## III. LOCAL GALACTIC STRUCTURE

### A. *General surveys*

Surveys by optical and radio techniques of stars, interstellar gas and dust, surface brightness of the Milky Way and other local features of the Galaxy form the contents of this Section. Overall structural properties, such as spiral structure in the large, will be considered in Section IV. Consider first the optical surveys.

An important contribution is the catalogue *Luminous Stars in the Southern Milky Way* [Stephenson and Sanduleak (06.041.023)]. The surface stellar distribution of OB stars clearly shows the well known concentrations in the southern Milky Way, particularly in the Carina complex.

Two catalogues by the Steward Observatory group under the direction of B. J. Bok should be valuable for studies of the southern Milky Way. *The Catalogue of Nebulae in Carina* by Mrs. Alice Hine-Ferguson (1971) is a valuable reference catalogue for both radio and optical studies in $282° < l < 302°$. Smith (1972) is extending the work into the section $302° < l < 335°$.

A search technique employing a transmission grating for detecting faint OB stars has been described by Graham and Miller (1972). They have used it to search for faint ($B \sim 15$ mag) OB stars in the southern Milky Way and the Large Magellanic Cloud. This new technique excels the multicolor *UBV* search approach.

The investigations by 3-color photometry of several fields in the Milky Way are continuing at Basel by W. Becker and his colleagues. Observational data mostly in the *RGU* system but some in *UBV* system are obtained with the 48-in. Palomar Schmidt-telescope and with the Asiago telescope. Small fields with a limiting magnitude between 17 and 18 are being observed near NGC 2360, 7062, 7067, 7235, 7510, 7654 and h and $\chi$ Per. Larger fields are under investigation in Scutum (M11) and near NGC 2168 (M35). In these the limiting magnitude is about 15. There is a special program dealing with fields in the direction of the galactic center.

At the Stockhom and Uppsala Observatories the large scale survey of the southern Milky Way begun in 1955 is still in progress the principal purpose being to provide observational data on O to B9 stars and those of late K and M together with emission line objects and other conspicuous phenomena. L. O. Lodén (02.114.089) has described the observational techniques employed, as have Nordstrom and Sundman (1972). Catalogues are in preparation.

The distribution of A stars over the sky has been studied by Kevanishvili (03.155.003) with data for some 55000 stars from the *Henry Draper Catalogue* and a Monte Carlo techique. The distribution of B8-A3 stars near the galactic plane has been studied in considerable detail by McCuskey and Houk (06.155.040) for the region $50° < l < 150°$, $|b| < 5°$. Lyngå reports that Stenholm at the Lund Observatory is making a search for Wolf-Rayet stars in the southern Milky Way between $l = 240°$ and 360°. Extension to other galactic longitudes is planned. This data will be used to study the distribution of the WR stars in the Galaxy. Crampton (06.114.015) has catalogued those WR stars which seem to be coincident with H II regions. Renson (05.155.038; 07.155.005) has compared the surface distribution of Ap and Am stars over the sky with corresponding distributions for normal late B and early A stars and finds that the distributions are similar.

A thorough discussion of the intrinsic properties and the galactic distributions of the gM, C and S type stars has been published by Mavridis (05.155.030). Multicolor photometry of high-luminosity M stars having $V \leqslant 9$ mag in $l = 0°$ to 240° has led Lee (04.113.038) to conclude that the galactic distribution of M supergiants is similar to that of the O and B stars. Velghe and Sanders at Uccle have underway a study of objective prism spectra in the infrared and yellow-red for the establishment of standards for classification of M stars and for a study of the distributions of M-type giant and dwarf stars in different sections of the southern Milky Way. Albers (1972) finds the distribution of supergiant M stars in the southern Milky Way to be patchy, the majority falling outside the known OB star groups.

The distances and galactic distribution of planetary nebulae have been studied by Cahn and Kaler (05.133.017). The distribution of 600 nebulae on the galactic plane shows a concentration near the Sun and another at about 3 kpc from the galactic center toward the Sun.

Statistical population indices have continued to be of interest at Torún. Iwanowska (1972) has determined population indices for M dwarf stars and for planetary nebulae. Her earlier study of giant M stars has now been published (Iwanowska 04.155.042). Basinska and Iwanowska have found that for a simple stationary galactic model the abundance of the heavy elements relatively to hydrogen could increase toward the galactic plane, through the process of gravitational diffusion, by an order of magnitude during a period of $10^{10}$ yr. Iwaniszewska (04.122.169) has completed her study of the statistical population indices of RR Lyr stars.

