecs	$0^{m}.5$
5	<300 parsecs	$0^{m}.8$ to $1^{m}.5$
9	600 parsecs	$1^{m}.7$
24	450 parsecs	$\geqslant 1^{m}.5$

4. 'The change of the luminosity function with height above the galactic plane', by J. L. Greenstein, *Astrophysical Journal*, **87**, 577, 1938. The stellar density gradient perpendicular to the galactic plane is determined as a function of absolute magnitude from an analysis of star counts in high latitudes. It is found that giants show much greater concentration towards the galactic plane than dwarfs. The investigation is based on the star counts of the Selected Areas in *Groningen Publications*, No. 43, 1929.

5. 'Absorption and density distribution in the galactic system', by J. H. Oort, *Bulletin of the Astronomical Institutes of the Netherlands*, **8**, 233, 1938.

If the surfaces of equal density are parallel to the galactic plane, it is shown that

$$A_b(m) = \frac{1}{\sin^3 b} A_{90}(m_{90}),$$

where $m_{90} = m + 5 \log \sin b - \Delta a$,

m = apparent magnitude,

b = galactic latitude,

Δa = difference between the absorption suffered by the light of the stars at latitude b and that for stars near the pole,

$A_b(m)$ = number of stars per square degree between the apparent magnitudes $m - \frac{1}{2}$ and $m + \frac{1}{2}$ and galactic latitude b.

The absorption is supposed to take place in front of the stars studied. The values of Δa have been estimated with the aid of counts of extragalactic nebulae in neighbouring fields.

It appears that this relation does not hold for the numbers of stars of specified photographic magnitude in the Selected Areas published in *Groningen Publications*, No. 43. Oort concludes from the deviations between the observed numbers of stars and the values derived from the quoted formula that the sun is situated in a region of relatively low density surrounded in all galactic longitudes by regions where the density is at least twice as high. These structural features extend on both sides of the galaxy to distances of 500 or 700 parsecs from this plane. At larger distances from this plane the unevenness in the density distribution disappears; at levels between 800 and 1800 parsecs the equi-density surfaces can be represented by planes inclined about 10° to the galactic plane.

These conclusions depend to a large extent on the assumption that the absorption takes place mainly in the galactic plane. The distribution of the absorbing material has been investigated by means of colour excesses of stars in Selected Areas as well as from B-star colours. The evidence points to a strong galactic concentration of the absorbing clouds.

6. 'Interstellare Verfärbung in ausgewählten Gebieten der Milchstraße', by W. Becker, *Zeitschrift für Astrophysik*, **17**, 285, 1939. The selective interstellar absorption is investigated for the Selected Areas nos. 1, 19, 26, 40, 42, 194 and some other fields not contained in the list of Selected Areas. The distances of the stars are found by means of the apparent magnitudes and assumed absolute magnitudes of stars of a specified spectral type. It is concluded that in most cases the differential absorption does not increase regularly with the distance but that the absorption is due to separate clouds of interstellar matter.

7. 'Red Indices in southern Selected Areas', by C. Payne-Gaposchkin, *Astrophysical Journal*, **90**, 321, 1939.

The Potsdam and Harvard systems of spectral classification are compared. It appears that the differences are systematic and depend on the apparent and absolute magnitude.

The red indices of 5000 stars in the Selected Areas at declination $-60°$, for which spectral classifications have been made at Potsdam, furnish material for a discussion of spectrum and colour in relation to galactic structure. The normal colours of stars of a specified spectral class are derived from the six areas at latitudes exceeding 20° where obscuration is probably negligible. The six low-latitude areas appear to differ in spectral make-up and in degree of obscuration. The importance of standardizing both spectral classification and magnitude systems is emphasized.

8. 'A determination of the longitude of the vertex and the ratio of the axes of the velocity ellipsoid from the dispersions of the proper motions of faint stars measured at the Radcliffe Observatory', by A. Blaauw, *Bulletin of the Astronomical Institutes of the Netherlands*, **8**, 305, 1939.

The longitude of the vertex and the ratio of the axes of the velocity ellipsoid are determined by means of the dispersions of the proper-motion components. It is assumed that one of the axes of the velocity ellipsoid is directed toward the galactic pole. The mean without regard to sign of the residual proper-motion components parallel to the galactic plane $|\bar{\mu}_l|$ is computed for the stars in each area and between specified limits of apparent magnitude. Residual proper motion = difference between the observed and average component. The mean values are corrected for various errors and the dependence of the reduced values $|\bar{\mu}_l|$ on the galactic longitude towards which they point is considered. The longitude of the vertex is indicated by the largest values of $|\bar{\mu}_l|$ and the variation with the longitude yields the ratio of the axes. The values of $|\bar{\mu}_l|$ computed in the same way from the proper-motion components in the direction of increasing latitude give information about the size of the third axis in zones of low latitude.

The longitude of the vertex is found to be 323°, differing appreciably from the value 336° derived by Knox-Shaw and Scott Barrett from the same material, see [22]. Blaauw's value agrees nearly with the direction towards the galactic centre. The ratio of the axes parallel to the galaxy is found to be 0·58, and the ratio of the axis perpendicular to the galactic plane and the greater axis in the plane is 0·55.

9. 'Das Verteilungsbild der Spektralklassen in den Selected Areas des Südhimmels', von F. Becker, *Zeitschrift für Astrophysik*, **17**, 148, 1939.

The numbers of stars in eleven subdivisions of spectral class and in intervals of half a unit of magnitude are derived from the *Potsdam Spectral-Durchmusterung*. The percentages of stars of each of the spectral classes B0 to B4, B5 to A4, A5 to F4, F5 to G4, G5 to K4 and K5 to M is computed for stars between specified limits of apparent magnitude, galactic latitude and galactic longitude. The main features of the distribution can be explained by the increasing number of stars along the main sequence from B to M, a decrease of the density at a large distance from the Sun and the spheroidal form of the stellar system.

10. 'The stellar distribution in high and intermediate latitudes', by B. J. Bok and D. A. MacRae, *Annals of the New York Academy of Sciences*, **42**, art. 2, p. 219, 1941.

The observational data used are partly derived from the Selected Areas as, for instance, the counts to various limits of apparent photographic magnitude in *Groningen Publications*, No. 43, the mean parallaxes derived by Oort in *B.A.N.* 290 from the Radcliffe Catalogue of proper motions, the spectral data by Schwassmann and van Rhijn in *Zeitschrift für Astrophysik*, **10**, 161.

The rate of decrease of the star density in a direction perpendicular to the galactic plane for different values of the absolute magnitude is found from the luminosity curve in the galactic plane, the star counts and the mean parallaxes in the direction of the north galactic pole for stars of all spectral classes together. This rate of decrease exceeds the value found by Schwassmann and van Rhijn in *Zeitschrift für Astrophysik*, **10**, 161, and by Oort quoted in the latter paper.

It is shown that the function $\phi\,(M, z)\,dM$ giving the numbers of stars per cubic parsec with absolute photographic magnitude between M and $M+dM$ at a height z above the

galactic plane is applicable to the entire polar cap between galactic latitudes 40° and 90°. A table (m, log π) is constructed giving the numbers of stars per square degree between specified limits of apparent magnitude and logarithm of the parallax for all spectral classes together and in the direction of the north galactic pole. By means of this table the ratios:

$$D\,(M, z) = \frac{\text{density for abs. magn. } M \text{ and height above galactic plane } z \text{ at gal. lat. } b}{\text{density for abs. magn. } M \text{ and height above galactic plane } z \text{ at gal. lat. } 90°}$$

are computed for areas between galactic latitudes $\pm 10°$ to $\pm 30°$ for which the absorption of light in interstellar space and the distribution of apparent magnitudes are known. It appears that the values of $D\,(M, z)$ are generally smaller than the values found by Oort in *B.A.N.* 308. The conclusion of the latter author that the density of stars in space at some distance from the Sun exceeds the values in the neighbourhood of the Sun is not confirmed by Bok's investigation.

11. 'The surface brightness of the Milky Way', by E. A. Kreiken, *Astrophysical Journal*, **94**, 259, 1941.

The amount of integrated starlight L for photographic and visual light is computed from the observed numbers of stars as a function of the photographic magnitude in the Selected Areas given in *Groningen Publication*, No. 43, p. 5, and the colour indices of the stars of a specified visual magnitude given in *Groningen Publication*, No. 43, p. 5. The observed values of the surface brightness are derived from Pannekoek's work in *Annalen Leiden*, **11**, pt. III, 1920; *Annalen Bosscha Observatory*, **2**, pt. 1, 1923; *Publications Astronomical Institute Amsterdam*, No. 3, 1933.

It appears that the surface brightness of an area at latitude $\leqq |\, 5° \,|$ is ten times larger than that of an area with the same value of L at higher latitude. Therefore, the integrated starlight is not the only source from which the surface brightness of the Milky Way originates. The effect just described can be explained either by an increase of space absorption near the Milky Way or as the result of increasing mean distance of the stars toward the galaxy.

12. 'The stellar distribution of two southern fields', by B. J. Bok and F. W. Wright, *Astrophysical Journal*, **101**, 300, 1945.

One of the fields investigated in this paper is Selected Area no. 193, galactic longitude 261°, galactic latitude +1°. It is found from colour data that the region is probably free from obscuration for distances up to 1600 parsecs. The densities are derived from the distribution of apparent magnitudes and the luminosity function for stars of different spectral types separately. The density of the B8 to A0 stars increases somewhat up to 500 parsecs and remains constant for distances 500 to 1000 parsecs. The density of the A1 to A7 stars drops to 35 % of the value near the Sun at a distance of 500 parsecs. The F stars show rather steep negative gradients. The gGo to gM stars yield slowly decreasing star densities.

The general luminosity function in the direction of Selected Area no. 193 appears to depend on the distance of the stars from the Sun.

11. PUBLICATIONS CONTAINING OBSERVATIONAL DATA ON THE PLAN OF SELECTED AREAS

Durchmusterung, Magnitudes and Variable Stars

1. Durchmusterung of Selected Areas, by E. C. Pickering, J. C. Kapteyn and P. J. van Rhijn. *Harvard Annals*, **101–103**, 1918 to 1924.

2. Reduction of the Harvard-Groningen Durchmusterung to the International System of Magnitude and Colour, by F. H. Seares, Mary C. Joyner and Myrtle L. Richmond. *Mount Wilson Contributions*, No. 289; *Ap. J.* **61**, 303, 1925.

3. Photographic and photovisual magnitudes of the stars in the zone +45°, by J. A. Parkhurst. *Publications of the Yerkes Observatory*, **4**, pt. 6, 1927.

4. Photovisual magnitudes for the Selected Areas at $\delta = +75°$, by P. J. van Rhijn and B. J. Bok. *Publications of the Kapteyn Astronomical Laboratory at Groningen*, **44**, 1929.

5. Mount Wilson Catalogue of photographic magnitudes in Selected Areas 1 to 139, by F. H. Seares, J. C. Kapteyn and P. J. van Rhijn. *Carnegie Institution Publication*, No. 402, 1930.

6. Study of colour indices of faint stars in five Selected Areas in the Milky Way, by L. F. Slocum. *Lick Observatory Bulletin*, No. 434, 1931.

7. Photographic magnitudes of stars brighter than $14^{m}{\cdot}0$ in 40 of Kapteyn's Selected Areas determined at the Royal Observatory, Greenwich, under the direction of Sir Frank Dyson, Astronomer Royal, 1931.

8. Observations of variable stars in the Selected Areas 1 to 115, by H. Knox-Shaw. *Astronomische Nachrichten*, **253**, 217, 1934.

9. Photographische Beobachtungen von Veränderlichen auf dem Kapteyn Eichfeld 41, von A. A. Wachmann. *Astronomische Abhandlungen der Hamburger Sternwarte in Bergedorf*, **4**, No. 5, 1935.

10. Théorie du spectrographe longitudinal et catalogue des couleurs des étoiles de la Bonn Durchmusterung dans les aires 1–43 du plan systématique de Kapteyn, par G. A. Tikhov, *Publications de l'Observatoire Central à Poulkovo*, Série II, **50**, 1937.

11. Variables in Kapteyn's Selected Areas 2 to 19, by E. A. Baker. *Monthly Notices of the Royal Astronomical Society*, **97**, 541, 1937 and **98**, 65, 1937.

12. Photographic magnitudes in Selected Areas at $-15°$, by Cecilia Payne-Gaposchkin and Sergei Gaposchkin. *Harvard Observatory Mimeographs*, Series II, No. 1.

Photographic magnitudes in Selected Areas at $-45°$ and $-60°$, by Cecilia Payne-Gaposchkin and Sergei Gaposchkin. *Harvard Observatory Mimeographs*, Series II, Nos. 2 and 3.

13. Photovisual magnitudes for the Selected Areas at $\delta = +75°$, by B. J. Bok and W. J. Swann. *Harvard Annals*, **105**, 371, 1937.

14. Standards for Selected Areas 140–206, by S. Gaposchkin. *Harvard Annals*, **89**, No. 9, 1937.

15. Farbenindices in den offenen Sternhaufen N.G.C. 1027 und IC 1805 und den Kapteynschen Eichfeldern 26, 35 und 40, von Martin-Christopher Clasen. *Astronomische Abhandlungen der Hamburger Sternwarte in Bergedorf*, **4**, No. 10, 1937.

16. Over kleuraequivalenten van sterren in Selected Areas 40 en 41 van Kapteyn, door A. Velghe. *Mededelingen van de Koninklijke Vlaamse Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Klasse der Wetenschappen*, **3**, No. 5, 1941.

17. Magnitudes and colours in the globular cluster Messier 12 and Selected Area 108, by J. J. Nassau and J. A. Hynek. *Astrophysical Journal*, **96**, 37, 1941.

Proper Motions and Trigonometric Parallaxes

18. Parallaxes and proper motions of 1041 stars in the zone $+45°$, by O. J. Lee. *Publications of the Yerkes Observatory*, **4**, pt. 4, 1926.

19. Proper motions of the special area no. 12, by W. M. Smart. *Cambridge Observations*, **26**, 1928.

20. Proper motions of some very faint stars, by A. van Maanen and H. C. Willis. *Mount Wilson Contributions*, No. 412, 1930.

21. Faint stars in the Selected Areas (zones $+75°$ and $+60°$) with large proper motion, by A. N. Deutsch. *Poulkovo Observatory Circular*, No. 8, 1933.

22. Radcliffe Catalogue of Proper Motions in the Selected Areas 1 to 115, compiled by H. Knox-Shaw and H. G. Scott Barrett, 1934.

23. General Catalogue of Positions and Proper motions of 1190 Standard Stars in the Areas 2 to 115 of Kapteyn's Plan of Selected Areas, by C. H. Hins. *Annalen van de Sterrewacht te Leiden*, deel **15**, vierde stuk, 1934.

24. Eigenbewegungen von 3189 Sternen in den Kapteynschen Arealen $\delta = +75°$ und $+60°$ und in dem Areal 28, von A. N. Deutsch und E. J. Perepelkin. *Publications de l'Observatoire Central à Poulkovo*, Série II, **45**, 1935.

25. Proper motions of 651 stars in 97 Selected Areas, by P. Th. Oosterhoff. *Ap. J.* **83**, 340, 1936.

26. Dark clouds in Kapteyn's Special Areas 2, 5, 9 and 24 and the proper motions of the stars in these regions, by B. Hiemstra. *Publications of the Kapteyn Astronomical Laboratory at Groningen*, No. 48, 1939.

27. The proper motions of 18,000 stars in 74 Kapteyn's Areas from +75° to +15° declination, by A. N. Deutsch. *Publications de l'Observatoire Central à Poulkovo*, Série II, **55**, 1940.

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28. Katalog von 1885 Sternen für das Aequinoktium 1925, von R. Prager. *Veröffentlichungen der Universitäts-Sternwarte zu Berlin-Babelsberg*, **5**, Heft 3, 1924.

29. Estrellas Kapteyn para las areas seleccionadas australes observadas, por H. A. Martinez. *Publicaciones Observatorio Astronómico La Plata*, **11**, No. 1, 1927 and **15**, 1939.

30. Katalog von 1172 Sternen in Kapteyn's 'Selected Areas' auf Grund der Beobachtungen am Repsoldschen Meridiankreise 1, von C. Mönnichmeyer und J. Hopmann. *Veröffentlichungen der Universitäts-Sternwarte zu Bonn*, No. 21, 1930.

31. Catalogue of 1172 reference stars in the areas 2 to 115 of the Systematic Plan of Selected Areas. Observations of the Leiden Observatory, by C. H. Hins and J. J. Raimond, Jr. *Annalen van de Sterrewacht te Leiden*, deel **15**, derde stuk, 1930.

32. Bestimmung der Oerter von 10 Polarsternen im Kapteyn Feld 1, von B. Sticker. *Astronomische Nachrichten*, **256**, 349, 1935.

33. Ortsbestimmung von zehn Polsternen, von L. Courvoisier. *Astronomische Nachrichten*, **261**, 5, 1936.

Spectral Classification

34. The space distribution of the stars of different spectral classes as determined from studies in the Cygnus region of the Milky Way, by A. D. Maxwell. *Lick Observatory Bulletin*, No. 390, 1927.

35. Spektral-Durchmusterung der Kapteyn-Eichfelder des Südhimmels, I. bis III. Teil enthaltend das Polfeld und die Zonen −75°, −60° und −45°, von Friedrich Becker. *Publikationen des astrophysikalischen Observatoriums zu Potsdam*, **27**, 1931.

35*a*. Spektral-Durchmusterung der Kapteynschen Eichfelder des Südhimmels, IV. Teil, Zone −30°, von H. Brück. *Publikationen des astrophysikalischen Observatoriums zu Potsdam*, **28**, 1935.

36. Spectral types of faint stars in Kapteyn's Selected Areas 1 to 115, by M. L. Humason. *Mount Wilson Contributions*, No. 458, *Ap. J.* **76**, 224, 1932.

37. Revised spectral types of a group of stars in Kapteyn area 98, by M. L. Humason. *Mount Wilson Contributions*, No. 560, 1937.

38. Spektral-Durchmusterung der Kapteyn-Eichfelder des Südhimmels Zone −15°, von F. Becker. *Publikationen des astrophysikalischen Observatoriums zu Potsdam*, **28**, Heft 2, 1938.

39. Spektral-Durchmusterung der Kapteynschen Eichfelder des Südhimmels, VI. Teil. Ergänzungen zu den Zonen −75° und −60° von F. Becker. *Publikationen des astrophysikalischen Observatoriums zu Potsdam*, **28**, Heft 3, 1938.

40. *Bergedorfer Spektral-Durchmusterung der 115 nördlichen Kapteynschen Eichfelder*, von A. Schwassmann und P. J. van Rhijn, Band I, Eichfeld 1 bis 19, 1935; Band II, Eichfeld 20 bis 43, 1938.

Spectroscopic Absolute Magnitudes and Intensity Measures of Fraunhofer Lines

41. Spektrale Intensitäts-Messungen an 1393 Sternen des Südhimmels, von F. Becker und A. Kohlschütter. *Veröffentlichungen der Universitäts-Sternwarte zu Bonn*, No. 27, 1933.

42. The spectroscopic absolute magnitudes and parallaxes of 4179 stars, by W. S. Adams, A. H. Joy, M. L. Humason and A. M. Brayton. *Mount Wilson Contributions*, No. 511, 1934.

43. Spektral-photometrische Parallaxen von 533 G und K Sternen, von F. Becker. *Zeitschrift für Astrophysik*, **10**, 311, 1935.

44. Spektral-photometrische Parallaxen von 205 G und K Sternen, von F. Becker. *Zeitschrift für Astrophysik*, **11**, 148, 1935.

45. Spektrale Intensitäts-Messungen an 1984 Sternen des Südhimmels, von F. Becker und A. Kohlschütter. *Veröffentlichungen der Universitäts-Sternwarte zu Bonn*, No. 29, 1936.

46. Preliminary report on a spectrophotometric investigation in Kapteyn's Selected Areas 2, 6, 7, 15, 16 and 19, by Tord Elvius. *Stockholms Observatorium Annalen*, Band **14**, No. 8, 1945.

RADIAL VELOCITIES

47. The radial velocities of 500 stars, by R. K. Young. *Publications of the David Dunlap Observatory, University of Toronto*, **1**, No. 3, 1939.

48. Studies of faint B-type stars, by Carl K. Seyfert and Daniel M. Popper. *Ap. J.* **93**, 416, 1941.

49. The radial velocities of 374 stars by R. K. Young. *Publications of the David Dunlap Observatory*, **1**, No. 13, 1942.

12. DESIDERATA FOR FUTURE WORK AND THE EXTENSION OF THE LIST OF SELECTED AREAS

1. The Durchmusterung of stars as faint as magnitude 19, which for the zones in declination $+90°$ to $-15°$ has been published in the *Mount Wilson Catalogue*, should be extended to the south pole. A re-examination of the scale of photographic magnitudes of the fainter stars in the southern hemisphere is urgently needed.

2. An extremely valuable addition to our knowledge of the galactic system could be furnished by the measurement of accurate colours down to the 17th or 18th magnitude.

3. The radial velocities of the areas south of declination $-15°$ are unprovided for.

The radial velocities of a number of stars in both hemispheres fainter than magnitude 9 would be very valuable even if the probable errors were larger than the values holding for the brighter stars.

4. An evaluation of the absorption of light in the Selected Areas is urgently wanted. This could be done by statistics of the numbers of extragalactic nebulae on the Selected Areas outside the zone of avoidance and for the other areas by a determination of the colour excesses and absolute magnitudes of B and A stars.

5. It was generally agreed among the members of the Commission at the Stockholm meeting that the present Selected Areas in the Milky Way are too far apart for a study of galactic structure and that a number of additional areas in or near the galaxy should be selected. The Sub-commission, which was appointed to consider this matter, came to the conclusion that the new Selected Areas should preferentially be taken in places where the absorption of light is inconsiderable, if these could be found (the so-called galactic windows). A search for these galactic windows can be performed according to two methods:

(i) By looking for areas in and near the Milky Way with a sufficient number of extragalactic nebulae. Mount Wilson astronomers intend to photograph the whole sky north of declination $-30°$ with the 120 cm. Schmidt telescope at Mount Palomar, in blue as well as in red light and to undertake a search for extragalactic nebulae in and near the Milky Way on these plates. The limiting magnitude of the nebulae will be 19 approximately. This work has of course been delayed through the war, but the survey will probably be ready within a few years.

(ii) Probably a new attack will be made on the structure of the galaxy by an investigation of the B stars brighter than say the 12th magnitude. The density of B stars in space can be found from the distribution of apparent magnitudes and absolute magnitudes, if the absorption of light in interstellar space is known. The latter can be found from the

colour excesses, adopting a constant ratio between the total absorption at some definite wave-length and the differential absorption found from the colour excess. The mean distances of the stars investigated can be found from the absolute magnitudes determined spectroscopically. Hence the absorption may be derived as a function of the distance.

This plan has been discussed with various astronomers. Plates for this programme are now being taken at the Tonanzintla Observatory, while the Tonanzintla astronomers are planning, in collaboration with the Yerkes Observatory, to determine accurate types and luminosity classes according to the scheme developed by W. W. Morgan. It is hoped that other observatories will eventually share in this investigation, and in particular that it will be extended to the southern parts of the Milky Way.

Any galactic windows which may be found in either of these investigations may be added as new Selected Areas to the original list prepared by Kapteyn.

It seems to me that a decision about the new Selected Areas must be postponed until some more progress has been made in the search for galactic windows. This point will be discussed at the Zürich meeting.

P. J. VAN RHIJN
President of the Commission

Report on meeting

ACTING PRESIDENT: Prof. J. H. OORT.

SECRETARY: Dr A. BLAAUW.

The Acting President, Dr Oort, forwarded to the members of the Commission the greetings of Dr van Rhijn who was prevented by illness from attending the meeting. He next invited the members of the Commission and other astronomers present to comment on the Report or make suggestions for changes.

Dr R. E. Wilson of Mount Wilson Observatory informed the Commission that good progress had been made with the determination of radial velocities of 300 stars in the Selected Areas (systematic plan), and that about 200 of these will soon appear in a general list of radial velocities of 1500 stars. Preliminary data will be sent to Dr Fehrenbach in connection with his programme of radial velocities determined by means of an objective prism, which has been recently started at the Observatory of St Michel (France). Stars brighter than apparent magnitude 10·5 in regions $3° \times 3°$ will be observed. The Commission agreed with Dr Fehrenbach that the new radial velocities are most urgently needed for the areas in the galactic zone. Dr Fehrenbach has already obtained the observational material for Sel. Area 41. Mr Velghe announced that for this area and area 40 measurements of effective wave-lengths have been made at the Astronomical Institute at Gent.

Dr Kharadze gave an account on work in Russia. In addition to the proper motions of 18,000 faint stars in the areas of the systematic plan measured by A. N. Deutsch, referred to in the Draft Report, about 3200 proper motions have been measured in the areas 9, 12, 17, 24, 25 of the Special Plan by Deutsch and Labadofsky, and a discussion of the interstellar absorption in these areas based on this material is under way. The determination at the Abastumani Observatory of colours of stars of magnitudes 10–13·2 in the Selected Areas of the systematic plan (see the Draft Report) has been completed for 14,000 stars in areas 1–43. The recent publication of the third volume of the *Bergedorfer Spektral-Durchmusterung* (areas 44–67) will render possible the extension of this work to the zone $+30°$ declination. The Abastumani Observatory considered the desirability of extending this work to the total areas of $3·5° \times 3·5°$. The Commission expressed the opinion that such an extension would be very valuable indeed for the areas at low galatic latitude, and this holds also for at least part of the areas at high galactic latitude. The President mentioned that photoelectric colours of A-type stars brighter than $m = 13$ in the northern selected areas will be determined by Dr Walraven in co-operation between the Leiden Observatory and the Observatoire de Haute Provence at St Michel.

Dr F. Becker communicated to the Commission that the Bonn Observatory intends to repeat the plates of Selected Areas taken by Küstner 40 years ago in order to determine the proper motions. Dr Hins suggested that in the first place those areas be measured which do not occur in the Pulkovo catalogue.

Dr Schilt reported on the proper motion programme of the southern Yale telescope, referred to in the Draft Report. The Commission discussed whether a repetition of the 1927 series of plates (taken without a grating) is desirable, notwithstanding the fact that it will be impossible to correct the resulting proper motions for magnitude errors. The question will be studied in detail by the President and Drs Schilt and Brouwer.

Dr Lindblad summarized the photometric and spectrophotometric investigation of selected areas by Mr Elvius at the Stockholm Observatory.

33. COMMISSION DE LA STATISTIQUE STELLAIRE

PRÉSIDENT: M. B. LINDBLAD, *Director of the Stockholm Observatory, Saltsjöbaden, Sweden.*

MEMBRES: MM. Ambartsumian, Baade, R. H. Baker, Blaauw, Bok, Chandrasekhar, Dziewulski, Fletcher, Freundlich, Gratton, Gyllenberg, Hertzsprung, Junkes, Lindsay, Link, Lundmark, Luyten, McCuskey, MacRae, Malmquist, F. D. Miller, Mineur, J. M. Mohr, Nordström, Ogorodnikov, Oort, Pannekoek, Ramberg, Reiz, Russell, Schalén, Schilt, Seares, G. A. Shajn, Shapley, Smart, Strömberg, Trumpler, van de Kamp, Vanderlinden, Van Hoof, van Rhijn.

Since the last meeting of the Union there has been considerable development in the field covered by the Commission, and the following report, which has been drawn up on the basis of reports by the members of the Commission, can only summarize very briefly some important lines of investigation in the recent development.

Photometry and Spectral Investigations in Various Regions of the Galaxy. In addition to the work in Kapteyn's Selected Areas, systematic investigation is in progress for a great number of galactic regions, and it seems to be an urgent need that such investigations be co-ordinated as effectively as possible in the future.

A number of Harvard investigations deal with the study of the anti-centre region of the Milky Way. In addition to a study of a Monoceros region,* B. J. Bok reports on similar work for eleven centres in Gemini and Orion using the spectra of the Henry Draper Extension and photometry in blue and red. The colour excesses yield information on the space absorption, and the spectra and star-counts give data on the density-gradient.

Colours of faint Cepheid variables are investigated at Harvard by F. J. Hayden, J. Ashbrook, and others, in Cygnus, Cassiopeia, and Ophiuchus, which will give important information on space reddening at great distances.

Bok and Miss F. W. Wright† have made a preliminary study of the stellar distribution in two Milky Way fields in the southern hemisphere. Mrs M. W. Mayall is working on the classification of the Henry Draper Extension in Monoceros, Canis Major, Puppis and Vela. The new Baker-Schmidt telescope for Bloemfontein, which is expected to be ready in 1949, will be used for a study of a limited number of regions in Carina, in and around the Southern Coalsack, and in the regions of the galactic centre.

S. W. McCuskey reports on the work in progress at the Case Institute of Technology in Cleveland. The collection of data on stellar spectra, photographic and photo-red magnitudes, and star counts, for studies of the galactic structure in twelve regions of the Milky Way are continued. The main purpose is to find out fluctuations of the luminosity function in the galaxy. Results for two regions have been published‡, and spectra and photographic magnitudes for two regions are nearly complete.

E. M. Lindsay reports from the Armagh Observatory the following work completed in 1940 and now being prepared for publication:

1. Star-counts down to phot. mag. 13·0 between galactic longitudes 290 and 360° and galactic latitudes $\pm 25°$. The magnitudes are those of the Harvard Standard Regions C, D and E.

2. Star-counts in the Coalsack and four comparison regions complete to phot. mag. 14·0. Spectra, blue, red and yellow magnitudes complete to $m = 10{\cdot}5$.

F. D. Miller reports from the Observatory of the University of Michigan that material is obtained for study of distribution of faint stars (to about mag. 17·5), spectral types and luminosities of brighter stars (to about 12·0), and of obscuring clouds, at galactic latitudes $\pm 30°$, between galactic longitudes 40 and 90°. The plates for investigating the distribution of faint stars and extragalactic nebulae are taken with the Harvard 24-inch Schmidt telescope, the plates for spectral types and luminosities with the 24-inch Schmidt telescope

* *Ap. J.* **101**, 280, 1945; *Harv. Repr.* 273.
† *Ap. J.* **101**, 300, 1945; *Harv. Repr.* 274.
‡ *Ap. J.* **106**, 1, 1947.

of the Warner and Swasey Observatory at nine centres, five in the southern strip (lat. $-30°$) and four in the northern (lat. $+30°$).

J. Junkes reports on the programme started at the Vatican Observatory to investigate the space distribution of stars. Selected fields of four square degrees in and outside of the Milky Way, in regions which are supposed to have very small obscuration, have been chosen. For four regions spectral types, photographic magnitudes and colour indices down to phot. mag. 14 were published in 1940 by M. Tibor. The present programme has been extended to cover:

Fourteen fields near the galactic plane at about gal. long. 7, 16, 25, 40, 55, 70, 87, 105, 121, 135, 148, 163, 174 and 188°; with gal. lat. for different fields ranging from $+4$ to $-9°$:

Twelve fields outside the galactic plane, one at the northern galactic pole, one at gal. lat. $+75°$, three at $+60°$, four at $+30°$, three at $-30°$.

It is also intended to determine photo-red magnitudes. Further star counts down to phot. mag. 17·5 are included in the programme. For the spectra a 4° objective prism in conjunction with the Zeiss astrograph and also with a 24-inch parabolic mirror is used. With the mirror spectra of late M stars can be reached to phot. mag. 16. It is intended to use also an objective prism giving a dispersion of about 1000 A./mm. at $H\gamma$, which would allow determination of the Harvard classes and separation of giants and dwarfs down to phot. mag. 15.

G. A. Shajn reports that work on faint stars in selected regions will be taken up at the Simeis Observatory with objective prism on the double 40 cm. astrograph for the purpose of a two-parameter classification.

At the Stockholm Observatory J. Ramberg is carrying out a photometric and spectrophotometric investigation in selected regions of the Milky Way in Lacerta and Cepheus. A series of quadratic regions, each one covering 11 square degrees, has been selected within a band at right angles to the galactic circle about gal. long. 69°. In these areas spherical co-ordinates, photographic and photovisual magnitudes, spectral types and spectrophotometric data, by which the absolute luminosities may be estimated, are determined down to phot. mag. 13·5. For two regions, about gal. lat. -3 and $-8°$, respectively, a considerable part of these data has been assembled for about 14,000 stars. Similar work has also begun for regions in Auriga on gal. long. 147°, in the first place two areas about gal. lat. $+4$ and $+9°$.

G. Malmquist* has treated extensively and with partly new methods the problem of determining distance, extension in the line of sight, and amount of absorption, for dark nebulae. At the Uppsala Observatory several statistical spectrophotometric investigations bearing on the dark nebulae have been performed. E. Vanäs† has investigated a region in Cygnus surrounding the northern 'Coalsack', G. Wernberg‡ has studied bright and dark regions in Cepheus. O. Eklöf determines red and blue magnitudes in the region of the dark nebula in Auriga which has earlier been investigated spectrophotometrically by C. Schalén. T. Adolfson has begun a spectrophotometric investigation in the dark region in Taurus. A. Velghe from the Royal Observatory in Uccle has gathered material for a spectrophotometric investigation of a dark nebula in Cygnus, together with a determination of red, yellow and blue magnitudes. A. Lundby§ has determined proper motions in and about the open cluster M52 and studied the absorption in this region.

C. Schalén‖ has investigated spectra, magnitudes and colours of 1430 stars down to phot. mag. 11 in a zone of 5° width at gal. lat. $+20°$, between gal. long. 65° and 90°.

Å. Wallenquist¶ has made a statistical investigation of the apparent distribution of multiple stars.

A. van Hoof reports on extensive star-counts at the University of Louvain in a region of the Ophiuchus-nebula of about 500 square degrees, extending between gal. long. 310°

* *Stockholm Annals*, **13**, No. 4, 1939; *Uppsala Annals*, **1**, No. 7, 1943, No. 8, 1945.
† *Uppsala Annals*, **1**, No. 1, 1939. ‡ Ibid. **1**, No. 4, 1941.
§ Ibid. **1**, No. 10, 1946. ‖ Ibid. In the Press. ¶ Ibid. **1**, No. 5, 1944.

and 355°, gal. lat. +15° and +25°, and in two comparison squares at gal. co-ord. 315°, −20°, and 335°, −20°, respectively. The counts were made on Franklin Adams plates.

Fundamental Astrophysical and Statistical Data. For statistical purposes using spectral types, spectroscopic and spectrophotometric criteria of absolute magnitudes, colour indices, etc., much attention must be paid in the future to improving our knowledge of fundamental astrophysical and statistical data.

S. W. McCuskey emphasizes that one of the most serious needs of those who are working in this particular field is a comprehensive and thorough summary of the current data on mean absolute magnitudes and dispersions as functions of spectral type. A summary from the current and past literature would be quite important. More information is needed also concerning the distribution of giants and dwarfs in various regions. A co-ordinated effort on the absolute magnitudes and giant and dwarf distribution would make possible more rapid and more uniform progress in studies of the density distribution.

L. Gratton recommends as follows: (1) that all data of trigonometrical parallaxes, radial velocities, etc., published yearly should be collected in the form of supplements of existing general catalogues. (2) That efforts should be made in order to obtain for all stars of particular astrophysical interest (e.g. the stars nearer than 20 parsecs) a spectral classification as uniform as possible in both hemispheres.

A question of utmost importance for statistical work will be an intense study of various types of 'populations' among the stars. W. Baade's* recent work on the population types I and II in the Galaxy and in extragalactic nebulae has been very stimulating, and has greatly emphasized the importance of considering this question in statistical researches. In this connection attention must also be paid to the variation of the spectral criteria of absolute magnitude for different population types, as indicated by W. W. Morgan and P. C. Keenan† and by D. M. Popper.‡

The stars in clusters are important in this connection, as they are likely to represent different kinds of population groups, as shown by G. P. Kuiper,§ and may help to isolate such population groups. The spectrophotometric criteria of absolute magnitude for the Hyades and Praesepe have been studied by J. Ramberg‖ who derived interesting differences against the stars in general. L. Gratton¶ had previously found differences in this respect for the Pleiades. H. L. Vanderlinden reports that he has determined the relations between photographic magnitude, colour and spectral types for M 67 on the basis of effective wave-lengths for 1153 stars. E. Holmberg** has discussed the stars in the Hyades region on the basis of colour determinations with the 18-inch Schmidt telescope on Mount Palomar.

Investigations on Density and Velocity Distribution and on the Statistical Dynamics of the Galaxy. A great number of investigations have appeared in this field, and only a few representing the main lines of work can be mentioned here without any attempt at completeness. A survey of important contributions has been published under the title 'The Fundamental Properties of the Galactic System'†† following a conference at the New York Academy of Sciences.

At the Leiden Observatory J. H. Oort‡‡ has studied the relation between density distribution and velocity distribution (deviation of the vertex, as determined from the brighter stars, from the direction towards the galactic centre). J. H. Oort and J. J. M. van Tulder §§ investigated the relation between density gradient and asymmetry of the velocity distribution for long-period variables, as well as their absolute magnitudes, and Oort‖‖ discussed the deviations which may occur in the constants of differential rotation and in the ratio of the axes of the velocity ellipsoid in case the peculiar motions are not

* *Ap. J.* **100**, 137, 1944.
† *An Atlas of Stellar Spectra.* Chicago, 1943.
‡ *Ap. J.* **105**, 204, 1947.
§ Ibid. **86**, 176, 1937.
‖ *Stockholm Annals*, **13**, No. 9, 1941.
¶ Ibid. **13**, No. 3, 1939.
** *Lund Medd.* Ser. II, No. 113, 1944.
†† *Annals of the New York Acad. of Sciences*, **42**, art. 2, 113–272, 1941.
‡‡ *Ap. J.* **91**, 273, 1940.
§§ *B.A.N.*, No. 353, 1942.
‖‖ Ibid.

negligible. De Vos van Steenwijk has computed the space velocities for all stars brighter than $6^{m}\cdot5$ for which Mount Wilson spectroscopic parallaxes were available and G. Pels has made similar computations for the stars of trigonometric parallaxes in excess of $0''\cdot066$.

J. H. Oort and A. J. J. van Woerkom* derived the attractive force of the galactic system in the direction perpendicular to the galactic plane, between $z=2$ and $z=10$ kiloparsec from RR Lyræ variables. Van Tulder is making a new and comprehensive determination of the force K (z) from all proper motions, radial velocities and other relevant data.

J. de Kort† studied the possible amount of rotation of the system of globular clusters, and Oort‡ investigated what information on the distribution of mass near the galactic centre could be obtained from the distribution and motions of the clusters.

A comprehensive new determination of the position of the galactic pole has been made by van Tulder.§

J. H. Oort and P. Th. Oosterhoff|| discussed the absorptions, distances and motions of four exceedingly distant Cepheids in the Cygnus cloud, as well as their bearing on the rotation of distant parts of the galactic system and the remarkable distribution of absorbing matter in this direction.

Oort¶ has discussed the systematic errors in the fundamental catalogues of positions and proper motions, and the manner in which they influence the determinations of precession and galactic rotation, for which new values were derived.

The Radcliffe and Pulkovo proper motions in Kapteyn's Selected Areas have been used by L. Binnendijk** for deriving mean parallaxes between magnitudes 11 and 15. C. H. Hins and A. Blaauw use the material, together with the McCormick motions, for a new determination of the longitude of the vertex. Even for stars in low latitudes the longitude of the vertex appears to coincide with that of the galactic centre.

Prof. Oort suggests that the question might be discussed in the Commission if it is desirable to have the proper motions resulting from the combination of the Radcliffe and Pulkovo catalogues published.

To what extent the measures of various interstellar lines may be used as a criterion of distance has been investigated by P. J. van Rhijn.†† He finds that the mean error of the logarithm of the distance derived from the equivalent width of interstellar D or K lines is $\pm 0\cdot13$. The individual distances of O and B stars can therefore be found from the equivalent widths of interstellar lines with a relatively high accuracy. The concentration of the interstellar gas towards the galactic plane is probably the same as that of the interstellar dust.

In a study of the luminosity law and the density distribution of the O and early B stars van Rhijn‡‡ finds the important result that the space density of O to B3 stars does not decrease with increasing distance from the Sun, in contradiction to the theory of a local cluster of B stars. He finds further that the constant term in the radial velocities of B stars is probably independent of the distance, and can be explained by the Einstein red-shift.

The Scorpio-Centaurus cluster among the bright southern B stars has been studied very extensively by A. Blaauw.§§ The stream motion corrected for solar motion is found to be 11·9 km./sec. towards gal. long. $=271°$, gal. lat. $=-11°$ and the cluster is much elongated in the direction nearly perpendicular to this stream motion. Blaauw gives an interesting dynamical explanation of these data. Between $0\cdot4 \cdot 10^{8}$ and $1\cdot5 \cdot 10^{8}$ years ago the cluster, which up to then may have been spherical in shape, was liable to a disturbing force which caused it to deviate from its regular orbit. It was then situated at a point which lies at present in the direction of gal. long. about 3° at a distance between 700 and 1800 parsecs from the Sun. The present shape and motion of the cluster are explained by the relative motions in the rotating galaxy since the disturbance.

* *B.A.N.*, No. 338, 1941.
‡ Ibid.
|| Ibid.
** Ibid. No. 362, 1943.
‡‡ Ibid. **51**, 1946.
† Ibid.
§ Ibid. No. 353, 1942.
¶ Ibid. No. 357, 1943.
†† *Gron. Publ.* **50**, 1946.
§§ Ibid. **52**, 1946.

P. Bourgeois and R. Coutrez* have made an extensive study of the motions of the B stars with special attention on a general K-effect and its dynamical interpretation in relation to a spiral structure of the Galaxy.

G. A. Shajn† has found a large negative K-term for white supergiants, and points out the importance of finding out to what extent this phenomenon may be ascribed to the outward motion of matter in the atmospheres of these stars.

J. M. Mohr has studied irregularities in the motions of 909 B stars and finds that the distribution of the space-velocities differs in various galactic longitudes. If the velocity ellipsoid is assumed identical for all regions, the K-term reduces to the value of Einstein's gravitational effect. He has also studied the relative space velocities and the differential rotation of the planetary nebulae.

The proper motions of the *General Catalogue* are analysed by W. M. Smart on the two-streams theory, dividing the material according to galactic latitude and spectral type.

P. van de Kamp reports on a study of proper motions, parallaxes and orbital motions of stars within 10 parsecs.

The calculation section of the Czechoslovakian Astronomical Society, under the direction of F. Link, has calculated Tables for computing the galactic space velocities of stars.‡ Tables have also been constructed for correcting stellar radial velocities for the solar motion. For printing these Tables, which are ready in manuscript, a grant has been obtained from the Union. The reduction of 8000 stellar radial velocities for determining the solar motion and the galactic rotation has been completed, and a summary has been published.§

At the Stockholm Observatory W. Tormund has tried to determine the main characteristics of the stellar velocity distribution from radial velocities without assuming a functional form for the distribution. The results are of interest especially for the high-velocity stars. Much of the work has been done on I.B.M. machines.

A most important contribution to the study of the dynamics of the Galaxy is Mayall's‖ determination of radial velocities for globular clusters. A solar velocity of 200 ± 25 km./sec. towards an apex close to gal. long. 55°, gal. lat. 0° is indicated. The mean residual without regard to sign is 101 km./sec. Mayall concludes from other data that the most probable value of the sun's orbital velocity lies about 280 km./sec., as generally adopted, which would mean that the globular cluster system partakes perceptibly in the rotational motion.

W. Baade's¶ work in the regions of the centre of the Galaxy using red-sensitive plates has revealed in a surprising way several features of the hidden nucleus of our system. He suggests that parts of the Sagittarius cloud actually belong to the central nucleus of the system.

A problem in the theory of regression lines which is of importance also in stellar statistics has been discussed by F. H. Seares.**

On the general subject of stellar dynamics are to be noted the monographs of W. M. Smart, *Stellar Dynamics*,†† S. Chandrasekhar, *Principles of Stellar Dynamics*‡‡ and E. von der Pahlen, *Einführung in die Dynamik von Sternsystemen*.§§ Chandrasekhar's‖‖ work on dynamical friction introduces powerful methods for the calculation of the stochastic effects of stellar encounters, and has given new insight into the relation between the time of relaxation and the age of stellar clusters.

E. Finlay-Freundlich has investigated the law of equipartition for B stars using well-established data for binary systems. The systematic deviation for these stars found by

* *Annales de l'Observatoire R. de Belgique*, 3e Sér. **3**, 1944 and 1945.
† *Bul. Acad. Sci. of the Georgian U.S.S.R.* IY, **2**, 1943; *Bul. Abastumani Astroph. Observ.* **7**, 1943.
‡ *Publ. de l'Observatoire National de Prague*, No. 17, 1941.
§ *A.N.* **273**, 243, 1943.
‖ *Ap. J.* **104**, 290, 1946.
¶ *Publ. A.S.P.* **58**, 249, 1946.
** *Mount Wilson Contr.* Nos. 698, 716; *Aph. J.* **100**, 255, 1944; **102**, 366, 1945.
†† Cambridge Univ. Press, 1938.
‡‡ *Astroph. Monographs*, Univ. of Chicago Press, 1942.
§§ Verl. Birkhäuser, Basel, 1947.
‖‖ *Ap. J.* **97**, 255 and 263, 1943.

Seares disappears for this material. In his work on the dynamical problems related to the structure of globular star clusters he proves on dynamical grounds the existence of solutions for spherical systems which are solutions of the hydrostatic equations of equilibrium.

Calculating Machines. In the future discussion of statistical methods the very rapid development of calculating machinery must be taken into account. H. Shapley calls attention to the fact that I.B.M. equipment has been installed in various American scientific institutions, notably the Naval Observatory, Columbia University and Yale Observatory for a variety of purposes, such as ephemerides, star positions, magnitudes, and asteroidal researches. Their great possibilities for statistical computations are obvious.

It is probable that the great calculating machinery developed in recent years, both the differential analyser type, the sequence-controlled digital computing machines, and the electronic computing machines, will have important bearing on the undertaking of enormous investigations, whether in the field of general statistics or in the carrying through of heavy problems in mathematical astronomy.

Dr Shapley suggests that the Commission recommends the Union to endorse effectively the proposal of U.N.E.S.C.O. to develop large computing laboratories, for example in India where the progress has already been notable.

BERTIL LINDBLAD
President of the Commission

Report of meeting

PRESIDENT: Prof. BERTIL LINDBLAD.

SECRETARY: Dr J. RAMBERG.

The Commission met on August 13, at 14.30.

The Draft Report as printed was unanimously adopted.

The President presented the tables, published with support from the Union by F. Link,* for correcting stellar velocities for the solar motion and for computing mean parallaxes and a note from Prof. Y. Hagihara, Tokyo, about astronomical work done in Japan during the war.

The President opened a discussion on selected subjects of the Report of the Commission, pointing out that the work of the Commission is very closely bound up with that of other Commissions, especially with that of Commission 32.

The President exhibited two maps showing the systematic determinations of magnitudes, colours, and spectra which, in addition to work of this kind in Selected Areas, are for the present going on at different observatories.

The President mentioned the work carried out at the Stockholm Observatory by J. Ramberg and asked some of the present members of the Commission to give accounts of their work, in this way completing the accounts given in the Draft Report.

Dr J. J. Nassau reported on the work in progress at the Warner and Swasey Observatory:

1. Determinations of photographic and red magnitudes and spectra in twelve areas of relatively clear regions in the Milky Way and, at the galactic longitude 43°, also in fields at the galactic latitudes 4°, 9°, 12° and 22°. Each area covers about 16 square degrees. The average number of stars in each area is about 1400, the limiting magnitude either 12·0 or 12·5. The stars are classified in three or, for stars brighter than $11^{m}\cdot0$, four luminosity classes.

2. Determinations of infra-red spectra with a 4° or a 2° prism in eighteen fields from Sagittarius to the anticentre.

* F. Link, 'Tables d'apex solaire', *Memoirs and Observations of the Czechoslovak Astron. Soc. at Prague*. Praha, 1948.

3. Determinations of blue and infra-red magnitudes in two fields, one in Cygnus (300 M-stars per square degree) and the other at a latitude of 9° (30 M-stars per square degree).

4. A programme of B-stars and other stars of high luminosity to the apparent magnitude 10·0 in a 3°·5 wide belt along the Milky Way from $-10°$ to $+180°$ in gal. longitude. This work is with the co-operation of the Yerkes Observatory.

In addition to what is said in the Draft Report Dr J. Junkes reported on the programme of the Vatican Observatory as follows: 'Work has been delayed by various difficulties. The 2° prism has not yet been delivered. Also there is hope that a Schmidt telescope will be built for the Vatican Observatory and therefore it seems advisable just now to postpone the main part of the programme. In the meantime, however, some preliminary work on these fields will be done, so that work can go ahead as soon as possible when the new instrument is available.'

The President emphasized the great superiority of the Schmidt telescope and mentioned that the Uppsala Observatory plans to build a 40-inch and the Stockholm Observatory a 26-inch telescope of this kind.

Dr H. Shapley mentioned the work going on at the Harvard Observatory:

(1) The search for variable stars of Cepheid type in and around the central region of the Milky Way.
(2) The programme on the nucleus of the Milky Way comprising star counts and determinations of colours and spectra.
(3) The work with the 60-inch telescope in South Africa on the Magellanic clouds in order to determine the characteristics of the general luminosity curve.
(4) Work at the Oak Ridge Station after the same lines as mentioned by Dr Nassau.
(5) Mrs M. W. Mayall's completion of Miss Cannon's spectral classifications.

Dr E. K. Kharadze reported about the work at the Abastumani Astrophysical Observatory as follows: (i) The determination by Kharadze of colour indices of 505 extra-galactic nebulae to 13^m, partly published. (ii) The determination by Vashakidze of colours of 100 Cepheids to $12^m{\cdot}8$ (in print).

In addition to the Draft Report Dr C. Schalén pointed out that the regions investigated at Uppsala are chosen so as to contain both bright and dark areas, the main purpose being to study the dark nebulae. He mentioned that they have reached at present only the 11th magnitude, but hope to extend the investigations to fainter stars when they get their new Schmidt telescope.

Finally, Dr C. Fehrenbach gave an account of his determinations of radial velocities using a prism *à vision directe*.

After a few words from Dr R. J. Trumpler the President expressed his thanks to Dr Fehrenbach for his very interesting account, and the meeting was closed.

34. COMMISSION DE LA MATIERE INTERSTELLAIRE ET DES NEBULEUSES GALACTIQUES

PRÉSIDENT: M. JOEL STEBBINS, *Washburn Observatory, University of Wisconsin, Madison Wisconsin, U.S.A.*

MEMBRES: MM. Aller, Ambartsumian, Baade, Beals, C. Bertaud, Bok, Bowen, Cernuschi Dufay, Dunham, Greenstein, Henyey, Mlle Hoffleit, MM. McKellar, Malmquist Menzel, P. W. Merrill, F. D. Miller, Minkowski, Öhman, Oort, Schalén, V. M. Slipher B. Strömgren, Struve, Swings, ter Haar, Trumpler, van de Hulst, Whitford, O. C Wilson, W. H. Wright, Zanstra.

This Commission was organized at the Stockholm meeting of the Union in 1938, and now after ten years has the opportunity to make its first report. The rearrangement of the fields of the different Commissions at Copenhagen in 1946 gives Commission 34 some responsibility for the entire volume of space between the stars, if not between the galaxies Since the presence of interstellar material in any region of space may be revealed by emission, reflection, scattering, or absorption of radiation, the study of this material falls under or overlaps the activities of half a dozen other Commissions of the Union. Because of this extent of the relations of the Commission we may consider again the directions in which international co-operation may function to advantage. As pointed out by Schlesinger when the Union was organized, such co-operation is valuable in matters of convention; in avoidance of duplication; and especially in investigations too large for one institution or even one country to undertake.

Because of the world situation and the difficult times through which we have been passing, it seems advantageous to bring together brief summaries of the recent work of different members of the Commission and their plans for the near future, which, though necessarily incomplete, may serve as a basis for discussion and for formulation of further plans both individual and collective. In the nature of the case much important work has been done outside the membership of the Commission, but even a partial survey of the present situation should be of some value. The theoretical investigators presumably need little organization and advance planning, but information on current and future observational programmes can be of value to all workers in the field.

About half of the members of the Commission have responded to the chairman's communication, and these reports are given herewith without an attempt to classify them according to subject matter. Following the reports are some of the proposals which might well be discussed in the meetings of the Commission at the next General Assembly of the Union.

The Commission is indebted to Dr Walter S. Adams for permission to include in this report an abstract of the second Henry Norris Russell Lecture delivered before the American Astronomical Society in December, 1947. The abstract follows.

THE GASEOUS CLOUDS OF INTERSTELLAR SPACE

The material upon which this lecture is based consists of spectral observations of 300 stars, nearly all of types O to B9, observed with the Coudé spectrograph and 100-inch telescope at the Mount Wilson Observatory. Four-fifths of the spectra were photographed on a linear scale of 2·9A. to the millimeter, and one-fifth on the smaller scale of 10A./mm. The range of wave-lengths covered, $\lambda 3500$ to $\lambda 4700$, includes a large proportion of the more important interstellar lines.

A brief summary outlines the discovery of numerous sharp interstellar lines in addition to H and K which has raised the number now known to a total of 26; the complete identification of the new lines, and the recognition that no less than 11 of them originate in molecules of the diatomic gases CH and CN; and the discovery by Beals of the double character of the H and K lines in the spectra of a few interstellar clouds.

The study of the observational material has included: (1) a search for interstellar lines other than H and K, with especial reference to the molecular lines; (2) an examination of the structure of H and K; and (3) estimates of the intensities and measurements of the radial velocities of all interstellar lines including the components of H and K.

About one-sixth of the spectra of the 300 stars show the molecular lines in the intervening gaseous clouds. The chief conclusions to be drawn are:

1. Relatively few stars show essentially all the atomic and molecular lines at the same time. Examples are ζ Ophiuchi, ζ Persei, ρ Ophiuchi, and some others. H and K are not exceptionally strong in these stars.

2. Lines of ionized CH are usually stronger than those of neutral CH, and appear in many clouds in which neutral CH is not observed. The ratio of the intensities of ionized to neutral CH shows a wide range.

3. Neutral CN is usually present with neutral CH.

4. Lines of neutral iron and $\lambda 4227$ of neutral calcium are always faint, and seem to appear when H and K are very strong.

5. Stars close together in position usually show the same interstellar lines.

Of the stars investigated 122 show double or multiple interstellar H and K lines. They are divided as follows: double, 100; triple, 17; quadruple, 4; five components, probably 1 (P Cygni). With few exceptions the most complex lines appear in stars of very low galactic latitude, and very frequently the same structure is repeated in stars which lie close together. In only one star, HD 193322, is the strongest molecular line, $\lambda 4232$, clearly double, but when H and K are complex the molecular lines appear wider than normal.

The radial velocities given by the single H and K lines, or by their strongest component if complex, are, after correction for the solar motion, very low, averaging 5 km./sec. The molecular lines give values accordant with H and K. In a few stars like χ Aurigae, which show double H and K with nearly equal components, the molecular lines give velocities corresponding to the mean of the two components. Since most of the stars are bright and relatively near, the effect of galactic rotation should be small, and such is found to be the case.

On the other hand, some of the fainter components of H and K, originating probably in smaller and thinner clouds, show very considerable radial velocities. In 21 cases these exceed 30 km./sec. and in five cases 50 km./sec. The highest velocity observed is +96 km./sec. for a well-marked component in the spectrum of a seventh magnitude star, HD 169454, in Sagittarius. HD 199478 in Cygnus shows two components which give velocities of +41 and +60 km./sec., respectively. These motions may be those of small thin interstellar clouds moving rapidly with reference to the much larger and deeper clouds of low velocity.

The question whether the clouds which give rise to the molecular lines may differ from those which produce H and K, and may be considered as circumstellar and related to the stars by means of which they are observed, is of considerable interest. The consistency of the radial velocities derived from the molecular lines as compared with H and K, together with the lack of any correlation between the velocities of the clouds and those of the stars, indicates that such a relationship, if it ever existed, has probably been lost. Even in the case of the Pleiades cluster, for which the argument for circumstellar origin of the molecular lines may be considered strongest because of their abnormal intensities relatively to H and K, the radial velocities derived from H and K and the molecular lines show a difference of +10 km./sec. from the velocities of the stars forming the cluster.

WALTER S. ADAMS

During 1943, 1944, and 1945, thanks to the kindness of Drs J. H. Moore and C. D. Shane, the present writer, then at the University of California, was able to secure at the Lick Observatory spectrophotometric observations of some 45 planetary nebulae for a study of emission-line intensities and particularly the brightness distribution in the monochromatic nebular images. Special emphasis was placed on those objects that showed interesting

structural features, e.g. NGC 6720 and 6905 which show lines of the Bowen fluorescence mechanism, the high excitation objects NGC 4361 and 2022, and the binuclear nebulae NGC 6778 and 2440 which resemble NGC 7026. Crossley slitless spectrograms supplemented by plates taken with the Cassegrain spectrograph of the 82-inch McDonald Reflector provide material for a study of the brighter central stars of the planetary nebulae. An analysis of the spectra of the absorption-line nuclei of NGC 2392, 6891, II 4593, 6826, and 6210 suggest that these stars are dwarfs with masses comparable with that of the sun. Absorption lines of C III, C IV, He II, and emission lines of O VI characterize the spectrum of the central star of NGC 246. I have measured emission-line intensities in a number of objects, e.g. the carbon-oxygen type Wolf-Rayet nuclei of NGC 6751 and 6905.

In collaboration with R. Minkowski at the Mount Wilson Observatory I have undertaken an intensive spectrophotometric study of NGC 7027. Mount Wilson plates covering the region from λ9000 to λ3700 are supplemented by McDonald spectra in the interval λ5000–λ3200. Vega and Epsilon Persei are the comparison stars. We are measuring the intensity distribution in the continuous background as well as the emission lines in this rich, high-excitation spectrum.

LAWRENCE H. ALLER

Data on intensities of interstellar calcium and sodium lines have been collected at the Dominion Astrophysical Observatory for about 250 O to B0 stars, and it is proposed to prepare this material for publication as soon as possible. Parts of the work have already been published in *M.N.* **93**, 585, 1933; **94**, 663, 1934; **96**, 661, 1936; *Ap. J.* **87**, 568, 1938; *Pub. A.A.S.* **9**, 115, 1937. It is intended to collect all material on interstellar lines by the writer into a single publication giving intensity and radial velocity data for each line measured.

General reviews of the field of interstellar matter have been published in *M.N.* **102**, 96, 1942; and *Pop. Astr.* **52**, 47, 1944. A programme of observations of spectrophotometric gradients of early-type stars was begun at Victoria for the purpose of investigating the subject of space reddening and gradients were measured for about sixty stars. The transfer of the writer to Ottawa in November, 1946, has interrupted this programme, but it is hoped to carry it on with a different type of equipment.

The writer has felt the need for some means of unification for the numerous systems of indicating the colour of a star. A certain amount of confusion is inevitable in trying to correlate spectrophotometric gradients secured by photography, photoelectric gradients, photographic colour indices, and photoelectric colour indices of various kinds. If some means could be found of reducing all four to a common system, say that of photographic gradients, I believe that it would contribute to the advancement of the subject.

C. S. BEALS

The work by myself and my immediate associates at Harvard Observatory can be briefly summarized under the headings that follow:

1. *Colours of faint Henry Draper Extension Stars. Ap. J.* **101**, No. 3 of May 1945, contains two papers that deal largely with star colours. The first, written jointly with Mrs Rendall-Arons, deals with the section of the Milky Way in Monoceros, the second, written jointly with Miss Frances W. Wright, refers to two fields in the southern hemisphere. Miss Olmsted and I are now working on a similar investigation for eleven centres in Gemini and Orion. It is the primary purpose of these studies to obtain information about the stellar distribution for this section of the Milky Way. But, incidentally, we obtain colour excesses for many faint B and A stars, and star counts for the entire region under investigation, which together serve to fill in the detail about the distribution of interstellar dust as derived from the colour excesses of O and B stars.

2. *Faint Cepheids.* During the war Father Francis J. Heyden and I began to assemble plates for a study of the colour curves, blue and red, for seven faint Cepheids in Cygnus. The results of this work have been published by Father Heyden in the *Astrophysical Journal.* Dr Joseph Ashbrook has under way a similar investigation for a number of Cepheids in Cassiopeia, and I am now working with our Jewett Schmidt telescope on some faint Cepheids in Cygnus and in Ophiuchus. We are much impressed with the potentialities of this method, which promises to give accurate information about faint reddening at great distances.

3. *Theoretical Studies.* A full day of the Harvard Observatory Centennial Symposia was devoted to problems of interstellar matter. My own paper at this symposium dealt with condensations in interstellar material and their probable evolution, a subject on which I had done some preliminary work jointly with Miss Edith Reilly.

