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

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1. INTRODUCTION

According to Commission 33 traditions, the report contains contributions from a number of authors: §2, D.L. Crawford, §3, W.B. Burton and F.J. Kerr, §4, W.B. Burton, §5, K. Loden, §6 A and C, R. Wielen, §6 B, U. Haud and J. Einasto, §6 D and §7, D. Lynden-Bell, §6 E and F, M. Fujimoto.

The field of galactic research has been very active the last three years. It now actively covers the entire spectrum range, from gamma-rays to the long wavelength radio waves. Literally, many windows to the Galaxy are now open and in use. Data are flowing in.

Many other Commissions deal with areas that overlap or intersect or cover topics of great interest to Commission 33. Those interested in galactic structure and dynamics must also refer to those Commission reports that include data or techniques useful in galactic research.

During the triennium under review, proceedings have been published of several meetings containing contributions pertinent to the structure of the Galaxy. These meetings include ones on "Structure and Properties of Nearby Galaxies" (21.012.026), "Chemical and Dynamical Evolution of our Galaxy" (21.012.032), "Astronomical Papers Dedicated to Bengt Strömgren" (22.012.010), "The Role of Star Clusters in Galactic Structure" (22.012.023), "The HR Diagram" (22.012.012), "Optical Astronomy with Moderate Size Telescopes" (22.012.024), "Applications of Digital Image Processing" (22.012.025), "New Ideas in Astrometry" (22.012.029), "Spiralarmdichtewellen" (25.012.012), "Infrared Astronomy" (25.012.016), "Modern Astrometry" (25.012.018), "Mass Loss and Evolution of O-type Stars" (25.012.024), "Spectral Classification of the Future" (25.012.026), "Problems of Calibration of Multicolor Photometric Systems" (25.012.043), "Stars and Star Systems" (25.012.045), "The Large-Scale Characteristics of the Galaxy" (26.012.005), "X-Ray Astronomy" (26.012.012), "Stars and Star Systems" (26.012.018), "Radio Recombination Lines" (27.012.005), "Star Clusters" (27.102.007), "Star Catalogues, Positional Astronomy, and Celestial Mechanics" (27.102.038), "First Latin-American Regional Astronomy Meeting" (27.102.052), "Nuclei of Normal Galaxies" (28.012.023), "Interstellar Molecules" (28.012.033), "Spiral Structure of the Galaxy" (28.012.034), "Non-Solar Gamma Rays" (28.012.047), "Photometry, Kinematics, and Dynamics of Galaxies" (28.012.051), "X-Ray and Gamma-Ray Astronomy in the 1980's" (28.012.051), "X-Ray Astronomy" (28.012.055), "Giant Molecular Clouds in the Galaxy" (28.012.064), "Galaktische Struktur und Entwicklung" (Buser, 1981), "The Structure and Evolution of Normal Galaxies" (Fall, Lynden-Bell, 1981).

The book on "The Milky Way" by Bok and Bok (1981) entered its fifth edition. The textbook entitled "Galactic Astronomy: Structure and Kinematics" by Mihalas and Binney (1981) will no doubt be of long service to the field.

Bok's (1981) general review introduces many of the problems currently demanding attention in Milky Way studies.

The Annual Review of Astronomy and Astrophysics published survey articles on "Observed Properties of Interstellar Dust" (26.131.084), "Compact HII Regions and OB Star Formation" (26.132.027), "Masses and Mass-to-Light Ratios of Galaxies" (26.158.090), "Cosmic-Ray Confinement in the Galaxy" (28.143.029), "Nuclear Abundances and Evolution of the Interstellar Medium" (28.131.129) and "Chemical Composition, Structure, and Dynamics of Globular Clusters" (Freeman and Norris, 1981).

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2. BASIC DATA AND CALIBRATIONS

Volumes no. 22 and 25 to 29 of Astronomy and Astrophysics Abstracts cover the period of this report, and they are an invaluable reference source to locate data published that is useful in galactic studies, and for analysis of such data.

The Centre de Donnees Stellaires has continued to publish a wealth of information of importance for problems of galactic research. Their Information Bulletin summarizes the available information and catalogues, and is issued on a regular basis. Many useful catalogues are available on magnetic tape or microfiche. Some of this material is available from other sources as well, and the Information Bulletin summarizes such sources.

The above two sources of basic data and references are invaluable for all astronomers doing research in galactic structure and dynamics. Those involved in these activities have the great thanks of all of use active in galactic astronomy.

We note here only a very few of the highlights of data and calibrations published in the three year period.

Houk and Cowley published Volume 1 of the university of Michigan Catalogue of Two-dimensional Spectral Types for the HD Stars (Declinations -90 to -53 degrees) (22.002.034), and Houk published Volume 2 of the same series (Declinations -53 to -40 degrees) (26.002.029).

Hodge and Wright issued photographic charts of the Small Magellanic Cloud (202 charts) (22.002.064). The important fundamental Revised Atlas of the MK Spectral System, by Morgan, Abt, and Tapscott, appeared during this period (25.002.031).

Golay published a review paper describing in detail the Geneva seven color photometric system (27.113.074). Crawford compared the uvby, H-beta photometric systems with the MK classification system and with UBV photometry (22.113.025), and published his empirical calibrations of the uvby, H-beta systems for A-type stars (26.113.043). Straizys gave a review paper on the problems and prospects of multicolor photometry (25.113.027). Bessell published his investigation of the Cousins VRI system, and proposed it as the ideal near infrared photometric system (26.113.045).

There were many other important papers with general reviews and with specific data or calibrations or analysis of interest. Space does not allow individual mention, and we refer readers to the A and A Abstract volumes.

3. LOCAL GALACTIC STRUCTURE

A. General Surveys

This section 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. The overall properties of the Galaxy on a larger scale are discussed in Section 4.

The galactic distribution of 60 young open clusters has been discussed by Fenkart (26.153.010), and the role of clusters as good spiral tracers is confirmed. Lynds (28.155.001) has classified about 400 O stars over all galactic longitudes with respect to the presence or absence of bright nebulosity associated with the stars. Zavarzin (22.155.048) has presented an isophote map of the Milky Way from photometry in the red region (R system). Lotkin (26.155.067) has used observational data on 235 O and B stars to estimate the distance of the Sun from the galactic centere as 8.1 kpc. Vader and de Jong (1981) have carried out an extensive modeling study of the kinematical and chemical evolution of the galactic disk near the Sun.

Interstellar reddening in the solar neighborhood has been studied by Spaenhauer (27.131.060), Krautter (28.131.085), and Neckel and Klare (28.131.112). Knude (26.131.150) has published a catalogue of about 200 low-mass dust clouds in the solar vicinity. Zavarzin (22.155.046) has shown that the surface brightness of the Milky Way at 0.71 μm is controlled mainly by the distribution of absorbing matter in the solar vicinity.

The structure of Gould's Belt has been studied from both optical and radio data by Strauss et al. (25.131.020). The kinematics of the Belt has been discussed in detail by Tsioumis and Fricke (25.151.069), while Lindblad (28.155.016) has used a study of local kinematics to obtain information about the structure and dynamics of the Galaxy in the nearer regions.

Several optical studies of the Southern Milky Way have been reported. These consist of a photometric study of faint early-type stars by Muzzio (25.113.033) in four regions in Vela, Centaurus, and Circinus, contained studies of loose clusterings in the Carina-to-Norma region by Lodén (26.153.025), studies of the color excess and stellar distribution in five selected directions by Johansson (27.113.059), and observations in linearly polarized light of the intensity of the diffuse λ6180 band in 56 southern O, B, and A stars by Gammelgaard (22.156.012). Kilkenny (1981) has reported Hβ photometry for 209 southern early-type stars. A new survey of 21-cm emission from the Southern Milky Way has been reported by Kerr et al. (1981).

Extensive bodies of 21-cm data at intermediate and high latitudes have been published by Cleary et al. (25.155.015) and Colomb et al. (25.155.008).

They demonstrate the existence of extensive filamentary structures and large shells. A more limited study of local HI gas has been reported by Morras (26.131.027), while Chlewicki (28.155.040) has restudied the local spiral arm from 21-cm line profiles. Crovisier (22.155.023) has studied the kinematics of neutral hydrogen clouds in the solar neighborhood from the Nançay 21-cm absorption study.

New studies of the structure of the North Polar Spur have been reported by Sofue and Reich (26.156.017) and by Heiles et al. (28.155.045). Paseka (22.156.022) has found regions of specially high polarization in the Loop III region. Weaver (26.155.034) has given a general discussion of large supernova remnants as common features of the disk. Simard-Normandin and Kronberg (25.156.005) have derived a clearer picture of the magnetic structure of the Galaxy in the solar vicinity from a large body of rotation measures for extragalactic radio sources.

B. Regional Surveys-Low Galactic Latitude

This section is based on regional studies of galactic structure from both the optical and radio observational standpoints. In general, the results here will refer to galactic latitudes $|b| < 20°$.

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

The gas distribution in the central region of the Galaxy has been the subject of extensive study. Results for atomic hydrogen have been presented by Burton and Liszt (22.155.029) and by Sinha (26.155.007), and for carbon monoxide by Liszt and Burton (22.155.041).

Three-color photometry on 1934 stars in the SA133 field has been reported by Becker (26.113.039), and the area between the local and Sagittarius spiral arms has been studied by Kuznetsov et al. (28.155.030).

II. Sct-Agl-Vul ($10° < \ell < 60°$)

Karaali (25.113.002) has reported RGU-photometry of 1608 stars in a field in the direction of the Scutum cloud.

HI studies have been reported by Sato and Akabane (25.131.182) for the region $11°1 < \ell < 13°5$, while Berman and Mishurov (25.115.014; 27.155.042) have determined the parameters of the spiral structure for $30° < \ell < 60°$, using both a linear and nonlinear density-wave theory. Szabo et al. (27.131.001) have mapped the CO distribution around $\ell = 30°$, $b = 0°$, and found several giant molecular clouds.

III. Cyg-Cep-Cas-Per ($60° < \ell < 150°$)

In the Cygnus region, Dubyago (28.155.031) has investigated the galactic structure in the direction $\ell = 80°$, Lindgren and Bern (28.113.022) have obtained UBV data for 317 stars, and Yilmaz Esin (26.155.075) has derived absorption and density gradients in several fields in Cygnus.