Applications of infrared observational techniques to problems of galactic structure increase rapidly. Hoffman *et al.* (1971) have surveyed 750 sq deg of the galactic belt from $l = 335°$ through 0° to 88° at an effective $\lambda = 100\ \mu$ and have detected 72 sources, 60 of which were identified with continuum radio sources, bright nebulae, dark nebulae and infrared stars. These results follow a previous study of the galactic center region by the same authors (05.141.061). Hall (1972) has tabulated data for 383 objects reported in the literature as having infrared emission in the 8–14 $\mu$ range. Their distribution over the sky appears to be random but the number per unit area indicates a concentration toward the galactic plane.

Sharov (02.155.021) has calculated the flux at $\lambda = 9750$ Å and hence the infrared brightness of the Milky Way for 19 fields and finds that the maximum brightness occurs at about $l = 10°$. Pfleiderer and Mayer (06.113.025) have presented isophote maps in $U$ of the $UBV$ system for the galactic belt $-50° < b < +50°$ except for the northern region in Cep-Per-Cyg and Classen *et al.* (07.113.030) have found that maxima in $U - V$ color are particularly noticeable in Ophiuchus and in the region of the galactic center with a minimum in the region of Gould's belt. At the present time Miss Classen is reducing the pe photometry in $B$ for the southern Milky Way. Recently Roach *et al.* (07.155.036) have found that the observed diffuse galactic brightness peaks at $b \sim -5°$, and is asymmetrically distributed about $b = 0°$. Peters (03.155.016) has studied the correlation between fluctuations in brightness of the Milky Way and interstellar clouds.

The polarization of southern OB stars has been the subject of extensive research by Klare *et al.* (05.131.013), based on their recent catalogue [Klare *et al.* (07.131.011)]. They present a map showing the polarization vectors for $230° < l < 10°$ through $l = 0°$, and $-10° < b < +10°$. Serkowski and Robertson (02.131.095) have made $UBV$ polarimetric observations for 38 southern stars with large polarization and have continued the work into the northern sky.

Important contributions to the local galactic structure are being made by radio observational techniques. In the radio continuum, probably the most prominent local features are the well-known loops and spurs which run from the galactic ridge to high latitudes. There are no optical counterparts, and the features have been variously interpreted as geometrical effects of the local magnetic field on the apparent distribution of synchrotron emission or as nearby supernova remnants of large size.

The distribution of linear polarization in the North Polar Spur has been studied in detail by Spoelstra (05.157.009; 07.157.003), by Berkhuijsen (06.157.002), and by Holden (02.157.004). The polarization at 1415 MHz is as high as 65% in some regions, and in some sections the magnetic field is perpendicular to the ridges observed in the continuum radiation. Low-velocity neutral hydrogen on the outer gradients of the continuum features of the North Polar Spur [Berkhuijsen *et al.* (03.157.004); Verschuur (04.131.033)], and a correlation between H I and Loop IV [Fejes (06.157.005)] lend new support to the supernova remnant theory of the origin of these features. This conclusion is reached by Berkhuijsen *et al.* (06.155.009) and Haslam *et al.* (05.157.006), who have carefully examined the observational evidence of all kinds.

The high-velocity hydrogen clouds will be discussed in Section V. An extensive survey of the intermediate-velocity hydrogen ($30 < |V| < 70$ km s$^{-1}$) has been published by Tolbert (06.157.003). The Groningen group have pointed out that this gas appears predominantly in a large region where the low-velocity gas is deficient, and they suggest that some of the low-velocity gas has been pushed, probably by an extragalactic agent, to increase its velocity. Verschuur (05.131.083) has proposed a model in which a supernova in its late 'snowplow' phase of evolution has increased the momentum of the intermediate-velocity matter.

New methods of investigating the structure and kinematics of the Gould belt are now available through the radio lines from the OH and $H_2CO$ molecules closely associated with the local dust clouds which are so prominent in that region. The evidence seems to point to an expanding ring or shell of gas in the solar vicinity with its main plane in the plane defined by the bright *B* stars, inclined about 15° to the plane of the Galaxy. The expansion age is about $7 \times 10^7$ yr [see Section V B].

