Parsec–scale radio jets in γ–ray loud sources

Tiziana Venturi a, Daniele Dallacasa a,b

a Istituto di Radioastronomia, CNR, Via Gobetti 101, 40129 Bologna, Italy
b Dipartimento di Astronomia, Università di Bologna, Via Ranzani 1, 40127 Bologna

Abstract

We will present a multiepoch study of the three blazars 0954+658 (BL–Lac), PKS 1510–089 (HPQ) and 1749+096 (BL–Lac). The first two sources are known to be γ–ray loud. Our study is based on milliarcsecond resolution polarimetric observations carried out with the VLBA at 8.4 GHz. The observations took place between January 1999 and May 2001. Superluminal motion is detected along the jet of PKS 1510–089 and 1749+096, with \( \beta_{\text{app}} \sim 10 \) for all features. Magnetic field structure is revealed along the jets of 0954+658 and PKS 1510–089. The polarisation properties of the parsec–scale jets remain stationary in all sources, regardless of their total flux density variability in the radio band and of the presence of superluminal features.

Key words: Blazars: general, BL Lacertae objects, quasars: individual (0954+658, PKS 1510–089, 1749+096), radio emission

1 Introduction

The blazar phenomenon is now believed to be the result of an anisotropic relativistic jet propagating at a small angle to the observer’s line of sight. Variability at all wavelengths and the peculiar radio properties on the parsec scale, such as one–sidedness, jet bending, misalignment and superluminal features, can all be accounted for under these assumptions.

In a number of blazars the emission extends out to the MeV regime, i.e. to the γ–rays. Many models have been proposed to explain the origin of this very high energy emission, such as for example synchrotron self–Compton (i.e. Maraschi et al. 1992), inverse Compton scattering, with a variety of origins for the scattered photons (i.e. Dermer et al. 1992; Sikora et al. 1994), synchrotron emission by ultra relativistic electrons and positrons (Ghisellini et al. 1993). However, no consensus on the dominant process has been reached yet.

The connection between the γ–ray emission and the parsec–scale radio
properties is under study, and many questions are still unexplained. For example, it is still unclear if (1) \( \gamma \)-ray loud blazars are characterised by higher apparent speeds and/or higher Lorentz factors; (2) jet bending, wiggling and misalignement are more prominent in \( \gamma \)-ray loud sources. Beyond this, the correlation between radio variability and changes in the magnetic field structure is still unclear for all classes of radio loud AGNs.

In order to increase the statistics, and to shed light on these important questions, detailed multifrequency studies for a high number of radio loud blazars is necessary. In this paper we present a multiepoch study of three radio blazars, carried out at 8.4 GHz with the Very Long Baseline Array (VLBA). Among our sources, two are also \( \gamma \)-ray loud. We defined \( h = H_0 / 100 \) and \( q_0 = 0.5 \).

2 Observations and data analysis

We performed multiepoch VLBA observations of the three blazars 0954+658 (LBL, \( z = 0.368 \)), PKS 1510–089 (HPQ, \( z = 0.361 \)) and 1749+096 (LBL, \( z = 0.322 \)). The first two sources have a measured \( \gamma \)-ray flux (Hartman et al. 1999), while only an upper limit exists for 1749+096 (Fichtel et al. 1994). The angular resolution of the VLBA at 8.4 GHz is \( \sim 1 \) mas, and the typical noise on the images is in the range 0.07 – 0.3 mJy/beam, depending on the peak flux density value. Data calibration and imaging were carried out with the AIPS NRAO package. The final datasets were then exported into the Difmap package, where modelfitting of the visibilities was performed. In Figs. 1 and 2 contour plots of 0954+658, PKS 1510–089 and 1749+096 are given, with superposed magnetic field vectors.

