16. COMPARISON OF THE GALACTIC SYSTEM WITH OTHER STELLAR SYSTEMS

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A comparison of the Galactic System with other stellar systems might be based on:

(*a*) the regular aspect (the population II);

(*b*) what we might call the semi-chaotic aspect, presented by the gas and the other population I objects;

(*c*) the spherical corona of continuous radio-emission.

As far as (*a*) is concerned we are not yet in a position to say very much. The only type of objects of extreme population II that we have recognized with certainty in the Galactic System as well as in other comparable systems are the globular clusters. They are very incompletely known in the Galaxy, perhaps somewhat more completely in the Andromeda nebula, but few systematic studies have been made in other systems. So far as we can tell, the Andromeda nebula and the Galactic System are comparable in the number and general distribution of globular clusters.

The bright yellow giants that show such a regular distribution in the disk of the Andromeda nebula have still hardly been recognized in our own Galaxy.

There is, however, one other type of information concerning the general distribution of population II in the Galactic System, namely through measures of rotation. These yield information on the mass distribution. It appears likely that most of the mass consists of population II objects. Concerning the mass distribution, however, the information on *other* stellar systems is still fragmentary. The most we can say at present is that, up to about 7 kpc from the centre, there seems to be reasonable agreement between the rotation curve of the Andromeda nebula and that of the Galactic System (see Fig. 1). The absolute velocities may be a little higher in the Andromeda nebula.* The rotation curve observed in M 33 appears to be considerably different.

* *Note added November 1956.* Recent measures of the 21-cm radiation from the Andromeda nebula have shown that there is no observable difference between the rotational velocities of the south-preceding and the north-following half of the nebula, and that the velocity remains practically constant from 8 to 22 kpc distance from the centre. In the Galactic System, on the other hand, there appears to be a considerable drop in rotational velocity beyond 7 kpc.

The evidence available points strongly to an Sb type for the Galactic System. If it were of type Sa, the strong central bulge would certainly be expected to show up very clearly in the general region surrounding the centre, which it does not.

