Polarimetry of the Interstellar Medium
ASP Conference Series, Vol. 97, 1996
W. G. Roberge and D. C. B. Whittet, eds.

Submillimetre Polarimetry of Blazars

R. Nartallo[1]

Institute for Astronomy, University of Edinburgh, Edinburgh UK

W. K. Gear

Royal Observatory, Blackford Hill, Edinburgh, UK

A. G. Murray

Physics Department, Queen Mary and Westfield College, University of London, UK

E. I. Robson

Joint Astronomy Centre, Hilo, Hawaii, USA

J. H. Hough

Division of Physical Sciences, University of Hertfordshire, Hatfield, UK

Abstract. We report on preliminary results from the first monitoring campaign of the submillimetre polarization of a sample of Blazars. The observations have been carried out with the James Clerk Maxwell Telescope between 1991 and 1994.

1. Introduction

Blazars are radio-loud extragalactic sources which boast large amplitude variability on short timescales, flat-spectrum radio emission, steep optical-infrared spectra and substantially polarized continuum emission (e.g. Angel & Stockman 1980). They have a compact radio core and jets that lie close to our line of sight, giving rise to highly beamed emission (Blandford & Rees 1978). Flares are believed to originate from the nucleus of the AGN giving rise to shock waves that travel relativistically along the jet, compressing the material and the magnetic field associated with it. Stages in the evolution of the shocked regions are characterized by different energy loss mechanisms: Compton scattering, synchrotron emission and finally adiabatic expansion. The most energetic early stages occur at the base of the jet when synchrotron losses dominate and the emission peaks in the submillimetre (Marscher & Gear 1985). Polarization measurements esti-

[1]Present address: Physics Department, Queen Mary and Westfield College, University of London, UK

mate the degree of ordering and orientation of the magnetic field, which can be used to test and place constraints on theoretical models.

2. Observations

A sample of Blazars has been observed with the James Clerk Maxwell Telescope at wavelengths 0.8 and 1.1 mm, using the bolometer receiver UKT14 (Duncan et al. 1990) coupled with the Aberdeen/QMW polarimeter (Murray et al. 1992). The data acquisition techniques and data reduction algorithms employed are discussed in Murray (1991) and Nartallo (1995). The sources observed so far comprise 10 BL Lac objects and 16 highly polarized Quasars. At present, the database at 1.1 mm includes seven epochs on 5 sources, four epochs on 7 sources, two epochs on 6 sources and single-epoch observations on a further 8 sources. Simultaneous photometric measurements at 0.8, 1.1 and 2 mm have also been made, which allow us to estimate the spectral index in the range 150–375 GHz. The position angle on the sky of the sources' jets, determined from high frequency VLBI observations, has been obtained from the literature. This allows us to estimate the orientation of the magnetic field relative to the structural axis from the polarization position angle.

3. Results

The variability of most of these sources can begin to be characterized after they have been observed at a number of epochs. The database has been analysed in terms of individual objects by looking at their polarization properties, and also according to object type, treating each measurement as an independent observation of a BL Lac object or a Quasar. Looking at the polarization variability in each object, a distinction can be made between sources whose magnetic field has a preferred geometry (either aligned with or perpendicular to the jet) and sources where the magnetic field has been observed to change readily between the two configurations. Sources with a mainly perpendicular magnetic field are the most highly polarized, with mean polarizations $> 9\%$, those with swinging magnetic fields have mean polarization levels of $\sim 5\%$ and those with parallel magnetic fields average to $< 3\%$. A Spearman rank-order correlation test between percentage polarization and magnetic field orientation gives a correlation coefficient of 0.5 with 99.99% significance. The analysis in terms of object type yields no significant differences between the polarization from BL Lac objects and Quasars, other than a lack of low polarization measurements of BL Lacs. The photometric measurements indicate that Quasars are usually brighter and have on average a steeper submillimetre spectral index than BL Lacs[1]. The lower intrinsic brightness of BL Lacs may explain the scarcity of low polarization detections. A more interesting feature of the data is the relation between the variability of the total flux density and the percentage polarization. From the sources with at least four observation epochs, we find a trend for these two parameters to be correlated in the Quasars, but anticorrelated in the BL Lacs.

[1]This was also found to be the case in a larger sample presented in Gear et al. (1994).

In a couple of sources a change in the sense of this correlation has been observed at an epoch of maximum emission. In those sources with swinging magnetic fields a correlation can also be established between the variations in flux density and field orientation.

4. Discussion

The observations are best explained within the theoretical framework of the shock-in-jet model. The basic scenario contemplates the interaction between the polarized emission from two orthogonal synchrotron components: a *steady* component due to the underlying flow (with a magnetic field weakly aligned with the jet due to shear) and a *shocked* component produced as the source flares. The field in the shocked region is mainly perpendicular to the jet (parallel to the shock front). Compression by a shock is likely to be a more efficient mechanism for ordering a magnetic field than shear, which explains why higher levels of polarization are associated with perpendicular magnetic fields. If the polarized emission from the two components is comparable, their superposition could lead to mutual cancellation and position angle swings of up to 90°. Further complexity needs to be added to the model in order to explain other features of the observations, such as the correlation between polarization and flux density, or their rapid and chaotic variability. Relativistic aberration between the observer's and the fluid's frames of reference can greatly enhance the observational effects of small changes in the viewing angle, perhaps induced by small deviations in the trajectory of the shock as it moves down the jet (Gopal-Krishna & Wiita 1992). In this scenario, the expected variation of the total intensity and the polarization is a function of the viewing angle: these two parameters are correlated if the viewing angle is greater than its critical value (defined as $\theta_c = \sin^{-1}(1/\Gamma)$; see e.g. Marscher et al. 1992) and anticorrelated if the viewing angle is less than critical. This has important implications for the parent populations of BL Lac objects and flat spectrum radio Quasars, since the discrepancy in the sense of the correlation between the polarization and the flux density hinted at by the observations, could mean that their differences can be attributed to viewing angle effects. If this result is confirmed by further observations, it will lend credibility to the unifying theories of extragalactic sources.

References

Angel, J.R.P., & Stockman, H.S. 1980, ARA&A, 18, 321

Blandford, R.D., & Rees, M.J. 1978, in BL Lac Objects, ed. M.A. Wolfe (University of Pittsburgh), p. 238

Duncan, D.W., Robson, E.I., Ade, P.A.R., Griffin, M.J., & Sandell, G. 1990, MNRAS, 243, 126

Gear, W.K., et al. 1994, MNRAS, 267, 167

Gopal-Krishna, & Wiita, P. 1992, A&A, 259, 109

Marscher, A., & Gear, W.K. 1985, ApJ, 298, 114

Marscher, A.P., Gear, W.K., & Travis, J.P. 1992, in Variability of Blazars, eds. E. Valtaoja & M. Valtonen (Cambridge University Press), p. 85

Murray, A.G. 1991, Ph.D. Thesis, University of Aberdeen

Murray, A.G., Flett, A.M., Murray, G., & Ade, P.A.R. 1992, Infrared Phys., 33, 113

Nartallo, R. 1995, Ph.D. Thesis, University of Edinburgh