CONCLUDING LECTURE *by*

H. C. VAN DE HULST
Leiden Observatory, The Netherlands

This session contained all the papers that did not fit very well in the other sessions, i.e., those papers dealing neither with the solar system nor directly with problems of galactic structure nor with the faint sources and their statistics. This negative criterion has led to a variety of contributions, the common denominator of which is that we try to find out as much as we can about everything. I shall try to summarize the main points and add my own comments.

1. BRIGHT IDENTIFIED SOURCES

There have been several mild controversies in this Symposium. Fortunately nobody has tried to argue radio astronomy versus optical astronomy. The comparison is too uneven! The beautiful photographs brought before us by Minkowski, Bok, and others are not even remotely approached by the radio maps of the sky, in spite of the fact that the biggest gain since the last symposium has indeed been a gain in resolving power. Therefore, the first aim of the radio astronomers must remain high angular resolution, which may lead to optical identifications, allowing more detailed studies.

The identification marks an enormous step ahead. Think of what we would know of Cygnus A, or of Cassiopeia A, or even of the Crab nebula, if there had been no optical photographs, spectra, and radial velocities. I do not think I have to recall the results of the optical studies in detail. Minkowski has had the difficult problem for the past five years of reporting almost every year to a symposium about the progress made in this work. He has brought some variation to it by changing the excitation mechanism of the Cygnus loop several times and by radically changing the distance of Cassiopeia A from 500 to 3400 parsecs, which shows how difficult the optical observations are also. But the series is convergent and we hope very much that Minkowski and the other experts in optical astronomy will continue to devote such a large fraction of their attention to problems related to radio sources as they have been doing until now.

Does this mean that the task of the radio astronomer is over once he has delivered an object into the hands of Minkowski, Dewhirst, or Bok? By no means! Everything has to be observed more accurately. This holds in particular for the following groups of data:

(*a*) position, size, brightness distribution;
(*b*) polarization;
(*c*) absolute flux densities, radio spectra.

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Under (*a*) fall the communications by Jennison and Laffineur and a number of details contained in the work of Mills, Shain, Boischot, Westerhout, and Elsmore. Only one paper (Kuz'min and Udal'tsov) fell under (*b*). Only two papers (MacRae and Whitfield) fell under (*c*), but we should also add the beautiful results of the Naval Research Laboratory at 10 cm and with a maser at 3 cm, which are hidden in Part I.

The small number of contributions under (*b*) and (*c*) is not in proportion to the importance of these subjects but reflects the fact that these measurements are difficult. A special report (URSI Subcommission Vd) has been devoted to the problem of absolute measurements. May I just recall that in one discussion remark it was reported that one author whose point did not fall on the line had rechecked the receiver linearity and that the point is now all right. Would everybody please make sure that he checks his receiver linearity even if his point does fall on the straight line? I am sure that an increase in accuracy will reveal points of interest that may prove extremely helpful for the theoretical interpretation.

2. EXTENDED SOURCES

The fainter point sources were discussed in session IV but the extended objects, with diameter between 0.1 and 10 degrees, may be mentioned here. In it are the extragalactic nebulae M 31 and NGC 5128, for both of which radio-brightness maps have been presented that agree quite well at different frequencies. Both radio sources are much larger than the optical image.

Other extended sources are the H II regions seen in emission and in absorption; they appear to fit the theoretical expectations very well, so that nothing more has been said about the theory in this Symposium. One new use of the H II regions, however, has been indicated. At the low frequencies they provide nearly black screens at a known distance so that the emission in the galactic halo and even its distribution with distance can be more readily estimated. Shain has used both galactic H II regions and 30 Doradus for this purpose.

From the extended sources we gradually drift into objects like Cygnus X, the "supergalaxy," and the "$l = 0°$ belt," which have in common the feature that they can be quite well mapped, with agreement between different frequencies and between different observatories. Westerhout, Drake, Mills, and Baldwin have presented the evidence. They also have in common the fact that they are not or may not be individual objects. Cygnus X has been resolved into a set of different sources; the "supergalaxy" and the "$l = 0°$ belt" are features of the galactic continuum whose nature is doubtful.