There have been many studies of interstellar clouds. The two-component model by Hjellming *et al.* (01.131.055) and by Field *et al.* (01.131.039) has been the basis of this work. The medium is found to consist of cold clouds with a mean column density $3 \times 10^{20}$ atom cm$^{-2}$ and spin temperature 60–80 K, embedded in a hot diffuse intercloud medium of column density $1{\cdot}4 \times 10^{20}$ cosec $|b|$ atom cm$^{-2}$ and spin temperature $> 750$ K. In the solar neighborhood the gas is divided about equally between the two phases. Two-component models have also been derived by Hughes and Routledge (04.131.113) and by Rohlfs (05.131.055). The procedure used by the latter has been criticized by Burton (07.131.012).

The association of gas and dust in the Galaxy has been discussed by Menon (1971), Rohlfs (05.131.099), Wesselius and Sancisi (05.131.016), and Knapp (1972). It is clear that there is a partial correlation between H I and dust, but this is incomplete in regions of high absorption. Rohlfs examined the hypothesis that the dust is associated with just the cold gas. Kerr and Knapp (1972), using globular clusters as background objects for comparing column densities through the galactic disk, found a ratio of H I to dust of $2 \times 10^{21}$ cm$^{-2}$ mag$^{-1}$ and an OH-to-dust ratio of less than $5 \times 10^{13}$ cm$^{-2}$ mag$^{-1}$.

Several investigations have provided new evidence on the galactic magnetic field in the solar neighborhood. From the difficult observations of the Zeeman splitting of 21-cm absorption lines, Verschuur (05.131.078) has found a strong field (30 $\mu$G) in the direction of M17, and Brooks *et al.* (05.114.071) have confirmed his value of 50 $\mu$G in the direction of Ori A. Considerably lower values were found in some other directions. For the geometry of the field distribution, Gardner *et al.* (02.141.184) explain their Faraday rotation data for 355 extragalactic radio sources in terms of a field along the local spiral arm, deformed by magnetic 'loops' in the solar neighborhood. Fujimoto *et al.* (1971) interpret rolling motions along the local spiral arm which, they derive from 21-cm surveys, in terms of a helical magnetic field. All the observational aspects of galactic magnetic fields have been reviewed by Verschuur (04.156.002).

### B. *Regional investigations – low galactic latitude*

This part of our Report summarizes by sections of galactic longitude some of the detailed studies of galactic structure near the galactic plane (in general $|b| < 20°$). Many of the radio line and continuum surveys noted in Section II A of our Report cover these parts of the Galaxy. In addition there are numerous studies of individual sources which are discussed in the Commission 40 report.

#### 1. *The galactic center* ($350° < l < 10°$)

A photometric study by van den Bergh (06.113.050) of a region centered on NGC 6522 yields a distance of $9{\cdot}4 \pm 2{\cdot}0$ kpc for the distance from the Sun to the galactic center. Plaut (06.120.010) has catalogued the variable stars in Field 3 of the Palomar-Groningen survey ($l = 0°$, $b = -10°$) and has determined the space density functions for RR Lyr and long-period variable stars (04.122.020). Indications of a distance to the galactic center considerably less than 10 kpc result.

At the Stockholm Observatory K. Lodén is studying the distribution of B9-A0 stars brighter than $V \sim 12.5$ in a region $348° < l < 10°$, $|b| < 4°$. Wramdemark and Ardeberg at Lund are studying by *UBV* photometry the interstellar absorption and stellar space density at $l = 352°$, $b = +2°$.

Radio surveys in this region have been made by Simonson and Sancisi (1972), Robinson *et al.* (03.131.123), Beard *et al.* (02.157.013) and Sinclair and Kerr (06.157.008). Riegel and Crutcher (07.155.025) have followed the whole extent of an elongated H I self-absorbing cloud which appears in $l = 345°$ to 25°, $|b| \leqslant 6°$. Crutcher (1972) has also looked for OH in two positions in this cloud and found two components which agree in velocity with the two H I self-absorption components.

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2. *Sct-Aql-Vul* ($10° < l < 60°$)

Kuznetsov (1968) has summarized the results of many studies at the Abastumani Observatory for $l = 10°$ to 54° for the A stars and the interstellar matter. High stellar space density and high density of interstellar matter appear to coexist. Grigoréva (02.155.010) has reanalyzed the space distribution of early type stars in this part of the galactic plane.

Schubarth (04.113.025) finds the Scutum cloud as defined by main sequence stars to be at $r = 0{\cdot}6 - 1{\cdot}2$ kpc from the Sun. A search by Sturch and colleagues at the University of Rochester for halo-type population stars in Scutum is underway. An extensive investigation of interstellar reddening in Ophiuchus by Schalén (07.155.078) and a photometric study by Ardeberg and Wramdemark (04.113.067) should be mentioned.

