33. STRUCTURE AND DYNAMICS OF THE GALACTIC SYSTEM (STRUCTURE ET DYNAMIQUE DU SYSTÈME GALACTIQUE)

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1. INTRODUCTION

As usual, this report contains contributions from a number of authors, as follows: § 2, P. D. Jackson and M. P. FitzGerald; §§ 3 and 4, F. J. Kerr and D. L. Crawford; § 5, P. O. Lindblad; §§ 6A and C, R. Wielen; §§ 6B and 7, J. Einasto; §§ 6D and E, K. C. Freeman, § 6F, M Fujimoto. The layout follows previous practice, except that a new Section 7 on the galactic environment has been added. A longer version of the Report will be published by the University of Maryland and will be distributed to all members of Commission 33 and to astronomical institutions.

During the triennium under review, proceedings have been published of meetings on "HII regions and related topics" (18.012.026), "HII regions and the galactic center" (18.012.031), "Galactic and extragalactic radio astronomy" (18.012.049), "The Galaxy and the Local Group" (19.012.018), "The structure and content of the Galaxy and galactic gamma rays" (20.012.009), and "The large-scale characteristics of the Galaxy" (*IAU Symposium* 84, in press). The introductory paper and concluding summaries at Symposium 84 give an excellent picture of the current problems in galactic astronomy.

The *Annual Review of Astronomy and Astrophysics* published survey articles on the interstellar magnetic field (Heiles, vol. 14), the morphology of hydrogen and of other tracers in the Galaxy (Burton, 14), the radio continuum morphology of spiral galaxies (van der Kruit and Allen, 14), theories of spiral structure (Toomre, 15), the galactic center (Oort, 15), and the kinematics of spiral and irregular galaxies (van der Kruit and Allen, 16).

2. BASIC DATA AND CALIBRATION PROBLEMS

A. *Basic Data*

The increase in numbers and quality of astronomical instruments in the world has resulted in a tremendous flow of new basic data of importance to galactic studies. Fortunately, there has also been an increasing improvement in the centralized collection of this data and its availability in machine readable form. Issues 8-15 of the "Bulletin d'Information du Centre Donneés Stellaires" have appeared during the triennium under review. Collins (20.002.025) has presented a collection of nearly 2500 catalogs that have appeared in the literature from 1951 to 1975 inclusive.

Luyten (13.112.012, 14.112.017, 020 and 021, 17.112.006 and 21.112.012) has presented data on a number of galactic fields as part of the series "Proper Motion Survey with the 48-inch Schmidt Telescope". He also presents (17.112.007) data for 10,831 stars in the region of the North Galactic Pole (NGP) with proper motions greater than 0."179 and (18.112.008) a catalog of stars with proper motions exceeding 0."5. Rakhimov (14.112.007, 20.112.010, and 014) has presented three catalogs of proper motion data and, in addition, three catalogs (20.112.011, 012 and 013) of proper motions of stars relative to galaxies.

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A continually updated catalog of 60,800 stars from 30 photometric systems is described by Magnenat (18.113.030).

The *UBV* photometric system continues to be the most commonly used. Mermilliod and Nicolet (20.002.003) describe a magnetic tape catalog of 73,000 measurements on 53,000 stars. Nicolet (1978) presents a homogeneous *UBV* photoelectric catalog of 53,845 stars. Voroshilov *et al.* (18.113.001) present a catalog of *BV* magnitudes and spectral classes of 18,000 stars. Nicolet (14.113.035) describes a catalog of Cape *UBV* photometry.

Klare and Neckel (19.113.008) have published *UBV*, *H*β and polarization measurements of all 1660 southern OB stars of the Heidelberg catalog.

Havlen (13.155.038) presents results of extensive *UBV* and *H*β observations on southern OB stars and Drilling (13.113.010) has obtained *UBV* data for 164 OB^+ stars north of $\delta = -15°$. The following authors present *UBV* photometry and MK classifications: Humphreys (13.114.013) for luminous stars in Centaurus-Norma, Herbst (13. 132.018) for stars in southern reflection nebulae and Hill and Lynas-Gray (20.113. 005) for 193 northern early-type stars at intermediate galactic latitudes. Chromey (21.113.018) gives *UBV* data for 96 faint blue stars near the galactic anticenter. Madore (14.122.002) gives new *UBV* photoelectric data for 46 long-period cepheids in the southern Milky Way. Mendoza *et al.* (21.113.061) give results for *UBVRI* photometry of 225 Am stars.

Absolute proper motions of B stars are given by Karimova *et al.* (13.112.004) and a catalog of proper motions of 5965 stars is given by Rhynsburger and Gauss (14.041.029). Other catalogs give proper motions for 84 Mira Ceti type stars (21. 112.014) and Trapezium-type multiple systems (21.112.010).

The exceedingly crucial data on trigonometric parallaxes continues to come in, but slowly. Dahn *et al.* (19.002.064) present results for 93 stars, Vilkki (1978) for 12 stars and Auer *et al.* (21.111.008) for 11 stars. Gliese reports that the Astronomiches Rechen-Institut, Heidelberg, maintains a continually updated list of the stars within 22 pc.

Parallax determinations are also given by Upgren and Weis (14.111.007) for 21 stars, Upgren (14.111.005) for 23 stars, Harrington *et al.* (14.041.035) for 88 stars, von Altena (14.111.002) for 12 stars and by Ianna *et al.* (17.111.003) for 31 stars.

Important galactic fields have been studied with *UBV* (14.113.032, 21.155.017) and *UBVR* (13.113.053) photographic photometry.

Many observations have also come in using the Strömgren *uvby*β system. Much of the work is on individual clusters. Blaauw *et al.* (17.113.011) give *H*α and *uvby* photometry for over 1000 stars brighter than $13^m\!.5$ located near the galactic poles.

Hauck and Mermilliod (14.113.034) describe a magnetic tape catalog of 9407 stars on the *uvby*β system. Grønbeck *et al.* (18.113.039) have carried out *uvby* photometry on 134 southern standard stars and Heck (19.113.007) gives *uvby*β data for equatorial and southern bright stars. Eggen (1978) presents a catalog of *UBV*, *RI* and *uvby* measurements of some 1000 stars. Grønbeck and Olsen (19.113.010) have published *H*β observations for 2742 stars south of declination +10°. Dachs and Schmidt-Kaler (14.113.001) present standard stars for *H*α photometry. Important catalogs on the Geneva seven-color system are by Rufener (18.113.056) and by Golay and Mandwewala (21.002.050).

Observations have been published of bright stars in the *UBVR* system (14.113. 055), cepheids and supergiants in Walraven's five-channel system (17.122.067) and early-type stars in the Barbier-Morguleff system (13.113.011). McClure (17.113.026) presents standard stars for DDO photometry and Johnson and Mitchell (14.113.069) present observations of 1380 bright stars in their 13-color system. Nicollier and Hauck (21.002.028) describe a magnetic tape catalog of 1297 stars measured in the Stebbins-Whitford six-color system. White and Wing (21.114.037) have used a photoelectric system defined by eight narrow bands between 0.7 and 1.1 μm.

Catalogs of Milky Way (19.002.015) and high latitude (18.113.054, 19.002.014) fields in the *RGU* photographic system are presented by Becker and Fenkart and collaborators.

The immense task of providing two-dimensional (MK) classification of the Henry Draper catalog is proceeding. Volume II (Houk 1978) covers 29,555 stars between declinations -53° and -40°

Buscombe (20.002.004) has compiled the "Third general catalog" of MK spectral classifications. Garrison *et al.* (20.114.044) give MK classes for 1113 southern OB stars.

Spectral classifications are given for F stars (14.114.022, 17.114.036) and for proper motion stars (13.114.026).

Parts II and III of the Stockholm Observatory Southern Milky Way Survey (14. 114.013, 17.114.008) cover the galactic longitude range ℓ=237° to 306°, giving objective prism classifications for early and late type stars. MacConnell and Bidelman (17.114.029) give objective prism classifications for 149 southern O stars and supergiants, most of the latter not having been previously recognized as supergiants.

Seitter (19.002.068) has produced an "Atlas for Objective Prism Spectra". Schmidt-Kaler *et al.* (20.114.017) discuss a new method to calibrate accurately objective prism spectra.

Rapid advances are being made in the field of ultraviolet spectral classification (20.114.038 and 041, 21.114.007 and Cucchiaro *et al.* 1978).

Heck *et al.* (20.114.043) apply cluster analysis methods to detect errors in spectral classification and find inconsistencies in catalog data for 249 stars.

Important radial velocity programs have yielded results for over 200 O type stars (19.112.006), for 67 OB supergiants (17.114.063), 30 OB stars near the galactic anticenter (20.114.016), 68 early-type stars at intermediate galactic latitudes (14.112.002) and 92 B8-B9 stars (20.112.005). Stock *et al.* (20.112.009) and Fehrenbach and Burnage (21.112.008) report objective prism radial velocities, claiming an accuracy of 5 km/s.

Morel *et al.* (18.114.130) present a catalog of [Fe/H} determinations for 515 stars. Axon and Ellis have prepared (18.131.216) a catalog of linear polarization measurements for 5070 stars. The data is presented in the form of vector maps on the sky in several distance intervals.

Berger (18.113.051 and 052) has presented an evaluation and a catalog of stellar spectrophotometry covering some 2000 scans. All data are transformed to the Hayes-Lotham calibration of Vega.

Snow and Jenkins (19.002.022) give a catalog of ultraviolet spectra between 1000 and 1450 Å for 60 O- and B-type stars observed by Copernicus. Hack (21.114 .096) reviews existing ultraviolet observations of early-type supergiants.

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Large amounts of data have become available on specific classes of stars. Much of this work can merely be tabulated here.

Stenholm (13.155.027) has searched for Wolf-Rayet stars and discussed them in terms of galactic structure. The physical plane of the Wolf-Rayet stars is tilted by about one degree to the galactic plane.

Cruz-González *et al.* (13.113.008), Houk *et al.* (17.113.025) and Goy (18.114.054) give catalogs of 664, 75 and 763 O-type stars respectively.

Muzzio and Orsatti (20.114.002) have found 162 OB stars in the Vela region. Walborn (17.114.025) reviews the knowledge of OBN and OBC stars.

New Hα emission objects have been found in Cygnus by the Vatican Observatory workers (17.114.051, 052 and 053, 19.155.053). Stephenson and Sanduleak (19.114.042) give data on 455 new Hα emission stars in the Milky Way; Henize (17.114.042) presents a catalog of 1929 Hα emission stars in the southern Milky Way. Dolidze (17.114.045 and 046) lists groupings of emission line stars.

Data for carbon stars are listed in 18.112.001, 18.114.139, 21.114.043 and 045. The first paper, by Dean, concludes that carbon stars are dynamically similar to the dwarf F5 stars.

Westerlund and Olander (21.002.045) and Stephenson (18.114.141) give catalogs of S stars. Dolidze (17.114.045) lists S, C, and MS stars. Keenan and McNeil (18.114.132) give "An atlas of the spectra of the cooler stars: types G, K, M, S, and C".

Other catalogs are for RR Lyrae stars (14.120.002, 18.120.001, 20.002.028), low luminosity stars (21.002.003, 21.114.063), white dwarfs (21.002.025), dwarf K and M stars (14.114.114), extremely red stars (19.155.003, 21.113.055 and 058), blue stars at high galactic latitudes (19.002.019, 21.113.014), stellar data in galactic polar areas (20.155.035).

Lists of stars having radio continuum emission are starting to come out more frequently. Such lists are by Altenhoff *et al.* (17.141.016), Walter (20.041.026), Wright and Allen (1978) and Spinrad and Smith (1978).

Gill *et al.* (14.114.047) give 479 MK classifications of 186 close binary systems. The "13th complementary catalogue" of spectroscopic binaries is available (19.002.001), as are MK classifications by Edwards (17.118.014) for components of 208 visual binaries.

Mermilliod (18.153.023) describes the second edition of the catalog of *UBV* photometry and MK spectral types in open clusters. Philip (20.154.041) gives a compilation of *UBV* color-magnitude diagrams of galactic clusters. A uniform survey of clusters in the southern Milky Way is given by van den Bergh and Hagen (13.153.001). Moffat and Vogt (13.153.016 and 018) give *UBV-Hβ* results for 44 southern clusters.

Catalogs of HII regions are presented by Dubout-Crillon (17.131.541) and Bernes (19.002.042). Studies of infrared emission from HII regions (19.132.003, 022, and 030, 19.133.014) have been made. Pankonin *et al.* (19.132.008) have surveyed radio recombination lines from HI regions and associated HII regions.

New planetary nebulae (PN) have been catalogued by Longmore (19.135.001) and Kohoutek (19.135.028, 21.135.032). MacConnell (1978) gives a list of suspected new PN's.

Herbig (13.132.036) has presented a "Draft Catalog" of Herbig-Haro objects. Böhm (21.131.122) reviews all available data on Herbig-Haro objects.

Holmberg *et al.* (14.113.044, 19.002.002, 21.002.001 and 051) present parts III, IV, V and VI of the "ESO/Uppsala survey of the ESO (B) atlas of the Southern Sky". Objects of galactic interest covered are star clusters and planetary nebulae.

Alcaíno has produced a catalog (20.002.005) giving color-magnitude diagrams for globular clusters and has given (20.154.034) basic data for globular clusters. Harris (17.154.005) presents new color-magnitude data for 12 globular clusters. Philip *et al.* (18.154.044) present 165 color-magnitude and two-color diagrams for globular clusters compiled from the literature.

