LETTERS TO THE EDITOR

RADIOASTRONOMY

Faraday Rotation Effect in Extragalactic Radio Sources

Cooper and Price[1] have shown that the polarization of radio emission measured at three different points in the radio source Centaurus *A* rotated progressively with increasing wave-length. They found the rate of rotation to be proportional to the square of the wave-length. This fact suggested to Cooper and Price a direct explanation in terms of Faraday rotation in a magneto-ionic medium. Recently, Gardner and Whiteoak[2] measured the polarization of 18 radio sources at different wave-lengths in order to investigate whether Faraday rotation was present. All the sources showed the quadratic dependence of polarization position-angle on wave-length characteristic of Faraday effect. In the discussion of their results, Gardner and Whiteoak suggested the possibility that some of the Faraday rotation occurs in our Galaxy (Fig. 1 in ref. 2).

The Faraday rotation θ of the plane of polarization of radio radiation from an extragalactic source at a wave-length λ can be expressed as a sum of four different terms:

$$\text{const}\,\frac{\theta}{\lambda^2} = \underbrace{\int N_{e1}H_1\,dr}_{\text{ionosphere}} + \underbrace{\int N_{e2}H_2\,dr}_{\text{galaxy}} + \underbrace{\int N_{e3}H_3\,dr}_{\text{intergalactic space}} + \underbrace{\int N_{e4}H_4\,dr}_{\text{radio source}} \quad (1)$$

each of which contributes to the integral effect observed. The symbols N_{ek} and H_k stand for electron density and longitudinal magnetic field. When θ is measured in radians, λ in metres, N_e in particles/c.c., H in gauss and r in parsecs, the constant has the value $0{\cdot}124 \times 10^{-5}$. According to results obtained by Evans[3], the first integral is nearly two orders of magnitude smaller than the observed value of the left-hand term in equation (1); therefore the ionospheric contribution to the Faraday rotation effect in radio source radiation is negligible. Also, the third term in equation (1) appears to be negligible, because although the path of radiation through intergalactic space is very long there is no evidence of sufficiently high magnetic fields and electron densities. This point of view seems to be supported by the lack of correlation between the Faraday rotation measure and the distance of the radio sources, although such a correlation might not occur if the intergalactic magnetic fields were not sufficiently regular. Hence the majority of the rotation probably occurs either within our own Galaxy or within the radio source itself.

Gardner and Whiteoak[2] discussed the possibility of a galactic origin for the main part of the Faraday rotation. Although they showed that sources with the smallest rotations are at high galactic latitudes, the considerable scatter in both magnitude and sign of the rotation at intermediate latitudes makes the galactic origin of the main part of Faraday rotation less probable.

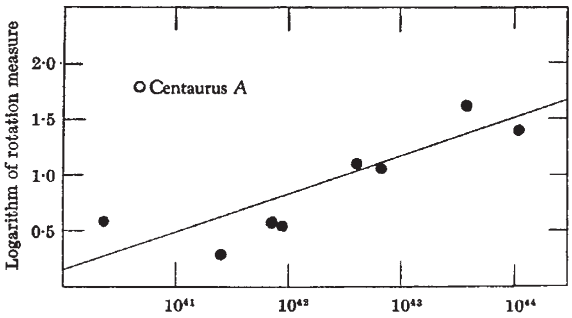

Fig. 1. Total luminosity versus Faraday rotation measure for extragalactic radio sources

Let us examine in more detail the hypothesis that Faraday rotation is produced mainly within the source itself. Under the condition of minimum total energy of a radio source radiating by means of an acceleration-radiation mechanism, the prevailing magnetic field is:

$$H \propto \psi^{-2/7} L^{2/7} r^{-6/7} \quad (2)$$

where L is the total radio luminosity, ψ is a 'filling factor' determining the portion of the source's volume occupied by filaments and knots of the magnetic field and relativistic particles trapped in it, and r is the radius of the emitting region[4].

The Faraday rotation measure depends on r and H through the relation:

$$\lambda^{-2}\theta \propto N_e H r \quad (3)$$

For the purpose of correlation testing, it is reasonable to assume that the magnetic field in expression (2) and the longitudinal magnetic field in expression (3) are comparable. Therefore, on the basis of the order-of-magnitude relation:

$$L \propto \psi H^{1/2} N_e^{-3} (\lambda^{-2}\theta)^3 \quad (4)$$

we can expect a correlation between radio luminosity L and rotation measure $\lambda^{-2}\theta$, if the rotation is produced mainly in a radio source itself.

The correlation between total radio luminosity L and rotation measure $\lambda^{-2}\theta$ for extragalactic radio sources is shown in double logarithmic scale in Fig. 1. The polarization data were given by Gardner and Whiteoak[2] and the values of total luminosities by Maltby, Matthews and Moffet[4]. The points in Fig. 1 represent those extragalactic radio sources from Gardner and Whiteoak's list for which the distance is known. The full line represents the expected relation between total luminosity and rotation measure given by (4), provided the factor $\psi H^{1/2} N^{-3}$ does not change considerably. The line has a slope equal to 0·33.

The open circle in Fig. 1 corresponds to the values of L and $\lambda^{-2}\theta$ for the central source of Centaurus *A*. As is well known, the central source of Centaurus *A* is immersed in a large radiation halo of complex structure. It is very probable that polarized radiation from the central source, passing through the extended halo region, will be subject to additional Faraday rotation, the amount of which may be very large because of the size of the extended source and the magnitude of possible magnetic fields (6×10^{-6} gauss (ref. 4)). This could explain the deviation of the open circle in Fig. 1.

In so far as it is possible to draw conclusions on the basis of only eight points, the correlation expressed in Fig. 1 strongly suggests that the Faraday effect occurs mainly within radio sources, not in the Galaxy or in intergalactic space. Furthermore, the rather small scatter of points in Fig. 1 indicates that the factor $\psi H^{1/2} N^{-3}$ does not vary greatly from one radio source to another.

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[1] Cooper, B. F. C., and Price, R. M., *Nature*, **195**, 1084 (1962).
[2] Gardner, F. F., and Whiteoak, J. B., *Nature*, **197**, 1162 (1963).
[3] Evans, J. V., *Proc. Phys. Soc.*, B, **69**, 953 (1956).
[4] Maltby, P., Matthews, T. A., and Moffet, A. T., *Astrophys. J.*, **137**, 153 (1963).