Rapid Multiwavelength Polarization Correlation in OJ287 and Other Blazars

F. D. D'Arcangelo[1], A. P. Marscher[1], S. G. Jorstad[1], P. S. Smith[2], V. M. Larionov[3], V. A. Hagen-Thorn[3], G. G. Williams[2], D. P. Clemens[1]
[1]Boston University, [2]University of Arizona, [3]St. Petersburg State University

Legend
R (Optical) — solid red line
H (Infrared) — dashed line
43 GHz core — dotted line

2453669 October 25, 2005
2453820 March 25, 2006

Introduction

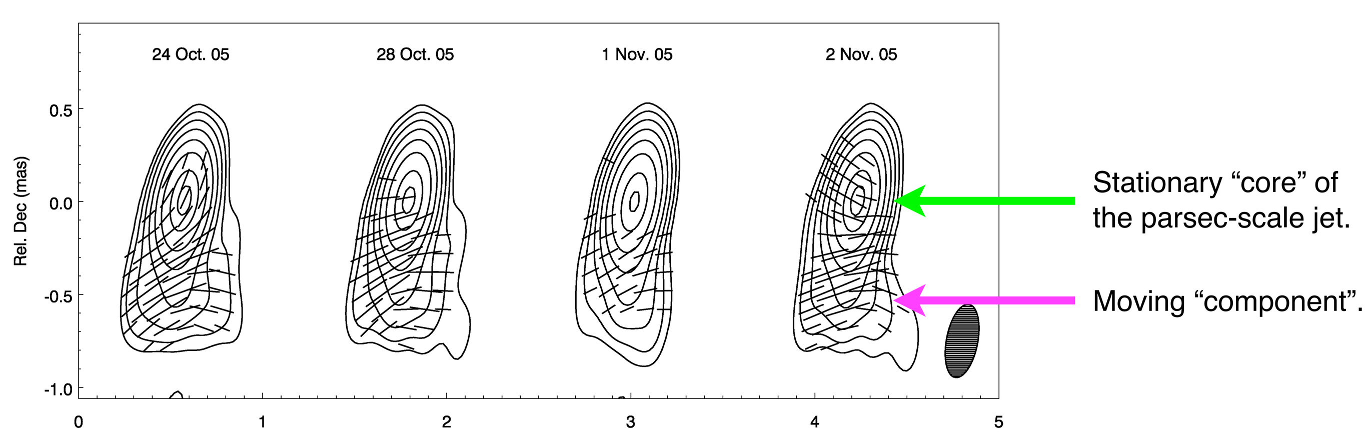
Blazars are a class of Active Galactic Nuclei in which jets of high-energy, magnetized plasma flow outward from the central engine at near-light speeds. These objects thus show fast, powerful variability and strong linear polarization across the spectrum. The compact regions of blazars are areas of great interest; study of them can potentially reveal the mechanisms behind the launching and sustainment of a relativistic jet.

At optical wavelengths, blazars are unresolved, and so appear only as a point source. However, with images from the Very Long Baseline Array (VLBA) at 43 GHz, we can resolve their complicated structure on parsec scales, with a resolution of ~0.1 milliarcsecond. At this wavelength, we are able to explore regions within 1-10 parsecs of the supermassive black hole.

Using day-scale plots of variability in polarization percentage and electric vector position angle (EVPA), we can search for correlations between optical emission and the emission from each part of the radio jet. Once a cospatial origin is established, we can then use the polarization and multiwavelength light curves to explore the physics of the jet in these compact regions.

Method

In order to link the optical emission with emission from the resolved jet, we use polarization characteristics at each wavelength as our point of comparison. The polarized light observed in blazars is emitted by the process of *synchrotron emission*, wherein relativistic electrons are accelerated by magnetic fields in the jet. The acceleration produces linearly polarized light with an EVPA perpendicular to the magnetic field. Thus, by observing the EVPA, we are in turn observing the magnetic structure of the jet. We obtain highly sampled data at optical and infrared wavelengths and images at 43 GHz in order to compare the variability of the EVPA and of the percentage polarization. A set of 43 GHz images is shown below:



The EVPA produced in the core of the jet rotates with time, while the EVPA of the component stays approximately static. Thus, we can compare the EVPA behavior at the optical waveband with these two distinct signatures in order to locate the origin of the optical emission.