The interstellar medium has been probed by absorption studies of various kinds: diffuse interstellar bands (19.131.102); interstellar sodium and calcium toward stars (21.131.161); HI absorption in the 21-cm line towards pulsars (17.131.035, 18.141.302), extragalactic sources (21.002.039), and the galactic center region (19.132.017); HI absorption in the $L\alpha$ line (Bohlin *et al.* 1978); and H_2 absorption toward stars (21.131.036).

A number of radio line surveys have covered the Milky Way and higher latitude regions. In the 21-cm hydrogen line, survey observations in the Southern Milky Way have been published by Kerr *et al.* (18.155.015), Ball *et al.* (18.155.017), Garzoli (21.002.062) and for higher latitude regions in the southern sky by Colomb *et al.* (18.155.050, 19.132.039), Bajaja and Colomb (21.002.063) and Cleary (1977). Mirabel (19.156.016) and Franco and Pöppel (21.131.116) present HI data for intermediate latitudes toward the galactic center region. Braunsfurth and Rohlfs present a low latitude survey with the Bonn telescope for $20°\leq\ell\leq42°$ (21.002.038).

Drift-scan observations for the zone $-29°\leq\delta\leq+40°$ have been published by Bystrova and Rakhimov (20.002.034). Burton *et al.* (20.155.001) have carried out broadband observations of HI within 10° of the direction of the galactic center. Schober (18.155.018) has used various published surveys to make a compilation of HI data over almost the whole sky in the form of velocity-latitude contour maps. Photographic presentations of HI data over large portions of the Galaxy have been given by Heiles and Jenkins (17.155.004), and by Valdes (1978).

The distribution of the CO line emission at 115 GHz has been surveyed near the equator in the first quandrant by Gordon and Burton (18.155.012), Scoville *et al.* (20.155.020), and Cohen and Thaddeus (20.155.025). A CO survey of the galactic center region has been reported by Bania (20.155.009).

Large-scale searches for OH sources at 1612 MHz (OH/IR stars) have been carried out by Johansson *et al.* (19.133.005), Bowers (21.122.063), and Glass (21. 133.001). Observations of OH emission at 1665 and 1667 MHz in the galactic center region have been reported by Cohen and Few (18.131.042).

Surveys of radio recombination line emission from ionized hydrogen in the galactic plane have been reported by Lockman (18.155.030), Hart and Pedlar (18.157. 001), and Batty (18.157.019).

In the radio continuum, a map of the northern sky at 10 MHz has been published by Caswell (18.157.017), and a catalog of extended sources at low galactic latitudes has been prepared from a 408-MHz fan-beam survey by Felli *et al.* (19.141.007). For the southern sky, observations have been published for five frequencies in the range 2-20 MHz by Cane and Whitman (19.151.006), and for 5000-MHz emission at low latitudes by Haynes *et al.* (1978).

Radio observations of individual galactic sources, detections of new radio molecular lines, and detailed studies of the interstellar gas have been left to the reports of other Commissions.

The following infrared surveys of the Milky Way have appeared: Low *et al.* (19.156.015) between ℓ=348° and 32°.5 in the 60-300 μm band; Serra *et al.* (21.131.130) between ℓ=36° and 55° in the 115-196 μm band; and Hofmann *et al.* (19.156.014) for the central region of the Milky Way at 2.4 and 3.4 μm. Hansen *et al.* (17.141.006) have classified 831 Two-micron Sky Survey sources south of δ=+5° and find that 89% are M Stars. Price and Walker (19.133.017) give the spatial and brightness distribution of IR sources in the 3 to 30 μm spectral region.

Carnochan *et al.* (14.114.118) present first results of a *UV* sky survey and conclude that the frequency of hot objects lying a few magnitudes below the main sequence is much greater than expected. The galactic latitude dependence of the 1530 Å interstellar radiation field has been studied by Henry *et al.* (19.157.003).

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B. *Intrinsic Colors and Interstellar Reddening*

Work on determination of intrinsic colors has been leaning more to specialized photometric systems with little work now being done for the *UBV* system.

Gutiérrez-Moreno (14.113.048) has used the Q method to determine intrinsic colors in the *UBV* system for early main-sequence stars. Isserstedt (13.159.009, 19.159.005) has determined intrinsic colors for supergiants in the Large Magellanic Cloud. Kukarkin and Kireeva (17.154.006) have determined intrinsic colors and color excesses in the bands *U, B, V, I* for globular clusters.

Davis (19.114.030) rediscusses the relation between *UBV*β photometry and MK spectral class. Hayes (13.113.038) discusses the synthesis of *UBV* colors.

Numerous workers have determined intrinsic colors and calibrations in the Strömgren *uvby* system. They are: Philip and Matlock (13.113.030), Breger (13.113.029), Crawford (14.113.020 and 063, 21.113.002), Oblak *et al.* (17.113.013), Warren (17.113.001), Shobbrook (18.113.002), Crawford and Perry (18.113.063), Palmer (19.113.031), Philip *et al.* (19.113.056), Davis and Shobbrook (19.114.032), Kurilienė (20.113.023), Zabriskie (20.114.055), Reemann (21.113.037), Bessell and Wickramasinghe (21.126.002), Schulz (1978), and Knude (1978). Relyea and Kurucz (1978) have carried out a theoretical analysis of *uvby* photometry.

Determinations of intrinsic colors and calibrations for other photometric

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systems include those by Wiemer (13.113.060) for the *BVRIJKL* system; Kurilienė and Straižys (20.113.021) for the 13-color system; Janes and McClure (13.113.033), Janes (20.131.162) and Yoss (20.114.025) for DDO photometry; Straižys and Kurilienė (14.113.056) for the Vilnius system; Lub and Pel (19.113.012) and Pel (21.122.003) for the Walraven *VBLUW* system; Golay *et al.* (20.114.005) and Grenon (21.113.072) for the Geneva system; Parsons and Bell (13.114.056) for the Stebbins and Kron *UVBGRI* system and Nikonav and Terez (17.114.030) for the Oke-Schild spectrophotometric system. Buser (21.113.008) evaluated theoretically the *UBV*, *RGU*, and *uvby* systems and determined (21.113.009) transformations between the *UBV* and *RGU* systems. Eggen (21.113.038) calibrated indices for intermediate-band photometry of late-type stars. Wegner (1978) has established transformation formulae of the Turoń photometry (m_{pg}, m_{pv}) system to the international (B,V) system.

Data for calibrating the relation between effective temperatures and intrinsic colors are given by Dunham *et al.* (13.115.001), Code (13.115.008), Cox and Davis (13.122.062), Morrison (14.113.009), Canavaggia *et al.* (14.122.133), Code *et al.* (17.114.004), Mould and Hyland (18.113.003), Traat (18.113.021), Chalonge and Divan (19.114.015), Flower (19.115.001), Lesh (20.114.039), Cox and Davis (20.122.159), Philip *et al.* (20.153.023), Tsuji (21.064.003), Cogan (21.122.043) and Cohen *et al.* (21.113.042).

Interstellar reddening, E_{B-V}, has been determined towards various galactic objects: 161 cepheids (Nikolov and Ivanov, 17.122.072), 15 galactic fields (Crawford and Barnes, 13.131.063) and 4 galactic fields (Hesser 19.154.008) containing globular clusters, and towards 4 galactic clusters (Kuznetsov, 21.114.052). Rydgren (17.113.035) uses the (J-H), (H-K) infrared two-color diagram to determine E_{B-V} of T Tauri stars.

Dean *et al.* (21.122.124) determine the reddening for 60 cepheids using *BVI* photometry. They note that their results and other photometric results do not agree well with reddening determinations using spectral types, but do agree with each other. They conclude that the photometric reddenings are more nearly correct.

The ratio, R, of total visual extinction, A_V to E_{B-V} is very important for studies of distant Milky Way objects. Most investigations of R in the past three years seem to lead to a constant, or nearly constant, value for R in the Galaxy. Some determinations for R are 3.1 by Schaleń (14.131.051), 3.14 $\pm$ 0.10 by Schultz and Wiemer (14.131.101), 3.35 $\pm$ 0.29 by Sandage (14.131.195) using a new method based on intrinsic colors for E galaxies, 3.31 $\pm$ 0.13 by Herbst (14.152.001), 3.2 by Sherwood (17.131.072), 3.2 $\pm$ 0.2 by Turner (18.131.175), 3.4 $\pm$ 0.2 by Hawley and Duncan for planetary nebulae, 3.08 $\pm$ 0.03 by Turner (18.153.039), 3.2 $\pm$ 0.07 by Pottasch *et al.* (19.135.008), 3.3 $\pm$ 0.03 by Moffat *et al.* (19.153.026), 3.4 to 3.5 for globular clusters by Straižys and Sviderskiene (19.154.023) and 3.15 $\pm$ 0.15 by van Breda and Whittet (20.131.194).

Herbst (14.152.001) finds a constant value for R for "normal" regions of the Galaxy but finds anomalously high values of R towards some R-associations, in NGC 6250 (20.153.019), and in the Carina nebula (18.153.008). Moffat and Schmidt-Kaler (17.152.004) find that a normal value of R can satisfy Herbst's data for the "anomalous" R-associations, but Forte (1978) supports the high R value near the Carina nebula. Whittet (19.131.170) finds evidence for a small but significant variation of R with galactic longitude, being 0.3 higher in the southern Milky Way than in the north.

Many workers have investigated the form of the interstellar extinction law from infrared to ultraviolet wavelengths. Dorschner (17.131.076) finds that the extinction at the λ2175 Å "bump" correlates well with E_{B-V} while Deutschman *et al.* (17.113.032) find that the extinction law is more variable near λ1590 Å. Koorneef (1978) finds that the interstellar extinction law is not constant throughout the Galaxy, the 2200 Å

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feature showing variations. Schild (19.131.153) has also investigated the ultraviolet interstellar extinction law. Johnson (21.131.159) and Whittet (18.113.067) have investigated it over infrared and optical wavelengths, Johnson finding regional variations.

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C. *Absolute Magnitudes*

Barnes *et al.* (17.115.001 and 002) have introduced a new method applicable to distance determinations for variable stars. They find that a star's intrinsic (*V-R*) color correlates extremely well with the visual surface brightness. Lacy (19.121.002) and Fernie (20.122.001) have used the method to determine absolute magnitudes.

Upgren (13.111.002) determined a distance modulus for the Hyades cluster (DMH) of 3.22 ± 0.04 based on trigonometric parallaxes for more than 100 nearby red dwarfs and *BVRI* photometry. Klemola *et al.* (14.111.001) determined DMH to be 3.19 ± 0.15 from direct trigonometric parallax measurements of 18 dwarf members. McAlister (20.153.001) reanalyzed Hanson's method for determining DMH but eliminated a magnitude equation in the proper motion data to obtain DMH = 3.18 ± 0.16. Bachholz (19.111.005) reanalyzed trigonometric parallaxes to determine DMH = 3.10 ± 0.17. Woolley (17.115.003) used trigonometric parallaxes to define a main sequence which lies $0^m.15$ above the Johnson and Knuckles Hyades main sequence. Anthony-Twarog and Demarque (19.153.022) determined DMH = 3.34 based on comparing stellar models to observational data for four Hyades binaries. Van den Bergh (20.153.002) showed that only about half of any change in the adopted DMH will be reflected in the extragalactic distance scale.

Turon and Crézé (19.111.001), Nørgaard-Nielsen (19.111.008) and Upgren (20.111.001) have investigated uses and pitfalls in statistical studies of trigonometric parallaxes.

Crawford and Perry (17.153.026) and McNamara (17.153.019) have used *uvbyβ* photometry of the Pleiades to determine its distance modulus (5.54) and calibrate the ZAMS.

Goy (17.115.008, 20.111.004) discussed problems in luminosity determinations of O stars; Carrosco and Crézé (21.115.011) determined, by means of statistical parallaxes, that runaway O stars are $2^m.7 \pm 0^m.5$ less luminous than normal O stars.

Maeder and Cramer (13.113.035) discuss the use of Geneva photometry to determine luminosities of B stars. Vreux and Swings (19.114.009) and Underhill and Silversmith (17.114.031) discuss luminosity-dependent features in ultraviolet spectra of B stars. Crawford *et al.* (13.113.019) and Cester *et al.* (20.113.024) show how *H*α, *H*β, and *H*γ photometry used together can eliminate emission line effects in luminosity determination in early-type stars. Egret (21.115.015) and Neckel and Klare (18.115.002) discuss the M_V - *H*β calibration for early-type stars.

Much progress has been made in determinations of luminosities and luminosity-dependent parameters for supergiants (SG) of various spectral types. Walborn (19.159.015) has studied O and B0 SG's in the Magellanic Clouds, concluding that Of stars have supergiant luminosity. Hutchings (17.114.006) estimates M_V for 65 OB SG's. Sterken (19.113.036) discusses how Balmer discontinuities of early type SG's can be

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calculated from [*u-b*]. Sterken (19.113.037) discusses correlations of light variations in extreme B and A SG's with M_V. Burki (21.115.014) determines the semi-period-luminosity-color relation for late B to G SG's. Feast (17.114.301) discusses problems with the Rosendhal equivalent-width-M_V relation for SMC A-type SG's. Imhoff (14.115.012, 19.115.007) and Imhoff and Keenan (17.114.336) discuss luminosities of late-type SG's. Flower (14.115.005) gives bolometric corrections for late-type giants and supergiants.

