Supplementary Discussion

We adopt a value of 7° for the angle that the jet axis subtends with the line of sight, similar to that found previously[7], and a Lorentz factor of 5.5 (speed of 0.983*c*). This combination is consistent with both (1) the observed apparent motion of 5.0*c* of the superluminal knot seen in Figure 1 and (2) the relatively high X-ray and radio flux in late 2005 compared with later times, which we interpret as the consequence of enhanced Doppler beaming. The observed time delay of 18 days, between the time when the optical EVPA rotation ends and the time of coincidence of the knot with the core in the VLBA images, then corresponds to a linear distance (after de-projection) of ~2 light-years ~ 2×10^{18} cm between the end of the ACZ and the core at 7 mm wavelength.

The flatness of the radio spectrum down to ~0.7 mm wavelength (~400 GHz)[23] implies that the jet is a self-similar cone with constant Lorentz factor downstream of the point where the jet cross-section becomes ~ 0.1 times its value at the 7 mm core, since for a flat synchrotron spectrum the transverse radius at the point where the jet becomes opaque is proportional to the first power of the wavelength[24]. Although the cross-sectional radius ρ of the jet at the position of the 7 mm core is too small to resolve on our VLBA images, we can estimate a value ~ 1×10^{17} cm from the timescale of radio flux variability and brightness temperature arguments.[25] If the site where the jet becomes optically thin at 0.7 mm wavelength is at the outer radius of the ACZ[26], the cross-sectional radius at that point is $\rho \sim 1\times10^{16}$ cm, equivalent to ~200 Schwarzschild radii (R_S) for a black-hole mass M ≈ 2×10^{8} solar masses, as estimated for BL Lac[27].

The observed rotation rate of the polarisation, 50° day^{-1}, corresponds to a single full twist of the streamline occurring in 7.2 days, across an incremental distance from the black hole of ~ 0.8 light-years ~ 8×10^{17} cm. The rotational velocity of the streamlines at the outer edge of the ACZ, where the circumference ~6×10^{16} cm, is then $v_{rot} \sim 0.08c$. At smaller distances from the black hole, down to the Alfvén radius where the flow speed equals the local Alfvén velocity, v_{rot} should vary as $1/\rho$ to conserve angular momentum. In this case, the rotational velocity v_{rot} is a fraction x of the speed of light c when the cross-sectional radius ~$8\times10^{14}\ x^{-1}$ cm, or ~$30x^{-1}R_S$. Inside the Alfvén radius the flow should co-rotate with the footpoint of the magnetic field in the accretion disk or ergosphere, so that $v_{rot} \propto \rho$. In the simulations of Vlahakis and Königl[4], $x \approx 0.3$. If we set the rotational speed at the footpoint (located a distance r_f from the black hole) as $v_{rot}(r_f) = xcr_f/(8\times10^{14}\ x^{-1}\ \mathrm{cm}) = (GM/r_f)^{1/2}$, we can estimate that the outer magnetic field of the jet is anchored at $r_f \sim 30\ R_S$. If instead $x \approx 1$, as might be expected for almost pure Poynting flux jets launched from the ergosphere of a rotating black hole[21,22] , we arrive at a value $r_f \sim 7R_S$. The uncertainties in both the numerical value of 7 and R_S are of order a factor of 2. Hence, these distances from the black hole are consistent with the expectations of models in which the jet is driven by twisting magnetic fields from the vicinity of an accreting black hole.

Supplementary Methods

Imaging with Very Long Baseline Interferometry.

We observed BL Lac at 7 mm wavelength (frequency of 43 GHz) with the Very Long Baseline Array (VLBA) at the epochs displayed in Fig. 1 as well as the following dates: 24 and 28 October 2005, 2 November 2005, and 12 March 2006. After correlation at the Array Operations Center of the National Radio Astronomy Observatory (NRAO) in Socorro, New Mexico, we passed the data through the VLBI routines of the Astronomical Image Processing System (AIPS) software supplied by NRAO for initial calibration and followed the procedures described in ref. 7 to create and analyze the resultant images. We refer the EVPA measurements to a stable feature in the VLBA polarised intensity image of the quasar CTA102. There is good agreement between the thus-calibrated EVPAs of several objects with archival data and with contemporaneous Very Large Array measurements (available at http://www.vla.nrao.edu/astro/calib/polar/). In our analysis, we subtract 16° from the polarisation angle in the core of BL Lac to compensate for Faraday rotation[28,29]. We note that essentially the same level of Faraday rotation at 7 mm wavelength was derived for the core from observations occurring about two years apart[28,29], a fact that implies that the value is not highly variable.

Optical observations.

We collected optical polarimetric data at Steward Observatory and the Crimean Astrophysical Observatory and photometry at these two sites plus three others. At the Steward Observatory 1.55 m Kuiper telescope at Mt. Bigelow, Arizona, USA, we used the SPOL spectropolarimeter[30], making a total of 34 measurements, each covering 400-800 nm during 12 contiguous nights from 2005 October 23 to November 3. Details of the reduction procedure can be found in, e.g., ref. 31. At the Crimean Astrophysical Observatory in Crimea, Ukraine, we performed *R*-band photometry and polarimetry on the AZT-8 70 cm telescope, with a prime-focus photometer-polarimeter equipped with two Savart plates.

