RADIO ASTRONOMY

Angular Size of Radio Stars

THE existence of a number of radio sources with an angular extension less than 1″ is well known[1]. Some of them were identified with star-like objects and therefore they are referred to as radio stars. Among these are 3C-48, 3C-119, 3C-147, 3C-273, 3C-286. Their non-thermal spectra and the evidence of a rather strong linear polarization suggest the synchrotron mechanism of radio emission. Twiss[2], Razin[3], and Le Roux[4] have shown that a self-absorption of synchrotron radiation by relativistic electrons must occur at frequencies $f < f_1$, f_1 depending on relativistic electrons concentration, normal component of magnetic field $H_\perp$, spectral index of radio emission α (the spectrum being of the form $S(f) \propto f^{-\alpha}$), and on linear dimension of radio-emitting region. At frequencies below f_1 the spectrum of radio emission is $S(f) \propto f^{2\cdot5}$ whatever α is, thus f_1 is a frequency where maximum flux density of a radio source occurs.

Using well-known formulæ for synchrotron radiation, it is possible to derive f_1 as a function of the observational values of flux density $S(f)$, apparent angular diameter θ and spectral index α:

$$f_1 = K(\alpha)\,[S(f_2)\,.\,\theta^{-2}\,.\,f_2^{\alpha}\,.\,10^{33}]^{\frac{1}{2\cdot5+\alpha}}\,H_\perp^{\frac{1}{5+2\alpha}} \quad (1)$$

where $K(\alpha)$ is the slowly varying function of spectral index α of order of unity, $S(f_2)$—flux density in M.K.S. units at a frequency $f_2 > f_1$, not affected by self-absorption.

$H_\perp$ is the only term in equation (1) which cannot be obtained through direct radio astronomy measurements, but there is a good chance for a reasonable use of equation (1), since f_1 appears to be quite insensitive of $H_\perp$ ($f_1 \propto H_\perp^{1/7}$). In this communication $H_\perp$ is equal to 10^{-4} gauss.

Considerations of possible red shift effects show that f_1 in equation (1) must be increased by a factor $(1+Z)^{\frac{1}{5+2\alpha}}$, where $Z = \frac{\Delta\lambda}{\lambda_0}$; for $Z < 10$ the red shift factor is less than 1·4. Therefore, equation (1) is also insensitive to red shift.

Inspection of equation (1) reveals dependence of self-absorption on the surface brightness temperature of a radio source. The sources with very high brightness temperature due to self-absorption must show a sharp 'fall-off' of the flux density at metre wave-lengths, while in sources with relatively low-brightness temperature the 'fall-off' occurs at decametre wave-lengths and is due mainly to absorption by ionized hydrogen. For example, the critical frequency f_1 for self-absorption in $M31$ (Andromeda nebula) is 0·1 Mc/s, in Cygnus-A, 10 Mc/s, in 'radio-stars' more than 20 Mc/s, depending on their angular size.

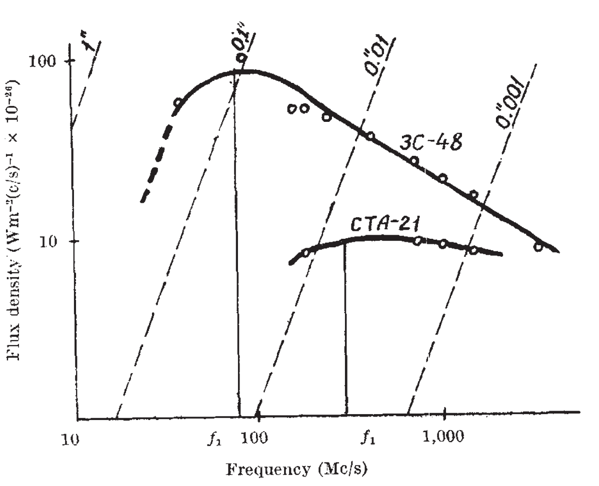

Fig. 1. Spectra of radio sources 3C-48 and CTA-21. Dashed lines represent equation $\log S = 2\cdot5 \log f + \log 0\cdot14\ \theta^2$ (S in 10^{-26} W per m² per hertz, f in Mc/s, θ in sec of arc)

The spectrum of 3C-48 is shown in Fig. 1, all data except for 81·5 Mc/s are taken from ref. 5 and flux density at 81·5 Mc/s is taken from 2C catalogue. The spectrum shows a distinct maximum near 70 Mc/s, which may be due to self-absorption. Apparently the self-absorption of synchrotron radiation may account for observed correlation of spectrum curvature and high brightness temperature[6].

It is possible from equation (1) to derive an expression for the apparent angular diameter in terms of maximum flux density and critical frequency f_1 (including the red shift correction):

$$\theta = 4\cdot3 \times 10^{16}\,[S(f_1)\,]^{0\cdot5}\,f_1^{-1\cdot25}\,H_\perp^{0\cdot25}\,(1+Z)^{0\cdot25} \quad (2)$$

The radio source 3C-48 then turns out to be 0·14″ in diameter. Fig. 1 also shows a spectrum of radio source CTA-21 with a maximum near 300 Mc/s, which corresponds to an angular diameter 0·01″. Dashed lines in Fig. 1 represent possible positions of maxima of spectra for radio sources with angular diameters of 1″; 0·1″, 0·01″ and 0·001″.

Comparison of Fig. 1 with spectra of all 160 discrete sources given in ref. 5 shows that there are no sources with apparent angular diameters less than 0·02″, except for CTA-21 and CTA-102 which may be of the order of 0·01″. The same conclusion holds for all sources of revised 3C catalogue. This means that angular diameters of all non-thermal sources known greatly exceed angular diameter of stars and therefore so-called radio stars identified with star-like objects in fact are not stars and there are no stars among the radio sources known at the present time.

This conclusion may be of interest to cosmology regarding the minimum angular size of radio sources predicted by cosmological models.

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V. I. SLISH

Sternberg State Astronomical Institute,
Moscow.

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A Radio Source with a Very Unusual Spectrum

Conway, Kellerman and Long[1] have recently determined the spectra of 160 radio sources in the wave-length range of 10 cm–26 m. Their results were obtained by combining measurements at nine wave-lengths made at the California Institute of Technology, Mullard and Nuffield Radio Observatories. At wave-lengths longer than 20 cm they found that most of the spectra could be represented by power laws and that the median spectral slope was 0·7. Two notable exceptions are the sources CTA 21 and CTA 102 (ref. 2) which have curved spectra with maxima in the region of 30–50 cm. These two objects were originally found from observations at 30 cm whereas all the others were selected from the 3C (ref. 3) and the Mills, Slee and Hill (MSH) (ref. 4) catalogues. As these surveys were made at wave-lengths of 2 and 3·5 m respectively, selection from them would tend to discriminate against objects of the type of CTA 21 and CTA 102. Kellerman (private communication) has pointed out that it is important to know the relative population of such sources because of their possible influence on source counts at different wave-lengths.

We have recently made a survey of the sky south of −20° declination at a wave-length of 75 cm with the