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Frequency Dependence of the Parsec-scale Polarization Structures of BL Lac Objects

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1. Introduction

BL Lacertae objects are active galactic nuclei with weak or undetectable line emission and strong variability in total intensity and linear polarization over a wide wavelength range from optical to radio. The radio emission and much of the optical emission is believed to be synchrotron radiation. Sources in the complete sample of BL Lac objects defined by Kühr and Schmidt (1990) have: 5 GHz fluxes of at least 1 Jy, radio spectral index $\alpha \geq -0.5$ ($S_\nu \sim \nu^{+\alpha}$), rest frame equivalent width of the strongest emission lines less than 5 Å, and optical counterparts on the Sky Survey plates with brightness greater than 20^m.

Previous VLBI polarization observations of radio-bright BL Lac objects have showed certain characteristic properties on parsec scales: one-sided core-jet structure with jet electric vector χ parallel to the local jet axis, and a tendency for the core χ's to lie either parallel or perpendicular to the jet axis (Gabuzda et al. 2000 and refs therein). Jet components are typically optically thin (as indicated by both their spectral indices and degree of polarization). Therefore, the jet magnetic fields are transverse, possibly indicating the presence of relativistic shocks (Hughes et al. 1989; Laing 1980), which we observe as distinct jet knots. Alternatively, the observed transverse fields may reflect the presence of helical magnetic fields associated with the jets (Gabuzda & Pushkarev 2001).

2. Brief Summary of Results to Date

Using our multi-frequency VLBA data, we have constructed the 5–8 and 8–15 GHz spectral index distributions for the core components for the 34 sources from the Kühr & Schmidt sample (Fig.1). Both distributions show that most of the cores have an appreciable contribution from optically thin components in the innermost jet, which make the "integrated" VLBI core spectra tend to be slightly negative ($S_\nu \sim \nu^{+\alpha}$). The $\alpha_{8-15\mathrm{GHz}}$ distribution (right) is slightly shifted toward more positive α compared to the $\alpha_{5-8\mathrm{GHz}}$ distribution (left): as we move toward higher frequencies, the optically thin contribution to the total

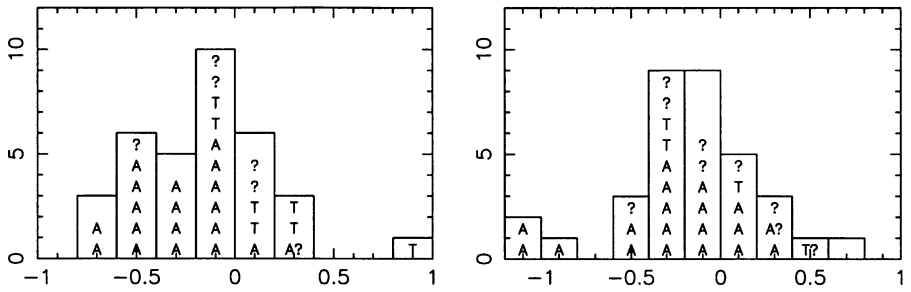

Figure 1. Distribution of core spectral indices $\alpha_{5-8\mathrm{GHz}}$ (left) and $\alpha_{8-15\mathrm{GHz}}$ (right) for all 34 sources in the complete sample of BL Lacs. "A" and "T" denote cores with χ aligned with and transverse to the inner jet direction θ, and "?" cores in which χ bears no obvious relation to θ, based on the core polarizations at 5 GHz (left) and 15 GHz (right).

observed core emission decreases. Most of the cores ($\simeq$ 65%) with detected polarization have χ aligned with the jet (**B** $\perp$ jet, if the polarized regoins are predominantly optically thin). We can see in Fig.1 (left) that all the 5 GHz cores that have χ transverse to the inner jet are relatively optically thick, so that plausibly **B** $\parallel \chi$ (i.e. **B** $\perp$ jet). This suggests that the intrinsic core fields may essentially always be transverse to the jet. In about 20% of cases, the core χ has no obvious relation to the jet direction, for reasons that are not yet clear.

The strong tendency for the jet magnetic fields to be transverse has been confirmed by our multi-frequency observations, and there is increasing evidence that we are detecting toroidal (helical?) fields associated with the VLBI jets (Pushkarev & Gabuzda 2000; Gabuzda & Pushkarev 2001). In most of the sample sources, the measured milliarcsecond-scale rotation measures are consistent with integrated values, but in a number, there is clear evidence for non-uniformity in the distribution of thermal plasma on parsec scales (Pushkarev & Gabuzda 2001). It is fairly common for sheaths of longitudinal field to form at some distance from the core, providing evidence for interaction between the jet and surrounding medium (Pushkarev & Gabuzda 2001).

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