33. COMMISSION DE LA STATISTIQUE STELLAIRE

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MEMBRES: MM. Alden, Ambartsumian, Baade, R. H. Baker, Blaauw, Bok, Bourgeois, A. Brown, Camm, Chandrasekhar, Delhaye, Durand, Dziewulski, Elvius, Fletcher, Freundlich, Fricke, Gyllenberg†, Heckmann, Hertzsprung, Ikaunieks, Junkes, Kuiper, Kukarkin, Lindblad, Lindsay, Link, Lundmark, Luyten, McCuskey, MacRae, Malmquist, Mergentaler, F. D. Miller, Mineur, J. M. Mohr, Nordström, Ogorodnikov, Pannekoek, Parenago, Ramberg, Reiz, Schalén, Schilt, Schürer, H. Shapley, Shiveswarkar, Smart, Strömberg, Trumpler, van de Kamp, Vanderlinden, Van Hoof, van Rhijn, Vashakidze, von der Pahlen†, Mme E. T. R. Williams Vyssotsky.

Because the domain of this Commission overlaps that of several others it is impracticable to give a complete survey in the present Report. I have attempted only to summarize the work on some topics that seemed to me to bear most directly on the structure and dynamics of the Galactic System.*

1. RADIO-FREQUENCY RADIATION

The two greatest recent advances in our knowledge of the Galactic System have come by the southern surveys of radio-frequency radiation and by the discovery of the monochromatic radiation at 1420 Mc./sec. emitted by the atomic interstellar hydrogen. Bolton and Westfold's survey at 100 Mc./sec.† and that of C. W Allen and Gum at 200 Mc./sec.‡ have permitted a determination of the position of the galactic centre which is more accurate than former determinations (from globular clusters, star-counts in intermediate and high galactic latitudes, or infra-red radiation). The position inferred from these surveys agrees well with the centre as usually adopted.§ These surveys also give data about the density distribution of the radio-sources in a part of the Galactic System which was hitherto inaccessible.§ In a general way the distribution conforms with what could be inferred about the mass distribution from dynamical considerations. A preliminary attempt to determine the galactic pole and 'dip' from radiation at 205 Mc./sec. has been made by Seeger and Williamson.||

Following a suggestion made by van de Hulst in 1944¶ attempts have been made at Harvard as well as in the Netherlands to measure the 1420 Mc./sec. radiation of interstellar hydrogen. The first successful observations were made by Ewen of Harvard.** A few months later C. A. Muller of the Netherlands Foundation for Radio Astronomy also observed the line, and made measurements of its intensity distribution and of galactic rotation.†† Subsequently the line was confirmed by measures in Australia.‡‡

2. RELATION BETWEEN EXTRAGALACTIC NEBULAE AND THE GALACTIC SYSTEM

Research into the structure of other stellar systems is becoming more and more important as a guide to indicate promising ways for obtaining insight into the general structure of the Galactic System. In this respect recent investigations by Baade§§ and by

* The Report is limited to investigations published or started since 1948. Previous work has been dealt with in the Report for the 1948 meeting (*Trans. I.A.U.* **7**, 347). For previous work in Germany further reference may be made to the *Fiat* publication on *Astronomy* (1947).

† *Australian J. Sci. Res.* ser. A, **3**, 19–33, 1950.

‡ Ibid. pp. 224–33.

§ Bolton and Westfold, *Australian J. Sci. Res.* ser. A, **4**, 476, 1951. Westerhout and Oort, *B.A.N.* **11**, 323, 1951.

|| *Ap. J.* **113**, 21, 1951.

¶ *Nederl. Tijdschrift v. Natuurkunde*, **11**, 201, 1945.

** Ewen and Purcell, *Nature*, **168**, 356, 1951.

†† Muller and Oort, *Nature*, **168**, 357, 1951. Cf. also *Versl. Kon. Ned. Akad.*, Amsterdam, **60**, 58, 1951.

‡‡ *Nature*, **168**, 358.

§§ *Publ. Michigan*, **10**, 7, 1951.

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Baade and N. U. Mayall* concerning the Andromeda nebula are of particular interest. Baade has discovered numerous diffuse emission nebulae on red plates taken with the 100-inch reflector. The arms are beautifully defined by these nebulae. They seem no wider than a few hundred parsecs in the plane of the spiral. Particularly interesting is the fact that the continuation of these arms into the nuclear part can be traced by the dark matter. Baade points out that also in the outer parts the absorbing matter appears to be largely confined to the arms, the spaces in between being transparent. In this connection mention should also be made of the identification by Haro of 58 emission nebulae in the Andromeda nebula, and 79 in M33.†

Baade believes that the Galactic System resembles an Sb spiral rather than an Sc. But it seems to me that the problem has not yet been brought to a decisive solution.

3. Different Populations

The striking differences in space and velocity distribution shown by objects of different physical characteristics have long been known as some of the most interesting features of the Galactic System. During the last six years a new impetus has been given to such investigations by Baade's discovery that elliptical nebulae as well as the central part of the Andromeda nebula contain red supergiants of presumably the same type as the brightest stars in globular clusters. Baade pointed out that stellar systems can be arranged in two main classes according to the types of stars contained in them. The 'population' of the first class may be characterized in a general way by the stars in our surroundings (population I), the second by the stars in globular clusters and elliptical nebulae (population II). A very inspiring extension of these important considerations may be found in a lecture that Baade has given in Ann Arbor in 1950.‡