Cepheid distances have been redetermined by Barnes *et al.* (19.122.060). The period-luminosity relation for cepheids has been investigated by Payne-Gaposhkin (13.122.113), Thompson (14.122.077), Fernie (14.122.027), Opolski (14.122.029), Mel'nikov (18.122.196), Butler (19.122.158), and Madore (19.122.157).

Breger and Bregman (14.122.081) have investigated the period-luminosity-color relations for various pulsating variable stars. The luminosities of galactic RR Lyrae variables is discussed by Heck and Jung (13.111.003), Fenina (17.122.075), Woolley and Davis (19.122.075) and Heck (14.122.080).

Wilson (17.115.012) has determined M_V for 700 late-type subgiants, giants, and supergiants. Absolute magnitudes based on DDO photometry have been investigated by Yoss and Deming (13.115.009) and Yoss *et al.* (19.112.001).

Luminosities of various classes of stars have been determined: Carbon stars by Bergeat (21.115.010); Miras by Cahn and Wyatt (21.122.040), K and early M stars by Bell *et al.* (17.113.010); S stars by Feast *et al.* (17.113.007); G5-K0 giants by Keenan and Wilson (19.114.047), late-type stars by Grenier *et al.* (19.155.004), A-F stars by Kilkenny (19.113.014), F stars by Heck (1978), white dwarfs by Greenstein (18.126.008), β Canis-Majoris stars by Shobbrook (1978).

Absolute magnitudes for planetary nebulae have been discussed by Heap (19.135. 029), Liller (21.135.031), and by Trimble and Sackmann (21.065.001).

Some authors have determined absolute magnitudes of low luminosity stars with results having bearing on the determination of the luminosity function (see following section). Weistrop (17.111.005) and Warren (18.155.009) obtained photometric parallaxes of faint red stars which place them much further away than had been thought on the basis of proper motion studies. Mikami (21.113.027 and 028) determined absolute magnitudes of M stars, and of F-G-K stars in the solar neighborhood, respectively.

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D. *The Luminosity Function*

There have been a number of studies of luminosity functions and space densities for various types or classes of stars. Sion and Liebert (19.126.014) and D'Antona and Mazzitelli (1978) have investigated the luminosity function of white dwarfs from observational and theoretical considerations respectively. Limits of the space density of hot white dwarfs in terms of extreme ultraviolet sources were calculated by Koester (21.126.031) and Henry *et al.* (17.126.009) who also considered the space density of O subdwarfs. Liebert (1978) considered the luminosity complete to $M_V=+15$, but much work is needed to be done on the fainter "red degenerates".

Tinsley and Gunn (17.115.015) have studied the luminosity functions and evolution of low-mass Population I giants and find results in agreement with theoretical work.

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3. LOCAL GALACTIC STRUCTURE

A. *General Surveys*

This Section of our Report deals with the distributions of stars, interstellar gas and dust, and the surface brightness of the Milky Way in the part of the Galaxy near the Sun. We discuss in Section 4 the overall properties of the Galaxy on the larger scale.

A general review of the solar neighborhood has been given by van de Kamp and Lippincott (18.155.092). A collection of super-wide-angle photographs of the Milky Way has been published by Schmidt-Kaler and Schlosser (19.155.026), and a four-color photographic atlas of the sky by Schlosser and Schmidt-Kaler (20.002.037).

The chemical history of the Galaxy in the solar neighborhood has been reviewed by Pagel (19.155.046), and the chemical and physical properties of nearby Population I stars by Cardini *et al.* (20.115.013). The metallicity distribution among old stars has been discussed by Biermann and Biermann (19.065.020), and a relation between orbital eccentricity and metallicity by Mayor (17.155.017)

Values for the ratio of total to selective extinction, R, have been deduced for stars in the Southern Milky Way by Whittet *et al.* (18.113.067), and the distribution of interstellar reddening material has been studied by Lucke (21.131.119). Interstellar absorption and the spatial distribution of stars in the galactic plane at $\ell = 55°$ (Guseva and Metrevali, 19.155.039), $\ell = 59°$ (Metreveli, Kuznetsov, 19.155.040), $\ell = 66°$, 77°, 113°, 186° (Kalandadze, *et al.* 18.155.040), Voroshilov and Kalandadze, 19.155.038) have been investigated.

The available data on the distribution of the O-B stars and diffuse matter in the vicinity of the Sun have been discussed by Voroshilov and Kalandadze (1978). The distribution of O-B2 stars along the z-coordinate has been studied by Kolesnik and Vedernicheva. Deviations of spiral arms from the galactic plane have been found.

The density and luminosity functions for 10396 stars in Kapteyn areas within a wide region of galactic latitudes (0° to +70°) on the basis of the results of the two-dimensional MK classification have been studied by Kharadze and Bartaya (1977, 18.114.030, 19.155.001). Also the space distribution of Ap and Am stars found during the classification has been studied.

Garmany and Ianna (19.113.026) have described the space distribution and kinematics of intermediate Population II stars. Alksnis and his colleagues (17.113.044, 17.114.360, 18.114.139, 19.114.045) have completed the search and carried out the photometry and classification of carbon stars near the galactic plane in the region of $68° \leq \ell \leq 184°$, and have studied their distribution.

A list of extraordinarily red stars on the Palomar Observatory Sky Survey has been given by Weinberger and Poulakos (19.155.003).

Of special emphasis during the period of this report have been observations and analyses of data for M dwarfs, particularly relating to their space density in the solar neighborhood. (See also Section 3C, which includes many other papers on this topic.)

New observational material has been published by Smethells (17.155.064) and Weistrop (20.155.004). The problem of determining the local space density of M dwarf stars has been discussed by Faber *et al.* (17.155.008), Weistrop (17.113.019 and 19.155.057), Jones (19.155.042) and Chiu (20.155.061). Gliese (18.155.041) has examined the luminosity function of stars in the solar neighborhood in relation to the problem of the "missing mass".

Kostyakova (1977) has analyzed the physical differences between the planetary nebulae of the general field and planetaries near the galactic center. The results obtained allow the objects studied to be placed in the general evolutionary scheme of planetary nebulae.

The spatial distribution of long-period variables in the Galaxy has been studied; their density near the Sun, total number in the Galaxy, and the number of stars of this type arising in the Galaxy per annum have been estimated (Gorbatski and Lebedeva, 19.155.023).

Fluctuations in the brightness of the diffuse galactic light and of the Milky Way have been studied by Mattila and Scheffler (21.155.026).

Heiles has published extensive discussions of the Hat Creek 21-cm survey for $|b| \geq 10°$ (17.131.044, 17.155.004, 18.131.518). The relation between HI, galaxy counts, reddening, and galactic latitude is found to be complex, but Burstein and Heiles (21.131.150) have developed a new method for determining the reddening of extragalactic objects. There is evidence for energetic expanding HI shells with typical diameters of tens of degrees. Preliminary southern sky data have been added to this project by Colomb *et al.* (19.132.039), again showing that the HI lies predominatly in long arcs.

A model for a local component of the interstellar hydrogen has been discussed by Grape (17.131.165). Kazes *et al.* (19.131.155) have studied the local region through a survey of OH absorption in the directions of extragalactic sources. A similar absorption survey at 21 cm has been presented by Crovisier *et al.* (21.002. 039) and the results have been used by Crovisier (1978) to study kinematics of neutral hydrogen clouds in the solar neighborhood.

The loops and spurs that are found in the radio continuum have received new attention. Weaver (1978) interprets them as expanding supernova shells, while Sofue(17.157.002 and 005, 20.155.013) regards them as part of a larger-scale phenomenon. Ellis and Axon (21.156.016), from a study of stellar polarization data, propose that the two largest loop structures are linked by the regular magnetic field. The distribution of neutral hydrogen in the Cetus-Eridanus ridge has been studied by Bystrova and Rakhimov (19.132.007), and Gosachinskii and Rakhimov (1978).

Hawley and Duncan (18.131.272) have determined the ratio of total to selective extinction by combining existing optical and radio observations. They find $R = 3.4 \pm 0.2$.

B. *Regional Surveys-Low Galactic Latitude*

Local sectional studies of galactic structure both from the optical and radio observational standpoints form the contents of this section of our report. In general, the results here will refer to galactic latitudes $|b| < 20°$.

I. *The Center Direction* ($350° < \ell < 10°$)

Whiteoak and Gardner (17.131.002) have studied the OH clouds along the line of

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sight towards the galactic center region, and Franco *et al.* (21.131.116) have studied the region 348° ≤ ℓ ≤ 12°, +3 ≤ b ≤ +17° in the 21-cm line.

Poulakos (18.155.001) has derived the space distribution of early type stars in a 34 sq. deg. area centered near ℓ = 355°, b = +2°. Antalová (18.113.088) has reported *UBV* photographic photometry of stars in a nearby area.

II. *Sct-Aql-Vul* (10° < ℓ < 60°)

Wramdemark (18.113.077) has measured *B* and *V* magnitudes and spectrophotometric quantities for stars in a field centered at ℓ = 36°.0, b = +8°.3. He has then investigated (19.131.120) the interstellar extinction and stellar space density in this field. Spaenhauer (20.155.023) has reported *RGU* three-color photometry of a field in Aquila near NGC 6755. He sees a density maximum at 2 kpc, related to the next inner spiral arm.

Serra *et al.* (21.131.130) have studied the far infrared emission of interstellar matter for ℓ = 36°-55°. The flux levels indicate a larger star-formation rate per unit mass of gas in the inner region of the Galaxy.

Sato and Akabane (17.131.166) have derived equal-velocity contour diagrams of 21-cm emission in the region 34°.0 < ℓ < 36°.3, $|b|$ < 1°, from the Maryland-Green Bank survey. A high-resolution 21-cm survey has been carried out by Braunsforth and Rohlfs (21.002.038) for the region 20° ≤ ℓ ≤ 42°, $|b|$ < 1°.5, extended to $|b|$ = 3° with the Maryland-Green Bank survey.

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

Wisniewski and Coyne (19.155.053) have published the fourth installment of a survey for Hα emission objects in the Milky Way. They discovered 95 new emission objects in Cygnus.

Balazs (18.155.080) has studied the spatial distribution of stars of spectral types F7 and earlier in a region of intermediate galactic latitude in Lyra.

Wramdemark (18.155.019) has carried out *UBV* photoelectric photometry for early-type stars in the Perseus arm direction. Stars were found beyond the Perseus arm in all directions examined, including a concentration at 6-7 kpc, ℓ = 102°, indicating an outer arm.

Särg and Wramdemark (19.155.006) report photoelectric *UBV* photometry for a Milky Way field in Cassiopeia at ℓ = 120°.5, b = 0°.0. The "discontinuity" in the galactic plane near ℓ = 140° has been studied by Dodd (18.155.053), Goldberg *et al.* (18.155.090), and Sparke and Dodd (21.155.001)

Neutral hydrogen in a region of Cepheus has been studied by Simonson and van Someren Greve, in relation to optical features (17.131.141). They discuss the history and structure of the region. Grayzeck (20.155.055) has mapped an intermediate-velocity cloud at ℓ = 122°, b = -15°, which is associated with the Perseus spiral arm.

Voroshilov and Kalandadze have studied the spatial distribution of stars and dust in an area of 18.3 sq. deg. centered at ℓ = 112°.6, b = +0°.5 (19.155.038).

Gosachinskii and Rakhimov (21.132.044, 21.155.008) have surveyed and discussed the neutral hydrogen in ℓ = 60° - 74°, b = ±15°, between spiral arms of the Galaxy.

IV. *The Galactic Anticenter* ($150° < \ell < 210°$)

Kalandadze and Kolesnik (21.155.027) have studied the space distribution of stars and interstellar dust in the anticenter direction. Becker and Svolopoulos (17.155.005) have reported three-color photometry of a field in the galactic anti-center section near M37, and Chromey (20.155.014) has observed blue stars near the anticenter. Christy (20.114.016) has determined distances and velocities for 56 early-type stars in the anticenter spur of the Orion arm. Cudworth (20.112.001) has used proper motions to find distant high-luminosity stars useful for studies of the anticenter region.

Hesser *et al.* (19.113.021) have studied stars in the Orion belt and sword regions. Vogt (18.155.058) has found four space groups in 111 luminous stars in Monoceros ($214° < \ell < 224°$).

V. *Pup-Vel-Car-Cru* ($210° < \ell < 300°$)

Much work has been done on distant objects in this region in the period under review. In Puppis, Havlen (17.152.002) has studied the association Pup OB2 and FitzGerald *et al.* (17.152.001) have reported on a new young stellar aggregate, Bochum 15, which makes a good spiral arm indicator.

In Vela, Muzzio and Orsatti (20.114.002) have searched for faint OB stars, and Denoyelle (19.155.055) has studied the space distribution of 358 early-type stars.

McCuskey and Lee (18.155.043) have investigated the distribution of B8-A3 stars near the galactic plane for $\ell = 270°-300°$, showing a relationship with the Carina spiral arm. Wramdemark (17.155.006) has studied faint early-type stars in Carina ($\ell = 290°$), Clariá (17.155.026) has discussed the relation of NGC 3590, Hogg 10, and Collinder 240 to the Carina spiral feature and Rickard (18.155.089) has looked at IC 2944 and streaming motions in Carina. Lodén *et al.* (17.114.008) have published the results of an extensive spectral survey of O-B9 and M stars in the region $\ell = 280°-306°$.

