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Two-Sided Radio Jets in B1524−136

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Abstract: We present global VLBI and VLBA observations of the compact steep spectrum quasar B1524−136. These observations reveal well-defined radio jets on both sides of the active nucleus. Also, the overall radio structure appears highly distorted and asymmetric with the counter-jet exhibiting several oscillations. A possible scenario is one in which jet and counter-jet are inclined at about 25° and 75° to the line of sight respectively and an environment which is dense on the jet side. Possible implications of these results are discussed.

Keywords: galaxies: active — galaxies: jets — galaxies: nuclei — quasars: general — quasars: individual (B1524−136) — radio continuum: galaxies

1 Introduction

Although most high-luminosity extragalactic radio sources (FR II radio galaxies and quasars) have two reasonably symmetric radio lobes on opposite sides of the parent optical object, the radio jets in these sources are overwhelmingly one-sided (cf. Bridle & Perley 1984). This is particularly true for quasars where radio jets are detected more frequently than in radio galaxies. Two of the good examples of counter-jets seen in FR II radio sources are associated with relatively nearby radio galaxies: Cygnus A ($z = 0.056$) and 3C 353 ($z = 0.03$).

We present here global VLBI and VLBA* observations of the compact steep spectrum source B1524−136. The source B1524−136 is identified with a quasar at $z = 1.687$. It has a steep radio spectrum $\alpha_{750}^{5000} \sim 0.64$ which appears to flatten below a few hundred MHz (cf. Steppe et al. 1995). The source projected linear size is ~3 kpc in a universe with $H_\circ = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and $q_\circ = 0.5$. VLA observations at 5 GHz show B1524−136 to be slightly extended, while at 15 GHz it is resolved into a double source (Mantovani et al. 1994). Observations with the VLBA show the northern region to have a very high rotation measure in the range of −3000 to −10000 rad m^{-2} in the rest frame of the source (Mantovani et al. 2002).

2 Observations and Data Reduction

The Global VLBI MK2 observations were made on 1992 September 21 at 1.66 GHz. The array consisted of five European antennas and seven VLBA antennas. The data were processed at the Caltech Block2 correlator and analysed using AIPS. The image of B1524−136 at 1.66 GHz is shown in Figure 1, left.

The VLBA plus VLA1 observations were made on 1996 February 4 at 8.4 GHz with a bandwidth of 32 MHz. Complex correlation coefficients were recovered at the Array Operations Centre in Socorro. Phase gradients in frequency and time were corrected by the use of global fringe fitting (Schwab & Cotton 1983). The image of B1524−136 at 8.4 GHz is shown in Figure 1, right.

3 Discussion

The component which we identify as the core, labelled C in Figure 1, right, has a jet-like extension along a similar position angle as the northern jet, is unresolved in the orthogonal direction, and has a flat radio spectrum ($\alpha \approx 0$, $S \propto \nu^{\alpha}$), estimated from similar resolution VLBA plus VLA1 images at 5 and 8.4 GHz.

The most striking result of these observations is the detection of a jet and a counter-jet in a quasar. We examine its consistency with the relativistic beaming model and discuss a possible scenario to explain the broad features of the source.

The value of R, the ratio of the core to extended flux density, in B1524−136 is 0.10. Adopting the values $R_T = 0.0008$ (R for objects transverse to the line of sight) and $\gamma = 10$ (Lorentz factor) derived for FR II 3CR sources (cf. Saikia & Kulkarni 1994), the observed value of R implies an angle of inclination to the line of sight $\theta \sim 20°$.

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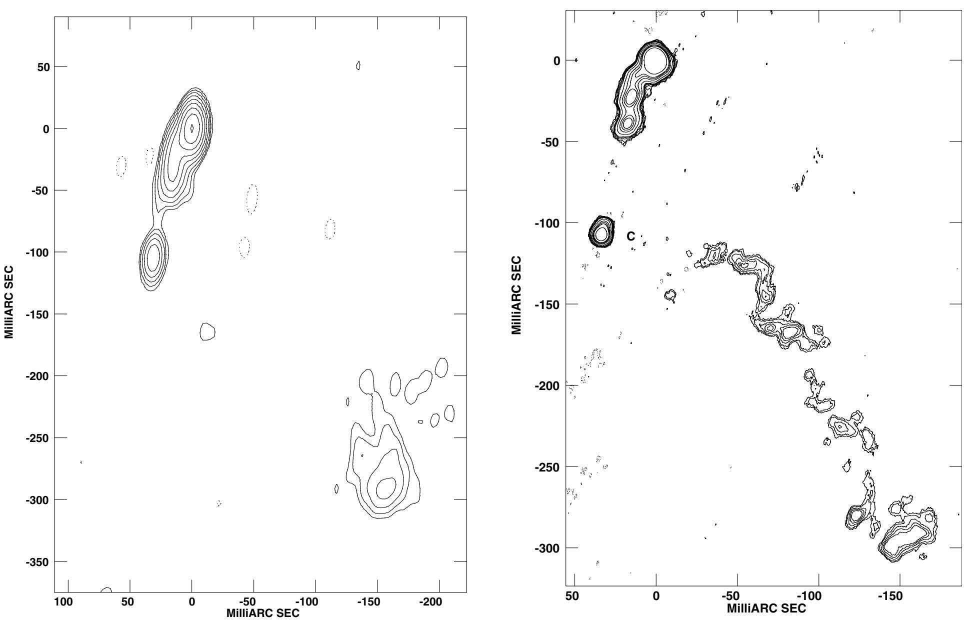

