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

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## 1. INTRODUCTION

In order to avoid any overlapping with the Reports of related Commissions, we shall strictly limit ourselves in the present Report to matters concerning the Structure and Dynamics of our Galaxy. We shall carefully avoid dealing with topics that are primarily the concern of related Commissions, such as Nos. 25, 27, 29, 30, 34, 37, 40, and 43. Sections I to IV and VI to VIII have been written by Bok; Section V by Becker; and Sections IX and X by Contopoulos. Bok wishes to acknowledge the assistance received from Jane M. Basinski, T. E. Margrave, and G. A. Chapman; Contopoulos, that from B. S. Barbanis and J. Hadjidemetriou. Mr. and Mrs Margrave kindly assumed responsibility for the final editing of the Report. The Report on Selected Areas is, as in the past, appended to the present Report; it was written by Dr T. Elvius, who wishes to draw attention to the increasing importance for galactic research of work on the Kapteyn Selected Areas.

Galactic Structure and Dynamics continues to be a very active and broad field of research. The year 1966 saw the publication of Volume V of *Stars and Stellar Systems* (**1**), which beautifully covers our whole field of research. The President wishes to draw attention to the review of Volume V written by himself (**2**), which was prepared with the work of our Commission in mind. All of us now eagerly await the publication of Volume VII of *Stars and Stellar Systems*.

Several Symposia were held that have advanced research in our areas. The most relevant IAU Symposia were No. 25 on 'The Theory of Orbits in the Solar System and in Stellar Systems' (August 1964, Thessaloniki, Greece), No. 30 on 'Determination of Radial Velocities' (June 1966, Toronto, Canada), and No. 31 (jointly with URSI) on 'Radio Astronomy and the Galactic System' (August 1966, Noordwijk, Holland). IAU Symposia Nos. 24 and 26 are also of special interest to the members of our Commission. A first, general, report on IAU-URSI Symposium No. 31 has been written by Bok (**3**).

During September 1964, the NATO Science Committee organized a two-weeks Summer Course on 'Observational Aspects of Galactic Structure'; many members of our Commission participated, with Blaauw and Mavridis acting as organizers. A volume based upon the lecture notes was prepared by Mavridis and has been made fairly generally available. A second NATO Summer Course was held at Herstmonceux in August–September 1965, on 'The Kinematical and Chemical History of the Galaxy'. Dr Bernard E. Pagel has kindly prepared a summary of the lectures for use by Contopoulos and myself in the preparation of the present Report. Members of Commission 33 will also be interested in the Report of the 'Tenth Herstmonceux Conference' held in April 1966 (**4**); we shall have occasion to refer to it in later Sections.

Two informal Symposia held in recent years concern Commission 33. In August 1964, a 'First Conference on Faint Blue Stars' was held in Strasbourg with about a dozen astronomers attending. The Observatory of the University of Minnesota has published the papers in a separate small volume (1965) with W. J. Luyten as editor. The summaries of the comments made at this Symposium following the presentation of each paper should be read by all members of Commission 33. The second informal 'Pre-Symposium' was one held in May 1966, at Mt Stromlo Observatory on 'Radio and Optical Studies of the Galaxy'. The proceedings have received limited distribution from Mt Stromlo Observatory.

Two other useful reports have been made available for use in the preparation of the present Report. One is a report by Kuzmin, which summarizes advances made over the past three years in the U.S.S.R. in areas of interest to Commission 33. The other report is by Nahon, and it concerns a Colloquium held at Besançon on 'Les Nouvelles Méthodes de la Dynamique Stellaire' (September 1966). The President and Vice-President of Commission 33 have been greatly assisted by these reports. We should also note that Kharadze's Report to the Fourth Full Session of the Commission on Stellar Astronomy of the Astronomical Council, Ac. Sci., U.S.S.R. (1964, Moscow) has now been published (**5**).

Survey articles relating to the work of our Commission have been published in several places. Particularly I wish to draw attention here to Volumes 7 and 8 of *Vistas in Astronomy* (**6**), (**7**). The first volume contains two articles that are especially relevant: one by Iwanowska on 'Statistical Population Indices', the other by McCuskey on 'The Stellar Luminosity Function'. Volume 8 contains the Proceedings of the 'Ejnar Hertzsprung' Symposium, which was held at Flagstaff, Arizona, in June 1964, and which dealt with 'Aspects of Stellar Evolution'. Three more volumes of the *Annual Review of Astronomy and Astrophysics* have appeared; each volume contains several articles of interest to our members.

The Fourteenth International Astrophysical Symposium held at Liège (June 1966) was devoted to problems of special interest to our Commission. The published volume of the Proceedings is awaited with interest.

Brief reference should be made to Joint Discussion A at the Hamburg General Assembly on 'Local Structure and Motions in the Galaxy', which was entirely concerned with problems affecting the work of Commission 33 (**8**). Finally, we should not fail to mention the publication of the New Series of Landolt–Börnstein (edited by Voigt (**9**)) which has several chapters with reference material that should be useful to members of our Commission.

The only major textbook that has been published in the area of our Commission is an English translation of a book by Ogorodnikov (**10**); it makes a very welcome addition to the literature.

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## II. THE OVERALL STRUCTURE OF OUR GALAXY

The major accomplishment of our Commission at the Twelfth General Assembly (Hamburg) of the IAU was agreement among the members present with regard to the adoption of standard values for the basic parameters of our Galaxy:

$R_0 = 10$ kpc.
$\Theta_0 = 250$ km s$^{-1}$,
$A = 15$ km s$^{-1}$ kpc$^{-1}$, and
$B = -10$ km s$^{-1}$ kpc$^{-1}$.

So far no major objections to these values have been raised, and there appears to be no need to start discussions anew at the Prague Assembly. The minutes of our Commission Meeting at Hamburg (*Trans. IAU*, **12 B,** p. 314 to 316) adequately summarize the situation. Kuzmin's Report (see Section I) has the following relevant paragraph:

'Theoretical foundations for obtaining a consistent system of galactic parameters on the basis of stellar dynamical equations as well as for constructing empirical models of the Galaxy have been worked out by Kutuzov (**1**) and Einasto (**2**). The latter has constructed a new composite model of the Galaxy. A preliminary consistent system of the local galactic parameters has been published (**3**), where, in particular, a moderate value for the dynamical parameter C has been accepted (cf. Einasto, *Trans. IAU*, **12 B,** p. 436). The system of galactic parameters has been discussed also by Genkin (**4**).'

We note that the 'consistent system of local galactic parameters' by Einasto and Kutuzov (3) has the following basic parameters:

$R_0 = 9{\cdot}0 \pm 0{\cdot}4$ kpc,
$\Theta_0 = 235 \pm 10$ km s$^{-1}$,
$A = 15{\cdot}7 \pm 0{\cdot}4$ km s$^{-1}$ kpc$^{-1}$, and
$B = -10{\cdot}3 \pm 0{\cdot}4$ km s$^{-1}$ kpc$^{-1}$,

in good agreement with the Hamburg values.

The principal difference that remains between the Tartu data and the values proposed by Oort concerns the dynamical value of the mass density in the galactic plane at the position of the Sun, which, according to Oort (**5**) and others, is equal to $0{\cdot}145\ \odot/\mathrm{pc}^3$ and which, according to Einasto and Kutuzov (**3**) and Einasto (**6**), amounts to only $0{\cdot}09\ \odot/\mathrm{pc}^3$. It seems very important that this discrepancy be clarified. The Oort value requires that, in addition to the known stars, atomic hydrogen and cosmic dust, there be a component of unknown origin contributing 30% of the gravitational mass density, which may consist of either gaseous molecules or sub-luminous stars. The lower value of the Tartu observers would imply that almost all of the mass density near the Sun has been accounted for. The discrepancy can be expressed most clearly in terms of Kuzmin's dynamical parameter $C$, which is defined (**6**) so that $-C^2$ measures the gradient of gravitational acceleration in the $z$-direction at the Sun, $z = 0$. The Tartu value is about $C = 73$ km s$^{-1}$ kpc$^{-1}$, whereas the values found by others are generally 25% higher. The only recent value for $C$ that agrees with the Tartu results is that of Stothers and Tech (**7**).

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Members of Commission 33 will remember the report by the late Dr R. M. Petrie, presented at the Hamburg Meeting, in which he gave a revised value for $A$, equal to 15·6 km s$^{-1}$ kpc$^{-1}$. His widow, Mrs J. K. Petrie, very kindly has written that a more refined study of the earlier material is in progress. She reports the following results obtained by S. C. Morris and herself:

1. From Stellar Velocities, O9–B8, 688 stars:

$$A = 15{\cdot}1 \pm 0{\cdot}4 \text{ km s}^{-1}\text{ kpc}^{-1},$$
$$K = -0{\cdot}6 \pm 1{\cdot}3 \text{ km s}^{-1},$$

2. From Interstellar Velocities, O9–B3, 286 stars:

$$A = 15{\cdot}7 \pm 0{\cdot}5 \text{ km s}^{-1}\text{ kpc}^{-1},$$
$$K = -0{\cdot}6 \pm 0{\cdot}3 \text{ km s}^{-1}.$$

Multi-parameter solutions yield essentially the same results.

W. Fricke reports that he has re-analyzed the McCormick and Cape proper motions, previously studied by Williams and Vyssotsky. On the system of FK4, Fricke finds:

$$A = +12{\cdot}4 \pm 2{\cdot}4 \text{ (m.e.) km s}^{-1}\text{ kpc}^{-1},$$
$$B = -7{\cdot}4 \pm 2{\cdot}4 \text{ (m.e.) km s}^{-1}\text{ kpc}^{-1}.$$

He reports, furthermore, that he has underway an investigation of 500 stars with known proper motions and at distances greater than 500 parsecs from the Sun. These stars, for most of which radial velocities are available, should serve for a study of the distance scale and of star streaming.

In contrast to Fricke's result, we quote a value of $B$ recently obtained by Wayman (**8**), who finds:

$$B = -15 \text{ km s}^{-1}\text{ kpc}^{-1}.$$

This value was obtained from an analysis of high-precision (mean errors less than $\pm$ 0″002 per year) proper motions in the FK4 Catalog for 34 O and B stars at distances greater than 300 parsecs.

A recent result by J. S. Miller of Washburn Observatory deserves to be noted. He has obtained radial velocities for about 30 H II regions for which distances are available. A preliminary analysis shows that deviations from circular motion average less than 10 km s$^{-1}$ and the tentative value for $A$ is 17 km s$^{-1}$ kpc$^{-1}$; there is a general agreement between the H I and H II velocities.

Attention is drawn to Blaauw's (**9**) useful tabulations and graphs relating to space distributions and motions of various classes of objects in our Galaxy.

Recent work by H. L. Johnson and associates (**10**) has given new arguments in favor of possible revision of the cosmic distance scale. In most earlier work, the assumption was made that the ratio between visual total absorption, $A_V$, and the color excess, $E_{B-V}$, was equal to 3·0 or, at most, 3·5. There were some known exceptions to this rule, notably for the Trapezium Cluster in Orion and for a region in Cygnus, but no major variations were suspected elsewhere. The far infra-red measures by Johnson and associates now make it seem likely that greater values of $R = A_V/E_{B-V}$ prevail in many directions close to the galactic plane. Values as great as $R = 6$ are indicated by the infra-red measurements, especially for the sector $100° < l^{II} < 200°$. This article is not the place to enter upon a full discussion of the implications of Johnson's work, but we note that W. Becker (**11**) and others have objected strongly to certain aspects of Johnson's approach. It would be wrong for the members of Commission 33 to ignore the new Johnson results, for, even if they are substantiated only in part, they contribute a major new element in the interpretation of color excess as an indicator of total visual absorption. One consequence of Johnson's work is that within the next decade we may have to revise rather drastically the values for the 'constants' for our Galaxy which were adopted at the Hamburg meeting and which are listed earlier in this Section. It becomes all the more important that, in our analyses relating to the overall structure of our Galaxy, we should, for remote objects affected by the least total absorption, make every effort to obtain the most precise possible color data, referring to the largest available color base. We note that Johnson has repeated the galactic-rotation analysis that he and Svolopoulos (**12**) performed some years ago and we note further that, on the basis of his new distances for open clusters, he finds:

$$A = 20 \text{ km s}^{-1} \text{ kpc}^{-1},$$
$$R_0 = 7{\cdot}8 \text{ kpc}.$$

Continuing attention to the whole problem of the galactic distance scale is obviously a matter of high priority in the years to come.

Most of the current work relating to the central region of our Galaxy belongs properly within the areas covered by Commissions 40 and, to a lesser extent, 34; we shall not trespass unnecessarily. However, we must draw attention here to the far-reaching results that are emerging from the study by radio-astronomical techniques of the radial-velocity fields in the central regions of our Galaxy. The new information comes not only from 21-cm research, but also from studies of OH lines and from high-level recombination transitions in H I that are materially increasing our knowledge in the area. We shall also not report here on the exciting new results obtained for X-ray sources in our Galaxy, but we note that this field may become the concern of our Commission if the suggested identifications with old novae are substantiated.

We should not close this Section without a brief reference to the importance that variable stars, especially RR Lyrae variables, continue to play in the study of the overall properties of our Galaxy. The chapter by Plaut (**13**) illustrates this aspect of variable-star research very well; the matter is also stressed in the series of papers by Kinman and associates (**14**) which are based upon observational work at Lick Observatory.

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### III. NEW BASIC MATERIAL

The past three years have witnessed the publication of much useful material for the study of the structure and dynamics of our Galaxy. While detailed and complete references belong in the Reports of other Commissions, we will note here some of the more important information that has come to our attention.

There continues to be much useful activity in the area of spectral classification. C. Jaschek, Condé, and de Sierra have published an extensive 'Catalog of Stellar Spectra Classified in the Morgan-Keenan System' (1). Seven additional parts have appeared of 'Luminous Stars in the Northern Milky Way': Volumes IV, IVa, VI, and VIa by J. J. Nassau, C. B. Stephenson, and D. J. McConnell of the Warner and Swasey Observatory, and Volumes I, III, and V by J. Hardorp, I. Theile, and H. H. Voigt of the Hamburg-Bergedorf Observatory. Stephenson and McConnell are planning to extend the survey over the remaining galactic longitudes $220° < l^{II} < 15°$. The work will be done with the 24–36 inch (61–91 cm) Curtis–Schmidt telescope of the University of Michigan, relocated at the Cerro–Tololo Inter–American Observatory in Chile. Bidelman reports that he expects the Curtis–Schmidt telescope to be in full operation in Chile by April 1967. The University of Michigan astronomers will retain one-third of the time of the instrument; they are planning to undertake a moderately high-dispersion blue survey of the entire southern sky, coupled with special studies for the galactic center and of southern associations. Bidelman reports that the search for $H\alpha$ emission objects has continued. H. E. Bond of Michigan Observatory has developed a fruitful technique for the discovery of metal-weak stars; four-color measurements are being made for all such stars found on the Schmidt plates with the 10° prism, and radial-velocity measurements are planned for many of the new discoveries. Bidelman (2) has written a comprehensive article on techniques of classification from objective-prism spectra.

Morgan will soon publish a new and revised edition of the *Yerkes Spectral Atlas*. At Steward Observatory, A. B. Meinel is working on an *Atlas of Stellar Spectra* that reaches to 3300 Å in the ultra-violet. We note that some time ago there was held at Kitt Peak National Observatory a very interesting 'Discussion on Spectral Classification' in which some of these problems and projects were summarized (3). Lindoff and Lyngå (4) have published a study of comparisons between spectra classified on the MK, HD, and HDE systems. At the Vatican Observatory, P. J. Treanor, M. F. McCarthy, and F. C. Bertiau have undertaken spectral surveys with the Vatican Schmidt telescope and its 2°5, 4°, and 12° objective prisms.

There is no need to review here in any detail the researches that were reported at IAU Symposium No. 24 (Stockholm, August 1964), since the Symposium Volume has been distributed. We note that there continues to be much activity in the field of photo-electric measurement of brightnesses and colors of stars. Strömgren (5) has written an excellent summary of techniques and results obtained from narrow-band photometry, including $H\beta$ photometry. The work in this area by Strömgren, Crawford, Perry, Graham and associates at Kitt Peak National Observatory is now being extended to stars of southern declinations observed from the Cerro-Tololo Observatory. The techniques of narrow-band photometry are also being applied extensively by Bigay and Mme Lunel at Lyon, by Gyldenkerne in Denmark, and by Golay in Geneva.

Schmidt-Kaler stresses the need for *UBV* photometry to supplement searches by the Warner and Swasey and Hamburg-Bergedorf Observatories for luminous stars. A joint effort is being made by Schmidt-Kaler, Haug, Bigay, and Mme Lunel to obtain *UBV* colors and magnitudes for 1400 stars in the Cleveland-Hamburg lists which lack such data. Cooperation is asked for the observation of the remaining 4800 stars. The European Southern Observatory's new Schmidt telescope will be used for the work on southern spectral classification. C. Jaschek reports that a comprehensive catalog of photo-electric magnitudes and colors is in preparation at La Plata; this catalog is intended to supplement the spectral catalog to which reference was made earlier in this section. At the Stockholm Symposium (IAU No. 24), Bok drew attention to the powerful new search techniques that are available now through combined photographic (*UBV*) and photo-electric work. He concludes that the discovery of OB stars to $V = 15$ and with total absorptions not exceeding $A_v = 5$ magnitudes is now within reach.

