# MEASUREMENTS OF THE FLUX DENSITY OF DISCRETE RADIO SOURCES AT 6 CM WAVELENGTH*

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The flux densities of 67 non-thermal radio sources have been measured at a frequency of 5000 Mc/s with the CSIRO 210 ft radio telescope at Parkes. The sources were chosen from the stronger objects in the 3C catalogue (Edge *et al.* 1959), the CTA and CTD catalogues (Harris and Roberts 1960; Kellermann and Read 1965), and the Parkes catalogue (Bolton, Gardner, and Mackey 1964; Price and Milne 1965; Day *et al.* 1966). In the selection of sources observed in this program, special emphasis was placed on objects whose spectra at lower frequencies showed significant departures from the usual power law with an index near $-0\cdot8$. Most of the sources reported here have not been previously measured at wavelengths shorter than 10 cm and thus the present observations extend the frequency range of their spectra by nearly a factor of two.

At 6 cm the efficiency of the 210 ft reflector is considerably reduced from its longer wavelength performance. Observations of the sources Hydra A and MSH 05$-$*36* over a wide range of zenith angles, made in collaboration with D. E. Yabsley and N. W. Broten, indicate an efficiency that is near 36% at the zenith and decreases linearly with zenith angle to about 28% at a zenith angle of 60°.

The receiver used for these observations consisted of a wide band tunnel diode preamplifier followed by a superheterodyne receiver having an i.f. bandwidth of 100 Mc/s. The total system temperature was slightly under 1000°K. Most of the observations consisted of scans across the source in right ascension and declination at a rate of $0\cdot1$°/min. The sensitivity and stability were such that a source of 1 flux unit ($10^{-26}$ W m$^{-2}$ (c/s)$^{-1}$) could be detected in a single scan with an output time constant of 10 sec. The half-power beamwidth was about 4 min of arc so that a point source passed through the half-power points in 40 sec. For a few of the weaker sources, the observations were made by alternately pointing the antenna toward and away from the source and integrating the receiver output in each position for 100 sec. Observations were made in two orthogonal planes of polarization. The gain of the receiver was monitored by regular calibrations with a noise signal from a gas discharge tube. The calibration of the flux density scale is based on an assumed value of $13\cdot0$ flux units for Hydra A, obtained from an extrapolation of its low frequency spectrum (Kellermann 1964).

The measured flux densities are given in Table 1 together with the classification of the radio spectrum. If the source has been optically identified with a galaxy or a quasi-stellar object (QSO) also, this is indicated in column 4, together with any alternative catalogue number. The estimated r.m.s. uncertainty in the relative flux densities is about 10% due to gain uncertainties and $0\cdot2$ flux units due to

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TABLE 1

6 CM FLUX DENSITIES

| Source | Flux Density (flux units) | Class | Notes |
|---|---|---|---|
| 3C 2 | 1·4 | S | QSO |
| 0008−42 | 1·5 | C− | |
| 0023−26 | 3·3 | $C_{max}$ | 00−*210* |
| 3C 15 | 1·6 | S | Galaxy |
| 3C 17 | 2·7 | S | Galaxy |
| 0039−44 | 1·3 | S | 00−4*10* |
| 0043−42 | 2·8 | S | 00−4*11*, galaxy |
| 0045−25 | 2·1 | ? | 00−*222* |
| 0157−31 | 1·4 | S | 01−3*15* |
| 0202+14 | 2·1 | C− | |
| 0229+13 | 1·4 | S | |
| MSH 02−1*10* | 1·2 | S | |
| 3C 71 | 1·9 | S | Galaxy |
| 3C 75 | 2·0 | S | Galaxy |
| 3C 76·1 | 1·5 | S | Galaxy |
| 3C 79 | 1·2 | S | Galaxy |
| CTA 21 | 3·0 | $C_{max}$ | |
| 3C 88 | 1·8 | S(C−) | Galaxy |
| CTA 26 | 2·6 | C+ | QSO |
| 0410−75 | 4·3 | C−(S) | |
| 0417+15 | 0·6 | C+(S) | |
| 0422+00 | 1·3 | S | |
| 0430+05 | 3·7 | C+ | Galaxy |
| 0438−43 | 5·5 | C+ | |
| 0451−20 | 1·9 | C− | |
| 0454+06 | 0·6 | S | 04+0*12* |
| 0507+17 | 0·3 | S | |
| 3C 138 | 3·9 | C− | QSO |
| 0521−36 | 8·2 | S | 05−3*6*, galaxy |
| 3C 161 | 6·8 | C− | QSO |
| 0637−75 | 4·8 | C+ | 06−7*1* |
| 0735+17 | 2·1 | ? | |
| 0736+01 | 1·6 | ? | QSO |
| 3C 212 | 0·6 | S | Galaxy |
| 0859−25 | 1·7 | S | 08−*219* |
| 3C 218 | 13·0 | S | Hydra A, galaxy |
| 3C 237 | 2·0 | C− | Galaxy |
| 3C 238 | 0·6 | C− | |
| 3C 245 | 1·6 | S | QSO |
| 1055+01 | 3·6 | C+ | QSO |
| MSH 11−1*8* | 2·2 | S | |
| 3C 272·1 | 3·3 | S | M84, galaxy |
| 3C 273 | 38·1 | C+ | QSO |
| 3C 274 | 57 | S | M87, galaxy |
| 1252+11 | 1·9 | C+ | QSO |
| 3C 279 | 14·5 | $C_{min}$ | QSO |
| 3C 287 | 3·6 | S | QSO |
| 3C 298 | 1·4 | $C_{max}$ | QSO |

