Proceedings of the 6th European VLBI Network Symposium
Ros, E., Porcas, R.W., Lobanov, A.P., & Zensus, J.A. (eds.)
June 25th-28th 2002, Bonn, Germany

Evidence for Non-Uniform Parsec-Scale Faraday Rotation in 2007+777

D. C. Gabuzda[1,2] and I. N. Pashchenko[3]

[1] Physics Department, University College Cork, Cork, Ireland
[2] Astro Space Centre, Lebedev Physical Insitute, Moscow, Russia
[3] Sternberg Astronomical Institute, Moscow State University, Moscow, Russia

Abstract. We present preliminary results of multi-frequency (5, 8.4 & 15 GHz) VLBA polarization observations of 2007+777. These data provide evidence for enhanced Faraday rotation near the VLBI core, most likely due to an increase in the density of thermal plasma in the core region. There is also tentative evidence that the rotation measure RM in the inner jet is enhanced but has the opposite sign (suggesting a change in the orientation of the B field along the line of sight to the Earth). It appears that the rotation measure has fallen to a value comparable to the integrated RM within about 1.5 mas from the core.

1. Introduction

2007+777 ($z = 0.342$, Stickel et al. 1989) is one of relatively few powerful BL Lacertae objects which have Fanaroff-Riley II luminosity and morphology (Antonucci et al. 1986, Kollgaard et al. 1992). Previous VLBI observations (Gabuzda et al. 1994, Krichbaum et al. 2000 and references therein) have shown the VLBI jet extending to the west and components moving outward from the core with modest superluminal speeds. As a whole, the polarization structure of this source (Gabuzda et al. 1994) is typical of BL Lacertae objects, with the polarization vectors in the jet roughly aligned with the jet direction, indicating the dominance of transverse magnetic (B) fields.

2. Observations and results

2007+777 was observed as a part of our ongoing study of the 34 sources in the complete sample of BL Lacertae objects defined by Kühr & Schmidt (1990). The observations were carried out in February 1997 (epoch 1997.11) at 5, 8.5 & 15 GHz using the NRAO Very Long Baseline Array. The calibration and imaging were done in AIPS using standard techniques, and model fitting of the fully calibrated total intensity (I) and polarization (P) data was performed using software in the Brandeis VLBI package. The images obtained are shown in Fig. 1. Although the I and P model fitting was done independently at the three frequencies, we took into account the results of the model fitting at other frequencies to arrive at an optimal set of models that described the data well and gave the best overall consistency at all three frequencies.

We were able to estimate the polarization of two components at all three frequencies – the core and a knot in the inner jet (at $r \simeq 0.6$ mas from the core). A comparison of the properties of these features at the different frequencies suggests a non-uniform frequency dependence for their polarization position angles χ . Fig. 2 shows the χ values for each component derived from our model fitting as a function of λ^2, where λ is the observing wavelength. The χ's for both components show a roughly linear dependence on λ^2, as is expected if the observed polarization angles are subject to external Faraday rotation along the line of sight from the source to the observer. The corresponding RMs indicated by the slopes of these dependences are $-193{\pm}15$ rad/m^2 for the VLBI core and $+167{\pm}73$ rad/m^2 for the component at $r \simeq 0.6$ mas.

We were able to estimate the polarization of another knot further out in the jet (about 1.5 mas from the core) at 5 and 8 GHz. It is impossible to test for a λ^2 dependence of the observed χ values, however, we can put limits on the RM by comparing the polarization angles at these two frequencies. Figure 2 shows that the 8 and 5-GHz χ values of this knot are very similar, indicating that the rotation measure is small, and consistent with both zero and the small integrated RM (-20 ± 3 rad/m^2; Rusk 1988).

3. Discussion

2007+777 is now one of four sources from the complete sample of 1 Jy BL Lacertae objects found to have non-uniform RM distributions on parsec scales (Gabuzda et al. 2001, Reynolds et al. 2001, Gabuzda & Chernetskii 2002). RM variations on such small scales must be associated with variations in the gas density and/or line-of-sight B field in the vicinity of the AGN. The simplest explanation for the enhanced core RM is an increased density of gas in this region. The detection of a RM with the opposite sign at $r \simeq 0.6$ mas is tentative, since the χ errors allow the RM to equal the integrated value at about the 2.2σ level; however, if this RM is confirmed, it will imply a change in the direction of the line of sight B field.

After correction for the RMs, the core polarization angle is about $-45°$, which appears to be oblique to the direction of the inner jet. However, there is some indication from our 15 GHz map and space VLBI observations

