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CIRCULAR POLARIZATION OF QUASARS AT λ21 CM

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SUMMARY

Measurements of circular polarization in 13 radio sources at λ21 cm are presented, and are compared with similar measurements at λ49 cm. Quasars appear to have polarization if opaque by synchrotron self-absorption, but not if transparent. The degree of polarization does not vary with wavelength in the theoretically expected manner.

INTRODUCTION

It has been predicted that synchrotron radiation from radio sources with sufficiently strong magnetic fields should show a circularly polarized component (Sciama & Rees 1967; Legg & Westfold 1968). In a few quasars, with flat or inverted spectra, a small degree of circular polarization has been detected at λ49 cm (Gilbert & Conway 1970). In order to test the predicted variation with wavelength we have made measurements at λ21 cm of approximately half the sources observed at λ49 cm.

OBSERVATIONS

The observations were made with the Westerbork Synthesis Telescope which consists of twelve 25-metre reflectors. Two of these are combined with the other ten to form 20 interferometers with different baselines of up to 1600 metres. A pair of crossed dipoles is mounted at the focus of each telescope. The four possible dipole combinations for each interferometer yield outputs which are related to the Stokes parameters of the source as follows: (Morris, Radhakrishnan & Seielstad, 1964).

$$R_{XX} = I+Q$$

$$R_{YY} = I-Q$$

$$R_{XY} = -U+iV$$

$$R_{YX} = -U-iV$$

where

$$i = \sqrt{-1}.$$

Since the sources were chosen to be unresolved even at the largest baselines, each interferometer yields an independent determination of the degree of circular polarization (V/I).

The calibration of the responses included corrections for the gain and phase variations of the system with time. Errors in the assumed baselines or in the assumed source position cancel in evaluating the quantity (V/I). The instrumental polarization for each interferometer was taken to be the mean value, weighted by flux density and observing time, of the apparent circular polarizations of 3C 48, 3C 147 and 3C 295. These three sources agree to better than 0·02 per cent; if the assumption that the mean value be zero is untrue, then all our results should be shifted by a constant algebraic quantity. The results are shown in Table I.

TABLE I

Circular polarization at λ21 cm

Source	Circular polarization (per cent)
3C 48	+0·015±0·010
3C 138	+0·066±0·027
3C 147	−0·006±0·008
3C 196	+0·005±0·013
PKS 1127–14	+0·117±0·027
3C 279	−0·152±0·046
3C 286	+0·043±0·046
3C 295	−0·001±0·010
3C 345	+0·008±0·026
3C 380	+0·031±0·027
VRO 422201	+0·112±0·026
CTA 102	+0·022±0·032
3C 454.3	−0·053±0·039

The errors in Table I are standard errors derived from the scatter of the measurements by the 20 interferometers about each overall mean value. Except in two cases they are consistent with thermal noise fluctuations. The two exceptions are 3C 286 and 3C 454·3, which have a rather high linear polarization (U/I). The residual phase uncertainties, although less than 1°, may introduce a spurious circular polarization. An estimate of this uncertainty has been included in the quoted errors for these sources.

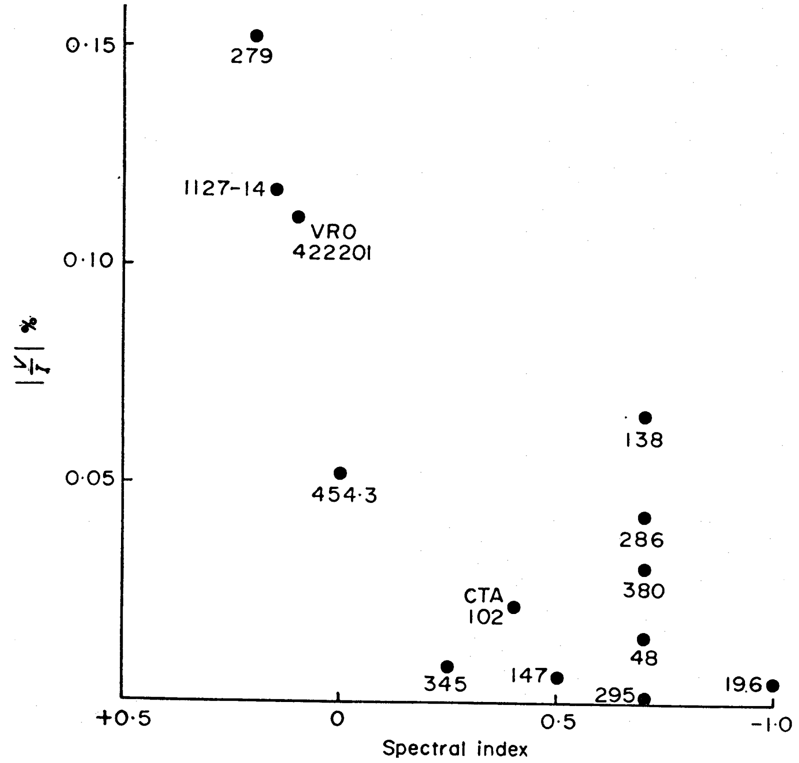

FIG. 1. *Degree of circular polarization at λ21 cm versus the spectral index at the same wavelength.*

DISCUSSION

The earlier measurements at λ49 cm showed a correlation between circular polarization and spectral index. Fig. 1 shows the results at λ21 cm plotted against α, the spectral slope at λ21 cm. The correlation is confirmed, even though two sources, namely CTA 102 and 3C 279, have curved spectra, and change spectral index markedly between λ49 cm and λ21 cm. If we interpret the spectral features in terms of components opaque below a critical frequency by synchrotron self-absorption (van der Laan 1966) then it appears that sources may show circular polarization at wavelengths at which they are opaque, but do not do so at wavelengths at which they are transparent.