Radio observations by Sancisi and van Woerden (03.152.013) have revealed an elongated filamentary nearby H I feature in Scorpius and Ophiuchus. Shane (06.157.001 and .006; 07.155.002) finds by observation of the H I distribution that the Scutum spiral feature appears to be a transition region between the strong radial motions of the inner few kpc and the density-wave velocity field. Density-wave streaming effects were clearly observed for the first time by Burton (04.157.004) in a cross-sectional study of the Sagittarius spiral feature.

3. *Cyg-Cep-Cas-Per* ($60° < l < 150°$)

Useful photometric data in this galactic longitude range have been provided by Haug (03.113.023), Jasevicius (04.113.008), van den Bergh (05.113.018), Bern and Virdefors (07.113.026), and Ardeberg and Sarg (04.113.068).

In a paper already mentioned Grigoréva (02.155.010) has summarized the spatial distribution of early *B* stars and of the B8-A0 stars in five regions ($80° < l < 136°$). Similar studies by Kolesnik (04.155.031) and Kuznetsov (06.114.027 and .028; 1972a, b) have been made. The B8-A0 stars in a region at $l = 133°$, $b = -1°$ (Stock 2) are being studied by Pesch and McCuskey to determine the reality of an elongated space concentration. Bern and Karlsson find at $l = 135°$, $b = 0°$ a maximum in stellar space density at $r = 300$ pc, about 100 pc in depth. They are now investigating some 15 regions in $80° < l < 195°$. At $l = 103°$, $b = 0°$ in Cepheus Kubinec (1973) finds an OB star maximum at $r = 3.4$ kpc from the Sun which may be the location of the Perseus spiral complex at this longitude. Martin (07.155.023) has observed spectral types and other data for a field in Cassiopeia at $l = 117°$, $b = 0°$ and finds a peak density of OB stars at $r = 2{\cdot}5$ kpc. The O–B2 stars have radial velocities which agree well with those of the H I gas.

Mrs. Dickel and colleagues are mapping the interstellar absorption around the Cygnus X complex [Dickel *et al.* (03.155.036)] by a comparison of Hα isophotes and corresponding 11-cm brightness temperature contours [Wendker (03.142.031)]. A simulated radio 'photograph' of the Cygnus X region has been produced by Winzer and Roberts (05.157.011). McCutcheon and Shuter (04.157.005) conclude that this complex is associated with the Orion arm.

Investigations of the space distribution of cool stars, principally M-giant stars, by spectral classification in the near infrared have been made by Poulakos (06.155.044) at $l = 120°$, $b = -2°{\cdot}7$, by Tsioumis at $l = 115°$, $b = -5°{\cdot}4$, and by Nandy and Smriglio (03.113.058) at $l = 88°$, $b = 0°$. All of these indicate space density maxima for M2-M4 stars at about 2·5 kpc from the Sun. A survey by Ackermann (02.113.065; 04.113.016) in regions at $l = 78°$ and 95° for extremely red stars indicates a high concentration of such stars toward the galactic plane. Ackermann's work is now being extended to $37° < l < 71°$ by Akyol and Hidajat.

4. *Galactic anticenter* ($150° < l < 210°$)

The distribution of gas and interstellar dust in the region $150° < l < 175°$, $-25° < b < -5°$ (Per O–B2) has been found by B. T. Lynds to form a cloud at 200–300 pc from the Sun. In the core of Per O–B2 Rydgren (06.113.043) finds $A_v = 1{\cdot}4$ mag at maximum between $r = 100$ and 200 pc.

Kalandadze (03.155.005) has found in three fields in $173° < l < 181°$, $-19° < b < 0°$ evidence for a concentration of hot early type stars at $r = 1{\cdot}5$ kpc from the Sun, and some lesser indication for a

second concentration at 2·5 kpc. In another investigation Kalandadze *et al.* (06.155.016) at $l = 187°$, $b = +0°.1$ obtained an increase in $A_v$ of 3 mag between $r = 0·5$ and 5 kpc from the Sun. From these results and the data provided by Bartaya and Kharadze (03.152.003 and .004), and by Metrevili (03.113.005) in the general range $120° < l < 173°$ there appears to be definite evidence for an extension of the Perseus spiral complex through the anticenter region. This conclusion is reinforced by the work of Martin (02.155.012) who finds at $r = 1·5$–3 kpc a population of O9-B2 stars in $185° < l < 190°$. A finding list for 63 faint blue stars, possibly OB, in this region has been published by Rubin and Losee (06.113.051). No evidence, however, for such an extension of the Perseus arm to $l = 203°$, $b = +2°$ is found by Karlsson (1972). He finds that the O-B2 stars decrease monotonically with distance to $r = 3$ kpc. Karlsson has also studied the spatial distribution of the common stars.