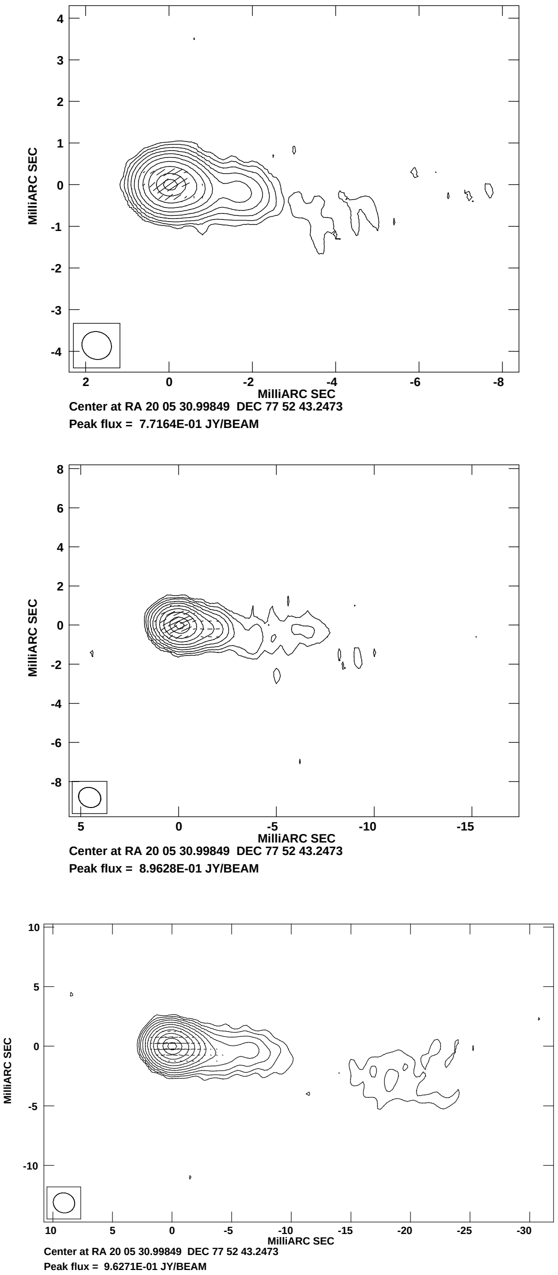

Fig. 1. Total intensity images of 2007+777 in February 1997 at 2 cm (top), 4 cm (middle) and 6 cm (bottom), with polarization sticks superimposed.

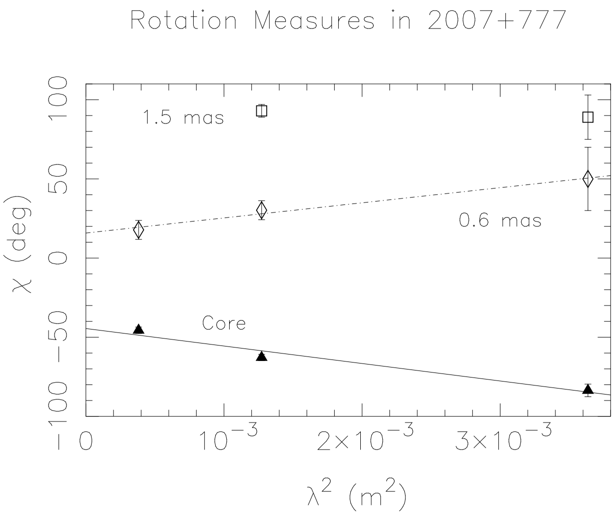

Fig. 2. Wavelength dependence of polarization position angles for the VLBI core and two knots in the VLBI jet. The polarization position angles for the core and inner knot ($r = 0.6$ mas) show roughly linear dependences on the square of the wavelength, as expected if they are subject to external Faraday rotation.).

(Krichbaum et al. 2000) that the jet initially emerges in position angle $\simeq -75°$ before turning toward the west, and it is possible that the core χ reflects the direction of the jet motion on somewhat smaller scales.

The de-rotated polarization vectors in the knot at $r \simeq 0.6$ mas are nearly perpendicular to the jet direction. If this region is optically thin, this implies a longitudinal B field. However, the situation is not yet clear, since there is evidence that the spectrum may flatten near this knot. If this component is actually optically thick, the dominant B field in this region is then transverse. We are in the process of a more detailed analysis to try to elucidate the nature of this feature.

Further from the core, where the jet is clearly optically thin, the de-rotated polarization vectors are aligned with the local jet flow, indicating that the transverse component of the B field is dominant. Such fields could be connected with the presence of transverse shocks propagating along the jet, or alternatively with a high-pitch-angle helical B field associated with the parsec-scale jet.

Acknowledgements. The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under cooperative agreement with the NSF. INP thanks the local organizing committee for partial financial support for his participation in the 6th EVN symposium.

References

Antonucci R.R.J., Hickson P., Olszewski E.W., & Miller J.S. 1986, AJ, 92, 1
Gabuzda D.C. & Chernetskii V.A. 2002, MNRAS submitted
Gabuzda D.C., Mullan C.M., Cawthorne T.V., Wardle J.F.C., & Roberts D.H. 1994, ApJ, 435, 140
Gabuzda D.C., Pushkarev A.B., & Garnich, N.N. 2001, MNRAS, 327, 1
Kühr H. & Schmidt G.D. 1990, AJ, 90, 1
Kollgaard R.I., Roberts D.H., Wardle J.F.C., & Gabuzda D.C. 1992, AJ, 104, 687
Krichbaum T.P., Jin C., Kraus A., Witzel A., & Zensus J.A. 2000, in Astrophysical Phenomema Revealed by Space VLBI, ed. H. Hirabayashi, P. G. Edwards, & D. W. Murphy (ISAS, Sagimahara), 133
Reynolds C.R., Cawthorne T.V., & Gabuzda D.C. 2001, MNRAS, 327, 1071
Rusk R. 1988, PhD Thesis, University of Toronto
Stickel M., Fried J.W., & Kühr H. 1989, A&A, 80, 103