Figure 1 Left: The global MK2 VLBI image at 1.66 GHz of B1524−136 with an angular resolution of 22 × 9 mas along a PA of −4°. The contour levels are 4 ×(−1, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512) mJy/beam. The peak flux density is 1085 mJy/beam. Right: The VLBA image at 8.4 GHz of B1524−136 restored with a circular beam of 6 mas. The contour levels are 0.3×(−1, 1, 2, 3, 4, 8, 16, 32, 64, 128, 256, 512) mJy/beam. The peak flux density is 110.8 mJy/beam. The letter 'C' denotes the radio core.

The ratio of the mean brightness of the knots in the jets to those in the counter-jet is 11, which implies a bulk velocity for the jet of $\sim$0.5 c if the apparent brightness asymmetry is entirely due to relativistic beaming. The large projected misalignment between the two jets, plus the oscillations in the counter-jet, suggest that the bending is three-dimensional, and that different sections of both jets could be inclined at different angles to the line of sight. Also, the jets will probably decelerate as they traverse outwards from the nucleus, and the degree of deceleration could be different on opposite sides of the nucleus. These would all affect the observed brightness ratio of the jets.

From the 8.4 GHz image we can reasonably assume that the main jet is straight till it bends by about 40° before entering the hot spot. The observed flux density of even the approaching jet will be Doppler diminished when $\gamma(1-\beta\cos\theta) > 1$, which would require that $\theta > 25°$ for $\gamma \sim 10$, the corresponding brightness ratio at this angle being >2000. A deceleration of the jets to about 0.5 c by the region where the jets are first detected would result in a decrease of Doppler dimming and might provide a viable explanation for the gaps in emission between the core and both the jet and counter-jet, and the detection of the radio jets at about 50 mas from the nucleus. However, we also need to explain the large observed misalignment of the source. A possible scenario is one in which the jet is inclined at about 25° to the line of sight, and the counter-jet is bent by about 50° such that it is about 75° to the line of sight. This will decrease the degree of Doppler dimming, making the counter-jet visible, and will also help explain the misalignment of the source.

Finally, the jetted side is closer to the nucleus, which is not consistent with expectations of a symmetric external environment. This hot spot being closer and brighter is possibly due to a higher dissipation of energy on the jetted side due to interaction with a much denser external medium on the northern side (RM measurements suggest the presence of dense gas there). The brightness asymmetry of the hot spots in the VLBA image is higher than that of the jets by a factor of six. Even if the hot spots are travelling close to the speed of the jets, the additional asymmetry in brightness would require the density in the northern side to be higher than in the southern side by about 40 using a model for the propagation of jets in an asymmetric environment.

4 Conclusions

We report the detection of a well-defined radio jet and a counter-jet in the compact steep spectrum quasar B1524−136, which is almost unique in a radio quasar. Among compact sources, well-defined, two-sided jets have been seen in 1946+708 (Taylor et al. 1996). We present global VLBI and VLBA observations of the source. The radio source is highly non-collinear and asymmetric, and was reported recently to have a high RM of several thousand rad m^{-2} on the northern side. An angle of inclination for the jet of about 25°, a jet speed of about 0.5 c, an intrinsic misalignment of about 50°, such that the counter-jet is at about 75° to the line of sight, and a density asymmetry on opposite sides of the nucleus by a factor of $\sim$40 provide a consistent explanation of the observed properties of the source.

References

Bridle, A. H., & Perley, R. A. 1984, ARA&A, 22, 319

Mantovani, F., Junor, W., Fanti, R., Padrielli, L., & Saikia, D. J. 1994, A&A, 292, 59

Mantovani F., Junor W., Ricci, R., Saikia, D. J., Salter, C., & Bondi, M. 2002, A&A, 389, 58

Saikia, D. J., & Kulkarni, V. K. 1994, MNRAS, 270, 897

Schwab, F. R., & Cotton, W. 1983, AJ, 88, 688

Steppe, H., Jeyakumar, S., Saikia, D. J., & Salter, C. J. 1995, A&AS, 113, 409

Taylor, G. B., Vermeulen, R. C., Readhead., A. C. S., Pearson, T. J., Henstock, D. R., & Wilkinson, P. N. 1996, in Proceedings of the Second Workshop on Gigahertz Peaked Spectrum and Compact Steep Spectrum Sources, ed. I.A.G. Snellen et al. (Leiden: Leiden Observatory), 263