33. COMMISSION DE LA STATISTIQUE STELLAIRE

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MEMBRES: MM. Bok, Eddington, Hertzsprung, S. Hirayama, Lundmark, Luyten, Malmquist, Mineur, Oort, Pannekoek, Russell, Schalén, Schilt, Seares, Strömberg, van Maanen, van Rhijn, von der Pahlen.

In the wide field of research covered by the Commission considerable progress has been made in recent years, and it is only possible here to touch briefly on the results of a few lines of investigation, without any attempt to completeness.

Stellar luminosities. On the basis of the new list of Mount Wilson spectroscopic parallaxes and a compilation of the long series of modern trigonometric parallaxes A. van Maanen finds 617 objects within a distance of 20 parsecs from the sun. It is very doubtful, however, if we know all the stars even in the region of 5 parsecs radius. Almost all the known stars within 20 parsecs belong to the main sequence, the faintest star being of absolute magnitude +16·6. The most interesting deviations from the main sequence are the three "white dwarfs", Comp. of Sirius, Comp. o_2 Eridani, and van Maanen's F type star. G. P. Kuiper lists 3 additional white dwarfs at larger distances which were estimated to be of types B0, B7 and A2. For the first two stars, A.C. 70°8247 and Wolf 1346, a revision of the spectral types by Adams and Humason gives A2 and A5, respectively, although the spectra differ considerably from normal ones. The A2 star in Kuiper's list is the one discovered by Oosterhoff in the region of the cluster h, χ Persei; its spectral characteristics have been examined by Öhman and by Humason. The absence of the high-numbered members of the Balmer series and of the continuous absorption at the Balmer limit seems to be an important criterion of such stars. A white dwarf of quite peculiar spectrum (type probably about B8) is the companion of *o* Ceti discovered spectrographically by Joy in 1922. There appear several additional deviations towards faint magnitudes from the main sequence which may be classed more or less safely among the white dwarfs. A few such cases have been discussed at Lund by J. Tuominen.

Concerning the available material on spectrographic parallaxes, W. S. Adams announces the completion at Mount Wilson of a catalogue containing 4200 stars; a detailed reduction of earlier catalogues of spectrographic parallaxes to a uniform system has been given by P. J. van Rhijn; and the spectrophotometric criteria to be used for faint stars have been further developed at the Stockholm Observatory.

Among recent investigations on the frequency-distribution of stellar luminosities we have to record especially G. Strömberg's method and his results for the distribution of absolute magnitudes in the series of spectral types. The luminosity function of K type stars has been studied by J. H. Oort and by L. Gratton.

Results bearing on the zero-point in the period-luminosity relation for Cepheids have been obtained by B. P. Gerasimovic, K. Lundmark, Mrs P. Fairfield Bok, Miss C. D. Boyd, J. J. Nassau, and others. Systematic search for Cepheids, including cluster-type variables, in various galactic regions is in progress, especially at Harvard and at Leiden.

Star-counts, photometric and spectral investigations of faint stars. B. J. Bok and E. M. Lindsay of Harvard continue their star-counting programme in the southern Milky Way.

K. G. Malmquist's photometric work at Stockholm on the stars near the northern galactic pole approaches completion and will be followed by a spectrographic analysis of the same stars. E. Stenquist continues his work at Upsala and Stockholm on the spectra and photographic magnitudes of the stars in Smart's regions of determined proper motions. The work at Stockholm and Upsala on the spectra and photographic magnitudes of faint stars in certain regions of the central galactic zone is in progress.

Å. Wallenquist at Lembang is investigating spectra and photographic magnitudes in the region of the galactic centre in Sagittarius.

Proper motions. In addition to the important work in the Selected Areas systematic investigations of proper motions down to faint limiting magnitudes have recently been completed or are well advanced. Statistical astronomy will have to acknowledge especially the proper motions derived by B. Boss and his collaborators at the Dudley Observatory, the proper motions derived at Yale by the re-observation of the Astronomische Gesellschaft zones, the proper motions for stars in the Selected Areas 1–115 determined at Radcliffe to about phot. mag. 15, the work carried out at Mount Wilson for determining the larger proper motions ($\geqslant 0''.040$ per year) in Selected Areas 1–139 down to about phot. mag. 18, the material collected by Mitchell and his collaborators, giving proper motions of 18,000 stars in parallax fields, and Luyten's work on Harvard plates for the southern sky, where in the area between Dec. $-30°$ and the South Pole more than 60,000 proper motions have been discovered, mainly for stars with phot. mag. between 12 and 18.

Interstellar absorption. The obscuring central layer in the Milky Way, which concerns intimately many vital problems in stellar statistics, has been subject to extensive researches in recent time.

As to the differential galactic absorption, expressing the variation of the absorption from one spectral region to another, the results derived by R. J. Trumpler, L. T. Slocum and R. S. Zug at the Lick Observatory, P. van de Kamp, A. N. Vyssotsky and Emma T. R. Williams at the Leander McCormick Observatory, C. Schalén and Y. Öhman at Upsala, W. Becker at Berlin-Babelsberg, J. Stebbins at Mount Wilson and Madison and J. J. Raimond at Groningen show fair agreement with each other. A mean value of the coefficient of differential absorption in the ordinary colour-index system between 0·3 and 0·5 mag. per kiloparsec seems to be fairly well established.

