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

I. INTRODUCTION

Galactic research in the triennium under review has made much progress. In the present Report, however, we can give only a cursory view of developments. A more comprehensive version will be available to those particularly interested in a detailed discussion together with more complete references. The period covered by this Report is approximately 1 October 1969 to 1 December 1972.

Several authors have contributed to this summary: S. W. McCuskey, F. J. Kerr and T. Elvius [Sections I-IV]; L. Perek and F. J. Kerr [Section V]; L. Perek, C. C. Lin, M. Lecar and L. Woltjer [Section VI]. In addition Dr T. A. Agekian has provided a summary of the current researches by the Soviet astronomers. The responsibility for the organization and editing of the Report is that of the President of the Commission, who wishes to express his gratitude to these colleagues for their important contributions.

Advances in observational techniques and subsequent enrichment of data pertinent to research in galactic structure are discussed in the Reports of Commissions 7 (Dynamics), 24 and 30 (Motions and Distances), 27 (Variable Stars), 25, 29 and 45 (Spectra and Photometry), 28 (Galaxies), 34 (Interstellar Matter and Nebulae), 37 (Clusters), 40 (Radio Astronomy), 43 (Plasmas), 44 (X-, γ- and Cosmic Rays) and 48 (High Energy Astrophysics). To these the reader is referred for many details concerning matters which cannot be discussed in the present Report.

It is always a difficult task to summarize briefly the important developments in a field as broad as that embraced by the title 'Galactic Structure'. We note, however, the considerable progress being made in the search for optical tracers of spiral structure and the acquisition of reliable data on distances and velocities. This combined with radio data is yielding an increased understanding of the relationship between the gas and the stellar components of the Galaxy. It has been shown rather convincingly that young stars and interstellar matter have similar kinematic properties. It has also been established that the velocity dispersion for stars increases with distance from the galactic plane which indicates a deviation from a steady-state situation in the Galaxy.

Many additional molecules have been detected through radio line studies. These reveal a great deal about the physical conditions in the interstellar medium, particularly the dust clouds and complexes, the galactic center region and the spiral arms. Excellent reviews of radio molecular spectroscopy have been published by Turner (04.131.042 and .093), Dieter (06.003.091), Rank *et al.* (06.131.137) and Buhl (06.131.087). Details are given in the Report of Commission 40.

The two-component model of the general interstellar medium has gained wide acceptance, and many studies have been concerned with deriving its physical parameters. This model has cool clouds immersed in a hotter distributed medium (see Section III A). Pulsars are valuable as interstellar probes, because the dispersion, depolarization, scintillation, and 21-cm absorption of their pulses can be measured. Extensive observational work on pulsars has been reviewed by Large (05.141.165).

A great increase has taken place in the number and variety of stars and starlike objects from which radio emission has been detected. In 1969, the list comprised only a few M-dwarf flare stars, and about 40 pulsars (neutron stars). Increased sensitivity, especially in work by Hjellming and Wade

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(06.141.109) with the Green Bank interferometer, has now led to the detection of radio continuum emission from several red supergiants, blue dwarf companions to red supergiants, novae, and X-ray stars. In addition to the continuum detections, OH emission has been detected from a number of M supergiants and late M-type Mira variables which are also 10 μ infrared sources, and also from some Mira variables which do not show an infrared excess. Sources of OH and H_2O maser emission are also very small in size, according to very long-baseline interferometer measurements, and they may be related to protostars.

Several studies have been concerned with radio recombination line emission which apparently comes from distributed ionization in spiral arms, in regions where there are no obvious discrete sources. If the interpretation is correct, these investigations provide a method for studying this previously inaccessible distributed ionization, and perhaps a new way of probing the spiral structure, although the emission is too weak to be very useful for the latter purpose so far (see Section IV A).

There have been several new surveys of the high- and intermediate-velocity hydrogen, and new interpretations have been proposed. Two workers have suggested that the high-velocity clouds are in high-z extensions of distant spiral arms in outlying parts of the Galaxy. The intermediate-velocity gas is probably more local, and may have resulted from a displacement of some of the low-velocity gas in a nearby part of the galactic disk (see Sections III A, IV B, V B).

The 'spurs' and 'loops' of radio continuum emission which extend to medium and high latitudes have long been a puzzle. Proposed interpretations have regarded these features as artefacts of the local (helical) magnetic field distribution or as rather extensive nearby supernova remnants. The supernova interpretation has been supported by recent discoveries of neutral hydrogen apparently related to some of the features (see Section III A).

The density-wave theory of galactic spiral structure has won wider acceptance. Various studies of our Galaxy and other galaxies show evidence for streaming motions and for the segregation of various constituents in good agreement with predictions based on the theory. Recent and current attempts to derive a galactic model from 21-cm hydrogen-line surveys have all been based on density-wave kinematics. At the same time, an alternative hydromagnetic theory of spiral structure has been proposed by Piddington (1972), based on gas motions mainly perpendicular to the disk caused by a large-scale magnetic field whose tilt varies sinusoidally with rotation (see Sections IV A, V, VI).