When Baade first introduced the notion of populations of types I and II the meaning of these terms was quite clear as applying to the general population of a certain type of stellar system or of a part of a stellar system.§ Recently a tendency has developed to designate various classes of stars as belonging to populations I or II, according to whether they show strong or weak galactic concentration, or have low or high velocities. This usage of the terms is liable to lead to confusion, because the objects in the Galactic System present all possible gradations of concentration to the galactic plane as well as of average velocity. It is an inadequate simplification to represent this as a mixture of two different kinds of populations. It does not seem expedient to extend the notion of population to cover these complicated phenomena. Not only would we have to introduce a large number of 'populations', but the term would lose its original, expressive meaning. It appears preferable to reserve the names populations I and II for characterizing the general type of population of a given stellar system, and to specify the degree of galactic concentration of a given type of *stars* by other terms.||

The objects that are most strongly concentrated to the galactic plane, viz. interstellar clouds, stars of spectral types W, O and B, supergiants of all types, δ Cephei variables and galactic clusters of Trumpler's type I, might be called 'galactic' objects. All these objects, except the interstellar clouds, show practically the same concentration to the galactic plane, the mean distance from this plane ranging from about 40 to 60 parsecs. On the other hand, classes of objects of which the average velocity in one co-ordinate is higher than, say, 30 km./sec. might be indicated as non-galactic or high-velocity types. Subdwarfs, most of the long-period variables, RR Lyrae variables with periods longer than $0^{d}{\cdot}42$, as well as the high-velocity objects among the common-type stars, belong to this category. As has been pointed out by several authors this class is very heterogeneous: the average velocities of different types of objects that would be classified in this group vary over a considerable range.

* *Problems of Cosmical Aerodynamics*, symposium organized by I.U.T.A.M. and I.A.U. in Paris, 1949; ch. 24.

† *A.J* **55**, 66, 1950 (abstract).

‡ *Michigan Publ.* **10**, 7, 1951.

§ *Ap. J.* **100**, 137, 1944; *Mt Wilson Contr.* No. 696.

|| Cf. *Note added to proof* at the bottom of p. 511.

All the stars mentioned so far are rare objects; the great majority of the stars contained in an arbitrary element of volume show a distribution in space and velocity which is intermediate between the two extremes described above, and which might be characterized as that of stars of the solar type. This category contains the main-sequence stars later than A, the ordinary giants, as well as probably subgiants and white dwarfs. If a name is desired to indicate this group as a whole we might refer to it as the group of 'common' stars. Also in this group the characteristics of velocity and space distribution exhibit a considerable range of variation. This is shown in a most interesting manner by recent results obtained by Miss Roman, who finds that if the F5–G5 stars are divided into two equally frequent groups according to the strength of their spectral lines, among the stars of the same subtype and absolute magnitude those with weak lines show an average velocity that is about $1\frac{1}{2}$ times that shown by the stars with stronger lines.* Moreover, the 'common' stars merge gradually on one side into the galactic stars (transitionary types F and A) and on the other side into the high-velocity types (variables of types M4*e*–M8*e* may be considered as an example of this transition).

A somewhat similar classification has been advocated by Kukarkin in his treatise, *Investigations of Structure and Evolution of Stellar Systems on the Basis of Studies of Variable Stars*.† Looking at the presumable distribution through the whole of the Galactic System he distinguishes 'subsystems' of varying degrees of flatness.

Known differences in population refer to intrinsically bright stars that are relatively rare. It is unknown whether also the bulk of the population is different in different types of systems.

Among the principal new results concerning relations between astrophysical characteristics and space- and velocity-distribution obtained after Baade's discussion, were: (*a*) the discovery of some minor peculiarities in spectra of high-velocity objects occurring in classes of stars that are generally of low velocity; (*b*) indications of systematic differences between light-curves and period-frequency curves of pulsating variables in different systems and different parts of the Galactic System.‡ From the material of radial velocities of RR Lyrae variables, which a recent publication by Joy has practically doubled, Struve has discovered that the variables with periods shorter than $0^d{\cdot}40$ show an average velocity that is less than half that of the variables with periods between $0^d{\cdot}50$ and $0^d{\cdot}70$.§ In this connection it may also be mentioned that according to Kukarkin there would be an indication that RR Lyrae variables with periods between $0^d{\cdot}425$ and $0^d{\cdot}435$ would be more concentrated to the galactic plane than the other variables of this type.|| A more general discussion has recently been given by Oosterhoff. He finds that the *a*-type variables with periods shorter than $0^d{\cdot}40$ (a kind that does not occur in globular clusters) show a much stronger galactic concentration than the RR Lyrae variables of longer period. The difference found corresponds, also quantitatively, with the difference in mean peculiar velocity as found by Struve.

It is not yet clear into what category the important new type of objects discovered by Humason and Zwicky in their search for 'blue' stars in high latitudes should be classed.¶ These early-type stars may either be high-velocity objects at large distances, or relatively near-by subdwarfs.**

* *Ap. J* **112**, 554, 1950.

† Moscow-Leningrad, 1949.

‡ Keenan, Morgan and G. Münch, *A.J.* **53**, 194, 1948; Mrs Payne-Gaposchkin, *A.J* **52**, 218, 1947 and **53**, 193, 1948; Kukarkin, *Investigations of Structure and Evolution of Stellar Systems on the Basis of Studies of Variable Stars*, chap. ii (Publ. House of Techn. and Theor. Lit., Moscow-Leningrad, 1949). Dr Mergentaler (Wroclaw) reports an unpublished study on the same general subject, in which he discusses the relation between the period of a δ Cephei variable and its distance from the centre of the Galactic System.

§ *Publ. A.S.P.* **62**, 217, 1950.

|| Kukarkin, loc. cit. p. 105.

¶ *Ap. J* **105**, 85, 1947; *Mt Wilson Contr.* No. 724.

