Bias of core shift effect measurement in the blazars jets

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The effect

The observed VLBI core in quasars is \( r_{\text{e,32}} \approx 1 \) surface and its position changes with frequency \( n[1] \). The value of the shift allows to estimate the magnetic field at 1 pc: \( B_r \sim (\Delta r_{\text{e,32}})^{-\frac{3}{2}} \) assuming equipartition [2] and \( B_r \sim (\Delta r_{\text{e,32}})^{-1} \) without [3]. It also can be used to constrain the flow speed in core region [4, 5] that occurred to be higher than estimated using kinematics of the jet components.

The problem is that...

...to measure the core shift one needs to know core position at different frequencies. Core is fitted with a Gaussian, but jet model [1] has more complex shape. Oversimplification brings biased estimates. Is that bias significant?

Method

To assess the bias one needs to know the true model. We created artificial sample of \(~1.5k\) sources using BK model [1] on a grid of the parameters conditioned on the observed MOJAVE sample (Luminosity Function [6], apparent opening angles [7] and speeds [8]). Using noise and \( \sigma \)-coverage of the real data we compared true values of the core shift \( \Delta r \) with those one would estimate by \text{difmap} modelfitting with circular and elliptic core model.

Results

Core shift estimates are biased by a typical factor \( \approx 2 \), but it depends on the observed core parameters in a highly non-linear way. Bias can be corrected using the flexible model trained on the results of simulations. Estimates of \( k \) from core shift frequency dependence (\( \Delta r \sim \Delta f^{-\alpha} \)) are unbiased if core is represented with equal number of components at each band.

Implications

- \( B_r \) estimated assuming equipartition [2] are \(~2\) biased upward.
- Reconciles \( B \) estimates from SED modelling and core shifts [9].
- Problem for MAD scenario [10].
- [3] found \( \Delta B \approx 0.033 \) after correcting for bias and \( \approx 0.005 \) for radiogalaxies (we found them to have practically unbiased core shift estimates).
- Bruning flow speed estimates [4, 5] closer to the kinematics ones.

By the way...

Using artificial sample we show that jet model [1] allows to estimate the (unbiased) core shift using VLBI-observables only at a single frequency.

Conclusions

Core shifts in blazars are typically overestimated. Therefore, magnetic fields deduced from the core shifts are also overestimated by a factor of \( \sim 2 \) (with) or \~10-100 \( (w/o \) equipartition assumption). Frequency dependence of the core shift is not biased if the core is modelled with the same number of components at each frequency.

References


Data used: This research used the data of the MOJAVE project (Frail et al., 2013).

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