4. *Plans for the Southern Hemisphere.* The principal large-scale project for the future is one that Shapley and I are planning to undertake jointly with the new Baker-Schmidt telescope at Bloemfontein. We shall have one-third of the observing time on this telescope with the remaining two-thirds going to the Armagh and Dunsink Observatories. If all goes well, we expect to have a large objective prism for use with this telescope; the free aperture will be 32 inches and the focal length 120 inches. Our first plans call for exhaustive star counts, spectra and colour surveys for a limited number of centres. Preference will be given to fields at low galactic latitudes, especially in Carina, in and near the Southern Coalsack, and in the central region of Sagittarius. I am now doing at Oak Ridge preliminary work on the establishment of photometric standard sequences in blue and red in some of the Harvard Standard Regions at $+15°$ (C-regions).

5. *Photoelectric Work.* Since the end of the war, we have become very much impressed with the need of supplementing our photographic and spectral work on colours and colour excesses with photoelectric work. One of our students, Albert Linnell, is building a photometer for use on the 61-inch at Oak Ridge, and if this works out successfully, and if we can find some cash for further development, we plan to build one or more additional photometers, especially with the idea of using one in the southern hemisphere. Not only would this instrument come in handy for work on individual Cepheids, O and B stars and the like, but such a cell could probably be used also effectively in the establishment and checking of the scale of our faintest blue and red standard sequences.

BART J. BOK

Terminology. There has been some discussion of the advisability of agreeing on an unambiguous and theoretically correct set of terms in the field of interstellar material. (1) The words 'dust' and 'smoke' refer to different types of small aggregates. Dust is the result of pulverization of larger pieces of solid matter; smoke, in the United States, is usually the end product of a chemical process involving oxidation. Use of one term or the other should only be in the proper context of a theory of the origin of the small interstellar grains. (2) The term 'particles' has become, in modern physics, applicable mainly to elementary atomic or nuclear particles, including photons. A more specific word like grain or granule may be preferable. (3) The term 'extinction' covers both absorption (involving change of frequency) and scattering.

Outline of Work since 1938. The general problem of the ratio of interstellar extinction to reddening has been treated in a series of papers; the goal was a distinction between the metallic and dielectric types of granules, and a determination of the distribution function of sizes. My own older spectrophotometric results have been recently surpassed in accuracy by the six-colour photoelectric photometry of Stebbins and Whitford; analysis of these data leads to a probable minimum value of A_{pg}/E_1 of about nine. An investigation by a completely non-spectrophotometric method (with L. G. Henyey) showed that the non-selective extinction is small. It may be suggested that care be taken in conversion of colour excesses on one colour system to another because of the 'curvature' of the relative energy differences between reddened and unreddened stars. The best technique for

calibration of the ratio of absorption to reddening at present seems to be a determination, on each colour system, of the colour-excess of stars whose reddening on a very wide base line is known. With L. G. Henyey a series of theoretical and observational investigations on the colour effects in reflection nebulae was made; unfortunately the multiple diffusion of light, if a nebula is optically thick, hides most of the differences between true absorbing and scattering grains. However, our investigations did indicate that the nebulae are slightly bluer than their illuminating stars, that the albedo of the material is high, and that most of the scattering is of a forward-throwing type, as is expected for dielectric granules. Observations which indicated the existence of diffuse 'galactic light' in the Milky Way also lead to the same conclusions.

A group of astrophysical problems is involved in the spectrophotometry of diffuse galactic nebulae. A steep Balmer gradient was found, probably due to interstellar reddening. The complex reflection, emission line and continuum spectrum of the Orion nebula has been accurately measured; the theoretical interpretation is not completely satisfactory. It may be noted that relatively high-resolution slit spectrograms with an $f/1$ camera can now be obtained of many galactic nebulae, and that this field is quite unexplored. Observations of nebulae at radio frequencies are to be desired. Recent work has been on stars deeply involved in bright and dark nebulosity; such as the T Tauri stars, and the variable nebulae, NGC2261 and 6729. The variable nebulae apparently produce absorption lines of hydrogen. Wide peculiar emission is observed near T Tauri stars in dense dark regions. In collaboration with Struve I found peculiar absorption lines in the variable stars in the Orion nebula. With Aller I found no peculiarities in giant stars in nebulae. Apparently the low radiation pressure in dwarfs permits both solid and gaseous components of the interstellar medium to approach more closely to the star. This field of the interaction of the interstellar medium with the stars may prove important also in the study of the interstellar grains.

JESSE L. GREENSTEIN

In three papers (*Stockholms Obs. Ann.*, Bd. **13**, No. 4, 1939; *Uppsala Astr. Obs. Ann.*, Bd. **1**, No. 7, 1943 and No. 8, 1945) I have treated the problem of determining the distance, radial extension and absorption of a dark nebula. E. Vanäs has published a spectrophotometric study of stars in Cygnus, embracing the well-known 'Northern Coalsack' (*Uppsala Ann.* Bd. **1**, No. 1, 1939), and G. Wernberg has made a spectrophotometric investigation on stars in bright and dark regions in Cepheus (ibid. No. 4, 1941). Works on dark nebulae in Auriga, Cygnus, and Taurus are in progress, embracing the determination of red, yellow, and blue magnitudes together with spectral classification.

K. G. MALMQUIST

In the series of papers 'Physical Processes in Gaseous Nebulae', published in the *Astrophysical Journal*, we have been attempting the solution of certain detailed problems of a rather general nature. In each case, we have adopted some idealized nebula and carried through a detailed solution, which I think is fairly accurate both physically and mathematically, to discover what effect the dilute high-temperature radiation from a star would have on a gaseous envelope.

In working out this series of papers, I have had the extremely valuable assistance of a number of scientists, physicists as well as astronomers. Without their aid, I should not have been able to carry the problem through as far as it is at present. We started out to study the luminosity of the hydrogen nebulae, since hydrogen appears by far to be the most abundant material. Later on we discussed the effect of other processes that arise from the presence of impurities, in particular the metastable ions of oxygen, nitrogen, neon, etc.

Our studies, therefore, are by no means limited in application to conditions in the planetary nebulae. In many cases they could be applied to determine the physical state of interstellar material.

It seems to me that the chief gap in our present knowledge, from the interpretation of both interstellar material and nebulae, lies in the field of atomic parameters needed to describe the phenomena. We need to know more specifically than we do at present the various excitation functions, collisional parameters, radiation transition probabilities, etc., for a number of atoms and molecules. Hebb and I made a start along this type of computation, but we limited our discussion to one of the simplest cases, namely O III. Certainly a great deal more work needs to be done here. I understand that Aller and Ufford have made some progress in the important case of O II, but I believe that their work relates more to transition probabilities in radiation than to those for collision. I have no work of this sort going on at the present time although I have been in correspondence with D. R. Hartree of Cambridge, England, with respect to some computations that he has been planning. I now have one student well trained in the method of wave mechanics, but he is working on problems more closely associated with stellar atmospheres and with interstellar space. However, some of his transition probabilities will be useful for calculating the densities of forbidden iron lines, like those that appear in Eta Carinae. Owing to the fact that so many of the physicists have rushed off to study the nucleus of the atom, we astronomers are left alone with respect to the exteriors of atoms and molecules. If we are to get the information, we shall either have to make the calculations ourselves or perhaps inspire some physicist to carry on the work. Shortley (of Ohio State University), Aller, and Herget have some long-range plans for the solution of atomic problems with the aid of the computing machinery at Cincinnati. I cannot now forcast what direction these calculations will take, but I am glad to note that Shortley has a continued interest in atomic exteriors.

I hope shortly to publish an investigation that I have carried out on the earth's ionosphere during the war. This treats the ionosphere in much the same way that we handled the nebular problem. Some of the new techniques that I have worked out for the ionospheric studies may be useful in further interpretation of nebulae and possibly even for matter in interstellar space.

With respect to the nebulae, I have one further improvement in mind. Our initial assumptions implied that the matter of the nebula was uniformly distributed in a shell around the central star. I now believe that the planetaries, like prominences, are distinctly filamentary. A recalculation will undoubtedly cause us to revise our estimates of densities and masses of the nebulae. The tendency will be to lower the masses and raise the densities.

From the standpoint of interstellar space, there is one factor that worries me. Lacking any direct information to the contrary, theorists have tended to calculate the ionization as if it were produced by dilute radiation from a large number of black bodies at the spectral temperatures of the stars. Now, the radiation of greatest interest to us is the radiation beyond the series limits—from 1500 A., let us say, to 200 A. or higher. I am not quarrelling with the black-body assumption as long as we remember that it is definitely an assumption. However, one may argue that the amount of available energy is far greater than that from a black body. For example, in the case of the sun, we know that the corona must send out large amounts of ultra-violet radiation at a temperature more nearly of a million degrees rather than a temperature of 6000°. I assume that other stars may do the same. In such a case, the ionization would be far greater than the simpler assumption would indicate. Or, perhaps, one might use inverse reasoning and say that the hydrogen layers of stars and the hydrogen immediately surrounding the star would tend to absorb a proportion of the ultra-violet radiation and convert it to the visible range, forming bright nebulae. In this case, we would have less radiation than our computations would indicate. I do not know the answer, and have thus tended to keep myself out of the interstellar field until I can get a better estimate of the spectral distribution in the far ultra-violet. Certainly, I see no real justification for the assumption that

a star must radiate like a black-body over so long a range of its spectrum. In some cases, I might even expect that the radio waves from stars might exert some effect upon the ionization in interstellar space. Also, the increasing evidence for stratification and for cloud formation in interstellar space must be taken into account.

DONALD H. MENZEL

General. It is now clear that the chief interstellar lines are formed largely in relatively thin curtains stretched at irregular intervals between the stars. Calculations based on uniform distribution of interstellar gas may, therefore, be greatly in error and are probably no longer profitable. More detailed investigations should be preferred.

Abundance of Chemical Elements. Further study is needed of the probable distribution of interstellar atoms among various stages of ionization. Condensation or chemical combination also should be given consideration because they might play an important part in removing atoms from the states in which they can produce the observed atomic lines.

Broad Unidentified Lines. These lines are probably caused by dust particles. The correlation of their intensity with space reddening should be further studied. Laboratory materials (perhaps in thin films) at very low temperatures would seem a promising method of attack on the identifications.

PAUL W. MERRILL

In connection with the general spectrophotometric work at the Stockholm Observatory much attention is being paid to different problems relating to interstellar absorption. In 1941 Ramberg's investigation of the Hyades (*Stockholms Obs. Ann.* **13**, No. 9) gave as a by-product some valuable information about the obscurations in Taurus. Among investigations in progress which are expected to give interesting contributions to our knowledge of interstellar absorption Elvius's spectrophotometric work in Kapteyn's selected areas and Larsson-Leander's study of faint open clusters should be mentioned.

Photoelectric work made by me on selected reddened B stars (*Stockholms Obs. Medd.* No. 55, 1944) have given evidence in favour of the opinion that the $1/\lambda$ law is not governing the selective absorption. In fact the observations indicate a steeper gradient of the absorption curve on the red side of $\lambda 5000$ A. than on the violet side of the same wave-length, a result which agrees well with determinations made by Baade and Minkowski, Strohmeier, and by Stebbins and Whitford. An improved photoelectric colorimeter is now being constructed which will allow measurements of two colour indices on each side of $\lambda 5000$ A.

Though not strictly in the scope of Commission 34, Lindblad's investigations of the interstellar absorption in some extragalactic systems ought to be mentioned here (*Stockholms Obs. Ann.* **14**, No. 3, 1942; *Ap. J.* **104**, 211, 1946, together with R. Brahde). Also my polarigraphic studies of illuminated clouds in the great Andromeda Nebula may be of a certain interest (*Stockholms Obs. Ann.* **14**, No. 4, 1942).

YNGVE ÖHMAN

The possible existence of a rough equilibrium between the solid particles of the gas in interstellar space was studied by van de Hulst and myself in *B.A.N.* No. 376, as well as in my George Darwin Lecture (*M.N.* **106**, 159, 1946). It was suggested that for gases other than hydrogen and helium the equilibrium was maintained by the evaporation of particles at mutual collisions caused by the random motions of the interstellar clouds. The investigation led to a theoretical determination of the distribution function of the radii of the particles, of the 'absorption' coefficient in the galactic plane, and of the way this varies with the wave-length.

I have indicated that with this mechanism there would only be a relatively narrow range of gas density at which solid particles could develop sufficiently to give rise to

absorption phenomena. This may possibly have a bearing on the occurrence of rings of absorbing matter, which are typical in early-type spirals (still unpublished).

I have also investigated the effects of the heating of the gaseous parts of the clouds upon encounter, and have shown that it may easily explain the luminescence of rim nebulae like that south of ζ Orionis. It is not unlikely that also some of the shells of old novae (Nova Persei 1901) and supernovae (Veil nebulae in Cygnus) derive their luminosity from such a process. This investigation has not yet been finished.

Some of the hydrodynamic problems connected with the motions and collisions of interstellar gas clouds have been studied by Prof. J. M. Burgers of Delft; these studies have appeared in *Proc. Amsterdam Acad. Sci.* **49**, 589 and 600, 1946; ibid. **50**, 262, 332, 442 and 573, 1947.

J. H. OORT

The distribution of particle sizes and the theoretical representation of observed absorption curves (Baade-Minkowski and Strohmeier) has been discussed in *Uppsala Ann.* **1**, No. 2, 1939. *Uppsala Medd.* **75** = *Zs. f. Ap.* **17**, 260, 1939, contains computations of the radiation pressure on small particles and the significance of radiation pressure for the formation of dark clouds. The structure of the dark cloud in Auriga is discussed in *Uppsala Medd.* **78**, 1940.

A study of reflection nebulae is in *Uppsala Ann.* **1**, No. 9, 1945. It is pointed out that a study of the variation of the colour of the nebula with the distance from the exciting star is of importance for the investigation of the constitution of the nebula. An attempt has later been made to measure the colour of the Merope nebula, but the results have not yet been published.

CARL SCHALÉN

1. *Galactic Nebulae*

My studies of planetaries and of their nuclei, during the period 1938–47, have mostly been published in *Ap. J.* and *Proc. Nat. Acad. Sci., Washington.* Here are some results:

(*a*) Certain nebulae which are very rich in nitrogen have a WC-nucleus which contains *no* nitrogen (Ex.: Campbell's envelope star; HD 167362).

(*b*) Certain nuclei of Wolf-Rayet (or Of-) type contain N and C with similar abundances, hence cannot be classified as WN or WC (Ex.: nuclei of NGC 6543, IC 4997, NGC 6572, NGC 6826(?); IC 418). Similar things are found in novae.

(*c*) In discussions of ionization in nebulae (Zanstra mechanism), the discrete far ultraviolet emission or absorption features of the nucleus should be taken into account (Ex.: NGC 6543), as well as stratification effects.

(*d*) In Of-nuclei of planetaries, peculiar line selectivities appear, presumably due to fluorescence effects.

(*e*) Recommendations: Forbidden lines of metals (Ex.: [Fe II, III, VII]) are observed in nebulae. It is essential that theoretical calculations be made of the transition probabilities in [Fe II] and [Fe III]. (Presumably, the strongest [Fe II] transitions have a much higher probability than [O I] or [N II]).

2. *Interstellar Material.*

(*a*) In 1937, in collaboration with L. Rosenfeld, an interstellar molecular line (CH) was identified.

(*b*) As is apparent from Herzberg's note (*Ap. J.* **94**, 381, 1941) and from Ledoux's article (*Pop. Astr.* **49**, 513, 1941), it was my discussion of the sharp unidentified interstellar lines which led Herzberg to the attribution of three of these lines to CH^+.

(*c*) In *Lick Contr.*, Ser. II, No. 3, I gave a discussion on cometary and interstellar molecules. This was developed in a report to the I.A.U. meeting in Copenhagen.

3. *Suggestions to encourage Laboratory Work*

(*a*) On absorption spectra at low temperature (around 3° K) of solids consisting of cosmically abundant atoms (for identification of Merrill's diffuse interstellar lines in the visual region; one may be due to solid oxygen).

(*b*) On the spectra of CH^{++} (the unidentified 'interstellar' line at $\lambda 3579$ may be due to CH^{++}), NH^{+} and CN^{+}, likely to be found in interstellar absorption.

P. SWINGS

The formation of smoke particles in interstellar space was investigated by Dutch astronomers and physicists in the years after 1942. It appeared (D. ter Haar, H. C. v.d. Hulst, J. H. Oort, A. J. J. v. Woerkom, *Ned. Tijds. v. Nat.* **10**, 238, 1943; D. ter Haar, *B.A.N.* **10**, 1, 1943; *Ap. J.* **100**, 288, 1944) that it was possible to account for their formation by assuming that they were condensation products. This condensation was possible, notwithstanding the low density in interstellar space, because of the low temperature ($\sim 3°$ K) of the particles. The condensation seems to be dependent on the gas density, the most favourable density being 2–200 atoms per c.c. The question of the density of diatomic molecules was also studied (H. A. Kramers, D. ter Haar, *B.A.N.* **10**, 139, 1946), and it was found that, taking into account all possible reactions, the observed density of CH, CH^{+} and CN, could be explained. The mechanism of the formation of these molecules was found to be radiation capture. This radiation capture will also be the main mechanism of the formation of larger molecules.

D. TER HAAR

The properties of the solid particles in interstellar space have been investigated both from a theoretical and from an observational point of view. In the theoretical study I considered the interaction between the interstellar gas and the solid grains. The results are that the temperature of the grains is 10 to 20° K, and that all the striking atoms and ions freeze down (Cernuschi's ideas are wrong). Most of the H, He and Ne will evaporate again from the particles. The final composition must be something like ice with impurities (certainly not plain metal). Consideration of the large-scale and long-range features of the theory leads us to believe that the particles grow gradually by accretion and then suddenly vaporize during a collision of two clouds.

The observational data required first a new study of Mie's theory. The main results of this investigation were: (*a*) an increased collection of numerical data, and (*b*) a new set of formulae and curves for refractive indices near 1, both with and without absorption. The observations themselves still admit of a fairly wide range of explanations. However, the possibility of strongly absorbing particles like metal particles is definitely excluded. The effective size can be estimated very well, but the size distribution is uncertain. An interesting by-product of the theory is that particles of this size cannot show absorption lines or bands similar to the unidentified interstellar lines and bands. Albedo and phase-function are in agreement with the observations. An estimate of the ratio A/E by extrapolation of the selective extinction curve leads to about the same value (with the same degree of uncertainty) as direct measurements of this ratio.

I have recently taken spectra of the Veil nebula and other diffuse nebulae in order to obtain some observational data pertinent to Oort's theory of collisions of interstellar clouds.

H. C. VAN DE HULST

The work of the Washburn Observatory on interstellar matter was at first devoted to a survey of the regions of the sky where its presence could be detected by the reddening of standard objects. Colours were measured photoelectrically by comparing the relative response through two filter glasses. The general survey of 1332 B-stars (*Ap. J.* **91**, 20,

1940), covering essentially all known stars earlier than B5 north of $-40°$, showed a very spotty distribution of interstellar material, but in general a high concentration near the galactic plane. Absorption in space near the sun was investigated at the north pole of rotation and in the region of the galactic poles using the colours of the more numerous A-stars. Here spectral classification difficulties enter (Keenan and Babcock, *Ap. J.* **93**, 64, 1941; Morgan and Bidelman, *Ap. J.* **104**, 245, 1946). While there may be a clear space out to about 150 parsecs in the direction of Polaris, the galactic caps show about the same reddening that would be expected on the average at an equal distance in low galactic latitudes.

Following the early proofs by Mrs Rudnick (*Ap. J.* **83**, 394, 1936), Hall (*Ap. J.* **85**, 145, 1937), and Greenstein (*Ap. J.* **87**, 151, 1938) that the reddening follows approximately a λ^{-1} law, further study was undertaken over as wide a range of wave-lengths as possible. At first a moving-slit spectrophotometer was used (*Ap. J.* **90**, 209, 1939), but later six filters with effective wave-lengths ranging from 3530 to 10,300A. were adopted. A comparison of reddened and unreddened B-stars showed (*Ap. J.* **98**, 20, 1943) a slightly 'curved' rather than a linear relation between absorption and inverse wave-length. All regions of the sky showed the same relation, indicating that the reddening portion of the interstellar medium has a uniform composition in all parts thus far investigated. The difficulty, emphasized by Greenstein (*Ap. J.* **104**, 403, 1946), that extrapolation of the observed curvature leads to an excessive ratio between total and selective absorption, was resolved when measures out to 21,000A. with a lead-sulphide photoconductive cell (*Ap. J.* in the Press) confirmed a reverse curvature in the infra-red predicted by Oort and van de Hulst (*B.A.N.* **10**, 187, 1946).

Two surveys of the sky brightness of the Sagittarius region, one with a caesium-oxide cell at effective wave-length 10,300A. (*Ap. J.* **106**, 235, 1947), and a second, at the Lick Observatory, with a lead-sulphide cell at effective wave-length 20,000A. (unpublished) showed a 'bulge' along the galactic equator centred at longitude 326°·5. This was interpreted as radiation from the central region of the galaxy. The total photographic absorption in front of the bulge may be as small as 6 magnitudes, a value lower than previously supposed, but perhaps plausible if the central region and parts of the path to it are of Baade's Population II, where interstellar material is believed to be non-existent.

The problem of the distribution of interstellar material is intimately related to study of galactic structure. Both depend upon the discovery of distant high-luminosity objects such as B-stars and Cepheids (such as the 'Oort Cepheids', *B.A.N.* **9**, 325, 1942). The recognition of the two population types means that we must expect regions of the galaxy where such objects do not exist, and where less satisfactory standard objects such as red giants and cluster variables will be the only ones available.

Almost all the observations by the staff of the Washburn Observatory in this field have been carried out at Mount Wilson and published as *Contributions of the Mount Wilson Observatory*.

A. E. WHITFORD

The problem of the determination of the abundances of H, Na, Ca, K, and Ti in interstellar space has been investigated. The degree of ionization of CaI, CaII, NaI, and KI in interstellar space was recalculated, taking account of the effect of recombination to excited states. Making use of theoretically calculated continuous absorption coefficients for the excited states of the atoms in question, correction factors to the previously used equation of ionization were derived. These factors range from 3 to 1600. The problem of the extension of HI and HII regions has also been considered. It was found that the typical gas cloud within 1000 parsecs is un-ionized, with a hydrogen density around 10 atoms/c.c. The relative abundances of the elements are similar to those derived for stellar atmospheres (*Ap. J.* **108**, 242, 1948, cf. also this volume, p. 471).

In collaboration with W. A. Hiltner a survey of interstellar hydrogen emission was undertaken, using a photoelectric photometer equipped with two interference filters

having maximum transmission at 4861 A. (H_β) and 4600 A. (comparison region). The photometer was attached to the 82-inch reflector of the McDonald Observatory. The intensity of fields 1°3 in diameter was measured through the H_β and the comparison filter, alternately. Fields with stars brighter than 15^m were avoided. The intensity ratio H_β:Comparison for the night sky plus faint background stars was determined from comparison regions, partly regions outside the Milky Way, partly regions of the Milky Way which according to the investigations of Struve and Elvey with the nebular spectrograph are known to have no interstellar hydrogen emission. The ratio H_β:Comparison observed in the absence of hydrogen emission proved very constant. Presence of interstellar hydrogen emission could now be detected through an excess of the observed H_β intensity over the value derived in multiplying the observed comparison intensity by the standard H_β:Comparison factor. The faintest interstellar hydrogen emissions observed by Struve and Elvey were just measurable with this technique. The total observing time for the measure of one field was about 4 minutes.

A survey of interstellar hydrogen emission in the Milky Way from galactic longitude 90° to 200° was made. Fields at galactic latitudes +3°, 0°, and −3°, and 3° apart in galactic longitude, were measured. A region of about one hundred square degrees containing the extended emission region around S Mon was covered with fields 1° apart. (The results of the survey will be published in the *Ap. J.*)

BENGT STRÖMGREN

PROPOSALS FOR DISCUSSIONS

Several topics from the foregoing reports may perhaps be discussed profitably at the time of the General Assembly.

The suggestion by Greenstein that some agreement on terminology might be advisable, such as the choices between dust and smoke, particles and grains, extinction, absorption, and scattering.

The unification of different systems of indicating the colour of a star, as pointed out by Beals, could well be discussed. While the North Polar Sequence and Selective Areas give standards of photographic magnitudes and colours for temperature-reddened stars, nowhere are there such standards for space-reddened stars. In view of the increasing attention that must be given to total and selective space absorption in all studies of the galaxy, a joint discussion of standards for space reddening with other Commissions such as 25, Stellar Photometry, 32, Selected Areas, 36, Spectrophotometry, and perhaps others, would seem to be in order.

The need of more spectra of faint stars, especially in the southern hemisphere, applies to the work of this Commission as to others. Luminosity classes for the B-stars in the *Henry Draper Catalogue* are needed to extend the study of space reddening in the southern Milky Way.

JOEL STEBBINS
President of the Commission

Report of meeting

PRESIDENT: Prof. J. STEBBINS.

SECRETARY: Dr C. SCHALÉN.

I. DARK MATTER

(1) The proposal by Greenstein concerning some agreement on terminology (dust-smoke, particles-grains, extinction-absorption) was discussed. On the suggestion of Dr Oort it was decided to leave the matter open.

(2) The proposal by Beals for the unification of different systems of indicating the colour of a star was discussed.

OORT: We must find the stars which are unreddened and which can serve as basis, e.g. A-stars near the galactic pole.

STEBBINS: Colour is very susceptible to spectral type; early B-stars are the only ones where the classification has no importance.

(3) The need of more spectra and absolute magnitudes of faint stars especially in the Southern Hemisphere was discussed. Recommendation adopted by the Commission: Spectra of early-type stars in the Southern Hemisphere should be determined at as early a date as possible.

II. BRIGHT NEBULAE

(4) Dr Zanstra summarized the main points of a theoretical paper on scattering with redistribution and radiation pressure in a stationary nebula ready for publication.*

SPITZER: I have only general feeling that it is important to compare the abundance of elements in the planetary nebulae and the stars.

Strömgren drew attention to gaseous nebulae where the geometrical conditions are less favourable. It is even more important to know the abundance of the elements in gaseous nebulae.

Ambartsumian reported that Prof. V. V. Sobolev of the Leningrad University has worked out a general theory of the radiative equilibrium for the case of the non-coherent radiation which includes also the theory of radiative equilibrium of planetaries as a special case. The paper was printed recently in the *Astronomical Journal of U.S.S.R.*

(5) Prof. Heckmann described W. Becker's method of deriving two different colour-indices from determinations of three magnitudes. The plates and filters are chosen in such a manner that the yellow-red colour-index represents the slope of the red gradient, the blue-yellow that of the blue gradient. The colour-index difference is almost independent of interstellar reddening. Prof. Heckmann pointed out that one of the last issues of *Ap. J.* contains a summary of Dr Becker's work.

APPENDIX

A theoretical paper on scattering with redistribution and radiation pressure in a stationary nebula is ready for publication. Work done thus far on $L\alpha$ scattering in nebulae has suffered from two serious imperfections: (1) the line profile has been treated as a rectangular one, whereas actually it is a thermal Doppler profile, and (2) the scattering within this profile has been assumed to be ordinary scattering, while actually it approaches more to one in which, for any frequency absorbed, the re-emission occurs with complete redistribution over the whole of the thermal Doppler profile on account of the individual thermal velocities (Henyey, Spitzer). When these two imperfections are removed, it is shown that, for a stationary nebula of total L_c optical depth unity, the force of radiation pressure for $L\alpha$ scattering with redistribution is only about 1/300 of the $L\alpha$ radiation pressure force under the wrong assumption of ordinary scattering, or about 20 times the radiation pressure force for L_c. A paper in Russian by Prof. Sobolev of Leningrad University which deals with the same subject and leads to similar results has appeared already in 1947, as Prof. Ambartsumian points out.

Reliable and accurate determinations of the magnitudes of the central stars of all known planetaries are long overdue. These, together with Vorontsov-Velyaminov's total brightnesses, or perhaps even better total monochromatic N_1+N_2 brightnesses of the nebulae, could be used for stellar temperature determinations and parallaxes. In this case it would be desirable to determine monochromatic magnitudes for the central stars as well. For such improved material the distance criterion: bolometric magnitude of the central star or total magnitude of the nebula or some other criterion should then first be established.

* See Appendix below.

The most direct and detailed method of comparing the luminosity of a planetary nebula with its central star appears to be the determination of the quantities A_ν which express the intensity of each monochromatic picture in terms of the adjoining star spectrum. It would be very desirable if for one test case one could determine this quantity with the star in the slitless spectrogram having various degrees of extrafocality so as to find its correct value and establish what are the best conditions for determining it. This is particularly of importance since the estimates of the electron concentrations based indirectly on the writer's A_ν values (*Zs. f. Ap.* **2**, 337, 1931) are a good deal lower than more recent determinations by Menzel and Aller (*Ap. J.* **93**, 195, 1947 and **102**, 254, 1945).

H. ZANSTRA

35. COMMISSION DE LA CONSTITUTION DES ETOILES

PRÉSIDENT: M. H. N. RUSSELL, *Princeton University Observatory, Princeton, N.J., U.S.A.*

MEMBRES: MM. Atkinson, Barbier, Bethe, Chandrasekhar, Cowling, Gamow, Hoyle, Kothari, Ledoux, Lyttleton, McCrea, Milne, Pannekoek, Randers, Rosseland, Schatzman, Schwarzschild, Severny, Strömgren, Tiercy, Tuominen, von Zeipel, Wasiutynski.

The study of the internal constitution of the stars has advanced rapidly in the past few years, especially for those of the main sequence. The present summary is necessarily brief.

For a star of uniform composition, whose interior is in radiative equilibrium, with or without a convective core, the constitution can be completely determined by successive approximations by quadratures, if there are given

(*a*) the atomic composition,
(*b*) the equation of state, defining the mean molecular weight μ,
(*c*) the equation defining the opacity for the outflowing radiation,
(*d*) the equation defining the rate of liberation of energy per gram.

There is now good reason to believe that most of the mass of a star consists of hydrogen and helium. In this case μ is substantially constant throughout the interior, depending on the ratio H/He with a small addition depending substantially on the total, but not the relative, abundance of the heavy elements. The opacity, however, depends primarily upon the abundance of these, and considerably upon what they are. If only lighter atoms of the 'oxygen group' are present, the opacity is less than if the heavier atoms of the 'iron group' are in equal amount. The liberation of energy in main-sequence stars depends upon the carbon cycle, and hence upon the relative abundance of carbon and hydrogen, the density of the hydrogen, and the temperature.

A satisfactory solution for the internal constitution of a star may be made on general physical principles if the proportions by weight of hydrogen, helium, and the heavier elements are given, and also the division of the latter between the oxygen and iron groups, and the proportion of carbon present.

This makes four independent parameters. Usually, only two other observational data—radius and luminosity—are available for a star of known mass. Assuming the distribution of the heavy elements, the abundance of hydrogen and helium may be calculated. Thus Schwarzschild* found for the Sun 47 % of hydrogen, 41 of helium, and a central density 79 times the mean—assuming a 'Russell mixture' of heavier elements, containing 2 % of carbon. This 'mixture' was based on estimates made at a very early stage of the study of the subject, and may underestimate the abundance of the oxygen group. On the limiting assumption that the heavy atoms all belong to this group, G. Keller† finds for the Sun a considerably greater central density and effective polytropic index, about the same central temperature, and a higher abundance of hydrogen.

The central concentration of density may be found observationally for eclipsing binaries with apsidal motion. The values differ from star to star, but cover almost the same range as is found in the theoretical solutions. No star is yet known for which the mass, radius, luminosity and central concentration may all be found by observation.

A fairly definite solution of the problem would be in sight if the relative abundance of carbon and oxygen could be predicted: but this is the one ratio which is known to vary widely—as in stars of classes M and N.

This matter has been discussed in detail, as illustrating past success and future promise. Others can be only briefly mentioned.

Whether different parts of a star are of the same composition is an important and difficult question. Within a convective region, this may be assumed; but outer layers in radiative equilibrium may represent 'unconsumed' material; and there may be an inner isothermal core, exhausted of all its hydrogen.

* *Ap. J.* **104**, 203, 1946.
† Columbia University (unpublished).

For stars not on the main sequence the situation is far less satisfactory, except for the white dwarfs, where the theory of relativistic degeneracy appears to be adequate. For the sub-dwarfs, it is not yet certain whether they represent an outer limit of dispersion for the main sequence, or another sequence parallel to it. So few of these stars are binaries that information regarding masses, densities, etc., is almost absent. Whether these, and the outer fringe of the main sequence on the other side, are explicable by the same physical process as for the main sequence, operating under different conditions, remains to be determined.

Very little is known about the constitution of giant stars, except that the relation between their masses and luminosities is roughly* the same as for the main sequence. The most serious lack is of information regarding the central condensation; and there is little present hope of finding this† by observation.

Energy can be obtained in these stars from the carbon cycle only if the central concentration is very great. No satisfactory physical theory of this has yet been developed in detail; nor has the possibility been disproved. With moderate concentration, the only known source of energy arises from irreversible transformation of light nuclei (Li, Be, B). It is hard to see how this could give the steady increase in the bolometric luminosity of normal giants from G 5 to M; but again the matter is not closed. The super-giants present the problem in an aggravated form.

Space fails for more than mention of the fascinating cosmogonic problems: why rotating stars have magnetic fields; what happens to a massive main-sequence star as it exhausts its hydrogen; why any super-giants remain in a universe more than 2×10^9 years old; and why any stars have yet reached the white-dwarf stage. There is abundant opportunity for theoretical investigation and urgent need of observation of stars which may provide critical information.

Informal and friendly co-operation among investigators appears to be all the organization which is required.

The writer is greatly indebted to Prof. Martin Schwarzschild for valuable discussions.

H. N. RUSSELL
President of the Commission

* The observational data for masses are rather weak.

† Apsidal motion must be present in ζ Aurigae—with a period of many thousand years.

Report of meeting

ACTING PRESIDENT: Prof. E. A. MILNE.

SECRETARY: Dr F. HOYLE.

The President's report was discussed and approved.

It was agreed that a reprint of the B.A. Tables of the Emden functions would be most welcome, possibly with the addition of tables of solutions possessing central singularities.

Several members gave short accounts of recent work on stellar constitution. There was general agreement that models involving discontinuities of molecular weight can be chosen so as to give red giant properties. The desirability of fitting such models into a satisfactory scheme of stellar evolution was emphasized.

36. COMMISSION DE LA SPECTROPHOTOMETRIE

PRÉSIDENT: M. M. G. J. MINNAERT, *Directeur de l'Observatoire, Utrecht, Pays-Bas.*

MEMBRES: Mlle Adam, MM. Adel, Allen, Aller, Atkinson, Barber, Barbier, Beals, Brück, Carroll, Chalonge, Dufay, Dunham, Elvey, D. S. Evans, Greaves, J. S. Hall, Hiltner, Houtgast, A. Hunter, Järnefelt, A. S. King, Lindblad, McKellar, E. G. Martin, Menzel, Mulders, Öhman, Page, Pannekoek, Plaskett, Redman, Righini, Shane, Spitzer, Strömgren, Struve, Thackeray, Whipple, Woolley, K. O. Wright, Yü.

By publishing at each meeting a report on the progress of astronomical spectrophotometry, our Commission has done in the past work which has been appreciated. Such a report may be expected to be of special usefulness in the present circumstances, after the disruption of normal communications for so many years. For this purpose, an attempt has been made to give a list of the most important publications, as a bibliographical appendix to this report. The titles are quoted in abridged form. My thanks are due to many members of the Commission, who contributed materially to this list and helped me with important information. I apologize for omissions, nearly inevitable in this post-war period. In future some restriction of the field of our activity ought to be considered; spectrophotometry is nowadays so general an astrophysical method, that it is nearly impossible to give a more or less complete survey of its applications to all different fields of our science. This report was finished on January 1, 1948. A few recent publications have been included in the bibliographical list.

A great number of papers on the spectrophotometric observational methods have been published in physical and in technical periodicals. In the *Journ. Opt. Soc. America*, the *Industr. Engineering Chem.* (anal. ed., 1941), and the *Bull. Acad. Sc. U.R.S.S.* 1940, etc., much useful information about these technical measurements may be found.

I. SPECTROGRAPHS

For solar spectrographs an important addition is the monochromator which is introduced before the first slit [1, 1, 2].* This instrument intercepts the particularly dangerous stray light of other wave-lengths. It may be made so selective as to transmit only a few angströms, so that even the ghosts of the neighbouring parts of the spectrum are eliminated. By a proper choice of the lenses, the monochromator at the same time magnifies the solar image and thus helps in studying details near the limb.

The construction of stellar spectrographs has been perfected by the introduction of mirrors instead of lenses: an off-axis parabolic collimator is used, and interchangeable Schmidt cameras of different focal length are available, adapted to the particular object under investigation. Thus the chromatic aberrations are practically eliminated. If lenses are used, stray light due to reflection against the glass surfaces should be avoided by coating all optical parts by an antireflex film, a technique now generally used. This not only increases the speed of the instrument, but is especially important for intensity measurements.

Some stellar spectrographs have been made with a dispersion already of the same order as that of a medium solar spectrograph [1, 3, 4]. The Coudé spectrographs of the McDonald and of the Mount Wilson Observatories yield star spectra in which the individual profiles of all stronger spectral lines may be studied (cf. section XI). Wood's aluminum on glass gratings give a dispersion which in many spectral regions is superior to that of prisms.

Attention is drawn to the enquiry of the Swedish National Committee of Physics, concerning the need of gratings and the possibility of manufacturing them.

In order to increase still more the resolving power, a new method may be found in the use of the Fabry and Perot interferometer. This instrument, formerly used for the investigation of extended sources of light, can be applied also to stellar spectra [1, 5].

* Figures in square brackets refer to entries in the Bibliography on pp. 385–98. The Roman numerals indicate the sections under which they are numbered.

Special instruments have been devised for the investigation of faint nebular spectra: the nebular spectrograph and the image-slicer [I, 6, 7].

By means of special spectrographs, located in the head of rockets, it has been possible to photograph the solar spectrum at altitudes of 135 km. and up to λ2200.

II. MICROPHOTOMETERS

A great variety of types for rapid technical measurements has been devised [II, 1]. The precision required for an astrophysical observatory will generally be higher. Some interesting new principles have been applied and will be briefly described.

Two galvanometer spots at a constant distance of say 20 cm. are recorded simultaneously; this device permits the measurement of densities up to 2 [II, 2]. A small part of the light is used for the formation of another spot which is followed by eye while the record is being made [II, 2].

The coupling of the plate motion with the motion of the recording paper can be obtained without gears or periodic errors by means of various devices [II, 2, 3].

An extremely quick record can be obtained by means of a photoelectric cell and a cathode-ray oscillograph [II, 4].

The reduction of transmission curves to intensity curves is a very lengthy process. By the Amsterdam and by the Victoria astronomers semi-automatic devices have been described, allowing even a correction for the instrumental curve [II, 7]. Two completely automatic instruments were devised at Utrecht and at Michigan, the one adapted more specially to the solar spectrum, the other one to stellar spectra [II, 8, 9]. The further development of such instruments is of vital importance for the systematic application of spectrophotometry on a large scale.

III. PHOTOGRAPHIC PHOTOMETRY

Excellent summaries of numerous recent papers on photographic methods are found in the Kodak Abstracts. Here the astronomical contributions only will be reviewed.

International comparison of standard lamps has proved an excellent method in investigations on gradients and colour temperatures. The gradient difference of the lamps is relatively easy to determine, the gradient itself is more uncertain [III, 2, 3, 4].

Apart from the usual incandescent lamps, other standard sources have been investigated, giving a spectrum of more uniform density in a prismatic spectrograph. The tube of molecular hydrogen has been used in the region λ2500–4000 and even λ4200–5000 [III, 6]. A fluorescent plate, illuminated by a mercury lamp, is suitable between λ4400 and 5500 [III, 7].

Recent experience has again proved that a calibration by rotating sectors is sometimes reliable [III, 8], sometimes not [III, 9], even if the flashes are very rapid. By using a quartz plate between two polaroid films, channelled spectra are obtained in which the intensity distribution is known and which may be used for calibration [III, 11].

The influence of humidity on photographic plates has been studied in detail. It effectuates not only a decrease in sensitivity but modifies also the density curves [III, 12]; in about two hours saturation is reached. In normal astronomical work the effect does not exceed $0^m{\cdot}03$ [III, 13]. When two successive, equal exposures on the same plate are found to have a different density, this is not due to humidity but to the fogging background light, the influence of pre-fogging being different from that of post-fogging [III, 13].

The effect of graininess prevents the discovery of faint spectral lines; in a well-studied case, it proved impossible to detect such lines by comparing a series of successive microphotometer records of the same plate and noting coincidences [III, 14].

In order to avoid halo formation by the reflection of the plate, it has been recommended to cover the back-side by an antireflex layer [III, 15]. Local sensitivity differences, due to a varying thickness of the emulsion, can be detected after development and corrected for [III, 17]. An increase of 1^m or 2^m in the sensitivity of plates has been obtained by

hypersensitizing with mercury vapour, by preference at a humidity around 75% [III, 18, 19].

Some special methods of photographic spectrophotometry have been applied, which in certain cases may be of great use. The measurement of stellar spectral lines with a wide microphotometer slit is found to be practical also when the spectra are unwidened and narrower than the slit length [III, 20]. The ratio of two neighbouring emission lines on a continuous background can be derived in first approximation from unstandardized spectra by assuming a mean value of the gamma [III, 21].

IV. DIRECT SPECTROPHOTOMETRIC MEASUREMENTS

Such techniques, used before for the continuous spectrum of the Sun, are being applied now with improved instrumental means to other problems in order to avoid the photographic intermediary. The profiles of solar lines are recorded by a photocell behind a narrow slit; changes in the atmospheric transmission during the record can only be partly compensated by means of a second photocell, used for control [IV, 1].

The photocell and the multiplier phototube have reached such a considerable sensitivity, that they may be combined with different colour filters and make possible a very precise *comparison* between the energy distribution in stellar spectra, though each individual curve is admittedly rough [IV, 2, 2*a*].

In the infra-red, important results have been obtained at the McDonald and McMath-Hulbert Observatories [IV, 3] with new PbS photocells, sensitive up to 3μ. In the McDonald instrument, the beam of light is intercepted 1080 times a second, and the resulting discontinuous photocurrent is amplified. By means of this apparatus, the energy distribution in the spectra of planets and stars has been investigated; recently the resolution has been considerably increased and a cooling system has been introduced. At McMath, solar lines with an equivalent width of only 0·01 A. are clearly recorded [IV, 6]. Several other types of cells have promising qualities for work in the infra-red and are gradually declassified ([IV, 4], an excellent survey).

The classic thermo-element is less sensitive, but is able to record the radiation far into the infra-red. This stresses the importance of instruments such as the beautiful infra-red spectrometer of the Liège Observatory [IV, 7].

A direct colorimeter has been constructed by making use of quartz plates and a rotating polarizer, combined with a multiplier; the alternating current produced is amplified and measured [IV, 5].

V. APPARATUS CURVE

Exact determinations of the apparatus curve have been made for the Potsdam and Arcetri grating spectrographs [V, 1, 2] and for the Oxford prism spectrograph [V, 3]. It is only in the first case that a comparison between different wave-lengths is possible, which showed that the width of the apparatus curve is proportional to λ. For the prism spectrograph, the assumption has been made that the line width is mainly due to inhomogeneity of the prisms and that it has the same value in millimetres through the whole spectrum. More experimental research upon this question is necessary. These apparatus curves were determined by measuring the profiles of krypton, neon, mercury emission lines, or from sodium or oxygen absorption lines [V, 3, 6]. From plates taken with the Mount Wilson solar grating for the Utrecht atlas, the asymmetry in the apparatus curve of this instrument was derived. A similar asymmetry was found in the apparatus curves of other gratings [V, 4].

Different mathematical methods have been devised, giving the relation between the observed profile, the true profile and the apparatus curve [V, 5, 6]; computations may be simplified by special apparatus [V, 7, 8]. In order to correct stellar spectra for the influence of instrumental broadening, the 'contraction method' is very practical, though not quite exact [II, 7; XI, 7, 8].

VI. INTENSITY RECORDS AND CATALOGUES

From Mount Wilson plates a photometric atlas of the solar spectrum has been published by the Utrecht Observatory, giving the intensity profiles between $\lambda 3332$ and $\lambda 8771$ [VI, 1]. Similar records have been published for nine representative star spectra, photographed with the Coudé spectrograph of the McDonald Observatory [VI, 2, 3]. Information about the apparatus curve of the *Utrecht Solar Atlas* is found in [V, 4], [V, 6], [VI, 4] and [XII, 4].

Allen's photometric catalogue of solar lines has been complemented by measurements in the region $\lambda 8800$–11000 [VI, 4*a*] and $\lambda 3530$–3915 [VI, 5]. The calibration of the Rowland scale has been perfected by several authors [VI, 6, 7, 8].

The total energy absorbed by all the Fraunhofer lines together has been redetermined [VI, 8]. The result (9·1 %) will have to be considerably increased by the new interpretation of the ultra-violet solar spectrum [IX, 5].

Concerning the most convenient unit in which equivalent widths should be expressed, a separate note is inserted at the end of this report.

VII. ATOMIC TRANSITION PROBABILITIES

The important task of publishing a catalogue of f values has been assumed by a subcommission of Commission 14. A provisional list of some directly available data is given in our literature list under section VII; they are intended to complement the tables in Unsöld, *Physik der Sternatmosphären*, pp. 128 and 191. These data have been found partly by quantum mechanical calculation, partly by laboratory measurements, either in absorption or in emission.

Among the collected data, the absorption coefficient of H^- is of particular importance; it was found by Wildt to play a preponderant role in the formation of the continuous spectra of the Sun and of G and F stars. Since then, several astrophysicists devoted their work to the calculation of this absorption, a probably definitive solution being given by Chandrasekhar. It would be interesting, but difficult, to make laboratory measurements.

Transitions between excited states were up to now only found by experiment. Goldberg, Aller and their collaborators are trying to find these probabilities from theory.

It would also be important to collect data about the probability of excitation by electron collision as a function of the electron velocity for as many lines as possible. These data are important for comparing the influence of collision and radiation in the formation of Fraunhofer lines; moreover, they are required for the theory of the corona and the gaseous nebulae.

VIII. MODEL ATMOSPHERES. TRANSFER OF RADIATION

The origin of the opacity of stellar atmospheres can now be considered as elucidated to a great extent:

–G o	Continua near series limits of metals. Perhaps O^-.
G o	H^- predominant; metal continua in the U.V.
G o –A o	H^- and increasing contribution of H.
A o	H predominant.
A o$^-$	H and electron scattering, sometimes He.

The strong continuous absorption in N stars to the violet of $\lambda 4300$ is perhaps due to an accumulation of molecule bands [XII, 28].

The importance of H^- in the Sun explains the absence of discontinuities in the spectrum, due to metal continua [VIII, 12, 13]. It is confirmed by the energy-wavelength curve [VIII, 7, 8, 10, 11] and, in a less clear way, by the limb darkening [VIII, 9]. Originally, it seemed that an extra absorption in the infra-red was left unexplained [VIII, 8]; this, however, was afterwards shown to be entirely accounted for by the free-free transitions [VIII, 11].

For the Sun and the other stars for which we now have an exact knowledge of the absorption coefficient, it has been necessary to revise our models of the outer layers [VIII, 24, 25, 25*a*; XI, 1*a*]; many considerations on the energy-wavelength distribution and the colour index, the limb darkening, the formation of Fraunhofer lines, the Balmer discontinuity, the conditions in sunspots, can now be established for the first time on a reliable basis.

For the mathematical treatment of the radiation transfer, new and very effective methods have been found especially by Chandrasekhar [VIII, 3], giving high approximations for problems hitherto scarcely tractable and involving absorption, scattering, polarization, line-formation.

The theory of neutron diffusion, applied to the transfer of radiation, has given for the first time a rigorous solution of the problem of temperature distribution in a grey atmosphere; a detailed table of Hopf's function $q(\tau)$ is now available [VIII, 3*a*, 3*b*, 3*c*]. By comparison, it is found that the 'variational' solutions converge much more quickly towards the exact result than other solutions.

For the real, non-grey atmospheres, there is for the moment a lack of precision in the theory of stellar atmospheres. It appears that the '*Rosseland mean*' $\bar{\kappa}$ is not entirely justified. Chandrasekhar, using a 'perturbation' method, finds that one should take the straight mean of κ_ν [VIII, 3]. Other authors find considerably different results: the methods used are semi-empirical [VIII, 3*g*], or iterational [VIII, 3*h*], or variational [VIII, 3*d* and *e*]. A definitive solution is not yet available.

Another difficulty is the unknown contribution of the far ultra-violet radiation to $\bar{\kappa}$ [VIII, 7 and 11]; this is essentially an astrophysical problem, which cannot be avoided by mathematical skill. The Sun is a real test-case which should be solved before reliable and precise results can be expected for the stars. *Deviations from thermodynamic equilibrium* have an influence which depends on the variation of κ_ν along the spectrum. For the Sun, deviations in the ionization will probably not exceed a small percentage [VIII, 14, 15]; deviations in the excitation were generally considered as noticeable only beyond 12 V [X, 18], but recent work on the infra-red spectrum reveals considerable superexcitation for high levels of Fe I [IV, 6]. The *convection* could also produce deviations [VIII, 16, 18, 18*a*]; but even if the stability condition is infringed, there is only a limited fraction of the energy which is conveyed by convection, while radiation is still responsible for the remaining part; the velocity of the currents is much smaller than one would expect [VIII, 17]. From these considerations it seems that the effect of convection on the structure of stellar atmospheres is only small. The *blanketing effect* has been treated in a more exact way and has been found different according to the stellar model, the ratio between scattering and absorption, and the distribution of the lines over the spectrum. In general, the boundary temperature is changed very little by the Fraunhofer lines; but in deeper layers the temperature is gradually increased [VIII, 19, 19*a*].—All these uncertain effects come in when the limb darkening of the Sun is calculated; considering the discrepancies between different observers, it is for the moment very difficult to draw definite conclusions concerning the factors involved [VIII, 19*b*].

For the outer layers of the Sun, the more inductive method therefore seems safer. From the observed limb darkening, the emissivity $J_\nu(\tau)$ is derived as a function of depth, almost without hypothetical assumptions [VIII, 8, 9]. Unfortunately, slight observational errors have a considerable influence on the results as soon as depths beyond $\tau = 1$ or 1·5 are considered. Therefore deeper layers can only be investigated by the deductive method.

In early-type stars, the electron scattering plays such an important role [VIII, 20, 21), that the limb of such stars must emit light polarized for 11%. This effect has actually been detected in some eclipsing binaries [VIII, 3, 22, 22*a*].

The radiation transfer in stars with extended atmospheres has been studied for the rather general case $\rho \sim r^{-a}$ [VIII, 27].

A very important undertaking is the systematic construction by Strömgren of theoretical stellar atmospheres, corresponding to different values of the composition, surface gravity, temperature, etc. Such models are a very useful starting point for many other

investigations and in due time it will become possible to decide which assumption conforms best to the observations. They have been published now for G, F and A stars [VIII, 23, 24, 25]. For the Sun, the model has been recalculated, taking into account the recent results on the absorption of H^- [VIII, 25*a*]. Calculations about model atmospheres for helium stars (B) are also available [VIII, 20, 28, 29].

IX. SPECTROPHOTOMETRY OF CONTINUOUS SPECTRA

The continuous background of the solar spectrum is an important object for exact measurement and comparison with theory. Some new observations have been made in the region λ3000–7000 [IX, 2, 3].

Very important is the new interpretation of the ultra-violet solar spectrum by Arnulf, Chalonge, Déjardin [IX, 3, 5, 6]; by selecting only the very highest maxima in the ultra-violet, they showed that beyond λ4000 only five windows are found where the real background is observed without influence of Fraunhofer lines; a few other points are only slightly weakened; for the rest, accumulations of Fraunhofer lines cover the whole spectrum. The real background has a gradient corresponding to $T = 6700°$ near λ4500 and $T = 6100°$ near λ3500.

It is now clear, both from theory and from observations, that the energy distribution in stellar spectra does not correspond to that of a black body. Data concerning colour temperatures and gradients have only a limited value. If slight deviations from the black-body curve occur, the colour temperature and the gradient will be abnormally high in some spectral regions and abnormally low in others. This explains the considerable divergency between authors, working in different parts of the spectrum. The observer only measures certain ratios, from which the temperature at any depth has to be deduced by theory.

The best *standard* for stellar spectra is the A0-star. The observations of Greenwich, Michigan and Göttingen in the region λ4500–6500 yield mean gradients of 1·00, 1·07, 1·19 [IX, 7, 8, 10, 11, 12]. Especially the Göttingen observers consider the observed deviations from this mean gradient along the spectrum as real [IX, 8]. In the violet and ultra-violet spectral region, the work of the Paris observers is of special importance [IX, 14]. For the region λ3700–4500 they find a gradient $\phi_1 = 1{\cdot}00$; beyond the Balmer limit the gradient is found to be $\phi_2 = 1{\cdot}39$.

For a great number of stars, *relative comparisons* have been made with this standard. The Göttingen observers have moreover intercompared the stars, making numerous combinations. The results agree beautifully; the divergencies are much smaller here than in the measurements of the A0 standard, because in this last case a comparison had to be made with a standardized lamp [IX, 7, 9, 10, 13, 14]. These relative measurements are beautifully supplemented by the photoelectric determinations over the whole region λ3530–10300 [IX, 15, 16]. The deviations from black-body curves are surprisingly small; in the violet and ultra-violet the results have a limited value, because of the accumulation of Fraunhofer lines.

The relation between gradient, colour temperature and colour index has been tabulated by several authors [IX, 17, 18, 19].

A detailed comparison between the theoretical and the observed energy distribution can be made for G0 and for A0 stars. For the Sun, the agreement is very satisfactory, except in the region $\lambda < 4000$ [VIII, 11]. For the A0 stars a precise agreement has not yet been reached [VIII, 4, 20*a*], but this is improved if the variation of κ_ν/κ with depth is taken into account [VIII, 4*a*].

The important relation between colour temperature and effective temperature may now be deduced by three methods:

(1) in a semi-empirical way, from observations on Cepheids [IX, 28, 29];
(2) from the scale of effective temperatures (Kuiper);
(3) from the theory of the absorption coefficient [VIII, 11].

The methods (2) and (3) give a satisfactory agreement, with which the results of method

(1) can be more or less reconciled. The relation between T_c, T_e and the brightness temperature may be deduced similarly from the methods (1) and (3).

By spectrophotometric comparison between stars in different directions and at different distances, the law of interstellar absorption has been determined with considerable precision and for six wave-length regions; this is approximately proportional to λ^{-1}, or more precisely to $\lambda^{-0.56}$ within the interval considered. The trapezium stars of Orion show the influence of an absorption of a different kind [IX, 16, 16*a*].

The Balmer discontinuity near $\lambda 3660$ has been measured for a great number of stars [IX, 14, 20, 21, 22] and has been accounted for by theory [V, 11]. It is interesting to follow its variations during the eclipse of Algol [IX, 23, 24].

Two direct determinations of the surface temperature T_0 have been made: (1) from the colour temperature in the region $\lambda < 3660$, for stars where the continuous Balmer absorption is sufficiently great [IX, 25]; (2) from the colour temperature of the sun at the extreme limb [IX, 26].

Special investigations relate to some individual interesting objects [IX, 16, 27, 28, 29, 30].

X. CURVE OF GROWTH AND QUANTITATIVE SPECTRAL ANALYSIS OF THE SUN

From multiplets and transition arrays, empirical curves of growth have been derived for the Sun by several authors. These curves again yield a value for 'the excitation temperature of the reversing layer' by assuming a Boltzmann distribution between the atomic levels of each element. In this way, temperatures of 4300°–4900° have been found [X, 1, 2, 3, 4, 5]. (For deviations from equilibrium conditions, cf. Section VIII).

A more detailed theoretical analysis of the meaning of this 'excitation temperature' has been made for the weak lines, taking into account the structure of the solar atmosphere as a function of depth. It then becomes apparent, that such a concept has only a formal significance; the temperatures may be expected to vary between 5000° and 7000°, depending on the wave-length and the excitation potentials [X, 7]. This dependence is qualitatively confirmed by the observations [X, 8]; excitation temperatures from weak lines only have not yet been derived.

From the general shape of the curve of growth, a kinetic temperature of 5400° was found [X, 6].

In a similar way it has proved possible to construct beautiful curves of growth from molecular lines [X, 12]. From such curves or from the intensity distribution in a rotation band, 'rotational temperatures' between 4370° and 5630° have been found [X, 9, 10, 11, 12].

The analysis of abundances in the solar atmosphere requires the solution of four distinct problems: the relative proportion of the metals; the proportion H : metals; the proportion H : metalloids; the proportion H : He. For the first problem, a knowledge of transition probabilities is essential; moreover, if strong lines are used, the damping constant must be known, which is often uncertain. For the second problem, our present knowledge about the continuous absorption in the solar atmosphere makes a direct solution possible, provided the necessary knowledge of atomic constants is available as for the first problem; so each single weak line of a metal atom originates by a competition between selective metal absorption and continuous hydrogen absorption, and therefore yields without any further comparison the ratio H : metal. The basis of an analysis along these lines has been laid in a fundamental paper by Strömgren [X, 15].

The third problem can be solved directly by an investigation of the molecular bands. The fourth problem has been solved only for the chromosphere and the prominences or for helium stars; it would be interesting to investigate the influence of the He concentration on different observable properties of the solar atmosphere.

Data about 'the number of atoms above the photosphere' have no precise meaning and should be translated into hydrogen/metal abundances [X, 13, 14].

Altogether, amazingly few results about the composition of the solar gases have been obtained in these years. They are summarized here (abundances are given in number of atoms).

	(15)	(7)	(12)	(16)
H	8000	8000	8000	8000
C	—	—	9·1	—
N	—	—	8·5	—
O	—	—	14	—
Mg	0·3	—	—	0·14
Ca	0·013	—	—	—
Na	0·007	—	—	0·008
K	0·0016	0·0008	—	—

The importance of the new results for C, N, O should be particularly stressed. A recent analysis of the solar atmosphere has been made by Menzel, of which only the results are published; another was made by Unsöld, but the data published are apparently derived partly from other objects [x, 17, 18].* The great hydrogen abundance, now generally accepted, has been confirmed along different lines of evidence [x, 19]. The discovery of this preponderant importance of hydrogen and of the strong continuous absorption of H^- has made the analysis of the solar atmosphere much easier than one could have hoped.

XI. CURVES OF GROWTH. GENERAL SPECTROPHOTOMETRY OF STARS†

The construction of curves of growth has been applied by many authors as a powerful tool for the analysis of stellar atmospheres; a paper such as that of Unsöld on τ Scorpii covers the whole field [xi, 26]. It has been shown that the f-values, given by the ordinary multiplet rules, are definitely less exact than values derived from laboratory intensities or from solar equivalent widths. These are therefore used by preference.

For stars of the later types, the greatest part of the lines is blended. In such cases, the Amsterdam workers [xi, 7, 8, 9] construct a preliminary curve of growth. They now calculate 'the theoretical spectrum': for each component of a blend, the solar intensity is reduced to the expected stellar intensity via the curves of growth; then the components are compounded. This theoretical spectrum is not yet identical with the observed spectrum; by least squares, differential corrections are applied to the temperature, Doppler effect, damping, ionization, etc., till the best possible fit is obtained. These authors contend, that entirely erroneous results are often obtained by following simpler methods.

Several difficulties have been met in the interpretation of stellar curves of growth. Sometimes the lines of one element do not fit the curve determined by another element [xi, 23]; or the Doppler effect from the curve of growth is not consistent with the line profiles [xi, 13, 14]. Apparently the stellar model for which the curve has been calculated does not correspond with the real star. The following complications have been suggested: special kinds of damping, interlocking, deviations from thermal equilibrium and chromospheric effects, turbulence increasing with height or with the E.P., velocity distribution of a non-Maxwellian type, stratification. The special characteristics of the curves of growth should be derived for each of these cases. More direct information can be obtained of course if it is possible to observe individual profiles on spectrograms with a high resolution. Generally speaking, the results of the curves of growth should be compared as much as possible with detailed profiles. The detailed investigation of profiles is also important because it informs us about complicated motions of the stellar gases; this is the case in M super-giants, in W stars and in stars with extended atmospheres generally.

In the literature list, a survey has been given of well-analysed stars roughly in the order of spectral types. Among the stars studied by general spectrophotometry, the

* *Note added in proof.* Very recently a systematic analysis of the solar atmosphere by the same author was published [x, 18].

† Special spectrophotometry of variables, stars with extended atmospheres, etc., has not been included.

super-giants are particularly well represented; some peculiar and metallic line stars have also been examined. Often, great differences are found between the Doppler temperature, the excitation temperature and the ionization temperature.