VII. *Cen-Cir-Nor-Sco* ($300° < \ell < 350°$)

Lyngå (19.155.009) has studied early-type stars in the Circinus galactic window. The galactic disk appears thicker at a galactic radius of 7 kpc than in the solar neighborhood. Muzzio and Forte (17.155.007) report photometry of faint early-type stars in Norma, and Topaktas (18.113.014) has carried out a photometric study of main-sequence stars in a field at $\ell = 330°$. Antalová and Graham (18.152.002) have studied interstellar absorption in the region of the association Sco OB 4. Hanner *et al.* (21.155.002) reported *UBV* surfact brightness photometry of the Milky Way in Scorpius from the space probe Helios 1.

Observations in the 21-cm line have been reported in two parts of this sector. Jackson (18.155.016) covered the region $305° < \ell < 309°$, $-2° < b < +5°$, and Colomb *et al.* (18.155.050) the region $290° < \ell < 314°$, $-32° < b < -17°$.

C. *High Latitude Optical Studies*

This section of our Report is concerned with optical studies of the stellar population in galactic latitudes $|b| > 20°$. Large-scale properties of the galactic halo will be discussed in Section 4D.

An extensive coverage of high latitude studies appears in the Proceedings of

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the Joint Discussion on "Galactic Structure in the Direction of the Polar Caps" held at the XVI General Assembly (Highlights of Astronomy, Vol. 4, Part II, 1977). New information on M dwarf stars at the galactic poles has been published by Eggen (17. 115.006), Warren (18.155.009), Pesch (18.114.167), Sanduleak (18.126.009), and Kron (20.155.011).

Blaauw *et al.* (17.113.001) have studied the space distribution and kinematics of intermediate Population II stars in the polar regions. Eggen (17.155.027) has observed 1505 proper motion stars, and derived the luminosity laws for the halo and old disk populations. Hill *et al.* (18.155.020 and 021, 18.112.005) have studied A and F stars in the region of the north galactic pole. Berger and Fringant (19.002. 019) have searched for faint blue stars in the nine PSS fields near the NGP, and Drilling (20.113.017) has carried out *UBV* photometry of 51 stars in a region near the SGP. Meinunger (19.122.083) has studied RR Lyrae stars in the Sonneberg fields near the NGP.

In the frame of the international program of investigation of stars in the McCormick proper motion fields, Bartaya (17.113.011) has completed the two-dimensional MK classification of numerous stars located generally in the galactic polar regions. Latyshev (21.155.023) has found that the spatial density of stars in the solar vicinity is not less than 0.15 stars/pc^3.

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4. OVERALL STRUCTURE OF THE GALAXY

In this section, we discuss the larger-scale features of the Galaxy, revealed largely by radio observing methods, coupled to some extent with the optical.

A. *Spiral Structure*

A review of the large-scale distribution of interstellar matter in the context of the density-wave theory has been given by Roberts and Burton (20.131.106), and summaries of the density-wave theory in relation to observations have been presented by Roberts (17.155.005, 20.151.027). Reviews of current studies of the spiral structure of the Galaxy have been given by Schmidt-Kaler (17.155.054, 21.155.049) and Rohlfs (17.155.056), and Weaver (17.155.031).

Reiche (21.151.038) has discussed the possibilities of observing effects predicted by the density-wave theory. Determinations of the spiral pattern speed of the Galaxy have been given by Gordon (21.155.020), Grosbøl (21.155.060) and Palous (21.155.062). Sawa (21.155.021) has found that the shock model fits observations better than the linear model.

A density-wave map of the galactic spiral structure has been derived from 21-cm observations by Simonson (17.155.003). This model changes from a two-armed pattern inside the solar circle to a multi-armed pattern further out. Four-armed spirals have been proposed by Henderson (19.155.033) and Quiroga (20.155.062), in each case based on both 21-cm and optical data. A spiral pattern determined from optical and radio observations of HII regions has been published by Georgelin and Georgelin (17.155.034).

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The fine structure of spiral arms has been discussed by Schmidt-Kaler and House (17.155.021, 18.155.034) and Quiroga and Schlosser (19.155.028), while Strauss and Pöppel (17.155.013) have carried out a detailed study of rolling motions in an inner spiral arm.

Gamma-ray and molecular-line observations have been used by Cesarsky *et al.* (20.155.007) to study the relation between cosmic rays, spiral structure and molecular clouds. Bash *et al.* (20.155.015) have discussed the galactic density wave, molecular clouds, and star formation, using CO observations and other considerations.

French and Osborne (18.155.076) have given an interpretation of the galactic continuum radiation, using a new composite map of spiral structure, based on earlier HII and HI studies. Gammon *et al.* (19.131.092) have considered water maser emission as a tracer of southern galactic structure.

A model for the local spiral structure of the Galaxy has been presented by Humphreys (18.155.094), based on optical spiral structure. Supergiants have been used by Warner and Wing (20.155.028) to locate two spiral features in the direction of the galactic center. Contopoulos and Grosbøl (18.155.038) have derived the past positions of the galactic spiral arms. From various optical indicators, Kostyakova (21.155.006) finds difficulty in tracing clearly localized arms in the solar neighborhood. Ardeberg and Maurice (21.155.030) have studied aggregates in the Carina spiral arm, and discuss evidence for the recent passage of a shock front.

B. *The Galactic Disk*

In this section, we consider items which refer to the disk in general, with no special connection with spiral structure.

The overall distribution of hydrogen and of other tracers in the galactic disk has been reviewed by Burton (20.155.021 and 027). Baker has shown from high precision measurements that the velocity distribution of the neutral hydrogen displays a sharp boundary (17.155.018). Colomb and Mirabel (17.131.035) have published 21-cm emission line profiles in the directions of 23 southern pulsars.

The existence of a ring of CO clouds between galactic radii 4 and 8 kpc has been discussed by Gordon and Burton (18.155.008 and 021, 21.155.004), Solomon and Stecker (18.155.062), Scoville *et al.* (20.155.020), and Cohen and Thaddeus (20.155.025). The width of the layer between half-density points is $\sim$100 pc, and the average displacement relative to the equator is -40 pc. A model for the CO cloud distribution has been proposed by Burton and Gordon (20.155.026). The dynamics of CO molecular clouds in the Galaxy and their relation to the galactic density wave have been studied by Bash and Peters (17.131.114, 20.155.015)

The galactic distribution of OH/IR stars has been discussed by Johansson *et al.* (19.133.005), Habing (21.115.018) and Bowers (21.122.063).

The radial distribution of ionized hydrogen in the galactic disk has been derived from H166α observations by Lockman (18.155.030) and Hart and Pedlar (18.157.001). Smith *et al.* (21.131.172) have used data relevant to giant HII regions to derive star formation rates in the Galaxy. Bieging *et al.* at Bonn are concluding an H110α and H_2CO survey of all the discrete sources in the plane between longitudes 359° and 50°.

The existence of broad systematic variations in the z-location of Population I objects has been described by Lockman (19.155.041), while large-scale hydrodynamic oscillations of the galactic gas layer have been discussed by Nelson (17.155.001). Spight and Grayzeck (19.155.018) have made a new study of the warping of the galactic plane by the LMC.

The galactic distribution of pulsars has been discussed by Taylor and Manchester (20.141.502) and Seriadakis (20.141.523).

Baldwin (20.157.010) has presented a review of the nonthermal continuum radiation from the galactic disk. Lipovka (19.156.008) has studied the disk emission at 4 cm in the region $\ell = 0° - 45°$. Novaco and Brown (21.156.009) have reported measurements of the nonthermal galactic radio emission at 6 frequencies below 10 MHz, using the RAE 2 lunar orbiting satellite. The spectrum of the background continuum emission has been studied by Belyaev *et al.* (17.141.071), Kuznetsova (18.157.004), Milogradov-Turin (18.157.006), and Vinyajkin (21.156.015).

Optical studies of the galactic disk have included the increasing interest in abundance variations and chemical history of the disk objects as well as star formation. Much of this work concerns the Galaxy as a whole, and not just the disk, but we have included such overall studies in this subsection. A conference held at Yale University in 1977 on "The evolution of galaxies and stellar populations" (20.012.005) covers many aspects of this subject.

Spinrad (18.114.126) has reviewed abundances in stellar populations. Mayor (17.155.020) has discussed the chemical evolution of the galactic disk and the radial metallicity gradient. Sivan (17.155.040) has derived the nitrogen-to-sulphur abundance gradient across the disk. D'Odorico and Peimbert (17.155.012) have determined radial abundance gradients from studies of planetary nebulae, and Peimbert *et al.* (21.132.013) have derived abundance gradients from HII regions. Kostyakova (21.155.005) has studied the integral spectrum of 20 Milky Way regions, finding an intrinsic reddening toward the galactic center.

Burki and Maeder (18.153.009) have shown that the mean size of very young clusters varies strongly with the distance from the galactic center in the 8 - 12 kpc range.

Frogel and Stothers (20.155.056) divide the local OB stars into the Gould and galactic belts, in order to study their kinematics. Crampton *et al.* (18.155.010) have studied OB stars near the solar galacto-centric circle, and find a value of $\sim$8 kpc for the distance to the galactic center. Klare and Neckel (19.113.008) have made a detailed study of 1660 southern OB stars.

The distribution of B5-A0 stars has been studied by Grosbøl (19.155.029), of southern B-F stars by Kilkenny (19.113.014), and of F stars by Blaauw and Garmany (18.155.035).

Deutschman *et al.* (17.113.032) have derived the galactic distribution of interstellar absorption from ultraviolet, *UBV* and $H\beta$ observations. Hayakawa *et al.* (17.155.032) have published an infrared profile of the Milky Way at 2.4 μm (17.155.035).

Upgren (18.155.088) has discussed an outward motion of the LSR defined by young stars, while Ovenden and Byl (17.155.037) find no evidence for expansion in the velocities of OB stars and cepheids. Guibert *et al.* (21.155.051) have studied the vertical and radial distributions of gas and young objects in relation to Schmidt's law of star formation.

The space distribution of open clusters in the Galaxy has been studied. An assumption has been made about the possible effect of hydrogen clouds of the Magellanic Stream and the Magellanic Clouds on objects of the flat subsystem of the Galaxy (Barkhatova and Pylskaya, 1977, 1978).

The places of formation of 24 open clusters have been found by Palouš *et al.* (1977). A number of wide stellar groupings, retaining traces of common origin, have been discovered in our Galaxy (Efremov, 1978).

C. *The Galactic Nucleus*

In this section we discuss structural information about the nuclear region; kinematic studies are summarized in Section 5B. The galactic center (especially Sgr B2 and Sgr A) is the principal place in the Galaxy where new molecules have been studied and their physics and chemistry investigated. This work, together with studies of detailed structure, is described in the reports of Commissions 34 and 40.

Important reviews of galactic center studies have been given by Oort (19.155.045, 20.155.058, 21.155.024). Clube (19.155.044) has discussed double structure and the galactic center.

The location and properties of the various 21-cm emission features in the central region have been discussed by Cohen and Davies (17.155.011, 19.132.017). More recent studies of the hydrogen distribution and kinematics have been given by Burton and Liszt (1978) and Sinha (1978). These authors have obtained new observational material, as also have Sanders *et al.* (20.155.029). High-velocity hydrogen, possibly ejected from the galactic center, has been described by Mirabel and Franco (17.155.014, 18.131.505).

Observations of OH and CO in the central region have been presented by Cohen and Few (18.131.042) and Bania (20.155.009) respectively. Molecular observations have led to an expanding-ring shock-wave model (Kato, 20.155.005, Saito and Saito 20.155.006), and a tilted-disk model (Liszt and Burton 1978). Clube (18.155.052) has proposed that the Galaxy is a rapidly expanding spiral system. Matsuda and Nelson (19.155.012) have suggested that an annular ring of very low density may be a consequence of a postulated stellar bar at the center.

Many papers have been published on the fine structure of the continuum and molecular sources in the central region. We mention here only the reports on the very small radio source (140-200 A.U. diameter, with a core of 10 A.U.) at the center by Kellermann *et al.* (19.141.096) and Lo *et al.* (20.141.136). High-resolution observations have also been reported by Berlin *et al.* (19.141.031).

Active work on late-type giants has yielded important information on the properties of these stars in the nuclear bulge (James 19.155.014; Neugebauer *et al.* 17.155.033; Evans 17.122.001). Similarly, activity continues on RR Lyr stars in the galactic bulge. Butler *et al.* (18.122.064) have studied metal abundances in Baade's window and Rodgers (19.122.039) has discussed the spectra of these stars. Oort (20.155.059) has estimated the number density of globular clusters near the galactic center.

Much impressive work in the near- and far-infrared regions is yielding new information on the structure of the galactic center. Becklin *et al.* (18.155.068) and Maihara *et al.* (21.155.011) present 2.2 and 2.4 μm maps of the region; Borgman *et al.* (18.155.069) discuss the dominant 10-20 μm source; Olthof (18.155.070) presents multicolor far-infrared photometry, and Capps and Knacke (18.155.059) have studied infrared polarization in the region. Andriesse and de Vries (18.155.002) have derived the distribution of stars and dust near the galactic center from infrared observations. Wollman *et al.* (17.155.023) have reported studies of 12.8 μm NeII emission, and Neugebauer *et al.* (21.156.005) present 2.2 μm spectroscopy. The detailed structure in the infrared has been studied by Gatley *et al.* (21.131.014) and Rieke *et al.* (21.156.008).

Ozernoy (21.155.048) has discussed constraints on the mass of a black hole at the galactic center.

D. *The Galactic Halo*

Some studies of the stellar populations in the halo have been included in Section 4B above.