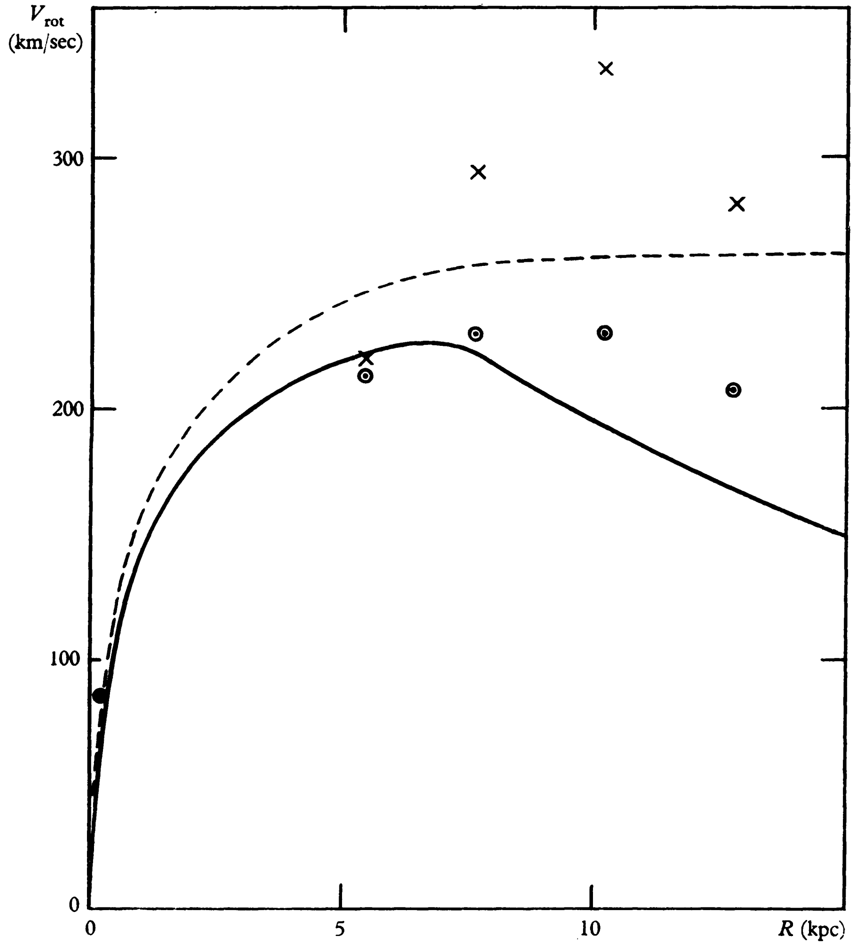

Fig. 1. Comparison of rotation of Andromeda nebula (dashed curve) with that of the Galactic System (full curve). Circles refer to the south-preceding, crosses to north-following side. They were read from smooth curves based on Mayall's and Humason's measures of emission patches. The filled circle at $R = 250$ pc refers to Babcock's observations of the inclination of absorption lines in the nuclear part.

As regards (*c*), observations are available for the Galactic System and the Andromeda nebula only. They indicate a similarity of the two systems in this most interesting and still barely understood feature. But observations are still uncertain in both cases.

By far the best material for a comparison of the Galactic System with other systems is furnished by (*b*), i.e. by the distribution of gas and supergiant stars. From the data on the distribution of gas over a large part of the system, as has been described by van de Hulst, we can infer directly that the Milky Way System must be an intermediate-type spiral. Outside the part within 3 kpc from the centre, which has not yet been studied satisfactorily, we find that a radius vector cuts four major arms plus a thinner outer arm. The major arms are spaced at distances of roughly 2·0 kpc and are thus wound moderately closely, such as we would find in an Sb spiral, possibly a somewhat early Sb. The outermost arm seems to deviate more strongly from a circle (cf. Fig. 1, p. 18, in the article by van de Hulst).

This picture shows much resemblance to that which has been described by Baade for the Andromeda nebula. According to his description there are beyond 3 kpc six spiral arms, of which the outermost may be no more than a few dispersed groupings of early-type stars with little interstellar material. On the basis of his new distance determination he estimates the average separation between the arms as about 3 kpc, against 2 kpc in the Galactic System.

In the region closer to the nucleus, however, we note several differences. At first sight it even looks as if the two pictures are to some extent complementary. In the Andromeda nebula the arms appear to grow heavier when we proceed inwards, and they extend down to the very nucleus. In the Galactic System, on the other hand, the density of hydrogen atoms is smaller in the central parts than in our neighbourhood, and we observe only little sign of spiral structure within 3 kpc from the centre. The hydrogen clouds observed in this part of the system appear to move with quite high random motions.

Does this mean that the two systems are radically different from each other? A possible alternative is that the hydrogen in the inner parts of the systems is largely molecular, so that it cannot be directly observed. The high-velocity hydrogen atoms that we do observe would then be only a small admixture.

It remains an intriguing problem to find out what causes these high velocities, and also why it is that in the very dense inner arms of the Andromeda nebula, that are full of heavy dust clouds, no high-luminosity early-type stars are visible.

An interesting set of data which is obtained by the study of the hydrogen distribution is the measure in which the hydrogen layer deviates from a plane. The deviations of the centre of the main layer from the average galactic plane as defined by the 21-cm measures are shown in Fig. 2. It will be seen that in the part within $R = 8$ kpc the deviations are everywhere surprisingly small. It is only in the outer parts that sensible deviations occur. These are still small compared to the distances from the centre. They have, however, an outspoken systematic character.

While the study of the Andromeda nebula and other spirals will help us to obtain a better picture of the general structure of the Galactic System, the study of spiral structure in the Galactic System is bound to become of considerable importance for the understanding of the mechanism that causes the spiral arms.

It has become increasingly probable in recent years that spiral structure is closely related to the gaseous constituent of a system: only systems containing a fair proportion of interstellar gas seem to be capable of developing spiral arms. It is indeed not improbable that the spiral arms *consist* largely of gas.

It is a remarkable fact that practically *all* systems that do contain gas, and that have a sufficiently short time of revolution to have made possible some measure of systematic arrangement of matter, show spiral structure.