In the determination of abundances there is often doubt whether the excitation of higher levels corresponds with thermal equilibrium. For such cases, two methods have been used with profit: (1) We assume that *equally strong* lines, originating from two different levels, are formed by the same number of oscillators (good results for α Orionis, 3). (2) We determine the population of an atomic level of high excitation; then we assume that the excitation is the same for such a level and for the neighbouring resonance level of the ion; by combining the laws of Boltzmann and Saha, we compute the population of the ions, which in many cases is practically the total population [XI, 26].

Variable stars often show such profound variations in their spectrum, that from an analysis along the classic lines considerable differences in chemical composition would be found for one and the same star, depending on the phase. This is the case for some long-period variables, showing an alternation between M and S characteristics; and for several groups of spectrum variables or metallic line stars. Such observational evidence shows that differences in chemical composition between stars may not be assumed, unless we have made sure that no other effects are involved: especially gravitational separation of the elements and superexcitation of some atoms should be considered. The abnormally great abundance of helium which is found in some early type super-giants has been attributed to such a superexcitation of high levels [XI, 27; cf. XIII, 18]; however, the abnormal weakness of the hydrogen lines cannot be explained in such a way. Also in other cases real differences in composition can hardly be denied (novae, W stars, carbon and oxygen stars). Especially interesting is the composition of R-type stars, where the investigation of C_2 bands shows that there occurs a group with a ratio $C^{12}:C^{13}=50$ or more, and another group where this ratio is 3·4 (cf. XII, 55).

XII. LINE PROFILES, THEORY AND OBSERVATIONS

(*a*) Doppler Effect and Damping

The role of the Doppler effect in the resonance process appears to be more complicated than what has been realized ordinarily [XII, 5]. It would be worth while to consider the influence of this detailed analysis on the line profiles.

The broadening effect of turbulence in the Sun has been found to correspond with a random velocity of 1·5–1·8 km./sec. [XII, 15, 63].

For the computation of theoretical profiles, widened by stellar rotation, one of the most practical methods is that of Unsöld. It has now been possible to extend this also to great rotational velocities [XII, 6]. The inverse problem remains difficult and can only be solved in a satisfactory way, if the profile of the undisturbed line is known by comparison with similar stars [XII, 7, 8].

The theory of damping has been clarified in several respects [XII, 9]. For the collisional broadening, treated up to now along the lines of Lenz and Weisskopf, Lindholm succeeded in calculating in a clean way the influence of individual passing particles at all different distances [XII, 10, 11]. The phase-disturbances, calculated by quantum mechanics, are practically equal to those found from the semi-classical theory, as long as the passage is described as a static process [XII, 12, 12*a*]. A more exact dynamic description, taking also into account a possible rotation of the radiating atom during the passage, gives somewhat different results [XII, 10, 13, 74].

For the statistical broadening, quantum mechanics have mainly confirmed the existing theory.

These two extreme models are to be compounded in the real cases. The central parts of the line are mainly determined by the collisional broadening, the wings by statistical broadening. A complete formula, giving the transition between both limiting cases, has

recently been derived [XII, 12]. In stellar atmospheres, the following effects seem preponderant [XII, 9]:

1. Linear Stark effect on Balmer lines and He II: statistical broadening by ions.
2. Quadratic Stark effect on metal lines and on some He lines: collisional broadening by electrons.
3. Special broadening due to the element itself: ineffective.
4. van der Waals forces on metal atoms: collisional broadening (chiefly by H).

The difficult case 2 has been treated in general and has been especially applied to Ca^+ [XII, 14].

The influence of Stark effect has been looked for, comparing the observed damping constant of iron lines in the Sun with the quadratic Stark effect in the laboratory, but the correlation seems poor [XII, 16]. The width of most Fraunhofer lines seems to be due to the collisions of the radiating atoms with the hydrogen atoms, these being so extremely abundant in the solar atmosphere (effect 4) [VIII, 25; X, 15; XI, 1*a*]. A direct demonstration for the preponderant importance of this factor has been given, by comparing the spectrum of the centre to that of the limb: the damping constants are found to be proportional to the gas pressure and not to the electron pressure in the two effective layers [XII, 63]. It is therefore of great interest to investigate theoretically the influence of H collisions on spectral lines of all different kinds.

By comparing the calculated to the observed damping, the effective level may be found where a Fraunhofer line is formed. For Na this is at $\tau = 0{\cdot}08$ [XII, 16*a*].

The theoretical combination of Doppler effect and damping can now be easily computed by means of several new tables of Voigt profiles [XII, 17, 18, 19].

(*b*) Scattering and Thermal Absorption

The relative importance of these two processes, which was discussed so eagerly some ten years ago, remains partly unsolved and has not been closely investigated further in the last period. This is understandable, in so far that both theories give more or less the same values of the equivalent width. From the experimental side, evidence may be obtained by observations concerning the centre-limb variations of the solar spectrum; however, this criterion is less decisive because of the complicating effects of non-coherent scattering. For strong lines, it seems well-established that thermal absorption is ineffective [XII, 65].

A theoretical approach would be relatively easy, if the effective cross-sections of excited atoms for collisions of the second kind were known. This again stresses the importance of such atomic data.

(*c*) Macroscopic Effects

The theory of faint Fraunhofer lines is in many respects of remarkable simplicity. In this case it is possible to take fully into account the detailed structure of the solar atmosphere and the changes of temperature and pressure with increasing depth. The integrations have been carried out once for all and the results are available in a practical form [X, 7]. This is a good standard case for studying the influence of the stellar model, of wave-length and of excitation potential. Here it becomes very clear that the concept of 'effective layer' is misleading and may be better left out.

For strong lines, the method which was used for faint lines may be applied to the wings. For other parts of such lines, the problem of radiation transfer may be treated only by numerical integration of the differential equations or by simplifying the model. So it has been recently solved analytically for a new special case: $1/1+\eta = a + b\tau + c\tau^2$ [XII, 20]. Combination of this case with $\eta = \text{const.}$ gives useful new possibilities [XII, 29]. Apart from such special cases the general macroscopic theory of line formation in model atmospheres has been refined by application of the new analytical methods of Chandrasekhar [XII, 66, 66*a*]. The inverse problem has been treated theoretically by Plaskett

[XII, 22] and applied by him to the Mg line $\lambda 5184$. From the observed profiles at different points of the solar disk, it is possible to derive the variation of the line absorption with depth, and subsequently the temperatures and pressures at different depths. The solution thus obtained is unique [XII, 23]; it was obtained first by numerical trials, later by direct analysis [XII, 24]. These methods will have their full use, when the brightness at the extreme limb of the Sun can be determined. It is interesting that a similar method has been applied to the same Fraunhofer line $\lambda 5184$ by Parchomenko, but the results are neither easily comparable nor complete [XII, 25].

The formation of absorption lines in a moving atmosphere gives considerable mathematical difficulties, due to the relative Doppler effects involved [XII, 25*a*]. For the case of a uniformly expanding atmosphere of the Schuster-Schwarzschild type (super-giant star), the lines are found to be displaced towards the violet, but to develop an asymmetric wing towards the red. For a differentially expanding atmosphere, the problem is much more complicated.

A general continuous absorption or a broad wing, superposed upon a spectral line, is known to weaken this line. Several new instances of this effect have been discovered, which in general are well explained by theory [XII, 26, 27, 28, 28*a*].

(*d*) Hydrogen Lines

Some new observations have been made about the profiles at different points of the solar disk [XII, 29, 30] or about the equivalent widths in stars [XII, 31, 32, 33, 34, 35, 51]. The well-known difficulty of drawing the continuous background for H_α has been solved by Evans [XII, 29] by photographing on the plate the continuous spectrum of a ribbon lamp (the run of the background being mainly determined by the change of plate sensitivity with wave-length); this practical method could be easily refined, taking into account the temperature difference lamp: Sun. A comparison of the results with the classical theory of Pannekoek and Verwey shows again that a general qualitative, but not a quantitative agreement has been reached. It should be noted that the original theory has been revived with an improved coefficient of continuous absorption and with improved values of the weights of the components. The effect of uncompensated cycles seems negligible [XII, 29]. The most probable hypothesis is a superexcitation of the high atomic levels in surface layers ($\tau < 1$) [XII, 30]. Very interesting are the numerous hydrogen lines of high levels in the infra-red solar spectrum between 7 and 14 μ [VI, 6].

Equivalent widths have been theoretically computed [XII, 35] in order to compare them to Redman's observations on eclipsing binary stars. Here also there is some agreement, though rather poor.

Several authors have tried to derive the electron pressure in a stellar atmosphere from the number of higher Balmer lines, visible as separate emissions [XII, 36, 37, 38]. Pannekoek's theory of this phenomenon [XII, 36], especially pp. 705–9, ascribes the main effect to statistical broadening; this has been confirmed since [XII, 38], while the observations seem to agree beautifully with the calculations [XII, 39].

(*e*) Special Lines

The helium lines have been first investigated in early stars, without a detailed discussion of the broadening effects [XII, 40]. It was shown that the apparently anomalous weakening of the singlet lines, as compared with the triplet lines, on either side of spectral class B4 results from the properties of the curve of growth and does not require departures from equilibrium conditions. Afterwards the mechanism of broadening was discussed, which for many helium lines is the quadratic Stark effect of colliding electrons [XII, 36]. Especially interesting is the complicated broadening of $\lambda 4471$ and 4062, investigated by three authors independently [XII, 41, 42, 43, 44]; Struve's interpretation is confirmed.

Measurements of the sodium lines have been made by several authors [XII, 45, 46, 48, 49].

An excellent discussion has been given of the central intensity, taking into account fluorescence by cycles involving free electrons [XII, 47].

The Mg line $\lambda 5183$ in K stars is very sensitive to surface gravity, but its behaviour is difficult to explain theoretically [XII, 49, 49*a*]. Calculations taking into account the new conceptions about H concentration and H^- have not yet been made.

Very interesting is the reversal in the core of the Ca^+ line K in red super-giants [XII, 52, 53; XI, 3], analogous to similar details in the solar K line. This is explained by temperature inversion in the facular regions.

Bands of CN and CH in late-type stars seem to conform well with theory [XII, 56].

(*f*) Spectrophotometry of Small Dispersion Spectra

The spectrophotometric investigation of small dispersion spectra especially for statistical purposes has been further developed chiefly at the Yerkes, Stockholm, Uppsala and Cleveland Observatories. This is now done mainly by visual inspection at Yerkes [XII, 57], from intensity drawings at Cleveland [XII, 58], from microphotometer records at Stockholm and Uppsala [XII, 59, 60].

(*g*) Centre-limb Variation of Line Profiles

Observations about these phenomena are the only way of ascertaining how Fraunhofer lines are formed and of obtaining information on the conditions in deeper layers of the Sun. While the profiles or equivalent widths are ordinarily measured for the centre of the disk and for 'the limb' only [XII, 45, 46, 61, 62, 63], it has been found now that they actually are changing in a systematic way all along the radius. The important investigation of these changes has been carried out for the strong Fraunhofer lines [XII, 64, 65]. The explanation of the observations is still incomplete. The following assumptions have been tried:

1. Owing to the roughness of the solar surface, even near the limb we are not really looking under grazing incidence; $\cos\vartheta = 0{\cdot}05$ corresponds effectively to $\cos\vartheta = 0{\cdot}20$ [XII, 61].
2. Reduced re-emission, due to interlocking. It has been proved that this in any case is not the whole of the effect [XII, 62].
3. Anomalous temperature distribution in the outer layers [XII, 62].
4. The methods of computation should be refined, better values for $\bar{\kappa}$ should be used [XII, 66].
5. By the scattering process, the frequency of the emitted line could be different from the frequency of the absorbed line. This process is predicted by quantum theory when both levels have a natural width ('Weisskopf doublet'). It seems probable that the same occurs, but to an increased amount, when the levels are also broadened by collisions [XII, 65].
6. Owing to collisions, an electron, reaching a sublevel of the higher level, could be 'redistributed' over the whole of these sublevels, independently of the absorption frequency. In this case, there is no correlation between an individual absorption process and the subsequent emission [XII, 65].

The assumptions 5 and 6 should be carefully distinguished. Eddington's 'redistribution of frequencies' is essentially different from 'redistribution of the electron' over the sublevels. In both cases radiation is transported from the wings to the core of the Fraunhofer line, but this effect is stronger for hypothesis 6 than for 5. In the assumption 5, there is phase coherence between the radiation absorbed and the radiation emitted; hypothesis 6 only should be called 'non-coherent scattering'. It seems probable that quantum theory accounts for one or for both of these assumptions [XII, 74]. Hypothesis 5 has never been carefully tested; hypothesis 6 was found to account for most of the observations [XII, 65, 72]. The equation of transfer for this last case has been derived and discussed by several authors [XII, 65, 71, 72]. It is not sure whether, from purely observational reasons, hypothesis 6 is to be considered as necessary; it may be that some of the other

assumptions proposed give also satisfactory results. Quantum theory should decide which processes are *a priori* excluded, possible or necessary [XII, 72, 74].

Closely related to these investigations is the search for polarization in Fraunhofer lines near the limb. That this effect has not been found [XII, 67, 68] has been explained by the collisions [XII, 69, 70, 73]. This is strong evidence in favour of the assumptions either 5 or 6.

(*h*) Composite Spectra

In double-star investigation, the determination of the magnitude difference between the components is of great importance. For about 10% of the binaries, the luminosities of the components are of the same order and the lines of the two components are seen periodically superposed or separated; in other cases the luminosities are more different, and the effect of the fainter star is only shown by a distortion of the profiles. A spectrophotometric analysis of the composite spectrum is now made, (*a*) when the lines coincide, (*b*) when they are displaced over a distance Δ. If the assumption is made that the lines have the same profile in both components, the luminosity ratio can be computed in a simple way; the dimensions, orbits and masses of the separate components are found; the mass-luminosity relation can be tested [XII, 75–82].

It is clear that the hypothesis of equal profiles in the component spectra should be improved. Working more carefully it has been possible to find both the spectral class difference and the brightness ratio [XII, 76]. These methods are now in regular use at the Victoria Observatory [XII, 77, 78]. They have proved of special importance for the detection of A or B sub-dwarfs [XII, 81].

XIII. SPECTROPHOTOMETRY OF SPOTS, FLARES, CHROMOSPHERE, PROMINENCES

From former researches it was known, that the temperature of *spots*, derived from the continuous spectrum, is found to be lower when the spots are larger. This has been confirmed for an exceptionally big spot of November 1938, where the record minimum of 3690° was found [XIII, 1], cf. also [XIII, 11]. An almost equally low excitation temperature of 3800° has been derived from the spectrum of other big spots [XIII, 2]. The curve of growth in spots, compared with that of the photosphere, is modified by: (1) the lower temperature; (2) the Zeeman effect, which may be treated more or less as a Doppler effect; (3) the different 'number of atoms' NH.

This ratio $\frac{\text{NH (spot)}}{\text{NH (phot)}}$ is found to be 9·1. The true width of the lines in the spot spectrum is nearly twice that of the photospheric lines [XIII, 2]. The profiles of the Mg *b* lines in the spot have been determined. A theory of the spot should provide the explanation of several of these spectrophotometric results; such a theory has been developed [XIII, 4, 5], but it has to be corrected, taking into account the overwhelming hydrogen content of the Sun and the importance of H^- absorption.

The first careful spectrophotometric analysis of the *faculae* has been carried out and has yielded information about temperature, electron pressure and ionization in these objects [XIII, 4*b*].

Spectrophotometric work has deeply modified our conception of *the chromosphere*. In 1938, we believed that the turbulent state of these layers was demonstrated by threefold evidence: (1) the direct picture of the very irregular spikes and jets; (2) the widths of the chromospheric lines, exceeding by far the normal thermal widths and independent of the element considered; (3) the decrease of chromospheric density as a function of height which was considered to be independent of the element (cf. Unsöld, *Physik der Sternatmosphären*, ch. 98). Since then, this beautiful agreement has been disturbed in a most surprising way: (1) The apparently turbulent motions became still more convincing by the films of Lyot and of the McMath Observatory. (2) However, the line profiles, measured

by Redman [XIII, 6] with great instrumental skill, proved to be narrower than expected, and to be markedly different according to whether H, He or metal lines were investigated; if these widths are considered as real thermal widths, a consistent temperature of 30,000° is found. (3) The gradients, derived by Wildt [XIII, 7] from a more extensive material and using recent information, were found different according to the elements, at least in the lower layers; they correspond with temperatures of 30,000°–100,000°. The contradiction between the first qualitative evidence and the other quantitative arguments is very striking, and will probably be explained only when the hydrodynamics of the chromosphere are better understood.

In the investigations just described, kinetic temperatures are derived from line widths and from the barometric gradient which amount to 30,000°. For the excitation temperatures, derived from the comparison of lines of different ionization potential, temperatures of the order of 5000° are found. From the comparison between singlet and triplet lines of He, similar temperatures of 4300°–6700° have been determined, which are essentially also excitation temperatures [XIII, 8].

The *solar flares*, which have proved so important for the investigation of solar and terrestrial relationships, are still imperfectly understood. Spectrophotometric research has been made first with very rough methods [XIII, 9, 10, 13, 14], later more precision has been reached [XIII, 11, 12]. The flare spectrum resembles an ordinary Fraunhofer spectrum of a temperature raised by about 100°, and upon which an emission spectrum is superposed. Compared with the flash spectrum, all Fe^+ lines and all low-excitation potential Fe lines are enhanced (in metallic prominences or hot chromospheric spots, only the Fe^+ enhancement is observed).

It is apparent that a clear distinction between bright flocculi and solar flares has not always been made; it seems that flares have a brightness at least equal to 2·8 times that of the chromospheric $H_{\alpha 2}$ [XIII, 11]. At the limb, most eruptions have between 0·4 and 1·4 times the brightness of the continuous spectrum [XIII, 12]. In flares called 1, 2, 3 on the international scale, the central intensity of H_α is of the order of 0·6, 1, 2 [XIII, 13, 14]. From estimates of the very slightly increased brightness of the continuous spectrum, the density in a flare is found to be 300 times the density in prominences [XIII, 13]. Much work remains to be done in this field; it will be especially necessary to take into account the slit-width and to distinguish between line-width, central intensity, total intensity, brightness area, etc.

Bright and dark flocculi have been compared to the adjacent areas in H_α-light; the Arcetri observers find somewhat higher results than the Greenwich measurements [XIII, 11]. Also bright K_3 flocculi have been examined [XIII, 15].

The older work of Minnaert and Slob on the spectrophotometry of *prominences* has been repeated with great care at Cambridge [XIII, 16, 17]. The results concerning the ration H_α: He have been mainly confirmed; the explanation by self-absorption in H_α seems to be correct, and the curve of growth is found to correspond to 5000°. In part of a prominence, however, this ratio was found to decrease with height (after correction for self absorption), apparently because of the increasing H ionization. Spectrophotometry of an eruptive prominence showed surprisingly small differences with ordinary prominences. The excitation and ionization are normal up to 10 V. and correspond to $T = 5000°$; for higher excitation potential the temperature increases, it corresponds to 20,000° between 20 V. and 54 V. [XIII, 18].

After strong solar flare, a search has been made for the Ca^+ absorption spectrum in the gaseous cloud ejected by the Sun. There is indeed an indication that the H and K lines are slightly enhanced at such moments, the additional absorption being displaced towards the ultra-violet by the Doppler effect. But the evidence is not yet conclusive [XIII, 20, 21].

XIV. ATMOSPHERIC LINES

The theory of atmospheric O_2 lines is much simpler than that of Fraunhofer lines, in so far that light absorbed or scattered can be considered as lost. The complications arise because of the decrease of T and P in the atmosphere at greater heights. These effects now have been accounted for very carefully [XIV, 1, 2]. Great discrepancies are found between the observations of different authors, probably because the continuous background has been drawn erroneously. Taking this into account, it may be said that the calculated intensities agree sufficiently with the observed values. Atmospheric temperatures may be determined rather precisely from the spectrograms. Theory predicts also variations in wave-length; O_2-lines should not be used as standards without some precautions.

From the emission of the Earth and of the Moon, compared in the region of the infra-red ozone band, reliable values have been obtained for the stratosphere temperature [XIV, 3].

The intensity of atmospheric vapour lines has long been used as a measure for the amount of water vapour in the atmosphere. Such determinations could be made in a more reliable way with modern insight. Trials in this direction have been made [XIV, 4, 5].

Many other investigations on the infra-red solar spectrum reveal telluric lines, but as yet the results seem to be more spectroscopic than spectrophotometric [XIV, 6].

XV. COMETS

The understanding of physical phenomena in cometary gases has considerably progressed, and a detailed explanation of several spectrophotometric phenomena has been reached.

Assuming that the cometary bands are produced by resonance, Swings pointed out that the accidental grouping of Fraunhofer lines in the exciting solar spectrum would lead to an irregular intensity distribution among the rotational lines of the comet [XV, 6]. McKellar was able to confirm this theory from the CH, CH^+, CN and other bands, to account in detail for the intensities of the rotation lines, and to detect the influence of the Doppler effect when the comet approaches or leaves the Sun, the Fraunhofer lines being shifted with respect to the comet lines [XV, 7, 8, 9, 10, 11]. Most kinds of molecules are found to exist in the lowest rotational levels. At smaller distances to the Sun, the rotational temperature of the molecules increases. For comet 1940c the rotational temperature from CN was 300° at 0·92 A.U., 435° at 0·54 A.U.; for comet 1942g at 1·38 A.U. the temperature was 200°. The temperature derived from CH was found to be 200° at 0·54 A.U. Only the homonuclear molecules $C^{12}C^{12}$, which do not emit dipole radiation in the infra-red, reach much higher rotational distributions, corresponding to temperatures of 2000–3000°. The difference between the $C^{12}C^{13}$ and the $C^{12}C^{12}$ bands is especially striking in this respect.

That the intensity distribution over the rotational lines varies with the distance of the comet to the Sun had long been observed in the bands of CH and CN; it was also known that the intensity maximum is in general shifted towards higher rotational quanta [XV, 3].

This effect is now analysed into two influences, which should be carefully distinguished: the apparently irregular shift is due to the Doppler effect, as explained above; the systematic increase in excitation is due to the increasing rotational temperature. This last phenomenon is attributed by Wurm to the effect of the greater radiation density on the number of emissions and absorptions [XV, 1, 12]. Alternative explanations seem now less probable [XV, 2, 4, 5].

Similar effects have been found for the distribution of the molecules over the vibrational levels: here also we find the influence of the distance to the Sun and the difference between homo- and heteronuclear molecules.

Our knowledge about abundances in comets is still very imperfect, especially because oscillator strengths are uncertain or unknown. There is no real evidence for differences in composition between different comets.

XVI. CORONA

Since the emission lines of the corona have been identified, photometric measurements on these lines take an increased significance. Progress in this field of observations has been slow, perhaps because of the variability of intensities and intensity ratios. The best intensity measurements are collected in [XVI, 1], to which some new results should be added [XVI, 2]. It should be recommended that equivalent widths be reduced to absolute values, if possible, and expressed in angströms of the adjacent continuum or in millionths of an angström of the photospheric spectrum [XVI, 3, 6, 7].

The radial intensity gradient of $\lambda 5303$ proves to be much steeper than for the continuous light. The profile has been measured by several authors and is described as a gaussian curve, corresponding near the limb to a mean velocity in the line of sight of 37 km./sec.; at a height of 3′ 38″ this has decreased to 19 km./sec. [XVI, 4, 5, 6, 7, 8, 9]. These widths have been attributed first to turbulence, but are now mostly considered as due to very high temperatures. In some bright patches, the line is broader and shows a central reversal [XVI, 5].

From the comparison between the intensities of several lines, an excitation temperature of $2 \cdot 10^6$ till $3 \cdot 10^6$ has been derived. From the absolute values of the intensities, the abundances of the several elements were determined. The number of electrons is found to be 10^7–10^8 times the number of these ions; since the corona must be electrically neutral, an enormous number of protons, invisible to us, has to be assumed [XVI, 10].

The importance of absolute data became clear when it was tried to explain the corona lines by emission of meteoric matter. It seems that the number of meteors of different sizes, as ordinarily assumed, is sufficient to explain the intensities observed. The kinetic energy of the falling particles is of the right order for an explanation of the high coronal temperatures [XVI, 11].

New careful spectrophotometric measurements of the Fraunhofer lines in the outer corona and of the polarization have furnished the data necessary for an analysis of the coronal radiation into two components: component I, scattered by the electrons around the Sun; and component II, scattered by the dust particles in the interplanetary space at great distances from the Sun. Component I is responsible for the polarization, component II for the Fraunhofer lines. The problems concerning the corona have been much clarified by this new insight [XVI, 13, 14, 15].

From the work of Grotrian, it was taken for granted that the corona shows the H and K lines as broad depressions, widened by the Doppler effect of the electrons. Menzel however did not observe these depressions at all. Doplicher finds them, but his records fail to show any broadening, the lines have exactly the same profile as in the solar spectrum [XVI, 16]. This interesting question should be elucidated.

XVII. INTERSTELLAR LINES

Total absorptions of interstellar lines, formerly often determined by estimation, are now generally measured by means of the microphotometer; there is no doubt that the accuracy has been greatly improved by this technique. The total absorptions of K, H, D_1, D_2 have been measured for a number of stars [XVII, 1, 2, 3]. They have been generally used as an excellent measure for distance, to which they seem to be proportional [XVII, 4*a*]. Unexpected difficulties were met [XVII, 5] in the interpretation of the line intensities, probably due to our lack of knowledge about the state of motion of the interstellar gas. These intensities could only be explained by assuming that the turbulent velocity of the Ca^+ atoms is about three times that of the Na atoms which seems hardly admissible. As long as this essential difficulty is not solved, the derivation of abundances in the interstellar gas becomes uncertain.

The discovery of complex interstellar H and K lines as of common occurrence is extremely important for our model of the interstellar medium; it looks probable that it

will give also the clue to the understanding of the intensity ratios [XVII, 5, 6]. From the number and the intensities of the components, statistical data are found concerning the size and the number of gaseous interstellar clouds [XVII, 7].

XVIII. NEBULAE

Spectrophotometric observations concerning the Orion nebula have been made by several authors [XVIII, 1, 2, 3, 4]. About the continuous background, the Balmer discontinuity, the colour of the nebula compared with the stars, etc., there has been considerable disagreement, which is probably explained now by the lack of resolution of some of the spectra used. The continuous spectrum is interpreted as a capture spectrum, to which some light diffused by the free electrons has been added. From this continuous spectrum an electron temperature of 28,000° or more is found, which looks abnormally high. Lines of high excitation are concentrated near the centre of the nebula, and in general the intensity of the lines is closely correlated with the intensity of the continuum.

From a comparison between the line width, determined with the interferometer, and the local wave-length differences, it is possible to estimate the size of the turbulent units composing the nebula [XVIII, 4].

Important observational and theoretical research has been done on planetary nebulae [XVIII, 5, 6, 7, 8, 9, 10]. The electron temperatures were found from the nebulium lines and from the Balmer continuum to be 6000–10,000°; from the continuous spectrum, a density of 10^4 electrons/cm.^{3} was derived. The origin of the visual continuous spectrum is uncertain. The derivation of abundances is still difficult, since discrepancies of a factor 50 may occur between different authors [XVIII, 10].

Two important papers on the Crab nebula give information about the very special character of this object [XVIII, 11, 12, 13]. The Balmer discontinuity is faint or absent, the colour temperature very low (6000–8000°); the hydrogen content must be very small. Here also, many divergencies between the authors are left open for discussion, as well about the observations as about the interpretation. Oort's recent explanation of the luminosity of this nebula should probably change the whole model.

Theoretical research on the population of the atomic levels and on the electron velocity distribution in nebulae is also of importance for the theory of stars with extended atmospheres. In several cases it has been possible to establish formulae, giving a continuous transition between both cases. It has been proved that in planetary nebulae the velocity distribution is Maxwellian [XVIII, 14, 15].

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REPORT OF THE SUB-COMMISSION ON THE UNIT FOR TOTAL ABSORPTION

At the Meeting of the I.A.U. at Stockholm, the following resolution was proposed by Dr Dunham to the Commission on Spectrophotometry:*

The Commission suggests that, in measurements of total absorption of stellar lines, a unit be used, defined as the light contained in a stretch of the continuous spectrum having a width equal to one-millionth of the wave-length of the line. This unit will be called the Fraunhofer, and will be abbreviated F.

After a short discussion, it was decided that the President of the Commission should nominate a sub-commission, in order to study the question and try to formulate a preliminary advice before the next Meeting.

The following scientists were so kind as to accept the membership of this sub-commission: MM. Dunham, Eddington, Menzel, Minnaert, Pannekoek, H. H. Plaskett, Russell, Struve, Unsöld.

In the spring of 1941, a preliminary note was sent to the members by the President. Seven of them replied that they were in favour of the resolution and gave several additional arguments. Two members had no objection, but asked to postpone the decision till the war was over in order to avoid confusion in the notations and units. Shortly afterwards the international connections were completely disrupted.

* *Trans. I.A.U.* **6**, 418, 1938.

The spectrophotometric work done since 1941 has not changed in any important respect the considerations which seemed valid then. We may assume that the majority of the sub-commission recommends the adoption of the resolution; full consideration is given to the wishes of the minority, since the resolution will be discussed at Zürich by the whole of Commission 36, after a long preparation.

The original note to the members, complemented in several respects by the answers received, is reproduced below.

Preliminary Note

Symbols used:

$\mathfrak{N}$ = number of effective atoms or ions 'above the photosphere' $\times f$;
i_0 = intensity in a point of the continuous spectrum near the line considered;
i = intensity in a point of the profile;
ν = frequency $= c/\lambda$;
γ = damping constant. For classical radiation damping: $\gamma = \gamma_0 \nu^2$;
k = selective absorption coefficient;
c = velocity of light;
v = velocity of the Doppler motion $= \sqrt{(v_{\text{therm}}^2 + v_{\text{turb}}^2)}$;
$\Delta\nu_D$ = frequency shift of a line by the Doppler motion;
μ = molecular weight;
const. = any constant, independent of the quantities mentioned in the formula, but different from one formula to another.

The equivalent width (= total absorption) of a Fraunhofer line is ordinarily expressed by: $\Delta\lambda$, $\Delta\nu$, or $\Delta\omega$, while Dr Dunham* proposes $\Delta\lambda/\lambda$. The relations between these symbols are:

$$\Delta\lambda = c/\nu^2\,\Delta\nu, \qquad \Delta\omega = 2\pi\Delta\nu,$$
$$\Delta\nu = c/\lambda^2\,\Delta\lambda, \qquad \Delta\lambda/\lambda = \Delta\nu/\nu.$$

In a private conversation, Dr A. S. Eddington proposed the use of $\Delta\lambda/v\lambda = \Delta\nu/v\nu$.

We shall first give a short survey of formulae for the equivalent widths of Fraunhofer lines, broadened by Doppler effect and damping.

1. Faint Lines

$$\Delta\lambda = \text{const. } \mathfrak{N}\lambda^2,$$
$$\Delta\nu = \text{const. } \mathfrak{N},$$
$$\Delta\lambda/\lambda = \Delta\nu/\nu = \text{const. } \mathfrak{N}/\nu = \text{const. } \mathfrak{N}\lambda.$$

2. Strong Lines (broadened mainly by damping)

$$\Delta\lambda = \text{const. } \lambda^2\sqrt{(\mathfrak{N}\gamma)},$$
$$\Delta\nu = \text{const. } \sqrt{(\mathfrak{N}\gamma)},$$
$$\Delta\lambda/\lambda = \Delta\nu/\nu = \text{const. } \sqrt{(\mathfrak{N}/\nu \,.\, \gamma/\nu)} = \text{const. } \sqrt{(\mathfrak{N}\lambda \,.\, \gamma\lambda)}.$$

For classical radiation damping:

$$\gamma = \gamma_0\nu^2 = \gamma_0/\lambda^2, \text{ and } \Delta\lambda/\lambda = \Delta\nu/\nu = \text{const. } \sqrt{(\mathfrak{N}/\nu \,.\, \gamma/\nu)} = \text{const. } \sqrt{(\mathfrak{N}\gamma_0)}.$$

* The same had already been suggested by D. H. Menzel, *Ap. J.* **84**, 465, 1936.

3. All Lines

Construction of Theoretical Curves of Growth

From the general formula of the equivalent width, it is easily seen that for the construction of theoretical curves of growth the number of variables may be reduced by a judicious choice of the co-ordinates.* It is therefore customary to plot:

$$\log \Delta\nu/\Delta\nu_D \text{ against } \log \mathfrak{N}/\Delta\nu_D, \text{ with the parameter } \gamma/\Delta\nu_D.$$

This is equivalent to

$$\log \Delta\nu/\nu v \text{ against } \log \mathfrak{N}/\nu v, \text{ parameter } \gamma/\nu v \text{ (classical damping } \gamma_0\nu/v)$$

or $$\log \Delta\lambda/\lambda v \text{ against } \log \mathfrak{N}\lambda/v, \text{ parameter } \gamma\lambda/v \text{ (classical damping } \gamma_0/\lambda v).$$

The curves thus obtained are valid for all wave-lengths and multiplets and could be called: 'reduced curves of growth'. These constitute *a uni-parametric family*, which is a great advantage and simplification for the computations.

However, it must be remembered that the parameter has another value in each wave-length region. When λ varies, a curve of growth with a given damping factor γ is inevitably modified and changes into another curve of the family. Only if γ should be proportional to ν, would the curve be independent of λ.

Construction of Curves of Growth from Stellar Spectra

In this case, we ordinarily assume that the damping factor γ has a certain mean value, because too little is known about its variations for the individual lines. Apart from this the most exact way of plotting these curves would be to use the same co-ordinates as for theoretical work. The suggestion of Dr Eddington is to adopt for the equivalent width the unit $\Delta\lambda/\lambda v$, which is directly suited to this graphical construction.

However, in many cases the temperature of the reversing layer is not well known *a priori*. It would, therefore, seem advisable to choose $\sqrt{(\mu)}\Delta\lambda/\lambda$ in order to eliminate the differences between the atoms. But then the difficulty appears, that there is also a part of the Doppler effect due to turbulence, which is independent of the atomic weight.

The proposition of Dr Dunham is to use $10^6.\Delta\lambda/\lambda$.† This is less far reaching and leaves it to every author to decide whether he will simply plot the values of $\Delta\lambda/\lambda$ which the observer has tabulated, and derive afterwards a mean value for v; or whether he will take into account the more uncertain difference between the Doppler effects of the several atoms.

The use of such 'reduced' curves of growth is of special advantage for the study of stellar spectra, where only a few lines are free from blends. Multiplets of all different parts of the spectrum are then used together in order to determine the curve of growth. Values of $\mathfrak{N}$ may be compared directly in any spectral region. By sliding the curve in the horizontal and vertical directions till it coincides with one of the theoretical curves, the absolute values of $\mathfrak{N}$ and v are determined. The influence of R_e, the central depth for strong lines, can be taken into account afterwards as a constant factor affecting ultimately v (Unsöld). The curve giving the best agreement determines the parameter $\gamma\lambda/v$ and thus γ.

By plotting as ordinates $\Delta\lambda/\lambda$, we must not hope that our curves of growth for different wave-length regions will coincide. We may slide them in a horizontal direction till the faint lines coincide, the important horizontal shoulder having more or less the same shape. But then in the region of the strong lines the curves for different wave-lengths will not check (factor $\sqrt{\lambda}$ in the ordinates); this is not too important, because there the points scatter anyway, due to the individual variations of the damping factor.

* Cf. van der Held, *Zs. f. Phys.* **70**, 508, 1931; Minnaert and Slob, *Proc. Acad. Amsterdam*, **34**, 542, 1931; Mitchell and Zemansky, *Resonance Radiation and Excited Atoms* (Cambridge, 1934); Unsöld, *Physik der Sternatmosphären*, pp. 168, 266, etc.

† This has already been done by Allen, *Mem. Commonwealth Solar Obs.* **5**, 21, 1934.

For the use of reduced curves of growth, the following restrictions should be made.

1. The determination of $\mathfrak{N}$ for a spectral line does not give directly the number of 'effective atoms above the photosphere'; a quantum-mechanical calculation or an experimental measurement of f is first required. It is not allowed to connect separate wave-length regions by multiplets or supermultiplets with distant members. A direct comparison between the concentration of the effective atoms is still less possible, because the 'height' of the photosphere varies with the wave-length.

2. The curves of growth have a slightly different form, according to the distribution of the effective atoms over the depth (ionization, excitation); the law $i/i_0 = F(k)$ is, strictly speaking, different for each spectral line.

3. If the damping were the classical radiation damping, it would vary proportionally to ν^2. The quantum-mechanical radiation damping should be roughly proportional to ν^3.* However, damping by collisions with H atoms seems to be the preponderant effect; this varies from line to line, and disturbs the exact run of the curves of growth.

4. The formulae used give a central intensity zero. Several more refined theories have been proposed, taking into account cyclical transitions, interlocking, etc. Unsöld has developed a semi-empirical formula, from which it is seen that the equivalent widths derived for a central intensity zero may be in error by 20% for strong lines, and by much more for lines of medium intensity.†

5. The formulae cannot be applied to H and He^+ lines, where the statistical broadening is preponderant.

Other Advantages of the New Unit

The introduction of the unit $\Delta\lambda/\lambda$ has also the following important advantages:

(*a*) It is a pure number. This advantage would not be reached if we adopted $\Delta\lambda/\lambda.c$ in km./sec. (Beals, Merrill).

(*b*) No constant factors are involved.

(*c*) 1 F corresponds to about 0·005 A. in the central part of the spectrum. This means that for most lines the new unit is adapted rather nicely to the present accuracy of the spectrophotometric measurements.

(*d*) $\Delta\lambda/\lambda = \Delta\nu/\nu$. This symmetry is useful in many cases. When $\Delta\lambda$ or $\Delta\nu$ were used, there was always some hesitation which of them should be preferred.

If it could be expected that more exact methods would soon be found for the investigation of star-spectra, it would be advisable to defer any decision about the units to be used. However, for the moment the construction of curves of growth in the simple way now used is practically the only systematical method of analysis, and a vast amount of work has still to be done on that basis; as long as this is the case, the unit $\Delta\lambda/\lambda$ for the measurement of equivalent widths seems very useful.

M. MINNAERT
President of the Sub-Commission

* Menzel, loc. cit. p. 472.
† *Physik der Sternatmosphären*, p. 269.

PRESIDENT: Dr M. MINNAERT.

SECRETARY: Dr D. BARBIER.

First meeting (Friday, August 13, at 10.30 a.m.).

The President reminded the Commission of the deaths of three of its members: Eddington and Fabry, whose contributions were outlined at the meeting of Commission 29, and E. G. Williams, whose achievements in the field of spectrophotometry of novae were outstanding; we shall remember him as an excellent member of this Commission.

The President intends to resign his functions after this assembly of the I.A.U. as is customary in this Commission.

Scope of activities. A survey of the whole field of spectrophotometry is not possible in future, said the President. The field is too comprehensive; it will be necessary to omit many special fields and to devote our attention primarily to spectrophotometry proper. Among the items in the Draft Report the President would suggest omitting the following: spectrographs; atomic transition probabilities; spectrophotometry of spots, flares, chromosphere, prominences; atmospheric lines; comets; corona; interstellar lines; nebulae; variable and abnormal stars.

Struve did not agree with this last point; he felt that it was not possible to draw the border-line between normal and abnormal stars, nor between variable and constant stars. Plaskett was not entirely satisfied with the idea of giving up transition probabilities to the Sub-Commission of Commission 14. Greaves emphasized that it is dangerous to forbid the President or the members to send reports on certain subjects; there should be left a certain freedom. D'Atkinson pointed out that the construction of spectrographs is correlated with the standardization devices, the losses of light, etc.

The President agreed that it is always very difficult to draw demarcation lines. But he thought that there was a general agreement for limitation. Therefore, although the President would be free to limit himself in writing his report, the members would still have the freedom to send contributions on related subjects.

Report of Commission. The President said that this report, held up on January 1, was not intended to review the publications of 1948. He thanked the members who had helped him by supplying information and contributions, and apologized for possible omissions.

It is very difficult to collect papers from certain countries. A short report from Hagihara (Japan) has just arrived. He, and his students, have worked out more than thirty papers on the theory of galactic nebulae. Japanese papers are available in the U.S.A. but not in other countries. Greaves suggested that the Executive Committee of the I.A.U. should be invited to write to the American Research Council, asking that one copy of each Japanese periodical should be sent to every country. According to Swings and Struve it would be safer to obtain film copies from an American observatory.

The President had received from the Optical Union seven copies of a paper by Rubinowicz dealing with multipole radiation, these being available for members interested in the subject.

As the results of an inquiry made by the President, it was ascertained that in most countries it is possible, after long delays, to get the necessary special photographic plates. The situation, therefore, is not good, but only tolerable. It thus seems unnecessary to take steps in this direction.

The President feared that there would not be much time left to discuss the other details of the Draft Report; he proposed that members, who wished to suggest modifications, should communicate with him. Lyman Spitzer then moved the adoption and Swings seconded. The Draft Report was then adopted.

Unit of line intensity. After the Stockholm meeting, the President invited the following scientists to form a Sub-Commission, in order to discuss the choice of a unit of line intensity: Dunham, Eddington, Menzel, Minnaert, Pannekoek, Plaskett, Russell, Struve and Unsöld. This Sub-Commission has not met, but work was carried on by correspondence and its

report issued in an Appendix of the Draft Report. Its aim had been to prepare the subject, leaving the decision to the Commission.

There is an amount of logic for each one of the systems proposed, said Menzel, but it seems that $\Delta\lambda/\lambda$ is generally more suited. Struve thinks that $\Delta\lambda$ is more appreciated by observers, but if theoretists prefer $\Delta\lambda/\lambda$ he is ready to make the divisions. The President suggested having two unities, $\Delta\lambda$ and $\Delta\lambda/\lambda$.

Struve would prefer that the Commission express a wish in favour of $\Delta\lambda/\lambda$, without forbidding $\Delta\lambda$. Greaves would agree if the wish were in favour of $\Delta\lambda$, without forbidding $\Delta\lambda/\lambda$.

The decision will be taken at the second meeting.

Infra-red spectrophotometry of the solar spectrum. Lectures on infra-red spectroscopy were given by Dr Struve (on behalf of Dr Kuiper), Dr Goldberg and Dr Migeotte. The President returned the thanks of the Commission to the lecturers. He had been very much impressed by the recent progress in infra-red spectroscopy which has been described and by the way in which different investigations complete each other. Struve emphasized that the discovery of methane in the earth's atmosphere by Migeotte had been a real sensation in America.

Second meeting (Tuesday, August 17, 9.30 a.m.).

Unit of equivalent width. From the report and from the previous discussion it has become clear that sometimes the one, sometimes the other of the two units has advantages, according to the problem in which they are used. This is the reason why there is no consensus of opinion among the members. Considering this situation, the President thought that it is impossible to impose one of the units and that they should both remain in use. Private discussions between the members of the Commission had shown that such a policy would be generally approved.

There remains the question of the symbols designating the *equivalent width* and the *reduced width*. Unsöld does not like the abbreviation $\Delta\lambda$ for an equivalent width, which is rather confusing for theorists; he would prefer A_λ. Menzel uses W_λ. Lyman Spitzer suggested writing $10^6 \frac{W_\lambda}{\lambda} = W_F$. Menzel objected that then the two units would differ only by the subscript; he suggested writing $10^6 \frac{W}{\lambda} = F$, W would be expressed in Ångströms and F in Fraunhofers.

The President proposed the following resolution, leaving to the Sub-Commission the question of designation.

Resolution. The Commission recognizes the usefulness of expressing line intensities in Fraunhofer units of $10^6 \frac{\Delta\lambda}{\lambda}$, as proposed by Dr Dunham and by the sub-commission on intensity units. However, it is of opinion that for many problems the ordinary units of equivalent width $\Delta\lambda$ retain their value. It asks that other units should be avoided unless in exceptional cases.

The resolution was accepted by the Commission.*

Creation of a Sub-Commission for the Establishment of a Standard system of Line Intensities. The President had received a letter from K. O. Wright suggesting the establishment of a uniform system of line intensities. This would necessitate, by a detailed intercomparison, the establishment of a system of standards for selected regions of the solar spectrum and for a few selected lines in certain stars. According to the President, the details are to be worked out by a sub-committee.

Greaves said that this proposition was premature and that the duty of the sub-committee should be to examine if it is time to take the proposition into consideration. Beals drew a parallel with the standards of radial velocities. The President suggested a sub-committee formed by Plaskett, Houtgast, Greenstein, Redman and K. O. Wright.

The Commission accepted his suggestion.

* After the meeting, the Sub-Commission decided: the equivalent width W shall be expressed ordinarily in milli-Angström (mA); the reduced width A shall be expressed in Fraunhofer (F).

Creation of a Sub-Commission for the Theory of Stellar Atmospheres. This second Sub-Commission should be very different, said the President. Our Commission is both theoretical and observational. At this meeting our activities have been more concerned with the observations, because in this field great progress is being made. At the next meeting it would be useful to devote more attention to theory and to have a sub-commission just to prepare these discussions; it did not seem advisable that the theoretical group should meet in a separate session. Greaves asked the President if he contemplated having also observers among the members of this Sub-Commission. The President thought that it ought to be rather constituted by theorists interested in observations.

Gratton agreed with the constitution of this Sub-Commission, but he suggested that an agreement could be reached with Commission 35 (Constitution of the Stars), which intends to extend its activities to stellar atmospheres. Kourganoff pointed out that theorists of stellar atmospheres are in many respects more interested in the work of Commission 36 than in that of Commission 35. The President has examined the question with Dr Milne, President of Commission 35, who fully agreed with the formation of the new Sub-Commission as proposed here. Greaves pointed out that the study of stellar atmospheres had progressed so rapidly because of the collaboration of theorists with observers. This subject is a classical example for inductive scientific research. It is important to co-ordinate and not to arrive at a divorce.

The President thought that theorists must have an outlet for their activity. The Sub-Commission could give a separate report and prepare a symposium for the next meeting of the I.A.U.

The creation of the new Sub-Commission was then adopted. The President proposed the members: Barbier, Chandrasekhar, Goldberg, Kosirev, Kourganoff, Menzel, Plaskett, Spitzer, Strömgren. Greaves suggested that the Sub-Commission could meet five minutes after the General Assembly to co-opt Dr Unsöld.

Joint Commission on Spectroscopy. The President read a proposition by the Commission Internationale d'Optique about the formation of a Joint Committee on Spectroscopy, together with members of the International Astronomical Union. For the time being, the purpose would be to co-ordinate work on term classification; in future the activities of this Joint Committee could be gradually extended.

Spectrophotometry of the Far Ultra-violet Solar Spectrum. Menzel gave a short lecture on ultra-violet spectrophotometry of the Sun with 'V 2' rockets.

The President returned the thanks of the Commission to Dr Menzel for his lecture on this spectacular subject and closed the session.

Abstracts of Lectures given at the Meetings of Commission 36

I. Spectrophotometry of Stars with Interference Filters.

Very promising results have been obtained by the use of interference filters and photoelectric photometry for spectral classification. Two interference filters isolating relatively narrow wave-length regions (width about 200 A.) around 4861 A. (H_β) and 4600 A. (comparison region) were used. For a number of stars of different spectral classes the ratio of the intensity through the H_β and the comparison filter, respectively, was measured with a photoelectric photometer attached to the 82-inch reflector of the McDonald Observatory. Results of nineteen measures of eleven stars on two successive nights are shown below:

Spectral class	B5	A0	A3	F1	G5	K2	M0
Intensity ratio H_β : Comp.	1·041	0·913	0·933	1·019	1·077	1·104	1·168

The effect of the absorption by H_β is clearly shown, superposed on a weak colour index effect.

From a comparison of the results obtained on different nights a mean error of the measured ratio corresponding to $\pm 0^{m}.006$ (one observation) was determined. It follows that spectral classification based on the measured ratios can be effected with an accuracy of, for instance, better than one-tenth of a spectral class in the spectral ranges A5–F0 (provided rough classification is available to eliminate the B-star ambiguity).

The influence of selective interstellar absorption on the intensity ratio in question is not very pronounced. It might be eliminated by the use of three filters, or materially reduced through the use of narrower filters with maximum transmissions closer together.

The filters employed were manufactured by Baird and Associates, Inc. These filters reduce the intensity by about three magnitudes. Still narrower filters are now available, the application of which would undoubtedly lead to improved results. A systematic development of the method using several interference filters is planned.

The results mentioned were obtained in connection with a photoelectric survey of interstellar hydrogen emission carried out at the McDonald Observatory by W. A. Hiltner and the author (cf. this volume, p. 363).

B. STRÖMGREN

II. The Far Ultra-violet Solar Spectrum from 'V 2' Rockets

Scientific applications of the German 'V 2' rocket include studies of the far ultra-violet solar spectrum. Spectrographs, sent to heights above the ozone layer, have recorded the hitherto inaccessible region from 2875 to about 2000 A.

The observations, made at the White Sands Proving Grounds in New Mexico, have been largely undertaken by two experimental groups. Personnel from the Naval Research Laboratory include Richard Tousey, Ernst Krause, C. V. Strain and E. Durand. J. J. Hopfield and H. E. Clarman, Jr. have been most active in the second group from the Applied Physics Laboratory of Johns Hopkins University. Many other persons have contributed ideas and effort to the success of the project.

The Naval Research Laboratory group employs a concave grating in a modified Rowland mount. An image of the Sun, formed by a lithium fluoride bead, acts as a slit. Much of the light is wasted, because of the wide angle of the rays emanating from the bead. However, this wide angle is necessary so that the grating will be filled as the rocket rolls or yaws. Beads on opposite sides of the rocket nose provided two entrance slits, so that one is always turned toward the Sun. The automatic recording camera employs motion-picture film.

The spectrograph employed by the A.P.L. group was similar to the one just described above, except for the slit mechanism. This spectrograph employs a conventional slit, fed by an ingenious system of 'homing' mirrors, controlled by photoelectric cells.

Both groups have obtained excellent spectra, but none of the records extends appreciably beyond 2200 A. The general intensity of the background, throughout the new region, is very much less than that to be expected from a black body at 6000°. At 2200 A. the discrepancy amounts to a factor of 10.

Lines of Fe II are conspicuous through the entire region. There are also many stray lines of Fe I and several fundamental lines of Si I. The resonance line of Mg I, at 3780 lies close to the ultimate pair of Mg II, at 2796 and 2803. This doublet is scarcely resolved, but intense central emissions mark the positions of each Mg II line.

Low dispersion, lack of resolving power, and calibration problems make the interpretation of these spectra difficult. The general low intensity of the continuum, I believe, results largely from the overlapping wings of the numerous lines in the region. Nowhere do we find a completely clear window. A theoretical study indicates that wing absorption can play a role analogous to that of continuous absorption. Undoubtedly some continuous absorption is present, but from about 3700 A. toward the shorter wave-lengths the absorption by line wings dominates.

Curve-of-growth studies are almost inapplicable in this region. Interpretation of the spectrum in terms of abundances is a complicated problem, involving many uncertain

factors, such as wing damping. The appearance of the spectrum suggests that only the very central cores remain for many lines. Theoretical calculations show that the equivalent widths of these lines should be many times greater than those measured directly from the tracing. The discrepancy must be attributed to the afore-mentioned weakness of the line wings.

The sharp central emissions in the Mg II doublet deserve some comment. They are, of course, analogous to the emissions H_2 and K_2 of Ca II. This emission undoubtedly arises in the Mg II flocculi, whose extent is appreciably greater than that from Ca II. We probably are to attribute both effects to a thicker chromosphere over the spot zones, increased temperature of the upper solar atmosphere, and high opacity at the line centre, so that we see down only into the hotter radiating layers. Theoretical considerations suggest that we should consider the process of line formation as one of absorption and re-emission rather than that of coherent scattering.

I wish to thank Drs J. A. Van Allen and J. J. Hopfield of the Applied Physics Laboratory, and Dr Richard Tousey of the Naval Research Laboratory, for their aid in assembling the exhibit of rocket photographs, which has been an interesting feature of the I.A.U. meeting.

DONALD H. MENZEL

A symposium on infra-red spectrophotometry was held, a report of which may be found on pp. 436–441.

37. COMMISSION DES AMAS STELLAIRES

PRÉSIDENT: M. H. SHAPLEY, *Director of the Harvard College Observatory, Cambridge* 38, *Mass., U.S.A.*

MEMBRES: MM. Bok, Chandrasekhar, Cuffey, Hertzsprung, Mme Sawyer Hogg, MM. N. U. Mayall, Mineur, Nassau, Trumpler, Vanderlinden, Wallenquist.

Unlike the investigations in many fields of astronomy, the work on star clusters offers few problems for practical international or inter-observatory co-operation. But there are two useful projects that the International Commission can undertake: the reporting of the researches in progress at the various observatories, and the co-operative listing of useful categories of research on star clusters. The list may serve as a guide for new workers in the field. Also there is, of course, much value in the mutual discussion of researches. Such interchange of ideas may be the most useful outcome of the Commission's conferences at the Zürich meeting of the International Astronomical Union.

Our preliminary and final report can be brief because surveys and bibliographies are being currently printed elsewhere. Mrs Helen Sawyer Hogg has completed for publication, from the David Dunlap Observatory, *A Bibliography of Individual Globular Clusters*, which will be of the utmost importance to all workers in the field henceforth. She expects to publish in a year or two a second edition of her catalogue of variable stars in globular clusters (originally published in 1939). The President of the Commission is preparing for publication in *Popular Astronomy* a generalized survey of work on globular star clusters during the past half century. Perhaps someone should undertake a similar bibliography and general survey for galactic clusters.

The members of the Commission have agreed that the following are the major categories of research on star clusters:

A. *Open Clusters of the Milky Way System.* (Here called galactic clusters)

1. Photometry in two or more colours and spectrum classification of individual stars.

2. Proper motions and radial velocities of galactic clusters and of the stars within galactic clusters, followed by studies of rotation and shear. Professor Hertzsprung emphasizes the importance of preparing, with great care, the first positions for stars in many clusters for studies such as have now been made for the Hyades, Pleiades, Praesepe, and Ursa Major; plate deterioration and magnitude equations must be guarded against.

3. Space structure and dynamics of the clusters (density distribution, stability, evidences of equipartition, etc.), and relation of galactic clusters to the Galaxy and its spiral arms.

4. Colour excesses, combined with photometry and spectrum classification, for estimates of distances and dimensions, and derivation of luminosity frequencies.

B. *Globular Star Clusters*

1. Photometry in the globular clusters of the galactic system, with special reference to colour-magnitude arrays and general luminosity curves. 'For one-third of accepted globular clusters, no magnitudes are known.' (Mrs Sawyer Hogg.)

2. Continued studies of variable stars in and near globular clusters, including further investigation of period changes.

3. Space structure and dynamics (density distribution, flattening, etc.), both observational and theoretical.

4. Radial velocities (and eventually proper motions) of globular clusters, and of the brighter stars in globular clusters.

5. Colour excesses, and revision of distances for globular clusters in low latitudes.

6. Spectra (and colours) of giant stars in nearest globular clusters.

7. Intensive search for additional globular clusters.

C. *Integrated Apparent Magnitudes of All Clusters (Globular and Galactic) in Various Colours.* (Wallenquist.)

D. *General Investigations of the Galactic and Globular Clusters of the Magellanic Clouds, the Andromeda Nebula, and Other Nearby External Galaxies.*

Dr Nassau suggests that the establishment of magnitude sequences for the work on clusters might be undertaken co-operatively.

The word photometry in the foregoing list is meant to include photographic, photoelectric, and radiometric methods.

It is proposed that brief statements of star-cluster work in progress at the various observatories will be presented at the Zürich meeting, and, together with summaries of work in two or three restricted fields, will be offered as an appendix to the present report.

HARLOW SHAPLEY
President of the Commission

VARIABLE STARS IN GLOBULAR CLUSTERS

By HELEN SAWYER HOGG

Considerable information has been added to our knowledge of variable stars in globular clusters since 1938. The publication in 1939 of *A Catalogue of* 1116 *Variable Stars in Globular Star Clusters* (Sawyer, David Dunlap Publ. no. 4) served to put the subject in a systematic form. It is hoped to issue a second edition of this work about 1950.

At present, 62 globular clusters have been systematically searched for variables, and the number known now in these objects is 1307. The majority of these stars, well over a thousand, are RR Lyrae type variables; periods have been determined for about 800 of them. About 80 stars have been shown to have periods greater than one day, though a number of these are not actual cluster members.

Clusters in which new variables have been found since 1938 include the following: NGC 5634 (Baade), 6093 (Sawyer), 6171 (Oosterhoff), 6229 (Baade), 6273 (Sawyer), 6284 (Sawyer), 6287 (Sawyer), 6293 (Sawyer), 6366 (Sawyer), 6656 (Sawyer), 6779 (Sawyer, Rosino).

Clusters in which new periods have been published since 1938 are: NGC 288 (Oosterhoff), 3201 (Wright), 4590 (Popper), 4833 (Wright), 5053 (Sawyer), 5139 (Martin), 5466 (Sawyer), 6121 (A. de Sitter, Oosterhoff), 6205 (Sawyer, Kollnig-Schattschneider), 6218 (Sawyer), 6254 (Sawyer), 6341 (Nassau, Hachenberg), 6656 (Sawyer), 6712 (Oosterhoff), 6779 (Sawyer, Rosino). Clusters in which more or less extensive period revision and correction have been accomplished are: 5024, 5272, 5904 and 7078.

Clusters which have been under investigation for a long while and for which more data ought to be published soon are: 6402, 6934 and 7006.

From the mass of individual detail, star to star and cluster to cluster, certain significant facts have arisen from the work of the past decade. These may be briefly summarized as follows:

(1) RV Tauri variables are now shown to be present in relatively large numbers as compared with the known galactic variables of this class. Special attention should be called to the importance of Joy's spectrographic programme for these stars, and others with periods greater than one day.

(2) Most of the typical Cepheids found are of the W Virginis type, with periods just over two weeks.

(3) There is a continuing absence of eclipsing variables and novae, and great rarity of long-period variables physically associated with the cluster.

(4) The distribution of types of variable stars found in globular clusters indicates that the population of these clusters is Type II as defined by Baade.

(5) The distribution of frequency of short periods is curious, with single or double maximum of the frequency curve, as discussed by Oosterhoff and Sawyer.

(6) There may be more very short period RR Lyrae stars than previously recognized in clusters (6205, Kollnig-Schattschneider, 6333, Sawyer, unpubl.).

(7) Extensive investigation of period changes shows no uniform pattern; periods are found to be increasing, decreasing, or remaining relatively constant.

Some of the problems to be stressed for future investigations are:

A. To establish good magnitude sequences over large intervals, sufficient to measure the very bright variables and the faint RR Lyrae type with equal accuracy.

B. The determination of the light curves of the RV Tauri and other variables with periods of some weeks, where dozens of nights, as nearly consecutive as possible, are necessary. The scale of the instrument must be sufficiently large to disentangle these stars from the background, but not so large that bright comparison stars are not nearby on the plates.

C. Research for variables in the highly obscured clusters. For some of the badly obscured clusters like NGC 6401, where it is suggested that even with the largest telescopes photographs must be taken in the red to reach the cluster stars, the problem of detecting variables and then determining their light changes seems to be a very serious one.

D. It is hoped that results on new or old variables will be published in a standard form; that authors will consult already existing lists and avoid renumbering known variables (as is done too frequently), thus causing an unnecessary amount of confusion in the literature. It is suggested too, that to conform to the homogeneity of the literature on the subject, authors publishing period determination work, publish an epoch of maximum (or minimum), and the actual value of the period.

Spectral Classes and Colour Indices in Galactic Star Clusters

By Robert J. Trumpler

The observational material on spectral classes and colour indices in galactic star clusters published during the last 10 years is not very extensive.

It seems, however, appropriate at the present moment to review and discuss the most promising points of attack in this field and the kind of data most needed for further progress. The principal lines of investigation for which spectral classes and colour indices in galactic star clusters are useful are:

(1) The determination of distances from magnitudes and spectral classes.

(2) The study of colour excess and its relation to interstellar absorption.

(3) The luminosity—spectral class distribution, or the population characteristics of galactic clusters.

(4) The study of spectral peculiarities.

From magnitudes and spectral classes of its stars the distance modul $y=m-M$ of a galactic cluster can be found with a fair degree of accuracy. To derive the distance from the distance modul it is necessary to allow for the effect of interstellar absorption. In view of the irregular distribution of interstellar matter the assumption of uniform absorption leads to considerable errors in the distances of individual clusters, particularly the more remote ones. A more reliable estimate of the absorption effect could probably be obtained by assuming it proportional to the colour excess. More extensive and more accurate data on colour excess in galactic star clusters are urgently needed. They serve not only for improved distance determinations, but are also of interest for studying the distribution of absorbing matter. Moreover, galactic clusters offer an opportunity for finding the average ratio of colour absorption to general photographic (or visual) absorption.

For work on colour excess both spectral classes and colour indices must be determined for the same stars; the list of stars observed in a cluster, however, does not need to be

complete nor very large. It is more important to observe a few stars (10–20) in each cluster, and to investigate a whole series of clusters (including near and distant objects) with uniform equipment and procedure. The principal difficulty at present lies in the lack of homogeneity of colour index data due to systematic differences depending on the magnitude and to differences of colour equation.