Nandy and Smiriglio (06.114.073) have obtained spectral types in the near infrared and I mag for M and C stars to a limiting mag $V = 15$ at $l = 185°$, $b = -0°.8$. While there is some indication of a space density maximum of M stars and of the interstellar absorption at 2·5 kpc the uncertainty is great. The authors prefer a mean density of 0·9 stars per $10^5$ pc$^3$ over the distance range 1·5–3 kpc from the Sun.

From an atlas of 1253 H I profiles in the galactic anticenter region Velden (04.155.040 and .041) has found a relative motion of 3·3 km s$^{-1}$ for the more remote gas. After correction for this outward motion the kinematic distance of the main hydrogen concentration from the galactic center shows an increase with increasing galactic longitude. Garzoli and Varsavsky (03.157.015) have compared the H I column density and the optical absorption by dust in the Taurus region ($l = 172°$, $b = -14°$). Gordon (04.157.006) has made a detailed comparison between the 21-cm emission and the optical data on Barnard's ring and the Orion nebula.

### 5. *Pup-Vel-Car-Cru ($210° < l < 300°$)*

This section of the Milky Way embraces the Carina spiral complex and hence has been under intensive study during the triennium under review. In addition to the data mentioned in Sections II and III A we note the useful calibration sequences published by Lodén (01.113.020 and .021) and by Seggewiss (06.113.035).

Photometric observations of OB stars primarily for use as spiral arm tracers have been made by Graham (06.113.049) at $l = 218°$, $b = -0°.5$; by Havlen (07.155.024) for all OB stars in the Tonantzintla surveys between $l = 240°$ and 250°; by Lyngå (01.115.008) at $290° < l < 311°$; and by Velghe (unpublished) at $263° < l < 273°$.

In $283° < l < 332°$ Lyngå (04.155.004) finds from a study of 1477 OB stars an asymmetry in distribution with respect to the galactic plane. There are more stars with $b < 0°$ than with $b > 0°$. A similar study by Graham (03.155.044) of the OB stars in $282° < l < 292°$ also indicates a bending of the OB star distribution below the galactic plane at distances $r > 4$ kpc. The distribution of the very distant stars is similar to that of the H I gas. The OB star population has a sharp boundary at $l = 284°$, there being very few stars with $l < 284°$. Velghe reports, however, that his recent observations of OB stars in Vela indicate a spiral feature containing the Vela OB 1 association stretching from the Sun toward $l \sim 270°$. He also indicates that Denoyelle (03.155.046) is making an intensive study of the OB stars in $257° < l < 285°$.

The conclusions about the Carina spiral complex deduced by Bok and his colleagues are summarized in Section IV A of our Report. Miller's (07.113.016) study of five fields in $275° < l < 300°$ is now being extended to the region $295° < l < 335°$. Recent pe observations confirm the existence of the association in Vela at $l = 275°$, $b = -1°.9$ found by Miller; he now has evidence for a second OB star group in Carina at $l = 289°.5$, $b = -0°.3$ which appears to be at $r > 8$ kpc behind 4–5 mag of absorption. If the great distances of these groups are proven correct, they may provide optical features of importance in relating the radio and optical aspects of the Carina spiral complex.

Studies of the stellar population in this section of the southern Milky Way are also being made by FitzGerald and colleagues at the University of Waterloo, Canada for five regions near the galactic plane. Two fields have been completed [Wilson and FitzGerald (1972); Stegman and FitzGerald

(1972)]; the first is in Puppis ($l = 245°$, $b = -0°.2$), the second in Vela ($l = 269°$, $b = -0°.3$). Lodén and Sundman (1972) have extensive data and an analysis of colors and spectral types for this section of the Milky Way. Wramdemark and Lyngå are investigating areas at $l = 280°$, 289° and 298° across the Carina complex. Wooden (1971) has published a detailed analysis of the galactic structure in LF 13 ($l = 281°$, $b = +3°.9$) and similar studies for LF 12 and LF 14 are underway at the Warner and Swasey Observatory.

The space distributions of M-stars in regions LF 13, 14, 15 ($l = 281°$, 298°, 330°) and in two new regions $l = 276°$, $b = -1°.6$ and $l = 286°$, $b = -1°.4$ are being analyzed by P. S. The and colleagues at Amsterdam.