** Cf. Perek and Pels, *B.A.N.* **11**, 281, 1951. Radial velocities measured by Humason now confirm that they are high-velocity objects similar in intrinsic brightness to the RR Lyrae variables.

4. General Investigations on Star-density and Absorption

Two surveys of basic importance are being carried out in California. Dr Shane reports that of the Lick Survey with the 20″ astrograph about three-quarters were finished in the autumn of 1950, about 900 of the 1246 plates on the programme having been taken. It is expected that the survey will be essentially completed in 1953. The plates are 17″, or 6°, square and are taken on a 103*a*O emulsion. They are centred on each 5° of declination starting with −20° In right-ascension they are separated by 5° or less, so as to give a full degree of overlap with adjacent plates. The exposures are of two hours' duration with a supplementary exposure on each plate of one minute. A 4-magnitude grating is used in front of the lens, which together with the one-minute exposure permits the connection of the faintest images with those of bright stars to about the eighth magnitude without requiring the measurement of over-exposed images. The limiting magnitude for stars is about 19. Dr Stanislavs Vasilevskis is investigating the field distortions, and finds that they amount to less than 1″ in the corners of the plates. The plates show extragalactic nebulae to a limiting magnitude about 18·4. Counts of nebulae have been made by Messrs Shane and Wirtanen on about 300 plates, from which they are preparing a chart showing contours of equal density for the region α 12^h to 18^h, δ −20° to +20°

The survey with the Palomar 48-inch Schmidt will reach stars down to about $20^m{\cdot}3$; it is being made in the red as well as in the blue, and will cover the whole sky visible from the Palomar Observatory. About 1000 plates of 14 × 14″ (about 40 square degrees) will be needed for each colour. The survey was started in November 1949, and will take about four years to be completed.

Work of fundamental importance for statistical investigations was done by Baade, and by Stebbins, Whitford and Johnson* in checking the magnitude scales in Kapteyn's Selected Areas 57, 61 and 68.† Considerable systematic errors were found for the fainter stars. In the Southern Hemisphere fundamental photometry of the brighter stars has been undertaken independently by the Cape and Leiden observatories (cf. Report of Commission 25).

The table on the next page lists a number of recent researches into the density distribution by means of magnitudes, colours and spectral types. The summary includes essentially studies that were either completed or started since the previous Report was written.

Counts of stars in the *Henry Draper Catalogue*, arranged according to galactic co-ordinates, were published by Nort.‡ Spectra of the McCormick survey were used by Drs Vyssotsky and Williams to compare the distribution of A and K stars in the zones between ±10° and ±20° latitude. They found the K and M giants to be relatively three times more numerous in the region around the centre than in the opposite direction, while no such difference is shown by the A stars.§ General star counts to $14^m{\cdot}0$ in a region of roughly 35° radius around the galactic centre were made by Lindsay.‖ Star counts to 15^m were made and discussed by R. E. Calvert for the region between 5° and 33° long., −3° and +29° lat.,¶ and by Heeschen for the region from 100° to 140° long., and −20° to +20° lat.** Bok, R. H. Baker and Mrs Gossner are engaged on a project which will provide a summary of surface distribution and absorption phenomena in the parts of the Milky Way covered by the Atlas of Ross and Miss Calvert.

Work bearing specifically on absorption was carried out, among others, by Schilt and C. Jackson, who measured colour-excesses of 286 bright southern stars of types O, B, A0 and K0,†† and by Oosterhoff, who determined colour-excesses for all O–B2 stars

* *Ap. J.* **112**, 469, 1950.

† This photometric work will be extended to six other Selected Areas, viz. 51, 54, 71, 89, 94 and 107. At the Mount Wilson and Palomar Observatories photo-electric and photographic standards as well as colours will be determined in these Areas from 9^m to $22^m{\cdot}5$.

‡ *B.A.N.* **11**, 181, 1950.

§ *McCormick Publ.* **10**, 1948.

‖ *Contr. Armagh Obs.* No. 4, 1951.

¶ *Ap. J.* **114**, 123, 1951.

** Ibid. **114**, 132, 1951.

†† *A.J.* **55**, 9, 1949.

south of $-40°$ as well as for a number of more northerly stars.* Both investigations were made with an IP21 multiplier. With a similar multiplier attached to the 120-cm. reflector of the Observatoire de Haute Provence Walraven measured colours of B and A stars between 9^m and 13^m in 54 of Kapteyn's Selected Areas (unpublished). Van Rhijn discussed colour-excesses of B stars with a view to obtaining information on the distribution of interstellar clouds.†

Infra-red radiation from galactic nucleus. Extending a former investigation by Stebbins and himself at $\lambda = 1\,\mu$ Whitford has made measures at $\lambda = 2\,\mu$. The results agree with those at $1\,\mu$ in indicating a maximum near 326° longitude.‡

