practically free from interstellar absorption up to a distance of about 1050 pc, after which rather suddenly a marked excess of colour appears with a simultaneous increase of the space density of the stars. The depth of the cloud appears to be about 800 pc.

References

ELVIUS, A. (1958).—*Pop. Astron. Tidskr.* **39**: 151.
ELVIUS, A., and HERLOFSON, N. (1960).—*Ap.J.* **131**: 304–9 (=Uppsala Obs. Medd. No. 128.).
ELVIUS, A., and LINDBLAD, P. O. (1959).—*Arkiv Astron.* **2**: 393–406 (=Uppsala Obs. Medd. No. 126.).
HÖGLUND, B. (1963).—*Arkiv Astron.* **3**: 215–72.
LINDBLAD, B. (1958).—*Stockholms Obs. Annaler* **20**: No. 4.
LINDBLAD, B. (1963).—*Stockholms Obs. Annaler* **22**: No. 5.
LINDBLAD, P. O. (1960*a*).—*Stockholms Obs. Annaler* **21**: No. 4.
LINDBLAD, P. O. (1960*b*).—*Pop. Astron. Tidskr.* **41**: 132–49.
MAYALL, N. U. (1960).—Colloque Int. CNRS. [Paris 1959] *Ann. d'Ast.* **23**: 344–59.
RAMBERG, J. M. (1957).—*Stockholms Obs. Annaler* **20**: No. 1.

Discussion

Bok: One should not overlook the fact that in many parts of the Southern Milky Way, the A stars are heavily concentrated in regions where there are not many OB stars or HII regions. The Carina region is a good example. One has a high density of A stars to a distance of 800 or 1000 pc and no OB stars until 2000 pc or a greater distance from the Sun.

Lindblad: Different constituents of the spiral arms will not always coincide. It is in fact not possible to argue a uniform composition of the arms. Great variation may occur and we should try to get information on the integrated composition. It seems that the dominating component as to spiral type can vary. In the actual cases the results cannot be doubted.

Buscombe: A good example is the prominent feature near Norma — the early O association for which Whiteoak from *UBV* photometry finds $r = 1400$ pc, and Drs. Feast and Thackeray the mean radial velocity -41 km/sec.

de Vaucouleurs: I should like to stress the importance of Dr. Lindblad's remarks on the inward-directed curl of the outer spiral arms in many galaxies. This is not a peculiarity but a normal feature in SB(s) systems, such as NGC 1300, where the arms seem to intersect without apparent disturbance. How is this possible if the arms contain gas? Or are they in different planes?

Lindblad: I am glad that you agree on the existence of the in-going branches. The condition of the outermost arms is complicated and the arms are rather broken up into pieces so that great variations may occur, probably also as to the plane. It seems that the importance of the returning matter for the dynamics of the system has not previously been fully realized.

22. COMPARISON OF HI SPIRAL PATTERN WITH OPTICAL STRUCTURE OF OTHER GALAXIES

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I. The maps of the spiral pattern of neutral hydrogen in the outer and intermediate regions of the Galaxy resulting from the 21-cm studies at Leiden and Sydney may be compared with the optical structure of other galaxies. If, as seems probable, most hydrogen arms coincide with or follow closely the optical arms marked by the blue supergiant stars, a comparison of the HI pattern with photographs in blue

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light should be meaningful. Such a comparison may lead to the identification of the galaxy type to which our Galaxy belongs. The regularity and symmetry of the HI spiral pattern indicates that our Galaxy is a normal system, and one to which, in principle, a definite type in the revised classification scheme (de Vaucouleurs 1958, 1959) can be assigned. If this assignment can be made successfully it should assist in the interpretation of the radio observations of the inner regions. There is a good