A recent study by C. Baum (unpublished thesis at the University of California, Berkeley) compares many of the magnitude and colour index measures in galactic clusters with each other. It finds the colour index series determined by Zug at the Lick Observatory by the half-filter method to be affected by appreciable systematic errors. The half-filter method, like the method of effective wave-lengths, requires laborious calibration and careful study of the peculiarity of the instrumental equipment used. When the derivation of colour excess is the main purpose, it seems therefore that comparisons with the North Polar Sequence (or other well-established photometric standard areas) are the most desirable procedure. They generally permit also a determination of colour equation and reduction to the international colour system. In such comparisons the precautions and reduction methods proposed by Blaauw and Weaver (*Ap. J.* **106**, 366, 1947) should be used in order to avoid systematic errors in the magnitude scales.

Baade's work on the two principal population types in stellar systems has brought renewed interest to the differences in luminosity-spectral class distributions of galactic star clusters which may be considered as variations of Baade's type I. Progress in this field has been made mainly through more detailed investigations of the nearer representatives of various cluster types. For such detailed studies the elimination of background stars is essential. Differential proper motion measures (van Maanen, Ebbighausen) on photographs taken with long-focus telescopes have now reached an accuracy which in many objects of moderate distance permits selection of cluster members with fair reliability. Radial velocity measures also have proved useful for this purpose at least for the brighter stars in a cluster. Some of the features brought out, such as:

(i) the absence of ordinary giants of classes F–M in clusters containing early B-type stars,

(ii) the occasional presence of super giant stars in such clusters but in no others,

(iii) differences among clusters in the central line or trend of the Main Sequence,

seem highly important and should be more completely verified.

Spectroscopic observations of stars in galactic star clusters made with slit spectrographs in connection with radial velocity measures have shown that certain spectral peculiarities (Hydrogen emission, narrow or weak Hydrogen lines in class B stars; abnormal intensity of Ca III lines in classes A–F, etc.) often predominate or occur in considerable number among the members of the same group. Such clusters furnish a rare opportunity for studying the relation of peculiar spectra to normal spectra of the same class as well as connections between spectral peculiarities and population types. This appears to be a promising field for exploration which so far has been barely touched.

The Dynamics of Globular Clusters

By Ivan King

Progress since 1938 has been greater in some phases of globular-cluster dynamics than in others. The most rapid strides forward have been towards an understanding of the evolution of the clusters. Of primary importance was the recognition of the fact that as a result of exchanges of energy between individual stars of a cluster some members of the cluster will acquire sufficient energy to escape from its gravitational attraction. Discussions by Ambazrumian, Spitzer and Chandrasekhar have shown that a globular cluster may be expected to eject half its stars in a time of the order of 10^{11} years. Of great significance for future work is the setting up by Chandrasekhar of the mathematical mechanism, based on a generalization of the Liouville equation to include the effect of stellar encounters, necessary for a more exact and detailed treatment of cluster evolution.

Closely linked with the problem of evolution is the observational determination of density distributions in clusters. Here the difficulties inherent in the photometry of crowded images are no less forbidding than in the past. Until a way is found to foil crowding and Eberhard effect—perhaps by direct photoelectric measurements—we can hope for little information about the highly interesting central regions of the clusters. Star counts in the outer parts, however, have been made in the past decade for Messier 92 by Hachenberg and Messier 4 by Greenstein. There is still need of more measurements of the relative density distributions at different magnitudes, with particular attention to the extended envelopes of faint stars. And star counts could well be supplemented by photoelectric tracings of surface brightness in the outer parts of clusters.

Studies of cluster dynamics will eventually have to consider the ellipticity of a cluster and its relation to the rotational motion (or perhaps its relation to encounters with other stellar groups). Although the exact problem is a forbidding one, it may be hoped that it will be possible within a few years to describe approximately the change of some suitably defined ellipticity parameter during the evolution of the cluster. New observations or new discussions of old observations of ellipticity have been few; worthy of mention is an attempt by Freundlich to correlate the ellipticity with the relative size of the envelope of faint stars about a cluster.

The application of the theory of cluster dynamics requires a knowledge of the masses of the clusters. Now that we have at our disposal accurate measurements by Christie of the total luminosities of the northern clusters, it is discouraging to realize that we cannot state with any degree of certainty the mass of a single globular cluster. Popper's recent measurements of radial velocities in Messier 13 indicate a mass for that cluster of not more than 10^5 solar masses; these measurements, however, were made on plates not well suited for the job, since the radial-velocity measurements were only a by-product of another observing project. Those astronomers having access to spectroscopic equipment on a large reflector should give the confirmation and extension of these measurements the highest priority, not only for the sake of cluster dynamics but also because of their importance to the general problem of stellar populations. Such a programme could well include an attempt to determine the order of magnitude of the rotational velocity of the cluster as well.

Another stumbling-block to practical applications of dynamical theory is our ignorance of the number of stars of small mass in a globular cluster. Since these stars are too faint to be photographed individually, the only way to estimate their number seems to be to subtract the total light of all stars photographed from the integrated light of the cluster. The accuracy of photographic photometry has proved inadequate for these delicate measurements, but the improved accuracy of the coming photoelectric age promises to bring them within the range of feasibility.

The Progress of Galactic (Open) Cluster Dynamics Since 1938

By Uco van Wijk

Substantial progress in the field of cluster dynamics was made during the period covered by this report. Our knowledge of the dynamics of galactic clusters under the influence of galactic shearing forces has been greatly extended by the work of Mineur, who found a relation between the shape and the density of a galactic cluster in statistical equilibrium, leading to a value of 0·6 solar masses per cubic parsec as the minimum density required for stability. In the same paper Mineur also made a thorough study of the distribution of the internal motions in galactic clusters. His work has been extended by Mayot who, in his doctoral thesis, considered the case of clusters which deviate slightly from a circular orbit around the centre of the Galaxy. A significant step forward in the correlation between theoretical studies and the observed shapes of clusters is the proof by Mayot that strongly elongated clusters are unstable.

The minimum density required for the stability of galactic clusters as found by Mineur has led to a reconsideration of the existence of the very loose clusters of A stars. Gliese, Vyssotsky and Mrs Gossner have all analysed the available data for the extended Ursa Major cluster and the extended Taurus cluster. It was pointed out that the space velocities of these two groups lie close to the vertices of Kapteyn, blending gradually into the distribution of the space velocities of all A stars as a whole. The existence of these extended clusters as isolated dynamical units may therefore be considered doubtful. The loose B-star clusters in Scorpio-Centaurus and in Perseus were the subject for a similar investigation by Smart, who cast considerable doubt on their existence as clusters. On the other hand, the existence of the Scorpio-Centaurus cluster has been ably defended by Blaauw, but some difficulties are still encountered in the past evolution of this cluster.

The most important point in connection with the evolution of clusters is the rate of escape of stars from the clusters, which has been studied by Spitzer and by Chandrasekhar. Although their work was primarily intended for globular clusters, their results are also applicable to the denser galactic clusters. In an unpublished paper, Van Wijk has obtained a relation which allows a direct comparison between the influence upon cluster evolution of the loss of mass due to escape of stars and of the gain in total energy of the cluster due to encounters with field stars; he also generalized Mineur's relation between density and shape of galactic clusters.

The identification of faint members by their proper motion is of course an essential step in the advancement of our knowledge of the structure of galactic clusters. This type of work has been carried out by Van Maanen who identified a considerable number of stars as members of several well-known clusters. Of great value are measurements of the dispersion in the proper motions of the stars in a cluster, such as were obtained by Hertzsprung and by Titus for the Pleiades and by Schilt and Titus for Praesepe. Researches of this nature should be extended to other clusters when better proper motion data will become available.

Valuable data regarding the structure of the more remote galactic clusters can be obtained from star counts along the lines of the work of Zug and Vogt, and it would be desirable to continue these researches using the high image quality of modern instruments now available.

A survey of the field of cluster dynamics up until 1942 is to be found in *Principles of Stellar Dynamics* by Chandrasekhar.

Report of meeting. Friday, August 13. 10.30–11.30 a.m.

PRESIDENT: Dr H. SHAPLEY.

SECRETARY: Dr R. J. TRUMPLER.

MEMBERS OF COMMISSION PRESENT: Shapley (*Chairman*), Hertzsprung, Mineur, Nassau, Trumpler, Vanderlinden, Wallenquist.

The Chairman stated that in addition to the report published in the Draft Reports he had at his solicitation received several reports on special problems or on work in progress. He suggested that these be included in the Commission report and that they be briefly discussed at the meeting.

A summary of the Report by Mrs Helen Sawyer Hogg on Variable Stars in Globular Clusters was presented by the chairman, who also drew the attention of the Commission to the complete bibliography on globular clusters prepared by Mrs Sawyer Hogg. He suggested that a similar bibliography for galactic clusters would be very useful.

Trumpler outlined the principal points of his report on Spectral Classes and Colour-Indices in Galactic Star Clusters.

Wallenquist elaborated on his suggestion for the determination of integrated apparent magnitudes in various colours; he advocated the use of photoelectric measures for this purpose.

Nassau explained that his suggestion for the establishment of magnitude sequences for work on clusters has mainly the purpose of obtaining greater uniformity in magnitudes. He would like to have the observers publish the sequences used in each case.

Shapley drew attention to the value of Küstner's early position measures in several star clusters for the determination of proper motions, and recommended to Dr F. Becker, Director of the Bonn Observatory, the repetition of Küstner's early plates.

In connection with the report by Ivan King on the Dynamics of Globular Clusters, Shapley drew attention to the importance of gaining more information on the luminosity distribution in globular clusters. A comparison of integrated light with the total light of observed individual stars does not seem to leave room for large numbers of dwarf stars. The cluster ω Centauri seems to be a favourable object for studies of the luminosity distribution, and is now being investigated at the Harvard Observatory.

A report prepared by Uco van Wijk is concerned with recent progress in the dynamics of galactic clusters.

The programme of radial velocity measures in galactic star clusters undertaken by Trumpler is now nearing completion, and a report on this work is published by Commission 30.

No resolutions were proposed to the General Assembly.

38. COMMISSION POUR L'ECHANGE DES ASTRONOMES

PRÉSIDENT: M. F. J. M. STRATTON, *Gonville and Caius College, Cambridge, England.*

MEMBRES: MM. Y. C. Chang, Danjon, B. H. Dawson, Lindblad, Minnaert, G. A. Shajn, Struve, van den Bos, Witkowski.

1. At the Meeting of the Executive Committee of the Union held at Copenhagen in March 1946 the following resolutions were adopted:

(*a*) That a standing Commission be appointed for facilitating the exchange of astronomers.

(*b*) That the attention of U.N.E.S.C.O. be drawn to the existence of this Commission as an advisory body to whom U.N.E.S.C.O. could refer questions of the exchange of astronomers.

Preliminary discussions with U.N.E.S.C.O. showed that the best way at the present juncture of carrying out the objects of the Commission would be to apply for a grant in aid from U.N.E.S.C.O. and to study the problem entirely inside astronomical circles. Accordingly a sum of £500 was asked for by the Commission for the year 1947; this has been granted, and a further amount of £1000 has been asked for for the year 1948. A grant of £750 was made by U.N.E.S.C.O. for 1948 and a grant of £1000 has been asked for again for 1949.

Regulations governing grants for travelling Fellowships have been adopted by U.N.E.S.C.O. at the conference of November 1947 and any future awards will be subject to these regulations.

2. An inquiry was sent to a large number of observatories to inquire about: (1) possible assistantships or research fellowships available for astronomers of other countries; and (2) known cases where students had been prevented from working at a foreign observatory owing to (*a*) currency restriction, (*b*) lack of the necessary funds. At the same time particulars were asked as to foreign astronomers who had worked at the observatories in recent years. The replies showed that over fifty astronomers had actually been working abroad from their own countries in recent years of whom over twenty had been working in war or post-war years. They also indicated a number of cases where it had proved impossible for students to work abroad for lack of the necessary funds. There were very few cases where currency restrictions had proved the actual bar.

From two observatories, Paris and Utrecht, came the very helpful suggestion that currency difficulties could be overcome in some cases by an exchange of two young astronomers between two observatories in different countries. It was hoped that each home observatory could be responsible for the stipend or maintenance of the visiting astronomer. One such exchange is already in operation between Blindern (Norway) and Paris.

This would not, however, be possible in all cases.

3. The inquiry showed the following facilities for visiting astronomers to hold Fellowships, studentships or temporary assistantships at various observatories.

Observatory	Type of post	Application to be made to
Arcetri-Firenze	Research Fellowships under the 'Fondazione Volta'	Fondazione Volta, c/o Accademia Nazionale dei Lincei, Umgara 10, Rome
Institut for Teoretisk Astrofysik, Blindern, Oslo	No formal Fellowship, but help can be found in special cases	The Director
Canberra	Occasional Research Fellowships	Advertised from time to time
David Dunlap	Part-time assistantships	The Director
Harvard	Agassiz and other Fellowships, Assistantships	The Director
Kirkwood, Indiana	Assistantships ($1000) and fellowships	The Director

Observatory	Type of post	Application to be made to
Leander McCormick	No formal Fellowships, but help might be found in special cases	The Director
Leiden	Temporary assistants. Possibly Fellowship from Government funds for promoting international contacts	The Director
Lick	Martin Kellogg Fellowships, $900 to $1500 a year. Two Lick Obs. Fellowships $900 a year	The Dean of Graduate Division, University of California, Berkeley, before Feb. 20 for award starting July 1
Liège Institut d'Astrophysique	One Research Fellowship (at present filled). American astronomer may get help under Belgian American Educational Foundation	—
Michigan	Two part-time Research Assistantships ($1200 for nine months). Visits of Professors in summer term	The Director
Mount Wilson and Palomar	Post-doctorate Fellowships and Fellowships for students. Not till after summer of 1948. Details not yet available	—
Ottawa	Assistantships for summer months	Civil Service Commission, Jackson Building, Ottawa
Oxford and Radcliffe	Radcliffe Travelling Fellowship	Is advertised when vacant. Next vacancy October 1948
Oxford	Skynner Senior Studentship for student working for a research degree	The Master, Balliol College, Oxford
Paris	Studentships provided by the Centre National de la Recherche Scientifique (exchange preferred)	The Director
Perkins	Fellowships of Ohio State University	The Director
Stockholm	No formal fellowships, but help might be found in special cases	The Director
Uccle	Belgian American Educational Foundation for countries with cultural agreements with Belgium. Apply Minister of Education of applicant's country	420 Sixth Avenue, N.Y.
Utrecht	Assistantships (exchange preferred)	The Director
Victoria	Research Fellowship in Astrophysics (temporary)	The Director
Warner and Swasey	Research Fellowship	Case Institute of Technology, East Cleveland, Ohio
Yerkes and McDonald	Post-graduate Research Fellowships, assistantships	The Director, Yerkes Observatory

Applications should give full qualifications of candidate and in case of University Observatories should state whether the student wishes to register for graduate courses or courses towards one of the higher degrees.

4. The Commission have already been able to help several times and are considering further cases. In all applications for grants they would wish to know: (1) that facilities detailed in section 3 have been explored where suitable; (2) how much further assistance would be required to meet travelling expenses or to make it possible for a candidate to make use of an offer from another observatory; and (3) whether the Committee can help to facilitate an exchange in any way other than by financial aid.

5. The sums made available by U.N.E.S.C.O. for 1947 and 1948 have been paid or allotted to meet the following cases:

(*a*) a Polish astronomer for six months' work at St Andrews Observatory, Scotland;
(*b*) a Chinese astronomer, at Arosa, Switzerland;
(*c*) a Finnish astronomer, at Delft, Netherlands;
(*d*) an Italian astronomer to take up a fellowship at the Warner and Swasey Observatory, Cleveland, U.S.A.;
(*e*) a Polish astronomer, in U.S.A., mainly at Yerkes Observatory;
(*f*) a Chinese astronomer, to work in Greenwich, England, and to take up a fellowship at Radcliffe College, Harvard, U.S.A.;
(*g*) an exchange between a Dutch astronomer at Paris and Haute Provence, France, and two French astronomers at Utrecht, Netherlands.

No further grants can be made until a decision is reached by U.N.E.S.C.O. as to a grant for 1949.

F. J. M. STRATTON
President of the Commission

Report of meeting. Saturday, August 14, 1948. 9.30 a.m.

PRESIDENT: Prof. F. J. M. STRATTON.

SECRETARY: Dr W. H. VAN DEN BOS.

Dr van den Bos was appointed Secretary; 28 members were present.

The President opened the meeting and gave some supplementary details to the Draft Report. These are now included in the final report printed in this volume.

Prof. Minnaert was of the opinion that the work done has been of great value, that with a minimum of expense a maximum effect had been obtained and that activities on these lines should continue. Even if no funds were available, the Commission might still give useful assistance in other ways.

Prof. Vonwiller remarked that visits to Australia and South Africa are greatly desirable, but realized that these would involve considerable expense.

The President drew attention to the passing of the Fulbright Act in the U.S.A., which may be helpful to the Commission's activities.

Prof. Lindblad moved, and Prof. Minnaert seconded the passing of the report, as supplemented. (Carried.)

Prof. Stratton explained the necessity for the President having authority to take quick action in individual cases. Prof. Lindblad supported this and expressed the wish that the President should notify members from time to time of the actions he has taken. (Agreed.)

The President then invited opinions on the type of case to take precedence: (1) a young, partly trained astronomer; (2) a proved, experienced man who could be expected to perform work of greater value for astronomy. Some members pointed out that in the case of a powerful, understaffed telescope, type (2) is greatly to be preferred. Others stated that in the case of poor countries lacking facilities for thorough training, type (1) becomes of the greatest importance.

The President explained that, of the nine persons assisted so far, five may be considered of type (1), and four of type (2). The general opinion of the members was that a similar judicious balance should continue.

Dr Jackson suggested that Directors of Observatories having large but inadequately staffed telescopes be circularized. (Agreed.)

Dr Goldberg mentioned that Prof. Rossiter will retire in 1951 and that suggestions will be welcomed at Michigan.

Dr Luplau Janssen stated that salaries are not always continued during a scientist's absence abroad and that this ought to be done. The President answered that the Commission has no power to give orders to authorities responsible for payment of salaries. The Committee expressed the hope that in the case of exchange a full salary would be paid to a visiting astronomer.

The President invited suggestions as to how we can augment the funds available. Prof. Shapley stated that Prof. Bok has made great efforts to raise funds in the U.S.A. Dr Douglas mentioned that Canada plans to spend about $180,000 on grants to visiting fellows (up to $3000 per person) and Dr Pearce advised that applications from astronomers to work at Victoria or Ottawa be sent to Dr C. S. Beals, Dominion Observatory, Ottawa, and to work at Toronto to Dr F. S. Hogg, David Dunlap Observatory, Toronto.

Prof. Minnaert proposed and Prof. Lindblad seconded that the Commission also ask for a grant of $500 from I.A.U. funds in addition to the grant that may be received from U.N.E.S.C.O. (Agreed.)

39. COMMISSION POUR LA CREATION D'OBSERVATOIRES INTERNATIONAUX

PRÉSIDENT: M. H. SHAPLEY, *Director of the Harvard College Observatory, Cambridge, Mass., U.S.A.*

MEMBRES: MM. Baade, J. G. Baker, Bowen, Gaviola, Spencer Jones, Lindblad, Lyot, Oort, Redman, G. A. Shajn, Struve, Waldmeier, Witkowski.

At this time (March 15, 1948), it is possible to make only a preliminary report on the development of the project of International Astronomical Observatories. Excellent discussions of the proposals, in response to an outline by the President of the Commission, have been received from Dr Ira Bowen and Dr Walter Baade (of Mount Wilson and Palomar); Sir Harold Spencer Jones (Greenwich); Dr R. O. Redman (Cambridge, England); Dr Otto Struve (Yerkes and McDonald); Dr Bertil Lindblad (Stockholm); Dr Enrique Gaviola (Córdoba); Dr M. Waldmeier (Zürich); Dr G. A. Shajn (Simeis); Dr Joseph Witkowski (Poznań); Dr B. Lyot (Paris). At my request Dr J. S. Paraskevopoulos, Superintendent of the Harvard South African Station, has reported on South African sites. All these reports should eventually be printed or at least fully summarized and mimeographed for the use of the International Astronomical Union. Of special value are Lyot's consideration of atmospheric conditions; the arguments of Bowen, Baade, Spencer Jones, and others in favour of a modest beginning with provision for growth when needs and directions are clearer, and Witkowski's reconsideration of our earlier plan for an International Observatory and Laboratories in southern Europe.

There is very general agreement on the following points: (1) Any new international observatory equipped with large telescopes should not be in the northern hemisphere, but preferably should be located between 10° and 40° southern latitude. (2) The problem of choosing a site for an important international southern observatory is transcendent. It should be done with much deliberation, and would require two or three years before satisfactory site-testing could be completed. (3) There is almost unanimous agreement that the basic equipment should consist of one large reflector (aperture between 75 and 125 inches) profusely equipped with spectroscopes at Newtonian, Cassegrainian, and Coudé foci; and one large-field Schmidt-type reflector of aperture somewhere between 30 and 60 inches, and this second instrument, which produces a high ratio of reduction time to observing time, should be built first. (4) There is no need of a solar telescope in the southern hemisphere, and little need of small cameras. (5) The southern international observatory should have a small but highly competent resident staff, and large funds to cover the expenses of visiting observers.

In the interest of the project of international observatories, I have had many conferences with astronomers, travellers, meteorologists, and, of most importance, with officials of the United Nations and U.N.E.S.C.O. The obtaining of effective sponsorship and financing may be difficult because of the extraordinary economic and political conditions of the times. But the picture should be clearer by August, when we meet in Zürich.

Some remarks on a site satisfactory for a large international observatory may be useful, as a point of departure for the discussions in Zürich.

Since large telescopes, with appropriate mechanical and electronic shops, require a considerable staff in residence, in addition to visting astronomers, the living comforts must be given some consideration. The observatory could not work satisfactorily if it is too severely isolated (as in central Australia, for example). It should be in a region free of the *Aurora Australis* and as accessible as possible (other things being equal) by train or plane. Almost certainly the site must be found in South Africa or in South America. Preferably the latitude should be between $-10°$ and $-35°$; the altitude between 6000 and 10,000 feet; the clear nights not less than 225 per year, with no two-month period on the average more than 50% cloudy; and the seeing of highest possible quality.

These conditions are very difficult to meet, but northern Chile, north-west Argentina,

the Bolivian plateau, possibly Southern Peru should be investigated in South America, and in South Africa consideration should be given to the Windhoek and Mount Brukkaros regions in south-west Africa, and various places in Bechuanaland, Transvaal, Mozambique, Angola, and Rhodesia. To approach some of the required ideals for a site, others must be compromised. For their very exacting work on the Sun, the observers of the Smithsonian Astrophysical Observatory have found Montezuma in Northern Chile the most satisfactory, and in south-west Africa worked successfully at Mount Brukkaros for several years. Dr L. B. Aldrich, Director of the Smithsonian Astrophysical Observatory, and Dr J. S. Paraskevopoulos merit membership on Commission 39.

At this stage of the development of the project, it would seem to me advisable to seek a grant of some $50,000 for a two-year investigation of astronomical sites. Such a survey, if properly planned and executed, could bring to astronomers and others very useful information about observing conditions throughout the southern hemisphere, even if the studies were not immediately followed by the establishment of a southern observatory. Careful study of existing meteorological and physiographic records would go a long way in limiting the regions that should be carefully examined. If the whole of the grant of $50,000 is not necessary, the remainder could be devoted to detailing the plans for telescopes, accessories, and buildings.

Dr Gaviola writes that two 12-inch *f*/15 Cassegrain reflectors could be built in Córdoba, if desired, under his supervision at a cost of about $1000 each; and he estimates that the total cost of building and using these instruments throughout the year would be about $12,000 ('experienced observers available').

But the problem of selecting a site, and testing the conditions, is so serious that a special sub-committee should be selected for the purpose of analysing methods and planning procedure.

HARLOW SHAPLEY
President of the Commission

Compte rendu de séance

PRÉSIDENT: M. H. SHAPLEY.

SECRÉTAIRE: M. D. CHALONGE.

Le Président fait d'abord un exposé général, développant les raisons qui militent en faveur de la création d'institutions astronomiques internationales. Cet exposé est résumé dans les paragraphes I et II, la discussion dans le paragraphe III et les vœux de la Commission dans le paragraphe IV de ce rapport.

I. INTRODUCTION

La création d'institutions astronomiques de recherche ayant un caractère international semble s'imposer pour diverses raisons.

La première résulte de la répartition très irrégulière des grands observatoires modernes à la surface du globe: certains pays, notamment en Europe, en sont complètement privés mais il ne serait ni possible, ni même désirable de pourvoir chaque pays d'un tel établissement qui côute fort cher et qui ne pourrait vraisemblablement pas toujours être utilisé à plein rendement par les seuls astronomes de ce pays.

Il serait plus avantageux à tous points de vue, et surtout eu égard aux extraordinaires conditions économiques du moment, de créer un petit nombre de centres de travail astronomique munis des instruments les plus modernes et dont l'utilisation serait permanente: les astronomes des pays défavorisés par leur équipement pourraient ainsi se procurer les données d'observations et les documents qui leur sont nécessaires.

Cette proposition a déjà été faite sous une forme plus ou moins générale par divers pays: lors de la réunion du Comité Exécutif de l'U.A.I. à Copenhague, en 1946, la Pologne

a proposé la création d'un observatoire international et, tout récemment, la délégation française au Comité Economique et Social réuni à Genève, a demandé de mettre sérieusement à l'étude le projet de création de laboratoires de recherches internationaux pour les sciences fondamentales. (Voir dans l'appendice de ce rapport.)

L'existence de foyers permanents de rencontre et de collaboration scientifique internationale aurait par elle même une grande valeur et serait sans nul doute une source féconde de travaux.

Enfin il ne faut pas perdre de vue que la coopération scientifique entre les divers pays, que ces établissements contribueraient à développer, constitue un aspect particulièrement important des relations internationales.

II. Propositions

Pour mettre en œuvre les idées générales qui viennent d'être énoncées, H. Shapley fait les trois propositions ci-dessous:

(1) Un Observatoire Astronomique International devrait être créé dans les conditions qui ont été définies dans son rapport, en tenant compte des suggestions faites par divers astronomes (voir, dans l'appendice, un résumé de ces suggestions): cet observatoire devrait être édifié dans l'hémisphère austral, de préférence entre $-10°$ et $-40°$ de latitude dans un site choisi avec soin en tenant compte non seulement des qualités de l'atmosphère et du climat, mais des conditions d'accès et d'habitabilité, car le personnel permanent d'astronomes et de techniciens s'accommoderait difficilement de conditions d'isolement trop sévères.

Les éléments principaux de son équipement seraient un grand réflecteur (de 75 à 125 pouces) muni de nombreux spectrographes et un réflecteur de Schmidt, à grand champ, de 30 à 60 pouces de diamètre. Aucun équipement solaire ne serait nécessaire.

(2) Un centre ou Laboratoire Astronomique International devrait être édifié, de préférence dans un petit pays d'Europe, comme la Suisse, le Danemark, la Norvège. Cet établissement devrait comprendre des laboratoires munis du matériel le plus perfectionné (spectrographes, photomètres, microphotomètres, etc.), des ateliers pour la construction et la mise au point d'appareils spéciaux, des bureaux de calculs équipés des machines les plus modernes, une bibliothèque internationale.

Des documents (photographiques, spectroscopiques et autres) obtenus dans un groupe de grands observatoires des divers pays, seraient en outre mis à la disposition des personnes fréquentant ce Centre qui serait accessible à tous les astronomes. Il faut en effet noter que beaucoup de documents astronomiques peuvent être étudiés très loin des instruments qui ont servi à les obtenir.

Un tel centre pourrait, à relativement peu de frais, être créé, équipé et mis en fonctionnement dans un laps de temps relativement très court. (Voir, dans l'appendice, le rapport de H. Shapley, concernant le projet pour la création d'un laboratoire international pour la recherche astronomique.)

(3) Pour rendre possible aux astronomes le séjour dans l'un des deux établissements internationaux dont il vient d'être question, ainsi d'ailleurs que dans les grands observatoires nationaux ouverts aux étrangers, un Fonds International de Voyages devrait être créé: il permettrait de couvrir les frais de voyage et de séjour quand ce serait nécessaire.

III. Discussions

F. Becker a été pendant trois ans membre d'une mission astronomique à La Paz en Bolivie. Il considère que La Paz remplirait les conditions demandées pour l'édification d'un grand observatoire austral: Latitude $-16°$, grande altitude (près de 4000 m.) ressources d'une grande ville. Il pourra fournir d'autres informations si cela est nécessaire.

H. Shapley pense que, du point de vue purement astronomique, la Station de Montezuma (Nord du Chili), qu'ont utilisée longtemps les observateurs du Smithsonian Astro-

physical Observatory of Washington, serait tout à fait excellente. Mais elle ne remplirait pas les conditions humaines car elle se trouve dans une région désertique. Il faudrait examiner les possibilités présentées par le Sud Ouest Africain (Transvaal, Rhodésie, Bechuanaland): les astronomes du Smithsonian Observatory ont travaillé avec succès pendant plusieurs années au Mount Brukkaros.

Bourgeois signale que l'I.R.S.A.C. (Institut de Recherches Scientifiques en Afrique Centrale) s'occupe depuis l'an dernier d'organiser au Congo Belge des Centres de Recherches qui seraient ouverts aux chercheurs des différentes disciplines et des divers pays. Une expédition a été envoyée il y a quelques mois au Congo Belge pour chercher un emplacement favorable pour un observatoire de haute altitude. Il faut un endroit élevé, situé au-dessus de la zône des précipitations, éloigné des volcans (fumées) et des tremblements de terre, assez proche cependant de régions habitées. Ces diverses conditions définissent un plateau situé à 3000 m. d'altitude, aux environs de $-6°$, entre le lac Kivu et le Tanganyika. Ce plateau est dominé par des montagnes plus élevées.

Les premières recherches ont commencé il y a quelques semaines sur un sommet de 3500 m. Le capuchon de nuages n'a permis le travail d'observation que pendant cinq nuits dont trois étaient très bonnes et présentaient une faible turbulence. D'autres lieux, moins humides, ont été et seront explorés en d'autres saisons.

Woolley signale qu'en Australie l'influence des aurores australes doit être négligeable.

G. Abetti mentionne une autre activité possible pour le laboratoire astronomique International: il pourrait être chargé de rassembler dans un délai aussi bref que possible toutes les informations concernant l'activité solaire, et aussi celles relatives aux comètes, novae, etc.—et de les diffuser.

Federer suggère que le laboratoire astronomique international soit installé, au moins partiellement, sans faire intervenir l'U.N.E.S.C.O., ceci afin d'éviter les retards administratifs et pour gagner du temps.

H. Shapley objecte à cette proposition qu'il semble au contraire très désirable que les établissements projetés apparaissent comme l'œuvre collective des nations membres de l'U.N.E.S.C.O.

O. Struve remarque que toutes les activités ne pourraient se manifester avec la même facilité dans le laboratoire astronomique international: il est parfois très difficile, selon lui, d'étudier les résultats des observations loin de ceux qui les ont faites.

H. Shapley répond que c'est une question d'espèce et que de nombreux travaux resteraient possible dans le laboratoire international: par ex. le long travail de dépouillement des clichés fournis par un télescope de Schmidt, ou l'analyse de spectres de grande dispersion obtenus à l'aide de grands télescopes pourraient très bien être confiés à des astronomes travaillant dans ce laboratoire astronomique international.

O. Struve se place à un point de vue assez différent de celui de H. Shapley. Alors que ce dernier accumule des documents aussi nombreux que possible en vue de travaux généraux, O. Struve s'intéresse à des recherches plus spécialisées qui exigent que les documents à analyser soient pris et calibrés en fonction de chaque recherche particulière.

R. E. Wilson approuve la création de l'observatoire et du laboratoire international. L'Observatoire du Mont Wilson a depuis longtemps une activité semblable à celle que devraient avoir ces établissements: des astronomes étrangers peuvent venir y travailler, des observations sont faites pour eux et des documents pourraient être envoyés au laboratoire international.

Woolley signale que dans l'hémisphère sud on manque d'astronomes et de techniciens mais que l'on a suffisamment de télescopes. Aussi le laboratoire astronomique international lui semble-t-il plus important que l'observatoire international proposé dans l'hémisphère austral.

Th. Dunham pense que le laboratoire international serait très désirable, mais qu'il devrait être spécialisé dans diverses directions. Il devrait comprendre, entre autres, un laboratoire d'essais photographiques, un laboratoire de recherches optiques, un laboratoire destiné au perfectionnement d'instruments de mesure existants et à la mise au point d'instruments nouveaux, etc.

O. Struve, appuyant une proposition contenue dans le projet de H. Shapley, pense qu'une des grandes machines à calculer modernes devrait être l'un des premiers éléments du laboratoire international.

Owren, appuyant la troisième proposition de H. Shapley, demande des fonds pour faciliter l'échange des astronomes entre les observatoires et instituts existants.

Lindblad approuve dans leurs grandes lignes les plans proposés et estime que la question financière sera la plus importante à résoudre.

Chalonge attire l'attention sur la Station Internationale du Jungfraujoch qui est, en petit, une réalisation du même type que celles que demande la Commission 39 et qui fonctionne avec grand succès depuis plusieurs années. Elle a été créée par la collaboration de divers pays, la Suisse (dont l'apport est le principal), la France, la Grande Bretagne, la Belgique, l'Allemagne et l'Autriche.

IV. Vœux de la Commission

A la suite de ces échanges de vue le président de la Commission remercie les personnes qui ont pris part à la discussion et demande si l'activité de la Commission 39 doit se poursuivre: un *oui* unanime lui répond. La création d'un observatoire astronomique international et d'un laboratoire astronomique international pourvus d'équipements modernes est demandée par la Commission. Il semble prématuré de demander dès maintenant la création d'un fonds international pour l'échange des astronomes, étant donné que pour l'instant, un comité pour cet échange est en fonctionnement avec l'appui matériel de l'U.N.E.S.C.O.

Stratton suggère que l'on adjoigne à la Commission 39 les personnes qui choisissent les emplacements possibles d'observatoires, ainsi que tous ceux qui ont envoyé des rapports. Il estime également désirable d'inclure dans la commission des personnes qualifiées pour juger des problèmes qui sont indiqués pour être analysés avec de grandes machines à calculer modernes.

APPENDIX I

Excerpts from letters relative to International Astronomical Observatories *and* Laboratories

Henri Laugier, Assistant Secretary-General of the United Nations:

It was a real pleasure for me to learn that a further step has been taken by your Union to achieve international scientific co-operation....Calling special conferences of experts and having exploration studies made by outstanding scientists are both necessary and useful for the preliminary report.

The establishment of International Research Institutions is a problem of long-range character. The preparations should consider both the moral as well as the technical aspects....

Bertil Lindblad, Stockholm Observatory:

The question of the International Observatory interests me profoundly....The question is a difficult one, but should mean an immense addition to astronomical activity if well handled, as I have no doubt it can be under the auspices of the I.A.U. and with the active help of those who have the greatest experience in this field, in the first hand the leading American astronomers....

The matter is of such great importance that it is much to be desired that preliminaries for site selection and instrument planning can be started at an early date. Regarding the instrumentation I agree in the main with your own list. Careful exploration should of course include tests for seeing, which can be made with fairly small telescopes, but has to extend over a considerable time. I suppose three or four separate expeditions would have to be active simultaneously on this problem. As each expedition would be quite small, the expenses would

not be considerable. Most of it would be travel expenses for the members of these expeditions. These may perhaps be partly recruited from observatories most closely situated to the regions to be investigated. For my own part I most heartily endorse your proposal to ask the Social and Economic Council of U.N.E.S.C.O. for a fund to cover expenses of site selection and instrument planning....

I. S. Bowen and *Walter Baade*, Mount Wilson Observatory:

It is the opinion of our group that the International Astronomical Union would be justified in asking for international support for an astronomical observatory only in case this observatory is planned to produce the maximum return in effective astronomical results. Even from the standpoint of international co-operation and good will we believe this is necessary....

The following comments on the proposed plans for the observatory, and the instrumentation that it is desirable to provide for the observatory, are based on the above assumption as to the fundamental principle that should govern the plans for the observatory:

(1) We agree thoroughly with your proposal that such an observatory should be located in the Southern Hemisphere.

(2) It is our opinion that the instrumentation of such an observatory should be limited to a large reflector of 80 to 120 inches aperture and to a large Schmidt camera for survey purposes. Our reasons for questioning the other items on the proposed list are as follows:

In general, there is no appreciable advantage in locating a coronagraph in the Southern Hemisphere over much more convenient regions in the Northern Hemisphere. In any case, the altitude requirements for such a coronagraph station are such as to preclude its location at the same station that would be suitable for stellar instruments. Furthermore, many of the investigations that should be carried out by a coronagraph involve systematic observations over an extended period of years. This type of investigation is obviously not suited to a staff whose personnel is made up largely of visitors that are changing at relatively short intervals. In other words, such a coronagraph would be much more effective if it were built in the Northern Hemisphere and provided with a permanent resident staff. There is therefore no great argument for such a station being undertaken as an international project.

The same reasons hold for the elimination of the equipment for the study of the ionosphere and related phenomena. Similarly, small cameras for patrol purposes and for the study of meteors, and so forth, should also be eliminated from the programme. These again are most effective when operated by a permanent staff. Furthermore, they are relatively inexpensive and are just the type of equipment that the small observatories in small countries should and can provide for their own staff.

Probably the most extensive study of the question of site that has ever been made was carried out by the 200-inch project. The preliminary studies were made with the aid of about ten 4-inch telescopes on stationary mounts. These were provided with high-power eyepieces and were permanently mounted to observe Polaris. A few months' observations were made at each of some two or three dozen sites. The small number of sites selected by this preliminary survey were then studied in more detail with the use of two 12-inch Cassegrain reflectors having equatorial mounts. This equipment at the present time would probably cost about $10,000. In addition, some five or ten man years of time would be required for the observations. It was found, however, in the 200-inch tests that relatively young and inexperienced men could be trained to take these observations.

The permanent staff of such an international observatory should be kept small and the major part of the observations should be handled by the visiting astronomers. However, we believe it would be necessary to have a small permanent staff of one astronomer in each of about three fields. This small group would be necessary to maintain and design auxiliary equipment, to provide instruction in the use of equipment and in the planning of effective programmes with these large instruments, and to give continuity to the work of the observatory....

[Several members of the Commission wrote similarly with regard to General Policy, Site Selection, Equipment, and Staff. H. S.]

Sir Harold Spencer Jones, Royal Observatory, England:

There are two alternative possibilities for the scope of an International Observatory. In the first place, it could be primarily an institution where qualified astronomers from observatories in other countries could come to secure observational data which are not obtainable in their own country, either because of lack of suitable instrumental equipment or because of difference in latitude or other reasons; the observational material would be taken back by the visiting astronomers to their own observatories and worked up there. For this purpose it would be advantageous that the programmes of observations should be of a type that require a large ratio of time spent in measurement and reduction to time spent in observations. It is desirable, however, that each observer should plan his own programme, secure his own plates, standardize and develop them himself, etc. It is not in general conducive to the best quality of material and the highest accuracy if the plates are obtained by resident staff and sent to various observatories. If the observatory is restricted to this sort of use, it would not need a large resident staff of trained astronomers, but a well-qualified astronomer with one or two assistants would be needed.

Secondly, the scope of the Observatory might be extended to permit of research students undertaking work there. Their supervision and guidance would necessitate a considerably larger astronomical staff. In my opinion, it is undesirable that the international observatory should cater for anyone with a status inferior to the advanced research graduate, who should be competent to work at the Observatory without detailed guidance....

Resident Staff. As a minimum staff I suggest a Director who should be a trained practical astronomer of some eminence with initiative, energy, and authority, but not too old; two scientific assistants; four mechanic night-assistants, who would be responsible for supervising the use of the telescopes by night, and for their maintenance (cleaning, oiling, testing, etc.) by day; day and night duties should be alternated. There should also be a secretary, who would be generally responsible for the business details, an assistant secretary, three or four typists, and a small workshop staff....

Summing up, I am in favour of the International Observatory not being started on too ambitious a scale and would favour in the first instance an equipment consisting of one or two Schmidt cameras (or alternative designs) and a large Newtonian reflector.

The programmes to be primarily of a type in which the ratio of time for working up the results is large in relation to observing time.

The astronomical staff of the observatory to be small. Advanced research graduate to be the minimum qualification for use of the equipment.

By starting on fairly modest lines, development is not excluded but the lines along which the development should proceed will be guided by the experiences gained.

G. A. Shajn, Simeis Observatory, U.S.S.R.:

It appears quite natural that the proposed International Observatory should be situated near or rather south of the equator, to balance at least partly the uneven opportunities for the study of the Southern Hemisphere as compared with the Northern one.

It is desirable that the new observatory should not be confined to conventional lines and routine way of using big telescopes. The great changes in optics and electronics (radiophysics, radio-astronomy) in the last decade should be carefully considered, since they could enormously increase the effectiveness of the telescopes....

From the very first the designing of the big telescope should be made in line with new trends, both in the instrumental technics and in the scientific tasks. In the light of this it may not be so urgent to have a reflecting telescope much surpassing 80–90 inches in size. In that case the building of such an instrument will become more realizable.

For many fundamental problems of stellar statistics the new-type telescopes of the size 40–50 inches (maybe of Baker-Schmidt or Maksutov type), supplied in addition with transmission grating or prism, will be a most effective instrument for many years.

A careful study of the conditions for good seeing is required. Particularly it is necessary to check Lyot's results concerning the influence of closed, skeleton, or open type of tube on the images....

Joseph Witkowski, University Observatory, Poznań, Poland:

I see from your letter that the two-hemisphere plan has been reduced to a Southern Observatory. The arguments for such a compression of the original project are valid only to a certain degree, and my personal opinion is that the experience of the future International Southern Observatory will be favourable for the foundation of a Northern Observatory. The two-hemisphere plan is certainly the one preferred by every astronomer as 'no matter what his country, he would be quite free to make use of the facilities available without any feeling of trespassing upon the welcome of the astronomers of the host country'. (Nat. Sci. Document 24, par. 21.)

I think besides that observing stations do not solve by themselves the problem of International Observatories. Remains the important question of

(1) Central Astronomical Library.
(2) Astrophysical Laboratory.
(3) Computing Department with modern calculating machinery equipment. A modern calculating equipment is of special importance, as none of the smaller countries can afford it.
(4) Department for the study of international astronomical projects.
(5) Central Bureau of Astronomical Telegrams.
(6) Instrument and Optical Shops for building of new instruments and modifying them as experience suggests.
(7) Borrowing Section for astronomical instruments.

All these sections could be located at the permanent seat of the Bureau of the International Astronomical Union. This seat should necessarily be chosen in a place having all the facilities of communication, modern civilization and highly developed techniques, e.g. U.S.A., England, France, Switzerland....

B. Lyot, the Observatory, Paris:

Exploration d'un site—Observatoire stellaire.

Pour l'étude de la qualité des images, plusieurs méthodes pourraient être employées simultanément, mais il serait bon que les différents sites soient examinés avec les mêmes méthodes et des appareils standard, pour obtenir des résultats comparables.

La méthode décrite par Danjon et Couder, dans leur ouvrage *Lunettes et télescopes*, p. 91, a l'avantage d'être visuelle, sensible et d'utiliser des observations faites à diverses hauteurs, dans différents azimuths, elle nécessite seulement un réfracteur court, de 15 à 20 cm. d'ouverture, monté sur un pied très stable et muni de forts grossissements. Cette méthode mesure principalement la courbure des ondes atmosphériques.

On pourrait employer, en même temps, une méthode qui mesure l'amplitude des réfractions accidentelles, telle que des trainées photographiques d'étoiles ou le dispositif visuel employé à Mount Wilson et Mount Palomar, ce dernier est d'un emploi plus commode, mais moins sensible.

Il serait bon d'enregistrer aussi les variations de la température, de l'humidité et la nébulosité.

Les sites vraisemblablement les meilleurs et, par conséquent, les plus intéressants à explorer, pourraient être choisis d'aprés certaines conditions locales:

A l'altitude la plus grande qui permette un accès et des conditions de vie assez faciles, sur un sommet isolé de préférence à un plateau et surtout à un col. Sur les plateaux, l'influence du sol refroidi par le rayonnement nocturne est beaucoup plus grande que sur les sommets, ainsi que la variation diurne de température. Au-dessus des cols, l'air est violemment perturbé par des courants ascendants, des tourbillons et la différence de température entre les deux versants.

La proximité de la mer peut être favorable, au moins en été, les vents froids à basse altitude, venant de large s'opposant aux courants ascendants (Lick Observatory).

Des îles peu étendues et possédant des sommets assez élevés, comme les Açores seraient à examiner; certaines îles, même de faible altitude, seraient à considérer, lorsque la variation diurne de température y est très faible, comme à Ceylon....

Otto Struve, Yerkes Observatory:

The permanent staff of the International Observatory should be small. I suppose that the principal purpose of the project is to provide facilities for observing to astronomers in those countries where there are no large observatories. I want to call attention to the great danger which would arise if American, English, French, and Swedish astronomers should fail to take an active participation in the operation of the new institution. Astronomers who have not had experience in handling large telescopes would probably be inefficient and unproductive. Hence, it would be desirable to have a thoroughly competent observational astronomer act as superintendent even though this person might not especially require the facilities offered by the institution. I am sure the representatives of the smaller countries will understand this point....

E. Gaviola, Córdoba Observatory:

Our limited experience with seeing in Córdoba, La Plata, Montevideo, Santiago, and Chaco points to the advantage of studying seeing in the north-western part of Argentina, the Bolivian plateau—12,000 feet high, with valleys at 9000 feet or less—the northern part of Chile, and the western part of Peru. The Smithsonian Institution has gathered experience about northern Chile, where it has one of the best solar stations (Montezuma).

I consider it advisable to send two observers equipped each with a 12-inch $f/15$ Cassegrain reflector to make simultaneous observations at points in the regions mentioned. The value of the observations would be increased by the ones already being made at Córdoba and Santiago.

The reflectors could be built at Córdoba, if desired—by a private firm—under my supervision; they would cost about 1000 dollars each.

Experienced observers are available. An observer could be paid 3600 dollars a year—all expenses included.

The site-testing would cost then—with two observers—2000 for equipment plus 7200 a year for salaries and expenses plus 2800 a year for supervision: 12,000 dollars the first year.

The resident staff needs to include an astronomer or physicist capable of aluminizing or silvering the mirrors, designing auxiliary equipment, and directing its construction in the observatory's shops, keeping the auxiliary equipment up to date, etc. On the ability of this man would depend the success or failure of the attempted work of the visiting astronomers.

Small but good mechanical and optical shops with capable workers are essential. Two mechanical assistants and one optical are indispensable. A business manager, one secretary, night assistants (two per large instrument), one cook, several peons and servants would complete the permanent staff....

L. B. Aldrich, Smithsonian Astrophysical Observatory:

Brukkaros in South-west Africa is none too good for night work because haze, clouds, and wind are too prevalent....

If our staff at Montezuma can help by making special night observations suitable to your purpose, please let us know.

M. Waldmeier, Zürich Observatory:

It seems to me of the greatest importance to discuss and to clear up, what kind of work is to be done at the international observatories in question, especially if it is to be routine work (in this case the instruments would be needed for the daily observations) or if the observatories should be reserved for certain researches of short period. It depends on this question, what sort of instruments we have to choose....

R. O. Redman, Cambridge Observatories:

Should we not try to outline in a general way, but not too vaguely, the programmes of observation which are likely to be attempted, and then try to provide instruments for these? It seems impossible to cater for every need. Perhaps it would be wise to envisage an observatory

beginning with only a small nucleus of instruments, but with opportunity to add to these at rather frequent intervals, when the need appears sufficiently urgent....

Resident staff. Yes, but plenty of technical knowledge should be available at the observatory. Many would-be observational astronomers are lamentably ignorant of the general 'know-how' of practical astronomy, or at least have been in the past. Much of this cannot be learned from books, and the technical staff would have to be prepared to cope with the weaker brethren as well as with observers of the very first rank.

Difficulties might arise with a multi-national resident staff, especially if the observatory were rather isolated. From this point of view it would be highly desirable to provide easy and frequent transport to the nearest large centre of population. This argues against any very remote site. Most of the maintenance staff would presumably be recruited locally. A good superintendent might need to be an exceptionally gifted man, humanly as well as astronomically....

APPENDIX II

Proposal for an International Laboratory for Astronomical Research

While a special Commission of the International Astronomical Union is considering the plan for a large international observatory with powerful telescopic equipment, it would seem appropriate to consider also the establishment in Europe of specially equipped laboratories for astronomical and astrophysical research, which could soon be available to the astronomers of many countries and very effectively contribute to astronomical knowledge and to the development of international co-operation.

The committee on the location and equipping of an international observatory, that would be owned and operated by the astronomers of all countries, has preliminarily decided, for excellent reasons, that the international observatory should be in the Southern Hemisphere, probably in South Africa or South America. The examination of potential sites for such an important observatory would require at least 2 or 3 years, during which all relevant astronomical and meteorological factors could be thoroughly investigated.

Although the international telescopes should be in the south, there is no need that all new international astronomical researches should be transferred to the Southern Hemisphere. The majority of astronomical researches are now best carried on away from the telescopes. That is, thanks to astrophotography, the detailed investigations of stars, stellar spectra, nebulae and galaxies are taken from the telescopes to the laboratories and measuring rooms of the astronomers. The situation is somewhat analogous to the researches of the botanist, who deals frequently with materials collected by others, or assembled by professional collectors who themselves are not prepared to carry on taxonomic or morphological studies.

It would be possible to assemble in a central laboratory both a good working library and the computing machinery, measuring engines, laboratory photometers, and microdensitometers that would make the analysis of astrophotographs fully as efficient as such analyses can be when made in the observatories where the photographs are exposed. If in this fully equipped astronomical laboratory we should make ample provision for a small resident staff, and for visiting scientists, and further an arrangement whereby photographic material covering many fields of astronomy is supplied in abundance, we could rapidly set up one of the most important astronomical centres of the world.

A basic requirement for the proposed international laboratory would be a plan whereby significant material for measurement, analysis, and discussion could be provided. Relying on the traditional co-operative spirit of astronomers, and the traditional hospitality of the great observatories, I suggest that we already have in existence an exceedingly effective international research institution. The most powerful and expensive part of an international astronomical institution already exists in the widely scattered large observatories.

I propose, therefore, that if the United Nations will endorse and provisionally finance the plan, we form, as a preliminary and basic part of the proposed international laboratory, an Association of Contributing Observatories. Perhaps ten of the active observatories now existing, in addition eventually to the proposed southern international observatory, could be counted in this plan. One naturally lists as sources of astronomical raw material three of the Harvard observatories—namely, the coronagraphic station in the Rocky Mountains, the southern station at Bloemfontein, the northern station at Oak Ridge—in addition to the collection of about half a million astrophotographic plates in Cambridge. Other American, South African, and European observatories could doubtless provide existing material, or better, provide by arrangement new series of astrophotographs for special projects. Presumably an appropriate budget would be available in the set-up of the International Laboratory to cover the expenses of photographic materials, telescope operations, shipping, and insurance. Expert and experienced supervision would be required to handle the many minor complications as well as guide the general policy. A committee of the I.A.U. should act as Board of Directors.

The question might be raised as to whether it would not be simpler to provide large travelling fellowship funds so that individual astronomers could be resident at selected observatories. Such a project is also good, but is quite different from the plan here sketched. The American observatories, for instance, are already crowded and cannot freely welcome unlimited visitations. A valuable telescope can often be more safely and efficiently handled by professional operators than by casual and inexperienced visitors. The peculiar advantages of assembling at a central laboratory the research astronomers from various countries and with various problems are not realized by the guest traveller, who himself has only the rights of a temporary visitor, and not the vested interest and responsibility of a participating owner of an international enterprise.

The plan I am exploring could be set up promptly. It should be situated, I would suggest, in one of the smaller European countries—Norway, Denmark, or Switzerland—easily and inexpensively available to the majority of the countries of the world in which astronomical research is carried on. In a year's time, if suitable quarters could be found, an international laboratory could be outfitted with some effective measuring machinery, a working library, a managerial establishment, and with thousands of astrophotographs suitable for research and as yet not studied. And in three years' time, a fully established astronomical laboratory could be in operation.

To begin with, no extensive telescopic equipment for observational work is recommended, but perhaps a few simple or special instruments that make no high demands on climatic conditions would not be inappropriate. When fully established, the International Laboratory should have spectroscopic, photographic, and possibly optic laboratories. There might be some laboratory equipment appropriate for the exploration of those borderline fields between astronomy and other sciences. Unquestionably the fully equipped laboratory should have one of the great modern digital calculators,* in addition to smaller calculating machinery, because this institution would also naturally be the headquarters for large endeavours in celestial mechanics, and possibly for the astrophysical work that gains through team work and the use of the utmost in calculational aids.

The proposed International Laboratory might naturally be the headquarters for international activities in astronomy—the place where some of the international ephemerides are prepared or published, the headquarters for bibliographies and special card catalogues, and possibly the home of the International Astronomical Union.

Naturally the study of the problem of developing an international astronomical laboratory should be the function of a special committee of the International Astronomical Union. A liaison committee serving the International Astronomical Union and U.N.E.S.C.O. and other United Nations sub-organizations would be appropriate. It should

* At the Zürich meeting it was generally agreed by Commission 39 that the proposed Central Astronomical Laboratory could and probably should be started with an all-science United Nations Computational Laboratory.

not be difficult to work out an initial budget for equipment, for buildings, and for annual operations as soon as the magnitude of the effort is tentatively decided upon. Whether this be only a small enterprise, or be one of moderate size, or one that aims to develop into the most important astronomical institution in the world—in any form its establishment would serve a useful purpose in science and in international relations. The returns will be proportional to the amount of time, spirit, and money invested, and the leadership which astronomers could provide through this activity might be of inestimable value in the promotion of the international co-operation that will be necessary if our immediate posterity is to have the privilege and honour of doing astronomical research.

March 1948 HARLOW SHAPLEY

17. COMMISSION DU MOUVEMENT ET DE LA FIGURE DE LA LUNE

Compte rendu des séances

PRÉSIDENT: Prof. T. BANACHIEWICZ.

SECRÉTAIRE: Prof. J. F. COX.

La Commission a tenu deux séances: la première le lundi 16 août, à $9^h\ 30^m$, la deuxième le mardi 17 août, à $9^h\ 30^m$.

1ère séance (Lundi, 16 août 1949)

Le Président rend compte supplémentairement des travaux dont il n'a pris connaissance que récemment, d'abord de ceux dont parle le rapport envoyé par M. Hagihara. M. Hirose a réduit les observations d'occultations faites au Japon pendant 2 ans et il en a calculé la longitude de la Lune excédant d'une demi-seconde d'arc celle obtenue par M. Brouwer d'après l'ensemble des observations; ceci correspondrait—si l'on devait attribuer cette différence à la déviation de la verticale—au déplacement géodésique du Japon de plus d'un km vers l'occident. Le Président est d'avis qu'aucune correction sensible du point observé d'équinoxe ne pourrait résulter d'un pareil déplacement. M. Ueta a déduit la correction de la longitude moyenne de la Lune donnée par les tables de Brown: $+3''6+4''6\cos\{6°\,(t-1920{\cdot}0)\}$.

Le Président signale l'apparition des tables auxiliaires de M. Koebcke de l'Observatoire de Poznań servant à calculer les heures du lever et du coucher de la Lune, pour l'année t, à partir des Almanachs de l'année $t-18$ ans.

M. Boneff, de l'Université de Sofia, a publié de nouvelles recherches sur la distribution des formations lunaires; en se basant sur la théorie des probabilités, il trouve confirmés les résultats de sa publication de 1936, d'après lesquels les formations de la surface lunaire ne paraissent pas distribuées fortuitement.

M. Volta a envoyé un bref rapport sur les observations des occultations par la Lune en Italie après 1938; à Milan, les observations durent être interrompues à cause de la guerre.

Le restant des séances a été consacré à l'examen des questions du *Draft Report* de la Commission. Le Président aborde la question du terme énigmatique de Yakovkin relatif au rayon apparent de la Lune. Ce terme est bien confirmé par les observations de longues années de Hartwig et il se retrouve aussi, suivant M. Kozieł, dans la série de Dorpat, où il disparaît toutefois quand on abandonne la méthode de réduction pratiquée depuis les temps de Bessel. Bien que ce terme paraisse donc être dû à la méthode d'ajustement favorisant l'influence des régions circumpolaires de la Lune, ces régions ayant des pentes particulières, son existence est très importante au point de vue de principes. Il en résulte notamment qu'il n'est pas permis d'admettre, comme l'a fait Hayn dans ses recherches, que le niveau moyen du disque apparent de la Lune soit toujours le même et égal au niveau moyen de la Lune toute entière. Dans les travaux de détermination des irrégularités du bord, on doit donc se baser sur les mesures absolues des rayons vecteurs du disque. Quand on obtient ces irrégularités d'après les photographies, il est nécessaire d'avoir—en dehors des angles de position des points observés—aussi l'échelle. Si l'on le néglige, on risque d'introduire des erreurs systématiques.

Le Président explique ensuite la méthode du calcul des constantes de la libration, appliquée à Cracovie par M. Kozieł. Cette méthode est rigoureuse au point de vue de la méthode des moindres carrés, et elle donne directement l'erreur moyenne *a posteriori* de chaque distance mesurée, erreur qui échappait aux procédés usuels. Les erreurs moyennes des inconnues deviennent beaucoup moindres, ce que le Président a confirmé aussi directement en calculant les constantes de la libration d'après les équations de M. Kozieł, traitées de la façon ordinaire. Relativement à l'inconnue principale dynamique f du problème, la solution satisfaisant la série de Dorpat est double, $f=0{\cdot}73$ et $f=0{\cdot}60$; le choix entre ces valeurs demande une base plus étendue et une discussion similaire d'autres

séries d'observations. Le Président partage l'avis de M. Kozieł, qu'il faudrait réduire toutes les observations de la libration lunaire par cette méthode. Ne pourrait-on proposer à l'Assemblée Générale de prendre une résolution recommandant le calcul d'ensemble des observations de la libration lunaire, faites pendant un siècle, par la méthode rigoureuse? Un pareil calcul serait facilité par la création de la section mathématique de l'observatoire ou laboratoire international projété.

M. Sadler is generally in favour of such a resolution. He would like, however, to defer it to a second meeting, when it would be possible to discuss it more in detail.

2me séance (Mardi, 17 août 1949)

La Commission adopte à l'unanimité la résolution suivante:

Il serait important d'entreprendre la réduction de l'ensemble des observations relatives à la libration de la Lune par une méthode rigoureuse.

L'exécution de cette grande tâche serait facilitée par la création d'un laboratoire mathématique international, qui serait une section de l'observatoire international projeté.

M. Orlov dit que M. Belkovitch a terminé le calcul de toutes les observations héliométriques de la Lune faites à Kazan, par la méthode usuelle, et qu'il a confirmé aussi le résultat de Yakovkin relatif à la variation du rayon lunaire.

Le Président insiste sur l'importance du terme de Yakovkin comme signal d'alarme contre la supposition de la constance du niveau moyen apparent et contre le manque de l'échelle des photographies lunaires.

La Commission entend un exposé de M. C. B. Watts (U.S. Naval Observatory) sur ses travaux en vue de l'enregistrement automatique du contour apparent de la Lune. Cette communication est résumée par M. Watts dans les termes suivants:

SURVEY OF THE MOON'S MARGINAL ZONE

(*Abstract of preliminary steps*)

In preparing the data for the new survey the photographic plate is supported in a horizontal position by an accurate vertical spindle and the image of the Moon is approximately centred. The spindle may be rotated in either direction at the rate of three degrees a minute by a synchronous motor. After the plate has passed through 180° of angular motion the motor reverses automatically and returns the plate to the starting-point.

A microscope, provided with a suitable slit at its focal plane, is mounted on a micrometer slide above the plate and is moved radially by a screw controlled by a motor forming part of a servo-mechanism. The servo can keep the microscope pointed at the limb of the Moon much more consistently than can a human operator. When it rotates the micrometer screw it also moves a recording pen a proportionate distance and is thereby enabled to trace a profile of the Moon's limb on a moving sheet of paper. The scale of the profile, as compared with that of the micrometer, is readily determined by making a few readings of the micrometer screw while marking the position of the recording pen.

Corrections for spindle errors, eccentricity, and differential refraction will be introduced graphically by altering the area to which the profile is referred. The measuring engine is nearly completed and has been given some preliminary tests.

It may be added that after the discussion of the observational material contained in the profiles is completed it is planned to exhibit the results in a manner that will utilize the three independent arguments (position angle, topocentric librations) directly, avoiding the use of the spherical co-ordinates P and D.