Observatory	Galactic co-ordinates of centres l	b	Lim. m_{pg}	Number of stars	Reference
Cleveland	165°	+1°	12·5	1600	McCuskey, *Ap. J.* **109**, 139
,,	133	+2	12·5	1800	Ibid. **109**, 414
,,	42	+3	12·0	1200	Nassau and MacRae, *Ap. J* **110**, 40
,,	70	−3	12·5	4300	McCuskey, *Ap. J.* **113**, 672
,,	97	−1	—	—	In preparation
,,	114	+4	—	—	,,
Hamburg	30–46	Small	13·0	26000	Wachmann, unpublished (8 fields)
Harvard	160–173	−3 to +9	11·5	—	Bok, Olmsted and Boutelle, *Ap. J.* **110**, 21 (7 centres)
,,	Sagittarius-Scorpius		—	—	Bok and Mrs Bok, in progress (down to limit of Armagh-Dunsink-Harvard Schmidt telescope)
,,	Carina-Crux				
,,		90	—	—	
Lick	10	−1	12·0[1]	400	Weaver, *Ap. J.* **110**, 190
McCormick	Various	±11 to ±15	12·0	8000	Dyer, unpublished (44 areas), 38 more areas in preparation
Stockholm	12 Selected Areas[2]		13·6	2600	Elvius, *Stockholm Ann.* **16**, nos. 4 and 5
,,	69°	−3°, −8°	13·5	7000	Ramberg, in progress
,,	146	+3°, +9°	13·5	—	
,,	251	±0°, +6°	—	—	(Plates from the Armagh-Dunsink-Harvard Schmidt telescope)
,,	299	−3°	—	—	
Uppsala	63–90	+20	11·0	1400	Schalén, *Uppsala Ann.* **2**, no. 4
,,	73–104	+40	11·0	1200	Ibid. **3**, no. 3

[1] Magnitudes and colours for 1900 stars down to $14^m{\cdot}0$ *pg*.
[2] Kapteyn Areas Nos. 2, 6, 7, 15–20, 40–42.

5. Distribution of Stars of Special Types; Absolute Magnitudes of B Stars

Our best chance for obtaining new insight into the structural features of the Galactic System appears at present to lie in surveys and accurate individual data of stars of high luminosity. Extended surveys of faint variable stars have been in progress during many years, particularly at Harvard, Leiden, the U.S.S.R. and Sonneberg. Although these are of eminent importance for the problems mentioned, a full discussion of this subject is outside the scope of the present report. I wish to refer, however, to recent surveys of early-type stars of high luminosity (called OB by W W Morgan) and of A and F supergiants. A survey over a belt of 12° width around the northern Milky Way from 333° to 202° longitude has been made by Nassau and W W Morgan with the 24-inch Schmidt telescope in Cleveland.§ It yielded 918 stars of spectral classes O–A2, the great majority of which have visual absolute magnitudes between −3 and −7. All of these objects, as

* *B.A.N* **11**, 299, 1951.
† *Publ. Kapteyn Lab. Groningen*, No. 53, 1949.
‡ *A.J* **53**, 206, 1948 (abstract).
§ *Ap. J.* **113**, 141, 1951.

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well as all other known O–B5 stars, are now being observed with the 40-inch Yerkes refractor for the determination of accurate spectroscopic absolute magnitudes; Morgan expects this programme to be completed by 1952. Photo-electric colours and magnitudes are determined by Whitford. The survey is extended along the southern Milky Way down to $-50°$ declination at the Tonanzintla Observatory. A list of 199 stars in a galactic belt of about 5° width extending from 180° to 240° longitude has been published by Luis Munch.* An additional B-star survey is being carried out by Nassau and Morgan. This is aimed at main-sequence stars of spectral classes B2 to B5; it will be completed by July 1951. These stars appear to form a rather compact group in absolute magnitude. The limiting magnitude of these various surveys is near 10·0 *pg*. The survey at Tonanzintla has been extended to $11^{m}·5$ (Terrazas).

The calibration of Morgan's luminosity classes for early-type stars has been investigated by Blaauw and W W Morgan. Because of the fundamental nature of this problem, and because it indicates ways in which a more satisfactory attack could be made, I quote a full report prepared by Blaauw:

Purpose of the calibration is: (1) the determination of mean luminosities for each of the luminosity classes I–V; (2) the determination of the mean deviation of the individual luminosities from these means. The determination of mean luminosities is based primarily on proper motions. Mean parallaxes are derived from the parallactic motions with the solar motion as found from radial velocities. The applicability of the method is limited by the precision of the proper motions and the available number of classified stars. Provisional mean visual absolute magnitudes are:

Type	Mv
B2 III	$-4·1 \pm 0·4$
B2 IV. V	$-3·0 \pm 0·18$
B3 IV. V	$-2·1 \pm 0·13$
B5 IV. V	$-1·3 \pm 0·12$

These values are for stars of a given apparent magnitude and do not hold for a volume of space. They are a few tenths of a magnitude brighter than those given in the Introduction to the Yerkes Atlas, except for B2 IV, V, where a larger correction is indicated. Classes IV and V were combined, as the provisional work did not reveal appreciable differences between the two. The same method cannot be applied to the higher-luminosity classes, as their mean distances are too large. For these we may either refer to the clusters containing these stars as well as B2–B5 main-sequence stars, and observe the mean difference between the luminosities, or we may derive mean distances from the effect of differential galactic rotation in the radial velocities of the non-cluster stars. The latter procedure involves the use of the constant A. Evidently, in order to avoid circular reasoning, the use of a value of A derived from earlier adopted mean luminosities of B stars should be avoided. Independent determinations from δ Cephei variables and *c* stars are only fairly accurate. An important step in the determination of reliable luminosities for classes I, II, III, and for B0–B1 main-sequence stars will therefore be a re-determination of the constant A from distant B2–B5 main-sequence stars, to be based on the fundamental values of the mean luminosities of the latter. The value $A = 20·0 \pm 1·8$ km./sec./1000 parsecs found in this way from the main-sequence B2–B5 stars for which radial velocities and colours were published by Popper, indicates that a quite satisfactory determination of A may be obtained from a more extensive and more accurate material of radial velocities of 10th magnitude stars, the classifications of which should, of course, be in Morgan's system.

Final values for the main-sequence classes for which provisional values are given above are now being derived with the aid of improved proper motions in the new system N30, kindly made available by H. R. Morgan. Colours of stars not contained in the list of Stebbins, Huffer and Whitford are being measured with the Leiden refractor at Johannesburg.

