Part V

DISCRETE SOURCES AND THE UNIVERSE

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PAPER 85

THE DISTRIBUTION AND IDENTIFICATION OF THE SOURCES
INTRODUCTORY LECTURE by

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At the present stage of radio astronomy it is convenient to divide the observed radio sources into two classes: Class I sources, which show a concentration into the galactic plane; and Class II sources, which are distributed more isotropically. In the present session we shall be concerned principally with the Class II sources.

It is generally believed that these Class II sources, which are by far the more numerous, are extragalactic. This belief rests on observations of their *distribution* and on the *identification* of a few sources with objects observed photographically. I will review briefly the evidence under both these headings and try to point out as we go along the relevance of the papers that we are going to hear.

1. THE DISTRIBUTION OF THE SOURCES IN SPACE

Surveys have shown that in separating Class I from Class II sources we find that the Class II sources show no evidence of concentrating in galactic latitude. Their distribution is consistent with an extragalactic origin; furthermore, it has been difficult to construct a plausible model of the source population on the assumption that they are members of the Galaxy.

If the sources are extragalactic then we must inquire whether their distribution is correlated with any well-recognized features of the distribution of galaxies. At the present time no such correlation has been positively established; we must conclude, therefore, that the majority of known sources are not associated with the nearby bright galaxies. At one time this fact was held to be an objection to the view that these sources are extragalactic; however, as we shall see later, it is now known that some galaxies emit vastly more radio flux in relation to their light than do the majority of galaxies.

The distribution of the sources in depth is a subject of great current interest and we shall hear two or three papers in which this is discussed. At the present time their distribution has been studied by counting the sources in each magnitude range and by observing the probability distribution of the deflections observed at the output of a radio telescope.

The reason for the particular interest in the distribution of the sources in depth is that it might be used to test cosmological theories and we are to

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hear a paper on this subject. I believe, however, that the papers in this session will show that the radio astronomers must make considerable progress before they can offer the cosmologists anything of value. Take first the method of counting the sources: this technique is subject to serious errors when the number of sources is too great in relation to the resolving power of the aerial system. We are to hear two papers on this subject. The limitations of the second method, namely measuring the probability distribution, are less well understood and perhaps we can touch on this subject in discussion. At first sight one would expect it to be significantly affected by the enormous dispersion in the apparent angular diameter of extragalactic sources that must presumably be produced by clusters.

Two obvious difficulties in drawing cosmological conclusions from the source counts are: (1) we have no distance calibration, and (2) there is no evidence that we are dealing with a homogeneous population. In dealing with both these difficulties it would be valuable to have observations of the apparent angular diameters of large numbers of the Class II sources. Such observations as have been made indicate that their diameters are consistent with those to be expected for extragalactic sources, but there are few published measurements. The measurement of a large number of diameters would permit us to test the homogeneity of the sources; furthermore, coupled with additional optical identifications, it might be possible to estimate the distances to which our measurements are reaching. It is also possible, and I hope we shall hear something about this in the present session, that measuring diameters is a more promising way of testing cosmological theories than counting sources in different magnitude ranges.

2. THE IDENTIFICATION OF SOURCES

A few sources, less than twenty, have been identified with *normal* galaxies, and in this context *normal* implies that these galaxies show no trace of abnormality when examined photographically. The apparent radio (m_r) and photographic (m_p) magnitudes of these few galaxies have been compared, and an attempt has been made to test whether the quantity $m_r - m_p$ is constant for a given type of galaxy and if it varies systematically with type. The published measurements show that radio emission is a common property of Sb- and Sc-type spirals, and the few available results show a scatter in the value of $m_r - m_p$ of about ± 2 magnitudes. It has also been suggested tentatively on the basis of these results that Sc-type spirals radiate less radio energy in relation to their light than Sb-type spirals do. Observations of the Magellanic Clouds, which are bedeviled by the problem of establishing reliable integrated magnitudes, suggest that irregular galaxies may be relatively weak radio emitters; while, so far, all attempts to detect the radio emission from a single E- or Sa-type nebula have failed.

Dr. Hazard and I are engaged in a further study of *normal* galaxies and I will give a short report on this work later. Briefly, we have found that for galaxies of type Sb and Sc there is a surprisingly close relation between the radio and light emission, the scatter in $m_r - m_p$ for the dozen galaxies so far observed does not exceed ± 0.5 magnitudes. The results also show that any systematic difference in $m_r - m_p$ for Sb and Sc is small and does not exceed 0.5 magnitudes. In analyzing our data we have tried to compare as closely as possible the total radio and light output from the galaxies. The photographic magnitudes must, of course, be corrected for galactic absorption and "diaphragm" effects, also for the orientation of the Galaxy with respect to the observer. The radio observations must be corrected for the apparent angular size of the galaxies in order to derive their integrated magnitudes. As an example of the importance of this last correction I would like to draw attention to the fact that when observed at 160 Mc/s the angular diameter of M 31 is about 10×5 degrees, and it is therefore reasonable to expect that an Sb galaxy of comparable size will have an angular diameter of at least half a degree even when it is as faint as apparent magnitude +10.

In addition to these *normal* galaxies a few radio sources have been identified with *abnormal* galaxies. The most striking examples are the colliding galaxies in Cygnus and Perseus, and the curious Galaxy NGC 4486 which has a jet protruding from the nucleus. These objects exhibit a far higher ratio of radio emission to light than the normal galaxies, and as an extreme example the value of $m_r - m_p$ for the Cygnus source is about -14 compared with a value of about $+0.5$ for normal spirals. More identifications are badly needed and we look forward to two papers on this subject. The difficulties of this work are great: first, the radio positions are generally too vague, and second, the majority of radio sources appear to be associated with faint objects.

In conclusion I must emphasize how far we are at present from understanding the extragalactic radio-source population; we have in fact no reliable idea of the shape of the radio-source luminosity function. We need to study the radio emission from galaxies, not only by type, but also under different conditions of space density and interaction. Our present data tell us about the behavior of single spirals in conditions of comparatively low space density such as that prevailing in the Ursa Major Cloud, and we also know something about the radio emission in the other extreme case where spirals are in violent collision. But, as yet, we have very little information about the radio emission in intermediate conditions; for example, how do galaxies behave in the space density that prevails in compact clusters such as the Coma and Perseus clusters? There is some evidence that the radiation from these clusters is greater than one would expect on the basis of the little that is known about individual galaxies under conditions of low space density. It may well be that in a compact cluster the individual galaxies effectively lose their individual identities as far as radio astronomers are concerned, and it will be of great interest and importance to extragalactic studies to test this by observation. I hope that if there is any observational evidence on this last point it will be brought forward in this session.

Discussion

Mills: Early Sydney results indicated some systematic difference in $m_r - m_p$ between the mainly northern Sb and the mainly southern Sc galaxies. This difference has, however, now been traced to calibration differences, and our latest results support those of Hanbury Brown.

Minkowski: The earlier results seemed to show a rather large scatter for Sb galaxies in the values of $m_r - m_p$. A very good correlation seemed to exist between the values of $m_r - m_p$ and the differences between the colors of the galaxies as a whole and the colors of their outer parts. This seemed to suggest a dependence on the relative importance of Population I and II. The new results with their small scatter leave no room for such a correlation.