So far, however, we have only the vaguest ideas, if any at all, of how a large-scale spiral structure, extending over an entire stellar system, can have originated, and it is even far from clear how, if once originated, it can subsist during several revolutions.

The study of spiral arms in the Galactic System will certainly help to bring us to a better formulation of these problems. The observations in our own Galaxy reveal several features that cannot be observed with comparable precision in other systems, such as the thickness of the layer to which the spiral pattern is confined, and systematic deviations from the average plane of the spiral. Further, we have in the Galactic System a far better knowledge of the gravitational field in which the arms move, while we can also hope, in this case, to obtain an approximate picture of the *stellar* population of a spiral arm. Finally, and perhaps most important, we can study in fair detail the systematic and random motions of the gas clouds that form the basic pattern of the arms, and we may thus be able in a near future to obtain a more complete picture of how the spiral structure might be kept in existence during 10 or 20 revolutions of the system.

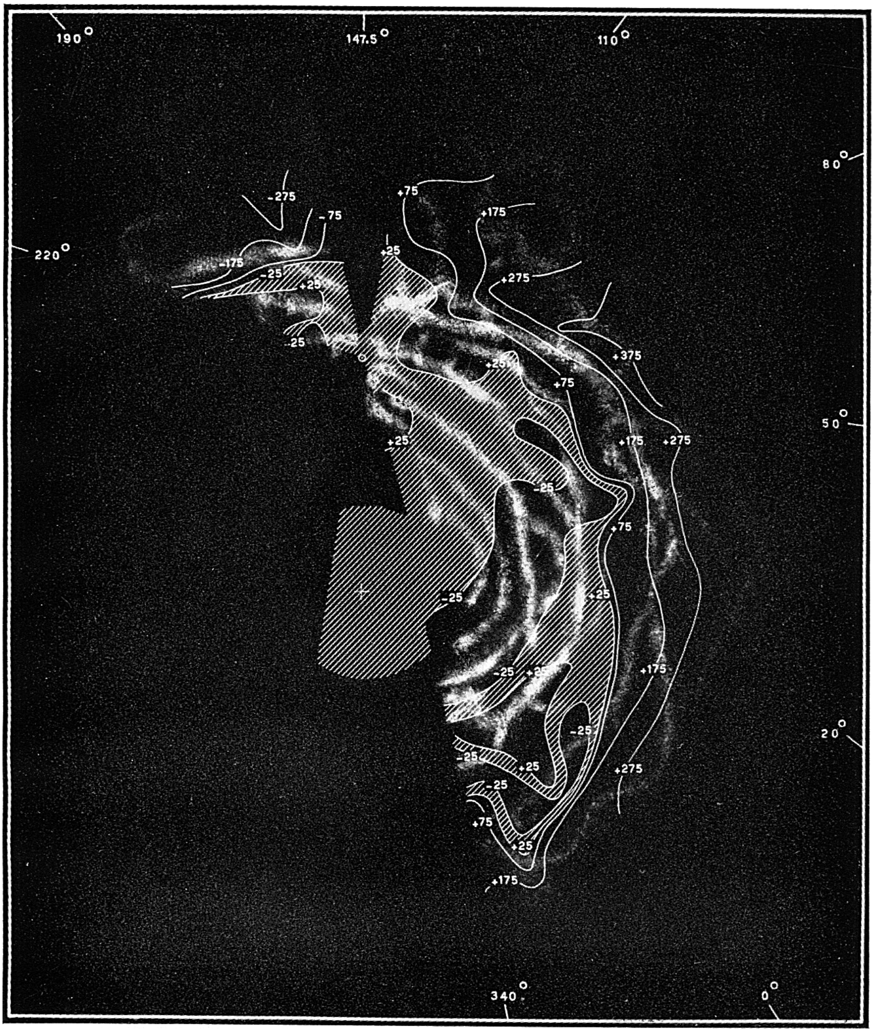

Fig. 2. Deviations of the hydrogen layer from the average galactic plane. This average plane is inclined 1°·5 to the standard galactic plane. In the hatched part the deviations of the centre of the hydrogen layer from the average plane are less than 25 pc. The curves are contours of equal distance from the average plane; the numbers indicate the distances in parsecs.

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