33. COMMISSION DE LA STRUCTURE ET DE LA DYNAMIQUE DU SYSTEME GALACTIQUE

PRÉSIDENT: Professor A. Blaauw, Director of the Kapteyn Astronomical Laboratory, Broerstraat 7, Groningen, the Netherlands.

MEMBRES: Ambartsumian, Baade†, Bidelman, Blanco, Bok, Delhaye, Fricke, Gyldenkerne, Haro, Heckmann, Ikaunieks, C. O. R. Jaschek, Kaburaki, Kerr, Kukarkin, Kuzmin, B. Lindblad, Luyten, MacRae, Malmquist, Mohr, Morgan, Nassau, Ogorodnikov, Oort, Parenago†, Perek, Petrie, Ramberg, Reiz, Mlle Roman, Schalén, Schilt, M. Schmidt, H. Shapley, Stibbs, van Hoof, van Rhijn†, Vyssotsky, Weaver.

La Commission a trois Sous-Commissions: 33*a*, 33*b*, 33*c*.

INTRODUCTION

The present report, like the preceding one, is mainly confined to those aspects of galactic research which are not covered by other Commissions. In cases of overlap with other Commissions where it is not obvious whether the work done should be mentioned here, the choice has been made rather arbitrarily. Thus, radio-astronomical research dealing with the distribution of neutral hydrogen in the galactic disk has been included, but radio work on the galactic halo has not. In this particular case the choice is the same as that adopted in the previous report. Similarly, references to observational programmes providing data basic to galactic research have been made with a certain amount of arbitrariness. In the choice of these, I have been led by the reports submitted to me in reply to a circular letter, requesting relevant information. This letter was given a rather wide distribution in addition to the membership of Commission 33. A number of important investigations not reported to me have been included in the report, but I am aware that it is still far from complete.

A number of handbook articles, symposium reports and reviews have appeared which are of interest to the student of galactic research. Among these are the following:

The report on the 1957 Vatican Symposium on Stellar Populations, edited by O'Connell (1);

The R.A.S. Report on the Progress of Astronomy: 'The Galactic System as a Spiral Nebula' by Oort, Kerr and Westerhout (2);

The Paris Symposium on Radio Astronomy, edited by Bracewell (3);

The IAU Symposia: on the *Large-Scale Structure of the Galactic System*, edited by Roman (4), and on *Co-ordination of Galactic Research*, edited by Blaauw, Larsson-Leander, Roman, Sandage, Weaver and Thackeray (5);

The Proceedings of the 1956 Cosmic Distance Scale Conference held at Charlottesville (6);

The 1959 Paris Symposium on Galactic and Extra-galactic Research and the Electronic Camera (7);

Volume 53 of the 'Encyclopedia of Physics' (*Handbuch der Physik*) (8), dealing with stellar systems, containing, amongst others, chapters on the kinematical basis of galactic dynamics by Edmondson; on galactic dynamics by Lindblad, and on radio frequency studies of galactic structure by Oort;

A chapter on the 21-cm line and galactic spiral structure in *Ergebnisse der exakten Naturwissenschaften* by Elwert (9).

Finally, reference is also made to the report of Sub-Commission 33*b* below.

NUCLEUS AND HALO

Properties of the neutral hydrogen in the central region of the Galaxy are described by Rougoor and Oort (**10**). Large deviations from the rotational motion are found beyond 600 ps from the centre and it seems most plausible that we are dealing with expansion velocities. A ring with density about 1 atom per cm^3 appears situated between 500 and 600 ps, it does not expand. Within it, the density increases strongly towards the centre where it forms a nuclear disk. The disk shows no signs of expansion, but is in a state of rapid rotation. If the mass density is derived from these velocities, supplemented by data from M 31, a central total mass density is found of 24 000 times the density near the Sun, almost all of which must be due to stars. The distribution and motion of the gas in the central part present most interesting problems with regard to the cause of the outward flow and the replenishment. The nucleus itself, according to Drake (**11**), contains two clouds of high interstellar density, about 15 ps from the centre.

Courtès and Cruvellier (**12**) have made a special effort to observe weak Hα emission in a direction close to the galactic centre; the large Doppler displacement of about 135 km/sec they find suggests that we are indeed dealing with gas in the surroundings of the nucleus.

A study of the M-type stars and red variables in the direction of NGC 6522, near the galactic centre, was published by Nassau and Blanco (**13**). Near the galactic centre a ratio of two is found for the space density of stars of type M 2 or later as compared to RR Lyrae stars. The proportion of variable stars among the types M 4 and later, found by comparing the Cleveland data with those of Baade's investigation, was compared with the preliminary results of the Groningen-Palomar survey. It appears that 60 to 80% of these late M stars are constant within 0·5 magnitude. Progress of the Palomar-Groningen variable star programme is reported by Plaut. A second series of plates has been taken with the Palomar Schmidt telescopes for each of the four regions. This serves especially for the long-period variables. The search and analysis of stars in field 2 ($l^I = 331°$, $b^I = +12°$) may be completed in 1961. A survey of all M stars in the four fields studied by Plaut, based on infra-red objective prism spectra, has been undertaken by Blanco and Mavridis at Cleveland. This will provide valuable material for the study of the space distribution of the M giants. Work on the variable stars in fields close to the galactic centre at Leiden is being continued by Kwee and Ponsen, and the same holds for Hoffleit's work in Sagittarius.

Arp (**14**) has studied the colours and magnitudes of 300 stars in directions close to M 22, where the line of sight passes at 2·3 kps from the galactic centre. He concludes that the majority of the redder stars are less luminous than globular-cluster giants of the same colour index and that these stars are nearer in luminosity to old galactic-cluster giants.