3. THE 21-CENTIMETER LINE AT HIGH LATITUDES

The papers on the 21-cm line were again divided between different sessions so that this session contains only the papers of "local" interest. Among these we should mention first the impressive set of results obtained with the 54-channel receiver of the Carnegie Institution (Department of Terrestrial Magnetism). Erickson presented a complete survey of the region with

$|b| > 20$ degrees with a beamwidth of 2°.5. As the half-density points of the H I gas are, in general, reached about $|z| = 100$ parsecs, most of the hydrogen observed in this survey may not be farther away from us than 100 or 200 parsecs. This means, first of all, that the region surveyed is invisibly small when seen on the scale of the usual maps of spiral arms. But, secondly, it means that the linear resolution is of the order of 5 to 10 parsecs, as compared to the representative value of 200 parsecs for the presently available spiral-arm pictures. The best resolution reached anywhere else is in the absorption lines on the bright discrete sources discussed in Muller's paper. These observations refer to a sample of interstellar matter with an angular diameter determined by the source. The angle of 5 minutes of arc at a distance of 2000 parsecs gives 3 parsecs as the linear diameter of the sampling cone. This material is very important but also it is severely limited by the fact that there are no more bright sources.

The results just mentioned put radio astronomy ahead of optical astronomy in the investigations of interstellar gas within 100 to 200 parsecs from the sun. Not only is the velocity resolution better but also the resolution in size, which can even be improved to 2 to 3 parsecs with a 25-meter telescope. I gave a complete review of the radio and optical evidence on cloud sizes and cloud motions in the Third Symposium on Cosmical Gas Dynamics [1]. The optical evidence comes mainly from an indirect argument. Let a be the radius of the spherical clouds and n the number per unit volume. Then we can separately estimate from observations the occupied fraction of space, f, and the number of clouds crossed by the line of sight, k. The estimates found in the literature vary between

$$f = \frac{4}{3}\pi a^3 n = 0.14 \text{ and } 0.07,$$

$$k = \pi a^2 n = 5 \text{ and } 10 \text{ kiloparsecs},$$

so that the size varies between $2a = 0.042$ and 0.010 kiloparsecs.

These clouds of sizes 40 to 10 parsecs would already be resolved in Erickson's survey. A more detailed study will probably reveal that the model of isolated, spherical clouds falls far from the mark. In the paper mentioned I also analyzed the few data of the 25-meter telescope that might be relevant to this point. The size and velocity width of the clouds fell in the expected range, but the model of isolated clouds led to the prediction of much stronger intensity variations from place to place. Finally, we may add that the chance of finding interesting individual objects of the size of 1 parsec or so is not excluded. Recently it has become possible to study also the optical polarization by interstellar dust in this nearby region. Behr [2] has found a local cloud in the direction of Boötes at a distance of 50 parsecs.

4. FURTHER LINE STUDIES

A number of contributions in session III referred to well-known optical objects, about which the 21-cm observations might be expected to give clues regarding their physical nature or evolution. The most striking example is Drake's study of galactic clusters, in which a direct correlation of the amount of atomic hydrogen with the age was sought. Similarly, Menon studied the Cygnus loop, van Woerden the Orion region, and Howard [3] (not presented at this Symposium) the stellar association I Lacertae. A weak point in such studies is that the observing time usually has been too short to make quite sure that the objects stand out sufficiently well against the galactic background (or foreground) in the 21-cm line. Some of the conclusions, therefore, may have to be revised when more detailed data over a larger region of the sky become available. It will be a big job to collect these, but the importance of studies of this type is beyond doubt.

Somewhat related problems occur in the attempts to detect regions in which the hydrogen is colder than normal. One conspicuous case, the absorption by the very near clouds in front of Sagittarius A and the surrounding region, was discovered several years ago and was mentioned again in Muller's paper. Davies mentioned five further suspect regions (low points of intensity in the l, b, v space). Here it is much more difficult to know if it is absorption or a chance effect due to the irregular distribution of positions and velocities of the emitting clouds.

One 5-minute paper of great importance was given. Adgie reported on new negative attempts to detect the deuterium line. He showed that further gain cannot be reached (in the point-source absorption method) by increasing the antenna size still further. We hope that he, or others, will manage to get another factor 10 farther in receiver sensitivity and the results, positive or negative, will be greatly welcomed by the theoretical astrophysicists.

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