La précision des déterminations est de 0″.1. Le Président pense que ce sera un grand progrès, en comparaison avec la précision de 0″.25 atteinte par Hayn.

La Commission décide de proposer à l'Assemblée Générale la motion suivante:

La Commission est unanime à estimer que les travaux poursuivis par M. C. B. Watts (Washington) sur les irrégularités du limbe lunaire sont importants et méritent tout l'appui de la Commission.

La Commission examine la question, soulevée par M. Sadler, de savoir quelle serait la valeur qu'il y aurait lieu d'adopter, en vue des calculs d'occultations, pour k (rapport du diamètre de la Lune à celui de la Terre).

Il est convenu que M. Sadler présentera un rapport sur cette question lors de la réunion de 1951.

La valeur de k dépendant un peu de la valeur de la parallaxe de la Lune qu'on conclut des observations de $\delta_{\mathbb{Q}}$ à Greenwich et au Cap, le Président pense qu'on pourrait essayer d'estimer les déviations relatives de la verticale dans ces observatoires à l'aide des mesures gravimétriques.

M. Sadler tient à consulter la Commission sur les limitations du programme de prédiction des observations. Après une discussion à laquelle prennent part MM. Brouwer et Jackson et au cours de laquelle l'attention de la Commission est attirée en particulier sur l'intérêt que présentent les données relatives aux occultations d'étoiles doubles, il est reconnu que ces limitations sont en général rationnelles et utiles. En conclusion, la Commission décide à l'unanimité de proposer à l'Assemblée Générale la motion suivante:

La Commission 17 est unanime à donner acte au 'Nautical Almanac Office' de ce que les prédictions d'occultations telles qu'elles sont calculées par ses soins sont fort utiles et contribuent au progrès dans ce domaine de l'astronomie.

Un échange de vues auquel prennent part MM. Banachiewicz, Brouwer, Clemence, Maître, Meyer, Orlov et Sadler, s'engage sur les problèmes soulevés par l'observation des occultations d'étoiles peu brillantes, les méthodes de réduction, l'équation personnelle des observateurs, les règles à suivre pour obtenir un système homogène de résultats d'observations. Les progrès nouveaux qui résulteront d'une connaissance détaillée des contours apparents de la Lune renouvelleront les données de ces problèmes et pourront apporter des arguments en faveur de l'observation des étoiles faibles. Mieux vaut observer une étoile peu brillante que renoncer à observer. Les observations d'occultations faibles qui seront publiées pourront être réduites ultérieurement.

[Ce rapport a été rédigé à l'aide des notices qu'a bien voulu faire M. le Prof. J. F. Cox (Bruxelles).]

T. BANACHIEWICZ

PART IV
SYMPOSIA

I.

On August 10, before the General Assembly of the I.A.U., a meeting was held of the Joint Commission on Solar and Terrestrial Relations, presided over by Dr L. d'Azambuja. This meeting was followed by a symposium in which the following papers were presented:

(1) S. CHAPMAN and F. D. KAHN (read by Prof. E. A. Milne): 'On the possibility of detecting streams of corpuscles emitted by solar flares.'

(2) J. S. HEY: 'Recent work in galactic and solar radio noise at the Army Operational Research Group (Great Britain).'

(3) C. W. ALLEN: 'Solar noise and its relation to solar activity.'

(4) J. DENISSE (read by Mr M. Laffineur): 'Etude des conditions d'émission par l'atmosphère solaire d'ondes radioélectriques métriques.'

(5) M. LAFFINEUR and J. L. STEINBERG: 'La mesure de l'intensité des ondes radioélectriques solaires à l'Observatoire de Meudon et à l'Ecole Normale Supérieure de Paris.'

(6) K. O. KIEPENHEUER: 'Quelques remarques sur l'émission du rayonnement solaire de fréquence radioélectrique et ses effets terrestres.'

(7) M. WALDMEIER: 'Distribution spectrale et variation du rayonnement de fréquence radioélectrique entre le centre et le bord du Soleil.'

II. INFRA-RED SPECTROPHOTOMETRY

Summary of Infra-red Observations on Stars and Planets

By G. P. Kuiper
Yerkes and McDonald Observatories

The observations were made with a stellar spectrometer containing a Cashman PbS cell as receiver constructed in 1946 for the 82-inch telescope. The radiation is interrupted 1080 times per second; the small A.C. signal produced by the cell as a result of the fluctuating resistance and 90 V. D.C. voltage is amplified up to 30 million times, rectified, and recorded on a D.C. milliammeter.

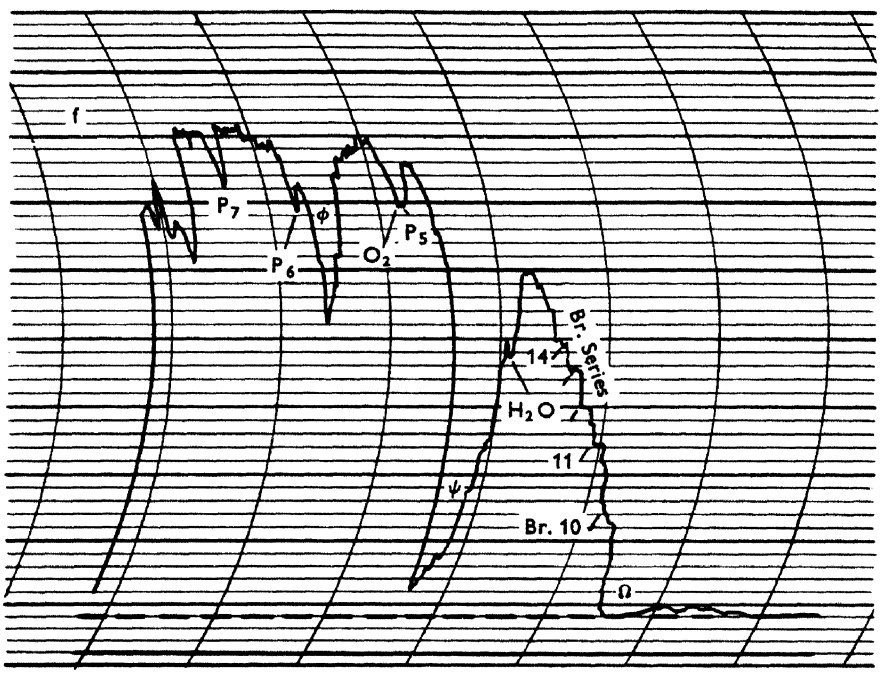


Fig. 2. *Infra-red spectrum of Sirius.* 0·9–2·5 μ.

Fig. 1 shows the equipment attached to the 82-inch telescope. On the table are shown the amplifier and meter, on the floor the crystal-controlled constant frequency unit driving the rotating sector (right), voltage control of same unit (centre), and condenser box (left) which lengthens the period of the recording meter to 6 seconds if desired.

The region covered with the PbS cell is from 0·8 to 2.5 μ. The very heavy water vapour absorption (Langley's *X*, centred at 2·7 μ) blocks out the region from 2·5 to 3 μ to which the cell is still sensitive. Cells cooled with dry ice are sensitive to 3·5 μ, but so far all observations have been made with a cell at observing temperatures. The water vapour in our atmosphere is extremely disturbing; fortunately, some exceedingly dry nights occur at the McDonald Observatory, sometimes equalling the best of Abbot's observing conditions in several desert mountain stations selected for low humidity, including Mt Montezuma, Chili, at 9000 ft. elevation.

The stellar records obtained so far have resolving power $\lambda/\Delta\lambda = 80$. Only for Venus has it been possible to increase the resolving power substantially by the addition of an analysing slit over the cell which reduced the effective receiver width from $\frac{1}{4}$ to 0·08 mm.

(resolving power about 250). It is hoped that with a new grating spectrometer now being designed some of the brightest stars like Betelgeuse may be observed with resolution 500; the records shown here are all with resolution 80 except for Venus.

With the low resolution employed so far the only stars which show stellar absorptions are type-A stars and the banded stars (M, N, R, etc.). Fig. 2 shows Sirius with Brackett 10–14 of Hydrogen as well as P_5, P_6, and P_7 (P_β, P_γ, P_δ). Especially interesting is R Leonis, showing heavy absorptions at 1·1 and 1·2μ as well as in the 1·5μ region. R Leonis was of visual magnitude 10·8 when recorded.

The determination of the energy curves from the material illustrated is awaiting the results of absorption studies of air and water vapour now in progress in the laboratory in collaboration with Dr Herzberg. Both low resolution curves are obtained for direct comparison with stellar observations and curves with resolution up to 2000, obtained with an analysing slit over the cell. The stars are always recorded with the spectrometer in slitless form (slit width 2 mm. or 15″) which ensures freedom from disturbances such as atmospheric dispersion. Seeing fluctuations are minimized by the use of a long period (about 6 seconds) for the recording system.

Fainter stars may be recorded with resolution 9, obtained by a single 25° quartz prism replacing the two heavy flint prisms normally used. This low resolution still records the islands of continuous spectrum between the water absorptions. With this combination comparatively faint sources like reddened B stars of 7^m–8^m, the polar cap of Mars, and the rings of Saturn may be observed.

Planetary Studies

In the spectrum of Mercury no planetary absorptions are indicated, but the 2·2μ maximum is greatly strengthened owing to planetary heat radiation. Venus is shown in Fig. 3 up to 1·8μ. Several new CO_2 bands are shown, each marked by a dot. The other absorptions are due to H_2O except the one O_2 absorption. This record was compared with laboratory spectra of CO_2 having 1400 m. atmosphere path length, obtained jointly with Dr Herzberg. The bands near 1μ are stronger in Venus than corresponds to 1400 m. atmospheres of CO_2, but the three bands near 2μ correspond to only about 50 m. atmospheres of CO_2. This enormous difference is partly due to pressure broadening in the laboratory experiment, as was found by additional runs with lower pressure and partly due to decreased penetration into the Venus atmosphere within strong bands. The true amount of CO_2 must be at least 1 km. atmosphere above the cloud layer on Venus (2 km. atmospheres in the observed path).

The reflection curves of Mars and the Moon show that Mars is bluer in the infra-red than the Moon. Other records have shown it to resemble α Persei, type F 5, for the region from H_α to 2½μ. This peculiar reflection curve, coupled with the red visual colour, is not matched by the red rocks of the Painted Desert as has been assumed in the past; instead it was found to correspond closely to a brownish, fine-grain igneous rock, felsitic rhyolite. Comparisons of this kind and also with lunar formations are continuing.

The Mars polar cap was found to have a sharply diminished reflectivity beyond 1·5μ resembling that produced by fine frost crystals deposited on a piece of dry ice (−78° C.). Snow at ordinary temperatures has a characteristic reflection curve. This reflection curve may be compared with that of the transmission of a water cell. Melting snow corresponds to a water cell equivalent of about 2 cm., normal snow kept at 0° C. to about 1 cm., and frost deposited on dry ice to about 1 mm. The difference must be caused by the difference in crystal size; evidently in very cold snow total reflection takes place after only about ½ mm. penetration, on the average. The Mars polar cap corresponds to about 1 mm. water-cell equivalent; the rings of Saturn, which show the same characteristic reflection spectrum, to roughly ⅔ mm. Both may be assumed to be covered with H_2O frost at very low temperatures. On the other hand, CO_2 snow reflects uniformly (white) up to 2½μ, except for three minor absorptions near 2μ corresponding to the gas absorptions (ω_0, ω_1, ω_2).

The green areas on Mars have approximately the same contrast with the surrounding desert regions at 0·6, 1·0 and 1·6μ, as was ascertained from drift curves obtained with the spectrometer locked at constant wave-length and with an entrance slit adjusted to the size of the largest available green spot (Syrtis Major). The intensity of the green spots was in each case between 0·5 and 0·6 of the surrounding desert region. The conclusion is that these green areas are very different from terrestrial foliage which is dark at 0·6μ, very bright at 1·0μ, and nearly black at 1·6μ. The only terrestrial growth having a similar reflection is that of lichens and certain dry mosses; they fail to show the water-cell type of reflection near 1·5μ. Fig. 4 shows the 1·6μ region of Mars; the two CO_2 bands indicated were calibrated against telluric absorptions. It is found that the Mars atmosphere contains $10-1=9$ times as much CO_2 as the atmosphere above McDonald, distributed over the average path length through the Mars atmosphere, which for a uniformly illuminated disk is four times the amount in a vertical column. Hence the Mars atmosphere contains about $0{\cdot}8\times 2\frac{1}{4}=1{\cdot}8$ times as much CO_2 as the Earth's atmosphere per square centimetre of surface, the pressure at McDonald being 800 mb.

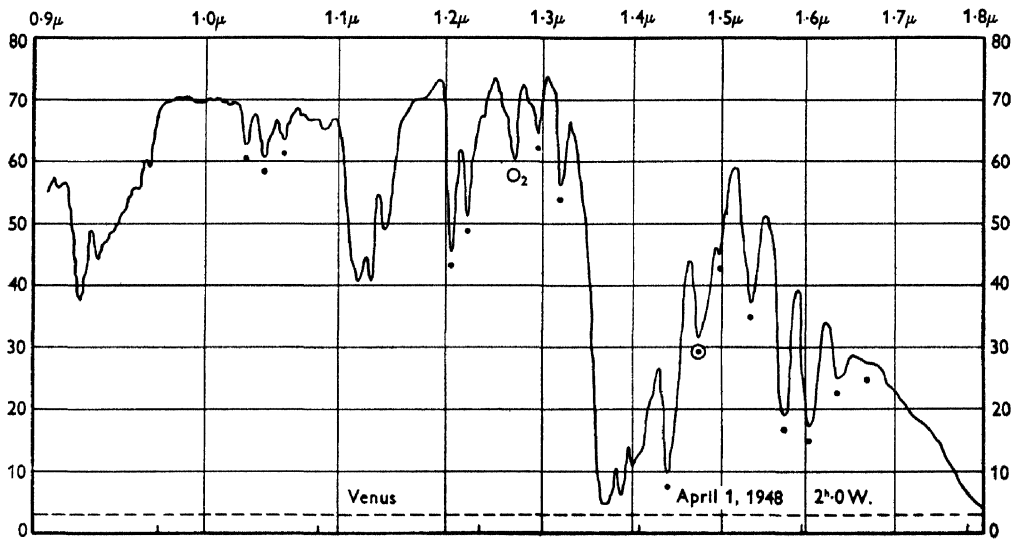


Fig. 3. *Infra-red spectrum of Venus.* • CO_2 bands; ⊙ C^{13} isotopic band of 1·435μ (C^{12}), somewhat blended with telluric H_2O. Unmarked: telluric H_2O.

The correctness of the identification of the 1·6μ bands was recently confirmed when during the Mars opposition in February 1948 the three bands at 2μ were found greatly strengthened over the telluric spectrum.

Sensitive spectroscopic tests near 0·3μ failed to reveal the presence of SO_2 or O_3 on Mars. The upper limit on SO_2 is about 0·03 mm. at atmospheric pressure.

Jupiter and Saturn reflect practically no radiation from 1·6 to 2·5μ, as was confirmed with the low dispersion quartz optics. The quantitative interpretation in terms of CH_4 and NH_3 absorption is in progress, using for comparison low dispersion laboratory curves taken jointly with Dr Herzberg. The maximum path length which may be obtained in the laboratory is over 5 km. obtained by multiple reflections; the maximum pressure 10 atmospheres.

Reference has been made to frost on the rings of Saturn. This conclusion was based on the steep drop in reflectivity near 1·5μ. It is entirely consistent with the unusually high albedo of the Ring. From the fact that the outer ring did not form a satellite, an upper limit to the mean density of the ring's particles may be found; it is near unity. Further, the diameters of the inner five satellites of Saturn were measured or estimated.

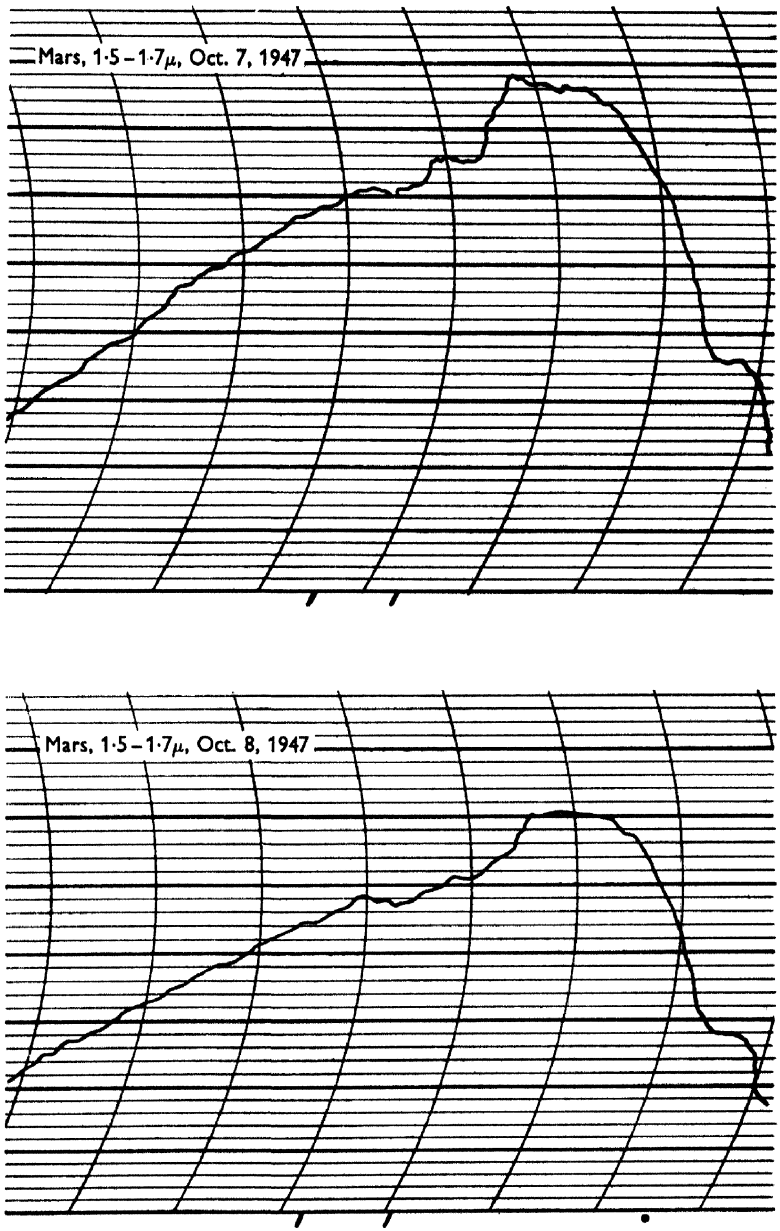


Fig. 4. *Infra-red spectrum of Mars.* CO_2 bands at 1·575 and 1·605 μ; • H_2O at 1·471 μ. Left extreme: 1·8 μ.

It was found that these diameters lead to albedos of about 0·8 and densities near unity, except for Dione, for which the density comes out somewhat greater (its mass value may be in error). Pending the derivation of more accurate masses and magnitudes it may provisionally be concluded that the five inner satellites as well as the Rings of Saturn are composed of ice. The rate of evaporation is found to be so small that this constitutes no objection to the conclusion unless the Ring particles are exceedingly small. The high emissivity of frost in the infra-red and the high albedo in the visual cause the equilibrium temperature to be much below the black-body temperature (about 70° K. instead of 100° K.).

Infra-Red Solar Spectroscopy with a Lead-Sulfide Cell

By Robert R. McMath, Orren C. Mohler and Leo Goldberg

McMath-Hulbert Observatory of the University of Michigan

The McGregor Tower telescope and spectrometer of the McMath-Hulbert Observatory have been employed in conjunction with a Cashman PbS cell to secure a direct-intensity map of the solar spectrum in the region of 0·8μ to 2·5μ, with a resolution of about 50,000. The spectrometer is of the Pfund type, consisting of a 15,000-line plane reflection grating together with two parabolic and two plane mirrors, the equivalent focal length being approximately 23½ feet. The solar image was produced by a 10½-inch Cassegrain reflector, which has recently been replaced by a 12-inch by 50-foot off-axis parabola. Spectrometer accessories include a low-dispersion monochromator, designed to eliminate interference from overlapping grating orders, and a light chopper that interrupts the sunlight 1080 times a second. An amplifier designed and constructed by Mr Wallace Wilson of the Northwestern Technological Institute is employed together with a Leeds and Northrup Speedomax pen-and-ink recorder.

The solar map is recorded on very nearly a direct-intensity scale with a dispersion on the recording paper of about 5 mm./A. The solar spectrum in the regions 1·3–1·5μ and 1·75–1·95μ is heavily obscured, due chiefly to absorption by H_2O in the earth's atmosphere. The intervening regions, however, are relatively clear and contain a wealth of solar atomic lines, as well as numerous isolated telluric molecular lines and bands.

A systematic programme of identification and measurement, both of solar and telluric lines, is now under way at the McMath-Hulbert Observatory. Progress with the identifications has been slow, largely because of the almost complete absence of high-resolution laboratory studies in the lead-sulfide region of the infra-red spectrum. The wave-length scale has been established by the method of overlapping orders, to an accuracy of about 0·1 A. The measurement of wave-length is now complete in the 'window' between 1·52 and 1·75μ and the measurement of lines in the region 2·1–2·4μ is in progress. Approximately three hundred new solar atomic lines have been found in the first window by comparison of tracings made with high and low sun. Nearly one hundred of these lines have been identified on the basis of wave-lengths computed from differences between known atomic energy levels. The elements for which lines have been found include H, C, Na, Mg, Al, Si, Fe, Mn and Ni. No ionized atoms have as yet been identified, although a preliminary search has been made on the basis of published term lists. The vast majority of the identified lines have excitation potentials in excess of 5 V.; analysis of their intensities both at the centre of the solar disk and at the extreme limb should have an important bearing on the solar-atmospheric model.

Among the most interesting features of the infra-red spectrum are the band systems of molecules originating in the Earth's atmosphere. Among these are the four well-known bands of CO_2 in the 1·6μ region, which have been resolved for the first time, and three strong bands of CO_2 at 2·1μ. The solar map reveals also a number of new molecular band systems, the most interesting of which are four bands at 1·66, 2·30, 2·32 and 2·37μ, which have been identified as the $2\nu_3$, $\nu_1+\nu_4$, $\nu_3+\nu_4$ and $\nu_2+\nu_3$ transitions of CH_4 in the Earth's atmosphere. A comparison of the $2\nu_3$ telluric line intensities with those produced by a

measured quantity of methane in the laboratory indicates an abundance corresponding to 1·7 atmo-cm. An analysis of the CH_4 spectrum is now in progress and will be published in the *Astrophysical Journal*. Eight telluric lines in the 2μ region have been tentatively identified as arising from NH_3. Confirmation of the NH_3 identifications must await observations of the fundamental bands in the 10μ region.

In process of preparation is an atlas of the infra-red solar spectrum, which will consist of reproductions of the direct-intensity tracings throughout the region from 8000 to 25,000 A. The new atlas will therefore partially overlap with, and extend the valuable map by Minnaert, Houtgast and Mulders in the photographic region.

Sur la Présence de CH_4, N_2O et NH_3 dans l'Amosphère Terrestre

Par Marcel Migeotte

Institut d'Astrophysique, Cointe-Sclessin (Belgique)

Durant ces derniers mois, nous avons eu la possibilité d'enregistrer le spectre infra-rouge du soleil, à grande dispersion, entre $2{\cdot}8\mu$ et $5{\cdot}1\mu$ ainsi qu'entre 7μ et $11{\cdot}7\mu$. Ces observations ont été effectuées à l'Université d'Ohio State (Columbus, Ohio, E.U.), en utilisant un spectrographe prisme-réseau, construit par le Dr R. Noble, sous la direction du Prof. H. H. Nielsen.

Les enregistrements obtenus ont conduit, en janvier 1948, à la découverte de méthane dans l'atmosphère terrestre.* Ce gaz a été identifié en repérant, dans le spectre solaire, treize raies de la bande fondamentale de CH_4, située à $3{\cdot}4\mu$. Dans la suite, des raies de la bande fondamentale de CH_4 située à $7{\cdot}7\mu$ ont aussi été identifiées dans le spectre solaire.† De plus, en mai 1948, R. McMath, O. Mohler et L. Goldberg‡ ont signalé que quatre bandes de CH_4 apparaissaient dans le spectre solaire entre 1μ et 2μ. Notons que les raies observées à $3{\cdot}4\mu$ et $7{\cdot}7\mu$ sont perturbées par des raies de vapeur d'eau. Elles ne peuvent être utilisées pour une estimation quantitative du CH_4 atmosphérique; mais les raies observées à $1{\cdot}6\mu$ conviennent particulièrement bien dans ce but.

Les nouvelles observations du spectre solaire ont aussi permis de confirmer la présence du N_2O atmosphérique, proposée pour la première fois par A. Adel en 1939.§ La structure fine des bandes de N_2O à $3{\cdot}9\mu$, $4{\cdot}5\mu$ et $8{\cdot}6\mu$ apparaît nettement sur les spectrogrammes obtenus à l'Université d'Ohio State.

Concernant NH_3, signalons que la présence de ce gaz dans l'atmosphère terrestre a été récemment proposée par O. Mohler, L. Goldberg et R. McMath.‖ D'après ces auteurs, les nombres d'ondes de huit raies intenses du spectre de NH_3, situées vers 2μ concordent à $\pm 0{\cdot}05$ cm.$^{-1}$ près avec des raies observées dans le spectre solaire. Notons que ces raies sont dans une région où seules des bandes de combinaison de NH_3 ont été signalées. Comparativement à celles-ci, les bandes fondamentales de NH_3 devraient donc être intenses dans le spectre solaire. La bande fondamentale de NH_3 à $10{\cdot}5\mu$ est particulièrement bien située pour vérifier la présence du NH_3 atmosphérique, car, dans cette région, il y a relativement peu de raies dans le spectre solaire.

Nous avons comparé de nouveaux spectres de NH_3 pris, en laboratoire, dans la région $10{\cdot}5\mu$, par R. Chapman, à l'Université d'Ohio State, d'une part avec les spectres du soleil obtenus à Flagstaff (Arizona, E.U.) par A. Adel en 1940,¶ d'autre part, avec de nouveaux spectres du soleil enregistrés à Columbus, le 3 et 8 juillet 1948. Nous avons constaté que les raies de NH_3 n'apparaissent pas dans les spectres solaires considérés. De nouvelles observations sont nécessaires pour déterminer s'il existe une concentration locale de NH_3 près de Pontiac (Michigan, E.U.), où les enregistrements de O. Mohler, L. Goldberg et R. McMath ont été obtenus.

* *Phys. Rev.* **73**, 519, 1948; *Ap. J.* **107**, 400, 1948.
† *Phys. Rev.* **74**, 112, 1948.
‡ *Phys. Rev.* **73**, 1203, 1948.
§ *Ap. J.* **90**, 627, 1939; **93**, 509. 1941.
‖ *Phys. Rev.* **74**, 352, 1948.
¶ *Ap. J.* **94**, 451, 1941.

III. THE SPECTRAL SEQUENCE AND ITS ANOMALIES

August 17, 1948. 10.30 a.m.

CHAIRMAN, Prof. P. SWINGS

1. OBJECTIVE PRISM SPECTRA

By J. J. NASSAU

Warner and Swasey Observatory, Case Institute of Technology, Cleveland, Ohio

This report deals mainly with the study of spectra secured with a 4° objective prism attached to the 24–36-inch Schmidt-type telescope of the Warner and Swasey Observatory of the Case Institute of Technology. The dispersion at H_γ is 283 A./mm. Spectra obtained with a 2° objective prism will be dealt with briefly. We will consider first spectra secured by means of long exposures intended to be used for statistical studies; second, spectra of relatively short exposures for detailed study of individual stars and, third, infra-red spectra for the classification of low-temperature stars.

Part I. Here we are concerned with spectra of stars of limiting photographic magnitude of 12·5 secured with an exposure of 30 minutes on plates of intermediate speeds. From such spectra stars are classified in four sub-classes in each spectral class. In the case of the B stars five classes are assigned. Between F0 to K5 we are able to distinguish four luminosity classes for stars one magnitude brighter than the limiting magnitude of the plate; for the other spectral classes three. The probable error of one estimate of spectral type is ±0·12 and for one estimate of luminosity class ±0·30. The interval between I, III, IV and V (Morgan, Keenan and Kellman notation) is taken as one unit with the exception of the interval between III and IV, which is taken as one half unit. Although it is possible to classify I*a* stars, they are not included in the calculation of the probable errors.

At present it appears that it is possible to increase the accuracy in the classification of the B stars by adding a step between B2 and B5.

Spectra secured with the 2° prism are employed primarily in order to avoid overlaps in crowded regions. They reach stars about 0·4 of a magnitude fainter than with the 4° prism and compare in accuracy with the faint stars of this prism.

Part II. Spectra from which detailed study of individual stars is possible are made with short exposures on intermediate or slow emulsion plates and are from 0·3 to 0·4 mm. wide. From such plates the sky fog is materially decreased, and seeing and differential refraction effects are diminished. The resulting spectra show clearly all the features upon which the criteria of temperature and luminosity classifications are based. As, for example, in the case of the F-type stars between the spectral region of $\lambda 3706$ and H_γ 30 lines and line-blends are recognized and used in the classification. Comparison with standards are made by means of visually drawn profiles which show the depth and width of such lines for all stars between F0 to K5 and for all four or five luminosity classes. Assignment to a class becomes certain provided conflicting criteria do not exist and other peculiarities are not present.

The classification of the normal main sequence A stars is relatively simple as the growth of the K line with respect to hydrogen is a safe criterion, provided the G-band and other metallic lines are not present. Our practice has been to give two classes to such stars, although according to Greenstein the F class seems more appropriate. The recognition of peculiar A stars such as silicon and strontium stars is also possible. For luminosity classification, the narrowing of the H lines and the strength of certain lines and blends are employed.

The accurate classification of B stars both in the temperature and luminosity classes seems probable.

A survey with high-quality spectra of a 12°-belt along the galactic equator from longitude 333° to 197° is now in progress as a co-operative project between the Yerkes and Warner and Swasey Observatories. It aims to reach stars to the 10th photographic magnitude with high-quality spectra for the discovery of B stars and other stars of high luminosity.

Part III. The spectral region between λ6800 and λ8800 with dispersion at the A band of about 1700 A./mm. with the four-degree prism and 3400 A./mm. with the two-degree prism proved successful in classifying M-type, carbon, and S-type stars. The classification of the M stars is based solely on the TiO bands. The probable error of a single estimate is equal to ±0·3 decimal division. M stars as faint as 14·4 infra-red magnitude are classified. No means for establishing luminosity criteria have been found. Carbon stars are identified from the band of CN, while a new band, λ7950, which according to Keenan is due to LaO, is utilized in the identification of S stars.

2. CLASSIFICATION SPECTRALE DES ETOILES DES PREMIERS TYPES SPECTRAUX D'APRES LA GRANDEUR ET LA POSITION DE LA DISCONTINUITE DE BALMER

Par DANIEL BARBIER et DANIEL CHALONGE

Institut d'Astrophysique et Observatoire de Paris

RÉSUMÉ

I. Rappel de la définition des grandeurs utilisées D et λ_1.

II. La classification spectrale (type spectral et magnitude absolue) des étoiles normales par leur structure et leur composition chimique dépend de deux paramètres T_e et g. Il en est de même de D et λ_1. Il est donc possible de faire une classification spectrale à partir de ces deux derniers paramètres. L'intérêt d'une telle classification provient de ce qu'elle ne fait intervenir qu'un seul corps, l'hydrogène, constituant principal des atmosphères stellaires.

III. Dans l'état actuel de la théorie on doit rechercher par une méthode empirique les relations existant entre le type spectral, la magnitude absolue et D et λ_1. Le nombre des étoiles observées est encore petit et les résultats obtenus doivent être considérés comme préliminaires.

IV. La corrélation entre le type spectral ainsi déterminé et le type spectral de Harvard est bonne. Les désaccords ne sont pas plus grands qu'entre deux classifications spectrales classiques.

V. La corrélation entre les magnitudes absolues ainsi déterminées et les magnitudes absolues provenant des parallaxes trigonométriques, des parallaxes de groupe etc. est satisfaisante. On peut même constater qu'à l'intérieur d'un type spectral déterminé (A_0) les nouvelles parallaxes absolues sont plus précises que les parallaxes spectroscopiques classiques.

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DANIEL BARBIER et DANIEL CHALONGE. *Annales d'Astrophysique*, **10** (1947), p. 195.

Discussion. Dr B. Lindblad pointed out the Stockholm observations of a strong Balmer discontinuity in super-giants.

3. ANOMALIES IN THE SPECTROPHOTOMETRIC CRITERIA OF STELLAR LUMINOSITY IN THE SPECTRAL SEQUENCE OF THE HYADES

By JÖRAN M. RAMBERG

Stockholm's Observatory, Saltsjöbaden, Sweden

At the Stockholm Observatory at Saltsjöbaden we have long been occupied with applications of the *spectrophotometric parallax method* originally introduced by Prof. B. Lindblad and developed by him and his collaborators at the Uppsala and Stockholm Observatories. At the Stockholm Observatory the work is mainly based on the 40 cm. Zeiss astrograph combined with an objective prism of the same aperture giving a dispersion on the plate of 1·8 mm. between Hγ and Hϵ. The plates are taken without lateral widening of the spectral images and are registered with a broad diaphragm by means of a Koch-Goos self-recording microphotometer.

The spectrophotometric parallax method consists essentially in the determination of the monochromatic intensities of the stars for a number of selected wave-lengths. From the reduced measurements of the tracings of the objective prism spectra a number of spectral quantities are obtained, defined as follows:

For the early-type stars: *the intensities of* Hγ *and* Hδ,

$$\mathrm{H}\gamma = m\mathrm{H}\gamma - \tfrac{1}{2}\,(m_{4400} + m_{4260}),$$
$$\mathrm{H}\delta = m\mathrm{H}\delta - \tfrac{1}{2}\,(m_{4140} + m_{4050}).$$

For the late-type stars: *the break of intensity at the G-band, g, the cyanogen equivalent, c, and the intensity of the calcium line* λ4227,

$$g = m_{4260} - m_{4360},$$
$$c = m_{4180} - m_{4260},$$
$$\lambda 4227 = m_{4227} - \tfrac{1}{2}\,(m_{4260} + m_{4200}).$$

In addition to the spectrophotometric measurements, the spectra are classified on the basis of those characteristics which are most readily identified in our spectra.

For the present I am occupied in a spectrophotometric survey of selected regions in and around the central band of the Milky Way in Lacerta, Cepheus, and Auriga. Some time ago I made a survey of the same kind of the central part of the region of the Hyades.* The test of the spectrophotometric criteria of stellar luminosity on the physical members of the Hyades may be of interest here.

The investigation comprised in all forty-eight physical members of the cluster. The Hertzsprung-Russell diagram of the investigated cluster members is shown in Fig. 1. The absolute magnitudes of the cluster members were computed, adopting Smart's† value of the parallax of the cluster

$$\pi = 0''.028.$$

The dotted line in the figure defines the ridge-line of the normal main series as determined from the Mount Wilson catalogue of spectroscopic parallaxes. The line is drawn with attention paid to the differences in the Stockholm system of spectral classification from that of the Mount Wilson Observatory. It is seen from the figure that, apart from the latest type dwarfs, the members of the Hyades appear to be systematically fainter than the random stars of the main series. The systematic departure of the cluster members from random stars may of course partly be explained by the fact that the average absolute magnitudes obtained from the Mount Wilson catalogue refer to scattered stars brighter than a certain magnitude, but the corrections to the element of volume for the Mount Wilson system of absolute magnitudes are likely to be small. The departure considered may also be partly ascribed to uncertainty in the parallax of the Hyades cluster, but

* Ramberg, J. M., 'A Spectrophotometric Study of the Regions of the Hyades and Praesepe', *Stockholm Annaler*, Band **13**, no. 9, 1941.

† Smart, W. M., 'The Moving Cluster in Taurus', *M.N.* **99**, 168, 1939.

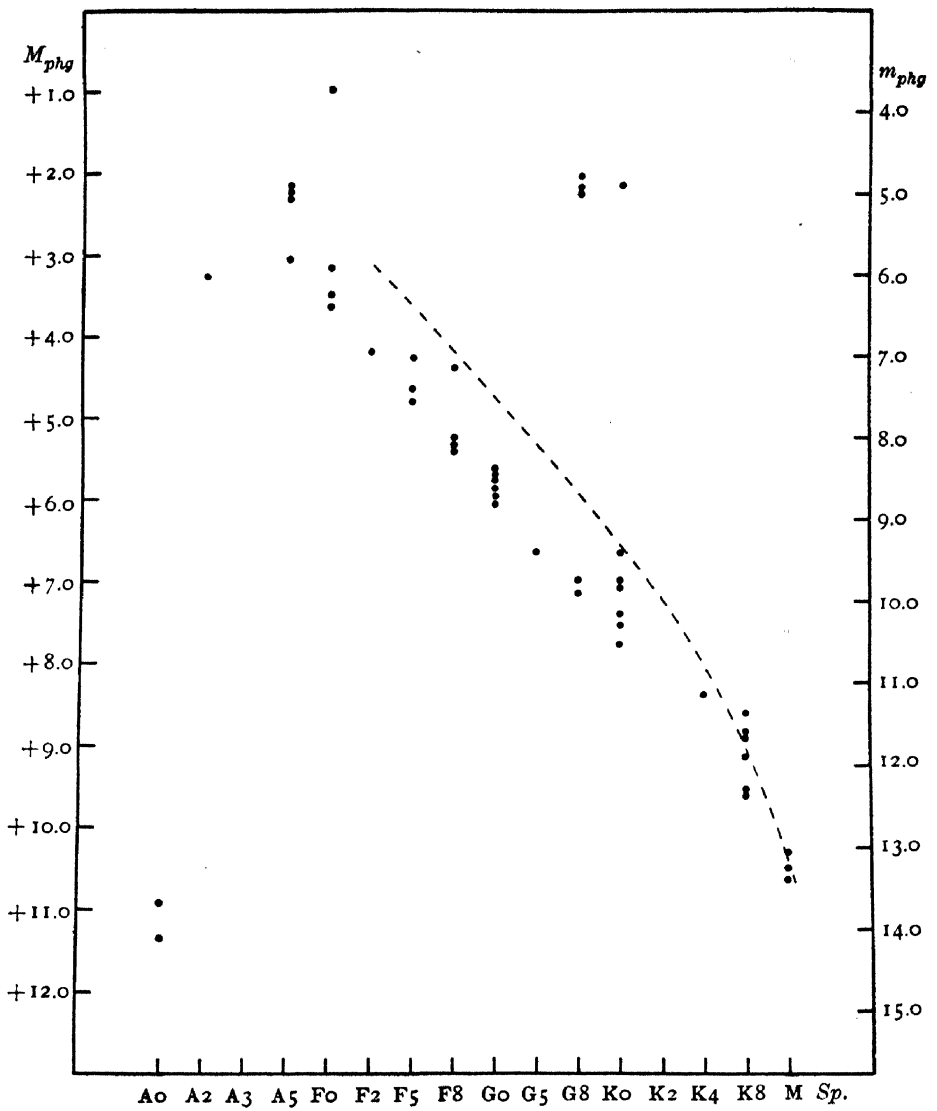


Fig. 1. Hertzsprung-Russell diagram of the members of the Hyades included in the present investigation. The dotted line defines the ridge-line of the normal main series.

even this seems able to explain only a small amount of the systematic difference observed. Furthermore, the fact that the latest type dwarfs among the cluster members appear to be quite normal argues against the assumption that Smart's value of the parallax is too great.

In Fig. 2 the hydrogen intensities of the A–F-type Hyades stars are drawn against the photographic absolute magnitudes. In the same figure a luminosity diagram for the spectral classes B–A3 and F2–F8 and valid for scattered stars is copied. The diagram was deduced by the author on the basis of measurements published by Lindblad, Schalén, and Öhman.

In Fig. 3 the measurements of the cyanogen absorption in the dG0–dM stars belonging to the cluster have been plotted. In the same figure the curve showing the connection between the cyanogen absorption and the absolute photographic magnitude in scattered stars is copied. In Fig. 2 as well as in Fig. 3 the deviation of the cluster members from the scattered stars is striking. The break of intensity at the G band and the intensity of the calcium line $\lambda 4227$ show the same deviations. Accordingly, all spectrophotometric results

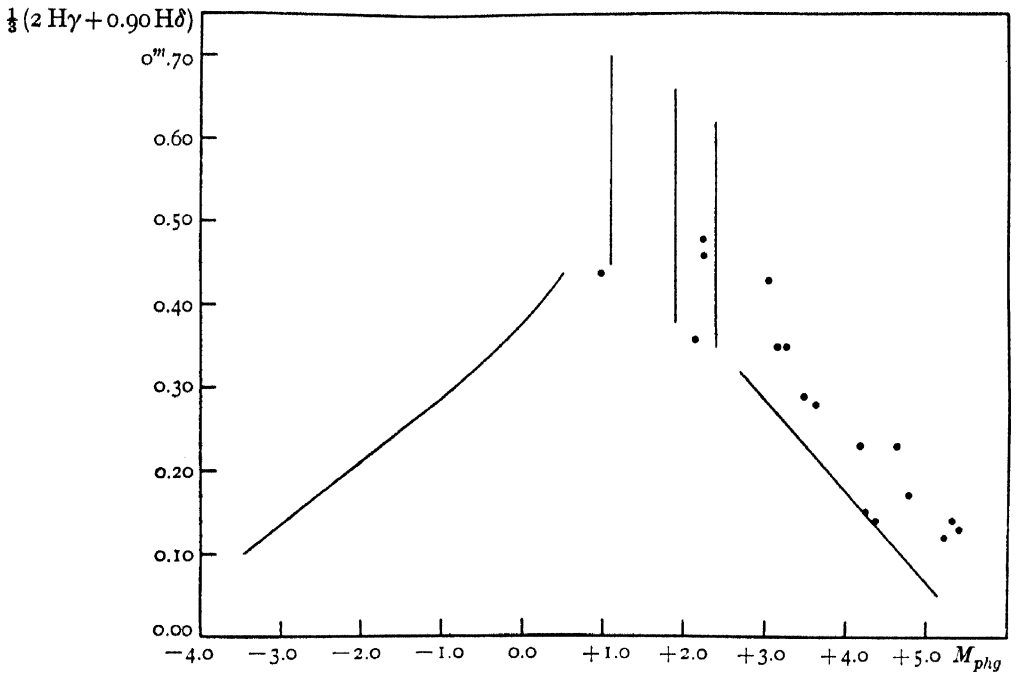


Fig. 2. The relation between the hydrogen line intensity 1/3 (2 Hγ + 0·90 Hδ) and the photographic absolute magnitude for the A–F-type members of the Hyades. The diagram valid for random stars is copied in the figure.

argue in favour of the reality of the phenomenon appearing in Fig. 1. The members of the Hyades belonging to the main series are systematically fainter than random stars of corresponding spectral types. The departure in magnitude is maximal early in the spectral sequence and seems to decrease with advancing spectral type and to disappear in late K and M dwarf stars.

It is possible that the shift observed in the absolute magnitudes of the Hyades in relation to random stars corresponds to some spectral peculiarities in one way or another. No such peculiarities could, however, be traced in the astrographic spectra considered. Judging from the astrographic spectra the members of the Hyades must be characterized as typical dwarf stars without any peculiarities with regard to the distribution of intensity in the spectrum. This fact seems to force upon us the opinion that within each spectral class of the main series we have a rather considerable cosmic dispersion.

The fact that the very late-type dwarfs among the Hyades members appear to be 'normal' in respect of absolute magnitude may be explained by assuming that the cosmic dispersion in luminosity within each spectral class of late K and M dwarfs is on the whole small. The view is supported also by the Hertzsprung-Russell diagram of the nearest stars. Furthermore, there is to be noted in this connection the result found by Kuiper*

* Kuiper, G. P., 'On the Hydrogen Content of Clusters', *Ap. J.* **86**, 176, 1937.

that the main sequences of different clusters are crowded closely together in the lower part of the main series.

The results obtained argue in favour of the opinion that the main series is built up of different *star families* among which the members of the Hyades cluster form one. Early in the main series the families deviate considerably in absolute magnitude but converge with advancing spectral type.

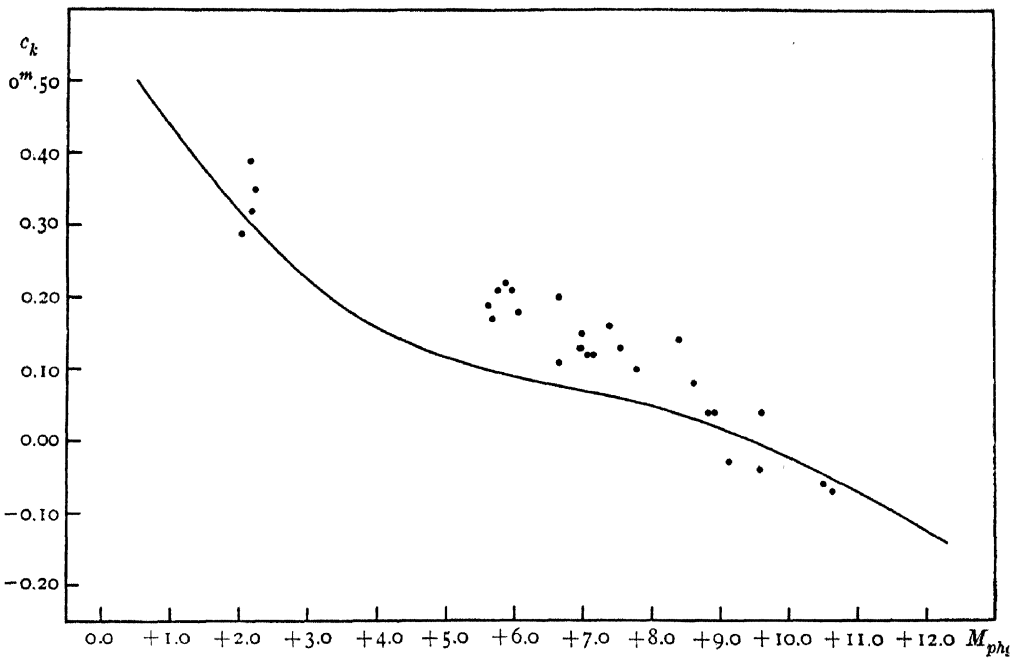


Fig. 3. The relation between the reduced cyanogen equivalent c_k and the photographic absolute magnitude for the G–M-type members of the Hyades. The curve valid for random stars is copied in the figure.

It is obvious that the spectrophotometric criteria of stellar luminosity in their present state do not enable us to distinguish between the different sub-classes of dwarfs in a direction perpendicular to the main series. It seems highly desirable that wide dispersion spectra of bright cluster members and of stars with well-determined trigonometric parallaxes are photometrically investigated with respect to luminosity criteria. Work along this line is going on at the Stockholm Observatory.

Discussion

R. E. WILSON. Recent studies of the motions of the Hyades at Mt Wilson show that Smart's parallaxes of these stars are definitely too large. It is also known that the Mt Wilson absolute magnitudes for the A and F stars are too bright by at least 0·5 magnitude. Comparisons between these two sets of data necessarily lead to erroneous conclusions regarding the luminosities of the Hyades stars. If the absolute magnitudes derived recently from new cluster parallaxes in the Hyades are compared with those derived by Hopmann for the stars with best-determined trigonometric parallaxes the maximum mean separation of the two Hertzsprung-Russell main sequences is of the order of 0·15 magnitude.

The difference in the dispersion in M between the early- and late-type stars has recently been explained through the work of Dr O. Eggen at the Washburn Observatory. His

observations of photoelectric magnitudes of the brighter stars in the Hyades and several other open clusters (observations which show remarkably small dispersion about a mean H–R sequence) establish a split in the sequence for the early-type stars. The brighter branch contains the metallic line stars and others which show in their spectra differences from the characteristics of the main sequence stars. When this split is taken into consideration, the dispersion in M of the early-type stars on the main sequence is essentially the same as that of the late types.

4. PECULIARITIES FREQUENTLY ENCOUNTERED IN SPECTRA OF SHORT DISPERSION

By A. N. Vyssotsky

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The McCormick objective prism plates, which cover the sky from the north pole to declination $-15°$, show classifiable spectra down to twelfth photographic magnitude. The dispersion at Hγ is about 300 A./mm. Because of the steep colour curve of the instrument the portion of the spectrum between λ4100 and λ4000 remains unobserved.

While relatively few features are available for temperature classification with our instrumental arrangement, additional details are frequently visible. The significance of only a few of these is understood. The following list contains the peculiarities most frequently encountered.

(1) Simultaneous strengthening of the G band and Hγ in certain G stars. We have correlated this feature statistically with larger than average proper motions.

(2) A line or group of lines near λ4300 in A stars. So far we do not know the significance of this 'pseudo-G band'.

(3) Very narrow H and Ca II lines in certain F stars, which thus resemble RR Lyrae stars but are not known to be variable.

(4) A strong narrow line near λ4175 in certain A and F stars. If this is the Ti II–Y II line which appears in the super-giants of these classes, it is difficult to explain why these spectra are occasionally found in high galactic latitude.

(5) A depression in the continuous spectrum of K stars between λ4400 and λ4500 which is sometimes very pronounced and gives the impression of a band.

(6) Strong CN absorption at λ4215 is conspicuous in K super-giants and in certain K giants on a given plate. What differentiates these K giants from the others in which cyanogen is not conspicuous is not known. In this connection sharp CN absorption at λ4215 distinguishes very early-type R stars which otherwise resemble G5 stars.

(7) Finally, we do not know the physical cause of the 'Lindblad depression' between λ4227 and λ4310 in all M dwarfs.

Discussion

Dr B. Lindblad. When the absorption due to the CN band is measured with a microphotometer, it is found to be a good criterion for an absolute magnitude classification of G and K stars, with the exception of the stars of high velocity.

Dr L. Gratton. On high-dispersion spectra of K giants the close doublets which form the rotational components of the CN band have a very different aspect in high-velocity stars as compared with ordinary stars. For instance, in α Bootis the two components are almost blended, whereas in ordinary giants they are very well separated; the same is true also for γ Leonis and η Cephei. On the other hand, there are also some ordinary stars, like β Aquilae, which show the same characteristics.

Dr P. Swings. Is the strengthening of the G band and Hγ in certain G stars related to the high-velocity CH stars? Of course, if hydrogen is enhanced, we may expect CH to have a chance also to be enhanced.

Is the 'pseudo-G band' near λ4300 present in early or late A's? If there are stars with abnormal Eu II, Dy II or such things, we may possibly expect others with abnormal Eu III, or Dy III. Observations of these spectra with higher resolution are much needed.

Is the depression near λ4450 in K stars symmetrical? How is the G band in these K super-giants?

In the absence of any other interpretation of the 'Lindblad depression' in M dwarfs, I think that Lindblad's own original interpretation is still worth considering (quasi-molecule of Ca_2).

Dr VYSSOTSKY. The depression near λ4450 in K stars is practically symmetrical. In K super-giants the G band is faint but quite normal. The 'pseudo-G band' is present in the early A stars.

5. THE PLACE OF THE WOLF-RAYET STARS IN THE STELLAR SEQUENCE

By C. S. BEALS

Dominion Astrophysical Observatory, Victoria, B.C., Canada

The spectrum of a typical Wolf-Rayet star consists of a continuous spectrum on which are superimposed numerous broad emission bands due to atoms of high ionization potential. The breadth of the bands may be anywhere from 15 to 100 A. and their combined width and intensity is often such as to obscure the underlying continuous spectrum.

An analysis of the atoms present in Wolf-Rayet spectra indicates that the stars are divided into two parallel sequences which are designated as the Carbon Sequence and the Nitrogen Sequence respectively. The Carbon Sequence exhibits bands due to He I, He II, C II, C III, C IV, O II, O III, O IV, O V and O VI with nitrogen weak or absent. The Nitrogen Sequence has bands due to He I, He II, N III, N IV and N V with carbon and oxygen weak or absent.

A good criterion of excitation is provided by the He I/He II ratio making use of the lines λ5875 of He I and λ5411 of He II. Making use of this, as well as a number of subsidiary ratios, the stars were divided into a number of classes as outlined in the report of Commission 29 of the I.A.U. in 1938. The distribution of the classes is as follows, where WC refers to the Carbon Sequence and WN to the Nitrogen Sequence.

WN	WC
5	—
6	6
7	7
8	8

The two sequences are roughly parallel as regards excitation.

The two sequences, as might be expected, are also parallel in temperature. Values of photoelectric temperatures derived by Zanstra's method indicate values ranging from 60,000 to 110,000°. These values refer, of course, to the atoms of highest ionization potential and there is undoubtedly some stratification in the atmospheres.

Diameters computed on the basis of the above temperatures and the observed apparent magnitudes are of the order of 1·0 to 4·0 $\odot$. Since these computations did not take into account the effect of general absorption by interstellar material, they are probably too low and may require to be increased by a factor of two or more.

An astrophysical problem of great interest is whether the Wolf-Rayet stars represent an extension to earlier spectral types of the absorption O's or whether they constitute a separate sequence.

It is doubtful whether the observations at present available are sufficient to decide this question. It may be noted, however, that in a number of O-type stars of earliest spectral type, lines due to He II, N III and C III appear in emission and it is lines of C III and N III which appear strongly in the Wolf-Rayet stars of lowest excitation. It may further be remarked that there is a complete lack of absorption line stars of type earlier than O5. It is perhaps possible that the nuclei of certain planetary nebulae which do not show emission bands may correspond in excitation to this part of the stellar sequence, but unfortunately, with the exception of certain objects of relatively low excitation, the presence or absence of an absorption spectrum associated with these stars has not been determined.

It is possible that a clear understanding of the physical relations between the Wolf-Rayet stars and the rest of the sequence will only come about as a result of theoretical studies of the origin of Wolf-Rayet emission.

The theory now most commonly accepted is that the emission is a consequence of the continuous ejection of atoms from the stellar surface, although some astronomers are not convinced that this is a satisfactory explanation.

Even if this general mechanism be accepted, the cause of the ejection of atoms is still unknown. Presumably it arises as a consequence of some combination of mass, diameter, surface temperature and rate of energy generation in the star. Little, if any, theoretical work has been done on this problem and our knowledge of the fundamental physical processes responsible for the unique characteristics of these stars is very inadequate.

For the more numerous stars of the main sequence, models of inner structure and atmosphere have been proposed which account satisfactorily for the principal observed spectral features. This is not the case for the Wolf-Rayet stars, and until it is possible by theoretical and observational studies to determine the particular physical characteristics of a stellar model which is responsible for the unique features of Wolf-Rayet spectra, the relationship of these objects to the rest of the stellar sequence is likely to remain obscure.

In the same connection it is also highly desirable to examine in greater detail the nuclei of planetary nebulae of high excitation. Such observations are rendered difficult by the faintness of the stars and by the superimposed nebular line spectrum. It is to be hoped that observations of sufficient dispersion may eventually be possible with the aid of powerful telescopes, and when such observations are available they should help to clarify the general problem of the classification of the hotter stars.

6. ANOMALIES IN THE EARLIEST SPECTRAL TYPES

By P. Swings

Institut d'Astrophysique, Liége (Belgique), and Yerkes Observatory, Williams Bay, Wis. (U.S.A.)

The spectral classification in types and luminosities is based on the absolute or relative intensities of the absorption or emission lines of one or several atoms or molecules. The absorption or emission intensities, or more generally the profiles, result from the combined effects of absorption and emission in the stellar atmosphere. Certain geometrical, physical and dynamical factors may affect the intensities of emission or absorption of certain lines, rendering them anomalous in the sense that they differ from those of most stars having otherwise the same general characteristics. Since these factors may thus upset the spectral classification or even render it precarious or erroneous, it is important to gain a general understanding of them. Such a study will help in realizing the full meaning of normal intensities, hence of the normal classification. Actually one may wonder whether any star may be regarded as entirely free of peculiarities, or at least of a predisposition to develop them from time to time.

The factors introducing spectral anomalies are best studied in the case of conspicuously peculiar stars. In such cases, the mechanisms producing ionization and excitation must be examined individually. My purpose is to mention some of the factors affecting the spectra of early-type stars. All the objects considered in this report possess extended shells. There is a wide variety of such stellar shells, corresponding to great ranges in conditions of temperature and density.

The Wolf-Rayet stars. Beals's outstanding contributions to these stars gave rise to the classification in WC and WN stars, officially adopted by the I.A.U. at its 1938 meeting. Recent investigations make it desirable to complete this classification. It has been shown recently that C IV is present in early WN stars, reaching its maximum in WN 6, but being still present in WN 7. On the other hand, no nitrogen line has been found so far

in typical WC stars which are not nuclei of planetary nebulae. Special difficulties arise in the classification of these nuclei of WR type for the following reasons:

(*a*) many reveal lines of C, N and O simultaneously, with similar intensities (Ex.: nuclei of NGC 6543, IC 4997, IC 418);

(*b*) the lines are often relatively sharp;

(*c*) it is often difficult to separate the nuclear and nebular contributions in the H, He I, He II and other lines.

For these and other reasons, the classification of the WR stars should profitably be re-examined. Suggestions on this matter are made in the complete paper.

Great care has to be exercised in the interpretation of the Zanstra temperatures obtained for the WR stars, because of the stratification effects and of the photo-ionization by emission lines.

The Of stars. The spectra of these stars are superpositions of typical spectra of absorption O stars and of shell lines of high excitation, principally N III and He II; sometimes also of H, He I, N IV, N V and Si IV. All varieties are observed between pure absorption O stars and pure WR stars. There is also a wide variety in the relative intensities of the N III and C III lines, going from Of shells with strong N III and no C III, to Of shells with strong C III and weak N III.

A very striking selection is found among the emission and absorption shell lines observed in Of stars. The observed selection has no connection either with the metastability of certain spectral terms or with the excitation potentials. This selection decreases when the emission and absorption in the shell increase. The selection has actually disappeared in WR atmospheres.

Anomalous intensities. Anomalies are found for practically every atom. Their interpretation reveals a variety of physical processes which are able to affect considerably the relative intensities or, more generally, the profiles of certain lines within a specific atom. It is useful to examine each atom individually. A few general results are:

(*a*) Monochromatic fluorescence due to wave-length coincidences enhances certain lines in O III, N III, He II and O I (Bowen's fluorescence mechanism).

(*b*) Fluorescence excited by the underlying continuous radiation (sometimes with absorption or emission lines) modifies the intensities in He I, N III, N IV, C III, Si III and other atoms. (Example: the singlet/triplet intensity ratio of He I.)

(*c*) The mechanisms (*a*) and (*b*) depend greatly on dynamical factors, such as ejection, rotation and turbulence, since the wave-length coincidences are affected by the radial velocity displacements within the atmosphere. For example, axial rotation should be considered not only as a dynamical agent in the formation of a shell, but also as a mechanism influencing the fluorescence excitation and the expansion which might possibly result from the corresponding radiation pressure. The absence of Bowen's fluorescence mechanism on O III in WR stars is probably a result of velocity effects.

(*d*) Elements such as Ca II and Si II reveal the abnormal populations of certain levels due to absorption of radiations (such as L_α) beyond the ionization limits;

(*e*) Elements such as He I, Fe II, Fe III, Ni II, Mg II, etc., reveal striking effects due to the geometrical dilution of the exciting radiation. It may happen that the only strong sharp shell line in the spectrum is $\lambda 3889$ He I.

The presence of absorption or emission lines (or of continua at the series limits) in the underlying radiation affects considerably the excitation and ionization (and dissociation in late-type stars). It gives rise to anomalous distributions among the various stages of ionization. Coupled with stratification effects (somewhat along the lines of Strömgren's zones), these mechanisms explain extremely abnormal relative intensities.

Since the fluorescence excitation in the shell depends on the velocities of the atoms, different shell lines of a specified atom (also lines belonging to different atoms) may give different profiles and radial velocities, both of the absorption and of the emission components. Actually the physical interpretation of the profiles and of the measured line displacements in shell stars is a matter of extreme complexity. For example, the radial velocities of the He I triplets may differ from those of the singlets.

Differences in relative abundances of the elements should be considered only as a last resort. In fact, great caution is required when trying to estimate the abundances of elements in peculiar stars, including novae.

Discussion

Dr Zanstra. The temperature of Wolf-Rayet stars has no clear meaning when the optical depth in the ultra-violet is too small or too large. In both cases the theory of recombination will predict wrong values of the temperature.

Dr Ambartsumian. The theory of extended atmospheres leads to large departures from a black-body energy curve. On this account, too, the temperature loses its usual significance.

7. ON THE PATCHY STRUCTURE OF THE INTERSTELLAR ABSORBING LAYER

By V. Ambartsumian

Burakan Observatory, near Erevan, Armenia, U.S.S.R.

More than ten years ago it was clearly brought out that the interstellar absorbing medium has a very irregular, patchy structure. During the last years we in the Soviet Union have done some work with the purpose of studying more in detail the structure of the system of absorbing clouds and of obtaining some numerical parameters describing this variety of clouds.