A new analysis of the radial velocities of globular clusters was made by Kinman (**15**). It is based on 70 objects, for 20 of which the velocities had been newly determined. The solar motion is found to be 167 km/sec ± 30 (p.e.); both this and the direction of the motion are about the same as that found in earlier work by Mayall. Kinman finds that the motions of the globular clusters are the same as those of cluster-type variables of the period range occurring in globular clusters. An attempt to find the distribution of galactic mass from the peculiar motions of the clusters leads to results consistent with Schmidt's model.

Luyten has continued his investigation of faint coronal blue stars. Proper motions were measured for 250 faint stars; they indicate that genuine white dwarfs are rare among this category, at least among the stars brighter than 16th magnitude. Luyten presumes that they represent a large variety of objects, ranging all the way from the main sequence, through 'horizontal branch' stars to SS Cygni variables of absolute magnitude +7 and fainter. A search near the south galactic pole has been made jointly with Haro, on Palomar Schmidt plates. About 10 000 faint blue stars were recorded in this survey. As a by-product of this investigation, Luyten finds the stars of colours *f* and *g* to be very numerous even down to $m = 19$, indicating that either their density at large distances from the galactic plane is much higher than has been supposed, or that the luminosity function at large distance from the plane resembles that in the globular clusters more than that in the solar neighbourhood.

Stars of spectral classes B 0 to A 2 in the northern and southern galactic polar caps were also searched by Cowley (**16**), who lists 93 objects. For 20 of these, photo-electric photometry was made, and for 38 proper motions are available.

Evidence for resemblance of the space distribution of early-type sub-dwarfs or horizontal branch stars and the distribution of the cluster-type variables was found by Emoto (**17**). From the analysis of the proper motions of the faint blue stars this author concludes that the mean rotational velocity of these objects around the galactic centre at several hundred parsecs from the galactic plane is considerably slower than that for the stars in the plane (**18**).

SPIRAL STRUCTURE AND GALACTIC ROTATION

A general discussion of the Galactic System as a spiral nebula has been given by Oort, Kerr and Westerhout (**19**); this made use of all available radio and optical information. The radio data of Leiden and Sydney have subsequently been compared in more detail by Kerr. From a small asymmetry of the measured velocities, Kerr has introduced an additional solar motion component of 7 km/sec in a direction outwards from the galactic centre. Since this motion is relative to very distant hydrogen, this result is not in conflict with optical results on the solar motion relative to nearer objects. The analysis suggests that the expanding motion of the gas in the inner parts of the Galaxy extends to the Sun's distance. This new concept of the general state of motion in the Galaxy leads to a revised spiral structure diagram which seems somewhat more reasonable than the earlier one.

Rougoor and Oort, in the 21-cm investigation quoted already, describe strong observational evidence for the existence of a well-defined expanding arm at about 3 kps from the centre; the velocity with which the arm recedes from the galactic nucleus being about 50 km/sec.

The general spiral structure of the Galaxy has been discussed by Bok (**20, 21**), who expresses the opinion that the evidence favours a general picture somewhat different from the one proposed by Morgan and associates. Bok stresses the fact that the Carina arm may prove to be a direct continuation of the Cygnus arm. The structure of the outer arm in the region between $l^{\mathrm{I}} = 10°$ and 120° is being studied by Van Woerden and Habing. This arm appears to extend to distances of several thousand parsecs above the galactic plane on the side of the north galactic pole.

Mills (**22, 23**) has drawn attention to a series of steps in the longitude distribution of the disk component of the 3·5-metre continuum radiation. He suggests that these indicate directions at which spiral arms are seen tangentially; most of them agree well with the corresponding directions from the 21-cm observations.

An interesting attempt at unravelling the spiral structure of the Galaxy has been made by Elsässer and Haug (**24**) by means of measurements of the surface brightness of the Milky Way in different colours. Peaks in the general distribution of brightness, occurring in both colours, are interpreted as indicating the direction at which the line of sight runs along the inner side of spiral arms. The picture of the spiral structure thus obtained is in agreement with that obtained by other optical methods in the solar neighbourhood.

The problem of the cause and the maintenance of the spiral structure of stellar systems in general involves, among others, the question of possible differences between the mean velocity of spiral arms of neutral hydrogen and the velocity of the flat disk population. A first attempt at such a comparison for regions outside the solar neighbourhood was made by Münch and Münch (**25**). Radial velocities and photometric distances were obtained for 18 very distant OB stars between longitudes $l^{\mathrm{I}}=345°$ and 35°. The stellar motions suggest for the rotational velocity at a distance of about 6 kps from the galactic centre, a value somewhat higher than that indicated by the neutral hydrogen, whereas at 4 kps the difference is in the opposite direction. These provisional results indicate the desirability of pursuing this sort of investigation on a much larger scale.

A careful analysis of radial velocities of distant B-type stars, incorporating the new Radcliffe observations of radial velocities and MK classifications, was published by Feast and Thackeray (**26**). It results in a new determination of the constant A of galactic rotation: 17·5 km/sec ± 1·5 (p.e.), in good agreement with recent determinations based on Cepheids and independent B-star data (see the previous report of this Commission). The distance of the galactic centre is found to be 8·9 kps, making use of both the Camm linear approximation of the Bottlinger formula, and of a relation due to Titus, connecting A, R_0 and the ratio of the axes of the velocity ellipsoid. Shingi, using data on motions and distances of Cepheids, arrived at a distance of 8·8 kps for the galactic centre. The parameters of galactic rotation were also studied by Pskovsky (**27**) with radial velocities of Cepheids and neutral hydrogen emission data.