3 The parsec–scale radio jets

All sources in our project showed considerable total flux density variations during the period of our monitoring,
Fig. 1. Left – 8.4 GHz image of 0954+658 (epoch December 2000). Superposed vectors represent the fractional polarisation. HPBW = 1.07×0.65 mas, p.a. 14°. Image peak 349 mJy/beam. Contours are −0.4, 0.4, 0.8, 1.6, 3.2, 6.4, 12.8, 25.6, 50, 100, 200 mJy/beam. Right – 8.4 GHz image of PKS 1510–089 (epoch December 2000). The superposed vectors represent the fractional polarisation. HPBW = 2.44×1.00 mas, p.a. −20°. Image peak 726 mJy/beam. Contours are −0.6, 0.6, 1, 2, 4, 8, 16, 32, 62.5, 125, 250 mJy/beam.

up to ≈ 40%.

We modelfitted the final visibilities at each epoch for each source with gaussian components, in order to investigate the presence of moving features.

PKS 1510–089 shows major structural changes. The inner 6 mas are well fitted with two components along the jet, labelled as B and C in Fig. 1, whose location with respect to the core (most likely associated with the image peak, based on multifrequency analysis, Venturi et al. in prep.) increases with time. The positions of B and C at the various epochs are given in Fig. 3. Here the position of component C at the epoch 1997 is taken from Homan et al. (2001).

Both components are found to be superluminal, with a similar value for the velocity, i.e. $\beta_{\text{app}}(B) = 10.0 \pm 0.3$ $h^{-1}$c, and $\beta_{\text{app}}(C) = 10.4 \pm 1.2$ $h^{-1}$c. These values agree, within the uncertainties, with the motion reported by Homan et al. (2001), and imply a Lorentz factor $\gamma_{\text{min}} > 10$.

The jet component in 1749+096 is also found superluminal, with $\beta_{\text{app}} \approx 8.2$ $h^{-1}$c.

Our analysis suggests that the jet in 0954+658 is stationary. A comparison among our epochs and literature images (Gabuzda & Cawthorne 1996) leads either to no apparent motion, or to very high superluminal speed along the jet, with $\beta_{\text{app}} > 50c$. Kellermann et al. (2003) show that very high superluminal features are found among the sources in the 2 cm VLBA survey, however the case of 0954+658 would be very extreme. We note that this source alternates core flux density flares to long periods of quiescence (Venturi et al. 2001).
A preliminary analysis of the polarised emission at 8.4 GHz shows that all sources have polarised flux in the core region and along the jet. The core polarised intensity and polarisation angle change in all sources from epoch to epoch. On the other hand, the polarised flux and the magnetic field orientation along the jet remain stationary, regardless of the flux density variability and of superluminal motion in the knot.

In PKS 1510–089 the magnetic field shows structure along the jet. From Fig. 1 (right panel) it is clear that the fractional polarisation is higher in the external part of the jet, while the jet spine is less polarised. This behaviour is found at all epochs.

4 Summary and conclusions

Our monitoring program on three blazars revealed different properties on the parsec–scale jets. In particular:

- superluminal motion is detected in PKS1510–089 (two superluminal knots) and in 1749+096. In all cases an apparent velocity $\beta_{\text{app}} \sim 10 \, h^{-1}c$ is found;

- a stationary jet is present in 0954+658, despite the major variability in the radio band during the period of our monitoring program;

- the polarisation properties along the parsec–scale jet remain stationary from epoch to epoch in all sources, regardless of their flux density variability and the presence of superluminal features;

- magnetic field structure is found in PKS1510–089, where a higher percentage of polarisation is detected along the outer edges of the jet.

References

Dermer, C.D., et al., 2002, A&A, 256, L27
Fichtel, C.E., et al., 1994, ApJS, 94, 551
Gabuzda, D.C. & Cawthorne, T.V., 1996, MNRAS, 283, 759
Ghisellini et al., 1993, ApJ, 407, 65
Hartman, R.C., et al., 1999, ApJS, 123, 79
Homan, D.C., et al., 2001, ApJ, 549, 840
Kellermann, K.I., et al., 2003, in High Energy Blazar Astronomy, ASP Ser., in press, astro–ph/0211398
Maraschi, L., et al., 1992, ApJ, 397, L5
Sikora, M., et al., 1994, ApJ, 421, 153
Venturi, T., et al., 2001, A&A, 379, 755