The first question to be answered is: It is known that each of the luminous diffuse nebulae is as a rule illuminated by some high-luminosity star. Are the stars and the corresponding nebulae connected genetically and dynamically or is this connection occasional, due to the fact that the star and nebula meet together by chance during their galactic motion and then separate again?

In order to solve this question it was decided to compare with observations a very important conclusion that can be reached from the hypothesis of the chance meeting.

It is clear that each star can illuminate around itself only a sphere of definite radius in the sense that the cloud situated within this sphere will attain sufficient illumination to be observed as a bright diffuse nebula. Evidently, the radius of such a sphere will be proportional to the square-root of the luminosity of the star.

Let us take a certain volume V of the galactic space. Stars of different spectral types and luminosities will appear in this volume. Let us imagine the spheres illuminated by these stars. Knowing the luminosity function and the star density for each spectral class we can immediately obtain the total volume illuminated by stars of each spectral type

O, B0, B1, B2–9, A, F, G, K, M.

In the case of the chance connection of the nebulae with the illuminating stars, the probability for any cloud to be illuminated by a star of some type, let us say A-type, will be equal to the total sum of volume illuminated by all A-type stars within the volume, divided by the whole volume V.

We are able to compute all these probabilities. If the hypothesis of the chance meeting is true, then the numbers of nebulae illuminated by stars of different types should be proportional to the corresponding probabilities.

The comparison of computed probabilities with the observed numbers of diffuse nebulae illuminated by stars of different types showed very close proportionality. We may conclude, therefore, that the hypothesis of chance meeting must be accepted.

These considerations lead also to another important consequence. It is easy to show that the stars of all types together illuminate only about 1/2000 of the volume of interstellar space. This means that a nebula has a probability of about 1/2000 to be illuminated.

It follows immediately that the number of all clouds in the part of the Galaxy accessible to our observations is about 2000 times larger than the number of the bright diffuse nebulae.

Following this line of argument we have established that the number of the cosmic clouds per ps^3 is about 1/10,000, $n \cong 1/10{,}000$.

If σ is the mean cross-section of a nebula, the number of clouds crossed by a ray along the path l will be equal to $ln\sigma$.

If, further, ϵ_0 is the mean optical thickness of a cloud expressed in stellar magnitudes, the total absorption caused by these clouds will be

$$\Delta m = ln\sigma\epsilon_0 = al,$$

where a is the mean absorption per parsec.

We know from the general data on the cosmic absorption the value of a (photographic or visual) and the order of magnitude of the cross-section σ.

Therefore, if we assume that the whole interstellar absorption is caused by our system of clouds (or obscure nebulae), we may derive the value of ϵ_0.

This first and very rough determination of ϵ_0 showed that it is of the order of $0^{m}{\cdot}2$ or $0^{m}{\cdot}3$ in the photographic region. It was clear that this value is not in contradiction to our ideas about the mean transparency of the diffuse nebulae.

It was concluded that the absorbing layer consists of a large number of discrete clouds, which are small compared with the distances between them. But it was desirable to have another, independent and more accurate method for the determination of ϵ_0.

The counts of extragalactic nebulae made by Prof. Shapley and Dr Hubble have demonstrated that the numbers of nebulae brighter than a certain magnitude per square degree show considerable fluctuations. We have shown that even for a given galactic latitude these fluctuations far exceed the chance fluctuations according to Poisson's Law. It seems at first sight that this may be attributed to the clustering tendency, which of course exists and the importance of which was emphasized by Shapley.

However, the clustering tendency alone is not able to account for the main part of the fluctuations. This is particularly clear from the following evidence: when we divide the whole sky into galactic latitude zones and determine the fluctuations in each of these zones separately, the relative magnitude of these fluctuations increases with the decrease of the galactic latitude of the zone.

It is evident, however, that the chance fluctuations in the numbers of the galactic absorbing clouds on the path of light coming from the different extragalactic nebulae will cause additional fluctuations in nebulae numbers.

It remained to investigate theoretically how these fluctuations depend on the galactic latitude b.

With this aim in view, let us compute

$$\overline{(N_m - \overline{N}_m)^2} = \overline{N_m^2} - \overline{N}_m^2,$$

where N_m is the number of nebulae brighter than some m per square degree. This number N_m in the absence of absorption must be

$$N_m = N_0 \cdot 10^{0{\cdot}6m}.$$

The transparency of a cloud is $q = 10^{-0{\cdot}4\epsilon_0}$. Therefore n clouds in the line of sight diminish the brightness of nebulae q^n times. The observable number of nebulae should therefore be

$$N_m = N_0 \cdot 10^{0{\cdot}6\,(m - r\epsilon_0)} = N_0\, 10^{0{\cdot}6m} q^{\frac{1}{2}n}.$$

The problem of the computation of $\overline{N_m}$ was reduced thus to the computation of $\overline{q^{\frac{1}{2}n}}$. At the same time the computation of $\overline{N_m^2}$ was reduced to the computation of $\overline{q^s}$. Using Poisson's Law for the probability of n we have, after some algebra:

$$\overline{N_m} = N_0 \cdot 10^{0{\cdot}6m} e^{-nb\,(1 - q^{\frac{1}{2}})}.$$

Here n_b is the mean number of absorbing clouds crossed by the line of sight at the latitude b.

In the case of the plane parallel layers of clouds we have

$$n_b = n_{\pi/2} \operatorname{cosec} b.$$

In the same way $$\overline{N_m^2} = N_0^2 \, 10^{1.2 m} e^{-n_b (1-q^2)}$$

and $$\frac{\overline{(N_m - \overline{N}_m)^2}}{\overline{N}_m^2} = e^{n_b (1-q^2)^2} - 1 = e^{n_{\pi/2} \operatorname{cosec} b \, (1-q^2)^2} - 1 \qquad (1)$$

On the other hand, we have $$\tau_{\pi/2} = n_{\pi/2} \epsilon_0 \qquad (2)$$

where $\tau_{\pi/2}$ is the optical half thickness of the galactic absorbing layer in the direction perpendicular to the galactic plane. According to the last determination of Parenago $\tau_{\pi/2} = 0^m \cdot 32$.

The equations (1) and (2) determine $n_{\pi/2}$ and ϵ_0. Using the counts of Shapley and Hubble we have computed the values of

$$\frac{\overline{(N_m - \overline{N}_m)^2}}{\overline{N}_m^2}$$

for different latitudes and obtained a value of ϵ_0 of the order of $0^m \cdot 25$.

It should not be forgotten that it is necessary to introduce a correction accounting for the dispersion of the limiting magnitude of different plates and for other observational conditions. This correction is somewhat indefinite. However, it is still certain that ϵ_0 is confined between

$$0^m \cdot 20 < \epsilon_0 < 0^m \cdot 30.$$

It is clear from (2) that $n_{\pi/2}$ will be of the order of unity.

Prof. Kukarkin has determined the dispersion of photoelectric colour-excesses of extra-galactic nebulae in different latitudes and therefrom obtained immediately the mean colour-excess of one single cloud equal to $0^m \cdot 05$. Multiplying this value by the corresponding factor he has found for the optical thickness of a cloud the approximate value

$$\epsilon_0 = 0^m \cdot 27.$$

Dr Markaryan from Burakan Observatory has determined the value of ϵ_0 from the comparison of the observed fluctuations in the numbers of the stars counted in low latitudes with the theory of fluctuations of star numbers in these latitudes based on the model of a layer of clouds as described above. His theory contains too much algebra to be exposed here. He obtained also $\epsilon_0 \cong 0^m \cdot 25$.

We may conclude that ϵ_0 is really of this order, although we do not exclude that the value of ϵ_0 may vary in different regions of our galaxy.

The theory of fluctuations in the total brightness of stars contained in a square degree in the galactic equator may take a very simple and elegant form. The distribution function of this quantity, which is nothing else than the intensity of the stellar component of the Milky Way radiation, satisfies a certain functional equation.

In the derivation of this equation I have used an invariance principle similar to that introduced by me in the theory of diffuse reflection from plane-parallel layers. More precisely, we have used the fact that the distribution function remains unchanged when the observer displaces himself by a distance Δr along the line of sight.

This principle gives the following functional equation:

$$\phi'(J) + \phi(J) = \frac{1}{q} \phi\left(\frac{J}{q}\right) \qquad (3)$$

for the distribution function, when J is measured in some convenient units.

From the equation (3) it is easy to obtain for the mean-square deviation of intensity

$$\frac{\overline{(J - \bar{J})^2}}{\bar{J}^2} = \frac{1-q}{1+q}. \qquad (4)$$

Unfortunately we have not at our disposal a sufficient number of determinations of f at different points of the Milky Way to check the solution of (3) and the formula (4).

Some years ago, Academician Shajn called attention to the too weak correlation of the colour excesses of the B and O stars as determined by Stebbins and his co-workers, and the brightnesses of the corresponding regions of the Milky Way.

The theory of the cloud-structure of the absorbing layer explains at once this phenomenon. The stars of Stebbins's list have a mean distance above 1000 parsecs, while the fluctuations of the Milky Way brightness are caused chiefly by clouds at distances of 200–500 parsecs.

Therefore the sets of clouds responsible for these two phenomena are quite different and the correlation must be weak.

The problem under consideration is connected with the gas clouds also. Under the assumption that the interstellar gas has also such a patchy structure Dr Melnikov has analysed the curve of growth for the interstellar lines and obtained dispersion velocities of the gaseous clouds of the order of 8 km./sec.

Dr Lyman Spitzer has told me that the observational data of W. S. Adams on the splitting of the interstellar lines into several components lead to a number of the gas clouds crossed by the line of sight equal to the number of the dust clouds computed from our theory. He identifies therefore the two systems of clouds. It follows from this identification that the clouds of interstellar gas should be comparatively small in size (about 8–10 parsecs in diameter). It is very important to prove this conclusion observationally.

In connection with the problem considered in this brief report a large amount of observational work is being done at the Abastumani Observatory under Dr Kharadze. The colour-indices of many thousands of stars in the selected areas are determined as well as the colours of many extragalactic nebulae.

However, the photo-electric data on the colour-indices of the external galaxies should be very important for the further study of the structure of the galactic absorbing layer.

Discussion

L. Spitzer, Jr. remarked that the very important work described by Ambartsumian cleared up two basic problems in the study of interstellar matter. In the first place the ratio of selective to general absorption found from the study of the external galaxies is the same as has been found by many workers for obscuring matter in the galactic plane. This removes the discrepancy found by Stebbins some time ago and emphasized by Seares. In the second place the close agreement between the number of obscuring clouds per kiloparsec found by Ambartsumian, by three quite independent methods, and the corresponding number of gas clouds per kiloparsec indicated by Adams's observations gives added confirmation to the picture of small, separate, randomly distributed clouds of gas and solid particles. This picture is in marked contrast to the previous one of a uniform interstellar medium. Spitzer concluded that to a first approximation the average characteristics of the interstellar clouds—size, separation, and general nature—now begin to be well established.

8. ADAPTATION OF TWO-DIMENSIONAL CLASSIFICATION TO OBJECTIVE PRISM SPECTRA

By Miss M. Walther

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A project has been undertaken at the Harvard Observatory to investigate the possibility of adapting a two-dimensional system of spectral classification, namely the Morgan-Keenan-Kellman system, to objective prism plates. Spectra obtained with an objective prism attached to the 12-inch Metcalf doublet are comparable in dispersion to

those used by Morgan and his collaborators. However, it was necessary to focus special attention on the improvement of the quality of the objective prism spectra. Experimentation revealed that the Eastman Kodak emulsion IIa–O is superior to other available emulsions suitable for the project in question. Equally important is the development process used for the plates. Development in the Eastman Kodak developer DK 20 at 65° F. for 12 to 14 minutes yields very satisfactory results.

For the purpose of establishing criteria for a two-dimensional classification, more than a hundred standard stars chosen from the Morgan-Keenan-Kellman Atlas were photographed with an objective-prism-telescope combination. From this material criteria for determining both spectral type and luminosity class have been established.

The fifteen regions chosen for classification include a number of Selected Areas of low galactic latitudes and fields which coincide with those studied at the Case Institute of Technology. The selection of these regions was made with the intent to use them as standard regions for which the Morgan-Keenan classification could be established.

A comparison of my classification with the Henry Draper classification is made for various magnitude intervals. For the stars brighter than $6^{m}\cdot50$ there is essentially no systematic difference. For fainter stars systematic differences become more evident. At A0 the two systems are in good agreement, but the following subtypes of the A stars are classified systematically earlier by Miss Cannon. The Henry Draper classification of the B stars, on the other hand, is later than the new Harvard classification, and the difference becomes more pronounced for successively fainter stars. The systematic differences for the later spectral types are relatively small.

The luminosity criteria established suffice to determine at least three luminosity classes for all spectral types except the late B stars and the A stars. A catalogue with luminosity classifications of approximately 600 stars has already been prepared for publication.

The dispersion and quality of the objective prism spectra are sufficiently high so that one may readily distinguish between the normal A stars and those which are called anomalous. These latter, belonging to two groups, the 'peculiar' and 'metallic-line' A stars, are found to occur quite frequently. The material examined thus far reveals 48 newly discovered anomalous A stars. From the data available it follows that 13% of the A stars in the magnitude interval, $5^{m}\cdot50$–$9^{m}\cdot50$, and at low galactic latitudes belong to the group of 'peculiar' A stars.

Discussion

Dr Gratton. The importance of a very accurate spectral classification, based on physically significant criteria is enormous. The Henry Draper catalogue is invaluable for studies on the distributions of the stars, but for studies on stellar structure it is almost useless. For instance, it cannot be used for tracing the fine structure features of the Hertzsprung-Russell diagram. Some years ago some doubts have been raised whether there exists or not a gap between giants and dwarfs for K-type stars. Using Mt Wilson or Kuiper unpublished observations of spectral types, one finds from the stars with trigonometric parallaxes larger than $0''.050$ a very well-defined main sequence with extremely small dispersion, besides nicely separated groups of giants and subdwarfs. With Harvard spectral types the dispersion around the main sequence is so large that these features are all obliterated; the gap between K0–K2 giants and the main sequence is completely filled.

IV. THE ABUNDANCES OF THE CHEMICAL ELEMENTS IN THE UNIVERSE

August 17, 1948

CHAIRMAN: Dr OTTO STRUVE

SECRETARY: Dr J. W. SWENSSON

1. THE COMPOSITION OF THE SOLAR ATMOSPHERE

By M. MINNAERT

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The analysis of the Sun by spectroscopic methods refers to an exceedingly thin layer, just above the photosphere, which has a thickness of only a few hundreds of kilometers. The deeper layers are inaccessible to our investigations, because there the matter becomes too opaque. The higher layers of the chromosphere and the corona again are less well known, because they are too transparent, so that deviations from thermodynamic equilibrium conditions may occur. So it is understandable that just the layer where the equilibrium is *nearly* established must be the only layer which can be fully investigated. Probably this is the best analysed sample of the universe. Whether the composition here found is really representative for the Sun as a whole depends on the importance of the convection, which tends to stir the gases into one homogeneous mixture.

The analysis of the solar atmosphere is of fundamental importance, because it may be carried out in detail and with a considerable dispersion, so that even very faint lines appear. Moreover, by a judicious comparison between the spectrum of the centre and of the limb, the uncertainties pertaining to the atmospheric structure may be in principle eliminated; or, an atmospheric model being assumed, a very detailed check on its validity may be found. All methodical questions can be especially well elucidated when describing the way in which the solar analysis is made.

The curve of growth is a wonderful method in order to get rapidly a working knowledge of a stellar atmosphere and to interconnect both faint and strong lines. From such investigations has been derived a pretty close, generally accepted description of the solar gases, their temperature, pressure and composition at each height. But for a more refined analysis, the mean curve of growth does not furnish sufficiently exact information. Its run is different from element to element, or rather from line to line: for there are differences in Doppler-effect, differences in damping and differences in the distribution over the height of the atmosphere.

For a more exact analysis we have to investigate individually each Fraunhofer line. This has been done first for *the strong resonance lines* of some metals. This method has several disadvantages for precise work: (1) From such lines the number of absorbing atoms can be found only if we also know the damping of the corresponding atomic transition; however, this damping depends on the conditions and is a rather uncertain coefficient. (2) The exact computation of the relation between the number of atoms and the profile of a strong line is difficult and is often done in an approximate way only. (3) Especially in the core of the line the profile is partially filled up by fluorescent or non-coherent radiation. Of these effects, the damping is the most important; effective progress has been recently made in the understanding of the damping mechanisms, but there remains to ascertain the value of the individual coefficients, which can be found only from theory. It is important that theoretical physicists should give us some help in this respect.

For the reasons just explained, there is now an increasing tendency to base the analysis of the Sun on *the individual investigation of the faint lines*(4). Indeed, their equivalent widths are independent of the damping; the relation between equivalent width and the

number of absorbing atoms may be tabulated once for all, taking into account the complete atmospheric structure without schematic models, by what I shall call 'the detailed theory'. Moreover, for these lines it seems that no special processes are involved which could influence the central intensity. The importance of these faint lines is so considerable, that special care ought to be bestowed on the determination of f-values for their atomic transitions. This does not necessarily involve great experimental difficulties; but it has been more or less neglected up to now, because nobody expected that these lines would become interesting. I hope that the sub-commission on intensity tables will pay due attention to this category of special lines.

It must be granted that only the very faintest lines are really well described by the simple theory. Stronger lines, however, are easily reduced to this standard case by means of the curve of growth; but then uncertainties come in, first about the state of turbulence and the distribution over the height; and, for still stronger lines, the uncertitude about the damping begins to play a role.

The accuracy of the results obtained either from strong or from faint lines depends on our knowledge of the following fundamental data:

Atmospheric model:

$$\left.\begin{array}{l}\text{He content}\\ \text{turbulence}\\ \text{far U.V. radiation}\end{array}\right\} \rightarrow \left\{\begin{array}{l}\bar{\kappa};\\ \text{possible deviations from Boltzmann and Saha;}\\ \text{relation between } T \text{ and } P.\end{array}\right.$$

Atomic constants:

f-values;
polarization of the atoms (radial eigenfunctions) → damping;
probability of de-excitation by electrons → absorbing or scattering.

From this survey, it will be clear that considerable improvement of our analysis is still possible, partly by ascertaining physical data concerning atomic properties, and partly by obtaining from general astrophysics a more exact picture of the solar atmosphere. The information about f-values is certainly of major importance.

We will now consider how the numbers of atoms corresponding to the several lines are converted into *abundances of the elements*. It will be clear from the first, that the most reliable results will be obtained for these elements where absorption lines originating from the most populated levels are observed. On the contrary, the determination becomes dangerous if the abundances must be deduced by means of very great Boltzmann or Saha factors. From this point of view the elements H, C, N, O, Si and S present considerable difficulties, their visible lines having very high excitation potentials. It is well to remember that the excitation temperatures recently found by excellent authors run from 4300° to 5700°. For an element with an E.P. of 9 V., this means that the Boltzmann factor would vary between $[-10{\cdot}5]$ and $[-8{\cdot}0]$: an incertitude by a factor of 300! For such cases all care must be given to the selection of the exact temperature (or equivalent temperature), most appropriate to the line considered. The 'detailed theory' of the solar atmosphere gives automatically the exact equivalent temperature for each individual line without additional assumptions.

Since many lines of low levels originate at a mean depth of only $\tau \approx 0{\cdot}1$ e.V. it is important to ascertain the run of the temperature especially for these high layers, where the blanketing effect may have an important influence.

It is customary to compute 'the number of atoms above the photosphere' for each element. In doing this, we refer to the Schuster-Schwarzschild model, which indeed is very practical and has a direct pictorial value. The sum of all these numbers of atoms may be put equal to 1, and the relative abundances may be derived. A closer analysis shows that this representation should be accepted only with some caution. Strictly speaking, nobody can tell where the photosphere really begins; or rather, for each spectral line there is an equivalent photospheric depth, varying according to the wave-length, the E.P. and the I.P. The effective layers having different thicknesses, it is clear that a clean

comparison between the abundances is not well possible. The detailed theory gives a more direct and complete determination of the relative abundances. For each line, the equivalent width determines $\sigma_\nu/\bar{\kappa}$, which is equivalent to the abundance of the H^- ion, or, again, to the abundance of the metal compared with hydrogen. Especially for faint lines, it is easy to take completely into account the variation of $\sigma_\nu/\bar{\kappa}$ over the height of the atmosphere; which means: whether the atoms are concentrated in the higher or in the lower regions, whether the effective layer is shallow or thick, etc. The results are therefore more precise, the relative proportion of the metals is determined according to an equitable standard. Another important advantage of such a theory will be pointed out presently.

The abundance of hydrogen is one of the most important and difficult problems of the solar analysis. It may be obtained by two methods:

(1) The spectrophotometry of the Balmer lines may be carried out by the methods used for strong metal lines. However, these results are uncertain, because the broadening of the Balmer lines is still imperfectly understood: this is demonstrated by the failure of theory to describe the mutual relation between the Balmer profiles and the modifications of profiles, when approaching the limb. It has been tried to measure the last lines of the Balmer series or of the Paschen series; these are so shallow that they may be considered as formed in an optically thin layer. But such measurements are difficult, their equivalent widths as published are not well in mutual agreement (2, 8, 5).

(2) As already explained, the theory of faint lines yields directly for each metal the abundance compared with hydrogen, without any measurement of a hydrogen line. This method, first applied by Strömgren (7) and made more exact since Chandrasekhar's work on the H^- absorption, gives an independent determination only when atoms of strongly ionized elements are used. It entirely avoids the Boltzmann factor, which for hydrogen is of the order of 10^{-9} and is always more or less uncertain; moreover, it is independent of the broadening either of the hydrogen or of the metal lines. Applying our reduction to a few suitable elements, we find that the abundance of hydrogen is in the mean [0·16] greater than found by Strömgren; this last value is thus practically confirmed.

The determination of *the abundances of the atoms C, N and O* is a very important question, because after H and He they are the best represented elements in the solar atmosphere. Their concentration determines the speed of the nuclear transformation in the interior parts of the Sun.

(1) Their abundances may be derived from the atomic lines; unfortunately these belong to the infra-red spectrum and have an excitation potential of 8 to 10 V.; so the Boltzmann reduction is dangerous. Probably more reliable is the reduction by means of the detailed theory.

(2) Bowen and, independently, Cabannes and Dufay have been able to identify the very faint forbidden lines of O in the solar spectrum, which are absorbed by very low levels of the atom. From these follows the abundance, without the danger of a wrong Boltzmann factor (1). Both results are in excellent agreement.

(3) Finally, the abundances of these elements may be found from the molecular bands of CH, OH, CN, NH and C_2, which are observable in the solar spectrum. The abundances of these four atoms determine the concentration of the molecules. You will hear presently how beautifully Dr Hunaerts applied this method.

The results of the three calculations are compared in the general table (11). It is at once clear that there are still divergencies which must urgently be solved.

There remains *the determination of the helium abundance.* As yet this has been derived only from the chromospheric lines and from the prominences (3, 9). Now the analysis of the chromosphere has shown that the abundance of the metals, compared with hydrogen, is distinctly smaller in the chromosphere, and that it still decreases at greater heights (13). The proportion of helium to hydrogen has been found sometimes to vary considerably in different parts of the same prominence (14). This proves that it is still uncertain whether the helium content of the chromosphere may be considered as equal to that of the deeper layers. It seems impossible as yet to derive any information from the line λ10830, which shows as a hazy absorption in the infra-red spectrum: the excitation potential being

19·8 e.V., the Boltzmann factor is enormous and entirely uncertain, the very existence of equilibrium conditions is doubtful. In principle, the helium abundance of the reversing layer could be determined by similar methods as the hydrogen abundance; for the admixture of helium will modify the structure of the atmosphere, especially the relations between T, P, P_e and κ, and this again must have an influence on the line intensities of the other elements. A systematic comparison between the intensities of atom lines and ion lines of the same element, either strong or faint, must yield not only the abundance of hydrogen but also that of helium.

The table of abundances in the solar atmosphere here presented summarizes most of the recent information. Tabulated are the logarithms of the number of particles (atoms or ions) of each element, this logarithm being put equal to 10 for hydrogen. The results of Menzel and his collaborators cannot be critically compared with the others, because details about the computations have not yet been published. The chief differences with Unsöld occur for those elements where the Boltzmann reduction becomes important (S, Si, Zn), apparently because Menzel used a lower temperature. The table shows that Unsöld's temperature is in much better agreement with the detailed theory, which is especially reliable for the deeper atmospheric levels. Since just these are determinant for the special lines in question, the higher temperature seems the best choice. Very striking is the difference between Menzel and Unsöld for Mg. For Fe, the values of Unsöld are probably not reliable, since there is doubt about the absolute f-values of King on which they are based.* The results of Unsöld are the most complete set now available; they have been reduced by himself to the hydrogen value of Strömgren. The next column gives for some elements the results obtained if Unsöld's data are treated by the detailed theory of faint lines, keeping the f-values as used by him; for iron, a value deduced directly from King has been added. The ratio to hydrogen is here determined directly and independently. The following conclusions may be drawn: (1) Compared with Unsöld-Strömgren, a slightly smaller abundance is found for most elements, with respect to hydrogen; the mean factor amounts to [0·16]. (2) The results for the individual metals deviate only in minor respects from those obtained by the Scharzschild-Schuster model; taking into account the changed hydrogen value, the greatest difference amounts to [0·31]; for the metalloids, the divergencies are greater. Consequently for more precise work it is advisable to use the detailed theory. For oxygen, the results of Bowen, Cabannes and Dufay have been first compared with hydrogen via Unsöld-Strömgren; the second number has been computed directly from the detailed theory.

For the rarer elements, the original table of Russell is still now of high value (6).

Especially interesting is the absence of the heavy hydrogen isotope. From our present knowledge of equivalent widths, we may assert rather safely that the ratio of the two isotopes is less than 10^{-5}. Traces of the carbon isotope C^{13} are lacking in the solar spectrum, but in this case it would be difficult to assign an upper limit to the abundance.

Abundance of the Light Elements in the Solar Atmosphere

Element	Menzel c.s.	Unsöld	Minnaert	Hunaerts (molec.)	Bowen, Cabannes and Dufay (forb. l.)
H	10·0	10·0	10·0	10·0	10·0
H^2	—	—	5·0	—	—
He	9·30	9·30 (promin.)	—	—	—
C	5·56	6·29	—	7·06	—
N	6·09	6·61	—	7·02	—
O	6·56	6·73	—	7·23	6·55–6·83 (M.) 6·27–6·73 (M.)

* Remark made by Menzel at the meeting.

Abundance of the other Elements in the Solar Atmosphere

Element	Menzel c.s.	Strömgren	Rudkjøbing	Unsöld	Unsöld (M.)
Na	4·56	3·96	4·00	4·28	4·09
Mg	6·39	5·60	5·25	5·51	5·48
Al	4·39	—	—	4·33	4·16
Si	5·87	—	—	5·29	—
S	5·57	—	—	4·92	—
K	3·09	3·32	—	3·20	3·00
Ca	4·57	4·23	—	4·23	—
Sc	—	—	—	1·33	0·98
Ti	2·57	—	—	2·96	2·76
V	2·09	—	—	2·06	1·81
Cr	2·87	—	—	3·58	3·00
Mn	3·09	—	—	3·46	—
Fe	4·99	—	—	5·72	5·29–5·59 (King)
Co	2·69	—	—	3·03	—
Ni	4·39	—	—	3·96	—
Cu	2·39	—	—	2·23	—
Zn	3·57	—	—	2·78	—
Sr	—	—	—	1·35	1·00
Y	—	—	—	1·21	—
Zr	—	—	—	0·37	0·10
Mo	—	—	—	0·78–1	—
Ba	—	—	—	0·95	—
Pb	—	—	—	0·6	—

In conclusion, I should like to emphasize some rather obvious recommendations for future work: First, that a high standard of accuracy in the determination of abundances must be reached and can be reached. Secondly, that all data should be published in full, in order to make a detailed discussion possible. Thirdly, that abundances should be determined for each celestial body independently, not trying *a priori* to confirm the uniformity of constitution of the Universe.

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2. SOLAR ABUNDANCES OF THE H, C, N AND O ATOMS DEDUCED FROM MOLECULAR ABUNDANCES

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A priori it would seem possible to determine the solar abundances of the H, C, N and O atoms on the basis of the solar abundances of the CN, CH, C_2, NH and OH molecules. Such a determination entails two distinct problems:

(1) The determination of the molecular abundances with the help of the measured intensities of individual rotational lines.

(2) The calculation of atomic abundances on the basis of the equations of dissociation equilibrium.

(1) *Molecular abundances.* We have recently (1) estimated the solar abundances of CN, CH, C_2, NH and OH. For this purpose we have measured the equivalent widths of a large number of rotational lines of CN, CH and C_2, using Minnaert's *Photometric Atlas of the Solar Spectrum.* The Nf-values obtained in this way enabled us to draw the curves of growth for these molecules. In the case of NH and OH the Rowland intensities were converted into equivalent widths by using a calibration by Roach and Phillips (2) and the Nf-values were deduced from the curves of growth thus established.

We calculated in the usual manner the molecular excitation temperatures which turned out to be of the order of 4500° K., hence correspond to the temperature of the solar photosphere at very small optical depth.

The conversion of the Nf-values into the absolute molecular abundances, requires the knowledge of the oscillator strengths f, on which a great deal of doubt still exists. There are experimental determinations of f (CN) and f (OH) which enabled Lyddane, Rogers and Roach (3) to compute the f-values for C_2, CH and NH. Moreover, Mrs Rieke (4) has estimated theoretically the f-values for OH, CH and NH.

	Lyddane *et al.*	Mrs Rieke
CN ($^2\Sigma^+ - {}^2\Sigma^+$)	$2{\cdot}6 \times 10^{-2}$	—
C_2 ($^3\Pi_g - {}^3\Pi_u$)	$2{\cdot}4 \times 10^{-2}$	—
OH ($^2\Sigma - {}^2\Pi_i$)	$3{\cdot}0 \times 10^{-4}$	4×10^{-4}
CH ($^2\Delta - {}^2\Pi$)	$4{\cdot}5 \times 10^{-4}$	10^{-2}
NH ($^3\Pi_i - {}^3\Sigma^-$)	$7{\cdot}2 \times 10^{-4}$	f (CH) > f (NH) > f (OH)

The abundances computed on the basis of the f-values of Lyddane, Rogers and Roach are

	CN	CH	C_2	NH	OH
log S	16·32	17·31	14·96	16·98	17·52

At this point it should be made clear that the adopted f-values may be wrong by appreciable factors.

(2) *Atomic abundances.* The relative atomic abundances of H, C, N and O may in principle be deduced from the molecular abundances on the basis of the classical equations of dissociation equilibrium

$$p(A)\, p(B) = K p(AB),$$

the p's being the partial pressures and K the dissociation constant. This has been done, following Russell's classical schematic procedure. Serious uncertainties already arise from the astronomical nature of the problem, since an idealized atmosphere has to be adopted. But additional uncertainties arise from inadequate data on several dissociation energies which play a role in the dissociation equilibrium. We have adopted the dissociation energies recently published by Gaydon (5).

D in e.V.	CN = 7·6	C_2 = 5	CH = 3·47	NH = 3·61	OH = 4·34
	CO = 11·11	N_2 = 9·764	NO = 6·49	H_2 = 4·4776	O_2 = 5·084

On this basis the atomic abundances turn out to be:

$\log T(\mathrm{H}) = 23{\cdot}97$	$T(\mathrm{H}) = 10{,}000$
$\log T(\mathrm{C}) = 21{\cdot}03$	$T(\mathrm{C}) = 11{\cdot}5$
$\log T(\mathrm{N}) = 20{\cdot}99$	$T(\mathrm{N}) = 10{\cdot}5$
$\log T(\mathrm{O}) = 21{\cdot}19$	$T(\mathrm{O}) = 17$

Since these values depend in a complicated fashion on the *f*- and *D*-values, it is impossible to estimate the accuracy of the calculated figures. If the values of the dissociation energies given by Herzberg (6) [$D(\mathrm{CN}) = 5{\cdot}95$ e.V.; $D(\mathrm{C_2}) = 3{\cdot}6$ e.V.] were adopted, much higher values of the abundances of C, N and O relative to H would be obtained: this is due to the essential role of $D(\mathrm{CN})$ in the calculations.

Slight changes in the *f*-values would give the abundance ratio of C and N obtained by Bethe.

Conclusions

1. The determination of molecular excitation temperatures gives consistent results. We have to admit low temperatures for the photospheric region of effective absorption of the faint molecular lines.

2. The estimated atomic abundances are very uncertain, owing mainly to the uncertainties of the *f*- and *D*-values. Experimental and theoretical work in this field is highly desirable.

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3. THE CHEMICAL COMPOSITION OF STELLAR ATMOSPHERES

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The quantitative analysis of stellar atmospheres requires—if we may put it somewhat paradoxically—already considerable knowledge of their composition and structure. In practice it is therefore necessary to begin with the simplest problems and even there to proceed in successive approximations.

Let us first consider *normal atmospheres* which are completely determined by stating their chemical composition, effective temperature T_e and surface gravitation g. We divide them best into three groups:

I. Early spectral types from O to A5: completely ionized. Continuous absorption by hydrogen and helium atoms. Scattering by free electrons.
II. Medium spectral types from A5 to K5: hydrogen neutral. H^- continuum.
III. Late types from K5 on: formation of molecules; molecular spectra.

We shall deal here mainly with early spectral types, the Sun as chief representative of group II being treated by Prof. Minnaert. Then I shall say something about *peculiar spectra* and finally add a few considerations on the *methods* which seem to be important for a successful development of our research.

I. Normal Stellar Atmospheres

(1) *Interpretation of Fraunhofer Lines.* To begin with, the following picture may be recommended. We imagine the atmosphere having—within a spectral line—an effective optical thickness x_ν which determines the 'depth' in the line $R=\frac{F_0-F}{F_0}$ according to the equation:

$$\frac{1}{R}=\frac{1}{R_c}+\frac{1}{x_\nu}. \tag{1}$$

The limiting depth R_c—corresponding to the black-body radiation for the boundary temperature T_0 of the stellar atmosphere—will be determined empirically. Then equation (1) can be well adapted to any reasonable type of radiative equilibrium. The effective depth of the atmosphere can be considered to be practically constant for $\lambda >$ resp. < 3650 A. The ratio of the depths for the two spectral ranges can be estimated.

By applying the well-known theory of the curve of growth—the damping constant being determined empirically or better avoided by using weak lines—we thus obtain the $\log N_{r,s}\, H.f$, where $N_{r,s}\, H$ is the number of r-times ionized atoms in the quantum state s above 1 cm.^{2} of the stellar surface, while f means the oscillator strength of the line.

(2) *Computation and measurement of oscillator strengths f.* The chief problem—more important, for instance, than minute details of radiative equilibrium—is now the determination of f-values.

Relative f-values within multiplets, super-multiplets and transition arrays can be computed for (LS)-coupling according to quantum theory—most easily by means of the tables by Russell, Goldberg *et al.*—or measured in the electric arc. For heavy elements calculation of other modes of coupling is occasionally possible. It might be very desirable to have suitable measuring methods for spectra like O II and III, Ne II ....

Absolute f-values can be calculated for simpler atoms according to quantum mechanics. Recently Biermann in Göttingen has made extensive computations, using Hartree's method.

It has not been sufficiently noticed until now that—especially for long wave-lengths and in spark spectra—there are many important transitions between hydrogen-like orbits, whose f-values can be easily got by means of the well-known hydrogen matrices. E.g. Mg II 3^2D–4^2F $\lambda 4481$ corresponds to the same transition in He II 4686. In other cases the f-sum-rule is useful. Its refined form, discovered by Wigner and Kirkwood, gives for the

Series:	s–p	p–d	d–f
$\Sigma f=$	1·00	1·11	1·40

(2)

Since the intensity-decrement in series with $\Delta l = +1$ decreases with increasing l, we may roughly state the rule: 'The first line of a series with $\Delta l = +1$ has $f \approx 1$ (limits about 0·5 to 2).'

Then the *measurements.* The range of the classical methods of anomalous dispersion, magneto-rotation, etc., is naturally rather limited. On the other hand, the importance of the absorption measurements by R. B. and A. S. King can hardly be overestimated. For higher excitation potentials the emission-work of the Utrecht school should also be quite useful.

Having—by means of the oscillator strengths f—transformed the $N_{r,s}\, H.f$, read from the curve of growth into numbers of atoms $N_{r,s}\, H$ we should take into account excitation and ionization using the Boltzmann and Saha formulae and thus determine the chemical composition of stellar atmospheres.

(3) *Average values of pressure and temperature in early-type atmospheres.* Within our limits of accuracy ($\Delta \log N = \pm 0{\cdot}3$) it should be allowed first to use suitably chosen average values of electron pressure P_e [Bar] and temperature T.

In early-type atmospheres P_e can be determined using the Stark-effect broadening of hydrogen lines. Either we start with the number of observable Balmer lines or we deter-

mine the number $N_{\gamma,\delta} H$ of absorbing atoms by means of the higher members of the series or of the intensity drop near λ3650 A. (in optically thin layer) and then make use of the broadening of H_γ and H_δ (absorbed in optically thick layer). Application of Saha's equation to elements which are present in several stages of ionization finally gives us the average temperature T. For the Oe5 stars λ Ori *b* and 10 Lac I obtained $T = 31{,}000 \pm 1000°$ K., for τ Sco (B0) $T = 28{,}150 \pm 750°$ K. The electron pressures decrease along the main sequence from $\log P_e = 2{\cdot}9$ for the two O stars somewhat towards the later types. An important by-product of such measurements is the absolute spectroscopic determination of the effective surface gravitation $g_{eff.}$ by connecting pressure and thickness of layer through the fundamental equation of hydrostatics. For the main sequence stars our $g_{eff.}$-values agree with the g's computed from the mass-luminosity relation; for the *c* stars $g_{eff.} < g$, perhaps the pressure of radiation comes into play there.

(4) *Excitation and ionization in medium spectral types.* For the Sun as a representative of medium spectral types it is—the only difference—no longer possible to get the pressure accurately from observations of the hydrogen lines. Here it appeared to be most suitable to determine simultaneously average values of P_e and T by considering the chemical equilibrium between any energy levels of two consecutive stages of ionization of the same element.

Using the excitation of the lowest energy levels of neutral atoms or molecules, numerous authors have obtained temperatures between 4500° and 5000° K. The difference against our $T = 5675°$ K. is almost certainly real. We shall come back to this point and show why we prefer to use the higher temperature as a general average value.

(5) *Abundance of the elements.* We deal now with our chief item, the abundance distribution of elements. In Table I we summarize some results for the lighter elements. The agreement between the solar values by B. Strömgren and myself is excellent. The agreement with the meteorite analyses by V. Goldschmidt and Noddack is better than in H. N. Russell's classical investigation—if we discard (reasonably) the lighter elements (up to Ne). We are surprised to see the complete agreement between the Sun and τ Sco, although these two stars are quite different cosmogonically. τ Sco is a member of the well-known moving cluster and should be of more recent origin than most of our galactic system. Even for *c* stars of the types O to B3 the ratio of H : He turns out to be about the same as for corresponding main-sequence stars within an uncertainty factor of about two—a fact of great cosmogonical significance.

II. Peculiar Stellar Spectra

Are there now any stars whose spectrum indicates that their composition differs essentially from the 'normal' ones? Among the light elements up to oxygen such differences might be connected with the energy-generation by nuclear transformations.

Especially hydrogen should in course of time undergo transmutation into helium. For the elements heavier than oxygen, however, we can see at present no possibility of transmutation, except perhaps in super-novae.

(1) *Helium in cA stars.* Mrs Payne-Gaposchkin was probably first to point out the unexpected strength of He lines compared with the Balmer lines in *A super-giants*. Recently more detailed papers on υ Sgr and other stars have been published by Greenstein and Popper. If the analysis follows the usual methods, one obtains a small abundance-ratio of H : He. However, even if a different explanation cannot yet be proved, I feel rather sceptical about the proposed one. The spectrum of eruptive solar prominences exhibits in emission exactly the same features, which the cA stars show in absorption although the composition of the prominences certainly is the same as that of the Sun. Probably we are dealing with a phenomenon of excitation and ionization not yet understood in detail.

(2) *Carbon and nitrogen in Wolf-Rayet stars.* We need not deal here with the well-known subdivision of the Wolf-Rayet stars into WC and WN. Reference to the Bethe-v. Weizsäcker process of energy generation is too obvious here. On the other hand, however,

we should point out also that the interpretation of Wolf-Rayet spectra in terms of transparent expanding envelopes has become very doubtful by recent studies of the eclipsing binary V 444 Cyg and other arguments.

(3) *Carbon and oxygen in late-type spectra.* H. N. Russell has, as is well known, attempted to explain the division of the Harvard sequence in the late types by the assumption that in S stars the abundance ratio $\frac{\text{oxygen}}{\text{carbon}} \sim 30$, in R and N stars only $\sim 1/30$. (For $\odot$ and τ Sco we found ~ 5.) However, in such complicated dissociation equilibria it might be well possible that some quantitatively important compound has escaped our attention. It need not show up at all in the accessible part of the spectrum! Furthermore, the curves of growth for molecular spectra and the influence of turbulence upon them urgently require a closer study. Van de Hulst's beautiful work on the telluric O_2-bands may indicate what is possible in this direction.

(4) *'Metallic line' stars.* Then we have the 'metallic line' stars which, according to Morgan, form a branch of their own in the H.R. diagram. From the viewpoint of nuclear physics it appears rather senseless to operate here with differences of abundance. Perhaps a recent paper by Greenstein on τ UMa and other F stars as well as the work of O. Struve may indicate that in the atmospheres of such stars turbulence which varies with height changes the curve of growth, the pressure-stratification and the excitation compared with normal stars. One might imagine that in such a way certain elements are considerably 'enhanced'. The problem may also be connected with that of the 'anomalous curves of growth' (K. O. Wright).

III. Some Questions of Principle

The difficulties which we have met emphasize the need of a critical examination and improvement of the applied methods. We shall note only in loose connection a few points which, in my opinion, have not always received sufficient attention.

(1) *Deviation of the temperature stratification from the limiting case of the 'grey' atmosphere.* In calculating the temperature T as a function of the optical depth $\bar{\tau}$ we must chiefly take into account the dependence of the absorption coefficient on wave-length and depth, since the 'grey' approximation is too inaccurate. A layer which gives strong absorption in a limited range of λ's dams, I should say, the flux of radiation. This results in heating its inner and cooling its outer parts. Evaluating for the Sun the temperature-stratification from the centre-limb contrast one should be aware that for $\cos\theta < 0{\cdot}3$ the observations are of rather doubtful accuracy. But just for $\tau < 0{\cdot}3$ we should expect steepening of the temperature gradient by the absorption within the Fraunhofer lines. Only in that way can we probably reconcile the low excitation temperatures measured spectroscopically with the results of Chalonge and Barbier.

Then it will be necessary to pay more attention to *zones of convection.* I have recently constructed an entropy-temperature-pressure diagram for stellar matter which enables us to overlook the constitution of any convective zone by just drawing one straight line $S = \text{const.}$

Besides closer study of convection and turbulence one should pay attention to possible effects of the inflow of cosmical matter into the stellar atmospheres. A paper by Biermann and ten Bruggencate tries to explain in that way the high temperature of the solar corona; investigations at the Mt Wilson and Yerkes Observatories on variables in dark nebulae point towards similar ideas.

(2) *Theory of Fraunhofer lines.* Recent papers by Houtgast, Spitzer *et al.* indicate—we cannot enter here into theoretical details—that within most weak lines and in the wings of strong lines it is legitimate to proceed according to Schwarzschild's schema of *true absorption* or local thermodynamic equilibrium. The difficulties concerning the centre-limb variation of Fraunhofer lines which first arose in this connection could be removed by paying more attention to the effects of stratification.

For computing line contours we have, beside the classical models of Schwarzschild, Milne, Eddington *et al.*: (*a*) *The method of weight functions*, which recently could still be

generalized. (*b*) The '*centre of gravity*' *method by B. Strömgren, which now can be* simplified considerably. (*c*) The '$\tau_\nu = 2/3$' method which, following Eddington and Barbier, was applied by the present author successfully, e.g. to the above-mentioned problem of centre-limb variation. (*d*) On the other hand, one should not forget that for true absorption also the *exact calculation of line contours* by simple numerical quadratures (cf. A. Rosa's paper on the hydrogen lines in the solar spectrum) is rather easy, in any case simpler than many of the usual calculations of models.

Looking finally into the future development of our branch we should already in the near future expect progress on the one hand from quantitative studies of peculiar spectra. Theoretical work will probably beforehand be centred mainly on the development of methods, first for normal and later for peculiar spectra. Besides this it appears possible, using high-precision measurements, to achieve already in some cases (e.g. the Sun) through a second approximation an accuracy of the 'astrochemical' analysis which should not yield to that of geochemistry.

Cosmic Abundance of Elements (log NH + const.)

(The additive constants have been chosen in such a way that the various columns become comparable.)

		Sun			
El.	τ Scorpii Unsöld	Unsöld	Strömgren	Russell	Meteorites Goldschmidt
1 H	10·00	—	10·38	8·8	—
2 He	9·25	—	—	7·3 ?	—
3 Li	—	—	—	0·3 :	1·74
4 Be	—	—	—	0·1	1·04
5 B	—	—	—	3·3 :	1·12
6 C	6·24	6·62	—	5·8	3·26
7 N	6·58	6·94	—	6·3 :	—
8 O	6·99	7·06	—	7·3	6·28
9 F	—	—	—	4·3 :	2·06
10 Ne	7·05	—	—	—	—
11 Na	—	4·61	4·32	5·5	4·39
12 Mg	5·76	5·84	5·96	5·6	5·68
13 Al	4·56	4·66	—	4·7	4·68
14 Si	5·80	5·62	—	5·8	5·74
15 P	—	—	—	2·3 :	3·50
16 S	—	5·25	—	4·0 :	4·80
17 Cl	—	—	—	—	3·4 (?)
18 A	—	—	—	—	—
19 K	—	3·53	3·68	5·1 :	3·58
20 Ca	—	4·56	4·59	5·0	4·50
21 Sc	—	1·66	—	1·9	0·92
22 Ti	—	3·29	—	3·5	3·41
23 V	—	2·38	—	3·3	1·85
24 Cr	—	3·91	—	4·0	3·79
25 Mn	—	3·79	—	4·2	3·56
26 Fe	—	6·05	—	5·5	5·69
27 Co	—	3·36	—	3·9	3·28
28 Ni	—	4·28	—	4·3	4·40
29 Cu	—	2·56	—	3·3	2·40
30 Zn	—	3·11	—	3·2	2·30
31 Ga	—	—	—	0·3 :	0·66
32 Ge	—	—	—	1·3	2·01
33 As	—	—	—	—	Trace
34 Se	—	—	—	—	0·92
35 Br	—	—	—	—	1·37

Cosmic Abundance of Elements (*continued*)

El.	Sun: Unsöld	Sun: Russell	Meteorites: Goldschmidt	El.	Sun: Unsöld	Sun: Russell	Meteorites: Goldschmidt
36 Kr	—	—	—	61 Il	—	—	—
37 Rb	—	0·0:	0·57	62 Sm	—	−0·2	−0·20
38 Sr	1·68	1·6	1·34	63 Eu	—	−0·3:	−0·81
39 Y	1·54	0·9	0·73	64 Gd	—	−0·6:	−0·04
40 Zr	0·70	0·8	1·88	65 Tb	—	—	−0·54
41 Nb	—	−0·7:	—	66 Dy	—	−0·1:	0·05
42 Mo	0·11	−0·3	0·72	67 Ho	—	—	−0·50
43 —	—	—	—	68 Er	—	−1·6:	−0·05
44 Ru	—	0·0	0·30	69 Tu	—	−1·2:	−0·80
45 Rh	—	−1·2	−0·15	70 Yb	—	−0·7:	−0·08
46 Pd	—	−0·6	0·14	71 Cp	—	−0·7:	−0·58
47 Ag	—	−0·7	0·25	72 Hf	—	−1·3	−0·08
48 Cd	—	0·5:	Trace	73 Ta	—	−1·7:	—
49 In	—	−1·7:	−0·90	74 W	—	−1·5	0·90
50 Sn	—	−0·5?	1·20	75 Re	—	—	−3·00
51 Sb	—	0·9:	Trace	76 Os	—	−1·2:	−0·02
52 Te	—	—	?	77 Ir	—	−1·9?	−0·50
53 J	—	—	−0·13	78 Pt	—	−0·1	0·20
54 X	—	—	—	79 Au	—	—	−0·50
55 Cs	—	?	−1·26	80 Hg	—	—	—
56 Ba	1·28	1·6	0·66	81 Tl	—	—	Trace
57 La	—	0·1	0·06	82 Pb	0·9	−0·5	0·70
58 Ce	—	0·7	0·11?	83 Bi	—	—	Trace
59 Pr	—	−1·1:	−0·28	90 Th	—	—	−0·49
60 Nd	—	0·3	0·26	92 U	—	—	−0·90

4. THE CHEMICAL COMPOSITION OF PLANETARY NEBULAE

By Donald H. Menzel

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Calculations of abundances of the elements in planetary nebulae depend on knowledge of the following factors: the physical processes involved in the production of any given line, the atomic parameters governing the excitation processes, and the distribution of matter in the shell surrounding the nuclear star. The basic observations are spectrophotometric, preferably reduced to an absolute scale of magnitude per square minute of arc in each significant spectral line.

Ionization and electron capture are generally recognized to be the primary processes responsible for the emissions of hydrogen, helium and ionized helium. Absorption and reabsorption of the emitted line radiation, in the far ultra-violet, lead to conversion of high-energy quanta into visible radiation. The atomic parameters are known accurately for hydrogen and ionized helium. They are known less accurately for neutral helium, but the uncertainties are probably not a major source of error.

We must estimate the abundances of N II, O II, O III, Ne III, Ne V, S II, S III, Cl II, Cl IV, A IV, and A V, from the intensities of the forbidden lines associated with the lowest electronic configuration of the atom. The line excitation results from electron impact. The transition probabilities for the emission are small but finite. The emission is possible because of the non-vanishing matrix components associated with a departure of the atomic energy levels from those of LS coupling.

Calculation of the Einstein A's for the forbidden lines is not a difficult matter, except for the p^3 configuration, where second-order effects control the magnitude of the result.

A recent analysis of the O II problem, by Aller, Van Vleck, and Ufford, has removed an old discrepancy in the relative intensities of the nebular pair 3727 : 3729. We can, therefore, apply the theoretical transition probabilities for spontaneous emission with some degree of confidence for all the forbidden lines.

The target areas for collisional excitation are a different matter. No laboratory measures of these atomic parameters exist or are likely to become available. And, until recently, theoretical calculations were available for only one atom, viz. O III, according to the studies by Hebb and Menzel. The earlier calculations of abundances were, therefore, based on the assumption that the target areas for collisional excitation were the same for all of the atoms. The assumption was certainly not correct, but no other one seemed possible at the time.

A recent study of the O II collision areas, by Lawrence H. Aller, has indicated that the foregoing assumption was very poor, for this atom at least. The parameter enters the nebular problem as the ratio of the Einstein A for spontaneous emission to the target area for collisional excitation. The A-values for O II are very much less than those for O III. Consequently, the aforementioned ratio of A to collisional target area differed greatly for O II and O III, according to our original assumption. The revised calculations, however, make this ratio almost the same for O II as for O III. In the absence of further information, therefore, it seems somewhat safer to assume that the ratio is constant for all atoms.

A constant ratio was to be expected for very fast electrons, which behave very much like light waves. But the electrons responsible for the collisional excitation are relatively slow and the result is somewhat surprising. Doubtless, exact calculations will show some interesting discrepancies, but we cannot make much further progress without these badly needed parameters.

Perhaps the most important factor of all is the distribution of matter in the shell of gas surrounding the nuclear star. Previous calculations have generally been based on the assumption that the material fills a spherical shell, whose inner and outer boundaries roughly conform to the interior and exterior limits of the ring, where such a ring is evident.

Even so, we have recognized the danger of this assumption. Aller and Menzel have pointed out the possibility that the seemingly continuous shell may possess a filamentary constitution. The structure of knots and striae in various nebulae has clearly suggested that some of the nebulae, at least, do not have a continuous shell of matter. Many of the records presented by Curtis (*Lick Obs. Publ.* vol. **13**) display a very complicated internal structure.

Recent unpublished photographs, by W. Baade of Mount Wilson Observatory, of the so-called Helical Planetary in Aquarius, N.G.C. 7293, depict this filamentary structure in considerable detail. In portions of the nebula where the shell is less brilliant, Baade has noted the existence of numerous, comet-like objects. Each possesses a condensed nucleus and the 'tail' generally points away from the central star of the planetary.

These filamentary objects doubtless possess some very important cosmogonic import, but our present study merely depends on the existence of the formations. From measures on photographs supplied by Baade, to whom full credit should go for the discovery of the 'comets', I have estimated that the tails may be some 30,000 astronomical units in length and perhaps 3000 astronomical units in diameter. The dimensions are based on Berman's parallaxes. The Helical nebula is probably the largest of its class and the above dimensions are certainly not typical of the average planetary. Very preliminary photographic estimates indicate that perhaps only 1/300th of the volume is filled with the luminous matter. The figure in the denominator may be even larger, since I have not taken into account the fact that many of the cometary tails possess a sort of 'beaded' appearance.

Dangerous as it is to assume that other planetaries have the same ratio of luminous to non-luminous volume, I feel that the correction is much safer to adopt than the earlier values. Until information on individual nebulae or better measures for the Helical nebula become available, we are forced to adopt the value of about 1/300 for the ratio.

The correction for the volume effect has its greatest influence in determinations of electron density, which come out about $\sqrt{300}$ or about seventeen times greater than before. For a typical group of planetaries the densities range from about 3×10^4 to perhaps 10^6 electrons per cm.[3]

Estimates of the total mass of the gaseous shell come out about seventeen times smaller than those given by our earlier calculations. This reduction in total mass is in the direction of making a nova outburst a less violent catastrophe in the history of a star. Even so, the total masses are still large. For example, the calculated mass of N.G.C. 7009 seems to be of the order of 10^{31} g.

The increased densities, coupled with the correction for target areas, previously mentioned, give revised values of the electron temperatures. The mean value is reduced from about 10,000 to 7700°. I.C. 4997, which was previously very discrepant with an electron temperature of 27,000°, now is in much better agreement with the other nebulae and a slight increase of the average density would serve to bring about exact agreement. Such an assumption would seem to be justified by the apparent compactness of this object.

The values of the hydrogen-helium ratios are essentially independent of the electron density, because the processes tending to produce the lines are analogous for these atoms. The primary uncertainty comes from a necessary correction for the relative volumes of gas tending to emit the various lines. Hydrogen, for example, is largely ionized throughout the nebula. Helium, however, may be doubly ionized only in the innermost parts of the shell, and singly ionized through most of the remaining region. If we assume that the emitting regions are the same for both sets of atoms we shall underestimate the true abundance of helium. That such a correction is necessary becomes especially evident when we come to the low-excitation objects, like N.G.C. 6826, N.G.C. 6543 and especially I.C. 418, all of which seem to show an abnormally low abundance of helium. The safest estimates for helium come from the observations of He II. We allow for the fact that the 4686 images are appreciably smaller than those of hydrogen, by assuming that the volume of emitting gas involved is less for H I, by a factor of about 1/2. The means for seven nebulae are very concordant and give a mean of 0·2 for the helium/hydrogen ratio.

The intensities of the nebular lines of O III and of the line $H\beta$ constitute our best data for determination of the abundance ratio of oxygen to hydrogen. If we employ the O II nebular lines, we obtain a very high abundance of oxygen. However, slitless spectra clearly show that O II tends to predominate only in the external regions of the nebula. In fact the lines at 3727 give by far the largest nebular images. Presumably the excess ionization of O II arises from the marked difference between the absorption coefficients of O I and H I. The curve for the former falls very slowly. Various helium emission lines may thus cause considerable ionization of oxygen and not affect hydrogen at all. If we are to employ O II lines for the abundance estimates, we must apply a very large and uncertain correction because the volumes of emitting hydrogen and O II are far from being similar.

The determined ratio of O/H for eight planetaries is 0·0020. This ratio depends markedly upon the density, because the excitation processes are different. The ratio, thus determined, is probably a minimum value. We shall have to increase it if any appreciable amount of oxygen exists in stages of ionization higher than O III. Such stages give no important lines in the visible region, but the occurrence of Ne V in some of the high-excitation planetaries leads one to conclude that the extra ionization may be appreciable. Unfortunately, there seems to be no completely unambiguous way of allowing for the effect, quantitatively.

For the abundances of all the remaining atoms, except carbon, we rely upon measures or, in some cases, upon visual estimates of the intensities of the forbidden lines. The abundances, relative to oxygen, are therefore essentially fixed. The group as a whole, however, depends upon the oxygen/hydrogen ratio for its validity. The spectrum of carbon is represented in planetaries only by a few weak permitted lines. The process of capture is similar to that for H and He, but the estimate here given is a distinct lower limit, because additional ionization stages may be represented.

Some recent observations, by Olin Wilson of Mount Wilson Observatory, have shown a remarkable phenomenon that leads us to wonder how far we may trust our assumptions concerning the sizes of emitting volumes for different atoms. In slitless spectra, for N.G.C. 2392, the inner rings of Ne III and Ne V display very similar patterns of illumination. One would suppose that the emitting volumes for these atoms were essentially identical. Slit spectrograms clearly depict the splitting phenomenon, discovered by Campbell and Moore, for the lines of Ne III. The splitting is, equally clearly, absent or vanishingly small for the lines of Ne V.

If we interpret the phenomenon in the usual sense, in terms of an expanding shell, we are forced to conclude that the Ne III nebulosity is moving through a stationary Ne V plasma, of nearly identical appearance. No simple interpretation of this phenomenon exists at the moment. Perhaps shock-wave action, of the type discussed by Oort, is responsible. But the mere existence of the peculiar discrepancy introduces uncertainties in our interpretations of the spectra of planetaries, where a knowledge of the volumes occupied by the emitting atoms is so important a parameter.

The calculated abundances, expressed as the logarithm of the numbers of atoms on an arbitrary scale, appears in Table I.

TABLE I

Abundances from Planetaries

	log N		log N
H	10·0	F	4·8
He	9·3	Ne	6·5
C	6·2	S	5·6
N	7·2	Cl	5·3
O	7·3	A	6·2

I wish to thank Drs Olin Wilson, W. Baade, L. Aller, C. H. Ufford and J. H. Van Vleck, for making available to me the observations and data previously reported upon, in advance of publication.

5. THE ABUNDANCES OF THE ELEMENTS IN INTERSTELLAR SPACE

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The early work on gaseous interstellar matter was confined to the lines of Ca II. Even after the discovery of interstellar Na I lines, the possibility of an interstellar gas consisting of a few special elements remained. By 1938, however, there was observational evidence of the presence of gaseous hydrogen, oxygen, calcium, sodium, potassium, and titanium in interstellar space. The relative abundances of these elements seemed to agree, very roughly at least, with the relative abundances found in stellar atmospheres. Since then interstellar absorption lines of the molecules CH I, CH II, and CN have been identified.

Our present knowledge of the density and chemical composition of the interstellar gas is based on observations of interstellar atomic and molecular absorption lines, and interstellar emission lines.

Methods of analysis of observed strengths of interstellar absorption lines were developed by Unsöld, Struve and Elvey (1930), by Eddington (1934), by Wilson and Merrill (doublet ratio method, 1937), and by Dunham (empirical curve of growth method, 1939). Through the application of these methods to an increasing material of observed strengths of interstellar lines it gradually became clear that the interstellar gas (around the galactic plane)

was not uniformly distributed in space. The observations by Beals (1936) of double interstellar Ca II lines in several stars pointed in the same direction.

The work of Adams (1943) on the multiplicity of interstellar H and K absorption lines has shown that the interstellar gas is largely concentrated in separate clouds differing in radial velocity, at least as far as calcium is concerned.

The realization of this fact has necessitated a revision of the methods of analysis of the observed strengths of interstellar absorption lines, in a direction indicated by the work of Wilson and Merrill (1937). First, it is necessary to consider the effect of the radial velocity distribution of the absorbing atoms corresponding to the combination of cloud motions, internal motion in the clouds, and thermal motion. Secondly, the concentration of the absorbing atoms in clouds must be taken into account, when densities are calculated. These problems have recently been considered by Spitzer (1948), and by the author (1948).

The analysis of observed line strengths of interstellar absorption lines yields numbers of absorbing atoms (or ions) in the column between star and observer. In order to derive relative chemical abundances it is necessary to consider the state of ionization of the interstellar gas.