Beer is reducing all measures of Balmer line equivalent widths for O7 to B9 to a uniform system, calibrated from cluster data. This material should be useful for the study of local spiral structure.

There has been a comprehensive survey of current work in the field of radial velocities at IAU Symposium No. 30, held at Toronto in June, 1966. The published volume is awaited with interest. Rapid advances in radial-velocity work for faint stars may be expected on the basis of recent developments involving applications of image conversion techniques. The measurement of radial velocities for faint stars of special interest has now become practicable with reasonably short exposure times. Bertiau, Burley, and McCarthy (**6**) have published new galactic coordinates for the 15 106 stars listed in Wilson's *General Catalog of Radial Velocities*. Recently Bertiau has devised a program for selecting and plotting various types and classes of stars according to their galactic coordinates.

For the field of proper motions, we refer to the Report for Commission 24. We note that Fricke has made a study of the distance scale and of galactic-rotation effects based upon proper motions reduced to the FK4 system (**7**). He concludes that mean parallaxes derived from proper motions can be expected to yield reliable results only for stars within 1000 parsecs of the Sun. A rather parallel type of study is reported at the U.S. Naval Observatory, where precision proper motions, based on FK4, are being determined for 1000 stars with known MK classes. The stars are a part of the $W^3_{50}$ Catalog, derived from observations with the 6-inch Transit Circle (**8**). The publication of a new edition of the *Yale Catalogue of Bright Stars* will assist greatly in the furtherance of galactic research (**9**).

There are many special varieties of stars that contribute to our knowledge of galactic structure, but none seems to be quite so useful as are the Wolf-Rayet stars. Their absolute magnitudes are becoming known with increasing precision through the work of Westerlund and Lindsey F. Smith on WR stars in the Magellanic Clouds. The current surveys, coupled with special narrow-band photometry for these stars, provide basic structural information to great distances. Westerlund (**10**) has measured photoelectrically, in a narrow-band four-color system, 35 objects listed by Roberts as WR stars. The as-yet unpublished doctoral thesis of Lindsey F. Smith contains a wealth of new material. One of her tables is a list of absolute magnitudes, color excesses, and estimated distances for 121 galactic WR stars; the results are based mostly on her own system of narrow-band photometry (six interference filters). The search for WR stars is being pushed to the faintest accessible limits in both the northern and southern hemispheres. Because of emission features in the spectra of these stars, their detection to $B = 15$ or $B = 16$ can be achieved with relatively small telescopes .C. B. Stephenson (**11**) has completed an objective-prism survey of WR stars for $10° < l^{II} < 240°$ in which seven new objects were found. None of these are in the range $135° < l^{II} < 225°$; this section of the band of the Milky Way apparently shows a very real gap in the distribution of the WR stars.

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## IV. CALIBRATION PROBLEMS; LUMINOSITY FUNCTIONS

We noted in our Report for 1964 that problems of the calibration of criteria for absolute magnitudes seemed reasonably well in hand, thanks especially to the work of Blaauw, Voigt, Strömgren and others. The Hyades moving cluster plays an important role in all this work. The recent publication by Hodge and Wallerstein (1) of a revised distance for the Hyades produces a correction of 0·39 magnitude to the distance modulus of the Hyades. If accepted, this result would radically change our concepts of the dimensions of our Galaxy and of most basic constants in current use. The zero-age main sequence would have to be revised and the distance from the Sun to the center of the Galaxy might be as great as 12 kpc! Hodge and Wallerstein place their confidence in the published trigonometric parallaxes and point out that small and, in their opinion, permissible systematic errors in proper motions in declination would make the moving-cluster parallax of the Hyades agree with their trigonometric value. This possibility seems supported by results based upon the mass-luminosity relation and by absolute luminosities estimated with the aid of the Wilson-Bappu effect. The required systematic errors in the proper motions seem excessive, but the paper shows once again how urgently we need reliable trigonometric parallaxes for a representative group of fainter members of the Hyades; possibly undetected systematic errors in proper motions may basically affect our work on even the nearest moving clusters.

During the next few years, we should plan to emphasize increasingly studies of nearby moving clusters, with, as the ultimate aim, the obtaining of improved calibrations of absolute magnitudes derived from narrow-band photometry and precise spectral-luminosity classification. The recent announcement (28 December 1966; Am. Astron. Soc. Meeting) by R. F. Garrison of a narrow main-sequence for B2 to F0 members in the inner region of the Scorpius-Centaurus Association is especially significant for future calibration developments.

Stars of various spectral classes have been the subject of extensive studies of their mean absolute magnitudes and dispersions around these mean values. McCuskey and Rubin (2) have made an analysis of proper-motion and radial-velocity data for 6th magnitude F0, F2, and F5 stars listed in the Third Edition of the *Yale Catalogue of Bright Stars*. From these data they find $M_v = +2{\cdot}6$ and a dispersion $\sigma = \pm 0{\cdot}9$ magnitude for this group as a whole per unit volume of space. Ljunggren and Oja (3) have studied similar problems for the MK and Uppsala giant stars of types G8 to K5; they used trigonometric parallaxes as well as proper motions and radial velocities. They have found indications that the mean absolute magnitudes of these stars are dependent upon their kinematical properties and their distances from the galactic plane. From trigonometric parallaxes they derive for the Uppsala giants, gG8 to gK5, and for the MK giants, G8III to K5III, an absolute magnitude $M_0 = +0{\cdot}9$ (visual), $\sigma = \pm 0{\cdot}6$.

Efforts are continuing to separate stars of given general characteristics into groupings according to chemical composition. A report on some of this work appears as Section V, and there is further information in Section IX. However, we note here that Iwanowska and her colleagues at Torun are developing a scheme according to which stars of certain characteristics are being separated statistically into two main population types: one originating in or near the galactic plane but far from the galactic center, and the other originating in the central regions of our Galaxy. We have already referred in Section I to her general report in *Vistas in Astronomy* (Vol. **7**, p. 133, 1966); more detailed reports are contained in *Torun Observatory Bulletin*, Nos. 32 (1962), 37 (1965), and 41 (1966). Statistical probabilities, called 'statistical population indices', are assigned to each star; these indicate that the object belongs to one of the two classes.

At the end of Section II we referred to the increasing emphasis that is being placed upon the study of RR Lyrae variable stars; therefore, it is important to note that much work on the basic properties of these stars is in progress. The Reports of Commissions 24, 25, 27 and 30 should be consulted for details. Van Herk has published a monumental study of the proper motions, mean parallaxes, and space velocities of RR Lyrae variables (**4**). His derived value for the median photographic absolute magnitude of these stars is $M_{pg} = +0{\cdot}87 \pm 0{\cdot}22$ (m.e.), and the average normal color index is $(B - V)_0 = +0{\cdot}19$. There are prospects of much additional radial-velocity work, especially through the collaborative efforts of the Royal Observatory and of Helwan Observatory (**5**). The results of a careful and extensive investigation of intrinsic *UBV* colors of RR Lyrae variables have been published by Sturch (**6**). Since the final probable error of Sturch's standard $(B-V)$ and $(U-B)$ color indices is only $\pm 0{\cdot}01$ magnitude, these colors should serve admirably for the detection of very small amounts of interstellar reddening and in studies of population differences for various classes of RR Lyrae variables. Photo-electric studies of magnitudes and colors are soon to be published by W. S. Fitch, H. L. Johnson, and W. Z. Wizniewski of the University of Arizona; I. Epstein of Columbia University is also making studies of RR Lyrae variables. Iwaniszewska-Lubienska of Torun Observatory has applied the statistical approach of Iwanowska to the population assignment of RR Lyrae variables and is studying their distribution. R. E. White (Univ. of Illinois, Doctoral Thesis, unpubl.) is attempting a re-analysis of the material used originally by Perek (**7**) and by Plaut and Soudan (**8**). He divides 1500 of the stars listed by them into two groupings: one metal-poor (Preston, $\Delta S \geqq 5$) and the other metal-rich ($\Delta S < 5$). They are considered the Halo–Population II component and the Disk component, respectively. At the position of the Sun, the Disk component outnumbers the Halo component by a factor of 6.

McCuskey (**9**) has written an excellent and comprehensive review of our present knowledge of stellar luminosity functions. It deals exhaustively with the earlier researches in the field, especially with the early work on the General Luminosity Function. The article reviews in considerable detail recent work on the faint end of the General Luminosity Function. The results of the analyses by Luyten, Warner, Upgren, and McCuskey are compared with van Rhijn's Luminosity Function, which is a useful standard for reference purposes. The two diagrams shown in McCuskey's article indicate that the General Luminosity Function, $\varphi(M_v)$, (the number of stars per cubic parsec with absolute visual magnitudes between $M_v - 1/2$ and $M_v + 1/2$), rises steeply until $M_v = +6$, then increases slowly until $M_v = +11$, and from there remains almost constant to $M_v = +16$ (Luyten). If anything, there may be an excess of faint M dwarfs in the range $+11 < M_v < +16$, as indicated by Sanduleak (**10**), who finds very large numbers of M dwarfs in the North Galactic Polar Cap. Useful information is also given regarding variations in the Luminosity Function, both in the galactic plane and for directions at right angles to it. The article concludes with a new determination of the evolutionary 'initial' General Luminosity Function, which agrees closely with an earlier determination by Sandage (**11**). We note that Eelsalu and Jôeveer at Tartu Observatory have investigated the luminosity functions for the A and gK stars (**12, 13**).

This Report is obviously not the place to write at length on the results of proper-motion surveys to very faint limits or on the results for searches of intrinsically very blue and faint stars. Luyten reports the discovery of many such faint blue stars in the galactic polar caps and for selected regions at intermediate galactic latitudes (3000 objects); he reports that the total number of available proper motions for these faint blue stars amounts by now to well over 1000. He concludes that to $B = 16$ the number of white dwarfs is small and does not begin to increase markedly until $B = 18$ or 19. He estimates that his General Proper Motion Survey has yielded to date well over 500 stars with $M_{pg} \leqq +16$. It is highly gratifying to note the rapid advances that are being made in our knowledge of intrinsically faint stars, first, through the proper-motion surveys of Luyten, Giclas and others and, second, through the search for very faint blue stars by Zwicky, Luyten, Haro and others (**14**).

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## V. SPACE DISTRIBUTION AND CHEMICAL COMPOSITION

(prepared by W. Becker)

Dr W. Becker, one of the members of the Organizing Committee, has prepared the following summary of recent work in an area that is more and more becoming the concern of Commission 33.

'The relation between spatial distribution and chemical composition is of increasing interest. The exact determination of the chemical composition presupposes an intricate photometric analysis of the line spectrum, which has so far only been undertaken for a few objects, mostly in our neighborhood. Therefore the search for relations between distribution and composition is based on indicators for the chemical composition which are calibrated with the help of only very few objects. Such indicators are: the general appearance of a spectrum, an ultraviolet excess, a certain type of light variation, or characteristic types of motion. The results so far are in general limited to analyzing the space distribution of objects of Populations I and II. Primarily, the results concerning the distribution give distances from the galactic center or from the galactic plane.

'General considerations concerning the concept of different populations are given by Blaauw (**1**). Best defined are, for the time being, the relations for globular clusters and RR Lyrae stars because of their easy identification. Sandage (**2**) and G. Burbidge (**3**) have found different relations between age and metal content in globular clusters within or outside the galactic plane. According to Arp (**4**), the globular clusters with higher metal content are closer to the galactic center than the others. According to Böhm-Vitense, Holweger, and Kohl (**5**), the metal content of a cluster depends less upon its age than on its distance from the galactic plane. This is at variance with the results of van den Bergh (**6**), whose study shows that in stars the enrichment of the heavy elements is rather a function of time than of location.

'Plaut (**7**) has given a comprehensive report about the behavior of RR Lyrae stars. According to Geyer (**8**), they belong partly to the Disk Population and partly to the Halo Population, depending on the intensity of their metal lines. Preston (**9**) finds that the separation of the two groups occurs between $P = 0^{d}.55$ and $0^{d}.44$, with the RR Lyrae stars of longer period being in the Halo Population. The extension of the galactic halo seems to be considerably larger than was thought until recently; Kinman, Wirtanen, and Janes (**10**) have found increasing values of log $N$ for RR Lyrae stars up to a distance of 25 kpc in the direction of the galactic pole (SA 57).

'Long-period variables seem to be present equally in both populations. According to Plaut (**11**), their mean periods increase with increasing distance from the galactic center. Preston and Wallerstein (**12**) found in two investigations that the halo variables contain about 50 times less metals than do the disk variables.

'The chemical composition of cepheids seems also to be a function of their distribution. Kraft (**13**) believes that cepheids beyond the Perseus Arm have a composition which is different from that of the nearer ones. This could restrict the general validity of the period-luminosity relation.

'Some results have been obtained for field stars. According to Wallerstein (**14**), the central galactic core, as far as it is represented by red giants of Population II, does not reach farther than 1800 pc above the galactic plane. The metal content of these stars seems to range between that of M67 and the halo-type globular clusters. Upgren (**15**) finds that the General Luminosity Function of stars brighter than $M = +15$ is the same to distances of 100 pc from the galactic plane as in the solar neighborhood. Only from about 200 pc outward do halo stars prevail, and from 400 pc outward disk stars disappear entirely. Becker (**16**) uses the possibility of separating disk and halo stars by means of three-color photometry to determine density gradients in the galactic halo. This gradient could be followed in the direction of the anti-center (SA 51) up to a distance of 15 kpc (or 25 kpc from the galactic center).

'General considerations about statistical population indices, which could be useful for studies of spatial distributions, are given by Iwanowska (**17**).'

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## VI. STELLAR DISTRIBUTION IN LOW GALACTIC LATITUDES

### *Summaries and General Surveys*

McCuskey's chapter on 'The Distribution of the Common Stars in the Galactic Plane' (**1**) will remain a basic reference for many years to come. It is comprehensive and complete, giving for each separate spectral group the best available picture of the stellar distribution in the galactic plane. McCuskey's analysis shows that, if we did not have distributional data for Extreme Population I, we would really have no inkling that our Galaxy possesses spiral structure. McCuskey has written two further survey papers; the first, an article to which we have already referred, is the chapter on the Luminosity Function (**2**), and the other is his contribution to Joint Discussion A on the Local Structure of the Galaxy (**3**). The latter paper deals specifically with the distribution of the A and F stars. In all three summaries it is clear that our knowledge of the stellar distribution for the southern Milky Way still lags behind that for the northern Milky Way; this situation justifies the increasing attention that is being paid to sections at far southern declinations.

It is of interest to note a revived interest in Gould's Belt and related problems. The phenomenon of Gould's Belt, which is inclined by 15° to 18° with respect to the fundamental plane of our Galaxy, is shown most clearly by the brighter OB stars and the Be stars within 400 pc of the Sun, by the nearest extended dark nebulae and the nearer diffuse nebulae, and by the nearby large complexes of H I. To these can be added the I Orionis, the II Persei, and the Scorpius-Centaurus Associations (**4**). These objects define a compact Local System, possibly a self-contained unit. According to recent work by D. W. Dewhirst, reported during the Tenth Herstmonceux Conference (**5**), Gould's Belt suggests the existence of a very thin sheet of young objects. The sheet is 700 pc in extent, but only 70 pc thick, and is somewhat like the flat ribbons which are characteristically observed in the outer arms of Sb and Sc spiral galaxies. Some of us have referred to these ribbons emanating from spiral features as 'spurs'. Much attention is being paid to the motions of the stars in this Local System. In 1965, Bonneau studied the motions of the nearby OB stars (**6**) and found evidence for expansion. Blaauw has confirmed and extended Bonneau's work (**7**) for the O to B3 stars and he has explored the hypothesis that these stars, or rather the gas from which they were formed, originally occupied a much smaller volume of space than is the case at present. The pre-stellar gas seems to have spread out from a small volume in about $4 \times 10^7$ years; this conclusion is supported by the observed velocity gradients exhibited by stars in Gould's Belt. S. V. M. Clube (**5**) agrees with Blaauw in accepting the hypothesis of a general expansion of the Local System, to which he assigns an age of $3 \times 10^7$ years. As a consequence of the large V-component of the stream motion (twice the basic solar motion!), he considers it likely that the absolute magnitudes of B stars in the Scorpius-Centaurus Association may have been underestimated by 0·5 magnitude, and that systematic effects may result in the derived proper motions, precessional constants, and the values of Oort's $A$ and $B$. Since the Scorpius-Centaurus Association plays, as does the Hyades (see Section IV), an important role in the calibration of absolute magnitudes, these problems are of more than local significance.

We should draw attention once again to the peculiar density distribution of the F0 to F5 stars, which appear to have negative space density gradients in all directions away from the Sun. McCuskey (**3**) finds an average density at a distance of 500 pc less than one-half that near the Sun. This result has been confirmed in a recent study by McCuskey and Rubin (**8**). McCuskey reports that the Warner and Swasey Observatory has begun a survey of a belt 12° wide to detect all main-sequence A stars and gK stars to the limit of $V = 13{\cdot}5$ along the central band of the Milky Way. The Warner and Swasey Observatory, in collaboration with Bosscha Observatory, is extending its general spectral-magnitude survey southward to include the following centers:

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| | $l^{II}$ | $b^{II}$ |
|---|---|---|
| LF 11 | 212°7 | +1°2 |
| LF 12 | 240°8 | −0°5 |
| LF 13 | 281°0 | +3°9 |
| LF 14 | 297°6 | +1°4 |
| LF 15 | 330°3 | −2°8 |

The approach is similar to that followed in the study of luminosity functions for the northern part of the Milky Way (**2**). Pik-Sin The reports that the basic spectral and magnitude plates are already available for four of the five areas. Mavridis (**9, 10**) has summarized his work and that of others on M, C, and S stars for different sections of the Milky Way.