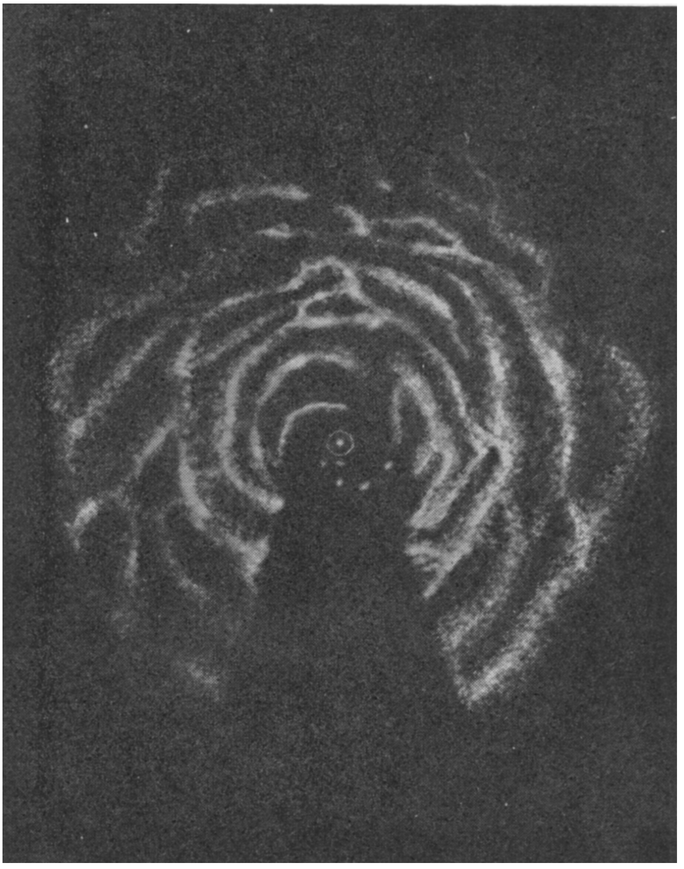

Fig. 1.—Spiral pattern of neutral hydrogen in the Galaxy. (An artist's impression, prepared by G. Westerhout from 21-cm results.)

possibility of at least restricting the range of galaxy types consistent with the HI spiral pattern of the outer regions because there is a high degree of correlation between galaxy type and multiplicity of the spiral pattern.

II. The main characteristic of the Leiden and Sydney maps of the HI distribution (Fig. 1) is the high multiplicity of the spiral pattern. This high multiplicity does not agree with the simple two- or four-armed pattern of SA(s) systems, such as M81 or M31, or SB(s) systems, such as NGC 1300 or NGC 1365. It is also

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unlike the three- or four-armed pattern of the SB(r) type, as in NGC 1433 or NGC 5921; the transition types SAB(s) (e.g. M83, M100) and SB(rs) (e.g. NGC 1073) are excluded for the same reasons. A high multiplicity is observed only in the systems shown in the upper right quadrant of Figure 2,* i.e. in types SAB(r), such as NGC 6744; SA(r), as M94, NGC 6753, or NGC 7217; and SA(rs), such as M77 or M63.

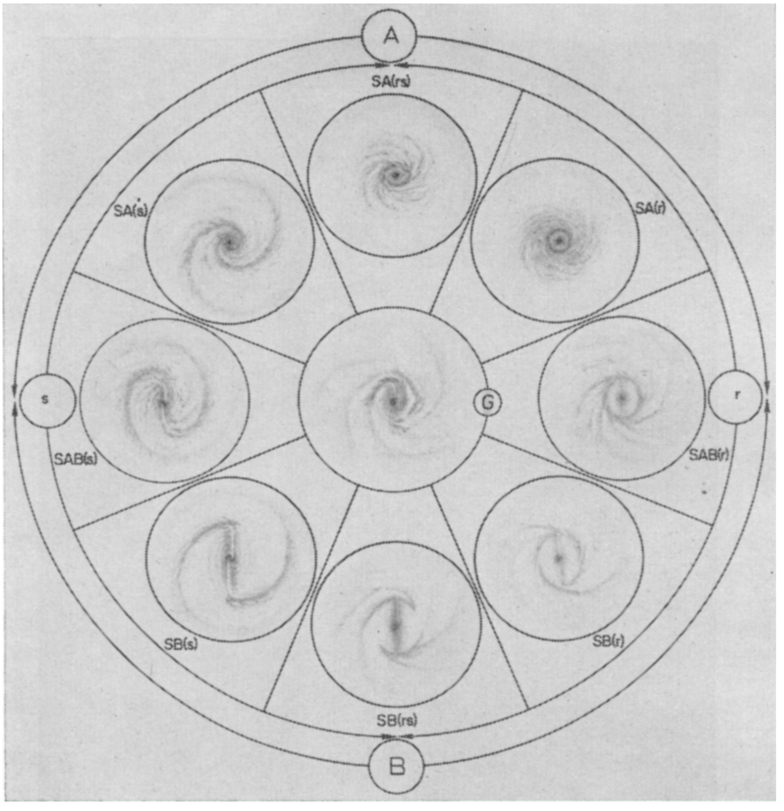

Fig. 2.—Cross section of classification volume at Sbc, showing probable position of our Galaxy (circled G).