* *Ap. J.* **113**, 309, 1951.

An important contribution to our knowledge of the central part of the Galactic System has been made by Baade and S. Gaposchkin in their study of variable stars on red plates of a region in the Sagittarius cloud. Besides giving a new determination of the distance to the centre, this investigation shows the extremely strong central concentration of the RR Lyrae variables observed in this direction, half of them lying in the interval between 6900 and 8700 parsecs distance from the Sun.*

At the Warner and Swasey Observatory a very interesting initiative has been taken with a survey of very faint M-type stars on red-sensitive plates covering the wave-length region from $\lambda 6800$ to about $\lambda 8800$. A first instalment, covering a field in the bright Cygnus cloud (centre $l = 41°{\cdot}2$, $b = +3°{\cdot}7$), has been published by Nassau and van Albada.† The survey is complete to 13·5 I.R. magnitude, and includes many fainter stars. Because the absorption is only about one-third of that in ordinary photographic light the survey reaches very large distances (5–10 kiloparsecs). It is intended to extend it to a considerable number of other fields. Besides, a programme is being organized jointly with W W Morgan for cataloguing all M giants to an infra-red magnitude limit of about 12·5 on objective-prism plates taken with the Cleveland Schmidt for a galactic belt 4° wide, and extending from longitude 325° northward to 210° It is hoped that the work will be completed by July 1952. In particular because of the so much lower absorption coefficient this survey will form an extremely valuable addition to the B-star survey.

Von der Pahlen reports on a project for determining the spatial distribution of A0–A3 stars down to the 14th *pg* magnitude in a field in Cepheus-Lacerta. The plates for this study were taken at Castel Gandolfo, magnitudes in two colours are being measured in Basle.

Vorontsov-Veliaminov has made a new investigation of the spatial distribution of planetary nebulae.‡

It has long been known that the distribution of B-type stars, and still more that of stars of types O and W, is extremely uneven, many of these forming groups or clouds extending over a few hundred parsecs (for instance the Orion group, the extended *c*-star cloud surrounding *h* and χ Persei, and the Scorpius-Centaurus cloud first studied by Kapteyn). Recently, Ambartsumian§ and Gursadian‖ have undertaken a statistical study of these 'associations' as they call them. They have called attention to some interesting facts, among others, that many of the associations have an open cluster near the centre, that nearly all P Cygni, W and O stars belong to associations, and that similar groupings are observed in the Large Magellanic Cloud. Ambartsumian includes under the same name the remarkable concentrations of emission dwarfs within near-by dark nebulae discovered in recent years by Joy and by Struve and Rudkjøbing. However, these groupings differ in so many important respects from the clouds of early-type stars that it is doubtful whether such a combination will prove useful. It is even uncertain whether the stars in these dwarf groupings are physically connected with each other. The authors further stress the interesting fact that new associations must continuously be formed.

6. Motions

A considerable number of investigations have dealt with stellar motions. For new lists of proper motions and radial velocities reference should be made to the reports of the Commissions concerned. A number of other investigations will be briefly summarized below.

Particularly important for the problem of fundamental distances and galactic rotation is the work by H. R. Morgan,¶ who determined a new system of proper motions based on a comparison of average positions from observations between 1920 and 1950 with the positions given in the *General Catalogue*. The mean epoch of the modern positions being around 1930 Morgan attached the name N30 to this system. It contains 5000 standard

* Cf. Baade, *Michigan Publ.* **10**, 7, 1951. † *Ap. J.* **109**, 391, 1949.

‡ *A.J U.S.S.R.* **27**, no. 5, 1950. § Ibid. **26**, 3, 1949. ‖ Ibid. **26**, 329, 1949.

¶ *A.J* **54**, 145, 1949 and **56**, 97, 1951. See also *B.A.* **15**, 199, 1950 (or *Colloques Internationaux du Centre National de la Recherche Scientifique*, **25**, 37, 1950). The detailed results will be published in *Astr. Papers of Amer. Eph. and Naut. Alm.* **13**, part 3, 1952.

stars spaced uniformly over the whole sky. The proper motions are practically independent of those given in the GC or FK3, and they are likely to be less subject to systematic errors. The individual motions have about the same weight as the GC motions for the bright well-observed stars but are considerably more accurate than the GC for the fainter stars. Morgan gives tables for the systematic corrections to be applied to the GC and FK3; he also derives a correction to the constant of precession. H. R. Morgan and Oort made a general determination of the constants of precession and galactic rotation, based on the N30 and FK3 systems.*

A study of large scope was published by Drs Vyssotsky and Williams.† Based on proper motions of over 29,000 stars between *pv* magnitudes 9 and 11, determined at the McCormick Observatory, on McCormick spectral data, and on approximately 40,000 Cape proper motions in the zone $-40°$ to $-52°$ declination, it yields new values of solar motion, mean parallaxes, luminosity distribution and velocity distribution for stars of different spectral classes. Among many other results they find that the apex of the solar motion for the faint A and F stars deviates from the standard apex in the same way as was found for the brighter A and F stars (the galactic longitude being about 15° lower than that of the standard apex).

The serious gap still existing in our knowledge of systematic motions in the southern Milky Way is being filled by an extensive programme of O- and B-star radial velocities started at the Radcliffe Observatory.

Concerning work on large proper motions Luyten reports as follows:

1. Proper motions have now been determined for all 82,000 stars found with the blink microscope to possess an appreciable proper motion, and south of declination $-20°$ 2. Colours are being determined for all 37,000 proper motion stars south of declination $-45°$, on a wholesale basis. 3. Similarly, individual colours are being determined for all stars north of $-45°$ with proper motions in excess of 0″·2 annually. 4. Accurate magnitudes and colours are being determined for all known white dwarfs. 5. Proper motions are being determined for all blue stars found by Zwicky and Humason. 6. Accurate relative positions are being determined for all binaries containing white dwarf components with a view toward ultimate statistical determination of their masses. 7. Surveys are being conducted to determine the frequency in space of white dwarfs and degenerate stars.