The Basel researches on stellar distribution at low galactic latitudes for rich fields in the Milky Way have thus far produced three papers (**11, 12, 13**). The limiting magnitude is 17. Density gradients have been derived for three fields. A new program has begun to study the density gradients for stars of lower luminosity than OB stars for the direction of a spiral arm (anti-center) and for an inter-arm direction (toward the galactic center).

Much new material has accumulated, and is continuing to accumulate, for the southern Milky Way. Graham and Lyngå (**14**) have published a finding list of 454 OB stars in Carina, and Lyngå (**15**) has published a similar list for the section $l^{II} = 310°$ to $334°$ (482 stars). Elsässer reports that E. Geyer, G. Klare, and B. Szeidl have in press two major papers with lists of OB stars complete to $m_B = 11{\cdot}5$, in the region $220° < l^{II} < 20°$, $-12°5 < b^{II} < +12°5$ (1660 $OB^+$ and $OB^-$ stars). Color searches for faint OB stars have been initiated by B. J. Bok (**16**). A comprehensive study of the spatial distribution of OB stars has been completed by Th. Neckel and G. Klare. The resulting distribution, clearly showing three spiral arms, is in general agreement with the model derived by W. Becker from OB star clusters. Much work has been done in recent years by Elsässer and associates at Königstuhl Observatory on problems relating to interstellar absorption, reddening, and polarization, but these researches fall strictly within the domain of Commission 34.

In the Sub-Sections to follow, we shall include the results obtained at observatories in the U.S.S.R. of work in areas contained in the Parenago Plan. We note here that the Observatory of the Ukrainian Academy of Sciences and the Abastumani Observatory have finished their assignments under the plan and that the Crimean Astrophysical Observatory has almost completed its share of the work.

### *Regional Surveys*

(*a*) *The section of the Galactic Center* ($350° < l^{II} < 10°$)

Much work is being done in areas in the general direction of the galactic center on the density gradients for the stars within 1500 pc of the Sun. Reference has already been made to the studies by W. Becker and associates at Basel, and, in passing, we should also refer to the work for Kapteyn Selected Area 158 (**17**); the matter is dealt with in more detail in T. Elvius' Report. The existing results imply that, for this direction, without fail, the star densities decrease with increasing distance from the Sun, as one would expect when proceeding from the position of the Sun, at the inside of a spiral arm, towards an inter-arm region.

McCuskey reports that Peter Wehinger has studied the interstellar reddening and the distribution of M giants for a field centered upon the radio source Sagittarius A at $l^{II} = 0°$. The derived total visual absorptions are as follows:

| $b^{II}$ | Distance (kpc) | | | | | |
|---|---|---|---|---|---|---|
| | 0·5 | 1·0 | 2·0 | 3·0 | 5·0 | 7·0 |
| +1°5 | 2·6 | 2·6 | 2·6 | 2·6 | 2·6 | 2·6 |
| −0°3 | 1·5 | 1·6 | 2·4 | 2·9 | 3·2 | 3·2 |
| −1°8 | 0·9 | 1·9 | 1·9 | 1·9 | 2·0 | 2·2 |

Spectral classification, supplemented by color work, yields the following space densities for the M2 to M10 stars:

| Distance (kpc) | 0·6 | 1·0 | 2·0 | 3·0 | 4·0 |
|---|---|---|---|---|---|
| Space Density (No. per $10^6$ $pc^3$) | 35 | 8·7 | 8·4 | 8·2 | 4·7 |

While these space densities decrease rapidly with distance from the Sun, they are twice the values derived for Palomar-Groningen Field No. 2 at $l^{II} = 4°$, $b^{II} = +11°$.

(*b*) $10° < l^{II} < 60°$ (*Sct, Aql*)

The Main Astronomical Observatory of the Ukrainian Academy of Sciences has finished work for a large region in Aquila ($l^{II} = 35°$ to $52°$); the area covers about 150 square degrees. The catalogue of stellar spectra and magnitudes and the study of the spatial distribution of stars and obscuring clouds in several areas in the Aquila region have been published by Apriamaschvili and Kuznetsov (**18**), Voroshilov and Poleshchuk (**19**), and Fedorchenko (**20**). Strong obscuration is present at relatively small distances from the Sun.

At Abastumani Observatory, Apriamaschvili (**21**) has classified, in two small areas in Aquila and Scutum ($l^{II} = 29°$ and $37°$), about 1900 stars to 14–15 pg magnitude and, moreover, about 900 faint M stars to the 18th photographic magnitude. The distributions of OB stars and obscuring clouds in both areas to distances of 8–10 kpc have been studied. A strong obscuration at small distances has been detected. OB stars show a remarkable clustering tendency, especially in the southernmost area.

McCuskey reports on an extensive investigation by R. B. Herr for the section $16° < l^{II} < 46°$. The study is based upon spectra of OB stars obtained in the Hamburg-Cleveland survey 'Luminous Stars in the Northern Milky Way' II and IV. It involves luminosity classification and (*U*,*B*) photometry of these stars. The former was done directly from objective-prism photographs. After being corrected for inter-stellar absorption, the derived space densities for the OB stars in two regions included in the survey are as follows:

| | No. Stars per $10^6$ pc. | |
|---|---|---|
| Distance (kpc) | Region A ($l^{II} = 19°$) | Region B ($l^{II} = 41°$) |
| 0·5 | 5·4 | 0·6 |
| 1·0 | 3·5 | 0·2 |
| 1·5 | 3·1 | 0·2 |
| 2·0 | 1·8 | 0·2 |
| 2·5 | 1·1 | 0·1 |
| 3·0 | 0·7 | 0·07 |

McCuskey comments that the OB-star space densities for Region A ($l^{II} = 19°$) run very similar to those for B8 to A0 stars at the same longitude (**22**).

Lisicki (**23**) has studied the absorption and other structural characteristics in a field in Aquila and Sagittarius, and Dolidze (**24**) has completed a survey of M stars for the region near ζ Oph.

(*c*) $60° < l^{II} < 150°$ (*Cyg, Cep, Cas, Per*)

In the U.S.S.R., much attention is being given to the study of the stellar distribution in Kapteyn Selected Area 40. Kolesnik (**25**) has found that the density maximum for the A stars coincides with the obscuring clouds. Kharadze, Apriamaschvili, and Kochlaschvili (**26**) have published a catalog of over 1000 stars near Selected Area 40. Kolesnik (**27**) stresses the urgent need for studies of galactic structure by means of spectroscopic and photometric data for the most distant stars within reach. We note that the Main Observatory of the Ukrainian Academy of Sciences is extending its photometric studies to $V = 14{\cdot}5$–$15{\cdot}0$ in several areas within the section under discussion and the anti-center region ($50° < l^{II} < 180°$). Kharadze reports that Abastumani Observatory, in cooperation with Kiev, is undertaking two-dimensional spectral classification and three-color photometry for eight areas along the galactic equator from Aquila to the anti-center. Two further studies of the Cygnus Region should be noted. Dolidze's (**28**) survey of M stars includes the region of the Cygnus Loop and NGC 6819. M. Lunel (**29**) has made *UBV* measurements of the highly reddened VI Cygni Association.

The program of the Crimean Astrophysical Observatory has included work by Masnauskas (**30**), who has determined the spectra and $B, V$ magnitudes for about 3600 stars in a 40-square-degree area in Cepheus ($l^{II} = 105°$), and by Brodskaya and Grigorieva (**31**), who have done the same for about 2700 stars in an area of comparable size in Cassiopeia ($l^{II} = 121°$). For the second area, the space distribution of obscuring clouds and OB stars has been studied. The OB stars show a considerable concentration to the Perseus Arm. A similar investigation in a neighboring area containing a stellar association ($l^{II} = 118°$, $b^{II} = +5°$) has been carried out by Raznik (**32**).

B. J. Bok and M. Smith have in progress a photometric study of a number of distant OB stars in a relatively unobscured region in Cepheus; similar work is under way for a region in Monoceros. The search for faint H$\alpha$ emission objects is continuing. Blanco and Fitzgerald (**33**) have studied the section near $\zeta$ Cep, with 26 new stars added to the lists.

There is much progress to report for the section of the Milky Way in Cassiopeia. H. Schmidt is working on a field near $l^{II} = 136°$, $b^{II} = -1{\cdot}^{\circ}5$, where 2000 stars to $V = 15{\cdot}5$ have been measured for a field of $1{\cdot}6$ square degrees. McCuskey and Houk (**34**) have published photographic photometric results for five clusters and 159 OB stars near $l^{II} = 129°$, $b^{II} = -2°$, where they find a high concentration of OB stars between 2 and 3 kpc from the Sun. They conclude that the clusters and the OB stars are probably in the Perseus Arm. Here we also note Ampel's work (**35**), which has yielded spectral-luminosity classes, photographic magnitudes, and colors for 275 OB stars in the Associations III Cassiopeiae, IV Cassiopeiae, and V Cassiopeiae. B stars in the Perseus Arm have been found in considerable numbers by Grigorieva (**36**) at distances of 2 to $3{\cdot}5$ kpc in the section $117° < l^{II} < 124°$. Extensive work on the IV Cephei Association is underway at Warner and Swasey Observatory.

An important study for this section is that published in Oja's doctoral thesis (**37**), which covers the range $112° < l^{II} < 133°$. Spectrophotometric data are now available for 2600 stars with $b^{II} \leqq \pm 3°$. An investigation in depth (**38**) was made for a region near $l^{II} = 128°$, $b^{II} = -2°$. Oja's catalog contains spectrophotometric data (derived from plates taken with the large Bergedorf-Schmidt telescope) and integral photometry (done with the Uppsala double refractor and the Uppsala-Kvistaberg Schmidt telescope) for about 1000 stars brighter than $14{\cdot}0$ magnitude (pg). All types of stars with $M < 0$ have a maximum space density at a distance of $3{\cdot}2$ kpc; this maximum may be identified with the 'spiral arm + I', according to W. Becker's notation, the Perseus Arm.

We note finally that Velghe is continuing his infra-red survey of C, S, and M stars (M2 to M10) to $I = 13{\cdot}5$ for a field in Cygnus and Draco (at $l^{II} = 77°$, $b^{II} = 0°$ to $+22°$). He reports that the $V$ and $I$ magnitudes are almost ready for publication.

(*d*) *The Anti-Center Region* ($150° < l^{II} < 210°$)

Two recent studies from the U.S.S.R. are to be reported. Kalandadze has published (**39**) a catalog containing 3600 stars for an 80-square-degree region near $l^{II} = 182°$, and Bartkus (**40**) has published one containing 2455 stars for the central part of the Orion Association.

McCuskey has finished a catalog of 3620 stars to $V = 12 \cdot 2$ for an area of 20 square degrees centered upon $l^{II} = 186°$, $b^{II} = +1°$. The catalog has spectral classifications and $V$ magnitudes for all stars and $(B-V)$ values for a representative sample. He expects that a comparison of the spatial stellar distributions for the regions of the center and the anti-center will help clarify the situation regarding the Sun's position relative to the local spiral structure.

In connection with her work on radial velocities of distant OB stars, Rubin (**41**) has begun a search for such stars in the range $139° < l^{II} < 216°$. She uses three-color Palomar-Schmidt plates for eight centers. McCarthy and Treanor (**42**) are studying fields in the anti-center section with the aid of the Vatican Observatory equipment. As part of the Basel program, Fenkart's (**12**) work should again be noted at this point. We should also mention the extensive program on spectral classification, objective-prism radial velocities, and photometry undertaken jointly by the Observatoire de Toulouse (by Bouigue and Mme Lunel) and by the Observatoire de Marseille. Finally, Karlsson (**43**) has published a first paper relating to the study of a region in Monoceros.

(*e*) $210° < l^{II} < 300°$ (*Pup*, *Vel*, *Car*, *Cru*)

Velghe has made an extensive OB-star spectral-color-magnitude survey for the section $257° < l^{II} < 285°$. The results have not yet been published in full. J. Denoyelle has now begun an extensive investigation of colors and magnitudes for 350 OB stars in two low-latitude sections bordering the section studied by Velghe. The work is being done at Boyden Observatory.

Much attention has been paid to the Carina section, $280° < l^{II} < 295°$. Sher (**44**) has published a comprehensive survey for this part of the Milky Way. He shows that the preceding edge of the Carina concentration of stars and gas, located at $l^{II} = 275°$, is real and not an effect caused by local obscuration. The Carina section shows a 'bewildering array of Population I' (Sher), but all clusters with estimated ages less than $10^8$ years appear to be at distances in excess of 1500 pc. Recent distance estimates for the $\eta$ Carinae Nebula (NGC 3372), and some of the clusters almost surely imbedded (Tr. 16) in it, place it at a distance of between 2500 and 3000 pc. Feinstein reports that 2500 pc appears to be the best estimate, which agrees well with his earlier published estimate of 2800 pc (**45**). D. J. Faulkner's value (**46**) is 2500 pc, whereas Graham has given 2800 pc on the basis of H$\beta$ photometry for peripheral stars. These are considerably greater than the earlier values of 1400 to 1800 pc. The gaseous and OB-star concentrations are obviously more distant than the known concentration of late B and early A stars, which occurs within 1000 pc of the Sun. Graham and Lyngå (**47**) have published a survey of faint OB stars in Carina. There was a useful discussion on the distance problems in the Carina section during the Hamburg meeting of Commission 37 (**48**). In his Report to our Commission, Feinstein announces his conclusions, which are, (1) that the main concentration of OB stars is at a distance greater than 1600 pc from the Sun, (2) that the normal value $R = 3$ applies to the highly-luminous stars outside the immediate surroundings of $\eta$ Carinae, and, (3) that $A_v = 0 \cdot 45$ magnitude kpc$^{-1}$ for the initial 1600 pc.

Westerlund (**49**) has made an infra-red survey of the region of Kapteyn Selected Area 193 at $l^{II} = 293°$. He has compared his results with those obtained earlier for five other fields, and certain patterns emerge. He finds that the M2 and M4 stars form a thin galactic layer with a half-thickness of 250 pc. They tend to concentrate toward spiral arms. The M5 to M6·5 stars show a marked concentration toward the galactic center, but the M7 to M10 stars form a homogeneous thick layer with negligible variations in space density. The carbon stars (Class N) are most likely spiral-arm objects.

(*f*) $300° < l^{II} < 350°$ (*Cen*, *Cir*, *Nor*, *Sco*)

It has become increasingly apparent that the galactic structure in this section is critical for our understanding of the local spiral structure of our Galaxy. Therefore, it is not surprising

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that much effort is being expended on studies of galactic structure for this section of the Milky Way. We shall leave a discussion of the spiral features for the next Section, but here we will briefly note some other structural features.

Lyngå (**50**) has published a series of five papers dealing with this section. He concentrates his efforts on the sector $311° < l^{II} < 332°$; the concluding paper has a summary of the overall results obtained from this work. He has written another summarizing article (**51**), which serves to complete the picture. Three OB associations have been found in this section, though it is recognized that one of them is very weak and that all three are inconspicuous groupings when compared to the objects generally classified as associations. Lyngå's Catalog for this section contains 482 OB stars. Three young open clusters have been studied in this section, and several new clusters are confirmed or suspected. The H II regions in the section are small and inconspicuous, but it is noted that they are spread fairly evenly in galactic longitude. Lyngå notes that more dramatic and conspicuous features are present for galactic longitudes $l^{II} > 330°$.

For the section $330° < l^{II} < 340°$, the stellar distribution shows the features generally associated with Population I and with spiral structure. B. J. Bok, P. F. Bok, and Graham (**52**) have studied the OB stars within one degree of $l^{II} = 327°$, $b^{II} = 0°$; they used the strength of H$\beta$ as a criterion for absolute magnitude. There appears to be a marked concentration of OB stars at a distance of 2500 pc from the Sun. Graham (**53**) has studied nine distant B stars in Ara at $l^{II} = 337°$ and finds (from radial-velocity data) that these stars are spread over a considerable range of distance. In agreement with Whiteoak's (**54**) earlier results, some of these stars are found at much greater distances than that of the I Ara Association. H. L. Johnson had indicated (**55**) that the ratio of total to selective absorption might be quite large for the Ara B-stars, but Graham points out that his radial-velocity data indicate a large spread in distance and that the more usual ratio $A_V/E_{B-V} = 3{\cdot}0$ seems preferable.

Haug, Pfleiderer, and Dachs (**56**) have studied 105 stars of early spectral class near $l^{II} = 332°$, $b^{II} = -2°$ and 38 stars near $l^{II} = 321°$, $b^{II} = -1{\cdot}5°$. *UBV* magnitudes and colors have been obtained for all stars on the list. Some highly reddened distant stars (to 4 kpc from the Sun) have been detected for the Norma field ($l^{II} = 332°$), but the greatest estimated distance for a star in the Circinus field ($l^{II} = 321°$) is considerably less than 3 kpc. Further work on this section of the Milky Way is in progress. G. Schnur at Heidelberg has reported that he has *UBV* data for 700 stars near $l^{II} = 332°$. Radial-velocity data for ten of the stars studied by Bok, Bok, and Graham (**52**) are now available (**57**). This information confirms the photometric distances.