Coyne et al. (25.113.084) have reported a survey of Hα emission objects in the Milky Way in Perseus, while Reynolds (27.155.002) has constructed high spatial and spectral resolution pictures of the faint galactic Hα background in a region in Perseus.

Kallas and Reich (28.156.006) have carried out a 21-cm radio continuum survey of the galactic plane region, 93° < ℓ < 162°, and $|b|$ < 4°, with Effelsberg 100m radio telescope.

IV. The Galactic Anticenter (150° < ℓ < 210°)

Chromey (25.114.068) has given spectral types for 49 blue stars whose photometry places them at large distances from the galactic center. Ito et al. (22.156.007) have reported near-infrared observations in the anticenter direction. Basharina et al. (28.155.019) have reported an investigation of the structure of the Orion spiral arm by statistical modeling methods.

Morris et al. (28.131.201) have carried out a survey of CO at negative galactic latitudes, mainly in Orion and Monoceros, finding some very long molecular filaments connecting molecular clouds at high latitudes to molecular features in the plane. Baker and Burton (25.155.002) have carried out a scan of 22° length across the galactic equator at ℓ = 197°3 with the Arecibo telescope, and describe the self-absorption and other characteristics of this high-angular-resolution scan. Burton and Moore (25.155.012; 26.155.055) argue that the anticenter anomalous-velocity streams of gas are located within the Galaxy.

V. Pup-Vel-Car-Cru (210° < ℓ < 300°)

FitzGerald and Moffat (28.152.006) have observed 51 luminous stars in a field at ℓ = 231°, and found that 29 OB stars appear to lie in an association at 4.2 kpc. Wramdemark (1980) has carried out photometry of 38 OB stars in an area in Puppis centered at ℓ = 236°, b = +2°, and finds that most of the stars appear to be in the Perseus-arm extension. Muzzio and coworkers searched for faint OB stars in the field of RCW38 in Vela (26.113.009), and also made a search for faint Hα emission-line objects in Ara (Vega et al. 1980) and also studied such objects in the Coalsack region (Martinez et al. 1980). Forte and Orsatti (1981) carried out an objective-prism survey for OB stars in the field of the Carina nebula.

Sundman (25.131.055) reported an investigation of the interstellar extinction in 11 selected directions in the Carina-Crux-Centaurus region. Lodén and Sundman (28.131.147) have studied the variation of the color excess in the Carina-to-Norma region of the Milky Way. Ardeberg and Maurice (27.155.007) have discussed the distribution of stars and interstellar dust along the inner side of the Carina spiral feature.

At 21-cm, Bajaja and Morras (27.131.168) have reported on a survey of HI at low latitudes in the region 220° < ℓ < 269°, and Bowers et al. (28.131.138) described HI self-absorption in the Coalsack dust complex.

VI. Cen-Cir-Nor-Sco (300° < ℓ < 350°)

Orsatti and Muzzio (27.114.046) searched for faint OB stars in the Circinus-Norma region. Grayzeck (25.155.017) described the galactic distribution of Cepheids between $\ell \sim$ 294° and 331°, and related it to the various spiral features in this region. Bajaja et al. (27.131.167) reported the results of a 21-cm line survey in the region 310° < ℓ < 325°, −32° < b < −17°.

C. High Latitude Optical Studies

This section 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.

A number of studies have been made in the region of the South Galactic Pole. Guseva (26.155.074) has studied stars of class B7-G4 and also dust, Yoss and Hartkoff (26.113.015) have investigated the K-giant population, Blaauw (22.113.026) has discussed the faint F stars, Pesch and Sanduleak (22.155.030) have compiled a catalog of probable dwarf stars of type M3 and later, and Eggen and Bessell (22.126.029) have searched for white dwarfs. Elias (22.133.001) has discussed the properties of all the 2.2-μ field stars seen near the North Galactic Pole, and shows that they can all be identified with stars of known spectral types.

Clube (22.112.004) has reanalysed some absolute proper motions of faint M stars in the region of the North Galactic Pole, and obtained some support for a higher space density of M stars. Hill et al. (25.155.013) have studied A & F stars in the region of the North Galactic Pole and have redetermined the local mass density at $0.108 M_{\odot} pc^{-3}$.

Interstellar reddening towards the South Galactic Pole has been discussed by Albrecht and Maitzen (28.131.081), while Markkanen (25.131.099) has used polarimetric observations of 70 stars near the North Galactic Pole to determine a lower limit of interstellar extinction in this area of 0^m03. King et al. (26.134.004) have found a very extensive nebulosity of low surface brightness in the region of the South Celestial Pole. They suggest it is predominantly reflection nebulosity, in a layer at 40-80 pc below the local galactic plane.

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4. OVERALL STRUCTURE OF THE GALAXY

A. General Observational Surveys

The triennium saw the completion of two surveys of the southern-sky HI emission. The surveys of Cleary et al. (25.155.015) covered δ < -30°, excluding the strip at |b| < 10° which was surveyed by Kerr et al. (1981, A & A Suppl.). Heiles and Cleary (26.131.106) published column densities of the southern HI. Synoptic views of the combined northern and southern data were published by Cleary et al. (25.155.015) for |b| > 10°, and by Valdes (22.155.008) for |b| < 2°. A photographic presentation of the Argentine data combined with the Hat Creek survey at |b| > 10° was published by Colomb et al. (27.155.008).

Franco and Pöppel (21.131.116) observed the field 348° < ℓ < 12°, 3° < b < 17° and interpreted the data in terms of Gould Belt kinematics. Olano and Pöppel (1981) likewise interpreted HI data of the region 320° < ℓ < 341°, 7° < b < 26°, in terms of the Gould Belt. Braunsforth and Rohlfs (21.002.038) observed the disk at |b| < 1°5, 20° < ℓ < 42°. Pöppel et al. (27.002.059) published an atlas of low-latitude southern HI.

Absorption by galactic HI was studied towards 819 sources by Crovisier et al. (21.002.039). Self-absorption characteristics of galactic HI were studied by Baker and Burton (25.155.002).

Several surveys of low-latitude ^{12}CO emission were published. The material of Burton and Gordon (21.155.004) covers emission at b = 0°, 10° < ℓ < 82°. The surveys of Solomon et al. (26.155.018) and Cohen et al. (26.155.019, 28.131.202, 28.155.014) provide more extensive coverage, especially in b. The analyses of these surveys stress galactic morphology. Liszt and Burton (Ap.J. 236) discussed aspects of the interpretation of CO emission from the ensemble of molecular clouds.

The isotope ^{13}CO was studied by Solomon et al. (26.155.005), with an analysis which stressed morphology, and Liszt et al. (Ap.J. 249), with an analysis which stressed length scales.

A large-scale OH sky survey at 1612 MHz was published by Bowers (21.131.024, 21.122.063). An extensive survey, on an irregular grid near the galactic plane, of all four 18-cm OH lines was published by Turner (25.002.035). Baud et al. (25.131.080) published a systematic search at 1612 MHz for OH maser sources between 10° < ℓ < 150°, |b| < 4°; the galactic distribution of OH/IR stars derived from this survey was discussed by Baud et al. (26.155.017).

Observations of H_2CO along the galactic equator at 8° < ℓ < 60° were published by Few (25.155.018) and additionally discussed by Davies and Few (26.131.066). Downes et al. (27.141.133) surveyed 262 galactic sources in the H110α line and in the H_2CO absorption line at 4.8 GHz. Radio observations of the galactic plane CH distribution at 10° < ℓ < 230° were reported by Johansson et al. (26.155.020). Genzel and Downes (25.131.024) interpreted H_2CO data in a galactic context.

Nonthermal emission observed at $\nu < 10$ MHz by satellite was reported by Novaco and Brown (21.156.009). Haynes et al. (22.002.031, 26.141.094) published a survey of the southern plane at 5 GHz. A survey of the plane at 4.875 GHz was made by Altenhoff et al. (25.141.002) from Effelsberg. A 21-cm continuum survey of the region 93° < ℓ < 162°, |b| < 4°, was carried out with the 100-m telescope by Kallas and Reich (28.156.006). A summary of the continuum surveys made with that telescope was given by Downes (26.156.008).

A correlation between discrete sources and the structure of the galactic background radiation was discussed by Larionov and Sidorenkov (21.141.116). Brindle et al. (22.156.002) gave a three-dimensional model of the galactic continuum emissivity. Wielebinski (25.156.009) reviewed the nonthermal radiation in terms of SNR's and pulsars. Using the nonthermal radio spectrum, Webber et al. (27.156.001) reexamined the interstellar electron density.

Several balloon surveys of IR radiation from the galactic disk were made during this triennium. Fazio (26.133.019) reviewed the results. Mahaira et al. (21.155.011) scanned the area 350° < ℓ < 27°, |b| < 10° at 2.4 µm. The near-IR surface brightness of the southern plane was studied by Hayakawa et al. (25.155.027). Mahaira et al. (25.156.003) amd Okuda et al. (26.156.012) observed the diffuse far-infrared and derived a surface-brigthness distribution of the plane at 340° < ℓ < 22°. Owens et al. (26.156.003) surveyed much of the sky with a large beam at mm and sub-mm wavelengths. Drapatz et al. (28.156.014) reported balloon-borne observations at $\lambda > 50$ μm of the inner Galaxy.

Hoessel et al. (25.156.008) carried out a near-infrared survey of the plane using the 1.2 m Palomar Schmidt.

The far-infrared emission from clouds was studied by Ryter (25.131.085). Drapatz (25.156.009) summarized properties of the disk consistuents in deriving the far-infrared diffuse emission as a function of longitude. Serra et al. (26.156.006) presented a longitude profile of the far-infrared diffuse emission. Viallefond et al. (27.156.002) scanned an area of the galactic disk from an airplane, and demonstrated a correlation between the far-infrared and the radio-continuum emission. Nishimura et al. (28.156.005) mapped from ℓ = 352° to 45° in the 100 - 300 μm band; they related their data to HII and CO sources.

The near-infrared surface brigthness of the galactic anticenter was observed with a rocket-borne telescope by Hayakawa et al. (22.156.007).