The early work on ionization in interstellar space by Eddington (1926), Gerasimovic and Struve (1929) and Rosseland (1936) was followed by investigations by Struve (1939) and Dunham (1939). These authors considered the role of the free electrons produced when interstellar hydrogen was ionized. The importance of hydrogen as a possible source of free electrons in interstellar space was clear after the observations of interstellar hydrogen emission by Struve and Elvey (1938) had shown that hydrogen has a very high relative abundance in interstellar space. Also, Struve and Elvey's observations with the nebular spectrograph of extended areas of hydrogen emission were direct observational evidence of the existence of vast interstellar galactic regions in which hydrogen is ionized (H II regions), while the areas with no observable hydrogen emission indicated regions of un-ionized hydrogen (H I regions). A method for calculating the extent of the H II region produced by a star as a function of the effective temperature and absolute magnitude of the star, was developed by the author (1939) and applied to the case of a uniform interstellar hydrogen gas, later to an interstellar hydrogen gas consisting of clouds (1948).

The distinction between H I and H II regions is essential in the calculation of chemical abundances in interstellar space from densities of absorbing atoms (or ions), since the number of free electrons per unit volume, for a given gas density, may well be expected to vary by a factor of more than 1000 from H I to H II regions, this being the order of magnitude of the ratio of the hydrogen abundance to the total abundance of the elements contributing free electrons in H I regions (probably chiefly carbon, also magnesium, silicon and iron).

The ionization equilibrium in interstellar space depends upon the local kinetic gas temperature. Spitzer has shown (1947) that in H I regions the inelastic collisions between hydrogen atoms and solid particles lower the kinetic gas temperatures very appreciably. Probably the temperatures are between 100° K. and 1000° K. The velocity distribution of the atomic particles in interstellar space can be assumed Maxwellian (Eddington, 1926; van de Hulst, 1946; Aller and Bohm, 1947).

It has been pointed out by Dunham (1939) and by the author (1939) that in calculating the state of ionization in interstellar space it is necessary to take account of the fact that ionizations occur practically only from the ground state, whereas recombinations occur also (and often largely) to excited states. Corresponding correction factors have to be introduced into the previously used ionization equation. Numerical values have been calculated by Bates and Massey (1941), and by the author (1948) for Ca I, Ca II, Na I, and K 5. For these atoms and ions the correction factors range from about 3 to about 1600.

An analysis of observed strengths of interstellar hydrogen emission lines yields densities of interstellar hydrogen. Work of this kind has been carried out by Struve (1939) and by the author (1939, 1948), following methods developed for planetary nebulae by Cillié (1932, 1936), and Menzel and Baker.

The strengths of interstellar molecular absorption lines have been observed in relatively few cases (Dunham, 1941), these lines being generally faint. The analysis of these observations hinges upon the determination of the dissociation and ionization equilibrium of the molecules in question in interstellar space. This problem has been attacked by Swings (1942), and by Kramers and ter Haar (1946). The results are as yet relatively rough. (The determination of the oscillator strength of the molecular lines in question also as yet presents certain difficulties.) The results derived from the molecular lines are, therefore, at present probably somewhat less accurate than those found from atomic lines.

From the observational material on interstellar absorption and emission the following picture of the interstellar gas, necessarily uncertain in many respects, is derived.

The interstellar gas is largely concentrated in clouds. In most of these clouds hydrogen is un-ionized, i.e. they are H I regions. The density of the average cloud in the neighbourhood of the Sun is about 10 hydrogen atoms cm.$^{-3}$. In between the clouds the density is probably less than 0·1–0·2 hydrogen atoms cm.$^{-3}$. There is considerable scatter in the density of the clouds, with densities as high as 50 hydrogen atoms cm.$^{-3}$ (absorbing cloud in front of χ^2 Orionis), or perhaps even more.

In the case of the dense cloud in front of χ^2 Orionis conditions are relatively favourable to the determination of relative abundances of the elements (cf. Dunham, 1939). Owing to the difficulties mentioned above regarding the molecular lines, however, the results are as yet rather uncertain. The relative abundances derived, taking account of the various circumstances mentioned above, are given below (the abundance of H being put equal to 10^6).

H	Na	Ca	K	Ti
10^6	6	10	0·4	0·2

On the whole, these relative abundances are remarkably close to those found in the stars.

With regard to the derivation of the relative abundances, the following points should be noted. In order to find the required result, it is necessary to know the number of free electrons per unit volume. This can be found from a comparison of the strengths of the Ca I line 4227 and the H and K lines of Ca II (Struve, 1939), and also by comparison of the lines of CH I and CH II (Swings, 1942; Kramers and ter Haar, 1946). However, in the case of χ^2 Orionis the Ca method is not very accurate owing to the approximate saturation of the H and K lines. Also the quantum-mechanical data are as yet very inaccurate in the case of CH II. The available data indicate an electron density around 0·2 in the case of χ^2 Orionis, as a compromise between the upper limit found by the Ca method, and the (considerably higher) rough value found from the preliminary data for CH I and CH II.

A value of the electron density which is probably not far from the truth may be derived from the observed strength of the Ca I line on the assumption that the ratio of the elements furnishing the free electrons (chiefly carbon) to calcium is equal to that found in stellar atmospheres. The important point in this connection is that the derived value of the electron density is proportional to the cube root of the hypothetical ratio. It is further assumed that we have to do with an H I region of kinetic temperature 300° K. The electron density thus found is 0·05 cm.$^{-3}$.

It should be noted that the relative abundances of H, Na, and K are practically independent of the electron density. The same is true of the geometrical mean of the abundances for Ca and Ti when compared with H, Na, and K.

For the average clouds the observational material available is much less complete. The abundance ratio of Ca and Na, however, can be derived. There is some indication that it is considerably smaller than in the dense cloud, but the calculation is as yet affected by many uncertainties, among which may be mentioned the uncertainty of the strength of the ionizing radiation in interstellar space in the wave-length region 1000–2000 A.

The H II regions have a total volume of perhaps about one-tenth of that of the H I regions in the galactic stratum in question. The average emission nebulae observed in H II regions seem to be comparable in density to the denser clouds (about 50 hydrogen

ions cm.$^{-3}$), although exceptional regions such as the centre of the Orion nebula have densities as high as 10^3 or 10^4 hydrogen ions cm.$^{-3}$ (Greenstein, 1946). It is yet an open question whether hydrogen in the H II regions is largely concentrated in clouds. This problem can possibly be solved through detailed observations of the structure of the hydrogen emission of these regions, especially if these are combined with observations of interstellar absorption lines on the spectra of stars seen through such regions.

A question that has not as yet been quite satisfactorily answered is whether or not hydrogen—in the normal H I regions—shows the same degree of concentration into clouds as, say, calcium. Increased accuracy in the analysis of the CH I and CH II lines will be important to the solution of this problem.

The investigations of Oort and van de Hulst (1946) on the building up and destruction of solid particles in interstellar space have lead to a picture according to which the interstellar gas and the interstellar solid particles are closely related and should show similar spatial distribution.

The measures of colour excesses by Stebbins, Huffer and Whitford (1940) have demonstrated that the solid particles are unevenly distributed in space and the work of Ambartsumian and Gordeladse (1938, 1940, 1944) indicates that the solid particles are probably concentrated in clouds similar in extent and number to the gas clouds (diameter about 10 parsecs, about 10^{-4} clouds per cubic parsec). It is indeed plausible to assume that the spatial distributions of solid particles and gas are generally similar (Oort and van de Hulst, 1946), although marked exceptions certainly exist (Greenstein and Struve, 1939; Morgan, 1939). (The exceptions may possibly be explained as a consequence of exhaustion of the gas through building up of solid particles.)

Spitzer (1948) has investigated the observed strengths and doublet ratios of the sodium lines for unreddened and reddened stars, respectively. He has found that the gas clouds producing the interstellar sodium lines in unreddened stars are considerably less dense than those giving rise to the lines in reddened stars. Thus the proportion of solid particles should be considerably higher in the denser gas clouds.

Problems regarding the solid particles are closely connected with the problem of the chemical constitution of interstellar matter. For although the amount of interstellar gaseous hydrogen is undoubtedly far greater than the amount of hydrogen in the solid particles, the amounts may well be comparable for other elements.

Further progress in the solution of problems regarding the abundances of the elements in interstellar space may be expected as a consequence of advances along several lines. The following points may be mentioned:

(1) Determination of the strengths of interstellar absorption lines from high-dispersion spectra for a large number of stars (cf. Adams, H. N. Russell Lecture, 1947).

(2) Extension of the high-dispersion observations to lines in the ultra-violet, especially the Na I and Ti II lines, for a not too limited number of stars. Observations of the Na I doublet of 3303 A. are especially valuable for strong Na I line absorption, when the D lines are saturated. Observations of the Ti II are a reliable indication of the total density in the column in question, largely independent of ionization condition.

(3) An extended survey of the interstellar hydrogen emission to determine the extent and properties of H II regions.

(4) Observations and analysis of emission lines of other elements in H II regions.

(5) Revision of the calculations of the ionizing radiation in interstellar space (intensity as a function of wave-length) with special regard to the far ultra-violet radiation and spatial distribution of the B stars.

(6) Improved calculations of the state of ionization and in particular the state of dissociation and ionization of molecules.

(7) Further investigations on the relations between interstellar gas and solid particles.

6. STUDIES OF STELLAR SPECTRA RELATED TO THE ABUNDANCE PROBLEM

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In accordance with the Russell-Vogt theorem, stars which have the same equation of state and the same chemical composition obey the relations

$$L=L\,(M) \quad \text{and} \quad R=R\,(M);$$

that is, the luminosity and the radius are uniquely determined by the mass. If, for a star of a given mass, we find a luminosity differing from the empirical 'mass-luminosity curve', we should then conclude that the chemical composition is abnormal: the brighter the star the smaller must be its hydrogen content and the larger must be its radius.

If we make use of the relation $L=4\pi R^2\sigma T^4$

in order to eliminate R, we obtain an alternative expression from the Russell-Vogt theorem:

$$L=L\,(T),$$

and since $T=f\,(Sp)$ we can use this relation to form for each set of abundance factors a theoretical HR diagram

$$L=L\,(Sp).$$

A family of curves with different values of X, the hydrogen abundance, and $(1-X)$, the Russell mixture, was published by B. Strömgren 15 years ago.

If a star falls within the region of the Strömgren diagram occupied by the curves, its H content may be immediately read off. If it falls completely outside the occupied area, its equation of state is not the usual one. This applied, of course, to the white dwarfs.

The empirical HR diagram contains stars in nearly all parts of Strömgren's diagram. It is therefore customary to say that we recognize the existence of stars with hydrogen contents ranging between about $X=0{\cdot}1$ and $X=0{\cdot}7$. This follows from Strömgren's own computations, as well as from Kuiper's study of Trumpler's HR diagrams of clusters. It may be noted that the dispersion in the empirical mass-luminosity relation is surprisingly small—though of course physically real. Russell has remarked that the great majority of stars with well-determined values of M and L agree quite closely with the relation derived in his and Miss Moore's work, so that the conclusion suggests itself that nearly all those *binaries* which were used in the derivation of the empirical relation $L=L\,(M)$ happen to have almost identically the same composition.

It is true that Kuiper has found appreciable departures from the $L=L\,(M)$ relation in the case of several visual double stars in the Hyades which lie above the empirical curve, and he, as well as Chandrasekhar, has stressed the fact that ζ Herculis with $M=0{\cdot}96\,M_\odot$, $R=2\,R_\odot$ and $L=4\,L_\odot$ also falls above the curve and requires $X=0{\cdot}11$ (or $\mu=1{\cdot}45$), while the Sun requires $X=0{\cdot}35$ (or $\mu=1{\cdot}00$). A recent determination of the parallax by G. Hall places ζ Her closer to the main sequence, but still appreciably above it.

Although the recent recognition of the high abundance of He will alter the numerical results, the picture, as a whole, remains essentially the same. We are therefore led to believe that some form of observational selection has resulted in our picking out a sequence of almost uniform X in the construction of the $L=L\,(M)$ diagram, while no such selection was operating in the construction of the $L=L\,(Sp)$ diagram. The fact that we know very little about the masses of the super-giants and of special groups of stars such as those with weak H, or strong Si II, Eu II, etc. may indeed account for this difference.

An obvious approach to the problem of chemical composition is thus offered through the study of (1) departures from the $L=L\,(M)$ relation, and (2) differences in the HR diagrams of closely related groups of stars, such as clusters. Both methods have been employed with notable success by Kuiper, Strömgren, and others. My approach is somewhat different. I have made two investigations:

(1) I have examined several groups of binaries in order to detect departures from the $L=L\,(M)$ relation and have then attempted to answer the following questions: (*a*) Are

there any spectrographic features which support the contention that the H-content is abnormal? (*b*) Are there any other factors involved which may explain the departures without resorting to differences in X?

(2) I have examined the spectra of members of two clusters, the Hyades and the Pleiades, in order to detect any spectroscopic features that might add or detract from the presently accepted view that the former is relatively poor in H, while the latter is richer, though not nearly as rich as the clusters near S and 12 Mon or as the ordinary galactic stars of types B and A of the main sequence.

The results of the first investigation are based mostly upon a large number of observations of spectroscopic binaries at the McDonald Observatory, although I have consulted the results of many other workers. There are, in addition to those departures which had been discussed by previous workers (Russell and Moore, Kuiper, etc.), four groups of binaries which show large departures from the mass-luminosity relation:

I. The mass-ratios of the W Ursae Majoris stars are, on the average, close to $\alpha = m_1/m_2 = 2{\cdot}0$. For some, such as V 502 Oph (Gratton), $\alpha = 2{\cdot}5$. Since in the region of the G-dwarfs $L \sim M^4$, we have $L_1/L_2 = (M_1/M_2)^4 = (2{\cdot}5)^4 = 40$ and $\Delta m = 2{\cdot}5 \log L_1/L_2 = 4$ mag. But both components are easily visible so that in reality

$$\Delta m \sim 0{\cdot}5 \text{ mag.}$$

There is a departure $\delta = 3{\cdot}5$ mag. in at least one of the components, but it is possible that both stars depart. The fainter component is in reality much brighter than can be explained with the $L = L\,(M)$ relation.

It is extremely improbable that the components have widely different X. Perhaps the velocity curves are distorted because of (*a*) the reflection effect, and (*b*) the gravity effect, but it is quite doubtful that the discrepancy can be removed in this way. I have recently proposed (see *Annales d'Astroph.*) that the stars may have a common envelope which tends to equalize the brightnesses of components of very different masses. There is no obvious relation between δ and other parameters of the stars or their orbits.

II. In the normal Algols we often find systems with very small values of K_1 and therefore with small mass-functions $f(M)$. In most of these systems K_2 cannot be observed, except as in U Sge during the total eclipse. Therefore α is unknown. But if we recognize that the spectra of the bright components have normal spectra of main-sequence type A or late B, we can assume that their masses are also 'normal' and then determine α from

$$M_1 = \alpha M_2 = \alpha\,(1+\alpha)^2 f(M).$$

In this manner we find for XZ Sgr approximately $M_1 = 3M\odot$; $\alpha = 17$; $M_2 = 0{\cdot}16M\odot$. Again, the luminosity of M_2 from the $L = L\,(M)$ relation would be some 10 mags. fainter than it is according to the light curve or according to the fact that we can photograph its spectrum during total eclipse with reasonable exposure times. Other systems of this kind are R CMa, DN Ori, BD Vir, and others.

But the departures δ range among the Algols all the way from 0 to about 10 mags. and I have found no correlation with other parameters. The spectra of at least some fainter components with large values of δ are quite normal sub-giant spectra of types G or K. The H lines are not unusually faint; on the contrary, they are strong in XZ Sgr B!

We cannot be as certain in the case of the Algols, as we were in the case of the W UMa systems, that differences in chemical composition are not involved. But the large range of the values of δ certainly is not favourable to the hypothesis. Perhaps we should first examine the possibility that evolutionary conditions have prevented the fainter components from reaching stability in the sense required by the theory of the interior of a single star. The primaries are, as far as we know, in agreement with the empirical $L = L\,(M)$ relation. The observational basis of the δ's rests upon the smallness of K_1—a quantity which, in these systems, cannot be vitiated by blending, and which is easily and reliably measured, but which conceivably could be distorted by absorption in gaseous streams.

III. Of special interest are several very massive binary systems. The best-determined data give for the empirical $L = L\,(M)$ relation about $M = 40M\odot$ with $L_{bol} = -10$ or

$L_{vis} = -7$. Plaskett's massive star HD 47129 gave larger masses, of the order of at least $85M\odot$ if the absence of eclipses is taken into account. But I have found that the fainter components in the spectrum show lines which vary erratically in radial velocity and in intensity, so that Plaskett's value of α is not reliable. It remains unknown, so that the individual masses must be larger than about $50M\odot$ each—by how much we do not know. The absolute magnitude is not known. It is probably very great—judging from the appearance of the spectrum.

More perplexing is Pearce's star HD 698 for which $\alpha = 2{\cdot}5$. With $f(M) = 3{\cdot}6M\odot$ this gives $M_1 = 113M\odot$ and $M_2 = 45M\odot$. These values are remarkable, since they exceed all others that are at present known, except perhaps those of the Trumpler stars.

But HD 698 is not a real *c*-star and its absolute visual magnitude cannot be much greater than -3. The H and He I lines (2^3P–n^3D and 2^1P–n^1D) have characteristic wings produced by Stark broadening. The H lines are relatively weak and the spectrum is of type B9s with Hα in emission. The lines of He I and Si II, Fe II, etc., are relatively strong. The star may lie above the main sequence, but it cannot have an absolute magnitude of the order of -8 or -9 on the visual scale such as would correspond to its mass (at B9 the bolometric correction is about 1 mag.).

Perhaps we have here a star of the kind of Maya in the Pleiades which (together with the other bright B-type members of that cluster) is about 2 or 3 mags. more luminous than the main sequence. If this were so, then the large mass determined by Pearce deserves special consideration. Unless for such large masses the $L = L(M)$ relation is altogether different from the one we usually accept, the departure δ would be negative, by something like -6 mags. But the empirical main sequence corresponds to about $X = 0{\cdot}34$. It seems quite doubtful that even $X = 1{\cdot}00$ would bring about so large a departure *below* the $L = L(M)$ relation. We would have to conclude that the equation of state is different—and for that there is at present no very good excuse.

It is, in my opinion, not entirely impossible that Pearce's value of α may be too large. It rests upon the measurements of K_2 and this is intrinsically difficult. My experience in the case of Plaskett's star leads me to be cautious about all values of K_2. Moreover, the second component is very faint. Petrie finds $l = L_2/L_1 = 0{\cdot}06 \pm 0{\cdot}02$ so that $\Delta m = 3$ mags. Observations made recently at McDonald (with M. Rudkjøbing) do not show the fainter component. They suggest that blending with faint lines of Fe II belonging to the primary may have affected Pearce's measures, but they do not disprove the existence of this component in the spectrum. They do justify caution with regard to α. Clearly we have here a most tantalizing case: $f(M)$ is so large for a B9 star, $\sim 3{\cdot}6M\odot$, that even with $\alpha = 1$ the mass of each component would be at least $15M\odot$, and since there are no eclipses the real masses may be considerably larger. But it is still possible that we may find that there is no great departure from the empirical $L = L(M)$ relation.

IV. The Russian astronomers Zverev, Kukarkin, and more recently Krat, have pointed out that UX UMa, with its period of only $4^h\,43^m$ has an absolute magnitude of the order of $L_v = +6{\cdot}5$. This result is very uncertain, being based upon proper motion data, but it does show that the system is intrinsically faint. In order to determine the mass-function I obtained two series of spectrograms covering the entire period. The velocity curve gives $K_1 = 250$ km./sec. and $f(M) = 0{\cdot}3M\odot$; $a_1 \sin i = 7 \times 10^2$ km. $= 1R\odot$. α is unknown, but assuming it to be $\alpha = 1$ we have minimum masses $M_1 = M_2 = 1M\odot$. The spectrum shows very remarkable changes. At maximum radial velocity there are strong absorption lines of H and He I so that Kuiper's classification as B3 is confirmed. But I count the Balmer lines to H15 and this is about normal for the class, so that at this stage there is no indication of sub-dwarf characteristics. About 15 minutes after principal mid-eclipse the absorption lines fade out almost completely. The spectrum is then practically continuous with a broad and faint Hβ emission line and it remains such until about phase $0{\cdot}75P$. The width of this line corresponds to Doppler motions of the order of ± 500 km./sec. The continuous spectrum is very blue, so that we should adopt an effective temperature corresponding to about B3, at all stages of the binary. I have not observed the spectrum of the fainter component.

This star is, of course, quite abnormal. It departs from the HR diagram in the direction of the white dwarfs and its equation of state must differ materially from that of the normal stars. The departure from the $L=L\,(M)$ relation is not striking—if we can rely upon the absolute magnitude, and our estimate $\alpha=1$. For $M_1=1M\odot$ we have $L_{bol}=+4{\cdot}5$. But the spectrum is B3, so that the bolometric correction is $-2{\cdot}0$ mag. and $L_{vis}=+6{\cdot}5$, which agrees with the Zverev-Kukarkin result from the proper motions. But if $\alpha>1$ we should have found a larger mass and thus a negative value for δ. In all probability causes other than chemical composition produce this result.

Before abandoning the subject of the δ's I want to call attention to the work of R. M. Petrie on several spectroscopic binaries with composite spectra. Of particular interest is HD 43246 with $P=23{\cdot}2$ days, $K_1=67$ km./sec., $K_2=31$ km./sec.; $\alpha=0{\cdot}45$. The brighter component is F5 with a spectroscopic absolute magnitude of $+2{\cdot}1$, the fainter—visible only through the 'window' of the strong K-line absorption of the F5 component—is B8 with an absolute magnitude of $+3{\cdot}6$ as determined from the spectroscopic difference Δm. If these data are reliable, they would imply a large negative value of δ because Petrie estimates $M_1=2M\odot$, $M_2=4M\odot$. Systems with underluminous early-type components are, of course, known even among the visual double stars: α Scorpii is an example. But W. P. Bidelman is not quite certain that the F5 components in these composite spectra are really dwarfs. If they were giants the masses and luminosities of the early-type components would be normal, but the mass-ratio α would give too small a mass for the F5 star so that the latter would not fit the $L=L\,(M)$ relation. In that case the departure δ would be similar to the one which we found in the Algols.

To summarize the results of this phase of the work, there appear to be many departures δ from the $L=L\,(M)$ relation which greatly exceed the errors of the observation. Most of these are probably not related to the abundance problem, but a few must be investigated further before a conclusion can be reached. The significance of these results lies in the fact that the mass-luminosity relation was, in the first place, derived from double-star observations. It now appears probable that many components of such systems depart greatly from the empirical curve. Hence, we should exercise caution in attributing differences of H content to stars—single or double—which fall above or below the mean curve.

The second procedure was to compare the spectra of the Pleiades with those of the Hyades. I used two sets of plates which I had obtained at McDonald for another purpose. The dispersion of the spectrograms was 40 A./mm. at λ3934. I had the advantage of being able to use the spectral types as determined by Morgan and Titus for the Hyades (*Ap. J.* **92**, 256, 1940) and by Morgan for the Pleiades (unpubl. material) based partly upon my McDonald plates and partly upon his own observations at Yerkes. The spectral types of the Pleiades range from B6 to K2, but only one member of the cluster was observed at this late spectral type. The great mass of the material ends at spectral type G0. The Hyades begin at class A1, but extend as far as F9 along the main sequence. In addition, the Hyades have the four well-known red giants whose spectral types are between G7 and K0. There are no late-type giants in the Pleiades and of course there are no B-type stars among the Hyades.

If we compare critically the main sequences of the two clusters, we find that at F9 and F8 the spectra are almost identically the same, so that even a fairly detailed study fails to reveal systematic differences between the two groups. At the other end of the main sequence where the two clusters overlap, namely at A1, the difference is most conspicuous and definitely systematic in character. The Hyades are much richer in the metallic lines, including not only Fe I and Fe II but also Ca I, Sr II, and probably Mg II and Si II. At the same time the lines of H and probably those of Ca II are much weaker in the Hyades than in the Pleiades. This effect is somewhat obscured in the case of the Pleiades because of the large rotational velocities which are frequently encountered in that cluster, but even allowing for the rotational broadening it is a most conspicuous phenomenon and one that cannot be attributed to observational effects. It is closely connected with the well-known tendency of the Hyades to possess members which Morgan described as

having metallic-line spectra. It is of course also known that these metallic-line spectra are not present in the Pleiades.

I have the impression that although not all the early and middle A's among the Hyades have been recognized as metallic-line stars, there seems to be a tendency of most members in this direction. It is true that there exists among the Hyades a marked range in their characteristics between a behaviour which differs only slightly from that of the Pleiades and that of the typical metallic-line objects. The latter have all been classified by Morgan as A stars and not as F stars. If, following Greenstein, we had described these stars as members of class F we should have found them to differ materially from the corresponding F stars of the Pleiades as well as from those normal F stars which Morgan has found in the Hyades. It is not necessary for us to decide at this stage which classification is the more correct one. The important thing is to recognize that there exists a striking systematic difference between the spectra of the Hyades and those of the Pleiades and that this difference is pronounced among the earlier types and disappears in the later ones.

It is of interest in this connection that most recent observers find that the main sequence of the Hyades falls below that of the Pleiades and even below that of the galactic stars in general. This tendency is most conspicuously shown in the work of Ramberg, who has found that the departure is greatest among the A's, F's, and G's, but disappears not far from K0. This latter point suggests that a serious error in π is not involved. Although the systematic difference in the absorption line spectra to which I have referred is hardly noticeable at F8 and even F5, it is tempting to relate the two phenomena.

The difficulty of classifying the metallic-line stars illustrates the problem we are facing when we encounter conflicting spectroscopic criteria as we always do when we examine stars of different hydrogen content. It is at present difficult and perhaps impossible to decide whether the tendency to develop the characteristic features of the metallic-line spectra may in some way be related to the low hydrogen abundance which has been suggested for this cluster. The criteria, however, are not unreasonable if considered from this point of view. Rather than attempt to predict theoretically what a star's spectrum would look like if the hydrogen abundance were small, we might consider the observed data in the light of information gathered from such a star as Upsilon Sagittarii. Greenstein's work has shown that if we analyse the spectrum by the conventional method we find a small hydrogen abundance and a relatively high abundance of helium and of the Russell mixture. Qualitatively this is the same sort of thing which we have observed in the metallic-line stars. They imitate stars of higher luminosity because they have relatively weak hydrogen lines, strong lines of other elements, spectroscopic characteristics of higher than average luminosity, and appreciable turbulence. It is not surprising that Greenstein's spectrophotometric study of the metallic-line star τ Ursae Majoris brings out precisely these characteristics. A difficulty is encountered when we consider the departures of these stars from the HR diagram. Are they members of the main sequence as previous workers have assumed, or are they several magnitudes brighter? Strömgren's original study of hydrogen abundances led us to expect that the main sequence of the hydrogen-poor clusters would lie higher than the main sequence of a hydrogen-rich cluster, but Kuiper's investigation in 1937 and Ramberg's, more recently, have placed the hot end of the main sequence of the Hyades lower than that of other stars. It seems to me that there is involved a serious difficulty because of the lack of knowledge of the precise relation between spectrum and temperature. Strömgren's curves related L with T. It is obviously not safe to apply to a hydrogen-poor cluster the same relation between T and Sp that was found correct for H-rich stars. This difficulty is illustrated by the uncertainty of placing the metallic-line stars in the HR diagram. If they are A's, then they cause the main sequence of the Hyades to curve downward at the earliest types, as it does in the work of Titus and Morgan. But if we should move these same stars over to the right until they coincide with the middle F's, their absolute magnitudes would be normal or perhaps even suggest a slight upward curvature of the main sequence.

Another difficulty in the interpretation in terms of hydrogen content arises from the great similarity of the spectra of the later subdivisions of class F, the G's and the K's.

If we had observed these same spectra without knowing that they came from different clusters we should certainly have assumed that they belong to the same spectral type and luminosity. We should have then obtained identical compositions from the equivalent widths of the spectral lines. The similarity of these spectra is really quite striking, and it was, to me at least, surprising. We must distinguish between the problem of determining absolute abundances and differences in abundance. The former is difficult and can at the very best be carried out with uncertainties of the order of a factor of 2 or by 100%. But the latter is much easier. If the curves of growth are similar, as they are in these dwarfs, it should be possible to detect differences in abundance of the order of 10%. I have not yet made any accurate measurements, but I believe that even a simple comparison of the spectra would readily reveal differences of the order of 25%.

It would be an unexpected and improbable coincidence if in these spectral classes a change in the hydrogen content would so completely simulate the spectral type and the luminosity of a star in a different part of the main sequence in the HR diagram. Hence I am somewhat doubtful about being able to attribute different compositions to the fainter members of the two clusters. It is much more probable that such a difference does play a role among the earlier spectral types.

In this connection it may be well to recall again that the B-type members of the Pleiades are systematically quite different from the ordinary galactic B stars. They are certainly more luminous than the main sequence, perhaps by as much as 2 or 3 mags. This fact led Trumpler and later Kuiper to draw in the HR diagram a curve steeply pointed upward on the side of higher temperatures than those corresponding to class A0. The similarity of this HR diagram with one of Strömgren's curves led Kuiper to the conclusion that the Pleiades had a smaller hydrogen content than the average B star in the Milky Way. It is again very difficult to decide whether the pronounced spectroscopic features of the brighter Pleiades necessarily indicate low hydrogen content in their atmospheres. The spectrum of Maya is particularly interesting because it is the only star of type B which has practically no rotation. The lines give conflicting results and do not permit us to assign to this star a definite spectral type and luminosity, unless we at the same time recognize the existence of a parameter other than temperature and pressure. On lower dispersion plates Morgan finds that the hydrogen lines of all the brighter Pleiades are fainter than they would be if the spectral type is assigned in accordance with the ratio He I to Mg II. Since this weakness of the hydrogen lines is consistent with higher luminosity he is inclined to attribute slightly later types to these brighter Pleiades than was customary when the hydrogen lines themselves served as a criterion of spectral type. This places Maya and the other bright Pleiades among the stars of types B6 to B8 with luminosities of the order of -3 to -2. There are, however, a few other B8 and B9 stars in the Pleiades which do not have these high absolute magnitudes and whose hydrogen lines are normal.

The weakness of the hydrogen lines in Maya, together with the relatively great strength of Mn II and Fe II and the simultaneous strength of He I, all combine to indicate fairly high luminosity of the order of -2 or $-2{\cdot}5$. Again, at least qualitatively, the spectroscopic criteria are in accordance with the hypothesis that the hydrogen content of the atmosphere is relatively low.

Since it must be even lower in the Hyades, it is reasonable to suppose that because of the short life times of the B-type stars they have already exhausted their supply of energy provided by the Bethe cycle and have been transformed into other types of stars. This would account for the absence of B stars in the Hyades and other hydrogen-poor clusters.

Again, as in the case of the Hyades, we must conclude that the spectra of the fainter and cooler Pleiades are not appreciably different from those of the great mass of galactic stars.

If present theories may be relied upon, it would perhaps be reasonable to suppose, as Vogt has done in his recent book, that only the original content of a cluster was the same for all its members. In the Hyades the B-type stars may have completely exhausted their supply of hydrogen so that they have disappeared as B stars. The A's and perhaps early

F's are deficient in hydrogen, but the later type members whose evolution proceeds much more slowly have not been greatly affected throughout the history of the cluster. In the Pleiades we must then assume that the B-type stars are in the process of burning up their supply of hydrogen while the A's, F's, G's, etc., still have their original composition. Finally, the great mass of galactic B and O stars are rich in hydrogen because they are relatively young, and we observe them only when they are producing the required amount of energy to give us a spectrum of class B.

In one way this picture differs from that proposed by earlier workers. I assume that the hydrogen content was at first essentially the same in all clusters and in the great majority of the stars of our galaxy. This is much more satisfactory, since we all seem to agree that stars are formed out of interstellar matter, and that in the course of their lives they throw back a part of their substance into the diffuse medium. The composition of the medium and that of young stars is about the same. I therefore suggest that we are concerned more with the evolutionary ages of the clusters, which may not necessarily be identical with ages measured on the ordinary time scale. On this picture then, the Hyades would represent an old cluster, the Pleiades a younger cluster and the greater mass of galactic O and B stars a group of particularly young objects.

I realize that the data at our disposal are entirely insufficient to resolve the many difficulties which this or any other hypothesis would involve. A disturbing thought arises immediately when we consider the wide range in L for a given spectrum, among the late B stars of the Pleiades and among the A stars of the Hyades, or when we examine the two distinct branches in Eggen's recent Colour-Absolute Magnitude diagrams of the Hyades and Coma clusters. It is not at present possible to overcome these difficulties, except by taking refuge in the fact that conflicting criteria prevent us from assigning these stars to their proper temperature classes. One of the most fruitful types of investigation would undoubtedly be the extension of Trumpler's work with the help of spectrograms of high dispersion. This can now be done for at least some of the clusters, and I conclude this report by expressing the hope that in the next few years stellar spectroscopists will make use of the facilities of the great telescopes and powerful spectrographs in order to elucidate some of the points I have raised.

7. THE ABUNDANCES OF THE ELEMENTS IN STELLAR INTERIORS

By F. Hoyle

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Provided it is assumed

(*a*) that the contribution of electron scattering to the opacity is negligible,

(*b*) that the distribution of the chemical elements is uniform throughout the star,

it can be shown that

$$L=\frac{A\,(\mu\beta)^{7\cdot5}\,M^{5\cdot5}\,R^{-0\cdot5}}{\tau\,(1+x)\,(1-x-y)}, \tag{1}$$

$$R=B\,(\mu\beta)^{0\cdot5}\,M^{0\cdot7}, \tag{2}$$

where τ is the guillotine factor, and

$$\mu=4/(6x+y+2),$$

$$(\mu\beta)^4/(1-\beta)=CM^2,$$

define μ, β when M, X, Y are given. A, B, C are known from calculation, and, to within a sufficient approximation for present purposes, may be regarded as constants. When (*a*) is changed to the opposite hypothesis (*c*) that the opacity is wholly due to electron scattering, the results (1), (2) are altered to

$$L=D\,(\mu\beta)^4\,M^3/(1+x), \tag{3}$$

$$R=E\,(\mu\beta)^{0\cdot6}\,M^{0\cdot75}, \tag{4}$$

where again, to sufficient approximation, the known quantities D, E may be regarded as constants.

The calculation of L is not much affected by hypothesis (b), but the formulae for R depend very sensitively on this assumption. It has been demonstrated* that a certain type of distribution, in which μ is appreciably less in the atmosphere than in the core of the star, leads to a large increase of radius (above the result given by the uniform model). Lyttleton has examined in detail a case where the extension in radius is by a factor of more than 40. Since this type of distribution for μ is exactly what we should expect from the conversion of hydrogen to helium, taking place within the core, it is clear that assumption (b) must be eschewed if we are to confine the present investigation to the most trustworthy considerations. Accordingly, we must drop (2), (4) and regard R as given by observation.

Our main purpose is to reach a decision between the hypotheses (a) and (c). As is well known, the observed luminosities of stars with masses $\geqslant 1{\cdot}5\ \odot$, if expressed empirically as a power of M, are best represented by

$$L \propto M^{3{\cdot}5}.$$

This gives a closer correspondence with (3) than with (1), and therefore suggests that (c) be adopted for stars in this mass range. This conclusion is confirmed by a detailed inquiry. Thus, using data given by Kuiper in his discussion of the empirical mass-luminosity relation, it is found that

(i) hypothesis (a) requires μ to decrease with increasing mass,

(ii) hypothesis (c) requires μ to increase with increasing mass.

The second alternative is much to be preferred, because the fraction of the original hydrogen converted into helium by thermonuclear reactions, must, on the average, increase with increasing mass. Accordingly, since such a conversion has the effect of increasing μ, we have a clear indication that case (c) should be adopted for stars with masses $> 1{\cdot}5\ \odot$.

When we turn to stars with masses $< \odot$ we meet a somewhat different state of affairs. The observational data then fit an empirical relation

$$L \propto M^{4{\cdot}5},$$

which is midway between (3) and (1). It appears therefore that the opacity changes from being predominantly due to electron scattering for masses $> 1{\cdot}5\ \odot$ to being predominantly of Kramers' form for masses $< \odot$. For the Sun we accordingly expect the two sources of opacity to make roughly equal contributions. This inference is confirmed by direct calculation, which shows that, for the conditions of density and temperature occurring in the central regions of the Sun, the opacity due to free-free electronic transitions in hydrogen (Kramers' form) is closely comparable with the opacity due to scattering by electrons. It is particularly to be noticed that no contribution from heavy elements is required. This means that elements such as Ca, Fe must have an abundance appreciably less than 1% by mass. C, O, on the other hand, can have abundances of several per cent. without affecting the opacity. These requirements are consistent with the heavy elements abundances found for the reversing layer of the Sun. Accordingly, there is no reason to believe that the composition of the interior of the Sun differs markedly from the constitution of the atmosphere, except in the helium to hydrogen ratio which may be expected to take its largest value in the energy-generating core.

* F. Hoyle and R. A. Lyttleton, *Mon. Not. Roy. Astr. Soc.* **102**, 177, 1942.

8. ON THE THERMODYNAMICAL THEORY OF THE ABUNDANCE DISTRIBUTION OF CHEMICAL ELEMENTS

By O. KLEIN

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As is well known, the attempts to develop a thermodynamical theory for the abundance distribution of chemical elements, although very promising, have met with great difficulties. Thus, on suitable assumptions about the temperature and the density of the original distribution of matter, it has been possible to give a fairly satisfactory account of the relative abundance of the lighter elements up to mass numbers of about 60, but, on the other hand, these same assumptions lead to impossibly small values for the heavier elements, those of the upper end of the periodic table coming out so rare that there would be a negligible chance of finding a single atom of them in the known parts of the universe (1). I shall review now some attempts to overcome the difficulties mentioned, which, although by no means completed, would seem to strengthen considerably the arguments in favour of the thermodynamical theory.

Thus Beskow and Treffenberg (2) have investigated the distribution within a star in temperature equilibrium embedded in radiation corresponding to the temperature in question taking into account the gravitational field not only of the matter inside the star but also of the radiation.

The relation between the concentrations of the different kinds of atomic nuclei, including protons and neutrons, in a temperature equilibrium are most easily expressed if the chemical potential introduced by Gibbs is used. Thus, let C_τ be the number of particles of the kind τ in unit volume, $\theta = kT$ the temperature modulus (k = Boltzmann's constant), M_τ the mass of the particle in question and E_τ its energy; then, according to classical statistical thermodynamics (neglecting quantum effects), the chemical potential μ_τ is defined by means of the relation

$$C_\tau = g_\tau \left(\frac{2\pi M_\tau \theta}{h^2}\right)^{\frac{3}{2}} \exp\left(\frac{\mu_\tau - E_\tau}{\theta}\right), \tag{1}$$

where h is Planck's constant, g_τ the multiplicity of the state of the particle in question (equal 2 for a proton or neutron due to spin), and where μ_τ and E_τ are measured from the same arbitrary zero-point. If the particle in question is an atomic nucleus consisting of N_τ neutrons and Z_τ protons, then the chemical equilibrium between the different possible compound systems is expressed by means of the simple relation

$$\mu_\tau = N_\tau \mu + Z_\tau \lambda, \tag{2}$$

where μ and λ are the chemical potentials of neutrons and protons respectively, and where for E_τ in (1) we may take the binding energy of the nucleus in the state in question. If the binding energies and multiplicities of all possible nuclei, in all possible states of excitation, are known, the distribution will, according to (1) and (2), be completely determined by means of the three parameters λ, μ and θ.

While for atomic nuclei the quantum-theoretical modifications of statistical thermodynamics will in general be negligible, playing a role only for the neutrons at the very highest concentrations occurring, they are of decisive influence in the case of electrons. Here the relation (1) has to be replaced by the following formula

$$C_e = \frac{8\pi}{h^3} \int_0^\infty \frac{p^2 dp}{\exp\left(\frac{E(p) - \mu_e}{\theta}\right) + 1}, \tag{3}$$

where $E(p) = c\sqrt{(m^2c^2 + p^2)}$ is the relativistic energy of the electron of rest mass m as a function of its momentum p, c being the vacuum velocity of light. Owing to the reaction neutron $\rightleftharpoons$ proton + electron + neutrino, there will be a relation between the chemical

potentials of the four particles in question which, assuming the potential of the neutrinos to be zero as in empty space, will take the following form

$$\mu_e = \mu - \lambda + \tfrac{1}{2}(M_n - M_p)\, c^2, \tag{4}$$

where M_n and M_p are the masses of neutrons and protons respectively. Thus the concentration of the electrons will also be given as a function of the three parameters λ, μ and θ, and the same will be the case with the positrons, their potential being equal to $-\mu_e$. As to the neutrinos and the electromagnetic temperature radiation they are given as functions of θ alone. We see thus that the electric density as well as the mass density will be a function of the three parameters in question.

At a given point in space the equilibrium is thus determined by the local values of λ, μ and θ and the problem now arises how these three parameters vary from point to point. Neglecting the modifications of general relativity theory, θ will be constant throughout space, while λ and μ according to Gibbs are governed by the following two conditions for the gravitational and electrical equilibrium respectively

$$M_n \phi_g + \mu = \text{const.}, \tag{5a}$$

$$M_p \phi_g + \epsilon \phi_e + \lambda = \text{const.}, \tag{5b}$$

where ϕ_g and ϕ_e are the gravitational and electrical potentials respectively at an arbitrary point of space and ϵ the electric charge of the proton. To these equations we have to add the Poisson relations in differential or integral form between the potentials and the corresponding densities.

The obvious way of procedure is now to replace the equation (5*b*) by the condition of electrical neutrality, which, owing to the enormous electric forces created even by a small deviation from this state, will be satisfied to a high degree of approximation. The relation between λ and μ following from this condition has been worked out by Beskow and Treffenberg for $\theta = 1$ Mev and by Beskow for $\theta = 0{\cdot}5$ Mev, using for the unknown nuclear binding energies an extrapolation formula given by Mattauch and Flügge, expressing the binding energy of the ground state of an arbitrary nucleus as a function of its charge number Z and mass number $A = N + Z$. Moreover, the influence of excitation, which is not very fundamental at the temperatures chosen, was estimated by means of well-known approximate formulae.

Using the λ-μ-relation for a given temperature the total mass density at an arbitrary point was expressed in terms of the value of μ at the same point. Applying this to a centrally symmetrical star model the following procedure was used. From equation (5*a*) it follows that

$$\frac{d\mu}{dr} = -M_n \frac{d\phi_g}{dr} = -G \frac{M_n M(r)}{r^2}, \tag{6}$$

$M(r)$ being the mass contained in a sphere of radius r around the centre of the star passing through the point in question and G the gravitational constant. If now μ and M are known for a certain value of r, equation (6) together with the equation

$$\frac{dM}{dr} = 4\pi r^2 \rho(\mu) \tag{7}$$

allows the calculation of μ, ρ and M for arbitrary values of r.

In the actual calculation of most of their models Beskow and Treffenberg have made use of the fact that according to the formula mentioned above for the binding energy of an atomic nucleus at a certain μ-value ($\sim 5{\cdot}7$ Mev) condensation into nuclear matter of arbitrary size will take place. Thus they have assumed the inner part of the star to consist of a core of such nuclear matter of a density of $\sim 10^{14}$ g./cm.^{3} starting the numerical integration of equations (6) and (7) at the surface of this core where, the radius given, M as well as μ is known. In some models they have started from the centre of the star with a μ-value $< 5{\cdot}7$ Mev.

While in the inner parts of the star model the material mass density will dominate, in the outer parts the mass density due to radiation (including electrons, positrons and neutrinos) will be predominant, so that, denoting the mass density of the radiation by ρ_s, equation (6) will here take the form

$$\frac{d\mu}{dr} = -GM_n \frac{4\pi}{3} \rho_s r \quad \text{or} \quad \mu = \text{const.} - G\frac{2\pi}{3} M_n \rho_s r^2; \tag{8}$$

from which follows for the material mass density (neutrons and protons being here predominant over other nuclei)

$$\rho \sim \exp\left(-G\frac{2\pi}{3}\frac{M_n \rho_s r^2}{\theta}\right). \tag{9}$$

Owing to this the star will have a finite mass and a comparatively well-defined radius, which in most of the models considered is about 10^{10} cm., the density ρ_s being $\sim 10^6$ g./cm.^{2} at the higher temperature and $\sim 10^5$ g./cm.^{2} at the lower temperature considered.

The results of the work of Beskow and Treffenberg are exemplified in the following table:

Abundances of certain nuclei in models with close-packed cores of radius $r_0 = 5 \cdot 10^5$ cm. at the two temperatures $\theta = 1$ Mev and $\theta = \frac{1}{2}$ Mev.

At 1 Mev the total mass is ~ 40 Sun-masses, which is the case for several models at this temperature, at 0·5 Mev the mass is ~ 5 Sun-masses, while the masses of the other models vary between 1 and 10 M. The abundances are given in powers of ten and related to hydrogen.

Element	H^1+n	He^4	C^{12}	30*	60*	90*	120*	180*	240*
$\theta = 1$ Mev	10·0	7·8	3·9	3·7	3·6	2·1	1·1	−0·1	+0·2
$\theta = \frac{1}{2}$ Mev	10·0	8·5	1·8	1·7	5·7	3·8	3·1	2·8	1·3
Empirical	H^1	He^4	C^{12}	Si^{28}	Fe^{56}	Zr^{90}	Sn^{120}	W^{184}	U^{238}
(Goldschmidt)	10·0	8·6	8·0	6·6	6·55	2·5	1·6	1·3	0·0

* Total abundance of nuclei with the given mass number, calculated on basis of Mattauch-Flügge's general expression for the binding energies. For comparison Goldschmidt's values are given for the most abundant of the adjoining elements.

As is seen from this table, both temperatures, and particularly the lower one, which with respect to the total mass would at first seem preferable, give much too small abundances for the common elements in the neighbourhood of oxygen, not only in comparison with hydrogen but also compared with the heavier elements. It is probable that a temperature somewhat above 1 Mev will give better abundances for these elements. Since this would seem to be a more crucial point than the total mass, one would then have to try the assumption that a considerable part of the mass, mainly consisting of hydrogen, is lost during and after the explosion mentioned below, not only from the stars but even from the galactic systems to which they belong. The resulting hydrogen content of intergalactic space would, however, seem to be hardly above the present limit of observability.

The most important result of the investigation reviewed here seems to me to be the fact that there is a range of models *where the abundance of the lightest and the heavier elements is of about the right order of magnitude and that the corresponding stars have masses of the order of magnitude of real stars.*

In connection with this work the question of the equilibrium of the radiation itself and its bearing on the transition to the present state of the universe will be shortly reviewed. Here the starting-point is the fact that a homogeneous universe of the high density of the radiation at the temperature in question (10^5–10^6 g./cm.^{3}) would either have a comparatively very small mass and radius or would have a very short life due to its rapid expansion. Thus, a total mass exceeding considerably 10^5–10^6 Sun-masses would lead to an expansion velocity whereby the density would fall to its half value in a time of the order of magnitude of a second. In order to surround all stars in a quasi-stationary way by an atmosphere

of such dense radiation it would thus be necessary to assume an accumulation around each star separately. An estimate of the mass of the radiation belonging to a single star might be obtained in different ways with approximately the same result. We might consider for instance a closed world and require that its density should be such that the velocity of expansion were momentarily equal to zero. This would give for the radius R and the mass M the expressions

$$R=\left(\frac{3c^2}{4\pi G\rho}\right)^{\frac{1}{2}}, \quad M=\left(\frac{27\pi c^6}{16G^3\rho}\right)^{\frac{1}{2}}, \tag{10}$$

giving with $\rho=10^6$ g./cm.^{3}

$$R=5{\cdot}7\times10^{10}\text{ cm.}, \quad M=1{\cdot}8\times10^6\,M_\odot,$$

where $M_\odot$ is the mass of the Sun. We see that the value of R is not very much larger than the radii of the Beskow-Treffenberg star models.

In order to get a somewhat clearer idea of the conditions governing such radiation stars a static solution of the Einstein equations of general relativity corresponding to a centrally symmetrical distribution of radiation has been investigated(3) with results very similar to those of Emden for an ordinary isothermal gas under the influence of its own gravitational field. Thus, at great distances from the centre, the density approaches more and more the singular solution

$$\rho=\frac{3c^2}{16\pi G}\cdot\frac{1}{R^2}, \tag{11}$$

and in a solution with the density 10^6 g./cm.^{3} for $R=0$ it has fallen to half its value for $R\simeq5{\cdot}10^{10}$ cm.

In close connection with the question of the quasi-stability of the radiation at the initial state stands the question of its disappearance in a later state of the universe by means of an accelerated process, the latter stages of which must have been very rapid. The reason for this may be sought in the decrease of the gravitational forces of the radiation itself, which in the beginning have maintained a state of approximate equilibrium. The radius of the star models being of the order of magnitude of a light-second, the latter stage of the disappearance would on this view take only a few seconds. The sudden disappearance of the large part of the gravitational force due to the radiation would lead to a violent explosion of the star and a corresponding rapid decrease of its density. At the same time the disappearance of the neutrinos would initiate a series of nuclear processes, the most important ones being such β-processes whereby the enormous neutron excess is removed. This again would entail a general decrease in reaction velocities, so that the freezing-in of the main features of the original state would not seem excluded.

In connection with the radiation the question of the evolution of the stellar systems should also be mentioned. Thus, it is reasonable to speculate on a primary quasi-statical state not only of each galactic system separately but also of the metagalactic system, the gravitational effect of the radiation contributing to the approximate equilibrium. On such an assumption the removal of the radiation would entail a process of evolution of the stellar systems and may possibly also constitute the beginning state for the expansion of the metagalactic system. This would raise a number of dynamical problems the solution of which may perhaps give a clearer view of the original distribution of the radiation density in the universe.

My thanks are due to Dr G. Beskow for his kind help during the preparation of this note.

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9. SUMMARY AND CONCLUSIONS

By OTTO STRUVE

The problem of the abundances of the chemical elements in the universe had its beginning almost 20 years ago when Russell published his fundamental paper on the composition of the reversing layer of the Sun. Since all the later investigations have been based upon this investigation, it will be of interest to you to hear an excerpt from a recent letter by Prof. Russell:

It may be pardonable to remark that the reconnaissance by my colleagues and me 20 years ago is a rather remarkable example of the results of an approximate theory applied to empirical estimates of low accuracy. The relative abundance of the commonest and the rarest elements was overestimated by a factor of the order of 10 and the absolute abundance of the former by about the same factor. Owing to ignorance of the correct damping factor the values given for the elements lighter than sodium were based on scanty uncalibrated data and extreme extrapolation. Fortune appears to have been remarkably kind to audacity. It is much to be hoped that accurate determinations for all the elements will soon replace this exploratory work. The successful study of the solar atmosphere may be attributed to its being nearly in thermodynamic equilibrium—at least for most radiations. The central parts of H and K and of the Mg II pair near λ2800 and still more the He absorption near λ10,830 would probably tell a different story. We are also fortunate in the wave-length region available for ordinary observation. If we had to work in the region short of λ2500 where the molecular absorption appears to distort the solar energy curve enormously, or long of λ15,000 where telluric absorption is heavy and solar lines feeble, the problem would be far more difficult.

Enormous progress has been made in determining the composition of the Sun's atmosphere and as we have learned from Prof. Minnaert's paper the advance was brought about partly by the creation of a more exact theory of the formation of an absorption line, partly through the determination of theoretical and accurate laboratory intensities of different lines and partly through better observations of the kind we now have in the photometric atlas of the solar spectrum.

Nevertheless, as Minnaert has pointed out, there are relatively large differences between the determinations made by different methods. It should be possible to measure the absorption of a spectral line to at least 10% of its value. Yet, as Minnaert has remarked, an incorrect assumption concerning the temperature may produce a difference in the resulting abundances by factors of the order of several hundred. No wonder then that he and other workers prefer to use methods which avoid these large uncertainties in the Boltzmann factor.

The theory of the formation of an absorption line has entered explicitly or implicitly into the results of almost all the workers in this field. It was referred to not only by Minnaert and Hunaerts, but also by Unsöld and Strömgren. One advance which is now possible results from the application of Chandrasekhar's exact theory of the Milne-Eddington transfer problem. Following Chandrasekhar, Marshal Wrubel has computed

a set of curves of growth, all based upon the exact theory, with η, the ratio of the absorption coefficient in the line to the continuous absorption coefficient, considered constant within the atmosphere. Wrubel has used as the parameters the ratios of the coefficients in the linear expansions of the Planck function with optical depth and the damping constant expressed in the usual way in terms of the Doppler broadening b. I am showing on the screen a set of his curves for one specific value of the first parameter and for six values of the damping constant. These curves of growth differ quite appreciably from those which Unsöld computed with the Minnaert approximation making use of the expression $1/R_c$. Chandrasekhar tells me that in some parts of the curves, notably those where $\log \eta_0$ is 0·8, Unsöld's curves run higher, so that the transition is less gradual than in the case of this exact theory. Different sets of curves computed with different values of the first parameter differ very greatly. Wrubel points out that if the observational data are approximated by means of a family of curves using the wrong ratio of B^0/B^1, the result may often be a serious error in the turbulent velocity and in the damping constant. Chandrasekhar is of the opinion that Wrubel's new curves of growth should be used in preference to other theoretical curves.

The seriousness of this problem is emphasized by some comments which I have recently obtained from Lawrence Aller and from K. O. Wright. The former has reduced his observations in several different ways. For γ Pegasi he obtains appreciable differences depending upon whether he uses Unsöld's method or Strömgren's curve of growth. For the ratio of H to O in this main-sequence B2 star he finds a value of the order of 10,000, which disagrees with the results from other stars. For τ Scorpii Unsöld finds 1000. Yet Aller is not prepared to attribute reality to this difference because there are large uncertainties not only from the choice of the theoretical curve of growth but also from possible departures from thermodynamic equilibrium. Similarly, K. O. Wright has experimented with different curves of growth in the case of stars of type F. He finds similar relative abundances in Procyon and the Sun and he also concludes that the giants agree among themselves. He suspects that the giants differ slightly from the dwarfs, with sodium and yttrium more abundant in the giants and with magnesium and silicon less abundant. Despite the importance of these results Wright and the other observers have all felt the need for a more exact set of theoretical curves of growth.

I hope that these details do not obscure the main purpose of this symposium. We have here been concerned with a problem of method. As the previous speakers have pointed out, our purpose is to determine the relative numbers of atoms of different elements within unit volume of stellar substance. We observe only a thin outer fringe and the spectroscopic results apply only to that fringe, but Hoyle, among others, has indicated that the stirring of the stellar substance through convection may be sufficient to bring about a uniform distribution of the elements. If this were absolutely certain, it would greatly simplify the entire problem. I understand, however, that some theoretical astrophysicists are not completely convinced that the stirring actually is adequate. I have only recently learned that Dr Ledoux of Liège has taken the opposite view. I hope that in the discussion at the end of this session he will tell us briefly about his work. Dr G. Gamow also recently wrote me that in his opinion 'the abundance of elements in stellar atmospheres must have very little to do with the reactions in the central regions.... How else could one understand the presence of Li, Be and B in the solar atmosphere in view of the fact that these nuclei would be completely destroyed in a few minutes under the conditions near the sun's centre? How else could one understand the presence of H in the white-dwarf atmospheres when we are sure now, after Kuiper's revision, that there is no H inside these stars?'

Most of the speakers have emphasized the problem of determining what might be called the absolute abundances of the elements. Perhaps the most striking result of the discussions is the remarkable degree of uniformity that has been observed in the most widely different astronomical sources. The sun, the main-sequence stars of type F and the He stars like Tau Scorpii and even the O-type star 10 Lacertae have all approximately the same composition. The observers tell us that the precision with which the abundances

are now determined corresponds to a factor of perhaps a little better than 2 or 3. Even more surprising is the fact that Strömgren's result for interstellar matter and Menzel's for the planetary nebulae also indicate a composition that is essentially the same as that of the normal stars. Even the interiors of the stars as investigated by Hoyle and others lead essentially to the same composition. Not many months ago Martin Schwarzschild made use of the mass-luminosity relation and of the energy-generation equation in order to determine the hydrogen and helium content of the Sun. His result lead to a ratio of hydrogen to metals or, as we say, of hydrogen to Russell mixture, that was considered to give an excessive amount to the metals. More recently Mrs Harrison has repeated Schwarzschild's computations through the addition of a separate parameter—the abundance of the elements of the oxygen group. These elements differ appreciably from the metals because at temperatures above about 2×10^7 degrees they rapidly become less efficient absorbers. The metals which are not stripped to the bare nuclei at these temperatures retain their high opacity. In this manner Mrs Harrison was able to adjust the observed mass and luminosity of the Sun by assuming a composition by weight of 59% of hydrogen, 30% of helium, 9% of the oxygen group and 2% of the metals. This is not unreasonable from the observational point of view.

The first conclusion of this symposium is the establishment of a list of what we might call the normal abundances of the elements in the universe. These abundances seem to have the character of a universal law of nature. They strikingly reflect the well-known terrestrial scarcity of lithium, beryllium and boron and they also bring out Harkins's rule concerning the relative abundances of the even and odd atomic numbers. It is with this normal distribution of the elements that Prof. Klein has been concerned in his analysis of the conditions that might have produced the heavier elements.

Our next big problem was to consider possible departures from the normal abundances. We are here encountering some disadvantages but also some decided gains. The stars which we suspect of having unusual abundances are often faint and therefore not within the reach of our most powerful spectrographs. Moreover, few of them are binaries, so that we are lacking the important information provided by the mass and even the luminosities of some of these stars and their temperatures are usually not known with the precision we would require for a complete analysis. However, there are also two important advantages. The first consists in the fact that we do not necessarily have to determine absolute abundances but may sometimes be satisfied with differential measurements against normal stars or against other stars of certain known characteristics. I have used this method in my discussion of the two galactic clusters. The second consists in the conspicuousness of the observational features and the ease with which they are measured.

Some of these important problems have only been touched upon in this symposium. Unsöld has already commented upon the metallic-line stars. They form a large group of objects with conflicting criteria so that if we use the hydrogen lines or the calcium line K we obtain spectral type A, while if we use the lines of the neutral and ionized metals we find a middle F. Greenstein has made a thorough investigation of some of these stars and if his results are interpreted in the conventional manner, there is no escape from the conclusion that certain elements, such as calcium, scandium, zirconium, and magnesium, have abundance deficiencies by a factor of 10, and that, as you know, is a large quantity when it is reflected directly in the equivalent width of an absorption line. Greenstein has struggled with this problem for a long time. Why should it be that these particular elements are deficient and is the deficiency real or only apparent? Unsöld has remarked that differences in turbulence may cause spurious abundances, but Greenstein finds that this alone will not account for the observations. After a long search he found that when he plotted the observed deficiencies against the second ionization potentials of the elements involved a definite regularity became apparent. All elements with second ionization potentials between 11·8 V. and 16 V. are deficient and no others. This range of potentials is close to the ionization potential of hydrogen, namely 13·5 V. However, they were not all on one side of 13·5, being distributed somewhat unsymmetrically about this value,

the maximum deficiency occurring for calcium at 11·8 V. and for scandium at 12·8 V. Greenstein correctly concludes that the hydrogen ionization potential must have something to do with the observed distribution. He has advanced two possible explanations, one in terms of Lyman emission lines and another in terms of a quantum-resonance collisional process in which a proton may remove an electron from a singly ionized metal and thereby cause an excessive ionization of those metals whose second ionization potentials are close to 13·5 V.

I have dwelt upon this result because it demonstrates how careful we must be in attributing reality to observed discrepancies in the abundances. At the same time we must not lose sight of the fact that some physical cause must exist that somehow produces the anomaly of the metallic-line stars but fails to produce it among the normal stars of similar effective temperature. I have already suggested in my own contribution to this symposium that the evidence from the Hyades suggests that we are, after all, concerned in the case of the metallic-line stars with a peculiar condition resulting from an abnormally low hydrogen content. If this were so, then we should be observing not so much the direct anomaly of the hydrogen scarcity which, incidentally, would not be very apparent by itself because the continuous absorption coefficient is also due to hydrogen so that the ratio of line absorption to continuous absorption would hardly be affected.

Another important group of stars with anomalous observed line intensities are those which resemble Upsilon Sagittarii. Unsöld has referred to these stars and attempted to explain them as a result of super-excitation. I believe that I must agree with Russell and Greenstein rather than with Unsöld that these stars cannot be simply explained in terms of a factor ϕ which measures the departure from the ordinary Saha ionization. Greenstein's most important result is the weakness of the hydrogen lines compared with the metals as well as to helium. It is this weakness which is also striking in the case of Popper's helium star HD 124448 and of Bidelman's recently discovered star HD 30353. The latter seems to form a transition between Upsilon Sagittarii and R Coronae Borealis. The former extends this unusual sequence towards the higher members. I agree with Greenstein, Popper and Bidelman that it is at present impossible to explain the almost complete absence of the Balmer lines through any known physical process. Because the hydrogen lines are so strong in the shells and even in the nebulae I am inclined to believe that these reversing layers are really deficient in hydrogen. But it would be unreasonable at this time to attribute this deficiency to any particular process such as the carbon cycle. Although I do not wish to draw a close parallel between the two cases, it does strike me forcibly that in the nebula surrounding the B3 sub-dwarf companion of Antares there are no hydrogen emission lines, but only the forbidden lines of Fe II. This case may have some similarity to the deficiency of hydrogen in the planets, satellites, comets and meteors. Perhaps we should not altogether lose sight of the possibility that gaseous masses could have been formed around certain stars through the vaporization of solid particles or chunks of matter which had previously lost their hydrogen content through causes altogether different from those that are involved in the carbon cycle. The possible association of Upsilon Sagittarii and Bidelman's star with R Coronae and the old theories of smoke-screens which produce the light variation of this famous variable lend some degree of respectability to the hypothesis I have suggested.