TABLE 1 (*Continued*)

| Source | Flux Density (flux units) | Class | Notes |
|---|---|---|---|
| 14–*121* | 1·5 | S | QSO |
| 3C 317 | 0·9 | C– | Galaxy |
| CTD 93 | 1·6 | $C_{max}$ | |
| 3C 348 | 13·7 (11·8)* | S | Herc A, galaxy |
| 3C 353 | 21·4 (15·6)* | S | Galaxy |
| 1932–46 | 4·1 | S | 19–*46* |
| 1934–63 | 5·0 | $C_{max}$ | Galaxy |
| 3C 409 | 3·2 | C– | |
| 3C 433 | 3·3 | C– | Galaxy |
| 2127+04 | 2·4 | $C_{max}$ | |
| 2145+06 | 4·8 | $C_{min}$ | QSO |
| 2149+17 | 1·1 | S($C_{min}$) | |
| 2152–69 | 10·3 | S | 21–*64* |
| 3C 444 | 2·2 | C– | Galaxy |
| CTA 102 | 4·1 | $C_{max}$ | QSO |
| 2247+14 | 1·6 | C+ | |
| 3C 454·3 | 12·5 | $C_{min}$ | QSO |
| 2328+10 | 1·4 | $C_{min}$ | QSO |
| 2331–41 | 1·4 | C– | 23–*44* |

* Extended sources, peak values in parentheses.

receiver noise fluctuations; the effect of confusion at this frequency is negligible. The calibration of the flux density scale is probably correct to within about 10%.

The classification of the spectra is given by the following notation based on log–log plots of flux density *v*. frequency.

- S The source has a simple power-law spectrum over the observed frequency range.
- C– The spectrum has negative curvature.
- C+ The spectrum has positive curvature.
- $C_{max}$ The spectrum has a maximum in the observed frequency range.
- $C_{min}$ The spectrum has a minimum in the observed frequency range.

As Table 1 is biased toward sources that were known to have unusual low frequency spectra, no conclusions can be drawn about the distribution of the source spectra among the spectral classes. The spectra of some of these sources, based on accurate observations over a wide range of frequencies, will be discussed in detail elsewhere (Kellermann, in preparation). The remaining spectra showing significant departures from a power law are shown in Figure 1.

The main features of the observed spectra are:

(1) In sources having negative curvature, the curvature exists only over a relatively small range of frequency. Above and below this frequency the spectra are close to power laws with the low frequency index generally in the range –0·25 to –0·5 and the high frequency index in the range –0·7 to –1·2.

(2) The increase in flux density observed at high frequencies for many sources is inconsistent with simple synchrotron radiation and suggests the presence of components that are optically thick at least up to several thousand Mc/s.

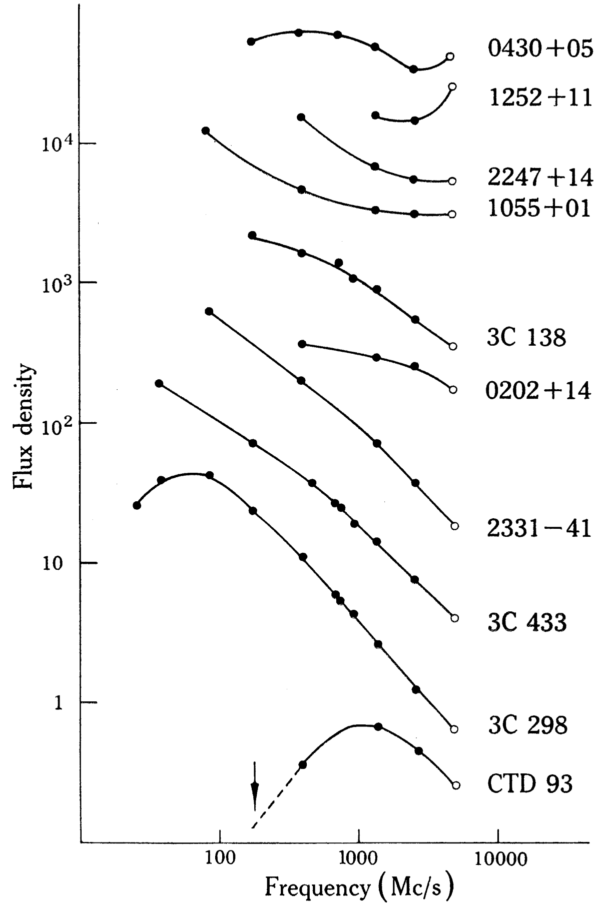


Fig. 1.—The spectra of 10 sources that show significant departure from a simple power-law spectrum (plotted on a flux density scale with displaced origins). The open circles at 5000 Mc/s are from the present work, while the full circles are taken from published flux densities.

(3) All sources that show large departures from a power law and for which measurements of angular size are available have components with dimensions less than a few seconds of arc. Many of these are identified with quasi-stellar objects although a few, such as 0430+05 (Bolton, personal communication) and 1934−63 (see Kellermann 1966), seem to be associated with galaxies having active nuclei.

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Cole, and some preliminary results have already been reported (Day *et al.* 1966). The 6 cm receiver was provided by F. Tonking and the author is grateful to him and also to B. F. C. Cooper, D. E. Yabsley, and N. W. Broten, who made many of the tests and calibrations just prior to these observations. Some of the identifications given in Table 1 are from unpublished work by J. G. Bolton.

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