The question of whether the polarization arises by the synchrotron mechanism is still indeterminate. On the simplest model, of a uniform magnetic field and a homogeneous population of radiating electrons, the degree of polarization should vary as $\lambda^{1/2}$. Fig. 2, which is a plot of the results at λ49 cm and λ21 cm, does not show such a variation. The observations might be interpreted as due to another process, such as plasma radiation or the ' Faraday pulsation ' discused by Pacholczyk & Swihart (1970). If, however, we assume that it is indeed the synchrotron process which is responsible, then the variation with wavelength requires a rather disordered magnetic field. Since the effective field is an average value, weighted by a volume emissivity at each point, the effective field at one wavelength may differ from that at another wavelength and may even reverse in sign, as in the case of PKS 1127–14.

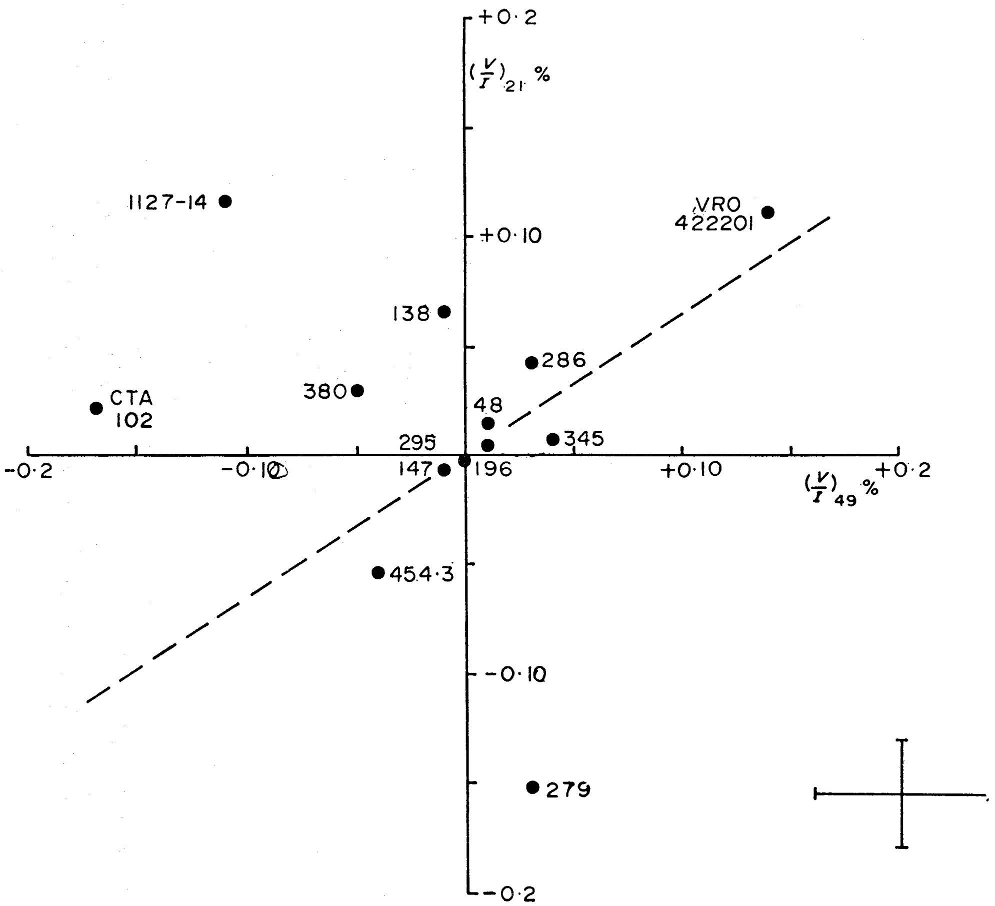

FIG. 2. *Comparison of circular polarization at λ21 cm and λ49 cm. The dashed line shows a $\lambda^{1/2}$ dependence. Typical error bars are drawn at the lower right.*

Under these circumstances, although one can evaluate an equivalent magnetic field, care should be taken not to interpret such values too literally. The formula of Sciama & Rees (1967)

$$\frac{V}{I} \sim 100 \left(\frac{3H}{f}\right)^{1/2} \text{ per cent,}$$

where f is the observing frequency in MHz, gives an equivalent uniform magnetic field H in Gauss. The values from the present observations range up to 10^{-3} Gauss. Such estimates are increased by about one order of magnitude if the disordering of the field is allowed for. It is not clear however whether the formula of Sciama and Rees applies to an opaque source.

Estimates of the magnetic field from the cut-off frequency for synchrotron self-absorption are $10^{-4\pm1}$ Gauss (Kellermann & Pauliny-Toth (1969)) and $10^{-3\pm1}$ Gauss (Clarke *et al.* 1969). Our values agree with these quite satisfactorily in view of the uncertainty of how to interpret circular polarization from opaque sources. A more exact estimate of the magnetic field would be possible if it were not for the disagreement between the circular polarization at different frequencies. The resolution of this disagreement requires further theoretical work, especially on models of opaque sources.

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