Since the spiral structure in the stellar distribution shows most conspicuously in the OB stars and super-giants, special efforts are being made to provide finding lists of these objects as a basis for further observations. Of primary importance is the combined effort of the Hamburg and the Warner and Swasey observatories. The technique employed has been described by Slettebak and Stock (**28**). OB stars together with super-giants of luminosity classes I and II of types B through F are segregated down to photographic magnitude 13 on Hamburg Schmidt plates. The programme covers the Milky Way north of declination −16° between latitudes ±8°. A first finding list, covering 600 square degrees in the Cassiopeia-Perseus region (about $80° < l^{\mathrm{I}} < 110°$) has been published (**29**). An area of the same size in Sagitta, Vulpecula and Cygnus has been surveyed at Cleveland on the Hamburg plates (about $15° < l^{\mathrm{I}} < 45°$), and will soon be published. The section in between these two is under investigation and for the remaining part, Perseus to Orion, most of the plates have been taken at Hamburg. Cleveland adds a similar survey with plates taken with the Warner and Swasey observatory Schmidt telescope for the region $342° < l^{\mathrm{I}} < 15°$: a strip 45° wide centred along the galactic equator is under investigation. Special plates including the Hα region have been added. Most of the search and classification have been done already. As part of this work, spectral data for eight clusters were already published by Roslund (**30**).

In the southern sky, Westerlund has searched a region of about 100 square degrees centred on the southern Coalsack for OB stars and emission objects. Photometry of these objects has begun. Photo-electric magnitudes and colours of 200 early-type stars in the vicinity of the association I Vel are being observed by Velghe. Walraven, at the Hartebeestpoortdam southern station of the Leiden observatory, is engaged in multicolour photometry of all southern HD and HDE O-B3 stars. At the Radcliffe observatory, Thackeray and associates are continuing the three-colour photometry and MK classifications for faint southern B stars. Also radial velocities of these stars are observed.

Bok and associates observe colours and magnitudes for all O and B stars in SA 193 down to 11th magnitude, with Buscombe and Morris adding MK classifications. Similar work is being done in SA 158. Special attention is also being given by Mount Stromlo observers to the region near $l^{\mathrm{I}}=262°$, where a slight concentration of early B stars suggests a spiral feature at a distance

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of about 2000 ps. Whiteoak is engaged in a survey of the region of the I Ara association near $l^{\mathrm{I}} = 305°$.

Tifft (31), using photometry approximately in Becker's system, has studied concentrations of early-type stars in the directions of NGC 6910 and NGC 6913 (M 29).

The radial velocities of O- and B-type stars down to the 12th magnitude along the Milky Way will be provided by the objective prism radial velocity observations of Fehrenbach, which are being extended to the southern hemisphere. Bouigue of Toulouse participates in this project for the determination of colour excesses and stellar line intensities for luminosity estimates. *UBV* photometry of O and B stars in 11 Selected Areas in the galactic plane, including about 1800 stars from the Bergedorfer Spektral Durchmusterung, is being made by Bigay. Most of the observations have been obtained; the work was described in a preliminary note (32).

Studies of the space distribution of the hot stars and later type super-giants were reported from many observatories. Regions in Cepheus and Cygnus were studied by Kostiakova (33). A general study of the distribution of groups of early-type stars was published by Kopylov (34). The distribution of O associations, H II regions and open clusters according to current work by Ishida tends to follow the periphery of the neutral hydrogen spiral structure. Kaburaki, studying the distribution of blue giants with large colour excesses, concludes that the interstellar dust follows the spiral structure.

A study of the galactic distribution, space motions and luminosities of the carbon stars was made by Ishida (35). It was found that the N-type non-variable stars are distributed similar to the OB associations. The distribution and space motion of the normal carbon stars suggest that these objects are younger than the M-type giants. Kaburaki, as a result of a study of the distribution of the super-giants observed by Kron and Westerlund, concludes that, contrary to the OB stars, the A to M super-giants show no preference for the spiral structure.

The space distribution of the northern Cepheids has been studied by Oosterhoff on the basis of new photometry (36). The pattern of the distribution is complicated and shows no simple relation to the spiral structure of early-type stars and neutral H. *UBV* photometry of faint Cepheids in the Cygnus cloud is being made by Wachmann. Photometric observation of Cepheids with a view to determining their space distribution has also been undertaken by Bahner and Mavridis.

Improvement of the distance determinations of individual stars on the basis of spectroscopic criteria remains of primary importance for the study of structural details in the Galaxy. In this context we refer to the further developments of luminosity criteria for O- and B-stars and later super-giants by means of multi-colour photometry by Walraven (37) and current work by Borgman, and to the extensive programme of measurements both of equivalent widths of H-gamma and the K line, and of radial velocities for B-type stars by Petrie. Data for 550 B-stars north of declination $+20°$ and between magnitudes 7·6 and 8·6 and their analysis will soon be published.

A study of the solar motion, *K* effect and of the constant of galactic rotation was published by Mirzojan (38). Another study of the velocity distribution of O to B 5 stars has been undertaken by Moerdijk at Gent.

PROPERTIES OF THE LOCAL POPULATION

Bright Stars

Investigations of spectral criteria which can be used for accurate luminosity determinations remain of fundamental significance for the study of galactic structure. A most important

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contribution in this field has been made by Wilson (**39**), who measured the widths of the bright reversals in H and K in late-type stars. It was shown that this quantity is closely related to luminosity over the wide interval of visual absolute magnitudes -6 to $+8$. For giant and sub-giant stars the probable error of a single measurement is $\pm 0{\cdot}26$ mag; the probable error due to intrinsic scatter is found to be $\pm 0{\cdot}20$ mag.