We should draw attention briefly to the distribution of planetary nebulae. Much new material for the southern sky is accumulating through the work of Henize and Westerlund and also from the color-filter studies of B. Louise Webster. She has noted that the density of planetaries in Norma (near $l^{II} = 330°$) is higher than for the section $270° < l^{II} < 320°$, and also that the planetary nebulae in Norma are found at greater distances from the Sun than in the Carina-Centaurus section. An atlas with photographs of 99 southern planetary nebulae is to be published shortly by Henize and Westerlund.

Roslund (**58**) is continuing his work on spectral classification, magnitudes, and colors for a field in Scorpius. *UBV* magnitudes and colors and H$\beta$ indices are available for 250 early-type stars, and MK classifications are available for 63 of the brighter stars. His results show that these OB stars form a homogeneous groups of young stars. Strong interstellar reddening in the northern part of the region appears to originate from insterstellar dust in the local spiral arm. Bok, Bok, and Graham (**59**) have published *UBV* and H$\beta$ photometry for the I Scorpii Association, for which a distance of 1800 pc is obtained. Graham reports that H$\beta$ photometry for seven open clusters in the southern section of the Scorpius-Centaurus Association is in press. Velghe and P. Sanders have underway a search for and study of new H II regions in Scorpius.

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## VII. THE SPIRAL STRUCTURE OF OUR GALAXY

The picture of the local spiral structure of our galaxy that appears to be generally accepted is that of W. Becker (**1**), published after our previous Report was completed. It is reproduced, with slight modifications, by Schmidt-Kaler (**2**). In our previous Report to Commission 33, we listed five basic approaches for the tracing of the spiral arms of our Galaxy. We can add the positioning of dark nebulae as a potential tool for the tracing of spiral arms, especially applicable to the insides of the spiral arms. Observations of faint emission stars, which are easy to detect from objective-prism spectrum photographs, can also prove very helpful; one should, however, bear in mind that Be stars probably have considerable dispersion in absolute magnitude. Analyses of spiral structure should continue to take into account the need for constant reference to the observed spiral features of galaxies other than our own. Becker has suggested that NGC 1232 (Sb) deserves special attention.

Kinematical features should not be overlooked. There is increasing, but conflicting, evidence for differences in velocity between the stars and the gas associated with a given spiral arm. Such effects have been detected by Abt and Bautz (**3**), who found that the radial velocities of the stars, presumably associated with the Perseus Arm, were 7 to 8 km $s^{-1}$ greater than the corresponding 21-cm H I velocities. They attributed their result as possibly being caused by binary effects in the stars, or atmospheric effects, rather than indicating a difference between stellar and gaseous velocities. In a presentation at the Colloquium held at Besançon on 'Les Nouvelles Méthodes de la Dynamique Stellaire' (September 1966), Dixon states that 'present data indicate that, near the Sun, the interstellar medium lags behind the gravitational circular velocity by 14 km $s^{-1}$'. A rather different conclusion is drawn by Fletcher (**4**) in an article that should have been included in the Hamburg Report. When comparing structural features on the basis of observed radial velocities alone, he finds good agreement between optical results for OB stars and radio results from 21-cm profiles. M. Mowat has made a strong plea (**5**) for more optical radial velocity data in sections of the Milky Way for which the galactic-rotation component of radial velocity varies markedly with distance from the Sun. The comparison between the radio (21 cm) and the optical results becomes then model-independent. However, the spiral pattern that is derived from radial-velocity data is still highly dependent on the law of rotational velocity that is assumed, and ultimately we must refer to the assumed model of rotation for the Galaxy. Large-scale non-circular gaseous motions, which have been observed to run as high as 10 km $s^{-1}$, can affect the derived pattern very much.

Several important papers on the spiral structure of our Galaxy have come from the U.S.S.R. Kardashev, Lozinskaya, and Sleptsova (**6**) have re-analyzed all available 21-cm observations and continuum data. They find that the most probable large-scale spiral features of our Galaxy can be represented by a logarithmic spiral with two arms and with an average 'pitch angle'

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of 84°. However, Kuzmin notes in his Report that these results are contradicted by the work of Kostyakova (7), who has analyzed for interstellar absorption the spectrophotometrically-determined color distribution along the band of the Milky Way. While this approach is useful, it is obviously subject to uncertainties of interpretation. No agreement is found with the spiral features derived from 21-cm data. A multi-arm model for the spiral structure has been proposed by Pskovskii (8), who derives from optical and radio data a series of logarithmic spirals with an average pitch angle of 72°.3. Pavlovskaya and Sharov (9) have generally confirmed the work of Pskovskii.

Mrs Pronik (10) has drawn attention to unevenness in the velocity picture for the outer spiral arms as shown by the 21-cm profiles. She has found many cases in which the velocities shown by the gas 2°.5 north of the galactic equator show different maxima and a different pattern from the gas at the same small angular distance south of the galactic equator.

General calibration problems of absolute magnitudes continue to be of much concern. W. Becker reports that corrected distances for H II regions have been obtained on the basis of Petrie's new calibration of absolute magnitudes of early B-type stars. He mentions that Fenkart has prepared a list of 90 O to B3 stars with $V < 10$, which are obviously responsible for 50 observed H II regions; luminosity estimates and colors are not yet available for these stars, which require urgent attention. The unpublished work of J. S. Miller of Washburn Observatory should fill some of these gaps.

Sharpless is extending his work on M-type supergiants through the application of narrow-band photometric techniques. He expects to identify older spiral features and obtain information on the evolution of the spiral structure of the Galaxy. He is also engaged upon the study of the cosmically very young multiple O-type systems of the Trapezium variety.

Lindsey F. Smith (11) has studied the distribution of the Wolf-Rayet stars in the galactic plane. On the basis of newly-established calibrations of absolute magnitude, she has determined fairly precise distances for the known galactic WR stars. These stars appear to fall along the inner edge of the Local Arm and are found in the Sagittarius Arm.

Muhleman and Walker (12) have investigated one of the causes for gaps in the H I distribution. They find that the observed gaps in part of the Cygnus Arm can be identified with regions of high ionization, since the concentration of OB stars is large for those regions without H I; these obviously have become H II regions.

In recent years, there has been much discussion about the possible uses of Be stars for studies of spiral structure. Schmidt-Kaler (13) and Behr (14) have taken opposite points of view on this question. Schmidt-Kaler claims that the Be stars are very well suited for this work, whereas Behr is of the opinion that their dispersions in absolute magnitude are too great for individual stars to serve as spiral tracers; he estimates the average dispersion to be greater than 0·4 magnitude. However, in a later paper (*Mitt. astr. Ges.*, no. 21, 68, 1966), Behr classifies the Be stars as good spiral tracers.

In an as-yet unpublished doctoral thesis (Northwestern University, 1966), J. D. Wray has surveyed the southern Milky Way, $240° < l^{II} < 10°$, for Hα-emission objects, which survey has yielded an additional 870 probable Be stars. The strong concentration to the Carina section has been confirmed and the arrangement of these stars follows the inner spiral arm defined by Morgan, Whitford and Code. The Be stars apparently provide a 0·5 to 1·0 kpc resolution element for the study of intermediate age spiral structure for distances up to 5 kpc from the Sun.

Isserstedt and Schmidt-Kaler (15) have analyzed the distribution of reddening as a function of distance from the sun for all directions and in different zones of galactic latitude for $-8°.5 < b^{II} < +8°.5$. They find two conspicuous 'transparency channels', one centered at $l^{II} = 45°$ and another at $l^{II} = 285°$. They argue in favor of a new interpretation of the

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surface photometry of the galactic belt by Elsässer and Haug (**16**). The criticisms by Isserstedt and Schmidt-Kaler are, however, rejected in a subsequent paper by Elsässer, Neckel, and Scheffler (**17**); see, however, Behr's comments (*Mitt. astr. Ges.*, no. 21, 76, 1966).

One of the most important investigations published during the past triennium has been a series of papers by Lyngå (**18**). He has studied extensively the sector of the band of the Milky Way, $311° < l^{II} < 330°$, and he has related the results of his work (already reported in part in the preceding Section) to that of Becker and others. In his most recent report (**19**), he has presented his views on the spiral structure for the fourth galactic quadrant. In agreement with Becker (**1**), he concludes that the Sagittarius Arm continues past Norma into Circinus and Centaurus and on into Crux and Carina. This situation is illustrated nicely in his diagram, which shows the location of the spiral tracers in the fourth quadrant; however, one should bear in mind when inspecting this diagram that Lyngå has plotted, with equal emphasis, the weak spiral features in the section $300° < l^{II} < 325°$ and the strong features in Carina, $275° < l^{II} < 300°$, and in Norma and Scorpius, $325° < l^{II} < 350°$. Lyngå mentions a divergence between the optical and the radio picture; the difference in longitude between the optical and the radio spiral arm in Carina amounts to almost 10°. I do not fully agree with this conclusion, for the coincidence between optical and radio features seems reasonably good; Kerr has recently derived a new diagram of spiral structure from 21 cm data, which shows good agreement with the optical result for the Carina section.

The detailed piecing-together of the recognized spiral features of our Galaxy remains one of the principal tasks for the members of Commission 33. The chapters in *Stars and Stellar Systems*, Vol. V, by S. Sharpless (Ch. 7), R. P. Kraft (Ch. 8), F. J. Kerr and G. Westerhout (Ch. 9), and G. Münch (Ch. 10) cover the earlier work in some detail.

While it is obviously important to attempt to establish differences between optical (stars and H II) and radio features (H I, radio continuum), every effort should be made to have the two general patterns agree before we attempt to distinguish differences. The major problem before us is that the pitch angle of the recognized radio spiral arms appears to be near 85°, whereas a preponderance of opinion favors a pitch angle in the range 70°–75° for the optical picture.

We note, first, that it is becoming increasingly apparent that the anlysis of the radio data has by no means been completed. The whole picture may change as it becomes necessary to assume new and different overall dimensions for our Galaxy, and such changes will certainly affect the law of circular galactic rotational velocity. Furthermore, recognition of the existence of large-scale deviations from pure circular motion are leading to fundamental changes in our interpretation of the radio data.

The present situation with regard to the optical picture is that by now we recognize certain spiral features as firmly established. These features are shown most completely in the spiral diagram proposed by W. Becker. However, the pattern may be more confused than is assumed by some. To simplify future optical work, it seems important that we should concentrate our efforts on the least questionable spiral tracers, which are the optically-recognized H II regions and their associated OB stars, and clusters with OB stars. For the present, long-period cepheids and cosmic dust clouds are to be looked upon with a degree of suspicion, since they may not represent tracers for the identical spiral structure which is presumably shown by the radio H I data and by the optical H II features. Interstellar absorption lines should enter the picture much more fully than they do at present. They promise not only to yield useful data on radial velocities of gaseous features associated with the spiral pattern, but they can also provide much information on possible deviations from pure circular motion.

It is well to stress here that we should be inherently suspicious of attempts to draw an overall spiral pattern from the available, limited, optical data. An inspection of the patterns found within 3 to 4 kpc of positions in selected outlying regions of half a dozen of the best-known spiral galaxies shows how easily one might draw the wrong overall spiral diagram on the basis of limited local information. In future optical studies of the spiral structure of our own Galaxy, we should proceed step by step. First, we should follow the pattern set by W. Becker and others, which is to delimit the clearest and cleanest spiral features (spiral knots, or established sections of what appear to be parts of a major arm pattern). However, we should not extrapolate unnecessarily and connect these features into a major, overall, pattern until radio and optical evidence jointly force us to do so. The second step should be to concentrate our efforts on the borders of established concentrations and on improved distances of spiral features for the sections where the situation seems confused. We should attempt to distinguish between spurs and stragglers and true connecting links between sections of a major arm. The third step should be a careful search for faint and remote OB stars and H II regions, and possibly also long-period cepheids, in those parts of the Milky Way for which we are viewing between spiral arms. In all of this work the 21 cm data should be fully considered. This applies especially to the location of true edges of spiral arms. Every effort should be made to distinguish between them and optical effects caused by overlying absorption.

The optical features that seem to be clearly present are the following:

1. The section of the Perseus Arm for $90° < l^{II} < 140°$ at distances from the Sun of 3 kpc and greater;
2. The section of the Local Arm for $60° < l^{II} < 210°$;
3. The section of the Sagittarius Arm for $330° < l^{II} < 30°$ at distances from the Sun of about 2 kpc;
4. The section of the Carina Arm between $280° < l^{II} < 310°$, pointing away from the Sun with established spiral features in the range of distance from the Sun of 1·5 to 6 kpc;
5. The connecting weak link, or weak part of the Carina-Sagittarius Arm, for $310° < l^{II} < 330°$ at distances from the Sun of about 2 kpc.

The recognized gaps in our spiral pattern to distances from the Sun no greater than 4000 pc are the following:

1. $30° < l^{II} < 60°$,
2. $270° < l^{II} < 280°$.

There are several sections of the Milky Way that demand urgent effort on the part of optical astronomers. The principal section of the northern Milky Way that requires prompt attention is at $140° < l^{II} < 180°$, where we must continue to search for evidence for or against an extension of the Perseus Arm; this search may involve detection of optical spiral tracers with distances between 3 and 7 kpc from the Sun. Greatest confusion exists in the section $180° < l^{II} < 270°$. There are some well-established remote features in this section, but it is difficult to judge their importance for the overall pattern. Mowat's (5) recent discussion lists one major concentration at great distance; it is the I Puppis Association, at approximately 5 kpc from the Sun ($l^{II} = 245°$). The nearby 'Gum Nebula' is a major local feature in this section. The situation in the next critical section, $280° < l^{II} < 295°$, and its bordering areas, has been well summarized in the recent paper of Sher (20). In a way, the most critical section of all is the Norma section, $325° < l^{II} < 335°$. Here we are faced with a choice between two alternatives. The first hypothesis is that at these longitudes our line of sight crosses two spiral arms, first the Sagittarius Arm, passing into Centaurus, second, the Norma-Scutum Arm, an inner spiral arm first suggested by Thackeray (21). The alternate hypothesis is that at these longitudes we are viewing tangentially an edge of the Sagittarius Arm pointing away from the Sun. The general consensus among members of our Commission apparently favors the first alternative, but the general appearance in the sky of the Norma section favors the second. Fortunately, the galactic-rotation component of radial velocities varies rapidly with distance from the Sun for the Puppis ($l^{II} = 245°$) and Norma ($l^{II} = 330°$) sections, thus making available an additional parameter for estimating distances. This situation, unfortunately, does not occur in the Carina section (**22**).

In the years to come, it will benefit us to pay increasing attention to the detailed structure of the Local Arm. There are many details here that require close study. The recent studies of Gould's Belt by Dewhirst and by Clube (**23**) show how it outlines a distinct feature of fairly large scale (70 by 700 parsecs) associated with the inner part of the Local Arm. The relative distribution of young stars, gas, and cosmic dust in the Local Arm must be explored in detail if we wish to interpret the difficult evidence presented by the Carina and other sections.

In conclusion, we should stress the increasing need for continued consultation between observers and theoreticians working on problems of the spiral structure of our Galaxy. Section X shows that there are several new approaches to the problems of the dynamical interpretation of spiral structure. In a recent communication, C. C. Lin asked that certain highly specific questions be answered by observers in the field. Some of these questions are as follows:

1. Is the Puppis-Vela Spur an extension of the Perseus Arm?
2. Can additional optical studies clarify the situation for the range $240° < l^{II} < 300°$ and $60° < l^{II} < 90°$?
3. Can one study further the distribution in depth for the range $315° < l^{II} < 340°$, especially for distances in excess of 2 kpc?

The study of the galactic spiral structure is presently passing through a difficult and confused phase, but we now have available the tools which should allow us to resolve most of the observational uncertainties.

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## VIII. STELLAR DISTRIBUTION IN HIGH AND INTERMEDIATE GALACTIC LATITUDES

During the past three years, much new observational material has accumulated for the study of density and velocity distributions in the two Galactic Polar Caps, but little or no progress has been made in the theoretical interpretation of new and old data. No clear-cut regularities have been established, and there continues to be much uncertainty about most basic features of the kinematics and dynamics of our Galaxy for directions from the Sun at right angles to the galactic plane. In other words: We cannot report at this stage any real improvement in our knowledge of the force law, $K(z)$, for values of $z$ less than 1000 parsecs, $z$ being the height above or below the galactic plane. Observations of two varieties are required; density distribution functions, $\Delta(z)$, and, preferably for a good sample of the same stars, the corresponding distribution function of velocities perpendicular to the galactic plane, $\varphi(Z)$, where $Z$ is the linear velocity perpendicular to the plane. If $\sigma^2(z)$ represents the square of the dispersion in random velocities $Z$, at height $z$, then the basic relation for a 'well-mixed' state of equilibrium perpendicular to the galactic plane is:

$$K(z) = \frac{1}{\Delta(z)} \cdot \frac{\partial}{\partial z}[\Delta(z)\,\sigma^2(z)] \quad , \qquad \text{(A)}$$

which, for the simplest case $\sigma^2(z) = \sigma^2$, of constant value, and for a Gaussian distribution of $Z$, reduces to:

$$K(z) = \frac{\sigma^2}{\text{Mod}} \cdot \frac{d\,[\log \Delta(z)]}{dz} \quad , \qquad \text{(B)}$$

where $\text{Mod} = \log_{10}e$.