Observations

We measured the polarization characteristics and total flux of 25 separate blazars over two intensive, multiwavelength campaigns, with 3 of those objects observed during both campaigns. The first campaign spanned from 23 October 2005 to 3 November 2005 and the second from 26 March 2006 to 4 April 2006.

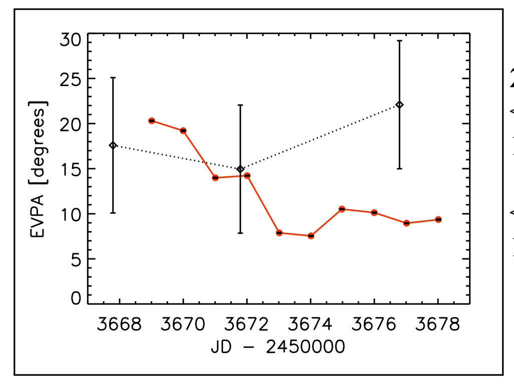
Optical: We performed optical spectropolarimetry on 13 objects in 2005 and 13 objects in 2006 in B, V, R, and I wavebands with the SPOL Spectropolarimeter on Steward Observatory's 1.5 m Kuiper Telescope. In addition, we took photometric and polarimetric measurements in the R band on the AZT-8 70 cm telescope at the Crimean Astrophysical Observatory.

Infrared: Infrared H band observations of photometry and polarimetry were provided by the 1.8 m Perkins Telescope at Lowell Observatory, equipped with the Mimir instrument fabricated by D. Clemens et al. We monitored 8 blazars in 2005 and 3 in 2006.

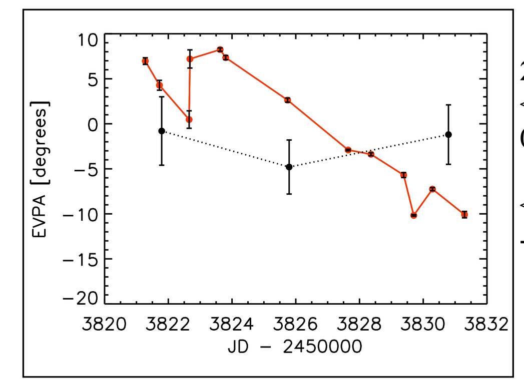
Radio: We imaged the blazars in total and polarized intensity at 43 GHz with the VLBA at 3 epochs for each campaign. Spacing of these epochs was determined so as to provide equal sampling through the 10-day campaigns. 15 blazars were imaged in 2005 and 13 in 2006.

OJ287

In the blazar OJ287, we observed the correlation of optical EVPA with 43 GHz core EVPA in both the 2005 and 2006 campaigns:



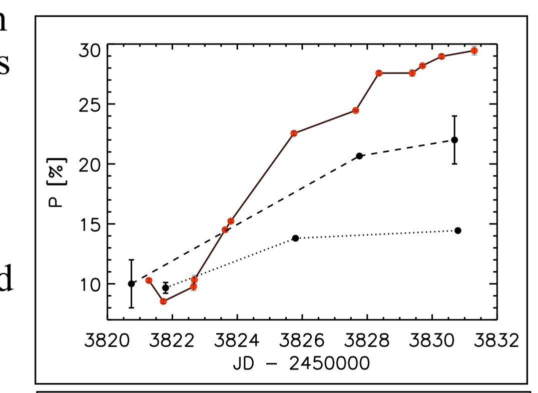
2005:
<R EVPA> : 12°±5°
<43 GHz EVPA>: 18°±4°