Gyldenkerne has measured Strömgren's colour index difference m for nearly all the G and K stars observed earlier by him for the K, n and g criteria (**40**). The material thus obtained provides the basis for a three-dimensional classification; a report on which is soon to be published. Exploratory work on the m criterion was published by Borgman (**41**). For A-type stars, Gyldenkerne has measured the Hβ -index, similar to work done by Crawford for B stars (**42**) and by Strömgren (**43**) for A and F stars. Future work by Gyldenkerne will include measurements in four or five wave-length regions.

A variety of spectral features are being measured at the Cambridge Observatories. Griffin and Redman have published work on CN 4200 (**44**), and work in progress deals with measures of CN 3880, Mg b lines, D lines, the 5250 Fe triplet, Hα and the interstellar 4430 Å band. Most of the work has been confined to G and K stars brighter than 7·5 mag. The 5250 Å triplet appears to be a good luminosity criterion, but may not be a population index.

In the present context, we also mention the work by Walraven (**37**), and the MK spectral classification of 533 B 8 to A 2 stars by Osawa (**45**). Evans, Menzies and Stoy (**46**) have continued the publication of fundamental data (magnitudes, colours, spectral classes and radial velocities) for southern stars.

Radial velocities and MK classification of 75 southern bright stars were determined by Buscombe and Morris (**47**).

Spectral surveys; studies of space distribution

A large number of studies of the space distribution of stars of various spectral types is underway, many of them inspired by the problem of the correlation between these distributions and that of the interstellar gas. Ramberg, after the completion of his survey in the Lacerta region (see the previous report) continues his programme at the Stockholm Observatory with a region in Norma ($l^I = 300°$) by means of plates taken at the Boyden Observatory. Elvius, now at Uppsala, continues his spectro-photometric work on the Selected Areas, started at Stockholm, in collaboration with K. Lodén. A catalogue of S.A.'s 11 to 14 was published (**48**). Work on S.A.'s 8–10 is in progress; this will complete the zones $+75°$ and $+60°$. Together with 4 areas in the zone $+45°$, material will then have been obtained for 22 areas in the region $l^I = 55°$ to $125°$, $b^I = +60°$ to $-20°$. Further, the 10 S.A.'s 91, 103, 115, 116, 126, 150, 166, 190, 192 and 193 at l^I 60° and 240° and covering a wide range in latitudes are being investigated with both Uppsala and Boyden material, partly overlapping to ensure homogeneity. Polarisation measures are being added for some areas by L. O. Lodén (**49**). In connection with the interpretation of the observed colours, new normal colours have been derived from areas with well determined magnitude scales (**50, 51**).

A systematic investigation of the southern Milky Way is being carried out at Stockholm embracing 159 fields in galactic bands at latitudes $+2°{\cdot}5$, 0° and $-2°{\cdot}5$, in the range R.A. $7^h\ 30^m$ to $18^h\ 0^m$. It is based on objective prism spectra taken with the ADH telescope at Boyden Observatory and on photo-electric photometry in blue and yellow.

At Torun Observatory, the stellar distribution and interstellar extinction in fields in Cassiopeia ($23^h\ 57^m$, $+59°{\cdot}6$) and in Sagitta ($19^h\ 39^m$, $+17°{\cdot}7$), each covering nearly 10 square degrees and down to 13th photographic magnitude, and based on spectral classification and colour indices has been investigated by Ampel and Iwaniszewska (**52**). At the Crimean Astrophysical Observatory, measurements of magnitudes, colour indices and spectral classifications down to photographic magnitude 12·5 were made in the following areas:

α(1950) h m	δ(1950)	areas	number of stars	reference
20 05	+36°	6°×6°	5000	**53**
18 10	−15·0	8×8	3915	**54**
2 30	+58·0	45	3340	**55**
21 24	+58·5	5×5	2060	**56**
20 16	+42·5	28	952	**57**
20 44	+45·0	7×6	3404	**58**

Kharadze and Bartaya (**59**) have carried out spectral classifications of 5000 stars down to 12th magnitude in regions in Cygnus, Sagittarius and Cepheus and around the clusters Tr. 1 and NGC 6913.

At the Hoher List station of the Bonn Observatory, W. Seitter is engaged in a study of absorption and density distribution in a region at $l^{\mathrm{I}} = 66°{\cdot}7$, $b^{\mathrm{I}} = -5°{\cdot}8$, based on photographic photometry in the *UBV* as well as in the *RGU* systems. Also, spectral surveys at low dispersion (560 and 1100 Å/mm) combined with two-colour photometry are being used, in an attempt to compare the results of the two observational approaches. Schmidt-Kaler uses spectral surveys and three-colour photometry (*UBV*) for an investigation of the distribution of the B 8 to A 2 stars and the interstellar absorption in the following five regions:

$$
\begin{array}{llllll}
l^{\mathrm{I}} = & 34°{\cdot}5 & 85°{\cdot}0 & 101°{\cdot}0 & 116°{\cdot}0 & 154°{\cdot}0 \\
b^{\mathrm{I}} = & -0°{\cdot}9 & -2°{\cdot}0 & -3°{\cdot}5 & -8°{\cdot}0 & +2°{\cdot}5
\end{array}
$$

The distribution of the B 0–B 3 stars, the late giants and the A 0–A 4 stars and the interstellar absorption is being studied in the four fields at $l^{\mathrm{I}} = 24°$, $b^{\mathrm{I}} = -25°$, $-10°$, $0°$, $+10°$ by Schäfer. The photometry is based on the *RGU* system, down to 14th magnitude. A correlation is found between the occurrence of interstellar matter and the A 0–A 4 stars. Also, it is found that, contrary to the expectation, at $b^{\mathrm{I}} = -25°$ early B stars and interstellar matter do occur. A similar project at $l^{\mathrm{I}} = 130°$ has been undertaken by Starischka.

