

### 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, Hertzprung, 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  $\pm 25^\circ$ . 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  $m = 10.5$ .

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  $\pm 30^\circ$ , 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.  $-30^\circ$ ) and four in the northern (lat.  $+30^\circ$ ).

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  $188^\circ$ ; with gal. lat. for different fields ranging from  $+4$  to  $-9^\circ$ :

Twelve fields outside the galactic plane, one at the northern galactic pole, one at gal. lat.  $+75^\circ$ , three at  $+60^\circ$ , four at  $+30^\circ$ , three at  $-30^\circ$ .

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  $4^\circ$  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 Å./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.  $69^\circ$ . 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  $-8^\circ$ , 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.  $147^\circ$ , in the first place two areas about gal. lat.  $+4$  and  $+9^\circ$ .

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  $5^\circ$  width at gal. lat.  $+20^\circ$ , between gal. long.  $65^\circ$  and  $90^\circ$ .

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.  $310^\circ$

\* *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  $355^\circ$ , gal. lat.  $+15^\circ$  and  $+25^\circ$ , and in two comparison squares at gal. co-ord.  $315^\circ$ ,  $-20^\circ$ , and  $335^\circ$ ,  $-20^\circ$ , 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.

† *Ap. J.* **105**, 204, 1947.

‡ *Stockholm Annals*, **13**, No. 9, 1941.

\*\* *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.

† *An Atlas of Stellar Spectra.* Chicago, 1943.

§ *Ibid.* **86**, 176, 1937.

¶ *Ibid.* **13**, No. 3, 1939.

||| *Ibid.*

negligible. De Vos van Steenwijk has computed the space velocities for all stars brighter than  $6^m.5$  for which Mount Wilson spectroscopic parallaxes were available and G. Pels has made similar computations for the stars of trigonometric parallaxes in excess of  $0''.066$ .

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  $\pm 0.13$ . 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. =  $271^\circ$ , gal. lat. =  $-11^\circ$  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  $0.4 \cdot 10^8$  and  $1.5 \cdot 10^8$  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  $3^\circ$  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  $200 \pm 25$  km./sec. towards an apex close to gal. long.  $55^\circ$ , gal. lat.  $0^\circ$  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; *Ap. 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  $43^\circ$ , also in fields at the galactic latitudes  $4^\circ$ ,  $9^\circ$ ,  $12^\circ$  and  $22^\circ$ . 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  $11^m.0$ , four luminosity classes.

2. Determinations of infra-red spectra with a  $4^\circ$  or a  $2^\circ$  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  $9^\circ$  (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  $3^\circ.5$  wide belt along the Milky Way from  $-10^\circ$  to  $+180^\circ$  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  $2^\circ$  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  $12^m.8$  (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.