Garzoli (04.155.003) has identified many discrete H I concentrations and has studied their connections by means of a detailed 21-cm survey in Carina ($l = 270° - 310°$; $-3° \leq b \leq +2°$). Goss and Radhakrishnan (02.132.020) have derived distances to two prominent H II regions NGC 3576 and 3603. The latter is at a distance of about 8.4 kpc, making it one of the most distant optically visible H II regions in the Galaxy and quite similar to W 49 intrinsically. A area in Vela containing the two intense H II regions RCW 36 and 38 has been mapped by Manchester and Goss (02.157.014). Manchester *et al.* (04.131.116) have surveyed this section of the Milky Way for OH sources; Thomas and Day (02.157.010) have mapped it at 11-cm in the radio continuum. The $H_2CO$ and OH absorption features have been mapped by Dickel and Wall (07.132.010). The observed velocity structure implies an expanding H I shell which surrounds the H II region and contains the molecules and dust.

6. *Cen-Cir-Nor-Sco ($300° < l < 350°$)*

Three elongated H I features have been found in this region by de Rocha Vieira (05.155.017). They appear to be parallel to the galactic plane and about 200 pc above it; they may be associated with the spiral arms in the plane. Other radio surveys in the region have been made by Goss *et al.* (04.131.047) and Robinson *et al.* (06.131.069) for OH; by Johnston *et al.* (06.131.003) for 1·35-cm water sources; by Day *et al.* (02.157.011) and Thomas and Day (02.157.012) in the 11-cm continuum.

Searches for high-luminosity objects which will help in clarifying the possible spiral structure in this region have been made by Schnur (03.155.018), by Drilling (1972), by Westerlund (02.125.003 and .004); by Velghe and Verbeiren at Uccle, and by Cordwell-McCarthy and Miller at the Steward Observatory. While Schnur finds no concentration of OB stars ($M_v \leq -2·5$) at $l = 332°$, $b = -2°.3$ in the Sagittarius arm, Drilling's analysis indicates one at nearly the same position ($l = 332°$, $b = -1°.1$), and also Nor OB 1 at 2.3 kpc from the Sun at $l = 328°$, $b = -0°.9$. The former grouping is near the supernova remnant RCW 103 investigated by Westerlund. In this field Westerlund finds a second grouping of OB stars at 1·8 kpc, which together with the first at $r = 3·9$ kpc appears in Drilling's analysis as an elongated ridge of OB stars. Cordwell-McCarthy and Miller have found recently, by a multi-color search at $l = 307°$, $b = +1°.3$, 19 faint OB stars which do not appear to be a prominent part of a spiral feature. The region covered by Velghe and Verbeiren and by Oyen at Uccle is $l = 316° - 328°$; Velghe *et al.* (04.155.006) also have searched two regions ($l = 303° - -308°$ and $l = 334° - 339°$) for Hα emission objects and find no definitive clusterings.

Studies of this section of the Milky Way by Haug, by Ardeberg and by L. O. Lodén and colleagues are also underway.

### C. *High latitude optical studies*

A large part of the observational work at high and intermediate latitudes has been centered on Kapteyn's Selected Areas (SA) and on the Cleveland (now Albany) Fields. Previously work within the SA was reported in a special Selected Area appendix. In the present Report this will not be the case. After some years it may, however, be useful to sum up in a special SA report the observational material collected.

When kinematical data are combined with stellar densities obtained as a function of $z$ in order to derive the run of the $z$-force component and the total density of matter close to the galactic plane, the results at present are often confusing. It appears highly desirable to try to obtain a truly three-dimensional picture of the structure and the dynamics in a wide region around the Sun as suggested

by the Tartu astronomers, Einasto and Kuzmin (04.155.021); Eelsalu (03.155.063), among others. It might be useful to arrange a conference for planning this.

The $z$-distributions of various spectral classes have been studied by Borzov (04.155.029; 06.155.043); the first paper gives references to several previously published Soviet investigations perpendicular to the galactic plane.

