E. JOINT DISCUSSION OF COMMISSIONS 28 AND 40

ON

RADIO GALAXIES

Thursday 27 August 1964 at $14^h 00^m$

ORGANIZING COMMITTEE: J. F. Denisse, G. C. McVittie, M. Ryle, B. E. Westerlund.
MEETING CHAIRMAN: R. L. Minkowski.
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1. A RADIO SOURCE MODEL BASED ON MEASUREMENTS OF POLARIZATION AND BRIGHTNESS DISTRIBUTION

A. T. Moffet

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The major portion of the observing time of the Caltech interferometer during the past three years has been devoted to studies of the polarization of discrete radio sources. Observations by G. L. Berge, D. Morris, V. Radhakrishnan, G. A. Seielstad and R. W. Wilson have yielded measurements of the polarization of the decimeter radiation from about 70 sources. Of these, about 40 have been observed at three wavelengths: 11, 18 and 21 cm. Rotation measures and depolarization rates have been calculated for this latter group of sources. Rotation measure is defined in the conventional manner. Depolarization rate is an indication of the decrease in per cent polarization between 11 and 21 cm.

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Seielstad, Morris and Radhakrishnan (1) have considered possible relations between the polarization properties and other characteristics of the sources. They conclude that depolarization occurs within the sources themselves. They find no relation between the depolarization rates and (*a*) the galactic latitudes of the sources, or (*b*) the component angular separations for 17 of the sources which are known to be doubles. On the other hand, there is an apparent inverse correlation between the degree of polarization at 21 cm and the volume emissivity of the sources.

Morris and Berge (2) have considered the relation between the intrinsic polarization angle (with the effects of Faraday rotation removed) and the major-axis position angle for a number of double sources. They found that sources with low average surface-brightness tend to have the polarization angle aligned with the major axis. Sources of high brightness tend to be polarized in a plane perpendicular to the major axis.

On the basis of these observations, Morris and Berge propose a model for double sources in which each component contains two regions: (*a*) On the outward side of each component is a region of high brightness in which the magnetic field is predominantly perpendicular to the major axis. In young sources, of high surface brightness, the particle densities and magnetic field strengths would be high enough to completely depolarize the radiation from these regions. (*b*) Between these high-density regions and the parent galaxy are regions of lower plasma density and field strength in which the magnetic field is aligned more or less parallel to the major axis. Synchrotron radiation coming from these latter regions would be polarized in a direction perpendicular to the major axis, accounting for the observed behavior of the high-brightness sources.

In a source of lower average surface brightness, total depolarization would not occur in the regions of higher density. The polarized radiation from these regions would dominate and would be parallel to the source major axis.

I have recently made measurements of the component shapes in double radio sources (3). Of the four sources studied, all showed evidence of relatively high-brightness regions near the outward edges of the components. This tends to support the model proposed by Morris and Berge. An obvious further test of the model is the measurement of the brightness distribution of the polarized emission from the sources. Such measurements are now under way at the Owens Valley Observatory.

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DISCUSSION

H. D. Greyber. Implications for Radio-Galaxies from the Galactic Dipole Magnetic Field Model. In 1960, the concept of a large-scale dipole magnetic field of galactic dimensions was proposed by Greyber (1, 2, 3) where the dipole axis is along the minor axis (and rotation axis) of the galaxy. The purpose was to explain the spiral pattern in normal spiral galaxies.

The beautiful photographs taken in the last 3 years by Halton Arp and Margaret Burbidge of peculiar and 'interacting' galaxies (the Vorontsov-Velyaminov types) tend more and more to emphasize the large-scale order in objects of galactic dimensions. In addition the remarkable work of A. Elvius (4) has demonstrated the existence in M82 of a galactic dipole magnetic field oriented exactly as predicted. The recent central contraction and explosion in M82 (Lynds and Sandage (5)) have introduced into the halo of M82 the energetic electrons, gas and dust to permit observation of the large-scale dipole magnetic field.

A specific prediction of the model is that sufficiently close to the galactic nucleus the magnetic field should be in one direction along the spiral arm *above* the plane of the galaxy and in the opposite direction *below* the plane. Some evidence for this effect has been found for our local spiral arm by Morris and Berge (**6**).

In our opinion the double character of many large extra-galactic radio sources can be understood in terms of an enormous dipole magnetic field centered at the optical object with its axis along the line of centers of the inner pair of sources. A reasonable mechanism for generating such a dipole magnetic field in astrophysical objects has been devised by Greyber (**7**). The identical mechanism was proposed much earlier by D. H. Menzel for the generation of a loop current during star formation.

After the gravitational contraction and explosion which generated the dipole magnetic field (many times the size of the optical galaxy or 'quasar'), two huge clouds of hot gas and relativistic electrons are expelled mainly along the minor axis (i.e. dipole magnetic field axis). A quadruple source such as Centaurus A would be interpreted as two successive contractions and explosions.

It is important to note that the line of centers of the inner radio sources in Centaurus A lies along the rotation axis of the optical object. It is also significant to note that up to now, only in two optical objects which are also strong radio sources, has the rotation axis been carefully measured—Centaurus A and 3C 33—and in both cases the rotation axis is also the line of centers of the radio sources. In M82, the dipole field axis is also found to be the rotation axis. The 'core-halo' radio sources are interpreted in this model as the case when we observe roughly along the dipole field axis.

The model is obviously crude and the evidence available so far is fragmentary and inconclusive. However, the idea that (on the galactic dipole magnetic field model) the creation of spiral structure in galaxies and the evolutionary dynamics of strong radio galaxies and 'quasars' are similar phenomena on very different scales is appealing on theoretical grounds.

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2. PROPERTIES OF QUASI-STELLAR RADIO SOURCES

M. Schmidt

The discovery of a large redshift in the star-like object associated with the radio source 3C 273 changed our concept of this class of object completely. Until that time, four similar star-like objects had been identified with radio sources (3C 48, 147, 196, and 286). They had been considered to be stars in our own Galaxy, but we now are quite certain that they are extragalactic, as I will discuss presently.