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Opening angles of parsec-scale AGN jets

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Abstract. We have investigated the difference between distributions of intrinsic opening angle for the parsec-scale jets of 44 quasars and those of 12 BL Lacs. We used 15.4 GHz VLBA observations of the 56 sources from the 2 cm VLBA MOJAVE program to determine their apparent jet opening angles by analyzing transverse jet profiles from the data in the image plane. We have found that BL Lacs have on-average wider intrinsic opening angles than those in quasars, while the corresponding distributions of the apparent opening angle are found to be similar.

Key words. galaxies: active – galaxies: jets – quasars: general – radio continuum: galaxies

1. Introduction

Using 15 GHz naturally-weighted VLBA images, we have investigated possible differences in the opening angles of quasars versus weak-lined BL Lac objects in the radio selected MOJAVE sample of Lister et al. (2009a). We also used jet speeds (Lister et al. 2009) and variability Doppler factors from the Metsähovi AGN monitoring program (Hovatta et al. 2009) to derive the viewing angles and, finally, the intrinsic opening angles. The overlap of the MOJAVE and Metsähovi programs forms a representative sample of 56 blazars.

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2. Results

The apparent opening angle of a jet was calculated as the median value of $\alpha = 2\arctan\left[0.5(d^2 - b_\varphi^2)^{1/2}/r\right]$, where d is the full width at half maximum (FWHM) of a Gaussian fitted to the transverse jet brightness profile, r is the distance to the core along the jet axis, b_φ is the beam size along the position angle φ of the jet-cut, and the quantity $(d^2 - b_\varphi^2)^{1/2}$ is the deconvolved FWHM transverse size of the jet. The direction of the jet axis was determined using the median position angles of all jet components over all the epochs from model fitting (see next section). The slices were taken at 0.1 mas intervals starting from the position of the VLBI core and continuing up to the region in which the jet either substantially curved

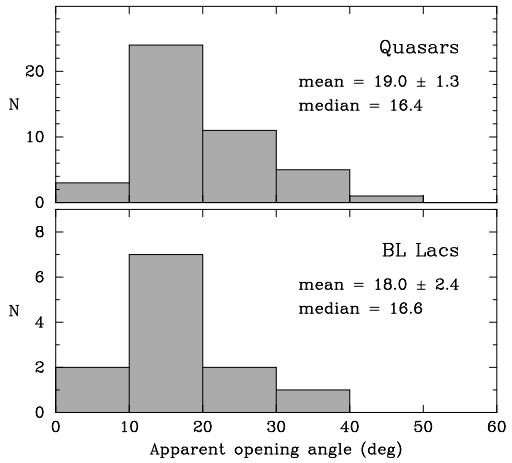

Fig. 1. Histograms of the apparent opening angle for 44 quasars (*top*) and 12 BL Lacs (*bottom*).

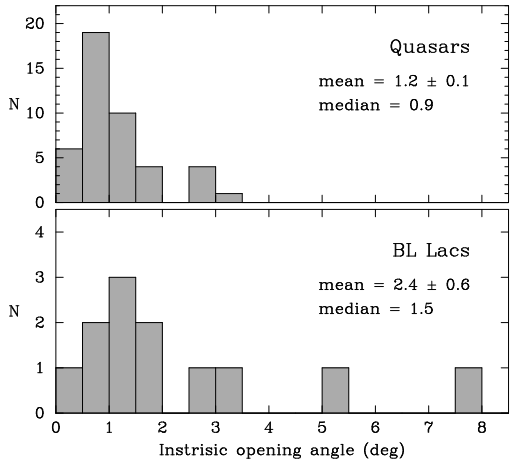

Fig. 2. Histograms of the intrinsic opening angle for 44 quasars (*top*) and 12 BL Lacs (*bottom*).

or became undetectable. Opening angle values were calculated using only those slices that had a peak of the fitted Gaussian larger than four times the rms noise level of the image.

The histograms of the apparent opening angle for 44 quasars and 12 BL Lacs are shown in Fig. 1. A K-S test indicated that the distributions are not significantly different.

The intrinsic opening angles were calculated as $\alpha_{\rm int} = \alpha_{\rm app} \sin\theta$, where θ is the viewing angle derived using the following relation:

$$\theta = \arctan \frac{2\beta_{\rm app}}{\beta_{\rm app}^2 + \delta_{\rm var}^2 - 1},$$

where $\beta_{\rm app}$ is the fastest measured radial, non-accelerating apparent jet speed from the MOJAVE kinematic analysis (Lister et al. 2009) and $\delta_{\rm var}$ is the variability Doppler factor from the Metsähovi AGN monitoring program (Hovatta et al. 2009). The apparent speed distributions of the BL Lacs (median of $6.1c$) and quasars (median of $13.9c$) differ at confidence level of 99.7% according to the K-S test. The values of $\alpha_{\rm app}$, θ, and $\alpha_{\rm int}$ are listed in Pushkarev et al. (2009).

BL Lacs showed on-average wider intrinsic opening angles ($2\overset{\circ}{.}4 \pm 0\overset{\circ}{.}6$) of their parsec-scale outflows than those of quasars ($1\overset{\circ}{.}2 \pm 0\overset{\circ}{.}1$). The corresponding distributions (Fig. 2) are different at confidence level of 94.6% according to the K-S test, the average values differ with a 96.1% confidence according to the Student's T-test. It is worth noting that the found difference is not a result of systematically lower redshifts for BL Lacs than those for quasars. According to the Kendall's τ test, there is no correlation ($\tau = 0.05$, $p = 0.58$) between the intrinsic opening angle and redshift. Thus, the difference in the opening angles, that should be tested on a larger sample in future, might be an another property that divides BL Lacs and quasars reflecting the difference in physical conditions in the parsec-scale jets of these two optical classes of active galactic nuclei.

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