RGU photometry down to very faint stars, based on Palomar Schmidt photographs, with the aim of determining the distribution of stars of different luminosity, and possibly separating disk and halo populations, is being carried out by Becker and associates at Basel-Binningen. The areas investigated and ready for publication are near M 35 and in Scutum, SA 57, Cassiopeia and Cygnus (limiting magnitude 15 to 17). Areas to be investigated are: SA's 51, 54, 57, 71, 82, 94, 107, 141, 158, M 5 and NGC 6356, and also Milky Way fields in Sagittarius, Aquila, Lacerta, and Cassiopeia; for these the limiting magnitude will be about 19.

A discussion of the existence of clusterings among A-type stars was published by Kevanishvili (**60**).

Parenago's (**61**) proposal for co-ordination of various kinds of observations in five selected regions has been followed up by a number of observatories. The Main Astronomical Observatory of the Ukrainian Academy of Sciences observed the photographic, photo-visual and photo-red magnitudes of more than 20 000 stars brighter than magnitude 13 in areas no. 1 (in Aquila) and no. 2 (in Cygnus); the Abastumani Observatory determined spectral classes and magnitudes down to magnitude 13 in all five areas of the plan, and the Sternberg Astronomical Institute classified the spectra of 5000 stars in region no. 5 (Orion) on Abastumani plates. Proper motions of 161 stars in the region of the Orion belt (area 5) were already published by Artiukhina and Karimova (**62**). Second-epoch plates for proper motions were taken at Pulkovo Observatory, which also observed radial velocities of 40 stars brighter than 8th magnitude.

Parenago (**63**) has investigated the use of the function $A(m, c)$, giving the number of stars of specified apparent magnitude and colour index, for purposes of stellar statistics. Starikova (**64**) has considered the determination of such a function as well as the comparison between observed and predicted numbers of stars in different parts of the sky.

An item of general interest for studies of the space distribution of stars based on star counts and the luminosity function, is Crowder's (**65**) attempt to perform the necessary computations with an electronic computer.

The problem of the giant-dwarf ratio among G-type stars was studied by McCuskey and McCuskey (**66**), who find that among 6th magnitude G 5 stars 25% are dwarfs.

The search of Hα emission stars connected with nebulosities was continued at Abastumani Observatory. Manova (**67**) published a list of such objects around λ Ori, and a similar list around ζ Oph was published by Dolidze and Atakelian (**68**). Dolidze and Viazovov (**69**) discovered 125 faint emission stars in the region of IC 1396, Dolidze 145 objects near the cluster NGC 7380 (**70**), 58 near the nebula S 147 (**71**), and 70 near the cluster ζ Scl (**72**).

Considerable work is being done on surveys in the red and infra-red. At the Warner and Swasey Observatory, where this work was initiated, the surveys of the northern Milky Way have been extended to higher latitudes. Ten 4°-wide belt-shaped regions oriented perpendicular to the galactic equator, reaching from $\pm 6°$ to $\pm 18°$ at every 21° in longitude from $l^{I} = 342°$ to 171° are investigated. The carbon stars found were published by Blanco (**73**); a catalogue of M-type BD stars is under preparation. Westerlund has carried out infra-red surveys in Cygnus (**74**), and in Aquila (**75**), and in the region of the southern Coalsack. With the Uppsala southern Schmidt telescope at Mount Stromlo, he is now carrying out a survey in a 10°-wide belt along the southern galactic equator, down to infra-red magnitude 13. Carbon stars, S stars and M super-giants will be searched for in the first place. A systematic search of M-, S-, and C-type stars belonging to galactic clusters, based on Cleveland plates, has been undertaken by Mavridis at Athens. Such studies should provide information on the intrinsic colours and the absolute magnitudes of these stars. A few cases of such membership were noted already; first results were published by Mavridis (**76, 77**). Velghe, in collaboration with Nassau, is carrying out an infra-red survey of cool stars in Cygnus and Draco at $l^{II} = 41°$. Velghe, at the Boyden Observatory, also is gathering red and infra-red photographic material in selected regions in the southern Milky Way, and is studying the most suitable criteria for the discrimination of cool stars by comparing low-dispersion spectra in the yellow, red and in the infra-red, using appropriate emulsions and filters. Blanco is engaged in a study to develop techniques for the detection of fainter red stars than was hitherto possible. It appears that types M 6 and later can already be recognized at a dispersion of 11000 Å/mm; types C, M 4 and M 5 at 6000 Å/mm, and M 2-M 4 at 4000 Å/mm. A gain of about one magnitude with respect to previous work is indicated.

Various observatories work on stars near the north or south galactic poles. Blanco and The (of Bosscha Observatory) are collaborating in such a study; it appears possible to segregate dwarf and giant M stars on the basis of the apparent magnitude. Preliminary observations yield a space density for M 5 and M 6 dwarfs that is 5 times higher than expected from the existing lists of nearby stars. Odgers and Petrie, at the Dominion Astrophysical Observatory, carry out a programme of spectroscopic observations near the north galactic pole: 120 A to F stars, $m < 9$ and within 10° of the pole. Radial velocities have been determined for 80% of these. The material will serve for a new estimate of the density in the solar neighbourhood.

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Bok and Basinski, at Mount Stromlo, are engaged in a photographic colour-magnitude survey in SA 141 near the south galactic pole, to be discussed in conjunction with the Uppsala spectral survey.