Becker (22.155.012) reviewed the use of optical material as a tracer of galactic structure. Parker et al. (27.002.011) published an emission-line survey of the Milky Way. The color distribution of the integrated spectrum of the Milky Way was surveyed by Kostyakova (21.155.005). Hanner et al. (21.155.022) used the Helios probe to measure the UBV brigthness along four strips through the Milky Way. Mattila and Scheffler (21.155.026) analysed fluctuations in the diffuse galactic light in a study of the statistical parameters of interstellar clouds.

Lucke (21.131.119) correlated the distribution of reddening material with the Gould Belt. Lynga reviewed the relationship of dust to galactic structure, based principally on latitude variations of extinction.

Several investigations dealt with uv-observations of the diffuse galactic light. Morgan et al. (22.155.027) derived the albedo of interstellar dust from satellite data in the range 1550-2740 Å. Henry et al. (21.157.007) scanned the far-uv and interpreted the data in terms of a hot, extragalactic plasma. UV scans in the vicinity of the O IV transition were interpreted by Jenkins (21.131.019) in terms of a hot galactic corona. The contribution to the interstellar uv-radiation from diffuse galactic light was studied by Gondhalekar et al. (27.157.003). A correlation of the uv radiation background with HI column density led Maucherat-Joubert et al. (28.157.002) to conclude that a significant portion of the diffuse uv is of galactic origin. Paresce et al. (28.142.053) discussed possible systematic contamination of far-uv background data.

Caplan and Grec (26.155.013) and Mattila (27.155.009) incorporated clumping of the interstellar dust into a model of the Milky Way disk. Grey-scale maps of the diffuse galactic Hα emission constructed by Reynolds (27.155.002) showed filamentary structures extending ∿ 1 kp from the galactic plane. Zavarzin (22.155.048) published isophote maps of the Milky Way constructed from photometry in the R system.

B. Overall Structure

The triennium saw efforts to refine the inner-galaxy rotation curve and to determine the rotation parameters of the outer galaxy.

Grape (22.155.039) took into account asymmetries in the HI distribution in suggesting rotation and expansion velocity fields at $R < 5$ kpc. Sinha (22.155.019) reexamined the rotation curve for $R < 10$ kpc by including southern and northern HI data and data at $b = 0°$. The apparent north-south asymmetry of the rotation curve was discussed by Jaakkola et al. (22.155.035) in terms of a general expansion of spiral arms rather than of the galactic disk itself. Petrovskaya (26.155.065) derived from HI profiles rotation curves separately for the first and fourth quadrants, assuming pure rotation. Haud (25.155.031), on the other hand, favored a rotation curve corrected for a general expansion of the gaseous disk. Burton and Gordon (21.155.004) compared the rotation characteristics at $R < R_0$ derived from CO observations with those derived from the more diffuse HI gas.

The rotation parameters at $R > R_0$ were the subject of several investigations. Using HI data, Knapp et al. (22.155.044) and Gunn et al. (26.155.011) found a linear curve near R_0 and lower values of the constants R_0 and Θ_0 than usually adopted.

Jackson et al. (26.11.008) and Moffat et al. (26.113.021) based their study of the outer-galactic structure on photometry and spectroscopy of O and B stars associated with HII nebulosities.

Blitz (26.155.003) and Blitz et al. (28.155.027) used velocities from CO observations of Sharpless HII regions of known distances in order to determine the rotation curve to $R \sim 17$ kpc.

Many studies during the triennium were directed toward the galactic distance scale and the fundamental kinematic constants.

Reviews of some of the recent accumulated evidence on Θ_0 were given by Knapp (26.155.028), who favored $\Theta_0 = 220$ km s^{-1}, and by Einasto et al. (26.155.029).

Loktin (26.155.067) derived a value $R_0 = 8.1$ kpc from data on 235 O and B stars. Surdin (28.011.018) introduced a method to determine R_0 based on the dependence of the metallicity of globular clusters on R. Quiroga (28.155.041) based a determination of R_0 on comparison of kinematic distances of HII regions and photometric distances of their exciting stars.

Celnik et al. (25.155.032) offered a determination of the thickness of the galactic disk based on HI observations. The displacement of major structures from the plane $b = 0°$ was studied by Kolesnik and Vedenicheva (25.155.033) for the case of O and B stars, by Lockman (25.155.025) for the case of HII regions, and by Cohen et al. (28.155.014) for the case of CO clouds.

The length scale of the exponential disk of the Galaxy was discussed by de Vaucouleurs (26.155.060, 26.155.027); the latter paper is a useful review of the morphology of our system.

Edmunds (26.155.004) reviewed the abundance gradient problem. Evidence for a gradient of stellar metallicity in the galactic disk was given by Janes (21.155.053, 25.155.021), by Kraft et al. (26.155.050), and by Marsakov and Suchkov (27.155.006). Panagia and Tosi (27.155.005) based discussion of the chemical gradient on analysis of the H-R diagrams of open clusters. Chiosi and

Matteucci (27.155.027) and Dluzhnevskaya et al. (27.155.026) discussed this problem also. Butler et al. (26.122.025) dealt with the metal abundances of RR Lyrae stars in different parts of the Galaxy.

Penzias (22.131.086) reviewed the relative abundances of the common elements and concluded that the distribution are rather uniform. Churchwell et al. (22.132.036), on the other hand, presented evidence for a gradient of HII region electron temperatures and helium abundance. Evidence for abundance gradients based on spectrophotometry of HII region emission lines was given by Peimbert et al. (21.132.013). Smith et al. (21.131.172) discussed star formation rates in the galactic disk. Mallik (21.131.252) discussed nitrogen enrichment across the Galaxy in the context of planetary nebulae observations.

Perspective on Milky Way studies can be gained by comparisons of our system with other systems. Humphreys (26.155.022) compared the distribution of young stars, clusters, and associations in the Milky Way with the distribution in M33; Talbot (27.155.001) compared various aspects of M83 with our Galaxy. de Vaucouleurs and Pence (22.155.031) compared photometric parameters of our Galaxy with those of other galaxies.

Comparative studies of the distribution in the Galaxy of interstellar gas and different tracers of star formation were given by Guibert et al. (21.155.051), by Quiroga (21.131.136), and by Voroshilov and Kalandadze (28.155.028).

Galactic structures as revealed by optical methods was discussed by Kostyakova (21.155.006); by Guibert et al. (21.155.051), who compared the disk thickness of young populations; by Spaenhauer and Fenkart (25.155.003), who derived the space density of late-type giants; by Lynga (27.155.024) for stars in clusters and associations; by Pavlovskaya and Suchkov (27.155.039) for cepheids; and by Lynds (28.155.001) for O stars.

Attempts to derive the galactic distribution of HI were described by Petrovskaya (22.155.059), Berman and Mishurov (27.155.042), Sawa (21.155.021), and Petrovskaya and Korzin (28.155.032). Kerr's (26.155.021) review of this problem incorporated the new southern HI data. Analyses of recent CO surveys by Scoville et al. (26.155.033), Cohen et al. (28.155.014), and Liszt and Burton (Ap.J. 236) offered different interpretations of the galactic distribution of molecular clouds. Galactic morphology as presented by OH/IR sources was reviewed by Habing (21.155.018). Puget et al. (26.155.024) and Serra et al. (27.156.003) derived the IR emission of the Galaxy as a function of galactocentric distance.

Weaver (26.155.034) and Ariskin (26.155.059) described the role played by supernova remnants as common features of the disk. The morphology of the North Polar Spur was studied by Heiles et al. (28.155.045) as an example of a giant HI shell.

The structural aspects of the Galaxy within several kpc of the Sun were studied using both radio and optical tracers. The Perseus arm feature received attention in papers by Sparke and Dodd (21.155.001) on photographic photometry, by Gosachinskij and Rakhimov (21.155.008) on the λ21-cm line, by Birkinshaw (21.132.002) on 5 GHz maps of HII regions, by Grayzeck (25.155.017) on Cepheids, and by Yuan and Dickman (26.155.025) on the CO distribution.

C. The Inner Core of the Galaxy

Observations made during the triennium over a wide wavelength spectrum advanced our knowledge of the kinematics and distribution of material in the nucleus of our Galaxy. Several papers serve as reviews of subject. Comparisons between the properties of our galactic nuleus and nuclei of other normal galaxies were made by Weedman (26.155.046), by Ekers (28.155.023), and by Liszt (28.155.024). A discussion of the properties within 300 pc of the galactic center was given by Audouze et al. (26.155.064); Geballe (25.155.039) reviewed the properties of the central parsec. Oort (21.155.024) reviewed the evidence for eruptive phenomena near the galactic center.

Bania (26.155.038, 28.155.042) studied the latitude and longitude variation of the 3-kpc arm as outlined by CO emission and concluded it is not a symmetric ring structure. Lockman (28.131.139) traced H166α recombination line emission throughout the arm and determined that it is not a site of active star formation.

The neutral gas within several kiloparsecs of the galactic center is tilted in a systematic manner with respect to the galactic equator. This conclusion gained support from the work of Cohen (26.155.036), Cohen and Davies (25.155.008), Sinha (26.155.007, 26.155.037), Burton and Liszt (22.155.029, 26.155.036, 28.155.048), and Liszt and Burton (22.155.041, 26.131.079, 27.155.012).

The distribution of OH sources in the core of the Galaxy was discussed by Baud (21.133.028), and Baud et al. (25.131.010, 26.155.017).

Information on the kinematics of gas in the central parsec was given by the IR spectroscopy of Dain et al. (21.132.017), Lacy et al. (25.155.001, 28.155.021), Willner (21.156.002), Lacy (28.155.025), and Watson et al. (28.156.008). The most probable mass distribution derived from IR line emission includes a central point mass of several x $10^6 M_\odot$. Wollman (26.156.011) reviewed the information given by infrared spectroscopy about the structure and energetics of the galactic center.

Discussions on the possible existence of a massive black halo at the galactic center were given by Ozernoy (21.155.048, 26.155.044), and Paczynski and Trimble (26.155.045).

The radio continuum structure of the compact sources in the central region was mapped by Downes et al. (25.141.001).