In the theoretical domain, the third integral has reached a stage of maturity when its role in stellar dynamics is understood, at least in general lines, and its study is directed to applications and consequences. Galactic orbits were computed in rather sophisticated gravitational fields. One question which received extensive attention was the place of origin of stars of different types.

There was no substantial improvement of the observations needed for constructing a galactic model and Schmidt's 1965 model continued to be an adequate representation, although new models have been devised with possible analytical advantages.

Many programs have been initiated for computing stellar orbits, spiral patterns, etc. from different galactic mass models. These should lead to a better understanding of the gravitational field of the Galaxy. Review papers by Contopoulos (05.151.049 and 06.151.039) present a picture of this activity.

The rapid advances in observational techniques leading to discoveries of infrared sources, X-ray and γ-ray sources and ultraviolet sources of energy are documented in the Reports of other Commissions. In Section VI E the relationship of some of these to galactic structure is summarized.

In addition to the review articles already mentioned we call attention to those by Eelsalu (03.155.063) on the *Smoothed Structure of the Galaxy*; by Eggen (02.155.013) on *Stellar Groups in the Old Disk Population* and (1970) on *Stellar Kinematics and Evolution*; by Woolley (05.013.003) on *The Stars and the Structure of the Galaxy*; by Carruthers (03.131.020) on *Atomic and Molecular Hydrogen in Interstellar Space*; by Wilson (02.155.024) on *The Large Scale Structure of Our Galaxy as Derived from Radio Recombination Line Surveys*; by Burbidge (01.156.001) on the *Galactic Magnetic Field*;

and by Courtés (1972) on *Spiral Structure and Kinematics of the Galaxy*. Other summaries are noted in the subsequent sections of our Report.

Several lectures, symposia and conferences of importance in galactic structure research have taken place. At the XIV General Assembly of the IAU in Brighton in 1970, B. J. Bok and C. C. Lin presented *Invited Discourses* on *Galactic Spiral Structure* (06.003.026). More recently the first Regional Meeting of the IAU, held at Athens, Greece in September 1972 provided a forum for many discussions of the structure and dynamics of the Galaxy. In addition to several contributed papers there were invited lectures on *The Theory of Galactic Spiral Structure* by Contopoulos and by Lynden-Bell; on *Gould's Belt* by Lindblad; on *Infrared Astronomy* by Borgman; on *Galactic Nuclei* by G. Burbidge and by V. Ozernoy; on *Molecules as Probes of Interstellar Matter* by Mezger; and on the *N-Body Problem* by Wielen.

Among other meetings we note *IAU Symp. No. 50, Spectral Classification and Multicolor Photometry*, 1971, Cordoba, Argentina; *IAU Symp. No. 52, Interstellar Dust and Related Topics*, 1972, Albany, N.Y.; *IAU Symp. No. 54, Problems of Calibration of Absolute Magnitudes and Temperatures of Stars*, 1972, Geneva, Switzerland; a *Spiral Workshop*, 1970, U. of Maryland (Simonson 04.155.012); an informal symposium on *Problems of Galactic Spiral Structure*, 1972, U. of Arizona (Bok *et al.*, 1972); a conference on *The Galaxy and the Distance Scale*, 1971, Herstmonceux Castle U. K. (Lynden-Bell and Yallop, 1972); *IAU Coll. No. 17. Ages of Stars*, 1972, Paris; *IAU Coll. No. 10, The Gravitational N-Body Problem*, 1970, (Contopoulos 05.151.039); a symposium on *Dark Nebulae, Globules and Protostars*, 1970, Tucson, Ariz. (Ed. B. T. Lynds 06.003.091); A NASA symposium on *The Gum Nebula and Related Problems*, 1971, Greenbelt, Maryland; a seminar on *High Velocity Hydrogen*, 1971, Green Bank, West Virginia.

In concluding this section we list briefly a few priorities, principally observational, for research bearing on problems of galactic structure.

(1) In the optical realm the need for detection, distance measures and radial velocity measures of faint supergiant stars, HII regions, young clusters, long period cepheids and other spiral arm tracers is urgent.

(2) To attain the above, improved calibrations of absolute magnitude, intrinsic color and other distance indicators, particularly in multicolor systems including the infrared are needed.

(3) An overall cooperative plan for studying the space distribution, orbital motions and the related dynamical phenomena for the region near the Sun both in the galactic plane and at higher latitudes is paramount.

(4) Southern hemisphere 21-cm HI observational data lag far behind that for the northern hemisphere. New studies are of urgent importance both for detail near the galactic plane and for more general coverage to $|b| = 10°$–$15°$.

(5) The interpretation of high-velocity hydrogen clouds is still controversial. A wider coverage of the sky by observational data, particularly in the southern hemisphere is needed.

(6) The spiral patterns derived from 21-cm HI observations and from Hα observations of HII regions show serious disagreements. It is important to determine whether these represent real differences in location of the two constituents, or are due to methods of analysis.

(7) Continued theoretical development and observational tests of the density-wave theory of spiral structure (and possibly of alternative theories) both for our Galaxy and for other systems should have high priority.

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