Among the anomalous A-type stars, those with strong lines of the rare earths deserve particular attention. Why should europium, for example, be unusually abundant in such a star as α Canum Venaticorum or β Coronae Borealis? A partial answer has been given in a paper presented last month by H. W. Babcock at a meeting of the American Astronomical Society. Many of these peculiar stars have strong magnetic fields. In at least one of them, HD 125248, the magnetic field varies between a large positive and a large negative value. When the magnetic field is strong the lines of europium are split into numerous Zeeman components. These components are blended, producing a broadened line. The result is a striking change in the curve of growth. When the magnetic field is strong the europium lines appear greatly enhanced. When the magnetic field is absent they are weak. I am sure that those who have not been previously acquainted with Babcock's

work will be as surprised as I was when Babcock announced that the line $\lambda 4205$ of europium II is enhanced by a factor of almost 10 when the field reaches its maximum value of 7800 gauss. This tremendous effect rivals that of turbulence in producing a change in the curve of growth. It almost certainly suffices to eliminate a large number of previously suggested anomalies in composition among the A-type stars.

I must next refer to the remarkable results of McKellar, Herzberg, and others on the abundances of certain isotopes. McKellar has sent us an account of his work on the carbon isotopes C^{12} and C^{13}. On the Earth the ratio is about $C^{12}/C^{13}=90$. In the N-type stars McKellar and Herzberg invariably find a much greater abundance of C^{13}. In the R-type stars, however, McKellar finds for three stars a ratio C^{12}/C^{13} greater than 50 which could well be similar to that of the Earth. But in 15 stars the ratio is between 3 and 4. It seems at present impossible to explain these differences either through the curve of growth effects or through any other simple processes. McKellar points out that two suggestions may be made: Klein, Beskow, and Treffenberg had found in their closely packed cores that values of the ratio between 10 and 50 may be produced in thermal equilibrium at about 1 million eV. This would in effect mean that the unusual abundances were formed in the prestellar state of the galaxy. The other suggestion is one advanced by Fermi. It presupposes that in the original medium the ratio was about 3. Since the capture cross-section of the nuclei of C^{13} for protons is about 70 times larger than that of C^{12}, the ratio would gradually change as a result of the carbon cycle from its original value of about 3 to its final value of around 70. This would, of course, mean that the Bethe cycle must have been operating for a long time, and the question to which as yet we have no answer is whether the effectively complete conversion to a ratio of even more than 70 in the Sun, the Earth and many stars would not at the same time require a pretty far-going degree of conversion of hydrogen into helium? It should be easy to give the answer, but I do not believe that this has been done. McKellar writes me that low C^{12}/C^{13} would indicate youth; high C^{12}/C^{13} would indicate more advanced age. But because of the extremely high temperature coefficient of the nuclear reactions the transition stage would be short. The conversion of H into He would start when the Bethe cycle goes into operation and would continue long afterwards. It would be reasonable to expect that in the stars with small C^{12}/C^{13} the ratio H/He would be as great as or greater than in stars with large C^{12}/C^{13}. There should be some interesting observational tests of Fermi's suggestion, and McKellar is working on some of them. Dr G. Shajn of the U.S.S.R. has also sent me some very interesting new results on the relative strengths of the bands of $C^{12}N^{14}$ and $C^{13}N^{14}$ in the N3 star Y Can Ven.

It is of interest that O. C. Wilson found for interstellar space that the ratio must be larger than about 5. Hence, it is not impossible that the interstellar medium may have a composition that would, on Fermi's hypothesis, correspond to the original condition.

We have not as yet discussed the question of the compositions of Baade's two populations. The observational data are quite scarce. Among the high-velocity giants which belong to population II and therefore represent the kind of stars that may have originated near the centre of the galaxy, the bands of CN are definitely weaker than in stars of population I. These and other spectroscopic results are mostly due to Morgan and Keenan. They also find that among the carbon stars of type R those of population II are marked 'by such tremendous strengthening of the G band that they have been called CH stars'. In both groups the molecules appear to be more sensitive to differences between the two populations than the atoms. The elements that are most affected are H, C, N, and possibly O. Keenan, Morgan, and Munch say that 'it is significant that these are among the abundant light elements the concentration of which appears to be a determining factor in the structure of a star'.

There are also some well-known anomalies among the RR Lyrae stars in which the hydrogen lines are systematically too weak when compared with the metallic lines and among the high-velocity dwarfs or sub-dwarfs which were first designated at Mount Wilson as 'intermediate white dwarfs'. Kuiper has suggested that the general weakness of the lines in these stars may be the result of small hydrogen content so that 'on the whole

the hydrogen content increases with decreasing ellipticity of the galactic orbits'. Within the last few days Morgan has found some rather striking indications that even among the high-velocity A-type stars the hydrogen lines are sharper and the metallic lines weaker than in normal stars of the same class, so that it is quite probable that there is a general tendency among all of these objects of population II to be characterized by the same general departure which, if Kuiper is right, may well be due to small hydrogen content. However, I must not conceal the fact that at least the sub-dwarfs most definitely fall below the main sequence and not above it as I had indicated might be the case with the hydrogen-poor stars in the Hyades and the Pleiades.

I am glad that Unsöld has mentioned in his report the great importance of the Wolf-Rayet C and N branches at the one end of the spectral sequence and of the work by Russell on the abundances of oxygen and carbon in the S stars on one side and the R and N stars on the other. Dr Beals of Ottawa and Dr Swings of Liège and Yerkes-McDonald are here and are much better qualified to discuss the Wolf-Rayet stars than I am.

Discussion

J. A. Pearce (Dominion Astrophysical Observatory, Victoria, B.C.): Dr Andrew McKellar of Victoria, B.C., has just completed a survey of 40 N-type stars. He had previously found a very strong line at $\lambda 6707$ in the spectrum of the 7th magnitude N-type star WZ Cas. This is the resonance line of lithium—some 10 A. wide; it was the first identification of lithium in a stellar source. His new survey shows that the N-type stars can be divided into three groups: (*a*) those showing strong lithium lines like WZ Cas, (*b*) those showing weak lines of lithium, and (*c*) those in which there is no evidence of lithium.

E. Schatzman (Institut d'Astrophysique, Paris, France): Les naines blanches se placent bien loin de la séquence principale dans le diagramme masse-luminosité. Ce fait peut s'expliquer par leur structure particulière. Dans le champ de gravitation extrêmement intense des naines blanches un triage des éléments se produit et l'hydrogène flotte à la surface de l'étoile. Ce fait explique l'absence générale de raies métalliques dans le spectre des naines blanches. Les métaux sont tombés à l'intérieur de l'étoile. Par ailleurs ce schéma semble bien s'accorder avec la théorie du débit d'énergie des naines blanches et semble prouver que la réaction proton-proton est permise.

P. Ledoux (Institut d'Astrophysique, Cointe-Sclessin, Belgium): In the Sun, the carbon cycle takes place at an appreciable rate, only in the convective core, very close to the centre of the star. However, owing to the convection currents, the chemical composition of the core remains uniform in the course of time, but it becomes progressively more and more different from the composition of the radiative envelope, hydrogen being continually transformed into helium. There does not seem to be any good reason, at the present time, to assume that a mixing will take place to any appreciable extent between the material of the core and the envelope. We are thus led to the study of configurations with different mean molecular weights μ and μ_2 in the core and envelope.

If one tries to find such a configuration having the characteristics of the Sun ($M\odot$, $L\odot$, $R\odot$) and in which the energy liberated by the carbon cycle is equal to the energy radiated, one reaches the conclusion that this will only be possible if the abundances by weight X_e of hydrogen and Y_e of helium in the envelope are high.

Adopting values similar to those given by Unsöld for τ Scorpii, namely $X_e = 0{\cdot}56$, $Y_e = 0{\cdot}40$ one finds that the equality between energy generated and radiated is realized for a model in which $\mu_i/\mu_e = 1{\cdot}35$, that is, $X_1 = 0{\cdot}26$, $Y_1 = 0{\cdot}70$.

If one supposes that the initial chemical composition of the sun were uniform, it is possible to evaluate the time necessary to bring about the difference found above. One finds that τ is of the order of $5{\cdot}10^9$ years. This can be called the 'age' of the Sun, since during that period, its state was never very different from the present one. There are still many uncertainties in the values of different constants appearing in the theory, but the results must be of the right order of magnitude. The agreement with other determinations

of the 'age' of the Sun is certainly arresting as it appears here simply as a by-product of the condition that, at the present time, the energy generated be equal to the energy radiated.

P. LACROUTE (Observatoire, Toulouse, France) signale une possibilité d'obtenir les proportions des éléments lourds dans l'univers, indépendamment de l'analyse chimique et de l'analyse spectrale.

Lorsque les éléments lourds se sont formés, les conditions physiques ont imposé certaines proportions entre les différents types de noyaux et toutes ces proportions étaient liées entre elles; certaines nous sont bien connues, ce sont les proportions des isotopes et ceci constitue une piste sérieuse pour atteindre les autres proportions. Les indications données par les isotopes ne peuvent cependant évidemment pas suffire, il faut leur adjoindre d'autres considérations.

On choisit par tâtonnement les proportions des éléments chimiques de façon:

(1) Que le total des noyaux de même nombre de masse, n_A, varie aussi régulièrement que possible.

(2) Que le rapport $\frac{n_A^2}{n_{A-1} \times n_{A+1}}$ varie aussi régulièrement que possible.

Ces deux règles simples ont été suggérées par certaines considérations sur la formation des éléments lourds (*C.R.* **224**, pp. 1481, 1541). Ces considérations et ces règles ne deviennent valables que pour $A > 80$.

La courbe de fréquence obtenue présente une grande analogie avec la courbe de fréquence obtenue par l'analyse des météorites. Dans l'avenir lorsqu'on comprendra mieux les conditions de formation, l'application d'une méthode de ce genre donnera peut-être les résultats les plus sûrs.

D. H. MENZEL (Harvard College Observatory, Cambridge, Mass.): Nova Pictoris (1925), with its intense sulphur lines, presents an interesting and unique spectroscopic anomaly. Whether the peculiarities arise from unusual abundances or from a special combination of physical conditions and distinctive excitation parameters of S II is not clear.

The use of King's laboratory *f*-values for iron, in the absolute sense, is somewhat dangerous. The details of the calculations have not been published. The *f*-values are probably much too small; any determination of iron abundance from them leads to a high value. I think that they may be wrong by a factor of 10.

A. UNSÖLD (Astronomical Observatory, Kiel, Germany): It may be that the abundance of iron in the Sun, which I determined using King's *f*-values, is somewhat too high. Evidence from the analysis of meteorites points in this direction. A factor of more than 2 or 3, however, appears improbable.

D. H. MENZEL: I disagree. When the sum rules are applied, with appropriate factors for equivalent electrons, the discrepancy is about 10. What did you use for Ni?

A. UNSÖLD: For Ni I used the *f*-sum rule.

V. JOINT MEETING OF COMMISSIONS 10, 11, 12 AND 13 ON THE OUTERMOST LAYERS OF THE SUN

Monday, 16 *August*

PRESIDING: G. ABETTI.
SECRETARY: M. MIGEOTTE.

MINNAERT explained the latest results on the measurements of the darkening at the sun's limb obtained from plates taken with the Lick refractor in two different wavelengths.

UNSÖLD gave a new theory on the variation centre-limb of the intensity of the faint lines in the solar spectrum, and of the variations of the wings in the intense lines. He deduced a new law for the variation of the temperature near the limb. By means of this new theory it is possible to interpret the results of Miss Adam and Redman (published in the *Memorie Società Astronomica Italiana*, **20**, 49, 1949).

LYOT showed the diagrams of the intensity of the coronal lines observed at the Observatory of the Pic du Midi and pointed out the differences between the appearances of the green and red corona lines.

ROBERTS reported on the corona observations made at Climax (Colorado), and explained the characteristics of the new type of Evans interference filter to take cinema-pictures of the chromospheric and coronal phenomena with the speed of 6 to each minute of time.

LINK spoke of the supposed fluorescence of the lunar surface as deduced from lunar eclipse observations.

MOHLER showed a film taken at the McMath-Lake Angelus Observatory, in which it is possible to follow the development of the solar phenomena during a whole rotation of the sun.

BAILEY showed a film showing the variation of the critical frequency of the ionospheric layers in various hours of the day and the perturbations of the same, following the ionospheric storms.

PART V

STATUTES, BY-LAWS AND REGULATIONS

UNION ASTRONOMIQUE INTERNATIONALE

STATUTS

I. Objets de l'Union

1. L'Union Astronomique Internationale a pour but:
   (1) de faciliter les relations entre les astronomes des divers pays lorsqu'il est utile ou nécessaire d'avoir recours à une coopération internationale;
   (2) de favoriser l'étude de l'astronomie dans toutes ses branches.
2. L'Union adhère au Conseil International des Unions Scientifiques.

II. Adhésion des Pays

3. Un pays qui adhère au Conseil International des Unions Scientifiques peut adhérer à l'Union (*a*) par l'organisme par lequel il adhère au Conseil International, ou (*b*) par un Comité national d'astronomie, formé ou autorisé par cet organisme.

Un pays qui n'adhère pas au Conseil International peut adhérer à l'Union par un Comité national d'astronomie accepté par le Comité exécutif de l'Union.

Dans le mot 'pays' sont compris les Dominions, les protectorats diplomatiques, ainsi que les territoires ayant une activité astronomique indépendante.

III. Assemblées Générales

4. Les travaux de l'Union sont dirigés par les Assemblées générales.
5. Pour toute question scientifique chaque délégué présent dispose d'une voix.

Pour les questions d'ordre administratif ou à la fois administratif et scientifique, mais sans répercussion financière, le vote se fait par pays, chaque pays disposant d'une voix, sous la réserve que ce pays ait acquitté ses cotisations jusqu'à la fin de l'année qui précède le vote.

Pour toutes les questions financières le vote se fait également par pays, sous la même réserve que pour les questions d'ordre administratif, le nombre de voix attribué à chaque pays étant égal à l'indice de sa catégorie (défini dans l'article IV, 9), augmenté d'une unité.

6. Un même délégué ne peut représenter plus de deux pays à la fois. Un pays adhérent, non représenté à l'Assemblée générale par son propre délégué, peut voter par correspondance sur toute question figurant explicitement à l'ordre du jour.
7. L'Assemblée générale peut établir des règlements concernant toutes questions non prévues par les Statuts.

IV. Budget

8. Le Comité exécutif prépare un budget de prévision pour chaque année de la période comprise entre deux sessions. Une Commission financière, nommée par l'Assemblée générale, est chargée de l'étude de ce budget et de la vérification des comptes de l'exercice précédent. Elle établit, pour le budget et pour la vérification des comptes, des rapports distincts qui sont soumis à l'Assemblée générale.

A la suite de cet examen financier, l'Union fixe le taux de la part contributive unitaire. La cotisation unitaire ne pourra dépasser 500 francs or.

9. Les pays adhérents à l'Union sont répartis en 8 catégories numérotées de 1 à 8. Chaque pays adhérent paye annuellement un nombre d'unités de souscription égal à l'indice de sa catégorie. Un pays désireux d'adhérer à l'Union doit spécifier dans quelle

catégorie il propose d'être classé. Sa demande d'adhésion peut être refusée par le Comité exécutif de l'Union si la catégorie choisie est jugée manifestement inadéquate.

Dans chaque pays l'organisme qui adhère à l'Union est responsable du paiement de la cotisation.

V. Modifications des Statuts

10. Les présents Statuts entreront en vigueur au moment de leur adoption par l'Assemblée générale et seront valables jusqu'au 31 décembre 1943. Après cette date, ils seront renouvelés pour une autre période de douze ans, sauf avis contraire des organismes adhérents.

11. Aucun changement ne pourra être apporté aux Statuts sans l'approbation des deux tiers des voix des pays adhérents.

12. Le présent texte français servira seul pour l'interprétation à donner aux Statuts et règlements.

RÈGLEMENT

I. Membres de l'Union

1. L'Union est constituée par des membres de deux catégories: (*a*) tous les membres des commissions de l'Union, (*b*) les personnes désignées par les organismes adhérents ou par les Comités nationaux d'astronomie.

La liste des membres est mise à jour par le Secrétaire général après chaque réunion ordinaire de l'Assemblée générale.

II. Assemblée Générale

2. Les membres de l'Union se réunissent en principe en Assemblée générale tous les trois ans. Si l'époque et le lieu de cette réunion n'ont pas été arrêtés par l'Assemblée générale précédente, ils sont fixés par le Comité exécutif et communiqués, six mois au moins à l'avance, aux organismes adhérents et aux Comités nationaux.

3. Dans des cas spéciaux, le Président peut, avec le consentement du Comité exécutif, convoquer une Assemblée générale extraordinaire; il est tenu de le faire à la demande d'un tiers des voix des pays adhérents.

4. L'ordre du jour d'une session est fixé par le Comité exécutif et communiqué au moins quatre mois avant l'ouverture de cette session. Toute question ne figurant pas à l'ordre du jour n'est prise en considération qu'avec l'assentiment préalable de la moitié au moins des voix des pays représentés à l'Assemblée générale.

5. Toute proposition à soumettre à l'Assemblée générale doit être reçue par le Secrétaire général au moins cinq mois avant l'ouverture de l'Assemblée générale. Toute proposition soumise par un organisme adhérent, par un Comité national d'astronomie ou par une commission de l'Union, et reçue par le Secrétaire général cinq mois en avance, doit être inscrite à l'ordre du jour.

6. Le Président de l'Union peut inviter des hommes de science à assister, à titre consultatif, aux séances de l'Assemblée générale.

7. S'il y a doute sur la catégorie (scientifique ou administrative) dans laquelle doit être rangée une question à discuter, le Président décide.

8. En toutes circonstances, s'il y a égalité de voix, celle du Président est prépondérante.

9. L'Assemblée générale désigne les deux membres qui doivent représenter l'Union au Conseil International des Unions Scientifiques.

III. Comité Exécutif

10. Le Comité exécutif de l'Union comprend un Président, cinq Vice-Présidents au plus et un Secrétaire général, élus par l'Assemblée générale.

11. Le Président demeure en fonction jusqu'à la fin de la réunion ordinaire de Assemblée générale qui suit celle de son élection: les Vice-Présidents et le Secrétaire

général demeurent en fonction jusqu'à la fin de la deuxième Assemblée générale ordinaire qui suit celle de leur élection. Le Président et les Vice-Présidents ne sont pas immédiatement rééligibles. L'élection des membres à remplacer dans le Comité exécutif a lieu dans la dernière séance, la présentation des candidats ayant été faite dans l'avant-dernière séance. Le Président sortant et le Secrétaire général sortant restent membres du Comité exécutif avec voix consultative, lorsque leur mandat prend fin et jusqu'à la fin de l'Assemblée générale ordinaire suivante.

12. Le Comité exécutif peut pourvoir aux vacances qui surviendraient dans son sein. Toute personne désignée dans ces conditions demeure en fonction jusqu'à la réunion ordinaire de l'Assemblée générale suivante, qui doit procéder à une élection définitive. Le membre ainsi élu achève le mandat de celui qu'il s'agissait de remplacer.

13. Un Bureau administratif, sous la direction du Secrétaire général de l'Union, expédie la correspondance, gère les ressources et assure la conservation des archives ainsi que la préparation et la distribution des publications approuvées par l'Assemblée générale.

IV. Commissions

14. L'Assemblée générale nomme des commissions pour l'étude de sujets déterminés d'astronomie, pour l'encouragement d'entreprises collectives et pour l'examen de questions de conventions et de standardisations internationales.

Ces commissions présentent des rapports sur les travaux dont elles sont chargées.

15. Le Président et les membres de chacune de ces commissions sont élus par l'Assemblée générale sur la proposition du Comité exécutif de l'Union parmi les savants appartenant aux pays adhérents. Ils restent en fonction jusqu'à la fin de l'Assemblée générale ordinaire suivante et sont rééligibles.

Lorsqu'une commission comprend des membres désignés en partie par l'Union Astronomique et en partie par une autre Union rattachée au Conseil International des Unions Scientifiques, elle a la faculté d'élire elle-même son Président.

Les commissions établissent elles-mêmes leur règlement d'ordre intérieur; elles peuvent s'adjoindre de nouveaux membres par cooptation et à la majorité des deux tiers des voix. Si les nouveaux membres n'appartiennent pas à des pays adhérents, ils ne prennent part aux travaux de la commission et de l'Assemblée générale qu'à titre consultatif.

16. Avec l'approbation du Comité exécutif, une commission peut avoir ses propres publications et confier une partie quelconque de ses travaux à des institutions ou même à des particuliers.

17. Dans les commissions les décisions sont prises à la majorité des voix des membres qui les composent et non par pays.

V. Comités Nationaux

18. Les Comités nationaux ont pour attributions de faciliter et de coordonner, sur leurs territoires respectifs, l'étude des diverses branches de l'astronomie, envisagées principalement au point de vue international.

Ils ont le droit de soumettre au Comité exécutif des propositions à discuter par l'Assemblée générale.

VI. Finances

19. Les recettes de l'Union sont consacrées à couvrir les dépenses suivantes:

(i) frais de publication et dépenses accessoires d'administration;
(ii) aide financière à des entreprises astronomiques qui nécessitent la coopération internationale;
(iii) cotisation due par l'Union au Conseil International des Unions Scientifiques.

20. Les ressources provenant de dons sont utilisées par l'Union en tenant compte des désirs exprimés par les donateurs.

21. Tout pays qui se retire de l'Union abandonne de ce fait ses droits à l'actif de 'Union.

VII. Publications

22. Les publications de l'Union sont envoyées gratuitement:

(i) aux membres du Comité exécutif et des commissions,
(ii) aux observatoires dont la liste sera approuvée par le Comité exécutif,
(iii) aux organismes adhérents et aux Comités nationaux d'astronomie.

23. Les membres de l'Union peuvent acheter les publications de l'Union à prix réduit.

VIII. Modification du Règlement

24. Aucun changement ne pourra être apporté au règlement de l'Union sans l'approbation des deux tiers des voix des organismes adhérents et représentés à l'Assemblée générale.

INTERNATIONAL ASTRONOMICAL UNION

STATUTES

I. Objects of the Union

1. The purpose of the Union is:
   (i) to facilitate the relations between astronomers of different countries where international co-operation is necessary or useful;
   (ii) to promote the study of astronomy in all its departments.
2. The Union adheres to the International Council of Scientific Unions.

II. Adherence of Countries

3. A country which adheres to the International Council of Scientific Unions may adhere to the Union (*a*) by the organization through which it adheres to the International Council, or (*b*) by a National Committee of Astronomy formed by or recognized by such organization.

A country not adhering to the International Council may adhere to the Union by a National Committee of Astronomy recognized by the Executive Committee of the Union.

The term 'country' is to be understood as including Dominions, diplomatic Protectorates, and any dependency in which independent astronomical activity has been developed.

III. General Assembly

4. The work of the Union shall be directed by the General Assembly.
5. On scientific matters each delegate present shall have one vote.

In questions of administrative, or of mixed administrative and scientific character, not involving questions of finance, voting shall be by countries, each country having one vote, with the provision that its subscription shall have been paid up to the end of the year preceding the voting.

In questions involving finance, voting shall be by countries, with the same provision as for administrative questions. The number of votes for each country shall be one greater than the number of its category of membership (as defined in article IV, 9).

6. No delegate shall represent more than two countries. An adhering country not represented by a delegate may forward by post its vote on any specific question of the agenda.
7. The General Assembly may draw up by-laws governing all matters not provided for in the Statutes of Convention.

IV. Finance

8. The Executive Committee shall prepare an estimate of the budget for each of the years intervening between two General Assemblies. A Finance Committee nominated for the purpose by the General Assembly shall examine this estimate together with the accounts for the preceding years. This Committee shall submit separate reports on the estimates and accounts to the General Assembly, and the General Assembly, having considered these reports, shall fix the unit of contribution for the succeeding period, such unit not to exceed 500 gold francs.
9. There shall be eight categories of membership of the Union, numbered 1 to 8. Each adhering country shall pay annually a number of units of subscription equal to the number of its category of membership. A country offering to adhere to the Union shall specify in which category it proposes to be classed. The offer to adhere may be refused

by the Executive Committee if the proposed category is judged to be manifestly inadequate. In each country the organization adhering to the Union shall be responsible for the payment of the contribution.

V. Revision of Statutes

10. The present Statutes shall come into force as soon as adopted by the General Assembly and remain in force until the 31st December 1943: they may then be continued for a further period of 12 years unless the adhering countries decide to the contrary.

11. No change shall be made in these Statutes except with the approval of two-thirds of the votes of the adhering countries.

12. The French text of these Statutes (of which the above is a translation) shall be considered to be the authoritative text.

BY-LAWS

I. Members of the Union

1. The Union shall be composed of two classes of members: (*a*) all the members of the standing committees of the Union; (*b*) members nominated by adhering organizations or by National Committees.

The list of members shall be published by the General Secretary after each ordinary meeting of the General Assembly.

II. General Assembly

2. The members of the Union shall, as a rule, meet in ordinary General Assembly once every three years. The date and place of the meeting, unless determined by the General Assembly at its previous meeting, shall be fixed by the Executive Committee and communicated at least six months beforehand to the adhering organizations and National Committees.

3. For special reasons the President of the Union, with the consent of the Executive Committee, may summon an extraordinary meeting of the General Assembly. He must do so at the request of one-third of the votes of the countries adhering to the Union.

4. The agenda of business to be transacted at a meeting shall be determined by the Executive Committee and communicated to the adhering organizations and National Committees at least four months before the first day of the meeting. No question which has not been placed on the agenda shall be discussed, unless a proposal to that effect be approved by one-half of the votes of the countries represented at the General Assembly.

5. Any motion to be submitted to the General Assembly must be received by the General Secretary at least five months before the beginning of the General Assembly. Any such motion submitted by an adhering organization, by a National Committee of Astronomy or by a Standing Committee of the Union must be put on the agenda.

6. The President of the Union may invite any scientific men to attend a meeting of the General Assembly. Such invited guests may take part in the discussions, but shall have no power of voting.

7. In cases of doubt as to whether a vote is of an administrative or scientific character the Chairman of the meeting shall decide.

8. When there is an equal division of votes the Chairman shall in all cases have a second or casting vote.

9. The General Assembly shall appoint the two delegates to represent it on the International Council of Scientific Unions.

III. Executive Committee

10. The Executive Committee of the Union shall consist of a President, not more than five Vice-Presidents, and a General Secretary, who shall be elected by the General Assembly.

11. The President shall retire at the end of the ordinary General Assembly following that of his election; the Vice-Presidents and General Secretary shall hold office until the end of the second ordinary General Assembly following that of their election. The President and the Vice-Presidents shall not be immediately eligible for re-election. The election of their successors shall take place at the last session, the names of candidates proposed having been announced at the preceding session. The retiring President and General Secretary shall remain members of the Executive Committee in a consultative capacity until the end of the next ordinary General Assembly following their retirement.

12. In case of any vacancy occurring among its members, the Executive Committee shall have power to fill up such vacancy. Any person so appointed shall hold office until the next ordinary meeting of the General Assembly, which shall then proceed to an election for the remainder of the normal tenure of the member who is being replaced.

13. There shall be an Administrative Office, which, under the direction of the General Secretary, shall conduct the correspondence, preserve the archives, prepare and issue the publications sanctioned by the Union and administer its funds.

IV. Standing Committees

14. The General Assembly shall appoint Standing Committees for the study of special branches of Astronomy, the encouragement of collective investigations, and the discussion of questions relating to international agreements or to standardization.

The Standing Committees shall present reports of their work to the Union.

15. The President and the members of each Committee are elected by the General Assembly on the nomination of the Executive Committee of the Union from among scientists of adhering countries. They hold office until the end of the next ordinary General Assembly, and are re-eligible.

When a Standing Committee is composed of members appointed partly by the Astronomical Union and partly by some other Union connected with the International Council of Scientific Unions, it shall have the power to elect its own President.

Standing Committees shall draw up their own by-laws. They may co-opt other members by a majority of two-thirds. If such co-opted members are not members of countries adhering to the Union they shall take part in the discussions of the Standing Committee and of the General Assembly but shall have no power of voting.

16. With the sanction of the Executive Committee, a Standing Committee may issue its publications independently. A Standing Committee may entrust any part of its work to any institution or to individuals.

17. Votes taken in the Committees shall be counted individually and not by countries.

V. National Committees

18. The functions of the National Committees shall be to promote and co-ordinate in their respective countries the study of the various branches of Astronomy, more especially in relation to their international requirements. They shall be entitled to submit to the Executive Committee motions for discussion by the General Assembly.

VI. Expenditure and Finance

19. The income of the Union is to be devoted to:

(i) costs of publication and expenses of administration;
(ii) the promotion of astronomical enterprises requiring international co-operation;
(iii) the contribution due from the Union to the International Council of Scientific Unions.

20. Funds derived from donations shall be used by the Union in accordance with the wishes expressed by the donors.

21. If any country withdraws from the Union it resigns at the same time its rights to a share in the assets of the Union.

VII. Publications

22. The publications of the Union shall be circulated free of cost:

(i) to members of the Executive Committee and of Standing Committees,
(ii) to observatories on a list approved by the Executive Committee,
(iii) to adhering organizations and National Committees.

23. Members of the Union may purchase the publications at reduced prices.

VIII. Revision of By-laws

24. No change may be made in the by-laws except with the approval of two-thirds of the votes of the adhering countries represented at the General Assembly.

CONSEIL INTERNATIONAL DES UNIONS SCIENTIFIQUES

PRÉSIDENT: Prof. A. VON MURALT
VICE-PRÉSIDENTS: Prof. E. BOREL
Prof. H. SOLBERG
SECRÉTAIRE GÉNÉRAL: Prof. F. J. M. STRATTON

Les Statuts du Conseil Internationale des Unions Scientifiques sont actuellement en voie de révision.

BUREAU CENTRAL INTERNATIONAL DES TÉLÉGRAMMES ASTRONOMIQUES

CIPHER CODE FOR ASTRONOMICAL TELEGRAMS

adopted by the International Astronomical Union at the Paris Meeting July 1935, and amended at the Zürich Meeting August 1948, to be used from 1948 November 1

(1) *Communication of discovery of comet or planet*

Discoverer, object, time of observation, position, motion, magnitude and description of physical appearance are communicated according to the following scheme:

(*a*) The name of discoverer or, in the case of the rediscovery of a periodic comet, the generally used name of object, for instance Neujmin 1. The rediscoverer of a periodic comet should be treated as observer.

(*b*) A word describing the nature of the object: comet, planet or object.

(*c*) The name of the observer.

(*d*) Group of five figures, giving the day of the month (two figures), the magnitude (two figures) and a communication concerning the physical appearance of the object (one figure) according to the following schedule:

	Nothing reported about tail	Tail < 1°	Tail > 1°
Stellar appearance	0		
Nothing reported about appearance of the object itself	1	2	3
Object diffuse, without central condensation or nucleus	4	5	6
Object diffuse, with central condensation or nucleus	7	8	9

(*e*) The name of the month.

(*f*) Group of five figures giving the time of observation (universal time, reckoned from Greenwich mean midnight). Hours (two figures), minutes (two figures) and tenths of a minute are given.

(*g*) Group of five figures giving the observed right ascension (mean place referred to the mean equinox of the beginning of the year, if not otherwise stated). Hours (two figures), minutes of time (two figures) and, for *approximate positions*, tenths of a minute of time are given (cf. Example 1), while for *accurate positions* the tens of the seconds of time are given (cf. Example 2).

(*h*) Group of five figures giving the observed declination (mean place referred to the mean equinox of the beginning of the year, if not otherwise stated). The first figure of the group is 1 or 2 according as the declination is *negative* or *positive*. The next two figures give the degrees, the last two figures the minutes of arc of the declination.

(*i*) Group of five figures, of which the first figure is 8. The next two figures give the units of the seconds of time and tenths of seconds of time of the right ascension (continuation of (*g*)). The last two figures give the seconds of arc of the declination. When the observed position is approximate, this group is omitted.

(*j*) Group of five figures giving the daily motion of the object in right ascension. The first figure of the group is 1 or 2 according as the daily motion in right ascension is *negative* or *positive*. The next two figures give the minutes of time and the last two

figures the seconds of time of the daily motion in right ascension. When no daily motion is to be communicated, this group is omitted.

(*k*) Group of five figures giving the daily motion of the object in declination. The first figure of the group is 1 or 2 according as the daily motion in declination is *negative* or *positive*. The next two figures give the degrees and the last two figures the minutes of arc of the daily motion in declination. When no daily motion is to be communicated, this group is omitted.

(*l*) Group of five figures (check number) computed as the sum of the preceding five-figure groups. If this sum is a number of six figures, the left hand figure (first figure) is discarded.

(*m*) The name of the communicator.

Example 1 (approximate position).

Telegram 1935 Jan. 9:

Johnson comet Johnson 08104 January 18282 00598 15103 20016 20103 82206 Johannesburg Observatory.

A new comet has been discovered by Johnson as follows:

1935	U.T.	$\alpha_{1935\cdot0}$	$\delta_{1935\cdot0}$	Mag.
Jan. 8	$18^h\,28^m\cdot2$	$0^h\,59^m\cdot8$	$-51^\circ\,3'$	10^m

Daily motion: $\Delta\alpha = +16^s$, $\Delta\delta = +1^\circ\,3'$. Object diffuse, without central condensation or nucleus, nothing reported about tail.

(08104 + 18282 + 00598 + 15103 + 20016 + 20103 = 82206).

(2) *Communication of an observed position*

The same scheme as under (1) is used. The designation of the object may be shortened or omitted if no confusion is possible.

Example 2 (accurate position).

Telegram 1933 Feb. 18:

Peltier comète Delporte 17091 février 21501 23003 25845 80336 67776 Stroobant.

Stroobant communicates the following observation of comet Peltier by Delporte:

1933	U.T.	$\alpha_{1933\cdot0}$	$\delta_{1933\cdot0}$	Mag.
Feb. 17	$21^h\,50^m\cdot1$	$23^h\,0^m\,30^s\cdot3$	$+58^\circ\,45'\,36''$	9^m

Nothing reported about appearance of the object itself, nothing reported about tail.

(17091 + 21501 + 23003 + 25845 + 80336 = ·67776).

(3) *Communication of other discoveries and observations*

A scheme analogous to the scheme in (1) should be used as far as possible.

(4) *Communication of parabolic and nearly parabolic orbits*

(*a*) Name of discoverer or generally used name of object.

(*b*) Nature of object.

(*c*) Name of computer.

(*d*) The word *parabola*; or the words *nearly parabolic* followed by a group of five figures giving *e*, the eccentricity, in units of the fourth decimal (unit and four decimals).

(*e*) Month of perihelion time. In case the perihelion time is so far from the actual date that doubt may arise as to the year, a remark should follow under (*l*)

(*f*) Group of five figures giving the day of the perihelion time (two figures) and decimals of a day (three figures) according to universal time.

(*g*) Group of five figures giving ω, the angle from node to perihelion, in degrees (three figures) and minutes of arc (two figures).
(*h*) Group of five figures giving Ω, the longitude of the node, in degrees (three figures) and minutes of arc (two figures).
(*i*) Group of five figures giving i, the inclination, in degrees (three figures) and minutes of arc (two figures). For retrograde orbits $i > 90°$ by definition.
(*j*) Group of five figures giving q (not *log* q), the perihelion distance in units of the fourth decimal (unit and four decimals).
(*k*) Group of five figures (check number) computed as the sum of the preceding five-figure groups. If this sum is a number of six figures, the left hand figure (first figure) is discarded.
(*l*) Remarks. It should be stated here if the equinox is not that of the beginning of the actual year (e.g. equinox 1900·0 or 1950·0).
(*m*) Name of the communicator.

Example.

See Example 3 under (7) with parabolic elements and ephemeris.

(5) *Communication of elliptic elements of comets and planets*

(*a*) Name of discoverer or generally used name of object.
(*b*) Nature of object.
(*c*) Name of computer.
(*d*) The word *ellipse.*
(*e*) Month of the epoch.
(*f*) Group of five figures giving the day of the epoch (two figures) and decimals of a day (three figures) according to universal time.
(*g*) Group of five figures giving M, the mean anomaly at the epoch, in degrees (three figures) and minutes of arc (two figures).
(*h*) Group of five figures giving ω, the angle from node to perihelion, in degrees (three figures) and minutes of arc (two figures).
(*i*) Group of five figures giving Ω, the longitude of the node, in degrees (three figures) and minutes of arc (two figures).
(*j*) Group of five figures giving i, the inclination, in degrees (three figures) and minutes of arc (two figures). For retrograde orbits $i > 90°$ by definition.
(*k*) Group of five figures giving ϕ, the angle of eccentricity ($e = \sin \phi$), in degrees (three figures) and minutes of arc (two figures).
(*l*) Group of five figures giving μ, the mean daily motion, in units of one tenth of a second of arc.
(*m*) Group of five figures (check number) computed as the sum of the preceding five-figure groups. If this sum is a number of six figures, the left hand figure (first figure) is discarded.
(*n*) Remarks. It should be stated here if the equinox is not that of the beginning of the actual year.
(*o*) Name of the communicator.

Example.

See Example 4 under (7) with elliptic elements and ephemeris.

(6) *Communication of a circular orbit*

The same scheme as under (5) is used with the following exceptions:
(*d*) The word *circular* is used instead of the word *ellipse.*
(*g*), (*h*) One group of five figures giving u, the argument of the latitude ($u = \omega + v$) at the epoch, in degrees (three figures) and minutes of arc (two figures) instead of the two groups giving M and ω.
(*k*) The group giving ϕ is omitted.

(7) *Communication of an ephemeris*

(*a*) Name of discoverer or generally used name of object.
(*b*) Nature of object.
(*c*) Name of computer.
(*d*) The word *ephemeris*.
(*e*) Group of five figures giving the universal time of the dates of the ephemeris in hours (two figures), minutes (two figures) and tenths of a minute. If, as will nearly always be the case, this group would be ooooo corresponding to an ephemeris for 0^h U.T., then the group is omitted.
(*f*) The month of the first ephemeris date.
(*g*) Group of five figures, of which the first two give the day of the *first* ephemeris date, and the last three the light $\left(\frac{1}{r^2\Delta^2}\right)$ of the object on this date expressed in units of one tenth of the light at the date of discovery. If no information concerning light is to be communicated the three last figures should be *yyy*.*
(h_1) Group of five figures giving the right ascension at the first ephemeris date in hours (two figures), minutes of time (two figures) and tenths of minutes of time.
(i_1) Group of five figures giving the declination at the first ephemeris date. The first figure of the group is 1 or 2 according as the declination is *negative* or *positive*. The next two figures give the degrees, the last two figures the minutes of arc of the declination.
(h_2), (i_2)... Analogous groups for the other ephemeris dates.
(*j*) Group of five figures, of which the first two give the day of the *last* ephemeris date, and the last three the light $\left(\frac{1}{r^2\Delta^2}\right)$ of the object on this date expressed in units of one tenth of the light at the date of discovery. If no information concerning light is to be communicated the three last figures should be *yyy*.*
(*k*) Group of five figures (check number) computed as the sum of the preceding five-figure groups. If this sum is a number of six figures, the first figure is discarded.
(*l*) Remarks. It should be stated here if the ephemeris places are not mean places for the beginning of the actual year.
(*m*) Name of the communicator.

Example 3.

Telegram from Kiel, 1930 March 16:

Beyer comet Ebell parabola April 22212 02641 11626 07128 20599 64206 ephemeris March 17*yyy* 06052 23436 06059 23613 06072 23745 06091 23911 29*yyy* 64979 Ebell

Ebell has computed parabolic elements and an ephemeris of comet Beyer as follows:

$$\left.\begin{aligned} T &= 1930\ \text{April}\ 22{\cdot}212\ \text{U.T.} \\ \omega &= 26^\circ\ 41' \\ \Omega &= 116\ \ 26 \\ i &= 71\ \ 28 \\ q &= 2{\cdot}0599 \end{aligned}\right\}\ 1930{\cdot}0$$

$$(22212+02641+11626+07128+20599=64206).$$

0^h U.T.

1930	$\alpha_{1930{\cdot}0}$	$\delta_{1930{\cdot}0}$
March 17	$6^h\ 5^m{\cdot}2$	$+34^\circ\ 36'$
21	6 5 ·9	36 13
25	6 7 ·2	37 45
29	6 9 ·1	+39 11

* See Remarks, p. 510.

No information concerning light is given.

(17000+06052+23436+06059+23613+06072+23745+06091+
+23911+29000=·64979).

Example 4.

Telegram from Copenhagen, 1933 Oct. 23:

Whipple comet Whipple Cunningham ellipse July 08430 00000 18210 18809 01004 02407 04313 53173 ephemeris October 27010 03199 20837 03175 20808 03150 20741 03124 20714 08010 30768 Strömgren.

Strömgren communicates the following elliptic elements and ephemeris of comet Whipple computed by Whipple and Cunningham:

$$\left.\begin{array}{ll} \omega = 182^\circ\ 10' \\ \Omega = 188\ \ 9 \\ i = 10\ \ 4 \end{array}\right\}\ 1933{\cdot}0$$
$$\phi = 24\ \ 7$$
$$\mu = 431''{\cdot}3$$
$$T = 1933\ \text{July}\ 8{\cdot}430\ \text{U.T.}$$

(08430+00000+18210+18809+01004+02407+04313=53173).

The fact that the perihelion time is 1933 July 8·430 is expressed in the telegram by the statement (cf. the word July and the two first five-figure groups) that $M = 0^\circ\ 0'$ for the epoch 1933 July 8·430.

		0^h U.T.	
1933	$\alpha_{1933\cdot0}$	$\delta_{1933\cdot0}$	Light
Oct. 27	$3^h\ 19^m{\cdot}9$	$+8^\circ\ 37'$	1·0
31	3 17 ·5	8 8	
Nov. 4	3 15 ·0	7 41	
8	3 12 ·4	+7 14	1·0

(27010+03199+20837+03175+20808+03150+20741+
+03124+20714+08010=·30768).

Remarks:

If it is desired to express in a telegram the fact that certain data are not given, a *y* or *y*'s are used instead of one or more figures in the five-figure groups, the *y*'s to be counted equal to zero when the check number is computed.

Examples:

If it had been desired in Example 1 to give the time of observation as $18^h\ 28^m$, instead of $18^h\ 28^m{\cdot}2$, the second five-figure group should have been 1828*y*, instead of 18282.

If it had been desired, in the same telegram, not to communicate any magnitude, the first five-figure group should have been 08*yy*4, instead of 08104.

Attention should be drawn in connection with orbits and ephemerides to the following resolution adopted at the I.A.U. meeting in Leiden 1928: 'That the dates used for ephemerides of comets and minor planets shall be the midnight following an integral Julian date which is exactly divisible by 8 (or 4, etc.)', and to the amendment adopted at the Zürich meeting 1948: 'That, from the beginning of the year 1950, the dates employed in ephemerides of comets should be in intervals of 10 days or 5 days, the dates being chosen to fit the standard 40-day dates'; further to the resolution accepted at the meeting in Paris 1935: 'That for the year 1935 the epoch of osculation July 17·0 should be chosen and thereafter every 400th day.'

JULIE M. VINTER HANSEN

November 1948

CODE CHIFFRÉ POUR TÉLÉGRAMMES ASTRONOMIQUES

accepté par l'Union Astronomique Internationale dans son Assemblée générale de Paris, juillet 1935, modifié à l'Assemblée générale de Zürich, août 1948, à utiliser à partir du 1er novembre 1948

(1) *Communication des découvertes de comètes ou de planètes*

La nature de l'objet, l'auteur de la découverte, l'instant de l'observation, la position, le mouvement, la magnitude et la description de l'aspect physique seront communiqués d'après le dispositif suivant:

(*a*) Nom de l'auteur de la découverte, ou, dans la communication de la redécouverte d'une comète périodique, la comète sera désignée par son nom habituel par exemple Neujmin 1. L'auteur de la redécouverte d'une comète périodique sera traité comme l'observateur.

(*b*) Un mot décrivant la nature de l'objet: comète, planète ou objet.

(*c*) Nom de l'observateur.

(*d*) Groupe de cinq chiffres, donnant le jour du mois (deux chiffres), la magnitude (deux chiffres) et une communication relative à l'aspect physique de l'objet (un chiffre), d'après le schéma suivant:

	On ne signale rien au sujet d'une queue	Queue < 1°	Queue > 1°
Aspect stellaire	0		
On ne signale rien sur l'aspect de l'objet lui-même	1	2	3
Objet diffus, sans condensation centrale ou noyau	4	5	6
Objet diffus, avec condensation centrale ou noyau	7	8	9

(*e*) Nom du mois.

(*f*) Groupe de cinq chiffres donnant l'heure de l'observation (en temps universel, compté à partir du minuit moyen de Greenwich). On indique les heures (deux chiffres), les minutes (deux chiffres) et les dixièmes de minute (un chiffre).

(*g*) Groupe de cinq chiffres donnant l'ascension droite observée (lieu moyen rapporté à l'équinoxe moyen du commencement de l'année, sauf indication contraire). On indique les heures (deux chiffres), les minutes de temps (deux chiffres), et, pour les *positions approchées*, les dixièmes de minute de temps (cf. Exemple 1), tandis que pour les *positions précises* on donne la dizaine des secondes de temps (cf. Exemple 2).

(*h*) Groupe de cinq chiffres donnant la déclinaison observée (lieu moyen rapporté à l'équinoxe moyen du commencement de l'année, sauf indication contraire). Le premier chiffre du groupe est 1 ou 2, selon que la déclinaison est *négative* ou *positive*. Les deux chiffres suivants donnent les degrés, les deux derniers chiffres les minutes d'arc de la déclinaison.

(*i*) Groupe de cinq chiffres, dont le premier est toujours 8. Les deux chiffres suivants donnent les unités des secondes de temps et les dixièmes de seconde de temps de l'ascension droite (suite de (*g*)). Les deux derniers chiffres donnent les secondes d'arc de la déclinaison. On omet ce groupe lorsque la position observée n'est qu'approchée.

(*j*) Groupe de cinq chiffres donnant le mouvement diurne de l'objet en ascension droite. Le premier chiffre du groupe est 1 ou 2 selon que le mouvement diurne en ascension droite est *négatif* ou *positif*. Les deux chiffres suivants donnent les minutes de temps, les deux derniers chiffres les secondes de temps du mouvement diurne en ascension droite. On omet ce groupe lorsqu'on ne communique rien sur le mouvement de l'objet.

(*k*) Groupe de cinq chiffres donnant le mouvement diurne en déclinaison. Le premier chiffre du groupe est 1 ou 2 selon que le mouvement diurne en déclinaison est *négatif* ou *positif*. Les deux chiffres suivants donnent les degrés, les deux derniers chiffres les minutes d'arc du mouvement diurne en déclinaison. On omet ce groupe lorsqu'on ne communique rien sur le mouvement de l'objet.

(*l*) Groupe de cinq chiffres (nombre de contrôle), qui donne la somme des nombres précédents de cinq chiffres. Si cette somme est un nombre de six chiffres, on omet les centaines de mille (premier chiffre à gauche).

(*m*) Signature de l'expéditeur.

Exemple 1 (position approchée).

Télégramme du 9 janvier 1935:

Johnson comet Johnson 08104 January 18282 00598 15103 20016 20103 82206 Johannesburg Observatory.

Une comète nouvelle a été découverte par Johnson comme suit:

1935	T.U.	$\alpha_{1935\cdot0}$	$\delta_{1935\cdot0}$	Mag.
janvier 8	$18^h\ 28^m\cdot2$	$0^h\ 59^m\cdot8$	$-51°\ 3'$	10^m

Mouvement diurne: $\Delta\alpha = +16^s$, $\Delta\delta = +1°\ 3'$. Objet diffus, sans condensation centrale ou noyau, on ne signale rien au sujet d'une queue.

(08104 + 18282 + 00598 + 15103 + 20016 + 20103 = 82206).

(2) *Communication d'une position observée*

On emploie le même dispositif que pour (1). La désignation de l'objet peut être abréviée ou omise si aucune confusion n'est possible.

Exemple 2 (position précise).

Télégramme du 18 février 1933:

Peltier comète Delporte 17091 février 21501 23003 25845 80336 67776 Stroobant.

Stroobant communique l'observation suivante de la comète Peltier par Delporte:

1933	T.U.	$\alpha_{1933\cdot0}$	$\delta_{1933\cdot0}$	Mag.
février 17	$21^h\ 50^m\cdot1$	$23^h\ 0^m\ 30^s\cdot3$	$+58°\ 45'\ 36''$	9^m

On ne signale rien sur l'aspect de l'objet lui-même, on ne signale rien au sujet d'une queue.

(17091 + 21501 + 23003 + 25845 + 80336 = ·67776).

(3) *Communication d'autres découvertes et observations*

On emploiera dans la mesure du possible un dispositif analogue au dispositif de (1).

(4) *Communication d'orbites paraboliques ou presque paraboliques*

(*a*) Nom de l'auteur de la découverte ou nom habituellement employé pour l'objet.

(*b*) Nature de l'objet.

(*c*) Nom du calculateur.

(*d*) Le mot *parabole*; ou les mots *presque parabolique* suivis d'un groupe de cinq chiffres donnant l'excentricité e en unités de la quatrième décimale (l'unité et quatre décimales).
(*e*) Le mois du passage au périhélie. Dans le cas où le périhélie serait tellement éloigné de la date de la dépêche que le doute fût possible quant à l'année, une note serait ajoutée en (*l*).
(*f*) Groupe de cinq chiffres donnant le jour du périhélie (deux chiffres) et trois décimales du jour (trois chiffres), en temps universel.
(*g*) Groupe de cinq chiffres donnant ω, angle nœud-périhélie, en degrés (trois chiffres) et minutes d'arc (deux chiffres).
(*h*) Groupe de cinq chiffres donnant Ω, longitude du nœud, en degrés (trois chiffres) et minutes d'arc (deux chiffres).
(*i*) Groupe de cinq chiffres donnant i, inclinaison de l'orbite, en degrés (trois chiffres) et minutes d'arc (deux chiffres). Pour les orbites rétrogrades, $i > 90°$ par définition.
(*j*) Groupe de cinq chiffres donnant q, distance périhélie (et non $\log q$) en unités de la quatrième décimale (l'unité et quatre décimales).
(*k*) Groupe de cinq chiffres (nombre de contrôle), qui donne la somme des nombres précédents de cinq chiffres. Si cette somme est un nombre de six chiffres, on omet les centaines de mille (premier chiffre à gauche).
(*l*) Remarques. On dira ici si l'équinoxe utilisé n'est pas celui de l'année en cours (*p. ex.* équinoxe 1900·0 ou 1950·0).
(*m*) Signature de l'expéditeur.

Exemple.

Voir l'exemple 3 de (7) avec éléments paraboliques et éphéméride.

(5) *Communication d'éléments elliptiques de comètes et planètes*

(*a*) Nom de l'auteur de la découverte ou nom habituellement employé pour l'objet.
(*b*) Nature de l'objet.
(*c*) Nom du calculateur.
(*d*) Le mot *ellipse*.
(*e*) Mois de l'époque.
(*f*) Groupe de cinq chiffres donnant le jour de l'époque (deux chiffres) et décimales du jour (trois chiffres) en temps universel.
(*g*) Groupe de cinq chiffres donnant M, anomalie moyenne pour l'époque, en degrés (trois chiffres) et minutes d'arc (deux chiffres).
(*h*) Groupe de cinq chiffres donnant ω, angle nœud-périhélie, en degrés (trois chiffres) et minutes d'arc (deux chiffres).
(*i*) Groupe de cinq chiffres donnant Ω, longitude du nœud, en degrés (trois chiffres) et minutes d'arc (deux chiffres).
(*j*) Groupe de cinq chiffres donnant i, inclinaison de l'orbite, en degrés (trois chiffres) et minutes d'arc (deux chiffres). Pour les orbites rétrogrades, $i > 90°$ par définition.
(*k*) Groupe de cinq chiffres donnant ϕ, angle d'excentricité ($e = \sin \phi$), en degrés (trois chiffres) et minutes d'arc (deux chiffres).
(*l*) Groupe de cinq chiffres donnant μ, moyen mouvement, en unités du dixième de seconde d'arc.
(*m*) Groupe de cinq chiffres (nombre de contrôle), égal à la somme des groupes précédents de cinq chiffres en omettant, s'il y a lieu, les centaines de mille.
(*n*) Remarques. On dira ici si l'équinoxe utilisé n'est pas celui de l'année en cours.
(*o*) Signature de l'expéditeur.

Exemple.

Voir l'exemple 4 de (7) avec éléments elliptiques et éphéméride.

(6) *Communication d'une orbite circulaire*

On emploiera le même dispositif que pour (5), avec les modifications suivantes:

(*d*) On remplace le mot *ellipse* par le mot *circulaire*.

(*g*), (*h*) Groupe de cinq chiffres donnant u, argument de latitude ($u=\omega+v$) à l'époque, en degrés (trois chiffres) et minutes d'arc (deux chiffres), au lieu de deux groupes donnant M et ω.

(*k*) On omet le groupe ϕ.

(7) *Communication d'une éphéméride*

(*a*) Nom de l'auteur de la découverte ou nom habituellement employé pour l'objet.

(*b*) Nature de l'objet.

(*c*) Nom du calculateur.

(*d*) Le mot *éphéméride*.

(*e*) Groupe de cinq chiffres donnant le temps universel des lieux de l'éphéméride en heures (deux chiffres), minutes (deux chiffres) et dixièmes de minute. Si, comme ce sera presque toujours le cas, ce groupe est 00000, correspondant à une éphéméride pour 0^h T.U., on l'omet tout simplement.

(*f*) Le mois se rapportant au premier lieu de l'éphéméride.

(*g*) Groupe de cinq chiffres, dont les deux premiers donnent le jour du mois du *premier* lieu de l'éphéméride, et les trois derniers l'éclat $\left(\frac{1}{r^2\Delta^2}\right)$ de l'objet à cette date, exprimé en unités de la première décimale de l'éclat à la date de la découverte. Si on ne communique pas de données sur l'éclat, les trois derniers chiffres du groupe seront *yyy*.*

(h_1) Groupe de cinq chiffres donnant l'ascension droite du premier lieu de l'éphéméride, en heures (deux chiffres), minutes de temps (deux chiffres) et dixièmes de minute de temps.

(i_1) Groupe de cinq chiffres donnant la déclinaison du premier lieu de l'éphéméride. Le premier chiffre du groupe est 1 ou 2 selon que la déclinaison est *négative* ou *positive*. Les deux chiffres suivants donnent les degrés, les deux derniers les minutes d'arc de la déclinaison.

(h_2), (i_2)... Groupes analogues pour les autres lieux de l'éphéméride.

(*j*) Groupe de cinq chiffres, dont les deux premiers donnent le jour du *dernier* lieu de l'éphéméride, et les trois derniers l'éclat $\left(\frac{1}{r^2\Delta^2}\right)$ de l'objet à cette date, exprimé en unités de la première décimale de l'éclat à la date de la découverte. Si l'on ne communique pas de données sur l'éclat, les trois derniers chiffres du groupe seront *yyy*.*

(*k*) Groupe de cinq chiffres (nombre de contrôle) égal à la somme des groupes précédents, en omettant, s'il y a lieu, les centaines de mille.

(*l*) Remarques. On dira ici si les lieux de l'éphéméride sont rapportés à un autre équinoxe que celui du commencement de l'année en cours.

(*m*) Signature de l'expéditeur.

Exemple 3.

Télégramme de Kiel, 16 mars 1930:

Beyer comète Ebell parabole Avril 22212 02641 11626 07128 20599 64206 éphéméride mars 17*yyy* 06052 23436 06059 23613 06072 23745 06091 23911 29*yyy* 64979 Ebell.

* Voir Remarques, p. 515.

Ebell a calculé des éléments paraboliques et une éphéméride de la comète Beyer, comme suit:

$$\left.\begin{array}{l} T = 1930 \text{ avril } 22{\cdot}212 \text{ T.U.} \\ \omega = 26^\circ\ 41' \\ \Omega = 116\ \ 26 \\ i = 71\ \ 28 \\ q = 2{\cdot}0599 \end{array}\right\} \ 1930{\cdot}0$$

(22212 + 02641 + 11626 + 07128 + 20599 = 64206).

0^h T.U.

1930	$\alpha_{1930{\cdot}0}$	$\delta_{1930{\cdot}0}$
Mars 17	$6^h\ 5^m{\cdot}2$	$+34^\circ\ 36'$
21	6 5 ·9	36 13
25	6 7 ·2	37 45
29	6 9 ·1	+39 11

On ne donne pas d'information au sujet de l'éclat.

(17000 + 06052 + 23436 + 06059 + 23613 + 06072 + 23745 + 06091 + + 23911 + 29000 = ·64979).

Exemple 4.

Télégramme de Copenhague, 1933 octobre 23:

Whipple comet Whipple Cunningham ellipse July 08430 00000 18210 18809 01004 02407 04313 53173 ephemeris October 27010 03199 20837 03175 20808 03150 20741 03124 20714 08010 30768 Strömgren.

Strömgren communique les éléments elliptiques et l'éphéméride suivants de la comète Whipple, calculés par Whipple et Cunningham:

$$\left.\begin{array}{l} T = 1933 \text{ juillet } 8{\cdot}430 \text{ T.U.} \\ \omega = 182^\circ\ 10' \\ \Omega = 188\ \ 9 \\ i = 10\ \ 4 \\ \phi = 24\ \ 7 \\ \mu = 431''{\cdot}3 \end{array}\right\} \ 1933{\cdot}0$$

(08430 + 00000 + 18210 + 18809 + 01004 + 02407 + 04313 = 53173).

Le passage au périhélie au 1933 juillet 8·430 T.U. est exprimé dans le télégramme par le fait (cf. le mot juillet et les deux premiers groupes de cinq chiffres) que $M = 0^\circ\ 0'$ pour l'époque 1933 juillet 8·430.

0^h T.U.

1933	$\alpha_{1933{\cdot}0}$	$\delta_{1933{\cdot}0}$	Éclat
Oct. 27	$3^h\ 19^m{\cdot}9$	$+8^\circ\ 37'$	1·0
31	3 17 ·5	8 8	
Nov. 4	3 15 ·0	7 41	
8	3 12 ·4	+7 14	1·0

(27010 + 03199 + 20837 + 03175 + 20808 + 03150 + 20741 + + 03124 + 20714 + 08010 = ·30768).

Remarques:

Si l'on désire exprimer dans un télégramme le fait que l'on ne peut pas communiquer certaines données, on remplace par un *y* ou plusieurs *y* un ou plusieurs des chiffres du groupe à cinq chiffres, le *y* étant compté comme équivalent à zéro lors du calcul du nombre de contrôle.

Exemples:

Si l'on désirait, à l'exemple 1 (position approchée), donner l'heure de l'observation de $18^h\,28^m$, au lieu de $18^h\,28^m{\cdot}2$, le deuxième groupe à cinq chiffres serait 1828*y*, au lieu de 18282.

Si l'on désirait, dans le même télégramme, ne communiquer aucune magnitude, le premier groupe à cinq chiffres serait 08*yy*4, au lieu de 08104.

En ce qui concerne les orbites et les éphémérides, il convient d'attirer l'attention sur la résolution suivante adoptée à l'assemblée de l'U.A.I. de Leyde, 1928: 'Que les dates employées pour les éphémérides de comètes et de petites planètes seront comptées à partir de minuit suivant une date Julienne entière qui soit exactement divisible par 8 (ou par 4, etc.)', avec la modification apportée à l'assemblée de Zürich en 1948: 'Que, à partir du début de l'année 1950, les dates employées pour les éphémérides de comètes aient un intervalle de 10 jours ou de 5 jours, les dates étant choisies de manière à correspondre aux dates standard échelonnées de 40 en 40 jours', et sur la résolution acceptée à l'assemblée de Paris, 1935: 'Que pour l'année 1935 on fasse choix de l'époque d'osculation juillet 17·0 et ensuite d'époques séparées de la première par des intervalles de 400 jours.'

JULIE M. VINTER HANSEN

Novembre 1948

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(Arrêtée en séance plénière à Zürich, le 18 août 1948)

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[1] Our aim, in making this index, has not been to refer to every page where a certain subject is mentioned, but, as far as possible, to all places conveying essential information. To our regret it cannot be given in more than one language.

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