Information on the sub-pacsec scale revealed by spectroscopy at the infrared wavelengths was supplemented by information on the scale of a few hundred parsecs revealed by mm-wavelength observations of various molecules. Davies and Cohen (21.155.047) and Gusten and Downes (28.155.049) gave brief reviews of the motions of the molecular gas in the galactic center. Whiteoak and Gardner (26.156.001) reported on an H_2CO survey of the inner 4 degrees, which showed the extended cloud complexes also seen in HI and CO surveys. Bieging et al. (28.131.111) mapped the 4.8 GHz H_2CO absorption in the region of the Sgr molecular complex; Gusten and Downes (27.131.183) interpreted these data in the context of expanding features. Fukui et al. (28.131.133) observed the 3.4 mm line of HCO^+ toward the Sgr complex. Fukui (28.131.203, 28.155.026) suggested a model involving a fan-shaped gas jet from the nucleus to account for these observations.

Several extensive surveys of emission from hydrogen recombination lines contributed to understanding of the nuclear kinematics and temperatures. Mezger and Pauls (26.155.039) reviewed the thermal component of the cm-wavelength continuum emission in the context of star formation in the core. Pedlar et al. (21.156.001) observed low-frequency recombination lines in the direction of the center. Pauls and Mezger (27.156.007) mapped the recombination line radiation from the arc-like galactic center source and found that emission near -40 km s^{-1} dominates. Hart and Pedlar (28.156.010) investigated the thermal structure of the nuclear gas using recombination lines and concluded that evolved HII regions contribute to a nuclear haze of ionized gas. Rodriguez and Chaisson (22.156.001) interpreted recombination line observations from Sgr A in terms of a core-halo model. Bally et al. (25.155.029) and Neugebauer et al. (21.156.005) discuss the arrangement of the nuclear clouds in terms of near-IR observations of the hydrogen bα and Bγ lines.

There was extensive observational activity in the infrared continuum during the triennium. Rieke et al. (21.156.008) discussed ground based and airborne observations between 10 and 56 μm. Willner et al. (25.156.007) derived the 4 to 8 μm spectrum of the center. Gatley et al. (21.132.014) discussed far-infrared observations within 1° of the center; their results are consistent with HII regions ionized by early-type stars. Andriesse and de Vries (22.155.004) analyzed data on the far-IR emission from dust near the center.

Working in the near-IR, Hofmann et al. (22.156.013) mapped the central region using a balloon-borne detector. Hough et al. (22.156.011) discussed polarization observations in the near IR in terms of aligned grains. Kobayashi et al. (28.156.001) mapped the 2.2. μm polarization of the central 7'. Oda et al. (25.155.016) mapped the 2.4 μm brightness distribution of the central region with a resolution of 0°6, and interpreted their data in terms of the dust distribution.

The well-known 2.2 μm map of the central 1° published by Becklin and Neugebauer (25.156.001) indicated the position of highest stellar density in the Galaxy. Bailey (27.155.003) derived a power-law variation of the central density. Liller and Alcaino (27.155.040) cataloged IR-bright stars in a region centered on the nucleus. UBV photometry of the nuclear bulge by Loibl et al. (21.155.017) showed the variation of red giant density near the center.

McCarthy et al. (28.156.015) observed 16-30 μm spectra of the Sgr A region and interpreted them in terms of the dust extinction and ionization structure of the gas. Harris et al. (28.156.007) showed by comparing CO profiles with 2.4 μm features that the IR data could be interpreted in terms of inhomogeneities in the interstellar extinction. Becklin et al. (21.133.014) derived the 1-2 μm extinction law from IR observations of compact sources. The nature of these sources was the subject of a paper of Becklin et al. (21.133.002).

Submillimeter observations at 540 μm were reported by Hildebrand et al. (21.156.003).

D. The Outer Reaches of the Galaxy

A review of the plausible properties of a halo component was given by Ostriker and Caldwell (26.155.048). Castellani (21.155.050) reviewed the chemical properties and age of the constituents of the halo. Woltjer (22.155.021) reviewed evidence relating to the mass of the halo. Kraft et al.

(26.155.050) reviewed methods by which metal-abundance gradients of halo stars can be obtained. Stecker (26.155.051) and Fichtel et al. (26.155.052) reviewed the γ-ray evidence for a galactic halo; Ginzburg (26.155.053) reviewed the relevant cosmic ray data.

The nuclear bulge component of the Galaxy was studied by Loibl (22.155.003) by means of photometry of late giants. Whitford (22.155.040) published scans of the integrated light from the bulge, and compared the situation in our Galaxy to that of external galaxies. Bregman (27.155.023) postulated a bulge wind to account for the deficiency of neutral gas in the disk at $R < 4$ kpc. Ostriker (21.155.057) also discussed several aspects of the interaction between halo and disk components.

Webster (22.156.014) analysed measurements of the galactic background radiation for information on the shape and size of the radio halo of the Galaxy. Saha et al. (22.155.002) gave a theoretical discussion of the plasma component of the halo. The signature of the radio halo at 38 and 404 MHz was studied by Milogradov-Turin and Ninkovic (27.156.010).

Becker (27.155.053) studied the distribution of metal-poor stars in the halo. Bahcall and Soneira (27.155.044) investigated the possibility of detecting a halo component with the aid of star counts. Van den Bergh (25.154.009) showed how the apparent flattening of the galactic globular cluster system is affected by extinction. Harris and Canterna (25.154.027) investigated the gradient of heavy-element abundance in the halo.

Mass exchange between the halo and the disk resulting from supernovae was studied by Chevalier and Oegerle (25.155.010). Sturrock and Stern (27.155.053) suggested that the halo might be heated from flares produced by distortions in the disk magnetic field. Mikhajlov and Syrovatksij (27.155.038) discussed the influence of the halo magnetic field on the arrival directions of high energy particles. Lipunov (26.156.020) identified the radio halo with a magnetosphere of the Galaxy.

5. KINEMATICS

A. Stars

I. Galactic Rotation

A colloquium on European satellite astronomy was held in 1978. The improvement of stellar kinematics that could be expected from data obtained by an astrometric satellite was pointed out by Crézé (25.155.048), Grosbol (25.155.047) and others.

Lindblad (28.111.015, 28.155.016) discussed the information about galactic structure and dynamics that can be obtained from studies of local kinematics.

Lin et al. (22.155.011) analyzed the observational determination of Oort constants and other Milky Way constants in the light of the density wave theory. Models of the solar vicinity are tested. From the accumulated current evidence Knapp (26.155.028) finds the circular velocity at the Sun = 220 km s^{-1} and R_0 = 8.5 kpc.

Relative proper motions for 1300 low galactic latitude stars have been derived by Stone (26.111.002), who determined the solar apex and the mean secular parallax for these stars. Tsioumis and Fricke (25.151.069) investigated the velocity field of Gould Belt stars using data given by Lesh.

Clube and Dawe (27.111.004) give a mathematical maximum likelihood model for determinations of stellar distances from proper motions and radial velocities. This technique is applied to RR Lyrae and Cepheid stars by Clube and Dawe (27.111.005). The galactic constants R_o, θ_o, A and B are derived.

Stock (27.155.062) informs that the Mêrida program for radial velocity determinations from objective prism plates so far has produced data for 5870 stars. This material will permit statistical treatment concerning kinematical characteristics of the Galaxy.

In order to improve the knowledge of the galactic rotation curve, Moffat et al. (26.113.021) observed OB stars in the neighborhood of H II regions obtaining UBV photometry, spectrograms for MK-classification and radial velocities. The aim is do derive distances for distant objects. Jackson et al. (26.111.008) used this material to construct a galactic rotation curve for R > R_o. Rubin (26.158.083) proposes, by analogy with other galaxies, that the rotation curve of the Galaxy is flat out to 60 kpc.

Ardeberg and Maurice (1981) have studied radial velocity data for young stars and interstellar gas from Ca II and H II lines along the border of the Carina arm. Pilowski (1981) has proposed a new basis for positional astronomy: an absolute stellar-geographical fundamental catalogue using geographical position determinations.

II. Velocity Distribution

Fujimoto (27.151.080) applied a theory of harmonic oscillation for a test star placed in a gravitational field of the Galaxy. He finds that the gravitational force due to CO clouds accelerate stars to a certain velocity dispersion.

Nakamura (22.155.033) formulates a constraint on the velocity dispersion of the missing mass in the solar neighborhood.

Chiu (28.111.019) has derived proper motions for stars from large telescope prime-focus plates. He developes a theory which leads to the suggestion that the Population I main sequence has a higher velocity dispersion than that of the solar neighborhood.

The mean angular momentum of stars in the solar vicinity varies with age. Grosbol (26.155.031) has computed models for investigation of the variation assuming that this could be caused by a density wave potential. In an article by Larson (25.155.009) a discussion is given of the increase of velocity dispersion with age and an explanation is attempted.

Menge de Freitas (28.111.005) computed velocity components for 726 nearby stars (data from Gliese's catalogue) along an axis parallel to the Cygnus arm and along another arm orthogonal to the first one. A discussion of averages and standard deviations is given. Peralta (25.155.006) studied the dispersion of velocity residuals for Population I stars and analyzed them as a function of galactic longitude and distance. Quiroga (27.155.010) compared results from stellar and interstellar medium studies and discussed the local galactic field of forces.

Stone (21.112.006) studied kinematics for groups of O stars. He suggests that high velocity O stars are produced in massive close binary systems and presents a model for the evolution of such systems. A sample of high velocity OB stars were investigated by Carrasco et al. (28.155.044). The solar motion and mean peculiar velocities are found to be related to population groups. Foy (27.114.142) made a chemical analysis of 5 high velocity stars. Runaway stars have been studied by Isserstedt and Feitzinger (1981). They derived the distribution function for groups of runaway stars from the radial components of the peculiar velocities.

Sion et al. (21.126.038) examined the kinematics of the variable and non-variable DA stars. Acker (28.135.017) derived relations between chemical, spatial and kinematic properties of planetary nebulae.

Feast et al. (27.122.008) derived the velocity of the local standard of rest for Mira variables in a galactic centre window. The solar motion for 27 S stars has been derived from available radial velocities by Stephenson (22.112.001), who found no deviation in the result from the "basic" solar motion. Luyten (25.126.033) made an analysis for solar motion for faint white dwarfs.