We also measured the optical R-band magnitude of BL Lac with the following telescopes: the 1.83 m Perkins telescope at Lowell Observatory in Flagstaff, Arizona, USA, the 0.4 m Automatic Imaging Telescope at Perugia University Astronomical Observatory in Perugia, Italy, and the 70 cm meniscus telescope[32] of Abastumani Astrophysical Observatory in Abastumani, Georgia. All telescopes are equipped with CCD cameras. For all flux measurements, we determined the magnitude of BL Lac relative to field stars calibrated by Smith et al.[33].

X-ray observations.

We observed BL Lac an average of 3 times per week for ~2000 s per pointing with the *Rossi* X-ray Timing Explorer (RXTE). For each X-ray observation, we determined the X-ray flux in photon counts per second over the energy range 2 to 10 keV by subtracting an X-ray background model (supplied by the RXTE Guest Observer Facility) from the raw spectrum, using the standard X-ray data analysis software package FTOOLS. We fit the photon spectrum (observed flux F_{obs} versus photon energy E from 2.4 to 10 keV) with a model consisting of a power-law intrinsic spectrum with spectral index α, $F_\gamma = E^{-(\alpha+1)}$, plus photoelectric absorption along the line of sight using the program XSPEC. For the latter, we adopted a hydrogen column density of 2.7×10^{21} atoms cm^{-2} (see ref. 34).

Radio flux density measurements.

We determined the flux density of BL Lac at a wavelength of 2 cm (frequency of 14.5 GHz) with the 26-m diameter antenna of the University of Michigan Radio Astronomy Observatory (UMRAO) near Ann Arbor, Michigan, USA and at 8 mm (37 GHz) with the 14 m antenna of the Metsähovi Radio Observatory in Kylmälä, Finland. The data displayed in Fig. 2 are nightly averages. Detailed description of the instrumentation and reduction procedures can be found from Aller et al.[35] for UMRAO and Teräsranta, H. et al.[36] for Metsähovi.

Supplementary Notes

Supplementary References

23. Impey, C. D. & Neugebauer, G. Energy distributions of blazars. *Astron. J.* **95**, 307-351 (1988).

24. Königl, A. Relativistic jets as X-ray and gamma-ray sources. *Astrophys. J.* **243**, 700-709 (1981).

25. Lähteenmäki, A., Valtaoja, E. & Wiik, K. Total flux density variations in extragalactic radio sources. II. Determining the limiting brightness temperature for synchrotron sources. *Astrophys. J.* **511**, 112-117 (1999).

26. Marscher, A. P. Relativistic jets and the continuum emission in QSOs. *Astrophys. J.* **235**, 386-391 (1980).

27. Woo, J.-H. & Urry, C. M. Active galactic nucleus black hole masses and Bolometric luminosities. *Astrophys. J.* **579**, 530-544 (2002).

28. Jorstad, S. G. *et al.* Multiwaveband polarimetric observations of 15 active galactic nuclei at high frequencies: correlated polarization behavior. *Astron. J.* **134**, 799-824 (2007).

29. Gabuzda, D. C., Rastorgueva, E. A., Smith, P. D. & O'Sullivan, S. P. *Mon. Not. R. Astron. Soc.* **369**, 1596-1602 (2006).

30. Schmidt, G. D., Stockman, H. S. & Smith, P. S. Discovery of a sub-megagauss magnetic white dwarf through spectropolarimetry. *Astrophys. J.* **398**, L57-L60 (1992).

31. Smith, P. S., Schmidt, G. D., Hines, D. C. & Foltz, C. B. Optical spectropolarimetry of quasi-stellar objects discovered by the two-micron all sky survey. *Astrophys. J.*, **593**, 676-699 (2003).

32. Kurtanidze, O. M. & Nikolashvili, M. G. in *Blazar Astrophysics with BeppoSAX and Other Observatories*, ASI Special Publication (eds Giommi, P., Massaro, E. & Palumbo, G., 189-196 (ESA-ESRIN, Frascati, 2002).

33. Smith, P.S., Balonek, T.J., Heckert, P.A., Elston, R. & Schmidt, G.D. UBVRI field comparison stars for selected active quasars and BL Lacertae objects. *Astron. J.* **90**, 1184-1187 (1985).

34. Madejski, G. *et al.* X-ray observations of BL Lacertae during the 1997 outburst and association with quasar-like characteristics. *Astrophys. J.* **521**, 145-154 (1999).

35. Aller, H. D., Aller, M. F., Latimer, G.E. & Hodge, P.E. Spectra and linear polarizations of extragalactic variable sources at centimeter wavelengths. *Astrophys. J. Suppl.* **59**, 513-768 (1985).

36. Teräsranta, H. *et al.* Fifteen years monitoring of extragalactic radio sources at 22, 37 and 87 GHz. *Astron. Astrophys. Suppl.* **132**, 305 (1998).