49. REVIEW OF GALACTIC PROBLEMS

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The original plans for this Symposium called for a review of galactic problems by the late Dr. J. L. Pawsey and myself. In the early days of radio astronomy Pawsey often represented CSIRO at international symposia. Many of us enjoyed the lucid reviews that he presented of the work done at CSIRO, much of which was carried out under his inspiring and energetic guidance. It is at a moment such as the present one that we remember him vividly and miss him deeply.

The assignment to review galactic problems has not been made any lighter by the excellent introductory lecture given by Professor Oort. The problems that he listed are still with us, even after so fruitful a conference. I would like to limit myself to a brief discussion of some major developments and problems. My choice is necessarily somewhat subjective and I hope you will forgive me if some of the excellent contributions to this Symposium will not be mentioned. I have listed below some of the major problems which come to mind.

Subject	*Some Major Problems*
Density distributions	1. Make-up of local density
	2. Density gradients toward centre
	3. Spiral structure
	4. Radio corona
Velocity distributions	1. Correlation with stellar mass
	2. Vertex deviation, spiral structure
Dynamics	1. Gas dynamics, magnetic fields
	2. Large-scale deviations from circular motion
Evolution	1. (All problems)

A good deal has been said in the Symposium about spiral structure and I would like to add a few words about some of the aspects of its determination. There are four ways (at least) to study spiral structure of a particular kind of object, or to study the relative distribution of different kinds of objects. These are:

(1) From surface distributions. When we talk about spiral structure, this is, in general, the longitude distribution.

(2) By comparing radial velocities. This refers to the comparison of spiral structure of different kinds of objects.

(3) By ordering in the line of sight.

(4) Through distances of individual objects.

I would like to mention a few examples illustrating the most effective use of these methods. Method (1) is specially useful at tangential points, if the objects in question show spiral structure. Studies at the tangential points of the hydrogen arms in the interior parts have played a crucial role in unravelling the hydrogen-spiral structure. Optically, the method is a powerful means to compare old and young spiral structure in the Carina and Cygnus arms. Longitude distributions in these directions can be converted into distributions across the spiral arm with distances of low accuracy. It is in these arms that we have the best opportunity to study the distribution of dust relative to that of gas, to find whether the period distribution of cepheids depends on radial position in a spiral arm, etc.

The second approach involves comparison of radial velocities of young objects with the velocities of HI in the direction of interest. This method is not used very often. If one finds agreement, one may hope, indeed can expect, that the distribution in space of the two kinds of object is similar. If one finds disagreement, especially systematic disagreement, between the velocities, there is the possibility of systematic relative velocities or of a different spatial distribution for the two kinds of object.

The third method, ordering in the line of sight, is a particularly powerful one in some cases, although it has not been used much as yet. This is done through absorption. An interesting case is that of the Perseus arm, studied by Guido Münch, where he found that the velocity displacement from the local standard of rest of the interstellar absorption lines is larger than that for the stars. This is the reverse situation of what is expected if stars and gas move in circular orbits, since the gas must be situated in front of the stars. Either the gas or the stars must have large deviations from circular motion. Another case of interest is the 21-cm absorption profile in the direction of the Crab Nebula, which shows gas receding with velocities between 5 and 10 km/sec. Since this is close to the direction of the anti-centre, the only distance indication for this gas, which is moving away from the centre of the Galaxy, is that it is in front of the Crab nebula. Another application would be through HI absorption on thermal sources. If one can find the HII regions one could compare the velocities of the HII regions and the HI, as discussed above. If the O stars can be observed, a tie-in between the stellar spiral structure and the HI spiral structure is possible.

The fourth method, involving distances, is of course the most straightforward one, but it is the most vulnerable one, too, for obvious reasons. Since most comparisons of the spiral structure of particular types of optical objects are done with HI observations obtained at 21-cm wavelength, for which the distance is determined kinematically, one must have some assurance that this distance scale and the photometric distance scale are consistent. HI distances have been based on a curve of circular velocity for which the value of the constant A is $19 \cdot 5$ km/sec.kpc. On the other hand, there is increasing evidence, as reported in the Symposium, that our present photometric distance scale corresponds to a value of A more nearly 15 km/sec.kpc. The inconsistency in the two distance scales has to be allowed for when we compare the distribution of young objects with that of hydrogen as given by published maps.

It is clear now — and this came out many times during the past week — that there are large-scale deviations from circular motion. A particularly serious deviation was noted quite some time ago by Dr. Kerr when he found that a part of the rotation curve observed from the southern side deviates from the corresponding part of the northern side. These large-scale deviations make our studies of the

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Galaxy quite difficult, but at the same time they provide us with information, the exact nature of which is not yet clear to us. These irregularities represent large energies and one may want to explain them in terms of nuclear energy through supernovae, or in terms of gravitational energy, or gravitational plus magnetic energy.

This brings us to magnetic fields. The work reported from Jodrell Bank shows that the general magnetic field is considerably smaller than 1 gamma, and this implies that its effect on the dynamics of interstellar gas is minor. If so, the only way to conserve some kind of spiral structure would seem to be through gravitational effects, which then probably also would have to account for some of the deviations of circular motion observed. Professor Lindblad indicated that this requires a considerable concentration of mass into the spiral arms, for which the collection of further observational evidence would be of great interest.

In connection with the make-up of the total density in the solar neighbourhood, the gas density is of importance. Densities from 21-cm work have been determined on the assumption that there are no large fluctuations of brightness temperature in the antenna beam. This is certainly not correct, as is shown for instance by absorption profiles obtained at 21 cm in the direction of bright radio sources. The true densities of hydrogen will be higher than those found from the above assumption. More absorption work on many sources at high resolution will be required to bring this question near to its solution.

The work on Faraday rotation and depolarization represents one of the most fascinating recent developments, largely due to our CSIRO colleagues. They find that a considerable part of the Faraday rotation and of the depolarization is correlated with galactic latitude and thus must be of galactic origin. The interpretation involves the small-scale structure of electron density, as well as the small-scale structure of the magnetic field. The radio radiation from the galactic halo is in turn dependent on the structure of the magnetic field and on the distribution of relativistic electrons.

We see that the interpretations of 21-cm observations, of Faraday rotation and depolarization, and of the galactic radio halo are strongly interrelated. It appears that results on the large-scale structure of the *interstellar* component of the Galaxy depend heavily on the small-scale properties of the interstellar gas. Study of the latter requires high resolution as is evident in the installations for radio astronomy in this and other countries.

Studies of large-scale structure of the *stellar* component of the Galaxy depend not so much on resolving power but rather on gain, i.e. on the diameter of the optical telescope. I think that all of us after the sessions that we have had are more than ever impressed with the opportunities for more penetrating studies of the southern sky in which the central parts of our Galaxy pass overhead. The relatively low interstellar absorption in some parts of the Milky Way south of the galactic centre makes this part a most favourable hunting ground for distant objects, from which highly desirable information about rotational velocities and distribution of velocities relative to HI could be determined. There can be no doubt that the establishment of a large optical telescope in this continent would represent a major step in obtaining this and other goals.