Various publications have dealt with the calculation of space velocities of stars.‡ Parenago has published new values for the solar motion with respect to stars showing various dispersions in velocity.§ Several other investigators have made computations of solar motion with respect to various types of stars.|| Studies of high-velocity stars were made by Fricke, who tried to obtain in this way the rotational velocity of the Galaxy,¶ and by Dziewulski (unpublished). Motions of near-by stars were subjected to a new discussion by Shimizu.** Delhaye†† has investigated the motions of A and F stars, with a view to obtaining information on the Ursa Major stream.

The distribution of the peculiar motions has been investigated by several authors. Delhaye‡‡ has investigated for this purpose the GC proper motions of 12,000 A, F and K stars between $6^m{\cdot}0$ and $7^m{\cdot}5$, using Schwarzschild's method. The results confirm the well-known deviation of the vertex from the direction to the centre of the Galactic System that had formerly been derived from brighter stars and radial velocities, in particular

* *B.A.N.* **11**, 379, 1951. † *McCormick Publ.* **10**, 1948; cf. also *A.J.* **53**, 49–101, 1948.

‡ Parenago has used a material of about 3000 space velocities (*A.J U.S.S.R.* **27**, no. 3, 1950); Perek computed space velocities of 4259 stars brighter than $6^m{\cdot}5$ (unpublished).

§ Parenago, loc. cit.; also Parenago and Masevich, *A.J. U.S.S.R.* **27**, no. 3, 1950.

|| Mohr, space velocities (unpublished); Moore and Paddock (from radial velocities of 820 stars between $8^m{\cdot}5$ and $8^m{\cdot}6$ *pg*, *Ap. J.* **111**, 48, 1950 or *Lick Contr.* No. 28); Gadzikowska and Iwaniszewski (double stars, using dynamical parallaxes, *Toruń Bull.* No. 9, 1950).

¶ *A.N.* **278**, 49, 1949.

** *Publ. Astr. Soc. Japan*, **1–2**, 43; **3**, 53, 90; **4**, 128, 1949; also *Jap. J Astr.* **1**, 47, 1949.

†† *B.A.N.* **10**, 409, 1948.

‡‡ Thèse, Paris, 1950; also *B.A.* **16**, 1, 1951. Summary in *C.R.* **230**, 1454, 1950.

for the A and F types. A discussion of the same material using the dispersions of the proper motions instead of their position angles is now being carried out by Delhaye in Paris. Similar discussions of the GC motions are in progress at Glasgow.

At Uccle Bourgeois and Coutrez have continued their studies on the space motions of B- and A-type stars.* They have developed a method for studying systematic motions varying linearly with the space co-ordinates, by which they found signs of 'local turbulence' Vyssotsky and Miss Janssen have studied the space motions of about 850 A and K giants within 100 parsecs of the Sun.† A co-operative project between the McCormick, Goethe Link and McDonald Observatories deals with the distribution, radial velocities, proper motions and luminosities of more than 1000 A and K stars between 10·0 and 11·0 *pv* magnitude.‡ The velocity distributions of some special types of objects have been studied by Mohr (planetary nebulae) and Perek (globular clusters§ and RR Lyrae variables).||

Schilt¶ has made a new discussion of stellar motions perpendicular to the galactic plane. In particular he investigated separately the distribution of these motions for stars very near the plane of symmetry and at small distances, z, from the plane. From this he was led to conclude that the amplitudes of the motions perpendicular to the galactic plane would have a preference for a number of distinct values (differing from zero) and that the mass density in a narrow galactic layer would be some hundred times higher than hitherto supposed. It is difficult to understand how such a peculiar distribution of velocities could have originated. It seems likewise difficult to explain the very large density near the galactic plane. This could hardly be ascribed to interstellar matter, as the high hydrogen density which this would probably imply, would conflict with observed interstellar emission. In my opinion, which, however, may be prejudiced, the evidence for the preferential amplitudes does not yet seem sufficient to counterbalance the weight of these difficulties. In any case, though deviations in $K(z)$ at very small z are *possible*, it would seem that, whether or not one introduces preferential amplitudes, the average value of $K(z)$ over the first few hundred parsecs cannot come out very different from the results derived previously.

Schilt reports that galactic components for all stars contained in the General Catalogue are being determined at the Rutherfurd Observatory.

7. Dynamics of the Galactic System

Computations of the gravitational potential of this system have been made by Parenago, who has also given equations for the 'presumed spiral' of the Galaxy.** Perek†† has likewise studied the distribution of mass in our Stellar System, and has combined this with an investigation of the dynamics of the RR Lyrae variables.

The investigations in the following list are not specifically concerned with the Galactic System, but deal with general problems of stellar dynamics: Camm investigated the dynamics of flat systems in the case that Poisson's equation is taken into account.‡‡ He has found similar systems with spherical symmetry. Coutrez has studied the motions neighbouring the quasi-stationary motions in stable systems, his considerations lead to the discussion of elliptical and of spiral systems.§§ He has also studied the unification of the approach through the 'hydrodynamical equation' on the one hand, and the statistics of the individual stellar orbits on the other hand.|||| In Hamburg Fricke has found a new

* *Communications Obs. R. Belgique*, Nos. 7, 11, 17, 18, 1949–50; *Bull. Astr. Obs. R. Belgique*, **4**, 51.

† *A.J.* **56**, 58, 1951.

