New VLBA Observations Of The Parsec-Scale Structures Of The TeV Blazars 1ES 1426+428, 1ES 1959+650, And PKS 2155-304

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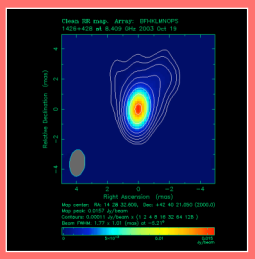
Abstract

We present new Very Long Baseline Array (VLBA) observations of the TeV blazars 1ES 1426+428, 1ES 1959+650, and PKS 2155-304 obtained during 2003 and 2004. New results include: the first VLBI images and jet speed measurement for 1ES 1426+428, improved jet speed measurements for 1ES 1959+650 and PKS 2155-304, the first VLBA polarization image of PKS 2155-304, and parsec-scale spectral index maps of 1ES 1959+650. This material is based upon work supported by the National Science Foundation under Grant No. 0305475.



1ES 1426+428

• 1ES 1426+428 is the faintest of the six TeV blazars we have studied so far in the radio (correlated flux density ≈ 15-20 mJy).

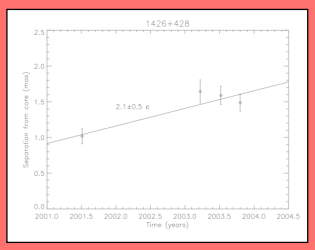
• Observed once with the VLBA in 2001 to verify that it had detectable structure.

• Observed three more times during 2003 to monitor changes in jet structure.

• Observations were made at 8 GHz for increased sensitivity relative to the 15 and 22 GHz observations in the rest of the poster.

• The morphology shows a jet to the northwest at position angle ≈ -25° that can be modeled with a single Gaussian component.

• The fitted apparent speed of the single jet component is 2.1 +/- 0.5 c, see figure.



PKS 2155-304

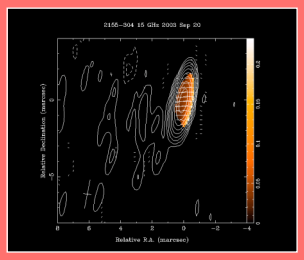
• PKS 2155-304 was observed three times with the VLBA at 15 GHz during 2000, those results were published in Piner & Edwards (2004).

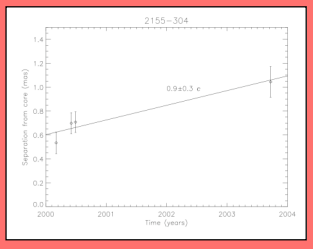
• Earlier results had a large random error on the apparent speed, so we observed this source again with the VLBA in 2003, this time with dual circular polarization, to obtain polarimetry information on the parsec scale.

• The 15 GHz VLBA polarization image is shown at right. The contours show total intensity, the color scale shows fractional polarization, and the tick marks show the magnitude of the polarized flux and the direction of the electric vector position angle (EVPA).

• The core is 4% polarized and the electric vector position angle in the core is ≈ 100°, nearly parallel to the parsec-scale jet. The inferred B-field direction is nearly perpendicular to the jet, indicative of a strong shock near the core.

• A single jet component is required in the model fitting, as at the earlier three epochs. Combining all four epochs gives a fitted apparent speed for this component of 0.9 +/- 0.3 c, see figure at right.





1ES 1959+650

• 1ES 1959+650 was observed three times with the VLBA at 15 GHz during 2000, those results were published in Piner & Edwards (2004).

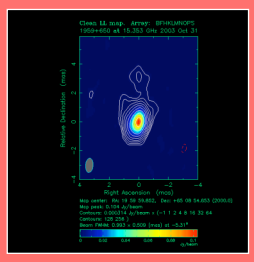
• The source had an intriguing morphology, with compact jet components detected to the south of the presumed core, and diffuse emission detected to the north. Our hypothesis was that the jet bends and crosses the line-of-sight, appearing first to the south of the core, then to the north.

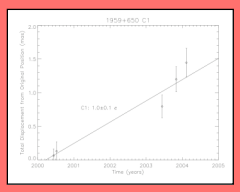
• To verify the location of the core and better quantify motions in the jet, we observed this source three more times with the VLBA in 2003 and 2004, at dual frequencies of 15 and 22 GHz.

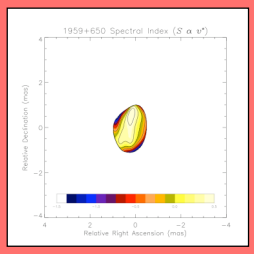
• A spectral index map made from the dual-frequency data (at right) confirms that the northern end of the compact portion of the source has the flattest spectrum, and is indeed the core.

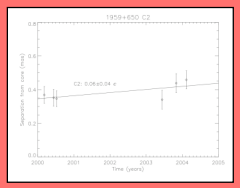
• We have also confirmed that the jet crosses the line-of-sight, because a jet component was observed to move from the south to the north of the core over the six epochs.

• The compact jet can be modeled by two Gaussian components. Component C2 is stationary (fitted speed 0.06 +/- 0.04 c), the position versus time fit is shown at right. Component C1 began to the south of the core but moved to the north of the core at the final two epochs. To measure an apparent speed for C1, we fit to the total displacement from its first measured position, and obtain an apparent speed of 1.0 +/- 0.1 c, see figure at right.









Apparent Speeds of TeV Blazars

• In Piner & Edwards (2004), we published a summary of our measured apparent speeds in TeV blazar jets, based on our VLBA observations of these sources.

• This poster has presented new or updated speeds for the jets of 1426+428, 2155-304, and 1959+650, so we give a revised version of the table from Piner & Edwards (2004) below.

• The table uses h=0.71, Ω_m=0.27, and Ω_Λ=0.73, and also includes updated speeds for Mrk 421 from Piner & Edwards (2005).

• We have also recently had VLBA observations approved to observe the several newly discovered TeV blazars, so observations of those are coming soon.

Source	Component	Apparent Speed (c)
Mrk 421	C4	0.09 +/- 0.07
	C4a	-0.06 +/- 0.09
	C5	0.10 +/- 0.02
	C6	0.03 +/- 0.03
	C7	0.06 +/- 0.01
1426+428	C1	2.08 +/- 0.53
Mrk 501	C1	0.05 +/- 0.18
	C2	0.54 +/- 0.14
	C3	0.26 +/- 0.11
	C4	-0.02 +/- 0.06
1959+650	C1	0.99 +/- 0.13
	C2	0.06 +/- 0.04
2155-304	C1	0.94 +/- 0.31
2344+514	C1	1.15 +/- 0.46
	C2	0.46 +/- 0.43
	C3	-0.19 +/- 0.40

Discussion

• To date, the VLBA observations show that the apparent speeds in TeV blazar jets are much slower than those in the EGRET blazars or in radio-selected samples.

• Combined with their low radio core brightness temperatures, low radio variability, and decollimation of the radio jets beyond a few milliarcseconds from the core, the lack of observable superluminal components implies only moderately relativistic Lorentz factors in their radio jets. These radio properties may be representative of high-frequency peaked blazars in general, not just the TeV-detected ones.

• These moderately relativistic Lorentz factors must be reconciled with the highly relativistic flows required by models of the TeV gamma-ray emission.

• Explanations that have been proposed for this include deceleration of the jet from the gamma-ray (light-day) scales to VLBA (light-year) scales, or stratification of the jet into a fast-spine slow-sheath structure, with the radio emission coming from the slow sheath.