ASYMMETRIC DEPOLARIZATION IN DOUBLE RADIO SOURCES

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ABSTRACT. The asymmetric depolarization seen in powerful extragalactic double sources with one sided jets may be explained in terms of differential Faraday effects in a halo of gas surrounding the source, provided the halo has a core-radius $\sim$30-100 kpc, and contains a magnetic field of order >1 μGauss tangled on a scale <5 kpc.

1. DEPOLARIZATION ASYMMETRY

Powerful radio sources, both quasars and FR2 radio galaxies, contain twin lobes of radio emission situated some 100 kpc on either side of an active nucleus. High resolution maps often reveal a jet connecting the nucleus to one of the lobes, but only on one side. There is still debate on whether this jet-asymmetry is intrinsic, or is an illusion due to relativistic beaming of the approaching jet.

In FR2 sources the jet side is systematically less depolarized by Faraday effects that the counter-jet side. Our published observations demonstrating this effect (Garrington et al. 1988) included 25 sources with angular size <30", mostly with redshifts >1.0. In Figure 1, we show these 25 and a further 20 sources, with larger angular sizes, and redshifts from 0.3 to 1.0. In both sets, the ratio DP = m_{20}/m_6 is systematically higher for the jet-side components. Several of the larger, low-z, sources show little depolarization at λ20 cm on either side (cf. Strom 1973), but are found to be asymmetric in the same sense at longer wavelengths from the ratio m_{49}/m_{20}. Including these sources, we find that out of 45 sources in total, 38 depolarize less on the jet side, 3 depolarize less on the counter-jet side, 2 depolarize symmetrically, and 2 show no depolarization on either side. This is a strong correlation, much stronger than the dependence of any other parameter on jet-sidedness, and is not likely to be a secondary effect due to correlation with some other property.

Depolarization is caused (Burn, 1966) by variations in the Faraday depth ϕ (= $\int$n.B.dℓ cm^{-3}μG pc) between different regions of the source. Assuming that the distribution function of ϕ is Gaussian, with a standard deviation Δ, the DP values provide estimates of Δ for each

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component. Typical values of Δ_j for the jet side are 10 - 100 $cm^{-3}\mu G$ pc, while Δ_{cj} for the jet side is 20-200 cm^{-3} μG pc. The asymmetry ratio $r_\Delta = \Delta_{cj}/\Delta_j$ has a median value 1.90.

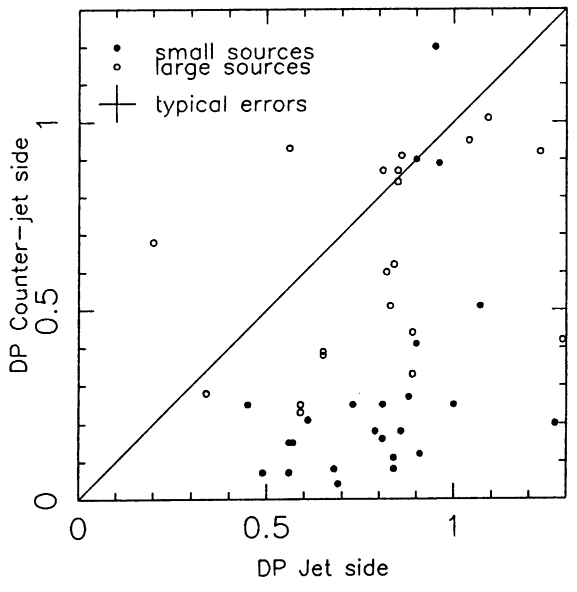

Figure 1. Depolarization ratio DP = m_{20}/m_6 for jet-side and counter-jet components. In general DP_{cj} is lower than DP_j, especially in small high-z sources (black dots); several larger sources with lower redshifts (white circles) show the same asymmetry at λ > 20 cm.

2. THE INTERPRETATION OF DEPOLARIZATION

The Faraday medium responsible for depolarization will lie partly within the emitting regions (cf. Strom, these proceedings) and partly in the foreground. The relative magnitude of these contributions is yet to be established. Depolarization by a foreground Faraday screen requires irregularities of scale size d less than the resolution of the observations, here about 5 kpc. For such a screen the Faraday dispersion Δ is given by

$$\Delta^2 = \int n^2 B^2 d \, d\ell$$

In the case of Cygnus A, Bicknell (these proceedings) suggests that the Faraday screen is in the form of a surface layer. Here, however, we consider an irregular Faraday medium disposed as a spherical halo around the central object. On the relativistic beaming hypothesis such a geometry predicts the depolarization asymmetry naturally. Since the visible jet is approaching, it is on the near side, and will be seen through less of the depolarizing medium, provided that the gas is distributed on a scale comparable to that of the source.