‡ Cf. Edmondson, *A.J.* **54**, 35, 1948 (abstract); Edmondson, Vyssotsky and Edith M. Janssen, *Ap. J.* **110**, 182, 1949.

§ *Ann. d'Ap.* **11**, 185, 1948.

|| *B.A. Czech.* **2**, 57, 1950.

¶ *A.J.* **55**, 97, 1950.

** *A.J. U.S.S.R.* **25**, no. 4, 1948, and **27**, no. 6, 1950; cf. also his monograph on 'The Structure of the Galaxy' (*Progress of Astr. Sciences*, **4**, 1948).

†† *Contr Astr. Inst. Masaryk Univ.* **1**, no. 6, 1948, and no. 8, in the Press.

‡‡ *M.N* **110**, 305, 1950.

§§ *Ann. Obs. R. Belgique*, 3e Série, **4**, fasc. 3.

|||| *Communications Obs. R. Belgique*, nos. 15 and 18, 1950.

class of velocity distributions which satisfy the equation of continuity and Poisson's equation, and can describe the phenomenon of the asymmetry of the high velocities (unpublished). Kurth (Bern) has made some general theoretical investigations on stationary and non-stationary systems, which he has applied to globular clusters.* In the George Darwin Lecture, 1948, Lindblad has given a review of his theory of spiral structure, and a comparison with observations.† The relation between density variation and velocity dispersion has been investigated by Lindblad‡ and by Tuominen.§ A publication by Milne deals with star-streaming and the stability of spiral orbits in spiral nebulae.|| A new study of stationary systems has been prepared by Ogorodnikoff.¶ Ten Bruggencate published an article on spiral structure and dynamics of the Galactic System.** Takase made an investigation concerning the fluctuations in the force exerted by a stellar system.††

8. Hertzsprung–Russell Diagram

Considerable progress has been made, in particular through the photo-electric work by Eggen. He has determined accurate colour-magnitude arrays in four galactic clusters‡‡ (Hyades, Pleiades, Coma Berenices cluster and Ursa Major cluster) and for near-by stars.§§ He confirmed the extreme narrowness of the main series that had formerly been found at Göttingen for Praesepe and the Pleiades, and indicated a number of other interesting features. The new class of subgiants at $M_{pg} = +3{\cdot}6$ had already been surmised by Strömberg in 1932.||||

The stars that lie just below the main sequence (subdwarfs) have been specially investigated by Kuiper, who also gave some general statistical data on the distribution in the Hertzsprung-Russell diagram.¶¶

9. Some Urgent Problems

Spiral Structure. The most important problem facing students of galactic structure and dynamics is that of tracing the probable spiral structure of the Galactic System. Kapteyn's Plan of Selected Areas is adequate for research into the general structure of the system outside the galactic plane; it may prove useful also for studying some aspects of the distribution in this plane, but it does not appear to be the most suitable for investigating possible spiral structure. The numerous investigations that have been carried out with the aid of star-counts, spectral types and colour-excesses for larger regions have gathered much valuable material. But even with the considerable number of regions investigated it has not yet been possible to form anything like a coherent picture of the density distribution in our surrounding. In several cases large density fluctuations are indicated, but they are elusive features, often differing widely in neighbouring regions studied by different observers. Even within one region densities derived from various spectral types sometimes do not show resemblance. No doubt, more refined investigations may obviate some of these difficulties, and will reveal the true structural features of that part of the Galactic System that is within about 1 kiloparsec from the Sun. Still, it would appear that the search for large-scale spiral structure should follow a different plan.

* *Zs. f. Ap.* **26**, 100 and 168, 1949.
† *M.N.* **108**, 214, 1948. See also his study in *Stockholm Ann.* **15**, no. 4, 1948.
‡ *Stockholm Ann.* **16**, no. 1, 1950.
§ *Proc. Amsterdam Ac.* **53**, 1049, 1950.
|| *M.N* **108**, 309, 1948.
¶ *Progress of Astr. Sciences*, **4**, 1948.
** *Zs. f. Ap.* **25**, 315, 1948.
†† *Publ. Astr. Soc. Japan*, **2**, 1, 1950.
‡‡ *Ap. J* **111**, 65, 81 and 414, 1950.
§§ *Ap. J* **112**, 141, 1950.
|||| *Ap. J.* **75**, 120; cf. also Adams, Joy, Humason and Brayton, *Ap. J* **81**, 190, 1935.
¶¶ *A.J.* **53**, 194, 1948 (abstract).

Such an investigation should concentrate in the first place on objects of great intrinsic brightness which we may expect to be concentrated in spiral arms. Such objects are diffuse emission nebulae and the luminous high-temperature stars, while it is not unlikely that the typically galactic variables of the δ Cephei type would also populate the arms. However, as Dr Blaauw has pointed out to me, the fact that Cepheids do not occur in the O- and B-star clouds of the Galaxy is a reason for some reserve on this latter point. They are most easily recognizable at large distances, while at the same time their absolute magnitudes are better known than those of other distant stars. The variable-star surveys carried out at Harvard, Leiden, in the U.S.S.R., and at Sonneberg have yielded considerable numbers of δ Cephei variables, several of which lie undoubtedly at distances that are sufficiently large to trace the large-scale structure of the Galaxy. The surveys are still very incomplete and inhomogeneous, they are also greatly influenced by large-scale irregularities in absorption. Nevertheless, the available material of δ Cephei variables could probably give important information on galactic structure if magnitudes, colour-excesses and radial velocities would become available for determining their individual distances and motions. For the Southern hemisphere such work is now being taken up by the Radcliffe and Leiden observatories. One of the most promising new plans that can be envisaged would be a survey for faint δ Cephei variables in the red or infra-red. But this is a long and difficult undertaking.