The absolute coefficient of absorption is certainly known with far less precision. The results due to Schalén (density distribution of early type stars in galactic regions), Trumpler (clusters), Bok (general density distribution in certain galactic regions), Joy (galactic rotation of Cepheids), and others, indicate a photographic absorption between 0·5 and 1·0 mag. per kiloparsec. Seares, however, finds considerable difficulties in reconciling even a mean coefficient of the amount $0^{m}.67$ per kiloparsec (Trumpler), which from the evidence just mentioned seems fairly conservative, with its consequent effects on the space density of stars. A possible way of harmonizing the respective results may, however, still be open, when we consider more closely the fact that in our surroundings of space a very pronounced maximum of absorption per unit distance will be measured in the case of objects of high luminosity and strong galactic concentration, on account of the small width of the zone of maximum obscuration. Besides this, we have to consider that the absorption probably varies greatly from one region of the galactic plane to another. The total optical thickness (photographic) of the stratum, determined from the obscuration effect on nebulae and clusters by van de Kamp and Hubble, seems to lie about 0·5 mag.

An important theoretical investigation on the cause of the interstellar absorption has been made by C. Schalén, who has applied Mie's theory of the absorption and scattering of light by small metallic particles to explain the absolute and differential obscuration effects in dark clouds. He finds for the general space density of the particles, outside of the cloud formations, $0{\cdot}4\times10^{-26}$ g/cm^3 and for the dark clouds in Auriga and Cepheus in the mean $0{\cdot}5\times10^{-25}$ g/cm.^{3} The diameter of a particle is found to be of the order of 10^{-5} cm. The total masses of the Auriga and the Cepheus clouds are estimated to be 35 and 300 solar masses, respectively.

Galactic rotation and related subjects. Statistics of stellar motions. J. H. Oort has determined the component of force in the direction perpendicular to the galactic plane, and in this connection, also a part of the curves of equal density in a vertical cross-section of the galaxy. The curves appear to coincide closely with ellipses having the same centre as the galactic system, which is supposed to be at a distance of 10,000 parsecs from the sun.

In a recent detailed discussion of the effects of differential galactic rotation by Plaskett and Pearce, a distance from the centre of 10,000 parsecs is derived with some confidence, in substantial agreement with earlier estimates (cf. "Die Milchstrasse", *Handbuch der Astrophysik*, 5, 2, 1933). A preliminary notice has been given by A. H. Joy concerning his extensive investigation of the differential rotation for distant Cepheids.

H. Mineur and P. Guintini have made an extensive investigation of the space motions of the B stars. The relations between the general characteristics of these motions and the rotation of the Galaxy have been examined in great detail according to general principles developed earlier by Mineur. The motions of the A stars have been studied by Ch. Bertaud following a similar line of investigation.

W. Gyllenberg has made an extensive study of stellar proper motions with the aim of distinguishing certain stream motions among the stars in our neighbourhood.

Dynamical theory. B. J. Bok has developed a theory for the disintegration of stellar clusters in consequence of the tidal stress exerted by the gravitational field of the galaxy. He thus finds $2{\cdot}10^{10}$ years as a reasonable limit for the age of our galaxy.

A mathematical theory of the state of motion in the neighbourhood of the sun, in which fluctuations relative to a stationary distribution are explicitly considered, has been developed by O. Heckmann and H. Strassl at Göttingen. New theoretical considerations regarding the motions of the nearby stars have also been developed by J. Schilt at Columbia University.

Theories of the origin and development of rotating stellar systems, with fairly wide cosmological applications, have been formulated independently by G. Strömberg and B. Lindblad.

Special recommendations by members of the Commission

On certain tables often needed in astronomical statistics. Dr G. Strömberg suggests that certain tables be prepared and published by an observatory willing to undertake the work and financed by selling the publication at the lowest possible price under the auspices of the I.A.U. The tables particularly recommended are the following:

1. A table giving the corrections to be applied to stellar radial velocities for the effect of the sun's motion relative to the group of stars studied. The formula is $\Delta V = x_0 \cos\alpha \cos\delta + y_0 \sin\alpha \cos\delta + z_0 \sin\delta$, where α and δ are the right ascension and declination of the star, and x_0, y_0 and z_0 are the equatorial velocity components of the sun's motion. It is practical to use a standard solar motion, for instance, $V_0 = 20$ km/sec, $\alpha_0 = 270°$, $\delta_0 = +30°$. If necessary to use another solar velocity,

a factor can be applied. If the apex differs less than, say, 20° from the standard apex, the table will still give useful results, as will be seen later.

The above reductions are usually made from graphs giving the angular distance from the sun's apex (λ), or from privately prepared tables. The table should give ΔV for intervals in α of 1° (4^m) and for intervals in δ not greater than 5°.