Halo density distributions have been determined by Fenkart and Schaltenbrand (19.155.007) for a direction close to the North Galactic Pole (NGC 4147), by Becker and Steppe (19.155.030) for SA 82 and SA 107 and by Lorenz (19.155.055) for blue horizontal branch stars. Fenkart (19.155.021) has derived upper and lower limits for the local halo mass density.

Sandage and Hartwick (20.154.003) argue from a study of the remote halo globular cluster Palomar 5 that the chemical enrichment of the halo was spotty. The space distribution of globular clusters has been restudied by de Vaucouleurs (20.154.002) and by Sharov (19.154.003). Sharov also reported on the dependence of the velocity dispersion on position in the Galaxy. Kukarkin *et al.* (17.154.006) have carried out a revision of the basic characteristics of globular clusters in our Galaxy. Pikel'ner (17.154.029) suggested a qualitative picture of the evolution of the globular clusters of the Galaxy, with their formation resulting from the fragmentation of a protogalaxy.

The probable existence of an extensive radio halo around the Galaxy has been discussed by Suh (18.157.002), Bulanov *et al.* (18.157.013), and Lipovka (20.156.021), based on the observed characteristics of the background radio continuum emission. Davies (18.131.545) has discussed gas and stars in the outer regions of galaxies.

Evidence is growing that the high-velocity hydrogen clouds may belong to more than one population, in terms of their origin and distance. The origin of the high-velocity clouds has been discussed by Shchekinov (21.132.045) and Giovanelli (21.155.029). Hulsbosch (1978a) has given a preliminary report of a high sensitivity survey of hydrogen at very high velocities. Mathewson *et al.* (20.159.003) have presented new observations of the Magellanic Stream, interpreting the Stream as the turbulent wake of the Magellanic Clouds. Other interpretations of the Stream have been given by Davies and Wright (19.159.021) and Haud and Einasto (20.132.038), and for high-velocity clouds in general by Eichler (18.131.516).

The small-scale properties of high-velocity clouds have been discussed by Greisen and Cram (17.131.012), Davies *et al.* (17.131.020), Cram and Giovanelli (17.131.090), Giovanelli and Haynes (18.131.604 and 19.132.012), and Hulsbosch (1978b). Payne *et al.* (21.131.071) have derived temperature estimates over a wide range from the first absorption observations of absorption in high-velocity clouds.

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5. KINEMATICS

A. *Stars*

I. *Galactic Rotation*

From proper motions of stars in the N30 and FK4 system, Fricke (19.043.007) derived precessional corrections and values for Oort's constants of galactic rotation amounting to $A = +15.6 \pm 2.8$ km s^{-1} kpc^{-1} and $B = -10.9 \pm 2.8$ km s^{-1} kpc^{-1}. From an analysis of proper motions of AGK3 stars of $m_{pg} \geq 8.0$, Asteriadis (19.043.003) has determined the solar motion and Oort's constants of galactic rotation. Excluding O to B2 stars he finds $A = +16.1 \pm 1.9$ km s^{-1} kpc^{-1} and $B = -9.0 \pm 1.9$ km s^{-1} kpc^{-1}. Values for the O to B2 stars deviate significantly from these. Dieckvoss (21.112.001) made a similar analysis for A to K stars of $8^m_.0 > m_{pg} > 10^m_.9$ in AGK3 and the southern part of the Smithsonian catalogue and found $A = +13.4 \pm 0.7$ km s^{-1} kpc^{-1} and $B = -14.8 \pm 1.8$ km s^{-1} kpc^{-1}.

Tsioumis and Fricke (1978) have analyzed radial velocities, proper motions and distances of bright O and B stars as given by Lesh. They find for 600 pc < r < 2000 pc the values $A = +13.1 \pm 3.2$ km s^{-1} kpc^{-1} and $B = -13.2 \pm 3.4$ km s^{-1} kpc^{-1}, while young nearby stars belonging to Gould's Belt give remarkably different results that cannot be fitted into the common model of galactic rotation. Frogel and Stodders (20.155.056) analyzed space velocities of O-B5 stars in the solar neighborhood with the stars divided into members of the Gould Belt and the galactic belt. Conti *et al.* (19.112.006) have investigated the K-term for O stars. For single O stars they find a value of $+0.6 \pm 1$ km/s.

New radial velocities, spectral types and Hγ equivalent widths have been derived by Crampton *et al.* (18.155.010) for 16 stars on the solar galactocentric circle.

From a study of proper motions of field stars around low latitude clusters, Cudworth (17.112.002) has derived a solar apex close to that of the basic solar motion. Gomez and Mennessier (19.155.010) assuming the existence of a spiral pattern as given by Lin and Shu, correct the asymmetric drift relation to derive a value of 6 km/s for the peculiar solar motion component in the direction of the galactic rotation.

Using six independent dynamical methods Einasto *et al.* (1978) have determined the galactic circular velocity near the sun to be 220 ± 7 km/s.

FitzGerald and Jackson (18.155.054) have obtained *UBV* photometry, MK slit spectra and image tube radial velocities for about 50 extreme Population I groups of stars lying between 10 and 18 kpc from the galactic center. They find that the rotation curve flattens out beyond the solar vicinity, indicating a mass for the Galaxy at least two times the currently accepted mass.

Clube (1978a) has reviewed evidence relating to non-circular motions in the Galaxy. It is suggested that the phenomena originate by violent action in the galactic nucleus and that recurrent activity of this kind characterizes all massive galaxies (Bailey and Clube, 1978). Ovenden and Byl (17.155.037) from an analysis of radial velocities of about 1000 O and B stars, cepheids and open clusters find that the data are incompatible with a global expansion of the Galaxy. They find (Byl and Ovenden, 1978) that the data can be fitted to a spiral density wave pattern with a spiral inclination of $-4^\circ_.2$. Upgren (21.112.009) has calculated space motions for 145 dK2-M2 stars with radial velocities and with parallaxes and proper motions determined and published at the Van Vleck Observatory. They show a mean motion of the young stars outward away from the galactic center of about 10 km/s when referred to the old stars.

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Humphreys (17.155.038) has obtained new radial velocity data for 27 supergiants in the Perseus arm. A clear separation in velocity between the inner and outer sides of the arm is interpreted in terms of the linear density-wave theory as streaming motions between the sides of the arm.

Grosbøl (21.122.007) has calculated photometric distances, space velocities, and ages for B0-A0 stars of $m_V \leq 6^m.5$. These stars have been used by Grosbøl (1976) to investigate birthplaces of the stars and to derive the parameters of spiral structure from the density-wave theory. Some aspects of this work emphasizing kinematic selection effects and the effect of a galactic shock have been discussed by Lindblad (18.131.119).

Augensen and Buscombe (1978) have calculated plane galactic orbits for several southern high-velocity stars which possess parallax, proper motion, and radial velocity data. Moffat and Seggewiss (1978) find that of 11 WN7/WN8 stars all but one have normal radial velocities as predicted by galactic rotation.

Kinematic properties of a number of galactic populations have been determined (18.112.009, 18.155.037, Karimova *et al.* 1976). Loktin (1978) estimated the distance of the Sun from the galactic center, R = 8.1 kpc, by a kinematical method. A large number of proper motions of stars of various galactic populations have been determined by Karimova *et al.* (14.112.004, 007, 008, and 013) and Rakimov (1977) Balakirev (19.155.024) discovered a rolling motion of B-type stars around the line joining the Sun with the galactic center. Petrovskaya (18.155.042) and Haud (1978) studied the rotation of neutral hydrogen in the inner regions of the Galaxy. Mishurov *et al.* (1978) suggested a kinematic method of studying the spiral structure of the Galaxy.

II. *Velocity Distribution*

A compilation of kinematic data for stars of the HD and HDE catalogues will soon be available (Mennessier *et al.* 1978) in a computer-readable form. Proper motions have been reduced to the system of FK4.

A number of investigations have been concerned with the determination of velocity ellipsoids for various types of stars. Karinova and Pavlovskaya (17.112.004) have derived the velocity ellipsoid for B supergiants using new proper motions obtained in the FK4 system. Dieckvoss (1978) from a statistical study of proper motions in the AGK3 and the SAO catalogue for the southern hemisphere has derived velocity ellipsoids for A, F, and G stars in the photographic magnitude interval $9^m.0$ - $9^m.9$. Woolley *et al.* (19.112.003) have obtained radial velocities for G- and K-type stars in six galactic directions. Mean space motions for various distance groups and velocity dispersions are derived. Tsioumis (1977) has determined the velocity ellipsoid for the early type M-giant stars (M0-M4) of the solar neighborhood using photometric data by Blanco and FitzGerald and space velocities by Eggen.

Balakirev (17.155.009) in an analysis of z motions of K giants in the polar zones derives $W_0 = +6.5 \pm 1.5$ km/s with no variation with z. A discussion of the dynamical parameter C is included.

Clube (1978b) has reanalysed absolute proper motions of faint M stars in the region of the north galactic pole obtained by Jones and Klemola with the Lick astrograph.

Sion and Liebert (19.126.014) compare the kinematics of subsets of DA and non-DA white dwarfs. The DB white dwarfs do not differ kinematically from the DA stars in the same luminosity or color range.

Dean (18.112.001) has determined radial velocities and spectral types for 179 carbon stars. He concludes that the majority of the carbon stars are dynamically similar to dwarf F5 stars. Peralta (21.135.013) has analyzed radial velocities of planetary nebulae with $|b| \leq 12°$. He finds a maximum eccentricity of their orbits of 0.2 for the whole sample (excluding the group of high eccentricity objects in the direction of the galactic center). For type B nebulae the maximum eccentricity is 0.1. Johansson *et al.* (19.133.005), in an analysis of unidentified Type II OH/IR sources found in their survey, estimate the velocity dispersion at 30-35 km/s. They suggest that these sources are Mira variables.

Wielen (20.155.008) derived the relation between velocity dispersion and age. He suggests local fluctuations of the galactic gravitational field to be the cause of this diffusion of stellar orbits. Magnenat *et al.* (21.151.070) have investigated the age dependence of stellar velocity dispersion in the case of a scale covariant gravitation. Yoshii and Saio (1978) have investigated the kinematics of 220 high-velocity dwarfs, 532 low-velocity dwarfs, and 114 RR Lyrae variables in the model Galaxy with three-dimensional treatment. Velocity components are derived and the relations between them and ultraviolet excesses are discussed in terms of the galactic evolution. Mayor (17.155.017) draws attention to the hidden complexity of the relationship between mean eccentricity of stellar orbits and [Fe/H].

Mayor and Martinet (19.155.016) give a critical discussion on determinations of the initial mass function and time variations of stellar birthrates.

Burki and Maeder (19.155.027) find a variation of the axial rotation of B0-B4 main sequence stars with galactocentric distance R in the accessible part of the local arm which can be approximated by the relation $\langle v \sin i \rangle \approx +160-70(R-R_0)$.

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B. *Interstellar Matter*

I. *Large-Scale Motions*

From data obtained with a Lyman-alpha photometer on the Soviet probe Mars-7 Bertaux *et al.* (17.131.015) have derived the temperature and velocity of the local

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interstellar wind. Crovisier (1978) has analyzed the Nançay HI absorption survey to study the kinematics of neutral hydrogen clouds in the solar neighborhood. The solar motion relative to HI clouds is found to be close to the standard solar motion.

Burton (20.155.027) has reviewed the large-scale kinematics and distribution of interstellar hydrogen and CO. Burton and Gordon (21.155.004) combining HI and CO data derive a new galactic rotation curve applicable in the first longitude quadrant of the galactic equator. Sinha (1978) has derived a new rotation curve for the Galaxy based on HI data in the first and the fourth quadrants of galactic longitude. Bash and Peters (17.131.114) have observed CO along the galactic plane at $30° < \ell < 60°$. They find a systematic difference between CO and HI terminal velocities and try to interpret this in terms of velocities of stars born out of a spiral shock.

Crampton *et al.* (21.132.053) discuss radial velocities and distances of newly detected HII regions at $20° < \ell < 115°$. The data seem to confirm the existence of another arm beyond the Perseus arm.

Strauss and Pöppel (17.155.013) studied the velocity change with latitude of the nearest inner spiral arm. They conclude that a rolling or shearing in the arm is in concordance with observations while a lateral shift of the arm is not.

Sandqvist *et al.* (18.131.121) and Sandqvist and Lindroos (18.131.185) have observed HI self absorption, H_2CO and CH in dark clouds along the plane of Gould's belt. Franco and Pöppel (21.131.116) studied the 21-cm HI velocities in the region $348 < \ell < 12°$, $+3° < b < +17°$ and in particular the extended positive velocity feature A of Lindblad. From high dispersion spectra Rickard (14.131.031) examined radial velocities of CaII K lines for $345° < \ell < 28°$. Form stellar distances larger than 500 pc he finds a systematic velocity for strong K-lines of the value of +5 km/s in agreement with local HI data. Heiles (18.131.518) points out that higher latitude HI, when viewed in narrow velocity ranges, is concentrated in arcs. He concludes that much of the interstellar volume is contained within expanding HI shells.

Jenkins (21.131.019) has scanned the OVI 1032 and 1038 Å lines of 40 O and B stars with the Copernicus satellite. The highly variable OVI densities and velocities seem to exhibit no systematic patterns and show no correlation with pronounced features of galactic structure.

Studies of high-velocity hydrogen are discussed in Section 4D.

II. *Central Region*

Oort (20.185.058) in an extensive discussion reviews the relavant data on the galactic center.