Motions and space distributions of special groups

A new analysis of the space velocities of the stars within 20 ps, based on Gliese's catalogue, was published by Woolley (**78**). Selection of stars with large proper motions is found to be still present among the K and M stars in this sample. The vertex of the velocity ellipse is shown not to differ significantly for various sub-groups selected according to the eccentricity of the galactic orbits. The dispersion in the velocities perpendicular to the galactic plane is shown to be correlated with the eccentricity of the orbit, but not with mass. A study of the colour-luminosity arrays of sub-groups selected according to the closeness with which they approach the galactic centre was made by Woolley and Eggen (**79**). These arrays appear to vary from that of 'new' clusters to that of 'old' clusters.

The velocity distribution of the M dwarfs with emission characteristics was investigated by Gliese (**80**), on the basis of McCormick data. Compared to the M dwarfs without emission characteristics, the group investigated shows much smaller solar motion (13 km/sec) and smaller velocity dispersion and a vertex deviation of 10° to 20°. A revision of Gliese's catalogue of stars nearer than 20 ps is in progress. The mean absolute magnitudes of M-type dwarfs were studied by Yasuda, Kitamura and Matsunami (**81**). Shimizu and Takayanagi are engaged in a study of the relation between the elements of the galactic orbits and physical characteristics of the stars within 20 ps. It is found that the mean values and the dispersions around the mean of the peri-and apo-galactocentric distances as viewed from the local standard of rest, increase with advancing spectral type.

Van Rhijn (**82**) investigated the velocity distribution of the A-type stars as a function of the distance from the galactic plane. He found increasing velocity dispersion with increasing distance, but a constant longitude of the vertex. Alexander (**83**) has investigated the motions of the AO stars brighter than 6·5 magnitude. The deviation of the vertex of the velocity ellipse, found by previous investigators and amounting to about 25° is confirmed, and the solar motion is found to be $18{\cdot}5 \pm 1{\cdot}6$ km/sec.

The space motions of sub-dwarfs were studied by Eggen (**84**), who found indications of clumpings in the velocity diagrams for these objects.

The motions and the absolute magnitudes of the R stars were investigated by Vandervoort (**85**), with new photometric and radial velocity observations. The solar motion is found to be 34 km/sec ± 5 (p.e.) and the absolute magnitude to vary from $+0{\cdot}4$ for the early R stars to $-1{\cdot}1$ for the late ones.

The high-velocity stars have been studied by various authors. Emoto (**86**), using Miss Roman's catalogue, found that these stars may be sub-divided into at least two classes: one of stars of a flat system that accidentally obtained high velocities, and one forming a different population component. According to Yasuda (**87**), sub-groups among the high-velocity stars when sub-divided according to *UV* excess and inclination of the orbit can be recognized: those with lowest *UV* excess being similar to the ordinary stars in the solar neighbourhood, the other extreme sub-group bearing resemblance to sub-dwarfs and globular clusters. The high-velocity stars are also being investigated by Vanderlinden.

Ikaunieks (**88**) has studied the spatial and kinematical differences between TiO giants of constant and variable brightness, and the statistical relations between the kinematical and spatial characteristics of long-period variables. Takayanagi (**89**) studied the motions of the

S-type stars and their mean absolute magnitudes. Sub-division according to amplitude of variability showed that the low- and non-variable stars have a space distribution following the spiral structure, whereas the Mira variables are differently distributed. The comparison between the space velocities and velocity dispersions of Mira variables in general with those of other stars is also being made by Osvalds and by Osvalds and Risley (**90**). Among the various period sub-groups, the one with periods between 150 and 200 days is found to have the largest space velocities and high luminosity—which confirms previous results. In general, stars with periods exceeding 300 days seem to belong to the flat systems, whereas the orbits of those with shorter periods are more inclined.

A study of the space distribution of planetary nebulae based on measurements of angular diameters is being made by Perek. The basic material consists of photographic plates taken with the Tonantzintla and Palomar Schmidt telescopes and with the Mount Wilson reflectors.

Ishida is engaged in a study of the space distribution of visual binaries in dependence of spectral type and period of orbital motion. Hoffleit intends to search for group motions among the stars in the Yale zone catalogues. The ellipsoidal velocity distribution of 4000 stars with proper motions exceeding $0''.02$ is being investigated by Nechvile, with particular reference to variations of this distribution with position in the Galaxy. Rudnicki (**91**) has discussed a method for the determination of the vertex direction from proper motions for groups with small numbers of stars. Brun reports recording large proper motions of very faint stars (down to magnitude 18) in comparing Mount Wilson SA plates with Palomar photographs.

K. Lodén investigates the tangential velocity distribution derived from proper motions for the stars in 19 of the SA's observed on the Stockholm programme. The determination of radial velocities of faint stars ($m < 12$) in Selected Areas by Fehrenbach now embraces 25 areas.

Nahon (**92**) has treated the mathematical problem of determining the stellar velocity distribution from the observed distribution of radial velocities.

Of special interest are Eggen's investigations (**93**) on the occurrence of moving groups among the neighbouring population. Although this subject more properly belongs to the domain of star clusters, it is mentioned here in connection with its possible significance for the study of the galactic population in general; some of these groups would seem to belong to the old disk and halo population.

A general survey of the distribution of neutral hydrogen over the whole sky visible from Sydney was carried out by McGee and Murray (**94**); it shows the main features of the distribution of H in the solar neighbourhood and indications of systematic motion of the hydrogen in the polar regions towards the galactic plane.