The hybrid type SAB(rs), in the centre of the diagram, exemplified by M61 or, at a later stage, M101, cannot be excluded, although the multiplicity of the pattern is usually less. The multiplicity is highest at type SA(r) and least at type SB(s).

* Figure 2 includes two significant revisions to the original illustration (prepared in 1956) of the main types as published in the *Handbuch der Physik* article: (1) the diameter of the inner ring (r) in the SA(r) systems is now known to be significantly smaller than in the SB(r) systems; (2) the structure of the SA(rs) type was not well understood in 1956 and the illustration then chosen (M51) was incorrect; actually in this type the inner ring is made up of bright fragments of spiral arcs around a relatively isolated nucleus, and the type example is M77. Transition types to SA(r) include M63 and M94, the latter being closer to the typical SA(r) systems such as NGC 7217.

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III. A more detailed comparison which the reader can repeat at leisure with the help of the Hubble Atlas (Sandage 1961) and by reference to the classification criteria of the revised system (de Vaucouleurs 1958, 1959) suggests that the HI spiral pattern in our Galaxy resembles most the optical structure of galaxies whose representative point lies in the area marked G in Figure 2, i.e. in the transition region between typical SAB(r) and SAB(rs) systems. Types SA(r) and SA(rs) are less plausible because the multiplicity and complexity of their spiral pattern appear to be greater than that disclosed by the 21-cm observations (assuming that it is not too limited by insufficient resolution). In these types also the main spiral structure is often surrounded by a detached outer ring structure of which there is no indication in the radio data for the Galaxy.

IV. The most appropriate comparisons among the brighter galaxies are with

(*a*) NGC 6744, SAB(r)bc, which has a broad, diffuse nucleus, a weak bar in a relatively faint ring, and many filamentary arms;

(*b*) NGC 4303, SAB(rs)b, which has a small bright nucleus in the centre of a broad bar with complex dark lanes, and a pseudo inner ring — almost a hexagon — formed by straight segments of three main spiral arms branching out into the fainter spiral structure of the outer regions. A "late" example of this second type is M101, SAB(rs)cd.

The correlation between multiplicity of the spiral pattern in the outer regions and the structure of the inner regions indicates that in the Galaxy a weak bar and incomplete ring structure may be present. This suggests a possible interpretation of the velocity distribution in these regions discussed in another communication.

References

SANDAGE, A. (1961).—"The Hubble Atlas of Galaxies." Carnegie Institution of Washington Publ. No. 618.

DE VAUCOULEURS, G. (1958).—*Rev. Mod. Phys.* **30**: 926–30. =*Symp. IAU* **8**: 926–30. [Cambridge, Mass. 1957].

DE VAUCOULEURS, G. (1959).—"Handbuch der Physik." (Ed. S. Flügge.) Vol. 53. pp. 275–310. (Springer–Verlag: Berlin.)

Discussion

Arp: In connection with an investigation of emission nebulae there, I have sketched the positions of the major spiral arms in M31.

The features have then been mathematically projected to give a flat-on view. The slide shows that the two major spiral arms and segments of three fainter ones all fit well a rather flat-pitched logarithmic spiral. In the very inner regions the pitch of the spiral steepens and in the very outer regions the pitch flattens. In view of the frequent comparisons made between our own Galaxy and the Andromeda nebula it is worth noting that the separation of the arms in M31 is of the order of 4 kpc. The three spiral arms known near the Sun, however, are only separated by the order of 2 kpc, and our own Galaxy then has either twice as many arms as M31 or they are wound twice as tightly as the already fairly tightly wound Andromeda galaxy.

de Vaucouleurs: I fully agree with Dr. Arp's remarks. The comparison with M31 was justified some 30 years ago when first attempts were made at demonstrating the spiral structure of our Galaxy. Now, however, we should look at other galaxies than M31 for a more appropriate comparison with the detailed structure of our Galaxy.