2006:
<R EVPA> : 0°±7°
<43 GHz EVPA>: -3°±3°

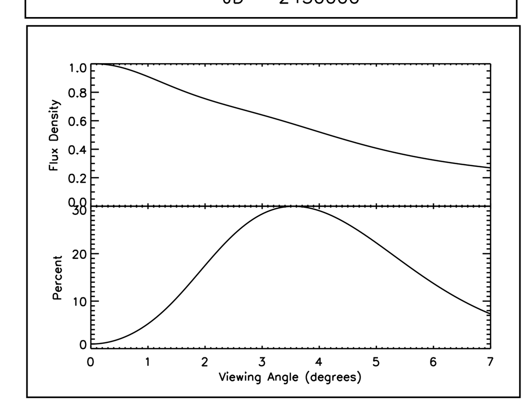
These EVPAs are consistently perpendicular to the flow of the jet, suggesting that the core of OJ287 has **a longitudinal magnetic field aligned by velocity shear in the jet**.

In addition, we find a correlated increase in percentage polarization during the 2006 campaign in optical, radio, and infrared wavebands (see *right*), further establishing that **the optical emission originates from the 43 GHz core**.



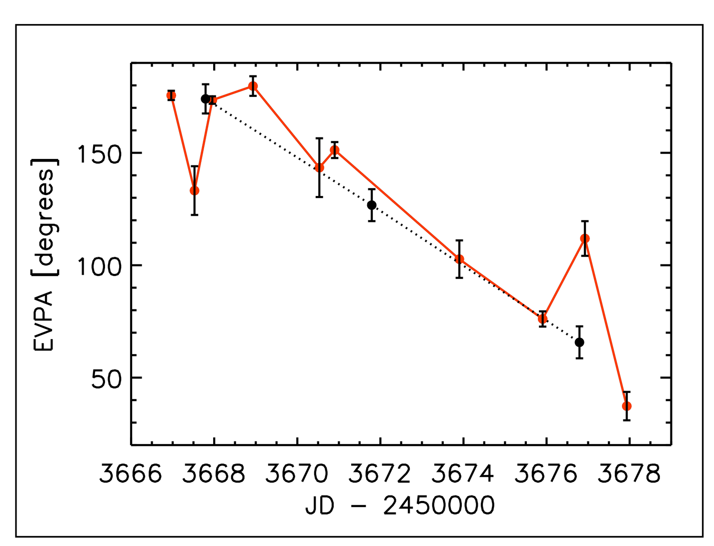
During this percentage increase, we also observe an increase, then decrease, in flux density across all wavelengths. To describe this behavior, we use a model in which shear between a slow sheath and fast spine create the observed alignment of magnetic field. We model the percentage polarization and flux density at optical wavelengths as a function of the viewing angle, the angle between the line of sight and the jet axis. We hypothesize that **slight changes in viewing angle due to instabilities in the jet can produce the behavior we observe**.

Shown at *right* is an example of our model, where the flux density is normalized to the peak. This model shows that the rise in percentage polarization and flux density which we observe can be the result of the angle at which the observer views the jet.