The galactic distribution of Cepheids is derived by Grayzeck (25.155.017) for a galactic longitude interval. Is is shown that H I and young stars share similar kinematics in this region of the Milky Way. A model for a "Centaurus Spur" feature is proposed.

The velocity ellipsoid for RR Lyrae stars has been computed by Woolley (22.112.003) from radial velocities and from radial velocities combined with proper motions. Saio and Yoshii (26.155.016) derived kinematical quantities for 850 dwarf stars and RR Lyrae variables. A statistical study was performed. A metal indicator, transformed into ultraviolet excess, was defined and used in the statistics. Yoshii and Saio (26.155.008) used the same material for a discussion of the earliest history of the Galaxy.

The kinematics and dynamics of the galactic globular cluster system was studied by Frenk and White (28.154.008). They compare models with observational data. Clube and Watson (25.154.013) discuss the radial motion in the globular cluster system. In both cases conclusions about the galactic halo are drawn.

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B. Interstellar Matter

I. Large-Scale Motions

From CO observations of molecular complexes related to H II regions Blitz (26.155.003) and Blitz et al. (28.155.027) determined the galactic rotation curve, the inner mass of the Galaxy and the velocity dispersions of the complexes. The observed north-south asymmetry of the rotation curve has been discussed by Jaakkola et al. (22.155.035), who present a model which tive an asymmetry in spatial distribution and in the kinematics of neutral hydrogen.

Gunn et al. (26.155.011) used published 21 cm H I observations for deriving the galactic rotation curve and values of R_o and θ_o.

The structure of Gould's Belt was investigated by Strauss et al. (25.131.020). They made a comparative study of optical and radioastronomical data. The possibility that Gould's Belt is either rotating or oscillating rigidly is discussed. Olano and Poeppel (1981) studied the kinematics of interstellar H I from an analysis of line profiles. The H I-shell of Gould's Belt was found to be strongly perturbed.

From Hα scans maps of diffuse galactic Hα emission were constructed by Reynolds (27.155.002). The maps display the Hα intensity distribution for a series of radial velocity intervals between -76 and +8 km s^{-1}. Contour diagrams derived from the Maryland-Green Bank galactic 21-cm line survey are presented by Sato and Akabane (25.131.182). Radial velocities between -30 to +70 km s^{-1} are covered.

Chlewicki (28.155.040) presents the results of a study of the local arm structure from 21-cm hydrogen line profiles. He uses the modelmaking method and finds a low value (1° - 5°) for the pitch angle of the local arm. Non-circular motions in this arm are also discussed.

Greisen and Lockman (25.155.025) studied the kinematics and distribution of cool H I clouds. The authors measured H I absorption profiles toward three galactic H II regions. Comparisons with synthetic spectra indicate that a nonlinear density wave model is to be preferred for this part of the Galaxy.

The molecular clouds have been studied from various aspects. Bash (26.131.069) has presented a model for the orbits of such clouds in the Galaxy. The clouds are assumed to be launched from a spiral-shock wave and to orbit like particles with gravitational perturbations due to the density-wave potential. The model has been tested by comparing its results with observations. Liszt et al. (1981) point out that the presence of a residue of cold H I in galactic molecular clouds has several demonstrable effects on H I line profiles. These effects can influence the interpretation of the large-scale kinematics of the Galaxy from molecular observations. Fleck and Clark (1981) discuss a turbulent origin for the rotation of molecular clouds: the shearing action of different galactic rotation could maintain the turbulent flow. Liszt and Burton (26.131.079) give results in form of longitude-velocity diagrams from simulated "observations" of a three-dimensional distribution of model molecular clouds. The effects of kinematic perturbations associated with spiral structure are also discussed.

A review of the observational evidence for high-velocity and high-temperature gas is given by McCray and Snow (26.131.085). A description of the physical processes in the medium and a theoretical model are also given.

Burton and Moore (25.155.012) give a discussion of a complex of forbidden veloctiy H I features in the anticenter region of the Galaxy. The location within the Galaxy of the cloud streams and their focus is demonstrated. Moore and Burton (26.155.055) have shown that the high-velocity H I clouds in the anticenter direction which is associated with a forbidden-velocity H I feature with negative value are correlated with a disturbance in the permitted-velocity gas. This disturbance is located within the Galaxy.

Giovanelli (27.155.057) discusses the extended, continuous stream of neutral hydrogen flowing at high velocity in the galactic anticenter direction. Interpretations of the nature of the stream are presented.

Knapp et al. (22.155.044) have searched for high-velocity 21-cm emission from a possible extended galactic neutral hydrogen disk. The H I surface density is compared with corresponding data for other galaxies. A model is given; the agreement with observations is best for a value of the solar velocity θ = 220 km s^{-1}. Giovanelli (26.131.081) described his large scale, high sensitive survey in the 21-cm line at NRAO. Hulsboch (26.131.080) gives a review of the observational properties of the high-velocity clouds.

Talbot (27.155.001) used observed intensities of CO and H I emission from the Galaxy to compute surface densities of hydrogen. From the densities the rate of star formation per unit mass of gas is computed. This rate is proportional to $\Omega - \Omega_p$. A comparison with data obtained for M 83 is carried out.

II. Central Region

Lacy et al. (25.155.001) observed Ne II within the central parsec of the Galaxy. They found small sources of various velocities. From the cloud velocity distribution a value for the inner mass of the Galaxy is computed.

Burton and Liszt (26.155.035, 28.155.048) present a model giving distribution and kinematics of H I gas within 1.5 kpc of the galactic center. Liszt and Burton (27.155.012) consider the gas distribution and kinematics within 2 kpc of the galactic nucleus and present a tilted-bar model (tilt 24°).

Rohlfs and Schmidt-Kaler (26.155.043) discuss the velocity field of the gas close to the galactic centre. Elliptical stream-lines have been proposed to explain the features along $340° < \ell < 22°$ which show expansion velocities. Another interpretation is given: the expansion field is considered as a description of a galactic wind.

Bania (26.155.038, 28.155.042) has studied the latitude distribution of CO in the 3 kpc arm by surveying ^{12}CO emission over a region in galactic longitude. The aim is to investigate whether the 3 kpc arm is a continuous ring, which has been doubted after earlier CO studies in the inner Galaxy. The ^{12}CO emission survey shows that much of the dense molecular gas is found in large-scale features. These objects show large deviations from circular motions observed for molecular gas.

A description of observations of molecular gas in absorption at large negative velocities is given by Linke at al. (1981). These millimeter-wave absorption features represent several molecules and can give evidence for a massive nuclear disk. Liszt and Burton (26.131.079) have traced the kinematic patterns of molecular material in the inner Galaxy. A region around ℓ = 0°, b = 0° is so far surveyed.

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6. DYNAMICS

A. Stellar Orbits - Third Integral

Although important studies have been carried out on stellar orbits in axisymmetric potentials, many papers consider now orbits in more complicated systems, e.g. in spiral or barred galaxies, or in systems with three degrees of freedom. Considerable attention has been given to resonant orbits or orbits near to resonances.

I. Axisymmetric Galaxies and General Problems

Kalnajs (26.151.082) gave a better epicyclic approximation for plane galactic orbits by perturbing the square of the radius instead of the radius itself. Agekyan and Saginashvilli (29.151.049) investigated the properties of nearly circular orbits in axisymmetric potentials. Baranov (26.151.062) studied periodic orbits in axisymmetric, nearly spherical systems. Allen and Moreno (21.151.098) computed orbits in a time-dependent axisymmetric galactic potential.

Contopoulos (26.151.093) reviewed the integrable and stochastic behavior of stellar systems. Manabe (26.155.009) examined the applicability of approximate third integrals for stellar orbits in the Galaxy. Resonant systems, orbits at or near resonances have been studied by Andrle (26.151.032), Contopoulos and Zikides (28.042.033) and Contopoulos and Michaelidis (28.042.059). Michaelidis (28.151.056) discussed in detail the 2/3 resonance, Contopoulos (1981a) the 4/1 resonance. Contopoulos (22.042.064) described a method for constructing integrable systems that have higher-order resonance. Other problems for systems with two degrees of freedom have been investigated by Magnenat (26.042.013) and Antonopoulos and Barbanis (26.151.028).

Dynamical systems with three degrees of freedom have been studied by Contopoulos (25.042.137), Contopoulos et al. (26.042.064), Martinet and Magnenat (29.151.039) and Martinet et al. (1981).

Various algorithms for calculating orbits numerically have been compared by Papp et al. (22.151.056, 27.151.034) and by House et al. (22.042.086).

II. Spiral Galaxies

Orbits in spiral potentials in general: Frahm et al. (25.151.029) and Frahm and Thielheim (26.151.038) calculated individual stellar orbits in order to demonstrate the response to a spiral perturbation. Fuchs and Thielheim (26.151.037) and Frahm et al. (26.155.001) obtained periodic orbits in the epicyclic approximation and illustrated spiral density waves by the superposition of such orbits.

Orbits at the inner Lindblad resonance have been calculated by Berry and de Smet (22.151.098, 22.151.099, 26.151.017). They find four subfamilies of stable, resonant orbits for an extensive inner Lindblad resonance region.

Orbits at the corotation resonance: Colin (26.151.002) discussed the angular motion of trapped stars. Papayannopoulos (26.151.023, 26.151.060) studied numerically and theoretically the properties of orbits near corotation and their invariant curves. Palous (28.151.002) described non-linear effects near the particle resonance.

III. Barred Galaxies

Vandervoort (26.151.008) investigated isolating integrals of the motion for stellar orbits in a rotating galactic bar. He concludes that the orbits behave as if there is an additional isolating integral (besides the Jacobi integral) and that this behavior is represented well in terms of a constructed formal integral. Contopoulos and Papayannopoulos (28.151.083) studied orbits in weak and strong rotating bars, especially the main families of periodic orbits. Contopoulos (1981b) studied the effects of resonances near corotation in barred galaxies and concluded that most bars end at corotation. Schwarzschild (26.151.009), Heiligmann and Schwarzschild (26.151.055) and Goodman and Schwarzschild (1981) calculated numerically orbits in a non-rotating triaxial stellar system and found evidence for three effective integrals of motion.