The most extensive recent study has been made in the doctoral thesis of Perry (1), which provides a wealth of new material for the A0 to A2 stars. His basic list of stars consists, first, of all (97) A0 to A2 stars in the North Galactic Polar Cap (NGPC), i.e. within 15° of the North Galactic Pole. To these are added 12 A0 to A2 stars between $m = 9.5$ and $11.0$ from the list published for the NGPC by Slettebak and Stock (2). Perry has determined for all 109 stars radial velocities as well as apparent and absolute magnitudes (the latter from narrow-band photometric measurements). He has, in addition, obtained similar material for all A0 to A2 stars (122) with known trigonometric parallaxes greater than 0".020. Perry's radial velocities increase slowly, but gradually, with distance from the galactic plane; $\sigma^2$ equals about 200 for distances $50 < z < 200$ pc, and $\sigma^2 = 700$ at $z = 650$ pc. However, a much smaller value, $\sigma^2 = 44.3$, is found for the sample of the nearby stars, all within 50 pc of the Sun. If the Z velocities for distances greater than $z = 50$ pc are averaged and represented by a single Gaussian distribution function, then their dispersion corrected for accidental errors of measurement comes out to be $\sigma = 11.9$ km s$^{-1}$. The density function for these A0 to A2 stars shows a strong negative density gradient in the range $0 < z < 350$ pc and a smaller gradient for the range $350 < z < 750$ pc, with the latter the limit of the survey. On the basis of the 'well-mixed' hypothesis, as expressed by equations (*A*) and (*B*), the above results would imply a force function reaching a fairly sharp maximum at $z = 200$ pc. Such a conclusion seems rather improbable, as Perry stresses, but solutions involving several Gaussian components do not seem to alter the situation basically. It is not unlikely that his sample of A stars is not sufficiently ancient to be considered as 'dynamically relaxed', especially since moving groups may contribute more than their share to the sample close to the galactic plane. There is also the possibility of two basically different populations of A stars within 750 pc of the galactic plane.

Stothers and Tech (**3**) have studied the force field perpendicular to the galactic plane and in the solar neighborhood with the aid of all available data on motions and distance moduli for OB stars, excluding recognized members of known moving clusters. They find a surprisingly consistent picture when they derive the force law, $K(z)$, from a plot of $Z$ against $z$. The force, $K(z)$, increases proportionally to $z$ up to $z = 200$ pc, which is the limit of their survey.

The chapter by Elvius (**4**) has a good summary of the earlier work in the field, especially of the Swedish work, the papers by Oort and Hill, and those by Upgren, to which reference has been made already in earlier Reports. One class of stars to which relatively little attention has been given in recent years are the F stars. Photographic and photo-electric techniques enable us to obtain information on their density distributions. Furthermore, radial-velocity measurements for a representative sample of these F stars can at present be more easily obtained than was the case a few years ago. Work on radial velocities for F stars in the NGPC is well advanced at the Dominion Astrophysical Observatory. Bok and Basinski (**5**) have published $B$ and $V$ magnitudes to $V = 16$ for stars in the range $+0{\cdot}30 < B-V < +0{\cdot}60$ in the SGPC. The space density (per unit volume) drops steadily with increasing $z$, as is shown in the following tabulation:

| $z$ | $\Delta(z)$ |
|---|---|
| 100 pc | 1·00 |
| 200 | 0·35 |
| 500 | 0·051 |
| 1000 | 0·0123 |
| 2000 | 0·0030 |

The F stars are probably a rather homogeneous group. A survey of their distribution to $V = 16$ and fainter in the NGPC seems highly desirable. The existing spectral surveys of Upgren (**6**) and of Slettebak and Stock (**2**) reach only to $V = 12$.

The work at the Basel Observatory by W. Becker and associates is progressing well (**7**). Results for the space distribution of Population II stars in the halo are now available for Selected Areas 51 and 57, the latter close to the North Galactic Pole. We refer to T. Elvius' Report on Selected Areas for details, especially regarding the work in progress for intermediate galactic latitudes. It is of interest to note that Terzan at Lyon has completed a three-color photographic survey (at $\lambda = 4400$, 6400, and 8100Å) for Selected Area 57 (**8**).

R. Bouigue at Toulouse reports good progress on the determination of colors, magnitudes, and objective-prism radial velocities for all stars brighter than 10th magnitude in the NGPC.

Blaauw reports that a collaborative project has been undertaken by the Kapteyn Astronomical Laboratory and the Leander McCormick Observatory to investigate the density distribution and kinematic properties of the intermediate-age G and K giants up to distances of several kiloparsecs from the Sun. Ljunggren has completed his studies for the NGPC (**9**). One important conclusion of his work is that there is evidence of irregular absorption and reddening over the NGPC, suggesting a patchy distribution of absorbing material mostly at distances, $z$, of 200 to 250 pc. We note that Perry's results gave no evidence for marked reddening effects in the NGPC.

We need not deal at length again with the derived value of the mass density near the galactic plane. However, we should draw attention once again to Einasto's spirited defense of the lower value for the density near the galactic plane (**10**). His result is more or less supported by Stothers and Tech (**3**), but is in conflict with most other recent results. However, our rather full description of the difficulties encountered by Perry in his analysis for the A0 to A2 stars shows that the issue is by no means a closed one. Sanduleak's work (**11**) on the faint M stars in the NGPC is relevant at this point. He found over 1200 such stars in an area of 120 square degrees from a survey with the Warner and Swasey Observatory Burrell-Schmidt telescope, a survey complete to $V = 17$. If his M stars were all dwarf M stars, then they may contribute 0·04 $M_{\odot}$ per cubic parsec to the mass density near the Sun. In his report to our Commission, McCuskey points out that proper-motion surveys do not confirm this large excess of dwarf M stars. If Sanduleak's stars are giant M stars, then they must lie at very great distances from the galactic plane, with a density of one such star per volume of $2{\cdot}5 \times 10^8$ $pc^3$ at $z = 20\,000$ pc. For the SGPC, on the other hand, Pik-Sin Thé and Blanco find space densities for M dwarfs that are not nearly as great as those of Sanduleak. McCarthy, Bertiau, and Treanor (**12**) have made a complementary survey for the SGPC, using ADH-Schmidt plates, taken with a 3° objective prism, which records the brighter stars of spectral class M2 and later. Their results agree with those of Pik-Sin-Thé and Blanco.

Davis Philip is continuing his comprehensive spectral-color-magnitude program for regions at intermediate galactic latitudes. The complete results have been published (**13**) for a region in Pegasus at $b^{II} = -29°$. His basic material consists of objective-prism plates obtained with the Warner and Swasey Observatory Burrell-Schmidt telescope and of photo-electrically (*UBV*) calibrated photographic magnitudes for these stars. A rapid decrease in space density is found for main-sequence stars of spectral class earlier than Go. At $z = 300$ pc, the space density of these stars is equal to only one-tenth that at $z = 100$ pc, or very much the same result as the one of Basinski and Bok, shown above. Constant density was found for the dwarfs to the limit of the survey. For the late-type giants, the space densities drop off much slower with z than for the early-type stars; at $z = 300$ pc, the average space density is one-half of that at $z = 100$ pc. The study is the first one published for an extensive general survey. The plan is to cover ultimately areas at $b^{II} = +75°, +60°, +45°, +30°, +15°, 0°, -15°, -30°, -45°, -60°, -75°$ for the four galactic longitude belts, $l^{II} = 76°, 290°, 0°$, and 180°. The results will be related to those obtained by radio-astronomical techniques for the distribution of H I (**14**). A remarkable blueing effect found by Davis Philip was traced in part to inconsistencies in spectral classification; the main cause for the effect remains lower metal abundance of the older stars.

J. S. Drilling of Warner and Swasey Observatory is studying the space distribution of stars in an area of 20 square degrees at $l^{II} = 330°$, $b^{II} = -30°$; this is a joint project with Bosscha Observatory. Spectral-photometric data, complete to $V = 10{\cdot}5$ or $11{\cdot}0$, will form the basic material for the analysis to follow.

McCuskey reports preliminary results for the stellar distribution for three of the Groningen-Palomar Fields used in the survey of faint RR Lyrae variables (**15**). Because of the importance of these fields for our future understanding of the overall properties of our Galaxy, we reproduce McCuskey's report in full:

'Absorption characteristics and the space-density distributions of giant M stars and of stars of types B8–A2 and gG8–gK2 have been determined for Fields 1, 2, and 4 of the Groningen-Palomar Survey of Variable Stars. The areas are located at $l^{II} = 0°$, $b^{II} = +28°$; $l^{II} = 3°$, $b^{II} = +11°$; and $l^{II} = 81°$, $b^{II} = +11°$ respectively. Each field covers 5 sq. deg. The principal results of this study, which was made by Dr B. Hidajat, are as follows:

(*a*) Photoelectric photometry on the *UBV* system for selected stars in each region, together with available data for nearby clusters, indicates the following run of interstellar absorption $A_v$, magnitudes:

| Field | Distance (pcs) 200 | 300 | 400 | 500 | Max. |
|---|---|---|---|---|---|
| 1 | 0·2 | 0·8 | 0·8 | 0·9 | 0·9 |
| 2 | 0·6 | 0·7 | 0·7 | 0·8 | 1·4 |
| 4 | 0·1 | 0·1 | 0·2 | 0·3 | 0·8 |

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The maximum values of $A_v$ refer to distances of the order of 1000–1500 parsecs. Beyond 1500 parsecs the values of $A_v$ were found to be sensibly constant.

(*b*) Space densities, *number of stars per* $10^6$ *cubic parsecs*, were derived as functions of distance, as follows:

| Field | | Distance (kpc) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | M2–4 | 3·8 | 1·4 | 0·7 | 0·4 | 0·3 |
| | M5–10 | — | — | — | — | — |
| 2 | M2–4 | 6·9 | 4·1 | 2·5 | 1·4 | 1·0 |
| | M5–10 | 0·5 | 0·5 | 0·4 | 0·3 | 0·2 |
| 4 | M2–4 | 2·3 | 3·0 | 2·0 | 1·3 | 0·6 |
| | M5–10 | 1·1 | 0·6 | 0·3 | 0·2 | 0·2 |

There appears to be an almost complete absence of late M stars in Field 1.

(*c*) The decrease in the numbers of giant M stars with distance from the galactic plane is marked. In Field 4, for example, stars of all classes (M2–M10) diminish from 3·8 stars per $10^6$ $pc^3$ at $z = 0{\cdot}3$ kpc to 0·9 at $z = 1{\cdot}0$ kpc. Similarly, stars of late type (M5–M10) decrease in density from 1·1 at $z = 0{\cdot}2$ kpc to 0·15 at $z = 1{\cdot}0$ kpc.

(*d*) In the galactic meridional plane defined by the Sun, the galactic center, and the galactic poles, the present study, in conjunction with similar studies by other investigators, indicates that the giant stars of the M5–M10 group are distributed symmetrically with respect to the plane of the Galaxy.

(*e*) There is some evidence, based upon the space densities obtained for the B8–A2 and the giant K stars in these three regions, of a correlation between the two groups. Furthermore, some evidence indicates that the A stars are located on the inner edges of the galactic spiral arms as delineated by the interstellar hydrogen. This possibility, along with a similar apparent correlation between the early (M2–M4) giant M star concentrations and the spiral structure, remains to be investigated further.

'The results of this study are being prepared for publication. The study was done under the supervision of Dr V. M. Blanco.'

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## IX. KINEMATICS

(prepared by G. Contopoulos)

This part of the Report is connected with Commissions 24 (proper motions), 30 (radial velocities) and 34 (kinematics of interstellar matter). Here, however, the kinematics of stars and interstellar matter is considered in connection with the problems of galactic structure and dynamics.

A number of articles in Vol. 5 of '*Stars and Stellar Systems*' are connected with this subject. Delhaye's (**1**) article on the 'Solar Motion and Velocity Distribution of Common Stars' gives a review of the determinations of the solar motion and the dependence of kinematic properties on spectral type and age.

Woolley's (**2**) discussion in 'Motions of the Nearby Stars' includes the galactic orbits of stars, the velocity ellipsoid, the connection between color-magnitude diagrams and orbital characteristics, the motions perpendicular to the galactic plane, and the kinematic properties of special groups of stars.

The 'Moving Groups of Stars' were discussed in detail by Eggen (**3**).

The motions of late-type giants, variable stars, planetary nebulae, high velocity stars, sub-luminous stars, blue stars at high galactic latitudes, globular clusters and interstellar gas in general and hydrogen in particular were considered by Blanco (**4**), Plaut (**5**), Minkowski (**6**), Roman (**7**), Greenstein (**8**), Luyten (**9**), Arp (**10**), Münch (**11**), and Kerr and Westerhout (**12**) respectively.

The relations between stellar kinematics and stellar populations were discussed by Blaauw (**13**).

A number of galactic kinematical problems were discussed by Bok (**14**).

Perek (**15**) published tables for the transformation of space velocities from the equatorial system to the new galactic system.

### *A. Stars*

*Solar Motion—Galactic Rotation*

New solutions for the solar motion with respect to the local group and other nearby galaxies have been given by Byrnes (**16**). Boulon (**17, 18**) found the influence of the $K$-term on the error of the determination of the solar motion. Petrie (**19**) determined the solar motion from radial velocities of nearby B stars. A program has been undertaken at Greenwich to find the solar motion with respect to old disk population stars.

Determinations of the constants of galactic motion were made by many authors.

Boulon (**18**) found the values $A = 17{\cdot}0 \pm 1{\cdot}7$, $K = +1{\cdot}2 \pm 3{\cdot}4$ from a study of ten galactic fields.

Howard and Kirk (**20**) discussed the variation of the parameters of galactic rotation with the distance scale, from a study of 144 cepheids and 39 galactic clusters; they adopted the values $R_0 = 11{\cdot}4$ kpc, $A = 13{\cdot}1$, $K = -3{\cdot}3$.

Fricke (**21**) found, on the basis of the FK4 proper motion system, the values $A = 12{\cdot}3 \pm 2{\cdot}4$, $B = -7{\cdot}8 \pm 2{\cdot}4$. Further work, including 500 stars at distances larger than 100 pc, is in progress. A similar analysis by Wayman (**22**) of the proper motions of 34 OB stars, taken from FK4, gave $B$ about equal to $-15$. An analysis of the radial motions of about 500 B-stars has been done by Petrie (**23**).

A very small value, $A = 7{\cdot}8 \pm 3{\cdot}4$, was found by Feast (**24**) for Me variables; he points out that this value is not basically out of line with $A = 15$, found for OB stars.

The $A$ constant derived from a study of B-stars, cepheids, galactic clusters and interstellar gas by Feast and Shuttleworth (**25**) is $A = 14{\cdot}3 \pm 0{\cdot}8$.

Rubin and Burley (**26**) found the values $A = 14{\cdot}5 \pm 1{\cdot}5$, $B = -9{\cdot}5 \pm 2{\cdot}5$, $K = -2 \pm 1$, from the study of O–B5 stars within 2 kpc from the Sun. The rotation curve for $R > R_0$ looks flatter than usually assumed. Barbier (**27**) found also, from a study of O, B and A stars in Cassiopeia, that, for large $R$, the velocity curve is above that of the new Schmidt model.

Radial velocities of early-type stars in the Perseus arm were studied by Abt and Bautz (**28**). A discrepancy between the stellar and the 21-cm rotation curve was explained by the fact that the velocities of spectroscopic binaries are systematically too large.

Radial velocities of early-type stars in the direction of the anticenter were determined by Rubin (**29**) and by Christy. Rubin found a rotation curve for $R > R_0$, which agrees with that given by Schmidt.

Bonneau (**30**) has found the relative velocity of the Perseus arm with respect to the Orion arm.

Münch and Münch (**31**) have found that the rotation curve of the inner parts of the galaxy derived from OB stars is below the corresponding 21-cm curve. However Feast, Shuttleworth and Thackeray (**25, 32**) found a better agreement between optical and radio velocity curves after correcting the stellar distances. In addition, they found a variation of the $K$-term with the distance of B-stars. Further work is being done on OB stars by Bonneau (**30**), Lyngå and Haug, and on cepheids by Feast.

A large $K$-term in southern B-stars was found by Thackeray (**33**). Mirzoyan and Kazarian (**34**) studied the $K$-term in the motions of OB-stars and cepheids; they found compatibility with Kerr's expansion.

A critical discussion of earlier determinations of the constant $A$ and the galactic scale was given by Stibbs (**35**).

Massonie (**36**) found a velocity of escape in the Galaxy of the order 340–345 km $s^{-1}$ and a rotational velocity $\Theta_0 = 256$ km $s^{-1}$.

*Velocity Distribution—Velocity Ellipsoid*

Eggen (**37**) has studied the kinematics of various groups of stars near the Sun. He has found a remarkable clumpiness in velocity distribution.

Van Wijk, Smith and Daniels (**38**) have computed the velocity distribution of low-velocity stars in the solar neighborhood assuming that the stars were formed with an isotropic, Maxwellian velocity distribution, followed by a dynamical mixing in the radial direction.

Perek (**39**) and Minkowski (**40**) have found a large dispersion of radial velocities of planetary nebulae close to the direction of the galactic center. Minkowski concluded that the motions of the planetaries are not circular. Feast (**24, 41**) explained this phenomenon by assuming that the planetaries cover a wide range of ages. In the case of Me variables he found that the velocity dispersion is remarkably constant over a large range of distances from the center (for a given period). An observed asymmetry of radial velocities indicates an excess of inward motions for $l > 0^\circ$ and of outward motions for $l < 0^\circ$. The velocity ellipsoid of Me variables was also studied.

