A Supernova Remnant in Centaurus

J. B. WHITEOAK and F. F. GARDNER
Division of Radiophysics, CSIRO, Sydney

Observations of the composite radio source which includes the catalogued components 1209-52 and 1209-51 (Bolton et al. 1964) have been obtained at frequencies 629, 1410, and 2650 MHz with the 210-ft Parkes telescope. The observations at the highest frequency are shown in Figure 1. The isotherms of full-beam brightness temperature correspond to the single polarization direction shown within the circle representing the half-intensity beamwidth. The polarization vectors (unbroken lines) along the two ridges represent 15-25% linear polarization. The intrinsic angles of polarization, derived from the 1410 and 2650 MHz observations, are represented by the broken lines. They are perpendicular to the magnetic field if the radiation is synchrotron. The corresponding rotation measures (Gardner and Whiteoak 1963) range between $-17$ and $-36$ rad. m$^{-2}$ along the eastern ridge, and between $-14$ and $-4$ on the western side.

In order of increasing frequency, the integrated flux densities are $62 \pm 6$, $40 \pm 4$, and $30 \pm 3$ flux units (units of $10^{-26}$ Wm$^{-2}$ Hz$^{-1}$). Incorporation of the value of 182 f.u. obtained by Mills et al. (1961) at 85 MHz yields a special index of $-0.52 \pm 0.05$.

The distribution of radiation resembles the shell-like appearance of radio emission associated with Type II supernova remnants, although its peak brightness temperatures are more than three orders of magnitude lower than those of Cassiopeia A (Ryle et al. 1965). Methods of Harris (1962) and Shklovsky (1960) provide distance estimates of 350 parsec and 2200 parsec respectively. Confinement of the source to within 200 parsec of the galactic plane yields a maximum distance and diameter of 1100 and 40 parsec. If the expansion velocity of the remnants were about 5000 km/sec, and if, as the uniformity of field alignment suggests, the age of the source is small, the diameter and distance must be considerably smaller than these limits.

The integrated flux density is sufficiently low to be accountable by either of the models of van der Laan (1962a,b), in
which the radiation emanates from the compressed interstellar field between the shock wave and the expanding shell. In one model the radiation is due to relativistic field electrons; in the other the electrons are provided by the shell plasma. However, no adequate means are provided for trapping the electrons in the compressed field in the former model. For the latter, Piddington (1966) has pointed out that considerable time would be required for the magnetic field to permeate through the shell plasma. The observed degree of alignment of the field and the location of the field to permeate through the shell suggest characteristics in common with the models. The interpretations suggest that the interstellar field must have a component, transverse to the line of sight, which is aligned perpendicular to the galactic plane. The distribution of radiation for the supernova 1006 A.D. (Gardner and Milne 1965), 30° away in galactic longitude, indicates a similar conclusion. In contrast, a similar interpretation for Cassiopeia yields a field component parallel to the galactic plane. The former results could represent field irregularities of moderate scale, since it is in the directions of these sources that integrated values of rotation measures through the Galaxy vary from large positive to large negative values over 20° of galactic latitude (Gardner and Davies 1966).

In view of the difficulties, and since the ratio of ridge intensity to central source intensity cannot be explained by a shell model, an anisotropic explosion and morphology similar to that used to explain extragalactic sources (Gardner and Whiteoak 1966) is suggested. The field observed is that accompanying the plasma. If one of the source components is located at the rear of the expanding shell, then the opposite senses of the rotation measures for the two components might be explained in terms of internal Faraday rotation.


Optical Observations of Extragalactic Radio Sources

B. E. WESTERLUND, J. V. WALL and N. R. STOKES
Mount Stromlo Observatory, Australian National University, Canberra

Photometric observations on the UBV system have been made of a number of optically identified radio sources. The measurements are basically of two types: (1) offset photometry with the Siding Spring 40-inch reflector of objects identified as probable quasars or N galaxies, and (2) observations with the Siding Spring 24-inch reflector of radio galaxies brighter than \( V = 14 ^{m} 0 \).

(1) Of the 29 objects observed with the 40-inch reflector, 25 have been taken from recent papers of Bolton et al.1,2,3,4; the remainder are from identifications on plates taken with the Mt. Stromlo 74-inch and the Siding Spring 40-inch reflectors. The confirmations, probable confirmations, and rejections are listed in Table 1, the criterion being the position of each object in the two-colour diagram. Of the 26 objects listed as confirmed or probably confirmed, 21 have been observed photoelectrically; of these, 10 are fainter than \( V = 17 ^{m} 0 \).

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Confirmed</th>
<th>Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000-17 Q</td>
<td>0440-00 Q</td>
<td>2111-25 Q</td>
</tr>
<tr>
<td>0021-29 Q</td>
<td>0518-45 N</td>
<td>2115-30 Q</td>
</tr>
<tr>
<td>0119-04 Q</td>
<td>*0521-36 N-Q</td>
<td>2135-14 Q</td>
</tr>
<tr>
<td>0130-17 Q</td>
<td>1233-24 Q</td>
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<td>1417-19 Q</td>
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</tr>
<tr>
<td>0202-76 Q</td>
<td>1420-27</td>
<td>2226-38 N</td>
</tr>
</tbody>
</table>

* See Westerlund and Stokes.5
Q = Quasar, N = N galaxy, E = E galaxy.

(2) For the observations of the bright radio galaxies, all from the Parkes catalogues6,7,8, the apertures used were generally at least 3 times the diameter of the visible galaxy. All but two of the galaxies were ellipticals. The probable errors of the colour indices are ±0.03 in (B-V) and ±0.05 in (U-B). The results show that the radio galaxies occupy exactly the same region of the two-colour diagram as do normal galaxies of the same morphological type. Several of the radio galaxies have 'companion' galaxies, i.e., neighbours of similar appearance, distant by no more than 20 min of arc. UBV measures obtained for these support the results stated above; in no case do the integrated colours of the radio galaxy differ from those of the companion galaxy by more than the probable error in the measurements.

For 6 relatively bright radio galaxies, radial velocities have been determined with the nebular spectrograph on the Newtonian focus of the Mt. Stromlo 75-inch reflector. The mean visual absolute magnitude (with \( H = 100 \text{ km/sec./Mpc.} \)) is \(-21.2 \pm 0.2 \) (p.e.).

The two brightest objects in the program, NGC 1068 and NGC 5236, have been measured with a series of aperture sizes ranging from 100-inch to 7-inch. With apertures of 80-inch diameter and larger, the B-V colours of the two galaxies are almost equal and are normal for the morphological type (NGC 1068 is an Sb Seyfert galaxy; NGC 5236 is an Sb pec.) NGC 1968 has a very bright nucleus of stellar appearance; the region of radio emission is centred on it. NGC 5236 has an associated radio source of the core-halo type, the core being centred on the nucleus and extending over about 30′ of arc.9 For this galaxy our observations show that the integrated colours become progressively bluer with smaller aperture size. Galaxies of this type normally become progressively redder toward the center.

It is concluded that the greater activity which must be present in a radio galaxy does not show up as an anomaly in the integrated colours when these colours are measured over the entire galaxy. However, it appears likely that measurements with a series of apertures may reveal anomalous colours for the region in which the radio emission is produced.

9 Ekers, R. D., Private communication.