We identify the Faraday medium with the gas giving extended X-ray emission from galaxies and clusters. Small scale irregularities may be present both in the density n and in the magnetic field direction. We assume a King model profile of density beyond a core radius a

$$n(r) = n_0(1 + r^2/a^2)^{-3\beta/2}$$

with $\beta \approx 0.5$-0.7. Typical values of n_0 and radius a derived from Einstein data (e.g. Sazarin 1986) are given in Table 1.

Taking the field strength to vary as $B^2(r) \propto n(r)$, and the tangling scale d to be independent of r, we find the magnetic field B_0 which will produce the required values of Δ_{cj}, typically 100 cm^{-3} μG pc. The lower limits to B_0 which appear in Table 1 correspond to the upper limit d < 5 kpc.

TABLE 1. Halo parameters required for depolarization

	a/kpc	n_0/cm^{-3}	$B_0/\mu G$
galaxies	2	0.1	>1000
poor groups	75	$3x10^{-2}$	> 0.3
rich clusters	300	$3x10^{-3}$	> 0.8

The depolarization asymmetry r_Δ will not depend on the actual values of n or B but only on the geometry, i.e. the angle of the source axis to the line of sight θ and the ratio, 2a/D, of the core radius to the source size. If 2a << D (e.g. the halo of an individual galaxy) the depolarization is very asymmetric, because the nearer component is virtually unaffected. On the other hand if 2a >> D there will be little depolarization asymmetry. In order to reproduce the observed asymmetry we require $2a/D \simeq 0.75$. Since the median projected linear size for these sources is 130 kpc, the core radius must be $\sim 65/\sin\theta$ kpc.

Thus a model of depolarization due to a tangled field in a halo of hot gas surrounding the radio source will produce both the observed amount of depolarization and the asymmetry in depolarization provided that the core radius is 30-100 kpc and that the magnetic field within this radius is at least 1 μG and tangled on a scale <5 kpc. Haloes of this size are associated with the cD galaxies at the centres of poor clusters of galaxies (e.g. Schwartz et al. 1980).

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BURNS: Are there any comparable asymmetries in the rotation measures between lobes in FR II sources?

GARRINGTON: In general the differences in the RM, i.e. the net Faraday depths, are less than the differences in the Faraday dispersions, as measured by the depolarization.

PERLEY: Barthel has recently proposed that orientation effects can explain nearly all observed differences between radio-loud quasars and powerful radio galaxies. One of the predictions of this theory is that the asymmetry you observe should be very much weaker for radio galaxies. Have you seen any difference in depolarization asymmetry between quasars and radio galaxies?

GARRINGTON: The present sample contains only 6 radio galaxies of which two are counter examples to the general trend in i.e. $DP_j > DP_{cj}$ and the other 4 have depolarization ratios that are typical of the quasars. Examination of a complete sample of sources (most of which do not have jets) also shows no difference in the depolarization asymmetry. We are presently making higher resolution observations to check this.

AKUJOR: Based on relativistic beaming or orientation effects, one would expect a correlation between depolarization asymmetry and percentage flux in the core for QSOs (particularly for sources with the same red-shift). Do you find any?

GARRINGTON: In the present data a correlation between the depolarization asymmetry (r_Δ) and the fraction of flux in the core, often used as an orientation indicator, is not observed. Perhaps variations in the size of the depolarizing medium relative to the source size introduce sufficient scatter in r_Δ to hide any correlation.

BURNS: From a recent survey of cD galaxies in clusters (Burns, 1989, Astron. J., in press) I have found that about 70% of clusters with X-ray cooling cores have radio-loud cDs. On the other hand, < 25% of non-cooling core clusters have radio emission associated with the dominant galaxies. Some trends are also emerging on the cooling core radio emission – those clusters have high RMs, small sizes, steep spectra, amorphous radio morphology and little or no jet structure.