Schlesinger (**42**) found that the velocity dispersion of metallic-line A-stars is similar to that of the normal A-stars.

The velocity ellipsoid of subdwarfs was investigated by Takayanagi (**43**).

Pavlovskaya (**44**) determined the velocity ellipsoids of stars of various spectral and luminosity classes.

Dahn (**45**) studied the velocity ellipsoid of carbon stars. Rudnicki (**46**) found that carbon stars far from the galactic plane have larger velocity dispersion.

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An increase of the velocity dispersion of main sequence stars with height above the galactic plane was found by Murray (**47**) from a study of proper motions of field stars near M 67. He suggested that most bright red stars and many stars of intermediate colors are distant halo stars. Similar results were found by Cannon for field stars near NGC 752.

The kinematics of Mira variables was studied by Smak and Preston (**48**). They derived values of $A$ ranging from 15 to 25.

Work on proper motions and radial velocities of RR Lyrae variables has been done by Woolley, Harding, Cassells, Saunders, Aly and Clube (**49, 50, 51**). This work continues with the aim of finding the orbital elements as functions of the metal abundances, period of the variables, etc. Further work is being done on semi-regular variables.

Van Herk (**52**) also made an extensive study of the motions of RR Lyrae variables.

A study of the motions of bright A and gK stars near the galactic equator has been made by Eelsalu and Jôeveer (**53**); in particular they determined the dispersion of velocities in the $z$-direction.

Shatsova (**54**) proposed a Planck law to describe the distribution of stellar velocities. A truncated Schwarzschild distribution of velocities was used by King (**55**), Bouvier (**56**) and others. Dzigvashvili (**57**) determined the parameters of the velocity ellipsoid and the rotation velocity according to Chandrasekhar's theory.

Motions of high velocity stars have been determined by Kennedy and Przybylski (**58**).

Vitrichenko, Gershberg and Metik (**59**) have studied the motions of 120 high-velocity OB stars; they found that probably all of them originated in groups of hot stars.

Blaauw is investigating the distribution and kinematics of intermediate age G and K giants in collaboration with the Leander McCormick Observatory.

The kinematics of the Gould belt has been studied by Bonneau (**30**) and by Blaauw (**60**). Blaauw found from a study of the velocity gradients of the stars in different directions that, about 40 million years ago, the prestellar gas probably occupied a small volume. This work continues, together with Lesh. Clube (**61**) found that streaming motions associated with the Gould belt may change appreciably the kinematics of nearby low velocity stars.

Mouchet (**62**) and Martinet (**63**) have found, from kinematic properties of peculiar A stars, indications that these stars are connected with the Gould Belt.

A few theoretical papers by Nahon (**64**) and Massonie (**65, 66**) deal with an application of the least squares method to the analysis of the radial velocities, the distribution of errors and the influence of selection on the determination of mean velocities.

*Kinematics, Age and Chemical Composition*

General articles on the connection between the kinematic properties of stars, age, and chemical composition were given by Delhaye (**1**), Cayrel and Kovalevsky (**67**) and Cayrel (**68**). Eggen (**69, 70**) studied the colors, luminosities and motions of more than 1000 nearby A and G stars; many of these stars belong to moving groups. He found that for stars of the same age the chemical composition may vary, but there is a rough correlation of age with metal abundance and with the space motions. The chemical composition and kinematics of disk high-velocity stars of the main sequence were considered by Strömgren (**71**).

A strong correlation between ultraviolet excess and space motion of high-velocity stars was found by Oosterhoff and Ponsen (**72**). Similar results were found by Kreiken and Yilmaz (**73**).

A study of the kinematics of planetary nebulae, carbon stars and RV Tauri stars in connection with population type was carried out by Iwanowska, Kanthak and Boenigk (**74, 75, 76**).

A correlation between age and velocity dispersion perpendiculary to the galactic plane was found by Dennis (**73a**).

Kinematic ages of stars were found by Schmidt-Kaler (77, 78) from the distribution of different groups in the spiral arms. Connections between the orbital characteristics of the nearby stars and their ages were found by Shimizu and Takahashi (79). An explanation of the age effect was based primarily on the variation of the force field.

## *B. Gas*

### *Galactic Rotation—Non Circular Motions*

A detailed discussion of the galactic rotation curve, based on radio observations, has been given by W. W. Shane and Bieger-Smith (80). If we assume the irregularities in the rotation curve to be due to lack of hydrogen then an improbable density contrast arises. A more plausible explanation is that there are irregularities in the large-scale motions associated with the spiral structure. Stream motions in the outer edges of the arms were suggested. Such motions were found by Burton (81) in the Sagittarius arm. The discrepancy between the northern and southern velocity curves, as given by Kerr (82), was verified.

Braes (83) tried to find the expansion motion suggested by Kerr, but reached a negative conclusion. The same conclusion was drawn by W. W. Shane (84). On the other hand, Locke, Galt and Costain (85) found evidence in favor of Kerr's hypothesis, from their study of the distribution of neutral hydrogen in the anticenter direction.

Pismis (86) suggested that the minima in the rotation curve are due to the existence of clouds with large radial and $z$-motions.

Dixon (87) found indications that the interstellar medium lags behind the gravitational circular velocity by 14 km s$^{-1}$, because of non-gravitational forces.

Agekyan, Petrovskaya and Fesenko (88) found a similar lag of 32 km s$^{-1}$. They derived a galactic rotation curve below the Dutch one. Non-circular motions in the outer spiral arms were considered by Pronik (89).

Detailed observations of the hydrogen velocity distribution at the anticenter have been done by Lindblad (90). Non-circular motions are apparent there.

The problem of the rotation curve has been discussed, along with other problems, by Kerr (91).

The smoothing of the 21-cm profiles has been discussed by Wilhelmsson and Winnberg (92).

### *Central Region*

The kinematics of the gas near the center of the Galaxy was described by Rougoor (93) and by Oort (94). There is a 'nuclear disk', inside 800 pc, rotating at about 200 km s$^{-1}$ and there is no evidence that it is expanding. The velocity decreases abruptly within 100 pc from the nucleus. Most of the gas in the nuclear region is expanding with high velocities. The properties of the gas near the center of the Galaxy were considered by Lequeux (95) and Kerr (96).

Expansion motions have been also found by observations of the OH radiation by Robinson *et al.* (97), Goldstein *et al.* (98) and Bolton *et al.* (99).

### *High-Velocity Clouds*

The evidence for the existence of many high velocity clouds approaching the galactic plane from both hemispheres has been increasing in recent years. Such evidence has been collected by Oort (100, 101, 102, 103) and other astronomers in the Netherlands, such as Blaauw, Tolbert, Muller, Raimond, Schwarz, Hulsbosch and W. W. Shane (104, 105, 106, 107, 108). Most of these clouds, with velocities above 100 km s$^{-1}$, come from longitudes between 60° and 200° (i.e. mostly between the direction of the anticenter and the direction of galactic

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rotation), and latitudes between + 10° and + 80°. The most probable explanation is that they are intergalactic in origin. Other possible explanations, e.g. that they are supernova shells, or remnants of a superexplosion, do not seem very probable.

The flux of the incoming high-velocity hydrogen is of the order of $10^{19}$ atoms $cm^{-2}$ per million years; this corresponds to an increase of the mass of the disk by $10^5$ $M_\odot$ per million years. Perhaps the high velocity clouds could replenish the hydrogen of the nuclear part of our Galaxy.

A different explanation for the high velocity clouds at latitudes below 25° was proposed by Habing (**109**), who considers them as belonging to an envelope of the Outer Arm.

Shklovski (**110**), based on a suggestion by Varshalovitch, advanced the hypothesis that these clouds radiate only when they approach the galactic plane, because of a maser effect due to the excitation by Lyman-alpha radiation of hot stars.

Dieter (**111, 112**) found many clouds with negative velocities of a few tens of km $s^{-1}$ near the galactic poles.

Smith (**113**) and Prata (**114**) found clouds with positive radial velocities of the order of 100 km $s^{-1}$, associated probably with the galactic structure.

A search for OB stars near one of the high-velocity clouds is being made by Svolopoulos.

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## X. DYNAMICS

(prepared by G. Contopoulos)

Oort's (**1**) chapter on Stellar Dynamics in *Stars and Stellar Systems*, Vol. 5, gives an account of the progress made in many traditional problems of Stellar Dynamics, emphasizing their relations to observation.

At the same time, a number of new developments in Stellar Dynamics should be noted.

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(*a*) An approach between Stellar Dynamics and Celestial Mechanics, as indicated by the IAU Symposium no. 25 in Thessaloniki (the Proceedings have been edited by Contopoulos (**2**)). The same trend was evident at the Besançon Colloquium in 1966 (*Bull. astr.*, Paris, 3ème série, **2**, fasc. 1, 1967).

(*b*) The use of experimental methods in Stellar Dynamics, with the help of fast electronic computers;

(*c*) The development of new statistical methods; in particular the use of methods developed in plasma physics;

(*d*) The development of new gravitational theories concerning the formation of galactic structure.

The Gas Dynamical Problems and the Magnetic Fields of our Galaxy have been discussed by Woltjer (**3**).

Three earlier review articles connected with Galactic Dynamics should be mentioned: the first, by King (**4**), refers to the Dynamics of Galaxies in general; the second, by Wentzel (**5**), refers to the Magnetic Fields and Spiral Structure; and the third article, by Contopoulos (**6**), deals with problems of Stellar Dynamics in general.

Other discussions of problems of Stellar Dynamics, and Galactic Dynamics in particular, were given by Oort (**7**), Prendergast (**8**) and Kuzmin (**9**). The connection between Stellar Dynamics and Celestial Mechanics was discussed by Kovalevsky (**10**).

A book on Stellar Dynamics by Ogorodnikov (**11**) appeared in English translation.

*Stellar Orbits—Third Integral*

Two review articles on the theory of orbits in the Galaxy have been written by Ollongren (**12, 13**).

Contopoulos and Strömgren (**14**) have calculated numerically tables of plane galactic orbits, with the aim of finding the places of formation of stars with ages of a few times $10^8$ years. Recent application to a sample of stars indicates that the stars of this age range originated either in the Orion or in the Perseus arm; one can even find the general areas where star formation has been most active.

The perturbations of the orbits, due to the spiral arms, have been considered by Barbanis and by Lin, and they were found to be small in general. An epicyclic theory for orbits in a spiral field has been developed by Woltjer and Barbanis.

Plane orbits in particular models of the Galaxy were studied by Woolley (**15**), Perek (**16**) and Genkin (**17**). Takayanagi (**18**) calculated plane orbits of subdwarfs. He found a concentration of perigalactic distances between 1·5–3·0 kpc; this indicates that the subdwarfs originated in the central bulge.

Orbits in special fields have been considered by Nahon (**19**) and Losco (**20**).

Three-dimensional orbits in particular galactic models were studied theoretically by Perek (**21**) and numerically, with limited accuracy, by Innanen (**22**).

Woolley (**23, 24**) continued his work on the galactic orbits of nearby stars and globular clusters.

The statistics and dynamics of the orbits of globular clusters in the Galaxy have been studied by Henry-Hillaire, and by Ogorodnikov (**25**). Matsunami (**26**) found correlations between various characteristics of the orbits of globular clusters and their physical properties.

Orbits of $n$ gravitating bodies have been calculated numerically by a number of authors such as Sherman and Kinman (**27**), Aarseth (**28**), Wielen (**29**) and Standish and Szebehely, in order to study the evolution of $n$-body systems.

The problem of the accuracy of the $n$-body problem calculations and the related problem of the reversibility in stellar dynamical systems was considered by Miller (**30**). Hayli (**31**) began $n$-body problem calculations taking into account also the external galactic field. Lindblad (**32**) continued his work on the evolution of a system of massive bodies (cloud complexes) in the galactic field. Van Albada (**33, 34**) and Worall (**35**) studied the evolution of many small stellar systems; they found that in most cases their final state is only a double star.

Collisionless orbit calculations were made by Aarseth (**36**) for $n = 1000$. Some insight into the $n$-body problem can be achieved by one-dimensional calculations, as done by Lecar (**37**) and by Hohl and Feix (**38**). One can investigate in this way whether or not there is a tendency to an equilibrium and the nature of this equilibrium, also the breaking up of the system into subsystems, etc.

Of interest are some calculations of the evolution of collapsing collisionless systems by Hénon (**39, 40**) and Campbell (**41**), by means of orbit calculations, as well as a few calculations of the acceleration of the rate of collisions at the center of very dense systems by Ulam and Walden (**42**).

A short discussion of the $n$-body problem from the numerical point of view has been given by Aarseth and Hoyle (**43**). An IAU Colloquium on the gravitational $n$-body problem is scheduled for the summer of 1967 in Paris.

Orbit calculations in connection with the existence of a 'third' integral of motion were made by many authors. Hénon and Heiles (**44**) have studied the intersections of many orbits by a surface of section in a simple dynamical problem of two degrees of freedom. They found indications for the existence of an isolating or very nearly isolating 'third' integral of motion for small energies, while for large energies the 'third' integral tends to become ergodic. Similar results were reported by Perek and Peterson and by Ollongren at the Thessaloniki 1964 Symposium. Hayli (**45**) and Aarseth (**46**) found similar results for high velocity orbits of our Galaxy, e.g. orbits of globular clusters, especially if these orbits pass through the central region of the Galaxy. It seems, however, that a third integral is nearly isolating when the velocities on a meridian plane do not exceed a few hundred km $s^{-1}$.

Barbanis (**47**) found empirically a third integral, which persists even when the energy exceeds the energy of escape, and which keeps some stars from escaping to infinity.

A classification of the integrals of motion into isolating, quasi-isolating and ergodic has been given by Contopoulos (**48**). The third integral in a non-smooth potential has been studied by Contopoulos and Woltjer (**49**). Other special cases of the third integral have been studied by Andrle (**50**).

Tables of the coefficients of the third integral in a special case have been prepared by Contopoulos (**51**). Contopoulos and Moutsoulas (**52, 53**) have studied the resonance cases and the effects of the small divisors in the third integral. The resonance effects were used by Contopoulos (**54**) to explain the tube orbits (i.e. elongated orbits near periodic orbits), that were found by Ollongren (**12, 13**) and others in our Galaxy.

Further work on the integrals of stellar motion has been done by Barbanis (**55**), Schmeidler (**56**), Kuzmin (**57**), Idlis (**58**), Ogorodnikov (**59**), Message (**60**), and Nahon (**61**). Gustavson (**62**) found a good agreement between a theoretical form of the third integral and the numerical results of Hénon and Heiles. A comparison of theoretical and experimental results was made also by Roels (**63**).

Hori and Liu (**64**) used a third integral in the theory of the velocity ellipsoid.

Recent developments in the theory of the third integral include numerical and theoretical results on the restricted three-body problem by Déprit, Hénon, Bozis and Contopoulos; the theories of satellite orbits around an oblate planet by Vinti, Conley, Kyner, etc., and many papers on non-linear mechanics with applications to various problems of mathematics, physics, chemistry, engineering and astronomy. In particular, the study of adiabatic invariants and experimental results in plasma physics and geophysics, as in the case of mirror machines and the van Allen belts, have much similarity with the astronomical problems mentioned above. No detailed reference will be made to these papers, however.

The theoretical problem of the existence of integral surfaces in non-integrable systems of two degrees of freedom has been solved by Arnol'd and by Moser. Arnol'd (**65**) has written a number of papers on this problem and related problems in recent years. Moser has proved recently that the motions near a periodic orbit or an equilibrium point are quasi-periodic for a set of initial conditions of positive measure. The corresponding expansions of the form of the third integral or the von Zeipel method are convergent. These theorems have been applied to various problems by Moser and Jefferys (**66, 67**). A similar theorem has been proved in a special case by Barrar (**68**).

These theorems, however, are proved only for a very small neighborhood of the periodic orbit or the equilibrium point. In order to study how far the third integral is applicable, numerical methods are necessary. Contopoulos (**69**) found that the breakdown of the third integral for large perturbations is due to a concentration of resonance regions; thus a numerical estimate of the breakdown perturbation can be found.

### *Models of the Galaxy*

A number of mass-models of the Galaxy have been proposed recently.

A simple formula for the force and potential on the plane of symmetry of the Galaxy has been used by Contopoulos and Strömgren (**14**).

Besides the well known new Schmidt (**70**) model, Innanen (**71**) constructed a number of galactic models, consisting of concentric spheroids, and studied their properties. Kuzmin and Kutuzov (**72, 73**) have also considered various models of the Galaxy. Genkin (**74, 75**) has studied models admitting an exact third entegral of motion. Further models have been constructed by Einasto and Kutuzov.

Self-gravitating models of galaxies, satisfying Liouville's and Poisson's equations have been given by Prendergast, Vandervoort (**76**), Aoki (**77**) and Perek (**78**). A self-gravitating model for a flat galaxy with a truncated Schwarzschild distribution of velocities has been given by Ng. Toomre (**106**), Hunter (**108**), and Barbanis and Prendergast have developed methods of finding the potential corresponding to a given density of a flat disk and vice-versa.

Wallace and Copeland (**79**) have studied the velocity field in a particular model of a spiral galaxy. The flux of the angular momentum in a spiral galaxy was considered by Starr and Newell (**80**). The distribution of mass and angular momentum in our Galaxy has been studied by Takase (**81**).

