

## Observations of Oblique Polarization Structures in Active Extragalactic Radio Jets

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**Abstract.** Results are presented from our study of ten highly active variable extra-galactic sources observed at multiple frequencies and epochs with the VLBA with the goal of testing whether the observed linear polarization structures are consistent with oblique shock models. We compare the VLBA images of sample member BL Lacertae with the results of simple models which account for relativistic aberration effects, and also with approximately weekly observations obtained with the University of Michigan 26-meter paraboloid, and show that the observed behavior is consistent with the oblique shock hypothesis.

### 1. Introduction

Past work showed that transverse shock models were in quantitative agreement with observed variations in linear polarization and total flux density during bursts in BL Lac, 3C 279 and OT 081 (e.g. Hughes, Aller, & Aller 1989, 1991). However, later events in BL Lac itself, and in many other sources, could not be fit with these models, and many objects exhibit EVPAs perpendicular to the flow direction indicated by VLBA structure, suggesting that the magnetic fields are aligned along the flow rather than transverse to it. Both shear and oblique shocks have been proposed to account for the range in magnetic field orientation.

### 2. Results

To test whether shocks alone (no shear) at oblique angles can, in fact, account for the observed structures during outbursts, ten variable sources were selected from the UMRAO variability program with the expectation that they would exhibit significant variability (outbursts) during the study period. These sources (DA 55\*, 0607-157\*, OJ 287\*, 1055+018, 3C 279\*, 1510-089, OT 081\*, 1928+738, BL Lac, and 3C 446) were observed with VLBA at nine epochs at 15 and 43 GHz; the five sources marked with an asterisk were also observed at 8 and 22

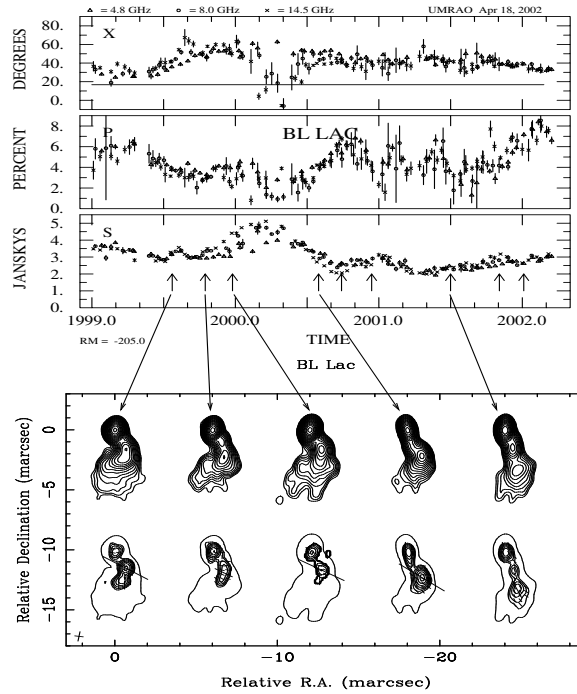


Figure 1. UMR AO total flux density and linear polarization for BL Lac and VLBA maps at 15.4 GHz. The image contours are total intensity (top) and polarized flux (bottom) with heavy lines showing the position angle and the peak polarized flux (1 mas = 10mJy/beam).

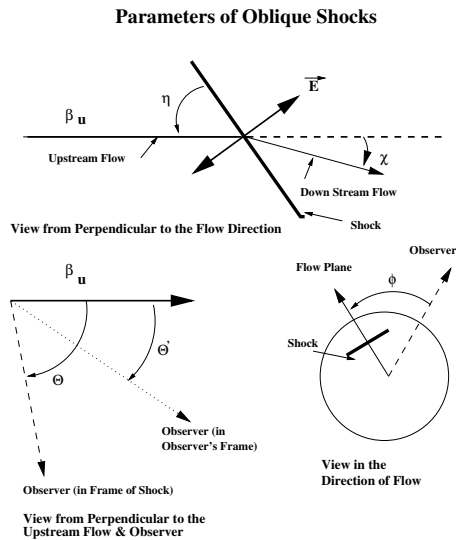


Figure 2. Oblique shock parameters: The strength of the shock is set by  $\beta_u$  and  $\eta$ . The observed polarization depends on shock velocity, the angle to the observer,  $\theta'$ , and the angle of the flow plane to the observer,  $\phi$ .

GHz. The VLBA observations were obtained over a 30 month period (3 epochs in the second halves of 1999, 2000, and 2001 each, separated by approximately 2 months). This spacing allowed us to follow the evolution throughout outbursts which can last for one to a few years. The instrumental polarization of the VLBA was calibrated at each epoch using OT 081 over a wide range of hour angles. This source was highly polarized at most epochs, so the absolute position angle reference could be determined by comparison with the integrated measurements made at the UMRAO. Weekly (single antenna) flux and linear polarization measurements were obtained at the UMRAO at 4.8, 8.0 and 14.5 GHz to follow the temporal evolution of the outbursts. Significant variability was detected in all program objects during this time period.

As an example, the VLBA maps and single dish monitoring are shown in Figure 1 for BL Lac. Note that the apparent motion of the shock front indicated by the motion of the most intense total flux and polarized flux knot is not in the same direction as the apparent deflection of the jet flow at the shock front: the apparent orientation of the shock front is perpendicular to the electric vector of the polarized emission. The deflected flow out of the shock plane is consistent in both direction and magnitude with the expected flow deflection at an oblique shock front.

The description of an oblique shock is more complex than for the case of a transverse shock. Following the notation of Cawthorne and Cobb (1990), we add to their four parameters which set the the shock strength and emitted polarization (see Figure 2), a fifth parameter  $\chi$ , the flow deflection angle that can be more directly compared to observations. Unfortunately, there are many possible combinations of shock obliquity and viewing angle that can produce the same apparent polarization structure. However, while we do not find a unique solution, our study identifies a plausible region of parameter space which could give rise to the range of observed fractional polarizations and EVPAs when the effects of relativistic aberration are taken into account, indicating that oblique shocks alone could produce the observed structure.

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