IV. Relaxation

The diffusion of stellar orbits by a stochastic component of the galactic gravitational field has been studied by Fujimoto (27.151.080), Fuchs (1980) and Icke (1980). Large molecular clouds are probably most efficient in perturbing the regular orbits of stars.

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B. Models of the Galaxy

I. Initial Data for Galactic Mass Modelling

Two observational trends affect galactic mass modelling: new data on the rotation curve and galactic constants.

Recent determinations (26.155.003, 26.155.011, 26.113.021, 27.155.028, 28.155.027) have confirmed earlier conclusions (based mainly on the analogy with external galaxies) that the rotation curve of our Galaxy is essentially flat or even rising from R=12 to 16 kpc. These data suggest the presence of a massive corona. High infalling velocities of hydrogen clouds (Mirabel 1981) also suggest the presence of the massive corona.

New data favour lower values of basic galactic constants, R_0=8.5 kpc and V_0=220 km s^{-1} (26.155.011, 26.155.026, 26.155.067, 28.155.041).

II. Mass Distribution Models

Caldwell and Ostriker (1981) have published a detailed version of their mass distribution model. A detailed version of the Einasto model (26.155.041) is in preparation.

A three-component model of the Galaxy consisting of a modified exponential disk, a spherical bulge and a massive corona has been suggested by Rohlfs and Kreitschmann (1981). In this model R_0=8.5 kpc, V_0=225 km s^{-1}, $M_{bulge+disk}=8.2\times10^{10}$ M_0 and $M_{corona}=5\times10^{11}M_0$.

De Vaucouleurs and Pence (22.155.031) presented a two-component model consisting of a spheroid with de Vaucouleurs density law and an exponential disk. This model attempts to represent photometric properties of the Galaxy. Another disk-spheroid model was constructed by Bahcall and Soneira (28.155.038) to calculate the expected distribution of faint stars in the galactic halo.

The motion of globular clusters was used to estimate the mass of the Galaxy (21.155.013, 28.155.020). The result was $3\text{-}8\times10^{11} M_\odot$. Gott and Thuan (21.158.236) and Einasto and Lynden-Bell (1981) calculated the orbit of M31 and Galaxy and deduced the total mass of these galaxies $4\text{-}8\times10^{12} M_\odot$.

Detailed mass distribution models have been calculated for M31 (25.158.131, 25.151.007) and M81 (21.151.068, 27.158.315, 27.158.305, 28.151.007, 28.151.008).

III. Hydrodynamical Models

Solving hydrodynamical equations of motion Bhattachryya and Basu (28.151.084) derived a flow model imitating closely the observed rotation velocity.

Waxman (21.151.041) constructed a model which exhibits main features of dynamical interaction between the gaseous component of the galactic disk and the surrounding halo. Bregman (27.155.023) examined the interaction between the stellar bulge wind and disk of gas. Stellar wind was studied also by Bardeen and Berger (21.151.018).

IV. Theoretical Models

A closed system of six hydrodynamic equations was derived by Hunter (25.151.001) to study the dynamics of perturbed motion in thin disk galaxies. A set of closed moment equations was presented by Berman and Mark (25.151.084).

Caimi and Dallaporta (22.151.080) presented a class of models consisting of two polytropic spheroids. Kutuzov and Osipkov (27.151.013) suggested a generalized model of the regular gravitational field of galaxies.

Methods of mass modelling were studied by Agekyan and Saginashvili (21.151.009), Spaenhauer (21.151.021), Kutuzov and Sergeev (22.151.097), Peng et al. (22.151.086), Munier et al. (26.151.026), Schorr (26.151.029) and Xu (28.151.028).

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C. Spiral Structure

I. Reviews

The spiral structure of galaxies is probably mainly due to density waves of some kind, primarily produced by gravitational forces. The stationarity of the lifetime, the maintenance and the origin of such density waves are under discussion. The density wave may be either supported by its own self-consistent field and caused by unstable global spiral modes or instabilities, as considered in the conventional density-wave theory. Or the density wave may be mainly forced by other internal or external perturbations of the gravitational field, such as neighbouring galaxies, oval distortions or bars in the inner regions of galaxies, circulating density enhancements of various nature and origin.

Reviews of the recent developments, theoretical problems and observational confrontations of gravitational theories of spiral structure have been given by Athanassoula (26.151.090), Bertin (27.151.094), Contopoulos (22.151.043), Edmunds (27.151.005), Jones and Tremaine (25.151.014), Lin (22.151.070), Lin and Lau (26.151.061), Lin and Yuan (22.155.022), Mark (28.151.102), Schmidt-Kaler and Feitzinger (eds., 25.012.012), Toomre (1981) and Wielen (25.151.076, 26.151.041).

II. Spiral Modes, Origin and Maintenance of Spiral Structure

The dispersion relation for density waves has been studied by Miller (22.151.050), Nishimoto (26.151.015) and Contopoulos (28.151.023). The response density and the behavior of the wave near the Lindblad resonances have been derived by Vandervoort (21.151.031), Contopoulos (25.151.003, 26.151.049) and Athanassoula (26.151.050), near the corotation resonance by Mennessier and Martinet (25.151.102) and Morozov and Shukhman (27.151.056).

Unstable spiral modes which can be responsible for the origin and maintenance of spiral density waves, have been investigated by Lau and Bertin (22.151.066), Pannatoni (1979), Pannatoni and Lau (1979), Mark et al. (26.151.044) and Lau and Haass (26.151.045). Astronomers in China have played an important role in the further development of the density-wave theory: Chin et al. (27.151.087), Hu (26.151.091), Huang (25.151.098), Huang et al. (26.151.039), Liu (26.151.064), Liu and Fang (25.151.012), Peng et al. (26.151.021), Qin et al. (26.151.065, 26.151.066), Song (27.151.040), Xu (26.151.020, 27.151.035, 27.151.036, 28.151.004, 28.151.071), Yue (26.151.019) and Yueh (15.151.088).

Global spiral modes in stellar disks have been numerically investigated by Zang (26.151.070) for the case of a flat rotation curve and by Haass (28.151.062) for a disk with Kuzmin's density distribution. Aoki et al. (26.151.103, 26.151.104) studied unstable global modes for gaseous disks with a density distribution according to Kuzmin-Toomre. Iye et al. (1981) investigated unstable global shearing modes for the same disk models.

Various aspects of the structure, maintenance and excitation of density waves or other spiral perturbations have been investigated by Abramyan (25.151.026), Ambastha and Varma (21.151.095), Drury (28.151.054), Fridman (26.151.001), Fridman et al. (29.151.003), Fujimoto and Tosa (28.151.076), Innanen and Papp (28.151.068, 28.151.117), Lapin and Raevskij (28.151.046), Morozov (25.151.078), Nishida et al. (1981), Nuritdinov (25.151.027), Raevskij (27.151.083), Robe (25.151.070), Waxman (27.151.011, 27.151.012) and Woodward (28.151.017).

In recent years, much theoretical work has been devoted to studies of the driving of density waves by bars or oval distortions in galaxies: Athanassoula (28.151.009), Berman et al. (26.151.027), Korchagin and Shevelev (29.151.007), Lynden-Bell (25.151.030, 26.151.047, 29.151.071), Sorensen (29.151.124), Thielheim (28.151.085, 28.151.118, 29.151.031) and Thielheim and Wolff (28.151.039, 29.151.052). Most papers consider now also stellar disks and include the self-gravity of the driven spirals.

Contopoulos (28.151.106) reviewed the stellar dynamics of barred galaxies and investigated problems of the extent (27.151.008) and self-consistency (1981) of bars.

Toomre (1981) and Zang (28.151.061) investigated the origin of spiral structure by "swing amplification", i.e. the collective response of stellar orbits (including self-gravity) to tidal forces (e.g. caused by neighbouring galaxies). Goldreich and Tremaine (26.151.054) studied the excitation of density waves at the Lindblad and corotation resonances by an external potential.

Mathematical tools for dealing with stellar dynamics of thin galactic disks, especially with respect to instabilities and waves in such systems, have been improved by Aoki and Iye (22.151.044), Berman and Mark (25.151.084), Bertin and Mark (26.151.069), Hunter (25.151.001) and Kalnajs (26.151.082).

Beside the density-wave theory and other gravitational explanations of spiral arms, there are various proposals for explaining the spiral structure of galaxies by other, non-gravitational mechanisms: Explosive origins of spiral arms have been studied by Havnes (22.151.052) and Schmidt-Kaler (26.151.043). Jaaniste (28.151.069) discussed an accretion theory of spiral structure by infalling gas. Piddington (22.151.081) advocates a hydromagnetic or magneto-tidel mechanism. Self-propagating stochastic star formation has been investigated by Gerola and Seiden (25.151.090), Seiden et al. (26.151.012), Seiden and Gerola (26.151.030), Comins (29.151.001) and Feitzinger et al. (1981).

III. Gas Flow and Shocks

Roberts (28.151.111) reviewed the gas dynamics in ordinary and barred spirals. Levinson and Roberts (28.155.009, 29.151.058) developed a cloud/particle model for gas flow in galaxies and studied the spiral structure for a cloudy, supernovae-dominated interstellar medium. Reinhardt and Schmidt-Kaler (26.155.062) and Schmidt-Kaler and Wiegandt (28.131.084) investigated the implications of a very hot and complex interstellar medium for the propagation of density waves and shocks. Cowie (27.131.066, 1981) discussed the dynamics of agglomerating ensembles of clouds and the formation of molecular clouds by instabilities of spiral arms.

Soukup and Yuan (27.155.017, 1981) studied the vertical extension of spiral shock fronts. Tubbs (28.151.026) determined the vertical gas structure of galactic shocks and discussed thermal phase effects and self-gravity of the gas. Nelson and Matsuda (27.151.021) investigated corrugation waves in the gas discs of spiral galaxies (including shocks) and the excitation of such gas oscillations in z by warps.