Bieging (18.131.066) has mapped Sgr A and Sgr B2 in the 1667 MHz absorption line of OH. Two dense clouds with radial velocities +25 and +45 km/s are observed in the direction of Sgr A. Fifteen discrete OH condensations are seen in the direction of Sgr B2. Cohen and Few (18.131.042) have carried out a survey of OH in the galactic center region. Several new OH clouds are found in positions and velocities corresponding to HI features. The authors discuss the possible evidence for explosive events or of a central bar.

Cohen and Davies (17.155.011) analyze Cohen's HI observations from the galactic center region. Expansional components of motions up to 175 km/s away from the center are found, with a tendency for higher expansion velocities to occur nearer the center. The rotational velocities out of the plane decrease markedly towards the center. Cohen and Davies (in press) have later surveyed the region $-1° < \ell < +1°$,

$-1° < b < 1°$ for HI. Non-circular motions seem to be present in the nuclear disk and are obvious in a number of features close to the center. It is suggested that a central bar might be the cause of these. Grape (1978) has examined terminal velocities of HI for $|\ell| < 30°$. Assuming a kinematic model with circular symmetry, he derives by least square fit the rotational and expanding velocities as a function of distance R from the center, mainly for 0.8 kpc $< R < 2.5$ kpc. Sanders *et al.* (20.155.029) have mapped the HI emission for $-3° < \ell < +3°$ at $b = 0°$ with the 100-m Bonn telescope.

Liszt *et al.* (19.155.017) have mapped the region $-1° \lesssim \ell \lesssim +1°$ in the CO line for $b = 0°$, $+ 2°$, $+ 4°$. Bania (20.155.009) has made a CO survey for $352° \lesssim \ell \lesssim 10°$ at $b = 0°$. The last-mentioned feature is consistent to a certain extent with a rotating and expanding kinematic ring, the so-called "molecular ring", but the pattern is incomplete as no connecting ridge can be discovered at $\ell = 1°$. On the other hand Burton and Liszt (1978) postulate a central disk of radius 1.5 kpc and scale height 0.1 kpc, which is tilted 22° with respect to the plane $b = 0°$ and 78° with respect to the plane of the sky. Within the disk the kinematics involve rotation and expansion of approximately equal magnitude, ~ 170 km/s.

Pauls (18.131.277) has observed radio recombination lines within 10' of the center. The strongest lines have velocities of -40 km/s with respect to the LSR.

Mirabel and Franco (18.131.505) have detected an HI object at $\ell = 8°$, $b = -4°$ with a radial velocity of -212.3 km/s. They conclude that this object has been ejected from the galactic nucleus.

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6. DYNAMICS

A. *Stellar Orbits - Third Integral*

Although important work has been done on stellar orbits in axisymmetric potentials, the majority of papers deal now with orbits in spiral or barred galaxies.

I. *Axisymmetric Galaxies and General Problems*

Martinet (14.155.013) and Martinet and Mayer (14.155.042) carried out a comparative study of the orbital behavior in various axisymmetric mass models and concluded that a third integral exists for most stars in our Galaxy. Agekyan and Yakimov (18.151.049) and Agekyan (18.151.030, 22.151.048) studied various properties of orbits in a rotationally symmetric potential. Osipkov (18.151.002, 005, and 016, 19.151.039, 19.155.011, 20.151.069) continued his studies on the third integral and related topics. Baranov and Volkov (20.151.035) considered the existense of additional integrals of motion in clusters. Contopoulos has studied and reviewed recent problems connected with the integrals of motion and their disappearance (1978 a, b, c, d).

II. *Spiral Galaxies*

Orbits in spiral potentials in general: Berry and De Smet (21.151.063) constructured surfaces of section for orbits in the spiral model of Barbanis and Woltjer and found well-defined invariant curves for nearly all orbits calculated. Schwerdtfeger (20.151.015) studied numerically periodic and other stellar orbits in the density-wave model. Frahm and Thielheim (21.151.013) discussed the persistence of spiral structure in the context of the position probability of stars along individual orbits.

Orbits at the Lindblad resonances: Orbits near the inner Lindblad resonance have been calculated by Mertzanides (18.151.012) and by Monet and Vandervoort (21. 151.017). In general, analytic approximations confirm the numerically obtained results. On the basis of orbit calculations, the density response at the inner Lindblad resonance has been discussed by Contopoulos and Vandervoort: While Contopoulos (21.151.115, 1978 e, f) stressed the strong four-armed component of the response and the corresponding problems for a self-consistent solution, Vandervoort (21.151.020) constructed self-consistent stellar-dynamical models of the region of the inner Lindblad resonance by using special prescriptions for populating and depopulating the two principal families of resonant orbits. Vandervoort's models (1979) are linearized in the amplitude of the spiral structure, but they retain the nonlinear effects intrinsic to the resonance phenomenon and extend the asymptotic theory of stellar density waves into the resonance region.

Orbits at the corotation resonance: Periodic orbits near the particle resonance were studied both theoretically and numerically by Contopoulos (21.151.039) and Papayannopoulos (1977). Barbanis (17.151.009) and Mennesier and Martinet (21. 151.054) investigated numerically the trapping of orbits around the stable Lagrangian points. The corresponding density response is largest at the maximum of the spiral potential and causes difficulties for a self-consistent model at the corotation region. Bertin, *et al.* (20.151.032) proposed a detrapping of the banana-type orbits by a gravitational scattering due to standing modes.

III. *Barred Galaxies*

Stellar orbits in galaxies with a bar or an oval distortion have been studied by various authors. Contopoulos and Mertzanides (20.151.041) calculated orbits near the inner Lindblad resonance for a barred galaxy. Vandervoort (21.151.102) investigated orbits in a uniformly rotating galactic bar and studied the existence and accuracy of additional integrals beside the Jacobi constant. Schwarzschild (21.151.097) found numerical evidence for three effective integrals in the case of a non-rotating triaxial stellar system. Smith and Miller (21.151.103) studied the particle motions in a self-consistent prolate bar.

IV. *Relaxation*

Wielen (20.155.008) derived quantitatively the diffusion of stellar orbits, which is probably caused by local irregularities of the galactic gravitational field, on the basis of the observed increase of the stellar velocity dispersion with age. The derived short relaxation time of disk stars has been interpreted by Stark and Blitz (1978) as due to the gravitational effect of giant molecular cloud complexes.

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B. *Models of the Galaxy*

The possible existence of a massive corona around the Galaxy has given rise to a revision of the system of galactic constants and mass distribution models.

In earlier studies the standard value, $V_o = 250$ km s^{-1}, has been adopted for the circular velocity in most models. Yahil *et al.* (20.160.033) and Lynden-Bell and Lin (20.155.019) have found the solar motion relative to the centroid of the Local Group, V(LSR) = 300 km s^{-1}, and suggested that most of this value is due to the solar motion within the Galaxy. Einasto *et al.* (1978a) and Knapp (1978), applying a variety of different dynamical methods, have found $V_o = 220$ km s^{-1}. This value corresponds to the motion of nearby companions of the Galaxy (R between 25 and 250 kpc); more distant members of the Local Group lead to the solution 380 km s^{-1}. The difference 160 km s^{-1} can be attributed to the velocity vector of the Galaxy.

Adopting $R_o = 8.5$ kpc, $V_o = 220$ km s^{-1} and a flat rotation curve at the V = 200-220 km s^{-1} level beyond R_o, Einasto *et al.* (1978a, b) constructed a new mass distribution model. The mass of visible galactic populations is $8 \times 10^{10} M_\odot$, the mass of the corona is $2 \times 10^{12} M_\odot$ and the escape velocity near the Sun is V_{esc} = 600 km s^{-1}. Ostriker and Caldwell (1978) adopted $R_o = 9$ kpc, $V_o = 247$ km s^{-1} and a flat rotation curve at the V = 170 km s^{-1} level. They found for the mass of visible galactic populations $1.5 \times 10^{11} M_\odot$, for the mass of the corona $2 \times 10^{12} M_\odot$ and for the escape velocity near the Sun 550 km s^{-1}. For both models projected densities, masses interior to the given radius R, the gravitational potential and its gradients have been found. For the Einasto model all hydrodynamic functions have also been calculated.

Einasto *et al.* (18.155.027) and Zasov (19.158.099) suggested that the disk of our Galaxy has a hole in the center, the density dropping to zero at R = 0. Such a model is stable if a compact bulge is present (Berman and Mark, in press).

Mass distribution models for M31 have been calculated in a number of papers (18.158.015, 19.158.061 and 185, Einasto *et al.* 1978c).

Methods of galactic mass modelling have been discussed in many papers (17.151.012 and 020, 17.158.089, 18.151.006 and 069, 18.158.189, 19.151.005 and 007, 19.158.095). Clutton-Brock *et al.* (20.151.062) suggested a simple analytic formula for the gravitational potential which produces economy for orbit calculations. Hydrodynamical functions for the model of the Galaxy (17.151.026) have been calculated by Satoh and Miyamoto (18.151.047). The construction of phase models of self-gravitating disks was discussed by Osipkov (21.151.064).

Theoretical problems of the modelling of gravitating systems have been discussed by Kalnajs (17.151.039 and 040), Bagin (17.151.006), Bisnovatyi-Kogan and Zel'dovich (18.151.068), Davoust (20.151.034) and Polyachenko (18.151.072).

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C. *Spiral Structure*

I. *Reviews*

The density-wave theory seems to be the most convincing dynamical explanation of the observed spiral structure of galaxies. Reviews on recent developments, theoretical problems and observational confrontations of the density-wave theory have been given by Kalnajs (21.151.069), Lin (18.151.020, 20.151.053), Roberts (17.155.055, 20.155.027), Rohlfs (20.003.139, 22.151.028), Schmidt-Kaler (17.155. 054), S. E. and K. M. Strom (21.151.067), Toomre (20.151.043) and Wielen (1979a, b).

II. *Spiral Modes, Origin and Maintenance of Spiral Structure*

Spiral density waves represent special cases of more general perturbations of stellar and gaseous galactic disks. The mathematical tools for studying modes in galactic disks have been improved by Kalnajs (17.151.039 and 040, 19.151.013), and Berman and Mark (20.151.009, 1978). Bertin and Mark (21.151.040) studied the behavior of spiral density waves in the regime where effects of the finite inclination of spiral arms are important. Norman (21.151.003) developed a non-linear theory of density waves in the tight-winding approximation.

Lin and his colleagues concentrated their efforts on explaining the origin and the maintenance of spiral structure by growing spiral modes. These discrete growing spiral modes have been calculated according to the asymptotic theory by Lau *et al.* (17.151.057), Mark (19.151.016), Bertin *et al.* (21.151.125). Mark discussed especially the reflection and amplifiction of travelling waves at the resonance regions (17.151.005 and 035). The amplifying effects can be greatly enhanced by the action of tangential forces (Lau and Mark 18.151.045, Lau and Bertin 20.151.012) or by interactions with the bulge-halo subsystem (Mark 17.151.055).

Zang (1976) and Toomre (20.151.043) have studied unstable global modes, unrestricted by the asymptotic approach, for galaxies with a flat rotation curve. Pannatoni (1978) has carried out such global modal calculations for general rotation curves. Bardeen (14.151.026) has carried out extensive numerical computations of unstable global modes in gaseous disks. Goldreich and Tremaine (21.151.060) developed analytical techniques for dealing with the excitation and evolution of density waves in a self-gravitating gas sheet, including resonance and corotation.

Hills (18.155.078) suggested as a possible origin of the spiral-arm instability the perturbation of the virial equilibrium by the cooling of the gas due to collisions. Various aspects of the excitation and maintenance of density waves have been investigated by Yueh (19.151.025), Hu (20.151.022), Fang *et al.* (19.151. 024), Korchagin (17.151.037, 18.151.080), Korchagin and Marochnik (18.151.026), Mishurov and Suchkov (17.155.010), Maksumov (17.151.048, 18.151.079), Maksumov and Mishurov (17.151.047), Nuritdinov (18.151.075), Ptitsyna (17.151.045), Maldybaeva and Ptitsyna (17.151.051), Kaplan *et al.* (22.151.022), Mikhailovskij *et al.* (1977), Morozov (22.151.024), Iye (22.151.015), and Takahara (22.151.016).

Feitzinger (14.155.068) studied the influence of the Magellanic Clouds on density waves in our Galaxy. Athanassoula (1978) discussed the spiral density wave induced in a disk galaxy by an orbiting retrograde companion and found a dominant one-arm spiral.

Beside the density-wave theory, there are still many other proposals for generating the spiral structure of galaxies: Explosive origins of spiral structure have been discussed by Barricelli and Havnes (17.151.019) and Schmidt-Kaler (21. 155.049). The propagation of a magnetohydrodynamical wave emitted from the galactic center region has been computed by Sofue(20.155.013) in order to explain the

3-kpc expanding arm. Jaaniste and Saar (18.151.024, 22.151.021) proposed an accretion theory of the spiral structure, based on the infall of gas onto a galactic disk. Self-propagating star formation has been proposed by Mueller and Arnett (18.158.172), Gerola and Seiden (21.151.075) and Davis *et al.* (21.151.096) for obtaining spiral structure in galaxies as far as young stars are concerned.

III. *Gas Flow and Shocks*

Roberts (21.151.108) reviewed the dynamics of the gas in spiral galaxies. Shu (21.155.028) discussed the implications of hot gas on galactic shocks. Van - dervoort and Keene (22.151.020) studied the relationship between gaseous streamlines and periodic stellar orbits and the occurrence of shocks. Nelson and Matsuda (19.155.035) studied the stability of galactic spiral shocks. Sawa (20.151. 073) examined the effect of the self-gravity of the gas on galactic shock waves in a cylindrical model of a galaxy and found that the self-gravity strengthens the shock. Kato (20.151.006) suggested that non-adiabatic processes in the gas behind the shock front amplify the density wave. Woodward (18.131.025) calculated the implosion of interstellar gas clouds after they encounter the galactic shock front.