Likewise important are the surveys for faint B-type stars near the galactic circle, in particular for high-luminosity B stars, such as have been started by the Warner and Swasey, Yerkes and Tonanzintla observatories. These also require the measurement of colour-excesses; while radial velocities are highly desirable.

Wolf-Rayet stars can be relatively easily identified, even among faint stars. The distribution of known stars of this type is most remarkable. Of the total of eighty-nine listed in 1930 by Miss Payne in her monograph on *The Stars of High Luminosity* no less than twenty-five are concentrated in two compact groups, from galactic longitude 40° to 45°, and from 251° to 259°, respectively, while a looser group of fifteen W stars lies between 306° and 328° From available evidence it has not yet been possible to decide whether the first two groupings are really compact groups ('stellar associations') or whether they are the projections of parts of spiral arms that are tangent to a radius vector to the Sun.

It seems probable that the new possibilities opening up in radio astronomy will contribute greatly to the problem of localizing spiral structure in the Galaxy. An attempt in this direction has already been made by Bolton and Westfold.* The greatest advance may be expected from the observations on the 21 cm. hydrogen line.

It is evident that besides the structure also the motions of the arms are of great importance. For this purpose radial velocities such as those determined by Joy for Northern δ Cephei variables are essential.

Absolute Magnitudes of Variables of δ Cephei and RR Lyrae type. The probable errors of both the zero point of the period-luminosity relation of δ Cephei variables, and the absolute magnitude of RR Lyrae variables, may be roughly estimated as $\pm 0^{m}\cdot 4$ or 20%. As all distances larger than 1 or 2 kiloparsecs are based on one of these two, greater accuracy is essential. Roughly half of the uncertainty may be ascribed to uncertainty in the interstellar absorption. The determination of accurate colour-excesses of these stars is therefore a first requirement. The other half is due to uncertainty of the distances. The distances of the RR Lyrae variables can be improved by obtaining more accurate proper motions from photographic plates. Because of the large peculiar motions photographic proper motions are adequate, even if there is some uncertainty in the zero point. First-epoch plates are available at the McCormick and Mount Wilson observatories. Their utilization for the determination of accurate motions would appear to be one of the most urgent undertakings. Improvement of the distances of δ Cephei variables can likewise be obtained by better proper motions. In this case the elimination of systematic

* *Australian J. Sci. Res.* ser. A, **3**, 251, 1950.

errors is the greatest difficulty. Morgan's N30 system (cf. p. 506) forms a notable contribution to this problem. Another way would be through a more accurate determination of the constant A of differential galactic rotation. The radial velocities of distant δ Cephei variables will then yield better average distances.

Constants A and B. The best way for determining A may be by means of radial velocities of 10th and 11th magnitude main-series B stars as proposed by Blaauw (cf. p. 505 of this Report). For the constant B we have to rely on amelioration of the fundamental proper motions of typically galactic stars; these will at the same time afford a welcome independent determination of A. Systematically very accurate proper motions with respect to fixed nebular standards will in the future become available through the survey with the 20″ Lick astrograph. Unfortunately the stars for which accurate systematic motions are most needed will not be obtained in this way because there are no extragalactic nebulae near the galactic equator. In order to be able in the future to draw full profit from this great undertaking it seems essential that with meridian circles strong connections be made of stars of types O, W, B0–B5, δ Cephei variables and supergiants with reference stars at galactic latitudes larger than 15°. Such a programme has in the past been suggested by Mineur. It is well to stress again its importance for our knowledge of the fundamental data of the Galaxy.

Distance to Centre and Distribution of Mass. The only reliable manner in which the distance to the centre of the Galaxy can at present be determined is by the study of RR Lyrae variables in southern galactic latitudes near 325° longitude. In this connection reference has already been made to Baade and Gaposchkin's survey in the Sagittarius cloud. Surveys in somewhat larger negative latitudes, where there is less absorption, have been made at Harvard and Leiden, but extensions to somewhat fainter magnitudes are highly desirable. Improvement of magnitudes and determination of colour-excesses are an essential requirement. Surveys of RR Lyrae variables coupled with radial velocity data for variables in the central region will also make it possible to determine the distribution of mass in the Galactic System. The latter distribution will also follow from the observations of the interstellar emission line at 21 cm.

10. Proposed Recommendation

J. M. Mohr submits the following recommendation for adoption by the Union: 'That for problems concerning galactic dynamics standard galactic co-ordinates be used: the x-axis directed toward the galactic centre at 327° galactic longitude, the y-axis toward $l=57°$, and the z-axis toward the north galactic pole.'

Mohr comments upon this as follows: 'Several authors (e.g. P. P. Parenago, G. Strömberg, J. M. Mohr) used already this or a similar system of rectangular co-ordinates. Nomograms for a direct transformation from the equatorial into these co-ordinates have been constructed (*Contr. Astr. Inst. Masaryk Univ.* Vol. **1**, no. 4, 1948). It would be advantageous to take as origin of the galactic longitude the direction toward the galactic centre.'

J. H. Oort
President of the Commission

Note added to proof. (*Section* 3.)

Since the above was written the author has had the benefit of personal discussions on this subject with Baade, Schwarzschild, Spitzer and others. From the arguments presented it appears quite probable that a very significant and sharp dividing line can be drawn between Populations I and II, the latter consisting of those stars that were formed either in the primaeval stages when the Galactic System just separated itself from the rest of the universe (globular clusters, RR Lyrae variables with $P > 0^d.4$, etc.) or in the intermediate stages before the original gas in the Galactic System had settled down to its present distribution. All stars formed in later times would be Population I.

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