Roberts (26.151.048) reviewed the gas response to bar-like distortions. Gaseous density waves and shocks in barred spirals have been studied by Roberts el al. (25.151.086, 26.151.031), Sanders and Tubbs (27.151.003) and van Albada and Roberts (28.151.016). Huntley (25.151.087, 27.158.322) investigated the self-gravitating gas flow in barred spiral galaxies. Schwarz (27.151.086, 1981) derived the gas response to a rotating stellar bar by following the orbits of particles which collide inelastically. Kato and Inagaki (22.151.018) examined the angular momentum transport and the change of gas distribution near corotation by a bar.

IV. Observational Aspects

Visser (28.151.007, 28.151.008) successfully explained the observed structure and kinematics of HI in M81 in terms of the density-wave theory including gas shocks. Kormendy and Norman (26.151.034) surveyed 54 galaxies with published rotation curves and concluded that global spiral patterns occur in differentially-rotating galaxies only in the presence of bars or companions. Feitzinger and Schmidt-Kaler (26.151.046, 28.151.005) calculated the energies and decay times of density waves for 25 galaxies of various types. Pence (1981) compared the observed velocity field in the barred spiral galaxy NGC 253 with the predictions for a linear density wave.

The galactic distribution and kinematics of giant HII regions have been discussed by Lockmann (26.132.004), using linear density waves, and by Wielen (26.151.041, 26.155.014), using non-linear gas motions including shocks. Other direct observational confrontations of the observed structure and kinematics of our Galaxy with the density-wave theory have been carried out by Suchkov (22.151.063), Pavlovskaya and Suchkov (22.155.057, 27.155.039), Mishurov et al. (25.155.026), Grosbol (26.155.031), Joshi (27.155.033), Lindblad (28.155.016) and Terzides (1981).

The drift and broadening of ageing spiral arms and their observational consequences for our Galaxy and other galaxies have been derived using density-wave-theory concepts, by Bash (26.131.069, 26.151.033), Wielen (26.151.041), Fuchs (1980), Fuchs and Thielheim (28.151.038), Yuan and Grosbol (29.151.021) and Bash and Visser (1981); see also Lynga (27.155.024). Feitzinger and Gisk (22.151.057) discussed the disruption of material arms by the tidal field of density waves. Innanen et al. (22.155.032) studied the orbit of the sun in the presence of a density wave. Star formation in galaxies with regard to density-wave theory has been studied by Davies et al. (21.151.096), Kaufman (26.151.013, 26.155.006), Cassé et al. (26.155.012) and Talbot (27.155.001).

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D. Stabililty and Evolution

I. Spiral Modes & Stability

Aoki and Iye (22.151.044) obtained a biorthonormal set of analytical solutions of the Poisson equation for disk galaxies. See also Hunter (27.151.078). Aoki et al. (26.151.103, 28.151.104) studied unstable global modes for gaseous disks with Toomre's density distribution.

Iye et al. (1981a) studied unstabel global shearing modes for the same disk models. Iye et al. (28.151.295) and Iye et al. (1981b) obtained Fourier spectra of observed spiral patterns of M51 and NGC4254.

A fine explanation of the mechanism behind the growth patterns of the different modes is to be found in Toomre's article describing work by him and Kalnajs. It is very interesting to see the bumps along the arms found in the modes of Iye et al. explained as the places where a weak leading wave propagates back out to be turned around and made visible by the swing amplifier near corotation. Goldreich & Tremaine (26.151.054) have discussed the response of a gas disk to a rigidly rotating external potential and show the torques involved to be identical to the stellar case. Reflection and transmission coefficients for modes propagating in the region of the swing amplifier are calculated by Drury (28.151.054). Dispersion relations for open spiral waves are considered by Contopoulos (28.151.023) and Morozov (28.151.012). Berman & Mark find the Ostriker-Peebles criterion fails for galaxies with strong nuclear bulges (26.151.022) while Abramyan & Oganessian discuss the stability of a disk surrounded by a spheroidal system.

Non-linear modes are considered by Polyachenko & Shukhman (26.151.073) and by Nuritdinov (27.151.073). Non-linear interactions between such spiral waves are discussed by Raevskij (27.151.083). Lebovitz has considered the slow evolution of gaseous bodies preserving circulations and Lynden-Bell & Katz have derived a new non-linear energy principle for the equilibrium and stability of all steady flows of barotropic fluid.

II. Barred Galaxies

The theory of barred galaxies has drawn much attention. Contopoulos (25.151.003, 25.151.097, 26.151.049, 27.151.008, 28.151.016) has continued his development of the theory of self-consistent bars and the periodic orbits in them. Lynden-Bell (25.151.030) suggested a mechanism for generating bars and has given a criterion for the mutual gravity of the populations of two elongated orbits to lead to their alignment. He also discussed the evolution of bars due to angular momentum loss. The latter has been studied in more detail in the computer simulation of Sellwood and James (25.151.035). Athanassoula (28.151.009) has constructed self-consistent models of the spiral structure driven by bars while Sellwood (28.151.037 and 28.151.040) has found bars grow naturally in computer models with "live" haloes. Nezhinskij (28.151.045) has suggested a binuclear origin of barred galaxies. Vandervoort (28.151.031) has constructed bars that are the stellar dynamical analogues of the uniformly rotating polytropes with hard equations of state.

Studies of gas flow in barred galaxies have been most encouraging: Berman, Pollard and Hockney (26.151.027), Roberts, Huntley and van Albada (26.151.031), Roberts (26.151.048), Saunders and Tubbs (27.151.004), Huntley (28.151.114), and Sorenson (28.151.115).

Many of these models show shock structures which appear to be related to the dust lanes and star formation regions seen in real galaxies. Some of the calculations are still plagued by spurious problems such as grid-viscosity, so they cannot be carried on for long without most of the gas accumulating at the centre. Dissipative particle methods such as those developed by Schwarz (27.151.086) do not suffer this particular difficulty and can be carried on for many rotations, however, they need many particles to produce accurate short structures. Burton and Liszt (28.155.048) apply a bar-like model to observations of gas flow in the central regions of the Galaxy. Kormendy has reviewed the stellar structure of the components of barred galaxies.

III. Warps of Galactic Disks

The problem of explaining the persistence of these warps has again proved popular. Tubbs and Sanders (25.151.074) have avoided the wrapping up problem of having a spherical halo which provides most of the gravity. Petrou (27.151.072) suggests a rapid change in the flattening of the halo as another way to reduce differential precession. A return to models based around simple precession is advocated by Pipunov (25.151.083). Bertin and Mark (28.151.013) consider that tidal interactions excite self-sustaining warps. There remains the heterodyne excitation mechanism of Binney and the possibility that galaxies might not be perfectly aligned with the axis of their haloes. If galaxies have masses of $10^{12}M_{\odot}$ then tides are larger and the tidal stretch of the halo may have a significant gravitational effect on a smaller disk.

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E. Computer Simulations

Computer simulations are now widely used for studies of the dynamics and evolutions of galaxies and their groupings.

Clustering of galaxies in an expanding universe has been studied extensively by N-body simulations (25.151.055, 26.160.042, 25.151.056, 27.151.032, 27.151.006, Miller 1981). All these simulations have been successful in reproducing the observed clustering properties of galaxies and they support the gravitational instability picture in which galaxies form first and the cluster follows via mutual gravitational interactions. Doroshkevich et al. (28.162.001) also demonstrated the formation of a large-scale structure of the universe by Vlasov simulations.

Galaxies are exposed to mutual interactions and environmental influences, and it is especially true in a dense cluster of galaxies. These effects on the dynamics and evolution of the galaxies can be seen in Miller and Smith (27.151.001), White (26.151.081, 27.151.022), Farouki and Shapiro (28.151.080, 1981), Efstathiou and Jones (25.151.004).

The collapse and accompanying rapid relaxation of stellar systems were investigated by N-body simulations, which would be realized at the galaxy formation (25.151.065, 25.151.013, Miller and Smith, 1981a, b).

Bar-like structure is very common to rotating stellar systems. Formation and dynamical characteristics of bars were studied by Combes and Sanders (1981) and Miller and Smith (25.151.041). Stability of rotating disks against bar formation was examined by Berman and Mark (26.151.022) and Sellwood (28.151.037).

N-body simulations was applied also to spiral structure by Sellwood and James (25.151.035). Miller and Smith (27.151.002) found that the rotation does not make the (axisymmetric) elliptical galaxy so flat as expected conventionally.

Alternative to the N-body simulation, the Vlasov simulation were applied to flat stellar systems by Fujiwara (1981), Watanabe (1981) and Nishida et al. (1981) and it was found that a large-scale prominent bar such as noticed in the N-body simulation does not appear in the Vlasov simulations.

Various responses of gas to gravitational forcing like bar and other density-wave potentials were studied by several authors: Berman, Pollard and Hockney (26.151.027); Huntley (27.158.322); Roberts, Huntley and van Albada (26.151.031); Sanders and Tubbs (27.151.003); Tubbs (28.151.026); Soukup and Yuan 1981; Visser (28.151.008); Levinson and Roberts 1981. Tubbs (28.158.207), Icke (25.151.051), Sanders (1981), Nelson and Matsuda (27.151.021) have conducted hydrodynamic simulations in order to understand some gasdynamical phenomena often observed in the Galaxy and galaxies.

The stochastic star formation was introduced by Seiden and Gerola (26.151.030) as a non-dynamical formation mechanism of a large-scale structure in galaxies and it was applied to the Large Magellanic Cloud by Feitzinger et al. (1981).

Murai and Fujimoto (28.159.018) conducted a numerical simulation of the Magellanic Clouds and the Galaxy with a massive halo of 7 x $10^{13}M_{\odot}$. and they have been successful in reproducing the geometry and the high-negative velocity of the Magellanic Stream.

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

I. Magnetic Fields

A review paper by Verschuur (26.156.021) summarizes observations of the galactic magnetic field. Parker (26.003.103) published a book on cosmical magnetic fields in which chapters 1, 2, 17, 18, 19 and 22 concern the galactic magnetic field.