Hodge (**82**) found limits of the mass of our Galaxy between $1.5 \times 10^{11} M_{\odot}$ and $6 \times 10^{11} M_{\odot}$.

Data about the galactic field have been derived by King from a study of the boundaries of globular clusters.

Kreiken (**83**) proposed a set of galactic constants $R_0$, $\Theta_0$, $A$ and $B$, derived from his polytropic galactic model.

The force perpendicular to the galactic plane has been studied by Stothers and Tech (**84**) through the kinematics of OB stars. Dorchner, Gürtler and Schmidt (**85**) derived, from the magnitude of this force, the density of molecular hydrogen near the Sun; they found that 80% of the hydrogen is in molecular form.

Belton and Brandt (**86**) succeeded in reproducing the rotation curve of our Galaxy by assuming that it consists of a set of spheroidal homoeoids; they concluded that the distribution of the 'missing matter' is like halo population II objects. Various assumptions about the distribution of the 'missing matter' were discussed by Oort (**1, 7**).



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Woolley found, through a study of the $z$-velocities of faint Ao stars, that the total density in the solar neighborhood is smaller than the accepted value; thus the amount of 'missing matter' is less than previously assumed. Similar results were found by Einasto (**87**).

The mass of the galactic nucleus was estimated recently by Lequeux (**88**) to be of the order of $10^8 M_\odot$. Rougoor (**89**) estimated the mass of the neutral atomic hydrogen in the central disk to be $3 \times 10^6 M_\odot$.

### *Statistical Methods—Stability Problems*

Lynden-Bell (**90, 91**) has developed a new statistics, similar to the Fermi-Dirac statistics, to describe the properties of a collapsing galaxy. A numerical example presented by Hénon at the Besançon Colloquium shows partial agreement with this theory.

A statistical theory of the gravitational forces in a stellar field has been given by Camm (**92**).

A Monte-Carlo method to deal with encounters in the $n$-body problem, was developed by Hénon (**93, 94**). This method appears very promising for obtaining quickly results on the evolution of stellar systems.

Massonie (**95**) began the study of a markovian process that changes progressively the velocity distribution in a stellar system.

Plasma dynamics has initiated the development of new methods in stellar dynamics in recent years.

Prigogine and Severne (**96, 97**) have developed statistical mechanical methods to deal with the gravitational $n$-body problem. They introduced non-markovian equations to take account of the 'memory' of previous conditions. The $n$-body system does not tend to an equilibrium state, but its final evolution depends on the initial conditions.

Application of the methods of plasma physics to stellar systems has been made by Lebedev, Maksumov and Marochnik (**98, 99, 100**). In particular they considered the growth of instabilities on a time scale of a few times $10^8$ years. On the other hand Antonov has shown that a one-dimensional stellar system is stable.

A general discussion of cooperative phenomena in stellar dynamics has been made by Lynden-Bell (**101**). He discussed, among other subjects, a necessary and sufficient condition, due originally to Antonov (**102**), for the stability of a stellar gas. Further Lynden-Bell continued Antonov's discussion of the entropy in stellar systems.

Gravitational instability plays a role in the formation of galaxies, of large scale structures of galaxies, and of stars. Only work connected with the second problem will be mentioned here.

The influence of rotation on the gravitational instability of a cloud has been considered by Arny (**103**) and by Simon (**104**).

A number of authors have discussed the stability of a disk of stars or gas against axi-symmetric perturbations.

Toomre (**105**) found that a velocity dispersion is needed to stabilize the galactic disk. The minimum velocity dispersion required for stability near the Sun is between 20 and 35 km $s^{-1}$. Non linear effects and other generalizations were given by Graham (**107**). Hunter (**108**) has studied free modes of oscillation in the plane of infinitesimally thin disks with no velocity dispersion.

The effect of the $z$-dimension on the stability of a disk of finite thickness was studied by Sweet and McGregor (**109, 110**).

The stability of a rotating disk of gas has been considered by Goldreich and Lynden-Bell (**111**). Lynden-Bell (**112**) has studied the large-scale instabilities of Maclaurin spheroids during collapse.

Owaki (113) has studied the stability of an incompressible galactic nucleus under the influence of the galactic disk.

Ostriker (114) has studied the stability of self-gravitating rings and cylinders.

Non-axi-symmetric instabilities of a generally spiral form are mentioned below.

There is a series of papers in the *Astrophysical Journal* on rotating gaseous masses by Chandrasekhar, Lebovitz, Roberts, Hurley and Limber. These papers, however, are rather loosely connected with our problems.

## *Dynamics of Spiral Structure*

Lin (115, 116) has emphasized the fact that the magnetic field of the Galaxy is quite insufficient to explain the main spiral effects of our Galaxy. On the other hand the winding difficulty of differentially rotating spiral arms is well known. Thus Lin developed a spiral pattern theory, of the type proposed originally by B. Lindblad, assuming that the stars move freely through the spiral pattern, which is a density wave rotating like a rigid body. Lin and Shu (115, 116, 117, 118) have found the response of gas and stars to an imposed rotating spiral field. A possible spiral solution is found when the induced field is equal to the imposed one. This method gives preference to trailing arms.

The effect of a finite thickness of the Galaxy has been considered by Shu.

A similar theory, which includes also non-linear effects and boundary conditions, was developed by Kalnajs (119).

A paper by the late B. Lindblad (120) describes his own views on the circulation of matter in a spiral galaxy.

The angular velocity of the spiral pattern was determined to be about 20 km $s^{-1}$ $kpc^{-1}$ by Strömgren, who compared the present position of the Perseus arm with its position when stars with ages of a few times $10^8$ years were formed.

Julian and Toomre (121) have developed a local theory for the formation of trailing spiral structures in differentially rotating stellar disks due to concentrated perturbations. If the perturbation is permanent, e.g. a point mass, the mass of the resulting trailing arms can be larger, by an order of magnitude, than the perturbing mass. If, however, the forcing is temporary, then the resulting spiral response is also temporary.

Rehm (122) found, under various conditions, both trailing and leading spiral patterns.

The problem of a gaseous disk was considered in detail by Goldreich and Lynden-Bell (123, 124) who found trailing (sheared) instabilities. These instabilities are transient, but they are regenerated continuously. Similar views were developed by Toomre.

Reviews of spiral structure theories were given by Lynden-Bell (125) and Prendergast (126).

Spiral instabilities in special cases were considered by Buggish and Kahn (127) and by Helfer (128).

Contopoulos (129) found a new integral of motion in a disk spiral galaxy. Barbanis found numerical evidence from orbit calculations for the existence of such an integral in most cases of actual interest. Such an integral may be useful for the construction of spiral models of the Galaxy.

Some *n*-body problem calculations are connected with the formation or evolution of spiral structures. Such work has been done by Lindblad (32). Prendergast, as well as Contopoulos and Barbanis, are studying the evolution of a plane galaxy by calculating a very large number of orbits.

A theory of galactic structure based on the accretion of interstellar matter has been developed by Lyttleton and Bondi (130).

*Magnetic Fields—Dynamics of Central Region*

Lynden-Bell (**131, 132**) has found that a magnetic field can initiate spiral instabilities in a galaxy.

Freeman and Mestel (**133**) indicated the difficulties of constructing a model, in which magnetic forces maintain a differentially rotating spiral pattern.

Pacholczyk (**134**) and Stodolkiewicz (**135**) have studied the stability of the whole Galaxy and, in particular, spiral arms, taking into account both magnetic and gravitational effects.

Similar work for the spiral arms was done by R. Graham (**136**).

A theory of the formation of galactic spiral structure through the contraction of metagalactic gas possessing a magnetic field has been developed by Pikel'ner (**137**).

Fujimoto (**138**) proposed a mechanism to explain the expansion of the 3 kpc arm. He assumed that circular orbits are unstable in this region and an inflow of gas from the halo takes place there. The expansion is produced by a coupling of differential rotation and the magnetic field. Ôki, Fujimoto and Hitotuyanagi (**139**) have developed a theory combining gravitational and magnetic effects in the formation of spiral arms. In addition, Fujimoto (**140**) has considered the formation of dark lanes in a galaxy by non-circular motions of gas.

Setti (**141**) found indications that the gravitational field of a spiral arm stabilizes it when the magnetic field is helical.

Arguments for the existence of a helical field were given by Hornby (**142**). A model of a helical field with inclined windings has been considered by Stepien (**143**).

Greyber (**144**) supported the view that the magnetic field above the galactic plane is opposite in direction to that below.

An attempt to consider the dynamics of a galactic plasma by using an ellipsoidal distribution law of velocities was made by Pratap (**145**).

Sakakibara (**146**) has studied the diffusion of the cosmic rays due to the magnetic field of the Orion arm, which results in an anisotropy of the cosmic ray flux.

Various determinations of the magnetic field in our Galaxy have been reviewed critically by Woltjer (**3, 147**). The arguments for a strong field in the spiral arms, of the order of $3 \times 10^{-5}$ gauss, arise from observations of synchrotron radiation, and considerations about the Faraday rotation, the alignment of dust grains and the solar wind. Arguments for a weak field of a few times $10^{-6}$ gauss, are based on the absence of a measurable Zeeman effect and considerations about star formation. The field in the halo seems to be of the order of a few times $10^{-6}$ gauss.

A recent review of the situation was given by van de Hulst (**148**). Mathewson and Milne have found a spiral pattern by radio studies of the Faraday rotation. Brouw has determined the magnetic field in the galactic spurs. The magnetic field in filamentary structures was studied by Pronik, who confirmed previous conclusions by Shajn.

A number of papers on the magnetic fields of our Galaxy by Jacklyn, Gardner, Whiteoak, Piddington, and Visvanathan were presented at the Mount-Stromlo 'Pre-Symposium' on 'Radio and Optical Studies of the Galaxy', in May 1966.

In some cases the field may be very strong, of the order of $10^{-3}$ gauss; such indications were found by Davies, de Jager and Verschuur (**149**) by studying the polarization of OH sources.

The magnetic field near the center of the Galaxy was estimated by Downes and Maxwell (**150**) to be between $5 \times 10^{-5}$ and $5 \times 10^{-4}$ gauss.

It is not clear how magnetic effects could explain the expansion motions near the center of the Galaxy.

An explanation based on an explosion of the galactic nucleus was proposed by G. Burbidge and Hoyle (151), Lequeux (152), and Ishida (153). Further support of this view was provided at the IAU Symposium no. 31, in Noordwijk.

Pikel'ner (154) suggested that the energy needed for the activity of the central region comes from the gravitational contraction of gas clouds.

The phenomena occurring during stellar collisions at the center of the Galaxy have been considered by Spitzer and Saslaw (155).

Lequeux (152) and Ginzburg and Syrovatskii (156) suggested that most of the cosmic rays come from the explosion of the galactic nucleus. This subject has also been studied by Rosen (157).

### *Miscellaneous Problems*

Mestel (158) has studied the evolution of a rotating spherical cloud into a thin disk. Depending upon the initial density distribution the final result is a spiral or a barred spiral. Lin, Mestel and Shu (159) have studied the collapse of a uniform spheroid. Crzedrielski (160) has considered the fragmentation of a galaxy during collapse. Milder (161) has considered the flattening of a rotating isothermal model.

A virial theorem for a continuous distribution of mass has been given by Camm (162).

King (163) has given a relation between velocity distributions and spatial gradients in a stellar system. He found the ratio of the axes of the velocity ellipsoid from moment equations.

The problem of the deviation of the vertex has been considered by Genkin (164). Kuzmin (165) has considered the conditions for the existence of a plane of symmetry in stellar systems.

Kitamura (166) has studied the effect of the encounters on a stellar velocity spheroid; in a time of the order of the time of relaxation, the velocity dispersions become appreciably smaller and approach each other.

Lynden-Bell (167) has considered the problem of the bending of the galactic plane. He attributed it to a 1° deviation between the galactic axis of symmetry and its angular momentum.

The same effect was attributed to the action of the Magellanic Clouds by Avner (168).

Toomre and Hunter have studied this problem from the point of view of the stability of a disk towards bending. Some bending modes are excited by the Magellanic Clouds.

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B. J. BOK
*President of the Commission*

## APPENDIX. REPORT OF THE COMMITTEE OF 'SELECTED AREAS'

CHAIRMAN: Dr T. Elvius, Astronomiska Observatoriet, Uppsala, Sweden.
MEMBERS: Kharadze, McCuskey, Plaut.

### *Introductory notes*

This committee serves in continuation of the previous Commission 32 and Sub-commission 33c (*Trans. IAU*, **11B**, 333, 1962). For a list of reports prior to those in *Trans. IAU*, **11A**, 389, 1962, and **12A**, 548, 1965, see *Trans. IAU*, **11A**, 397, 1962.

In the fifth volume of the series 'Stars and Stellar Systems' is an appendix by A. Blaauw and T. Elvius (**1**) giving a brief summary of Kapteyn's Plan of Selected Areas with a table of the centres of the areas of his Systematic Plan. In the following these areas are referred to as SA.

At the Hamburg meeting of IAU it was decided that this committee should deal also with plans for co-operative galactic research supplementing the Kapteyn Plan (*Trans. IAU*, **12B**, 317, 1966). In order to avoid waste of space, most reports on such work, e.g. on the results of work in the Parenago Plan (**52**) or on the Cleveland fields, cf. (**53**) are included only in the main report of Commission 33.

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*Progress of research*

1. *Durchmusterung and maps*

H. Vehrenberg has edited an Atlas (**2**), covering the Harvard-Groningen fields of SA 1–206, with pg-magnitudes of star sequences indicated.

2. *Photometry*

*Abastumani* (*Mt Kanobili*). E. K. Kharadze reports on catalogues which have been published for regions in Parenago's Plan (**52**). E. K. Kharadze, S. P. Apriamashvili and T. A. Kotchlashvili (**3**) give pv-magnitudes for about 1000 stars in Parenago field III (in Cygnus), identical with SA 40. S. P. Apriamashvili (**4**) publishes pg-magnitudes and CI for nearly 1900 stars in Parenago field I (in Aquila and Scutum) which includes SA 110. N. P. Kalandadze's catalogue (**5**) for Parenago field IV (in Taurus), which includes SA 49 and touches SA 50, contains photographic *UBV* data for about 3600 stars. Another group of papers has just been printed: S. P. Apriamashvili and V. I. Kutznetsov give pg- and pv-magnitudes for a region within Parenago field I (in Aquila) at SA 87 (**6**). A catalogue of magnitudes and colours in the *UBV* system for stars in Parenago field III (Taurus) is published in two parts by N. B. Kalandadze (**7**); two selected areas are in this region. A paper by A. D. Chuadze (**8**) gives pg-magnitudes for stars in one of the Parenago fields. Several of the Abastumani papers include spectral data, cf. Section 6.

*Basel.* Work on three-colour photometry in the *RGU*-system and partly also in the *UBV*-system has continued in SA 51, 54, 57, 71, 82, 94, 107, 133, 141, and 158. It is aimed at a limiting magnitude of 19, but for some fields photoelectric standards are available only to 16 or 17. For SA 51 and 57 the results are ready, cf. (**48**).

*Berkeley.* King is determining *B*, *V*, and *R* magnitudes in SA 51, 57, and 68, down to the limit of the 120-inch Lick reflector. The faint photometry is based on unpublished *P* and *V* photoelectric scales by Baum.

*Cape.* Among the 5000 stars included in the catalogue of photoelectric magnitudes and colours of southern stars by A. W. J. Cousins and R. H. Stoy (**9**), there is a considerable number of stars in Kapteyn's SA.

*Cracow and Crimea.* E. Rybka (Cracow) reports that the catalogue of photoelectric magnitudes and colours for photometric standard stars in Selected Areas 1–139 has now been published (**10**). It is the result of cooperative efforts between S. V. Nekrasova and V. B. Nikonov of the Crimean Astrophysical Observatory and himself. The observations and methods have been previously described (**54**). The catalogue contains magnitudes and colours, both in the natural *ubv* and in the *UBV* systems, for two 6 magnitudes stars in each area, of A and K spectral type respectively. In cooperation with Abastumani Observatory it is planned to extend the scheme to include three A and K type pairs of $V = 7{\cdot}5$, 9·0 and 10·5 in each of SA 1–43. Rybka mentions the desirability of extending his plan also to the remaining southern Selected Areas.

*Engelhardt* (*Kazan*). L. Urasin reports on the programme mentioned in the previous report. For SA 24–27 the photographic material has been obtained; its relation to the *UBV* system is described in (**11**). For SA 25 a catalogue of magnitudes and colours of 4700 stars has been published (**12**).

*Haute-Provence* (*Saint Michel*) and *Lyon.* J. H. Bigay reports on the previously announced investigation of O, B, and A0 stars in galactic areas, where photoelectric *UBV* measurements are made. Results have been published for SA 8 (**13, 14**) and previously for SA 9, 19, and 24 (**55**). For SA 40, 49, 64, and 110 the observations are finished and ready for publication. For preliminary reports on SA 40 and 64, cf. (**15, 16**). Observations are going on in SA 74 and 98. For SA 55–58, close to the north galactic pole, a similar programme for about 200 A stars is nearly ready. These investigations are performed in collaboration with Mme M. Lunel.