A rather new field has been opened by studying the gas flow and the shock fronts in galaxies with bars or oval distortions. Sørensen *et al.* (18.158.065) investigated the formation of large-scale shock waves in barred spirals. Sanders and Huntley (18.151.014), Sanders (20.151.028) and Huntley *et al.* (21.151.019) calculated the response of rotating disks of gas to bar-like perturbations or weaker oval distortions of the galactic potential. Liebovitch and Lin (21.151.027) studied the case where the perturbing potential is bar-like in the interior and spiral-like in the exterior of the galaxy.

Waxman (21.151.032 and 041) investigated possible consequences of the interaction of a rotating gaseous disk with a more slowly rotating gaseous halo. The resulting flow is a boundary-layer circulation and is vulnerable to a shear-flow instability. Some waves exhibit coherent, large-scale spiral structure.

IV. *Observational Aspects*

Wielen (1979a) has reviewed the comparisons between relevant observations and the density-wave theory, and emphasized that the behavior of young objects, predicted by the density-wave theory with shocks, is quite complicated. Reiche (21. 151.038) discussed the possibilities of observing density-wave effects in galaxies. Sawa (21.155.021) has developed theoretical predictions for the 21-cm profiles of HI in our Galaxy on the basis of shock waves. Wielen (1979a, c) predicted the behavior of giant HII regions in the observed velocity-longitude diagrams. The drift and broadening of ageing spiral arms have been theoretically studied by Schwerdtfeger (20.151.015) and Wielen (20.151.017, 1978, 1979a) for our Galaxy and for M51. The comparison with observational data seem to favor the formation of stars out of clouds which exist already before the shock front and move essentially with the pre-shock gas velocity. Bash *et al.* (20.155.015) and Bash (21.155.015) gave an interpretation of the observed distribution of galactic molecular clouds on the basis of post-shock velocities. Gordon (21.155.020) determined a spiral pattern speed of 11.5 km s^{-1} kpc^{-1} for our Galaxy from the spatial distribution of carbon monoxide.

Schmidt-Kaler and House (17.155.021) explained the filaments inclined to the galactic plane, observed in the next-inner spiral arm, in terms of self-consistent z-oscillations of the galactic disk.

Lin *et al.* (1978) have studied the effect of shock waves in HI on the determination of the local galactic differential rotations. Because of the special location of our Sun between the two principal spiral arms, the local values of Oort's constants A and B do not differ significantly from the axisymmetric average values. Lin and Yuan (13.155.037) and Wielen (1979a) discussed the effects of density-wave motions on the conventionally adopted local standard of rest.

Places of formation of now nearby objects have been obtained in order to study the history of spiral structure in our Galaxy and to determine the parameters of the density-wave pattern. Grosbøl (1976, 21.155.060) studied the birthplaces of B and A stars and obtained two possible values for the angular velocity of the spiral pattern, namely $\Omega_p = 14$ or 32 km s^{-1} kpc^{-1}. Birthplaces of open star clusters have been determined by Forte and Muzzio (18.153.019) and by Palouš *et al.* (20.153.011). The focussing effect of orbits of stars of a common origin in the presence of a density wave has been discussed by Yuan (19.151.030), by Yuan and Waxman (19.151.031) for the Pleiades group and by Grosbøl (19.155.029) for nearby B5-A0 stars.

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D. *Stability and Evolution*

For reviews and conference proceedings on stability and evolution, see 17.151.064 and 065, 17.155.055, 18.003.026, 18.012.002, 011, and 043, 18.151.046, 19.003.001 and 140, 20.151.043 and IAU Symp. 77.

I. *The Stabilizing Effect of Massive Halos*

This continues to be of great interest. The observational situation is reviewed by Faber and Gallagher (*Ann. Rev. Astron. Astrophys.* 1979). See also Section 6E for relevant numerical experiments.

Durisen (1978) studied the stability of McLaurin spheroids embedded in rigid uniform spherical halos. The dynamic barlike modes were suppressed when the ratio of halo to spheroid mass was large enough ($\sim \frac{1}{2}$ to 1, depending on geometry). However the secular instability was not completely suppressed. There was no simple general parameter characterising the instability points. Takahara *et al.* (18.151.083 and 21.161.010) discussed the collective instabilities of disk-halo systems. Berman and Mark found that the bar instability can be suppressed by a compact nuclear bulge, thereby separating the question of the existence of massive extended halos from the stability of the disk. Lucy (17.151.004) showed that, if the halo is to be the major mass contributor within the solar circle, the local density of halo stars $\sim 0.007\ M_\odot\ pc^{-3}$, which is not inconsistent with the observations.

II. *Spiral Modes*

The excitation, maintenance and stability of spiral waves in disk galaxies remains an active area. The role of wave angular momentum sources in amplification was stressed by Mark and associates. The circular rotation of the disk is an abundant angular momentum source (17.151.035). Amplification can occur through transfer of angular momentum from the disk to the bulge (17.151.055); this is more efficient for more open waves. Self-excitation can occur through waves propagating away from corotation carrying angular momentum of opposite sign to that in the wave system inside corotation (17.151.057). Effects due to differential rotation and tangential forces (18.151.045) and finite spiral arm inclination (21.151.040) were also studied.

The evolution of density waves from the unstable stage to the quasistationary phase was considered by Yueh (19.151.025). Fang *et al.* (19.151.024) discussed the role of star formation in the excitation and maintenance of spiral arms. Li *et al.* (18.158.182) used a second asymptotic approximation to derive the density wave amplitude over the whole disk. Hu (20.151.022) showed how the dispersion relation for marginally stable density waves is affected by the corotation singularity. Goldreich and Tremaine (21.151.060) studied the evolution of a wave packet, using a simple analog of a rotating disk.

Several authors studied the existence and maintenance of discrete spiral waves in disks (19.151.016; Kaplan *et al.* 1978; Polyachenko and Shukhman 1978; Lau and Bertin 1978). Berman and Mark (20.151.009) developed a formalism which allows close comparison between collective behavior and individual stellar orbits for disturbances in thin disks. Yue (20.151.054) showed that the evolution of unstable density waves as determined from stellar and fluid dynamics gives similar results. Ikeuchi (20.151.051) studied resonant three-wave interactions of density waves.

Nelson and Matsuda (19.155.035) showed that one-dimensional galactic shocks were stable over several rotations. Kato (20.151.006) found that nonadiabatic acceleration of clouds behind the galactic shocks can amplify the density wave against damping due to the shocks. Evangelides (20.151.058) studied density wave-star interactions, and found a resonance which can be unstable. Bertin *et al.* (20.151.032) showed how standing modes near corotation can have a fairly strong detrapping effect on trapped orbits, which can affect the growth and saturation of spiral waves.

Mueller and Arnett (18.158.171) suggested that propagating star formation can produce large-scale spiral-shaped regions of star formation; high-mass stars produce spherical shock waves which in turn produce further star formation. Gerola and Seiden (21.151.075) pursued this concept using stochastic star formation, and showed how differential rotation leads to a continually regenerating spiral structure of realistic appearance.

Hills (18.155.078) suggested that the spiral arm instability may result from the galaxy not being in dynamical equilibrium. Ambastha and Varma (21.151.095) discussed accretion-induced overstability of density waves. Norman (21.151.003) showed that nonlinear density waves do not tend to wind up; these could apply to the smooth spiral waves described by Strom *et al.* (17.158.095). Ikeuchi and Nakamura (18.151.081) studied the nonlinear modulation of density waves; nonlinear effects cannot be neglected. Morozov (1978) suggested that the gaseous component of a flat galaxy with a massive flat nucleus is unstable to the Kelvin-Helmholtz instability, which would lead to trailing spiral arms.

Vandervoort and associates have made an extensive study of the dynamics of spiral structure near the Lindblad resonance (Vandervoort and Keene 1978; 21.151.017 and 020). Contopoulos (20.151.072) and Contopoulos and Mertzanides (20.151.041) investigated the properties of orbits near the particle resonances. Mennessier and Martinet (21.151.054) discussed conditions for trapping orbits at corotation resonance for slow introduction of the spiral perturbation.

III. *Other Stability Investigations*

Antonov and associates studied the stability of two-dimensional systems. A flat McLaurin disk is unstable, although a superposition of disks of different angular velocities can be stable (17.151.043). Stability conditions were found for nonlinear nonradial homogeneous oscillations of these systems (20.151.002). Tremaine (17.151.042) and Nishida and Ishizawa (20.151.038) investigated the stability of Freeman's elliptical stellar systems; they are mostly stable to low order perturbations. Marcus *et al.* (19.062.042) calculated the stablest axisymmetric shapes for incompressible fluids with the same angular momentum distribution as the McLaurin spheroids.

Maksumov described the drift instability associated with differential rotation in an axisymmetric system (17.151.046; see also 17.151.047 and 048, and 20.151.004). Cantus *et al.* (1978) and Gillon *et al.* (17.151.034) found general conditions for the stability of two-dimensional uniformly rotating systems and for spherical systems respectively. Mishurov *et al.* (17.151.038) showed how the instability of gravitating rotating viscous gaseous protosystems can lead to ring structures in galaxies. Kato and Inagaki (1978) found that a weak bar can produce a ring structure near corotation. Korchagin (17.151.037) considered the response of a disk to a central bar: again a ringlike structure is generated near corotation. Aoki (17.151.066) investigated nonlinear effects on the Jeans criterion in isothermal systems.

Athanassoula (21.151.045) calculated explicitly the bar modes for a special uniformly rotating disk. Zweibel (21.151.042 and 043) constructed a new sequence of cool self-gravitating stellar disks and studied their axisymmetric stability. Kalnajs (19.151.013) discussed the integral equation for the normal modes of a disk system when Poisson's equation is solved by biorthonormal expansions. Hunter has derived a closed system of hydrodynamical equations for describing the dynamics of perturbations of thin disk galaxies. Hansen *et al.* (18.151.008) studied the stability of uniformly rotating isothermal gas cylinders. Inagaki and Hachisu (21.151.014) investigated the thermodynamic stability of rotating gaseous cylinders. Nakano and Nakamura (in press) studied the stability of an isothermal gaseous disk with a perpendicular uniform magnetic field.

Lovelace and Hohlfeld (21.151.016) showed that flat galaxies can be unstable when the angular momentum distribution function f has a turning point in radius. This could drive the galaxy towards a radially uniform f, and they show that f is indeed approximately uniform in the Galaxy and in M31. Staller (18.155.003) showed that the velocity dispersion for M dwarfs is greater than the minimum required for the local stability of the galactic disk.

Abramyan and Kaplan (18.158.211) discussed the equilibrium and stability of a uniformly rotating interstellar medium in a spheroidal galaxy. Fujimoto and Sørensen (20.151.008) studied the fission of elongated rotating gaseous disks. Shocks form along the major axis, and lead to a pearshaped deformation which then divides into independent objects. Hunter and Tremaine pointed out (19.151.028) that collinear configurations of galaxies can be stable, for a massive primary with two satellites. Biermann and Smith (19.155.015) studied the evolution of the galactic disk: its length scale is increasing with time.

Saslaw (20.151.010) showed how increasing central concentration, as a galaxy evolves, segregates orbits by eccentricity. Antonov *et al.* (17.151.052) studied the motion of stars during the collapse of a freefalling sphere; energy exchange between escaping stars and the remainder leads to more rapid collapse. Hara and Ikeuchi (19.151.043) discussed the formation of a massive nuclear disk of gas from gas supplied by stellar mass loss. Waxman considered the stability of the boundary layer circulation in disk-halo galaxies.

IV. *Warps*

It seems fairly clear that the HI disks of most galaxies show warps (18.158. 154): see however Byrd (21.158.172) for another opinion. The theoretical problems of maintaining warps against dispersive effects are reviewed by Binney (21. 151.059), who discussed the role of heavy halos in generating twisted and warped disks. Mark and Bertin found that the presence of a moderate bulge component drives warping motions in galactic disks. Fujimoto and Sofue (17.151.021) and Spight and Grayzeck (19.155.018) showed how at least some properties of the galactic warped disk can be understood as the result of interaction of the Galaxy and the LMC. Polyachenko (1978) discussed the hose-pipe instability in gravitating systems, and its application to the galactic warps. Nelson (17.155.001) studied large-scale hydrodynamic oscillations of the galactic gas layer; modes odd in z have properties similar to the observed corrugations of the galactic HI layer.

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E. *Computer Simulations*

Several authors have used simulations to test the stabilizing effects of velocity dispersion and massive halos on disk galaxies. Miller studied the early growth of disturbances in axisymmetric disks (1978a): the growth rates decrease linearly with increasing velocity dispersion. He also investigated the effects of a massive halo (1978b): a stable disk must have nonzero velocity dispersion, even in a massive halo, and stability requires an uncomfortably large halo mass or velocity dispersion. He finds that the $t < 0.14$ condition is not entirely adequate for defining stability. Hohl (17.151.015) showed how a halo of about 40 to 60 percent of the total mass is sufficient to stabilize the bar-forming modes. Hohl's three-dimensional simulations (1978) again showed the stabilizing effect of core/halo; also, the growth rate of the bar mode is significantly slower than in two-dimensional models. Zang and Hohl (1978) found that retrograde stars in disks can inhibit but not eliminate the bar-forming modes.