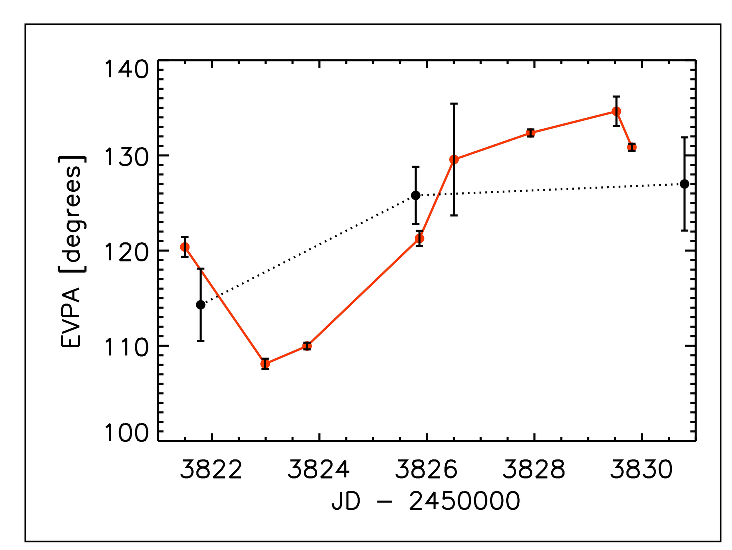
Other Examples

PKS 0420-014

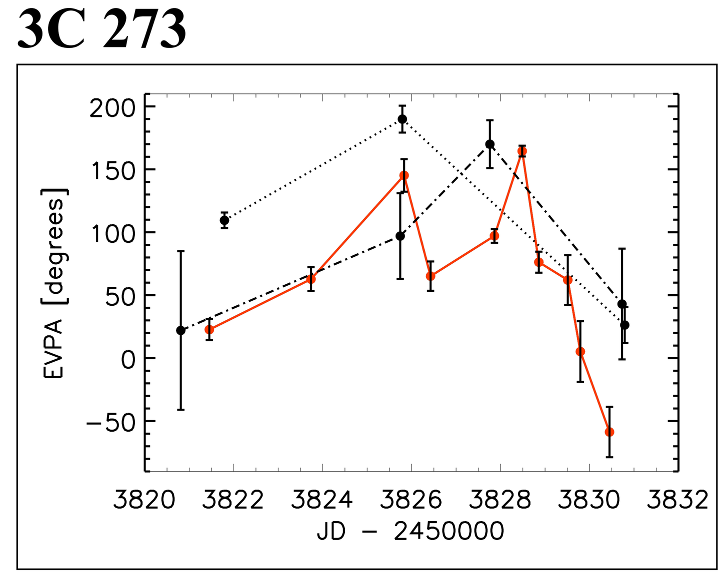


*corrected for Faraday rotation

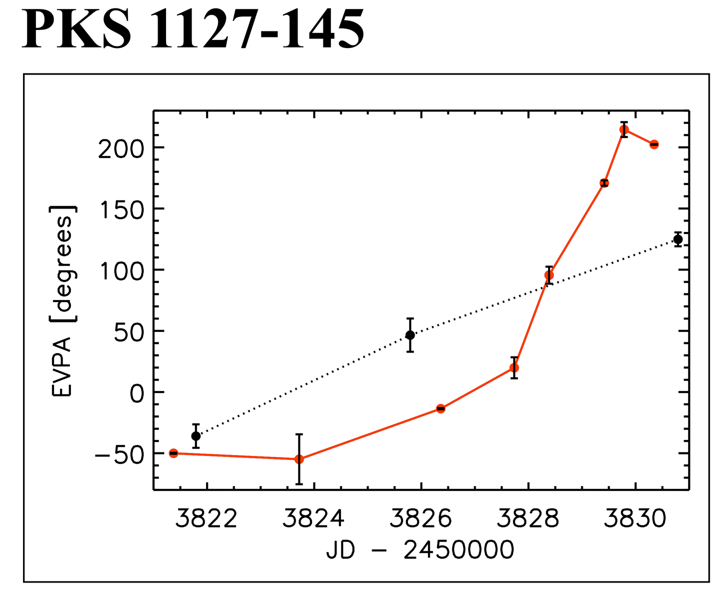
1418+546 (OQ 530)