A programme for narrow-band photometry in nine regions from $\lambda$ 3600–5000 Å for determination of Strömgren parameters and hydrogen line intensities has been initiated. Photoelectric measurements have been finished for SA 40, 64, 87, and 110, are on way for SA 9, 19, 24, and 49, and are planned for SA 8, 74, and 98.

A. Terzan has published a photometric study of the central condensation of the Galaxy, for which SA 57 was used as standard field (**17**). From plates taken at the Haute-Provence Observatory magnitudes in blue, red, and infrared have been derived for about 300 stars in SA 57, down to the limit 19·3 (pg). Terzan has published a catalogue (**18**) giving blue, red and infrared magnitudes for 2600 stars in the above-mentioned region including SA 157.

*Kiev.* V. I. Voroshilov reports from the Golossejev Central Astronomical Observatory of the Ukrainian Academy of Sciences on continued investigations into the Parenago fields. Voroshilov has published a catalogue (**19**) of pv-magnitudes for an area centered at $\alpha = 19^h$, $\delta = +11°$ within the Parenago field I, previously treated (**56**). G. L. Fedorchenko has published pg- and pv-magnitudes (**20**) for stars in the region of SA 87 also within Parenago's field I, cf. (**57**). Three-colour photometry will be undertaken for eight regions from Aquila to Cygnus and at the anticentre (including SA 19, 64, and 87) for an investigation in cooperation with Abastumani Observatory, which takes care of the spectral determinations.

*Lund.* C. Roslund reports on a photometric investigation in cooperation with K. Särg of a part of SA 195, based on plates taken with the Uppsala Schmidt telescope on Mt Stromlo in ultraviolet, blue and yellow light (limiting magnitude 15·2 in $V$). They take advantage of G. Lyngå's photoelectric sequence Sq III in SA 195 (**21**) derived from Mt Stromlo and Bingar observations.

*Mt Palomar* (*Pasadena*). H. M. Johnson has taken multicolour plates of SA 132 in connection with a search for the optical identification of the brightest X-ray source in Scorpius.

*Mt Stromlo* (*Canberra*). B. J. Bok has, in collaboration with Mrs J. Basinsky, completed the photometric work in SA 141, situated at the south galactic pole (**22**). Photographic $V$ and $B-V$ are given for over 1400 stars, and photoelectric $V$ and $B-V$ for 26 standard stars. Observations have been made for SA 161, 169, and 205. B. Westerlund has published an infrared survey of the region of SA 193 (**23**) giving $I$-magnitudes and $R-I$ colours for about 300 stars.

*Radcliffe* (*Pretoria*). A. D. Thackeray reports that photoelectric $UBV$ photometry is being carried out in SA 162 by P. J. Andrews to $V = 16$.

*Stockholm* (*Saltsjöbaden*). K. Lodén reports on the programme based on material from the Boyden Observatory (*Trans. IAU*, **11A**, 392, 1962) that for SA 193 photographically determined $B$ and $V$ magnitudes are ready for publication (limiting magnitude: $B = 13·0$; number of stars 447; size of area 1·0 sq. deg.). Photoelectric $UBV$ measures for 21 stars serve as standards. For SA 192 the photometric results are nearly completed.

*Sternberg* (*Moskva*). For a 45 square degrees field centered on $\alpha = 0^h\, 30^m$, and $\delta = +62°$, which includes SA 8, E. S. Brodskaya and N. B. Grigorieva (**22a**) have published a catalogue, with maps, giving, for nearly 2700 stars brighter than magnitude 12, photographically determined $V$ and $B-V$, together with spectral types.

*Tartu.* In connection with an investigation of eclipsing variables H. Albo has derived a photometric sequence in SA 18 (**24**).

*Toulouse.* R. Bouigue reports on a spectral and photometric investigation for determination of accurate stellar distances in selected regions. Observations have been performed in $5° \times 5°$ fields at the north galactic pole (with SA 57) and the galactic anticentre direction (including

SA 49). For *UBV* and narrow-band photometry (λ 3525, 3864, 4250, and 4990; band-width 70–90 Å) the same equipment with a Lallemand photomultiplier was used at the Toulouse, Haute-Provence, and Pic du Midi observatories (**25**). The programme is enlarged to include the direction and antidirection of galactic rotation (close to SA 40 and 172 respectively).

*Tübingen*. U. Haug reports on the photoelectric *UBV* measurements made in South Africa for SA 96, 100, 108, and 112. Results have been published (**26**) for 201 stars in these fields together with 120 stars of the southern *UBV*-system, including the Harvard E-regions; for E 1, 6 and 7 the catalogue gives data for several stars. Some of these stars have also been measured from the northern hemisphere: in SA 100 by Haug at Kitt Peak, Arizona, and in SA 112 by K. Walter at Serra La Nave, Sicily.

*Uppsala*. For SA 8–19, T. Elvius and L. Häggkvist have published photoelectric measurements of 73 relatively bright stars (**27**). For supplementing previous research (**58**) T. Elvius has derived photographic *U*-magnitudes for the region of SA 19 from plates taken with the Kvistaberg Schmidt telescope. Y. Ekedahl has concentrated his photometric work on SA 4. It should also be mentioned that SA 8 and 19 are covered by the Uppsala Milky Way Survey, Part III, by T. Oja (**28**), who also gives a useful survey of photoelectric data for the investigated galactic strip.

T. Elvius and G. Lyngå have published *UBV* photometry for 43 stars in SA 68, 92, 138, 164, 165, 188, 200, 201, 204, 205, and 206, measured at the Bingar Station of the Mt Stromlo Observatory (**29**). This programme has been continued by Lyngå and C. Roslund at the Siding Spring Observatory. They have also carried on observations with the Uppsala Schmidt on Mt Stromlo for areas at southern latitudes. From plates taken with the same telescope P. I. Eriksson has practically completed photographic determination of blue and yellow magnitudes for nearly 10 000 stars in a 30 sq. deg. field at the south galactic pole, which includes SA 141.

*Vatican* (*Castel Gandolfo*). M. F. McCarthy and P. J. Treanor have in collaboration with A. R. Upgren (now at van Vleck Observatory) begun a programme for studying stellar densities at intermediate latitudes by spectral and photometric observations within SA 28, 54, 106, and 107, cf. Section 6. Photometric plates have been taken with the 40 cm refractor. Cf. (**59**).

*Warner and Swasey* (*Cleveland*). S. W. McCuskey has published an investigation of a 25 sq. deg. area centered on SA 158 (**30**). For nearly 1700 stars pg-magnitudes are given and for 275 of them also colours, approximately in the $B-V$ system. The plates were taken at the Bosscha Observatory, Lembang. The investigation published by D. Philip of a region (HLF2) in Pegasus includes the field of SA 90 (**31**). The catalogue gives photographically determined blue magnitudes; for standardization a special *UBV* sequence was observed at the Kitt Peak and McDonald observatories. For further information on the Cleveland fields in low, intermediate and high latitudes reference is made to the main report of Commission 33.

*Washington*. From the Naval Observatory has been published a catalogue by D. L. Harris III and A. R. Upgren (**32**) which gives photoelectric magnitudes and colours in the *UBV* system for 280 BD-stars in a region at the north galactic pole which is identical with SA 57. The observations were made at the McDonald Observatory. V. M. Blanco reports that J. Priser has at the Flagstaff Station completed a photoelectric survey of 111 stars in even numbered SA of the 0° + 30° and + 60° declination zones (**33**).

Miss N. Roman, now with NASA, reports on her photoelectric work in a number of SA. The *UBV* observations are now reduced for nearly 800 stars in 40 areas. Generally, all proper-motion reference stars are included in the areas where observations have been made.

3. *Variable stars*

***Hamburg-Bergedorf***. The series of catalogues of variables in the southern part of the Cygnus

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cloud by A. A. Wachmann (**34**) include several stars in SA 64. Wachmann has also published catalogues of variables in the region of SA 98 in Monoceros (**35**).

*Harvard* (*Cambridge, Mass.*). Miss M. Olmsted reports that she has obtained photographic and photored light curves for nine cepheids in SA 193 (**35a**). She is engaged in a search for more faint cepheids in the same area, using plates taken with the Baker-Schmidt telescope of the Boyden Observatory.

*Haute-Provence* (*Saint Michel*) *and Lyon*. Terzan has published identification charts for new variable stars at the central condensation of the galaxy (**36, 37**); the field includes SA 157, cf. (**18**).

*Lick* (*Mt Hamilton*). T. D. Kinman, C. A. Wirtanen and K. A. Janes have in the course of the RR Lyrae star survey with the 20-inch (51 cm) astrograph published results for three fields near the north galactic pole (**38**); field RR 4 coincides with SA 57 whereas fields RR 2 and 3 are between this and SA 56. For SA 57 a couple of faint stars have been added to the photoelectric sequence by J. Stebbins, A. E. Whitford and H. L. Johnson (**60**). Kinman reports that the extended RR Lyrae programme will include SA 61; a survey of variables of longer period will include SA 27 and 28.

4. *Proper motions and positions*

*Bonn*. H. van Schewick reports the intention to measure relative proper motions for the northern SA which remain after the publication of data for 18 galactic fields, cf. *Trans. IAU*, **12A,** 550, 1965. SA 72, 95, and 115 have already been measured and relative proper motions have been derived. For SA 40 two more pairs of plates were measured in connection with an investigation of the galactic cluster An. Barkh. I (**39**). Similarly the proper motions of SA 98 have been used for a study of NGC 2301 (**40**). The results of the determination of the solar apex from high-velocity stars, mentioned in the last report, will soon be published. van Schewick has prepared a list of proper motions for variable stars, including several SA objects.

*Greenwich* (*Herstmonceux*). The possibility of improving the proper motions in SA is considered by C. A. Murray. The old Radcliffe Catalogue (**61**) should be used as 'first epoch' and be combined with plates taken with the 26-inch (66 cm) Greenwich refractor in addition to those obtained with the Radcliffe telescope at London Observatory, cf. *Trans. IAU*, **12A,** 551, 1965. The first area to be investigated is SA 57 at the north galactic pole.

5. *Radial velocities*

*David Dunlap* (*Richmond Hill*). J. F. Heard has published radial velocities and spectral classes of 55 fundamental stars in the high-latitude areas SA 13–15, 29–35, and 53–60 (**41**).

*Haute-Provence* (*Saint-Michel*) and *Marseille*. The following information has been obtained from Ch. Fehrenbach, in addition to the report in *Trans. IAU*, **12A,** 551, 1965.

Concerning work with the smaller objective prism (PPO):

(*a*) Results have been published for SA 9, 21, 29, 30, 46, 67, 69, 75, 90, 91, 94, and 113 by Ch. Fehrenbach, M. Duflot, J. Boulon, E. Rebeirot, and C. Lanoë (**42**).

(*b*) Results are close to publication for SA 41 and 43.

(*c*) Measurements are going on for SA 3, 4, 13, 22, 23, 35, 37, 39, 61, 62, 66, 68, 81, 85–88, 98, and 114.

Concerning work with the larger prism (GPO):

(*d*) Results are ready for publication for SA 15 and SA 19, northern part.

(*e*) Measurements are on way for SA 9, 11, 13, 36, 40, 41, 53, 58, 59, 61, 64 centre, 64 north, 81, and 110.

Measurements have been published during the years for altogether 1432 stars, of which 736 belong to types O, B, and A, and 696 to types F, G, K, and M.

Observations have also been made of a certain number of regions within the Parenago fields; results have been published for an area in field IV (**42** p. 185).

*Radcliffe* (*Pretoria*). A. D. Thackeray reports that slit spectroscopy will be undertaken by T. Lloyd Evans for stars down to $V$ about 12 in SA 141 at the south galactic pole.

6. *Spectral and luminosity classification; absolute magnitudes*

*Abastumani* (*Mt Kanobili*). Spectral types and luminosity classes are given in the catalogues mentioned above in Section 2, for stars in Parenago fields, including some SA (**3–8**). Investigations are going on for a number of regions in Taurus and Aquila. Two-dimensional spectral classification is planned for a series of areas uniformly distributed in the equatorial plane from Aquila to Cygnus and at the anticentre for which the photometric work will be undertaken by the Golossejevo Observatory at Kiev, cf. Section 2.

*David Dunlap* (*Richmond Hill*). Spectral classification in the MK system is included in the paper (**41**), cf. Section 5.

*Engelhardt* (*Kazan*). The previously reported spectrophotometric investigation of SA in the + 45° declination zone is continued, cf. Section 2.

*Haute-Provence* (*Saint-Michel*) and *Marseille*. In continuation of (**62**) Mme M. Barbier has published two lists of M, S, and C stars in several fields, among them Kapteyn areas in the declination zones + 75°, + 45°, + 30°, + 15° and 0° (**43**). She has also determined absolute magnitudes for 200 O, B, and A stars in SA 8 by spectrophotometric measurements of objective prism plates (**44**).

The catalogues referred to above in Section 5 as (**42**) include spectral and luminosity classification for a considerable number of SA stars. Here should also be mentioned the paper by Mme N. Martin (**45**) on the determination of absolute magnitudes by 'Öhman's method' (**63, 64**). Her catalogue for the Carina field includes stars in SA 193, whereas SA 18 is just outside the Cepheus field.

*Kiev*. Spectral classes have now been published by Voroshilov (**46**) for 3500 stars in two of the sub-regions in Aquila within Parenago field I, for which photometry has been reported (**19** and **56**). Cf. also I. I. Pronik's catalogues from the Crimean Astrophysical Observatory (**65**). Spectral classes are also included in Fedorchenko's catalogue for stars in the same Parenago field (**20**), mentioned in Section 2.

*Radcliffe* (*Pretoria*). MK classification will be included in the programme for SA 141 reported in Section 5. There are also plans for spectroscopy of stars within other southern SA in the R.A. range from $20^h$ to $2^h$.

*Sternberg* (*Moskva*). Spectral types have been published for a field including SA 8; cf. Section 2.

*Stockholm* (*Saltsjöbaden*). Spectrophotometrically derived spectral types and luminosity classes are included in the investigation of SA 193 just terminated by K. Lodén, mentioned in Section 2.

*Toulouse*. Spectrophotometric measurements from objective-prism plates are planned for the fields mentioned in Section 2 for determination of absolute magnitudes from equivalent widths of hydrogen lines.

*Uppsala*. For the Stockholm and Uppsala SA programmes reported in *Trans. IAU*, **11A**, 394 and 395, 1962, additional plates have been taken with the Uppsala Schmidt telescope on Mt Stromlo by Roslund and Lyngå. Eriksson's spectral measurements for the region of SA 141 are now ready. Oja's catalogue (**28**) mentioned in Section 2 includes data for stars in SA 8 and 19.

*Van Vleck (Middletown, Conn.)* and *Vatican*. A. R. Upgren has in collaboration with McCarthy and Treanor of the Vatican Observatory, cf. Section 2, outlined an observational programme to determine the inclination of plane-parallel layers of stellar density to the galactic plane. The regions chosen are SA 28, 54, 106, and 107. Spectral plates have been taken with the 24-inch (61 cm) Baker-Schmidt telescope of the Dyer Observatory, Nashville, and also, for smaller dispersion, with the Schmidt telescope of the Vatican Observatory.

*Warner and Swasey (Cleveland)*. Spectral types and luminosity classes have been published for SA 158 stars by McCuskey (**30**), and for stars in SA 90 by Philip (**31**).

7. *Polarization*

*Göttingen*. Stars in SA 40 and 97 are included in a polarimetric, photometric and spectroscopic investigation of stars in Cygnus and Orion by I. Appenzeller (**47**).

8. *Investigations based on the material of Selected Areas*

Several of the papers referred to above in the SA report and in the main report of Commission 33 contain investigations of galactic structure based on SA material.

Of special interest for the future is an investigation by W. Becker aiming at derivation of star densities in the galactic halo by means of three-colour photometry. The SA included in the observational programme were mentioned in *Trans. IAU*, **12A**, 548, 1965. A first paper treating SA 51 has been published (**48**), cf. also (**66**).

In (**44**) Mme Barbier investigates the absorption, the stellar distribution and the galactic rotation in the Cassiopeia field SA 8.

Here should also be mentioned the extensive study of stellar distribution near the south galactic pole (**22**) by B. J. Bok and J. Basinski. It is based on photometric measurements in SA 141. The density decrease with $z$ is derived for A and F type stars, thereby supplementing the discussion by T. Elvius (**49**) in his summarizing paper on the distribution of common stars in intermediate and high galactic latitudes, for which data from Selected Areas are fundamental. In this paper Elvius presents some not previously published results derived from the third Stockholm SA catalogue (**67**).

Studies of the distribution of stars and interstellar matter, based on data from the Kapteyn and Parenago fields, have been published by L. N. Kolesnik (**50**) for the Cygnus field SA 40 = Parenago region II), and by Fedorchenko for the Parenago region I in Aquila (**20, 51**).

## *Desiderata for future work*

Several members of the Commission 33 have expressed their view that the Selected Area Committee should once more emphasize the need for more observational data in the SA and similar fields in accordance with the Desiderata of the previous report, *Trans. IAU*, **12A**, 553, 1965.

Especially has been stressed the importance of having, for kinematical studies, more and better proper motions and radial velocities of faint SA stars. The value of such work would be increased if photoelectric data could be obtained for as many as possible of these stars.

It is obviously difficult in many cases to get a satisfactory survey of the existing data. The desire has therefore been expressed that for each individual area summaries should be prepared, facilitating the exploitation of existing material and also the planning for supplementary data.

T. ELVIUS
*Chairman of the Committee*

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