DYNAMICS OF THE GALAXY

M. Schmidt reports further work on the model of the mass distribution in the Galaxy: a revision of the earlier model—referred to in our previous report—appears to be in order. The steep density-gradient near the Sun according to the earlier model was due to the particular choice of the parameters A, B and R_0, and a somewhat different set of values of these is indicated. Test models are developed, based on the radial velocities observed at 21 cm, with different values of R_0, A and B. These, together with the local mass density are used for the computation of the local density-gradient and the 'effective axial ratio' c/a of the mass distribution. On the other hand, the value of the parameter A is revised on the basis of the work on Cepheids in open clusters, the value of R_0 is revised by means of photometry of globular clusters and new estimates of the absolute magnitude of the cluster-type variables, and the resulting values together with the above computations then lead to a value of B around -11

km/sec. The discrepancy between this value and those derived from proper motions is noted.

Wayman (**95**) has found that, with a little modification, Schmidt's model may be regarded as an example of a steady-state galaxy, described earlier by Camm, in which the velocity ellipsoid may have the three unequal axes.

Perek (**96, 97**) has studied the attraction of heterogeneous spheroids with Gaussian and exponential density distributions, *i.e.* with infinite dimensions but finite masses. On the basis of these, a composite model of the Galaxy was constructed (**98**). It leads to the conclusion that the disk population comprises at least two-thirds, population II probably 17% and extreme population I about 7% of the total mass. Near the Sun, about 4% of the mass density would be due to population II.

Ogorodnikov, in his monograph *Dynamics of Stellar Systems* (**99**), gives a systematic exposition of the statistical-mechanical theory of the structure and evolution of stellar systems developed by him. See also reference (**100**). A theory for dynamically unstable star clouds, continually dissipating as well as enriched by young stars, is treated and applied to the Local System. Kuzmin and Kutuzov considered a family of stationary self-gravitating axially symmetric systems. The model worked out for the Galaxy gives a theoretical velocity distribution in the vicinity of the Sun, similar to the observed one. Kiladze (**101**) deduced the mass distribution of the Galaxy from the observed rotational velocities. Takase has, in current work, also estimated the mass distribution in the Galaxy, using a model consisting of three non-homogeneous spheroids. The total mass is found to be about $1 \cdot 1 \times 10^{11}$ solar masses.

Janek (**102**) published studies of the rotational velocity curves of the Galaxy as found from OB stars, associations and Cepheids. Parenago (**103**) and Sharov (**104**) compared the observed rotational law of the Galaxy with that following from certain models.

Many investigations deal with the orbits of stars within model-mass distributions of the Galaxy. Perek has derived analytical solutions in terms of Weierstrassian elliptic functions. Nearly circular orbits near the centre are found to have successive apocentra 180° apart; with increasing size of the orbit the successive apocentra approach each other and for very large orbits a number of revolutions is necessary for the completion of the anomalistic period until the orbit becomes unstable at still larger distances. Abalakin (**105**) has undertaken to investigate periodical motions of a star within a system of which the density can be described by tri-axial ellipsoids.

Shimizu (**106**) has studied two-dimensional orbits in the galactic plane. A velocity diagram is given in which both the peri- and the apo-galactocentric distances and the period of the radial motion can be read for a pair of velocity components. Nahon (**107**), investigating non-stationary orbits, derives an integral equation which may be considered as a generalisation of Jeans' equation for stationary systems. The theory of a third integral of motion has been studied by Kuzmin, who finds that in a stationary axially symmetric gravitational potential there exists in addition to the energy and angular momentum integrals an approximate conservative integral; Contopoulos (**108**) gives a third integral in the form of a series, the convergence of which has not yet been demonstrated, however. Idlis published several papers (**109, 110, 111**) dealing with the integrals of motion which can serve in studying the phase density of a stationary stellar system.

Agekian has continued his studies of the action of irregular forces in stellar systems in connection with the evolution of the systems (**112, 113**). Various stages of permanence are distinguished (**114**).

B. Lindblad (**115, 116**) has continued his work on dispersion orbits in the Galaxy. The first mentioned article deals with a further development of the theory of these orbits and their evaluations in the galactic system of rotational velocities; it leads to a comparison with the observed run of spiral arm structures in the Galaxy. The second paper, dealing with the dynamics of the central layer in the Galaxy, discusses the type of disturbing gravitational field to be expected and the importance of resonance effects. Also, wave motions in the shape of sectorial harmonic waves and of elongated ring formations are studied. P. O. Lindblad (**117**) has studied the development of spiral structure by following the secular disturbances of ring formations on surrounding matter. Several resonance effects leading to a slow transformation of a system of rings into a spiral structure have been found.

EVOLUTION OF THE GALAXY

Theories about the evolution of the Galaxy, the first explorations of which were described in the previous report, have been further developed, especially in papers by Schmidt (**118**), Mathis (**119**), Salpeter (**120**) and Limber (**121**). These investigations deal with such items as the rate of star formation—especially that in the solar neighbourhood, to which most observational data are confined,—the shape and the universality of the initial luminosity function, the exchange of mass between stars and interstellar gas resulting from star formation and mass ejection from stars, the consequent change in the chemical composition of this gas, and with certain features of the composition and space distribution of stellar populations.