2. Tables giving the mean parallax for a group of stars from their α, δ, μ_1, and μ_2, where μ_1 and μ_2 are the proper motion components in seconds of arc, and projected on great circles. The equations of conditions are

$$A\pi_\alpha = \mu_1 \quad \text{and} \quad B\pi_\delta = \mu_2,$$

where

$$kA = x_0 \sin\alpha - y_0 \cos\alpha,$$

$$kB = x_0 \cos\alpha \sin\delta + y_0 \sin\alpha \sin\delta - z_0 \cos\delta,$$

and

$$k = 4{\cdot}738 \text{ km. year/sec.}$$

The usual mean parallax formula

$$\bar{\pi} = \frac{k\Sigma v \sin\lambda}{V_0 \Sigma \sin^2\lambda} = \frac{\Sigma\,(A\mu_1 + B\mu_2)}{\Sigma\,(A^2 + B^2)}$$

is the combination of π_α and π_δ; but since μ_1 and μ_2 are usually given separately and sometimes determined with different accuracy, the foregoing equations of condition are more convenient and also show the agreement between the results from μ_α and μ_δ. They can also be used on the supposition that the algebraic sum of the angular peculiar motions is zero.

If λ, v and τ should be needed, they can be derived from the formulae

$$\sin\lambda = \frac{k\sqrt{A^2+B^2}}{V_0}, \quad v = \frac{A\mu_1 + B\mu_2}{\sqrt{A^2+B^2}}, \quad \tau = \frac{A\mu_2 - B\mu_1}{\sqrt{A^2+B^2}}.$$

At present mean parallaxes are generally derived by computing in succession μ, ψ; χ, λ; v and τ, by a very laborious process. A depends only on α and is very easy to tabulate. B should be given with the same intervals as ΔV mentioned above. B can be derived from ΔV by changing the arguments and multiplying by a constant factor.

If ΔV, A and B are based on the same standard apex they can always be used in combination with each other. We are then projecting the velocities on an axis fixed in space, approximately coinciding with that of the actual group motion.

For stars close to the apex or antapex, A^2+B^2 is small, and v and τ are then very poorly determined from A and B. But in this case both μ_1 and μ_2 can be regarded as peculiar angular motions, equivalent to τ. Since the above formula directly involve μ_1 and μ_2, corrections to the proper motions—for instance for galactic rotation or for systematic errors—can easily be applied.

Other tables are also needed, as, for instance, tables giving the reduction of directly measured radial velocities from the earth to the sun ("sun reduction"), but such tables belong to methods of reduction rather than to stellar statistics.

Dr J. H. Oort favours the construction of an extensive table similar to the one given by Kohlschütter (*Bonn Veroffentlichungen*, No. 22, 1930, pp. 10–17), for the purpose of facilitating the computation of space velocities. A table given with intervals of 1° in Dec., so that interpolation only in α will be needed, should be of great convenience.

Dr K. Lundmark reports concerning the extensive work on the construction of tables, which is at present being carried out at Lund.

Dr J. Schilt calls the attention of the Commission to the importance of certain machines suitable for the computation of tables in the most efficient and economical way.

Co-operative study of open clusters. M. H. Mineur proposes that especially those observatories which have been engaged on the *Carte du Ciel* should co-operate in a general study of the open clusters, which are of such great interest and importance in many respects. He proposes a detailed scheme for deriving first the positions, then the proper motions, magnitudes, spectrographic parallaxes and radial velocities of stars in clusters. Extensive investigations in several of these fields are already in progress at different observatories, and it appears to be a question open to considerable discussion to what extent a co-operative organization may be of advantage at present. As the proposal concerns several other Commissions, it is desirable that the opinions of these Commissions on the subject be obtained.

Spectra and colour-indices of faint stars. It is evident that the use of colour-indices alone in the case of statistical work on faint stars is made very difficult on account of the selective absorption of light in space. The importance of studying the distribution of stars for which spectra (and a colour-equivalent) are available (to about mag. 12–14), in order that the selective absorption be determined as accurately as possible in different directions, is obvious. It is suggested by Dr C. Schalén that such investigations be recommended by the Commission.

Catalogues of known orbits of visual and spectroscopic binaries. Dr W. J. Luyten suggests a recommendation as follows. In the interest of statistical workers the Commissions on double stars and radial velocities are requested to arrange that some designated observatory publish at frequent intervals—say every five or ten years—complete catalogues of all known orbits of visual and spectroscopic binaries.

Systems of projection when studying apparent galactic distributions. Dr Const. Parvulesco calls the attention of the Commission to the advantages of Lambert's system of projection (or, for the whole sphere in one contour, the system of Lambert generalized by Aithoff according to Hammer's procedure) for the general study of galactic distribution, and to the desirability of uniformity concerning the system of projection used in stellar statistics. He states that the Laboratoire Astronomique de l'Université de Cernăuti, Romania, is willing to distribute on application model prints of Lambert's system of projection.

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