Previously reported observational programs at Lund and Uppsala are directed toward obtaining a 3-dimensional distribution of stars and interstellar matter [see Contopoulos and Elvius (03.155.160 and .068)]. For the Lund program a considerable amount of pe data has been obtained by Karlsson using the Mount Stromlo and Siding Spring facilities, and by Ardeberg working at ESO in Chile (to the previous list SA 164 and 205 have been added). Ardeberg has supplemented the sequence star program by polarimetric uvby measurements and by slit spectroscopy. Oja reports concerning the extensive Uppsala program for the NGP cap that pe data have been obtained for 600 stars at Uppsala, and for 2000 stars by Häggkvist at Flagstaff; emphasis has been on late-type giants and stars earlier than A3 (usually brighter than 11·5). Häggkvist also measured sequences to mag 16 in SA 4, 32, 55, 58, 60 and 81. Narrow-band photometry for studies of the $z$-distribution of late-type stars has been made in connection with Oja's program. Results based on Uppsala observations were published by Häggkvist and Oja (03.113.025). A catalogue covering all late-type stars in the sky brighter than $V = 6{\cdot}05$ will soon be published. A new high latitude program has been initiated at Lund; pe sequence data in four regions at $b = +60°$ have been obtained by Ardeberg *et al.* (1972). An extension by *pg UBV* photometry and low-dispersion spectra is planned. Spectrographic and photometric measurements of galactic stars in the directions of the Magellanic Clouds, reported by Ardeberg *et al* (07.159.022) and by Ardeberg and Maurice are of interest for studies of the galactic structure far below the galactic plane.

Becker and his colleagues have continued three-color photometry at high and intermediate latitudes [see Becker and Fenkart (03.155.041)]. Concentration is on the galactic halo, the NGP direction (SA 57) being treated by Becker (04.155.013). General surveys with comparisons between northern and southern directions have been published by Becker (04.155.032; 07.155.081). Stellar space densities in SA 71, $l = 167°$, $b = -34°8$, are discussed by Fenkart and Wagner (07.155.060). Becker reports that the high latitude work based on Palomar Schmidt plates is continuing in the relevant SA and in fields centered on M5, M13, and NGC 4147. From plates for SA 51, 54, 57 and 82, a search is being made for white objects; several hundred, partly diffuse ones, have been found.

At the ESO conference on the role of Schmidt telescopes in astronomy, A. G. D. Philip (1972a) gave a survey of the work performed or planned in high latitude regions in the Albany program. The average interstellar extinction is negligible in both galactic polar directions [Philip (1972b)]. Philip (1972a) also gives space density analyses for faint early-type stars which indicate that they are halo Population II stars and are observed to more than 2 kpc in $z$. These objects are probably horizontal-branch stars with large velocity dispersion, [Philip (03.112.003 and .008)]; they are of special interest for studies of the $z$-force law. Such stars are also treated by Philip and Tifft (06.113.007). Finding lists for high latitude fields have been published by Philip and Drilling (04.114.127 and .128) and by Philip and Relyea (06.114.023). UBV photometry and a density analysis in fields at $l = 0°$ and 180°; $b = -45°$ were performed by Drilling (06.113.048). Philip and Stock (1972) have investigated an extended region at the SGP for early-type stars; Stock reports that other programs based on material from Cerro Tololo, in search of stars of special types, will include high latitude areas. Drilling and Pesch have recently completed *uvby* and H$\beta$ photometry for stars earlier than A7 in $l = 179°$, $b = -47°$ for a study of the population mixture. A similar study is planned for a region at $l = 359°$, $b = -43°$. More recently Drilling has completed observation of the stars of spectral type later than A7 in areas at $l = 0°$ and 180° and $b = -45°$. The *pe* mag and color data (*UBV*) for some 62 stars will provide calibration for more extensive photometry and an analysis of space densities in these areas.

A finding list for early-type stars at the SGP has been published by Slettebak and Brundage (05.114.072). Peculiar stars from this list have been observed spectroscopically and by *uvby* photometry by Graham and Slettebak, who report that many of the O and B stars seem to be sub-dwarfs,

and the A and F stars horizontal-branch stars. T. L. Evans (04.155.027) has demonstrated that analyses of high latitude A stars from kinematic data are affected by the presence of previously unrecognized horizontal-branch stars. In papers of considerable interest Rodgers (05.114.058; 07.114.066) has discussed the nature of the halo A stars.

Upgren has continued his research on late-type giant stars at intermediate and high latitudes; a finding list for late-type objects was published by Upgren and Staron (03.155.052). Upgren also reports that Titter, analyzing this and previous material, has found for the late-type giants lower space densities at small $z$, and higher at high $z$, compared to Upgren's earlier findings. It is further reported that Dessureau has used Titter's results to determine in what degree the space density of giant stars can be represented by the sum of a number of Gaussian distributions. His solutions suggest the existence of four kinematically homogeneous groups of late-type giants: two groups associated with the young disk population, one with the older disk population, and one with an intermediate or halo population.