3C 273



PKS 1127-145



Results and Interpretation

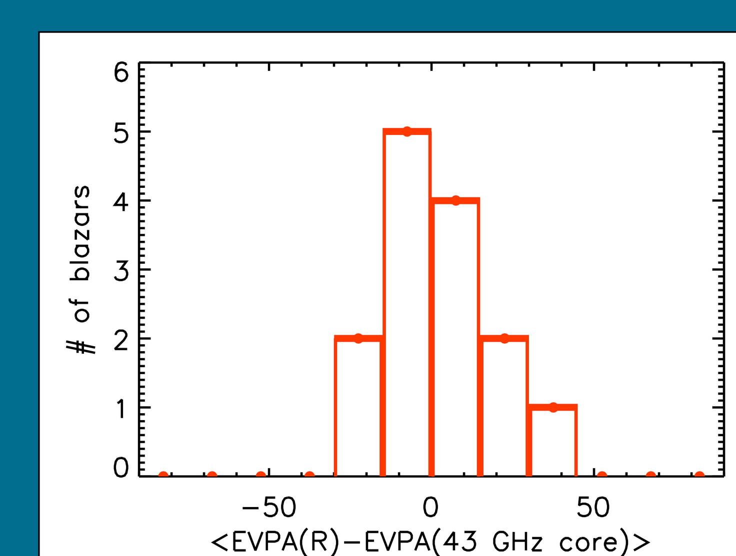
Of the 25 blazars we observed, 19 had sufficient multiwavelength data for correlation analysis, with 8 observed in October, 9 in March, and 2 at both epochs. In examining correlations, a focus was placed on similarity between EVPAs.

In the majority of the displayed blazars, a correlation is clear between the behavior of the optical EVPA and the EVPA of the 43 GHz core, with no evidence for time delay. We made a correction in a number of blazars for Faraday Rotation, a phenomenon in which polarized light is rotated when it passes through intervening magnetized plasma. Once corrected, there is agreement in value between the optical EVPA and that of the 43 GHz core. Furthermore, investigation of the complete sample of 19 shows that infrared polarization correlates well with optical polarization in 100% of cases.

In the majority of blazars with extended structure, we found that there was a dissimilarity between the optical EVPA and the EVPA of radio components separated from the core. The stability of the polarization characteristics of these components helps to support the claim of correlation, and thus spatial connection, between the variable optical emission and the VLBA core in these objects.

For a summation of the results, see the table below.

Blazar	Faraday Corr.	EVPA (R) ≈ EVPA (core)	Similar EVPA Behavior
3C66A	✔	✔	✔
PKS 0336-019 (CTA 26)			
PKS 0420-014	✔	✔	✔ (110° rotation)
PKS 0422+004		✔	✔
PKS 0735+178		✔	
OJ287	✔	✔	✔
PKS 1127-145		✔	✔ (160° rotation)
B2 1156+295 (4C 29.45)		✔	✔ (15° rotation)
3C273			✔ (complex rotation)
3C279			✔ (15° rotation)
1418+546 (OQ 530)		✔	✔ (10° rotation)
PKS 1424+240			
PKS 1510-089	✔		
3C345	✔	✔	
1652+398 (Mrk 501)		✔	✔ (55° rotation)
BLLac	✔	✔	✔
3C446		✔	✔
CTA102	✔		
3C454.3	✔	✔	✔ (60° rotation)



At left, a histogram of the average discrepancy in EVPA between the optical (R) and the 43 GHz core. This sample includes 14 of our 19 objects, excepting those with constant optical-43 GHz EVPA offsets but unknown Faraday rotation. Red boxes show the number of blazars with demonstrated discrepancies binned in segments of 15°. Nine of our objects, or 64%, have EVPAs that are consistent within ± 15°. A total of 93% of our objects are consistent within ± 30°.

Conclusions

We are able to conclude from our observations that **for the majority of blazars, the optical emission originates in the 43 GHz core**, with negligible time delay seen during large multiwavelength EVPA rotations.

Using this observed correlation, we are then able to utilize the direction and behavior of EVPA to determine the mechanisms behind the radio-to-optical emission. Mechanisms used in our study include standing and relativistic shocks, velocity shear, helical magnetic fields, and magnetic turbulence within the jet. From these models, we will determine whether a clear description can be made of the parsec-scale region in all blazars.

This work is supported by the NASA ADAP and the NSF under grant AST 04-06865.

For Further Information

Please contact fdarcang@bu.edu. See http://www.bu.edu/blazars for more information on this and related projects.