Numerical simulations were also applied to spiral structure theory. Berman *et al.* (1978) made three-dimensional models which showed several short-lived bisymmetrical waves, not adequately described by theory. Miller (18.151.007) showed that a wide variety of initial conditions leads to two-fold symmetries and hence the predominance of two-armed spirals. He also estimated the growth rates for axisymmetric disturbances in disk galaxies: these do agree adequately with those from the Lin-Shu dispersion relation (Miller 1978c). James and Sellwood's (21.151. 002) simulations showed bar formation and variable spiral structure. Sanders and Huntley (18.151.014) studied the response of gas to an oval distortion of the background disk: the gas forms an open two-armed trailing spiral wave rotating with the angular velocity of the distortion (see also 20.151.028). Huntley *et al.* (21.159.019) made similar experiments for waves driven by a central rotating bar. Shock waves in the gas flow in a bar-plus-disk potential were simulated by Sørensen *et al.* (18.158.065). Barbanis studied the density maxima formed by trapped orbits in a model spiral potential (17.151.009). Clairemidi performed numerical studies

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of the generation of spiral structure by ejection of a massive body from a galactic center.

van Albada and van Gorkhom (19.151.012) simulated the direct collision of two polytropic stellar systems. White (1978) investigated the mergers of galaxy pairs; tidal effects cause merging when the two galaxies overlap significantly at closest approach. Elliptical galaxies and the bulges of spirals may form in this way: see 20.012.005; Larson and Tinsley (in press).

Brahic has modelled systems of colliding bodies in a gravitational field. These interact through inelastic collisions (17.151.059, 19.151.014).

Binney pointed out (18.158.060) that the flattening of E galaxies is not necessarily due to rotation. It could result from the violent relaxation of pancakes of stars. Aarseth and Binney (1978) then showed how triaxial systems can result from aspheric initial conditions. Miller (21.151.074) simulated the free collapse of a rotating sphere of stars. A hot prolate bar results, which again suggests that many E galaxies are probably prolate, rotating about a short axis.

For reviews of work on detailed numerical simulation of galaxy formation, see 18.151.044 and 20.162.052.

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F. *Magnetic Fields, Pulsars, X-Ray and γ-Ray Sources*

Reviews of the galactic magnetic field are given by Heiles (20.156.012) and Spoelstra (1977). Measurements of the optical linear polarization for 5097 stars, including the southern hemisphere measurements of Schröder (17.156.001), have been collected and catalogued by Axon and Ellis (18.131.216). Magnetic lines of force are parallel to the local spiral arm near the Sun, and field fluctuations of the same magnitude are superposed.

In radio waves, new analyses of Faraday rotation of pulsars (Ruzmajkin and Sokolov 20.156.018) and of extragalactic radio sources (Carvalho and ter Haar 20. 156.017) have been made. The results are consistent with previous work (e.g., Heiles 20.156.012), and the field strength is $2-3\times10^{-6}$ gauss. A magnetic halo is also suggested in our Galaxy by Sofue *et al.* (1978) from the analysis of Faraday rotation of extragalactic radio sources and pulsars.

The large-scale structure of the magnetic field, which is not known in our Galaxy, becomes clear in some spiral galaxies by detailed measurements of radio polarization by Segalovitz *et al.* (18.158.161) and Beck *et al.* (1978) and studies of M51 data by Tosa and Fujimoto (1978). The study of M51 data by Tosa and Fujimoto (1978), suggest the presences of a well-ordered magnetic field parallel to the arms.

Paul *et al.* (18.155.004) and Badhwar and Stephens (19.156.003) have constructed models of the disk of the Galaxy which contain the magnetic field and cosmic rays to explain the nonthermal radio emission and γ-rays. Ichimaru (18.062.014) discussed magnetohydromagnetic turbulence in a rotating disk plasma and applied it to the Galaxy, providing an account of the observed magnetic energy density.

Three extensive pulsar surveys (the Molonglo survey, the Jodrell Bank survey and the University of Manchester-Arecibo survey) have increased the number of pulsars up to more than 150 whose period, luminosity at 400 MHz and dispersion measures are determined. The data indicate that the mean interstellar electron density is $\langle n_e \rangle = 2\text{-}3 \times 10^{-2} cm^{-3}$ and the birth rate of pulsars is one per 6-40 years. The total number of active pulsars is $1\text{-}6 \times 10^5$, taking into account the beaming effect (Taylor and Manchester 20.141.502 and 532). The high-latitude distribution of pulsars of $\langle |z| \rangle = 200\text{-}300$ pc is reconfirmed which is consistent with their high average space velocities in excess of 100 km s^{-1}, determined by proper motions.

Two acceleration mechanisms, the slingshot of runaway stars from disrupting binary systems proposed by Blaauw and the asymmetric radiation reaction on a rotating neutron star with off-centered oblique magnetic dipoles (Harrison and Tademaru 14.141.331, Helfand and Tademaru 20.141.512) have been examined through statistics of the polarization plane, the direction of proper motion of pulsars and their original site at supernova explosions (Morris *et al.* 17.141.321, 1978 and Tademaru 13.141.532).

After the discovery of X-ray sources in globular clusters by Giacconi *et al.* (11.142.035), seven globular clusters have been identified as X-ray emitters and two or more of the 30 X-ray bursters are found in globular clusters (Grindlay 20.142.060, Lewin 19.142.084, Lewin and Joss 20.142.069). Two classes of models have been proposed: binary star systems in which a normal primary transfers gas to a compact secondary, and supermassive black holes (100 to 1000 $M_\odot$) which may be located at the centers of globular clusters. The black hole model stimulates new dynamical interest in the final evolutionary state of globular clusters (Bahcall and Wolf 18.066.020, Shapiro and Lightman 18.151.009, Lightman and Shapiro 19.151.002, and Ipser 21.151.062) and also in nuclei of active elliptical galaxies such as M87 observed by Young *et al.* (21.158.111) and Sargent *et al.* (21.158.112).

As suggested theoretically by Cox and Smith (11.125.028), the hot interstellar medium (HISM) of more than 10^6K has been found by the diffuse component of soft X-rays as reviewed by Tanaka and Bleeker (20.142.129), and Kraushaar (19.142.163). The high temperature is considered as being maintained by repeated heating by supernova remants which are observed to be extended soft X-ray sources. The X-ray features are interpreted in terms of supernova remnant models (Clark and Culhane 17.125.023). Since half of the volume of interstellar space is occupied by the HISM, it must contribute to the global dynamics of gas in the Galaxy; perhaps the high-velocity hydrogen gas in the northern hemisphere, and the rising and falling motions of hydrogen gas above the Perseus and the distant spiral arms may be related to the HISM.

Since the pioneering work of Kraushaar *et al.* (08.142.081) with their OSO-3 satellite experiment in 1972, more detailed observations of diffuse γ-rays have been made of the Milky Way with the SAS-2 satellite experiments (Fichtel *et al.* 13.061.039) and the European COS-B satellite (Paul *et al.* 21.157.003). Analyses of the data (Fichtel *et al.* 18.143.014, Paul *et al.* 18.155.004, Stecker 19.157.001, Kniffen *et al.* 20.157.001) have given vast information about Galaxy-scale distributions of the cosmic-ray electrons and nucleons, interstellar matter and magnetic fields.

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7. GALACTIC ENVIRONMENT

A. *Optical Companions*

There are 20 known optical companions of the Galaxy between 25 and 250 kpc from the galactic center. These companions, together with the Galaxy as the main galaxy, intergalactic matter and a massive corona form an interacting system which can be called our Hypergalaxy. In order of increasing hypergalactic longitude, these companions are: Draco (= DDO 208), NGC 6229, Pal 14, Pal 1, UMi (= DDO 199), Pal 4 (= UMa), Pal 2, NGC 2419, Leo II (= DDO 93), Leo I (= DDO 74), Pal 3 (= Sex C), Carina, Eridanus, LMC, SMC, Fornax, Sculptor, Pal 12, Pal 13 (= Peg), and NGC 7006.

Optical companions are strongly concentrated to the hypergalactic equator. After translating the center of coordinates from the Sun to the galactic center, twelve objects have hypergalactic latitudes less than 6° (Kunkel, in press). The hypergalactic plane is highly inclined to the galactic plane (68°) as well as to the plane of the Magellanic Stream (35°) and the plane of the Local Group (48°) (18.155.027, Kunkel, in press).

Companion galaxies are segregated according to their morphological types: Spheroidal companions populate the inner regions, and irregular companions are located far from the main galaxy (17.158.025). A large range in metal-line strengths exists among stars in companion galaxies (Cowley *et al.* 21.114.010).

B. *High-Velocity Clouds and Streams, Gaseous Corona*

To obtain complete data on high-velocity hydrogen clouds (HVC) Hulsbosch (1978a, b) has carried out a new high-sensitivity survey in the velocity range $\pm$ 1000 km s^{-1}. A large number of small low intensity HVCs have been detected; most of them have negative radial velocities.

Many HVCs form long streams as the Magellanic Stream in the southern hemisphere (19.159.017) and Stream A in the northern sky (13.131.126). In some clouds steep edges have been observed which look like shockfronts (19.132.012, 20.159.003). Also around some other spiral galaxies extended HI regions have been detected (20. 158.059, 19.158.049).

C. *Massive Corona*

The mass of the galactic corona and of the Local Group has been estimated by several methods. Materna and Tammann (18.160.031) derived the mass of the Local Group from the velocity dispersion of its members and concluded that it can be stabilized with conventional masses of galaxies. Using the relative velocity of the Galaxy with respect to M31 and adopting the solar circular velocity in the Galaxy $V_o \simeq 300$ km s^{-1}, Yahil *et al.* (20.160.033) and Lynden-Bell and Yahil (20. 155.019) found lower limits of the mass of the system (Galaxy + M31) of $3 \times 10^{11} M_\odot$ and $9 \times 10^{11} M_\odot$, respectively. Einasto *et al.* (1978a) adopted $V_o = 220$ km s^{-1}, the total velocity of the Galaxy $V_{tot} = 170$ km s^{-1}, and the age of the system 15×10^9 years, thus the total mass will be $\simeq 6 \times 10^{12} M_\odot$.

The velocity dispersion of companions of the Galaxy was used by Einasto *et al.*

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(18.160.040) and by Hartwick and Sargent (21.155.013) to derive the mass of the Galaxy with its corona within the radius $R = 60$ kpc: $M(60) = 3.4 \times 10^{11} M_\odot$ for predominantly radial and $M(60) = 7.6 \times 10^{11} M_\odot$ for isotropic velocities.

The velocities of the clouds of the Magellanic Stream have been also used to derive the mass within $R \simeq 60$ kpc. The result depends on the adopted circular velocity V_0 and on the perigalactic distances; values between $3 \times 10^{11} M_\odot$ and $8 \times 10^{11} M_\odot$ have been found (Lin and Lynden-Bell, 20.151.026, Kunkel, in press).

Gunn, Knapp and Tremaine (in press), and Jackson *et al.* (1978) have demonstrated that our Galaxy has a flat rotation curve approximately at the $V = 220$ km s^{-1} level. Adopting a flat rotation curve and outer radius of the corona 250 kpc Ostriker and Caldwall (1978) and Einasto *et al.* (1978b) have derived the total mass of the Hypergalaxy $\simeq 2 \times 10^{12} M_\odot$. This value is in good agreement with the masses quoted above as well as with the total mass of the Local Group $\simeq 6 \times 10^{12} M_\odot$, since the mass of the M31 hypergalaxy is $\simeq 4 \times 10^{12} M_\odot$ (Einasto *et al.* 1978c).

D. *Interactions Between Hypergalactic Populations*

The tidal origin of the Magellanic Stream phenomenon was studied by Davies (19.159.018 and 021), Fujimoto and Sofue (17.151.021, 20.159.006), Lin and Lynden-Bell (20.151.026) and by Kunkel (in press). The tidal mechanism can also give rise to the bending of the disk of the Galaxy (17.151.021, 20.159.006, 20.151.026, 19. 155.018, Toomre 21.151.079).

Dynamical friction causes a steady decay of the orbital radius of companion galaxies till tidal forces disrupt the companions and their debris falls to the main galaxy (Tremaine, 17.159.003). Such cannibalism may give rise to a substantial increase of the luminosity of the main galaxy (17.151.001 and 003, 20.151.020, 20.160.036). Dynamical friction has destroyed all globular clusters in the central regions of galaxies (17.151.006, 20.155.059).

Moving through the gaseous corona companion galaxies are exposed to galactic wind. This effect is strong enough to sweep away the gas from the nearby companion galaxies and give rise to the segregation of companions according to their morphological types (17.158.025).

The Magellanic Stream can be considered as a turbulent wake in a gaseous corona (20.159.003).

Coronal gas can fall into the main galaxy which may be an important factor in the chemical evolution of the Galaxy (17.155.002, 20.151.020). The accretion of the coronal gas in a thin layer near the hypergalactic plane may give rise to the bending of the disk and trigger star formation (18.151.024, 20.132.038). Physical processes in coronal gas have been studied also by Waxman (21.151.041) and others (18.158.164, 19.155.034).

Recent numerical studies (Berman and Mark, 1978, Miller, in press) have shown that no bar will be formed in galaxies either with a nuclear bulge or with a massive corona.

Reviews of interactions between hypergalactic populations are given by Saar and Einasto (21.161.009), Saar (1978) and by Tinsley (1978).

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