Sturch and Helfer (05.113.036) have published *UBVRI* photometry for some stars for which Upgren could not obtain luminosities. They are probably giants, belonging to the halo population. On the other hand Sturch and Sharpless (1972) have observed some of Upgren's faint G5-G7 stars at the NGP and find that a majority may be dwarfs. This is reinforced by the results obtained by McClure and Crawford (05.155.013) whose intermediate band photometry of 207 K stars from Upgren's list revealed that many denoted as giants were actually dwarfs. Recently Sturch and Helfer have concluded that the frequency of extremely metal deficient halo giants among the normal giants with $B < 13$ mag is about 2%.

Schreur (06.155.049) from a newly developed system of photographic *uvby* photometry in SA 56 and SA 27 has found that he could separate the stars into four groups: halo giants and dwarfs, disk giants and dwarfs. Schreur (03.131.012) has also determined the interstellar absorption in the intermediate latitude ($b = -21°$) direction of SA 47. Evans (04.114.002) has presented observational data for K giant stars in SA 141 (at the SGP). He finds them to be evolved from F dwarfs. Evans reports that in collaboration with D. Crampton he has studied radial velocities of M giants in the SGP cap, finding a higher velocity dispersion than previously. Eggen (05.113.011) has found by *UBVRI* photometry of M stars near the SGP that the young disk stars reach a ceiling at 400 pc from the galactic plane, the old disk stars at $z = 900$ pc, and that the halo objects are distributed up to 1200 pc.

Weistrop (07.155.070) has examined the stellar population at the NGP by *UBV* photometry of several thousand stars with $12 < V < 18$. Assuming appropriate models for the luminosity and space density functions, and that all stars with $(B-V)_0 \leqslant 0{\cdot}5$ mag and $V > 17$ are Population II objects she finds an upper limit of $7 \times 10^{-5}\ M_\odot$ per pc$^3$ for the local Population II density. The proposed model for the disk population indicates 5 to 10 times as many red dwarf stars as previously thought. This is in accord with the finding of Murray and Sanduleak (07.112.013) and of Pesch (1972) who, from spectroscopic detection techniques and kinematic considerations, have concluded that most of the faint M stars observed in the NGP cap are dwarfs near the galactic plane in large numbers. These may contribute substantially to the stellar mass density in the solar neighborhood, possibly being responsible for a part of the 'missing mass', required to explain the $z$-force according to Oort's classical analysis. Pik Sin Thé reports that he is studying, in collaboration with van Paradijs, the luminosity function of M dwarfs in the SGP direction.

An interesting development is the extension by Hughes (1972) of the 1938 Oort method for obtaining equidensity surfaces for the stellar distribution at intermediate and high latitudes [see Section II D].

Haug and Walter (03.113.022) have published *pe UBV* photometry for the intermediate latitude areas SA 100 and 112; Iriarte (03.113.050) has observed by pe photometry faint blue stars in the NGP and SGP regions; a search for faint blue stars at the NGP was made by Bronkalla (06.113.013), and Priser (1972) reports that he is about to publish *UBV* sequences with charts for 24 SA in the 0° and +30° zones, covering magnitudes 6–17. High and intermediate SA are included in a pe *UBV* program undertaken by members of the Greenwich Observatory staff. Finally it may be added

that Urasin is making steady progress in the previously reported investigations at the Engelhardt Observatory, Kazan, including SA at intermediate and high latitudes.

A few radial velocity measurements for stars in the SA should be mentioned. Griffin (06.112.011) has published pe determined radial velocities for more than 500 stars in the $+15°$ SA-zone, including some high and intermediate areas. Bond *et al.* (06.112.014) have given radial velocities and spectral classifications for A-type stars near the SGP. It may also be mentioned that Berger *et al.* (06.112.004) propose that a *B* star in the NGP cap with high radial velocity and at a distance of about 5 kpc in $z$ may be ejected from disk to halo. Ardeberg's above mentioned spectrographic observations in the southern SA also include radial velocity determinations.

Haug reports that Schroeder of the Hamburg Observatory has made polarization measures at ESO for about 500 stars in the SGP cap ($b < -45°$). The data permit not only a discussion of the increase of polarization with distance from the Sun, but also a study of the differences in different directions. Ardeberg, also at ESO, has made polarization measurements for about 40 bright stars in SA 165, 188, and 205.

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## IV. OVERALL STRUCTURE OF THE GALAXY

Sections II and III of this report have dealt with details of the galactic structure within reach of