Most papers start from—or at least attempt to test—the hypothesis that the shape of the initial luminosity function is independent of time and of the conditions in the interstellar gas at the instant of the star formation (density, state of motion). In Schmidt's earliest work, the rate of star formation is supposed to vary with a power n of the interstellar density. Direct evidence on the value of n is obtained from a comparison between the present distribution perpendicular to the galactic plane of the interstellar gas and the youngest stars. Indirect evidence was obtained in the following ways: (*a*) by computing, for various values of n, the shape of the initial luminosity function and comparing it to that of young clusters; (*b*) by comparing the predicted and observed numbers of white dwarfs; (*c*) by comparing the predicted and computed helium abundance of the interstellar gas on the assumption that the gas initially consisted of pure H; and (*d*) by trying to explain the roughly uniform distribution of hydrogen over the galactic plane. This leads to $n=2$ as the most likely value. It should be stated, however, that whereas the comparison with the young clusters leads to $n < 2$, the other considerations lead to $n > 2$. From the evolutionary model thus obtained, Schmidt predicted that the helium/hydrogen abundance ratio should vary considerably with distance from the galactic centre. Recent work, however, indicates that in the Andromeda Nebula this ratio is approximately constant and the analogy between M 31 and the Galaxy therefore suggests that the above prediction was wrong. This, according to Schmidt, poses the problem whether an appreciable amount of helium existed already in the primeval matter or whether perhaps considerable mixing occurs between the central and the outer regions of the Galaxy. A quite different approach of the problem appears also in order: the shape of the initial luminosity function may be dependent on the conditions of the interstellar gas, for instance on its density.

Mathis stresses the importance of taking into account the change of luminosity of a star as it evolves from the main sequence, in deriving the initial luminosity function from the present one. This author's analysis leads to the conclusion that an initial luminosity function fitting the cluster data cannot be reconciled with the present helium abundance ratio. It suggests that the conventional luminosity function for the solar neighbourhood may not be the appropriate starting point for investigations of this sort because it is a mixture of stars formed in this neighbourhood and stars having originated at large distances from the galactic plane; also, the proportion of stars having escaped from this neighbourhood may have been different for different masses. Further, the composition of the gas now near the Sun may have been affected by matter ejected from classes of stars with large spread in distance z, which are not proportionately represented in the luminosity function for the solar neighbourhood.

Salpeter's discussion starts with his original assumption of the universality of the initial luminosity function for which that of young galactic clusters is adopted for the bright end, and that of the solar vicinity for the fainter end. Assuming the rate of formation to be proportional to the interstellar density, Salpeter draws attention to the rapid rate of star formation which must have taken place during the earliest times in the evolution of the Galaxy, and points out that the larger the power of n is chosen, the sharper the division will be between the stars formed almost immediately at the formation of the disk and those formed at later times. Some support is found for n exceeding unity on the basis of the observed helium abundance if the gas is well mixed over the whole galactic disk.

Limber studies the universality of the initial luminosity function with regard to its implications for the mass-to-light ratios for stellar systems. It is found that for many systems ages of more than 12 billion years are required, to reconcile the observed ratios with upper limits of this ratio based on the initial luminosity function determined from galactic clusters and the solar vicinity. (The ratio increases with increasing age of a system.) Limber therefore suggests that the initial luminosity function has at times differed significantly from the adopted one.

PROPOSALS AND DESIDERATA

1. It is suggested (by Mavridis) that it is desirable to compute and publish the galactic co-ordinates in the new system of all bright objects used as distance indicators (O-, B stars, galactic Cepheids, galactic and globular clusters, etc.). The question whether a special list of selected objects with the new galactic co-ordinates deserves separate publication deserves the attention of the Commission.

2(*a*) The preparation of the revision of the *General Catalogue* at the Astronomisches Rechen-Institut, Heidelberg opens up the possibility of adding stars to this catalogue. Dr Fricke would welcome suggestions on this subject from Commission 33.

(*b*) The observation of second-epoch plates for the Lick Proper Motion programme is approaching, and Dr Vasilevskis, who conducts this project, suggests that the selection of stars for measurement be discussed with Commission 33.

These two items might be most fruitfully discussed in a joint session of Commissions 24, 33 and perhaps 8 or 8*a*.

A. BLAAUW
President of the Commission

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33*a*. SOUS-COMMISSION DE CO-ORDINATION DES RECHERCHES GALACTIQUES

PRÉSIDENT: Professor J. H. Oort, Director of the University Observatory, Leiden, the Netherlands.

MEMBRES: Baade†, Blaauw, B. Lindblad, Parenago†, Thackeray, van Rhijn†.

The Sub-Commission has had no occasion to meet and, as a consequence, has nothing to report. Adequate reference to work done in the field of Galactic Research is made in the report of the main Commission. It is felt that the Sub-Commission should continue to exist, in this or some other form, if only to organize symposia on the co-ordination of Galactic Research whenever such a symposium is needed.

J. H. OORT
President of the Sub-Commission

33*b*. SOUS-COMMISSION POUR LA DETERMINATION DU POLE GALACTIQUE ET DES LONGITUDES GALACTIQUES

MEMBRES: Blaauw, Gum†, Pawsey, Westerhout.

At the Moscow General Assembly, a resolution proposed by Commissions 33 and 40 was passed which, among other items, contained the following recommendations:

'(*c*) That Sub-Commission 33*b* be authorized to define the exact values of the co-ordinates of the pole and of the zero of longitude, immediately after the final reduction of the relevant observations is finished.

(*d*) That Sub-Commission 33*b* be charged with the communication of these values to the Members of the IAU and to all other interested institutions and individuals.

(*e*) That Sub-Commission 33*b* be charged with the supervision of the publication of tables, accurate to $0^\circ{\cdot}01$, necessary for the conversion from galactic into equatorial co-ordinates and *vice versa*, and from co-ordinates based on the Lund pole into the newly defined system and *vice versa*, and of conversion charts'.

The task of the Sub-Commission described in (*c*) and (*d*) has been completed. The exact values of the co-ordinates of the pole and of the zero of longitude, as well as approximate values of a number of related useful quantities have been communicated to the General Secretary, who in turn communicated these values to Members in *Information Bulletin* no. 1 of June 1959. This bulletin also gives a short description of the basis for the choice of the new system.

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