Wasserman (22.151.012) formulated MHD galaxy formation and derived the present intergalactic magnetic field of $< 10^{-9}$G. Muradyan (22.156.018) considered the possibility that the galactic magnetic fields 10^{-6}G are relics of dipole field of Ambartsumyan's protogalactic matter. Jaffe (28.160.063) and Roland (1981) examined dynamo effect in the turbulent wake behind the rich cluster of galaxies to amplify the seed field 10^{-9}G to 10^{-6}G. De Young (28.141.103) indicated that the energy of extragalactic radio sources can be supplied by MHD turbulence. Bicknell and Henriksen (28.158.200) analysed beam dynamics including magnetic field to explain the radio jets emerging from active galaxies. Sturrock and Stern (27.155.043) showed that the MHD instability in the differentially rotating disk releases the excess magnetic energy out of the disk to heat the galactic corona to 10^6K.

The large-scale magnetic fields in galaxies are estimated to be plane-parallel to the symmetry plane from the observational data on optical polarization for the spirals NGC 3623 and NGC 4216 (21.158.239) and from stellar polarization data for our Galaxy (21.156.016). The bisymmetric open spiral configuration of magnetic fields is found in M31, M51, and M81 from rotation measures (RMs) of polarized radiation at wavelength 21 cm (22.158.044, 28.158.174, Sofue and Takano 1981) and possibly in our Galaxy from RMs of extragalactic radio sources (28.156.011) and RMs of pulsars (27.156.009). Sawa and Fujimoto (28.151.075) presented a mechanism by which the bisymmetric configuration is stationary in the disk without being twisted by differential rotation. In the bisymmetric magnetic field a conducting gas condenses in spiral to excite and sustain the density waves (28.151.076). A magneto-tidal model explains the broad optical arms and corresponding HI arms observed in M51-type spirals (22.151.081).

From the analysis on spiral arm spurs on B and I photographs, Elmegreen (28.158.230) concluded that spurs may be formed by large-scale wave processes. Heiles et al. (28.155.045) indicated that the north polar spur has a shell structure as the result of spherical shock; the outer is HI shell with $B < 6 \times 10^{-6}$G and the inner the radio continuum shell with $B > 1.2 \times 10^{-6}$G. Based on the theoretical analysis Lerche and Milne (27.131.026) interpreted the fluctuations in extinction of planetary nebulae as the result of turbulent interstellar medium. A correlation length and a fluctuating angle for the irregular magnetic fields were estimated by Nee (27.131.141) following Langevin's scheme. From the derived criteria for Parker instability a system of interstellar gas and magnetic field is unstable to permanent agitation if it is in horizontal equilibrium configuration (27.062.109) and also if in curved periodic configuration (22.062.019).

Brindle et al. (22.156.002) showed that the distribution of synchrotron radio in the Galaxy is explained by the model in which radio disk grows thin towards the galactic center. Higdon (26.156.004) derived a range of cosmic-ray intensities and magnetic field strengths in the Galaxy from the comparison of synchrotron and γ-ray emissivities. The diffusion coefficient of cosmic-rays in turbulent magnetic field is derived which confines cosmic-rays in the disk region $R \sim 5 - 6$ kpc (25.156.002) and which exhibits the compound diffusion (25.143.034).

II. Cosmic Rays

Large-scale characteristics of interstellar gas and magnetic fields have been discussed over many years from the cosmic ray data obtained in the solar system. New results about the Galaxy were provided steadily in these three years: the existence of a galactic halo and the lifetime of the cosmic-ray nucleons and electrons are examined critically, for example, in relation to their confinement in the Galaxy (28.143.029).

Cosmic-ray nucleons. The substantial amount of Li, Be and B in the cosmic-ray nucleon and the recent discovery of the radio isotope ^{10}Be enabled us to know the behavior of energetic particles in our Galaxy. The total amount of interstellar matter traversed by cosmic rays and their escape-time from the Galaxy have been evaluated as 5 gr cm^{-2} and 2×10^{7} years, respectively. If the average density of interstellar matter is 1.7×10^{-24} gr cm^{-2} (1 H atom cm^{-3}), however, these two values are inconsistent, from which a variety of models for the Galaxy were introduced. The energetic particles spend most of their lifetime for random walk in the halo and only its fraction for interaction with interstellar gas in the flat disk.

Among a number of papers which were published in the period of 1979 to 1981 for the confinement problems of the cosmic-ray nucleon, Ginzburg et al. (27.143.010) examined extensively the diffusion cosmic nuclei in the disk and static halo whose vertical thickness is respectively 100 pc and a few kpc.

A dynamical (convective) state of the halo was introduced initially by reasoning that the halo gas and magnetic field cannot be in a static state but it is driven outward through self-generated hydromagnetic waves. Jones (25.143.030) and Freedman et al. (27.143.009) solved analytically a one-dimensional (perpendicular to the galactic plane) diffusion-convection equation for cosmic-ray nuclei and showed that the observed mean path length (gr cm^{-2}) versus nuclear energy (GeV/Nuc) can be interpreted if the outward convection velocity is 8 km s^{-1}. (Note that these two papers are not all that were published about the halo problem. See references therein).

More details about other isotope measurements and the corresponding propagation problems can be seen in papers presented at the 16th International Cosmic Ray Conference, Kyoto Japan (1979).

Cosmic-ray antiprotons were discovered in the energy range of 200 MeV to 10 GeV, with the same power-law spectrum as the cosmic-ray proton but with the antiproton/proton ratio of $2 \sim 5 \times 10^{-4}$ (26.143.062, Bogomolov et al. 1979, Buffington et al. 1981). The data indicate that the cosmic-ray antiprotons were created by collisions of high-energy cosmic rays with interstellar gas and cosmic-ray protons have passed through substantially more than 5 gr cm^{-2} of material during their lifetime. Stochastic and energy-dependent processes in interstellar space have been suggested which act on the secondary antiproton after their creation. The upper-limited ratio $H_e/H_e < 2 \times 10^{-5}$ has been set.

Electrons. Measurements of cosmic-ray electrons have been continued to extend their energy spectrum up to 10^{13} eV. It is in a single power-law in the energy range 1 GeV to 10^{3} GeV, with a slight steepening toward higher energies (25.143.004), 27.143.072 and references therein). To reproduce this energy spectrum theoretically, they employed the diffusion model and the energy-dependent homogeneous leaky-box model, and obtained 1.0 (+2.0, −0.5) $\times 10^{7}$ years as a galactic electron residence time, consistent with that estimated from the ^{10}Be data.

The electron spectrum is expected to show nonstatic fluctuation at energies above 1 TeV due to the influence from a few nearby sources, since the lifetime with respect to energy loss at this energy is about 3 x 10^5 years for a total energy density of 1 eV cm^{-3} of the interstellar space (25.143.019, 27.143.072).

III. Diffuse Gamma Radiation in the Galaxy

Galactic gamma ray astronomy is now in exploratory phase, already shifted from discovery phase of the early 1970's. The gamma radiation data are due mostly to the observations by the SAS-2, COS-B and balloon instruments. The present status of this research field is seen in Proc. COSPAR Symposium "Non-Solar Gamma Rays" edited by Cowsik and Wills (28.012.047) and in her review article by Cesarsky (28.143.029), in which are summarized the latest data about the energy spectrum and the intensity distribution confined to the thin galactic plane (28.157.012, 28.157.013, 28.157.014, 26.157.003). Through constructing galactic models for the gamma radiation and nonthermal radio emission, two emission processes have been widely accepted to operate: (1) collisions of cosmic nucleus with interstellar matter producing π^0 meson which decays to γ photons and (2) bremsstrahlung from cosmic ray electrons accelerated by interstellar nucleus. The bright γ distribution at $50° < \ell < 310°$ suggests the enhanced fluxes of cosmic rays in the inner part of the Galaxy. The extended latitude distribution shows the presence of a diffuse halo above the disk, consistent with that derived from the model analyses of cosmic-ray nucleons and electrons. These large-scale characteristic of the Galaxy are, however, still qualitative and not firmly established, because the distribution of interstellar matter is not known in the inner Galaxy and we cannot separate the fluxes of cosmic-ray electrons and magnetic fields in the region beyond the solar system (25.157.008, 26.156.004, 27.142.501, 28.157.012, 28.157.016, 27.156.001).

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7. GALACTIC ENVIRONMENT

Absorption line measurements in the ultraviolet and visible have demonstrated the existence of a hot halo of 10^6 K gas along a number of sight lines through the halo. The strongest concentrations are found along low latitude lines of sight and these lines to the Magellanic Clouds and to the Magellanic Stream, (see Songaila, 1981, and Songaila, Cowie and York, 1981).

Dynamical modelling of the Magellanic Stream with many different assumptions has become quite an industry. The paper by Murai and Fujimoto (28.159.018) is a very thorough work tracing back the motions of both Magellanic Clouds in a heavy halo potential that gives V = 250 km/sec out to 200 kpc. Rather similar assumptions are used by Lin and Lynden-Bell who predict a measurable proper motion for the LMC of 2 milli-arc-seconds per year due East if the Galaxy has a heavy halo, and 1.5 if it does not. They have thus changed to "trailing stream" the sense of motion across the sky, advocated by Fujimoto and by Feitzinger, Schmidt-Kaler and Isserstedt. However, Tanaka using a Galaxy of much lower mass, has reproduced the stream quite well with a leading bridge model of the stream. It looks as though this controversy will only be finally settled when the proper motion has been measured. In the leading bridge models, the net proper motion will be much smaller than those quoted above.

Fine structure in the northern extension of the Magellanic Stream has been mapped by Ekers, Philip and Turner (27.159.028) and by Mirabel, Cohen and Davies (25.159.003). The velocity structure is considered by Hayes (26.159.003). Mirabel gives evidence for an interaction between the stream and the Galaxy.

Among the dwarf spheroidal satellites of the Galaxy, Carina and Ursa Minor have received much attention. Carina's radial velocity is exceptionally large -450 ± 50 km/sec for an object so far away, Cannon et al. (1981). Ursa Minor has an H.R. diagram with a blue horizontal branch which indicates great age and metal deficiency (Cudworth, Schommer and Olszenski).

Lynden-Bell has pointed out that both Ursa Minor and Draco are oriented with their major axis accurately along the extension of the Magellanic Stream around the sky. For Ursa Minor this indicates that it is being torn up by the Galaxy's tide as advocated by Hodge and Hickie. Its orbit is along the path of the Magellanic Clouds from which it may have been torn in the very remote past. Draco's orientation may likewise have been determined from the orbital plane of the Magellanic dêbris which formed it.

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