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EVN and MERLIN observations of nearby BL Lac objects and multiwavelength analysis

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We present new observations of BL Lacertae objects with the EVN and/or MERLIN, thus exploring their radio morphologies from sub-parsec to kiloparsec scales. We further consider broadband data from the Hubble Space Telescope and X-ray satellites, discussing the radiation mechanisms, the black hole mass, and the fundamental plane of the BH.

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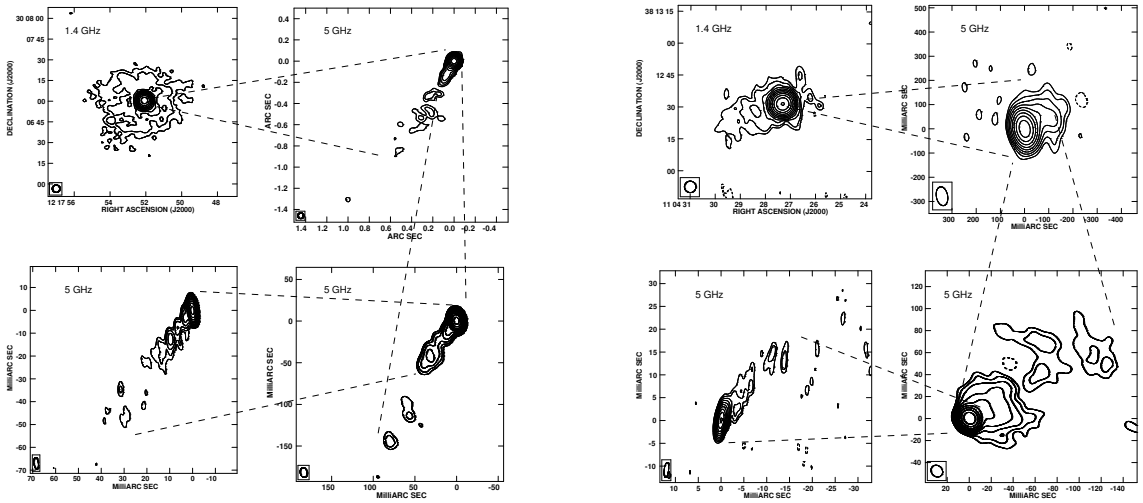

Figure 1: Clockwise from top left: VLA, MERLIN, EVN+MERLIN and EVN only images for 1215+303 (left) and Mrk 421 (right)

BL Lac objects are Active Galactic Nuclei whose basic radio properties are as follows: flat spectrum, compactness, variability, core dominance, and strong polarization. According to unified schemes, they are expected to be the beamed counterparts of FR I radio galaxies. Because of relativisting boosting, the parsec-scale properties of BL Lacs and FR Is are apparently different. In order to derive Doppler factors for BL Lacs and to provide support for unified schemes, we selected a sample of 29 nearby ($z < 0.2$) objects with HST images and we observed it with radio interferometers at arcsecond and milliarcsecond resolution [1, 2].

1. Radio observations

Nine BL Lac objects were observed at high resolution with the EVN. Their parsec-scale images reveal an almost ubiquitous presence of one-sided jets. Under the assumption of intrinsically symmetric jets, this provides evidence for relativistic velocities in the parsec-scale region of jets. This result supports the previous findings for the same sample [1], and we derive Lorentz factors in the sample clustered around $\Gamma = 4$. In the three sources observed also with MERLIN, i.e. with additional short baselines, we trace the jet out to several hundred parsecs, and still find no hint of counter-jets. On kiloparsec scales, the structure of 1728+502 remains aligned with the inner region direction, while 1215+303 and Mrk 421 reveal a symmetric structure without a clear connection to the parsec-scale jet (see Fig. 1).

In Mrk 421, we have also evidence of limb brightening of the jet, from the very inner regions out to ~ 30 mas, similarly to the other TeV source in the sample (i.e. Mrk 501 [3]). This result is of great importance for the development of jet launch models and the study of the jet–environment interaction.

2. Multiwavelength analysis

Thanks to the availability of X-ray fluxes and high resolution optical (HST) data for the whole

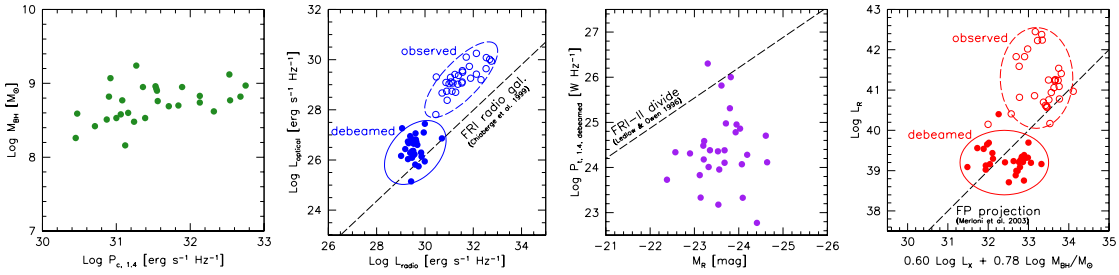

Figure 2: Multiwavelength data plots. See text for discussion.

sample, we carried out a multiwavelength analysis. In particular, by resolving the host galaxy and separating the non-thermal core, we can understand some physical properties of the BL Lac phenomenon. Given the distance-limited nature of the present sample, we are confident of the robustness of our results, which we illustrate in Fig. 2 and summarize as follows:

1. There is a significant correlation between the mass of the central SMBH and the radio luminosity, both nuclear and extended, regardless of any common distance dependence. However, there is a large scatter in the correlation, so that radio luminosity alone can not be used as a measure of the BH mass.

2. Radio and optical nuclear luminosities (and fluxes) show a strong correlation, indicating a common origin for the emission at both wavelengths, i.e. non-thermal synchrotron radiation. Moreover, if we de-beam the observed luminosities, the luminosities of the cores are ruled by the same correlation as that found for low power radio galaxies [4], in strong support of the unification of BL Lacs and FR Is based on the orientation.

3. Still in support of the BL Lac/FR I unification, our sources lie below the dividing line in the Ledlow & Owen diagram [5]; for any given $M_{\rm BH}$ (estimated from the host galaxy magnitude), low redshift BL Lacs have lower radio power than FR II radio galaxies with similar $M_{\rm BH}$.

4. The radio and X-ray luminosities do not follow the fundamental plane of BH activity found for other super-massive and galactic BH [6], clearly because of the relevant Doppler boosting of the jet. However, when we consider de-beamed quantities, the FP relation becomes quite well-reproduced, although some overall scatter and the LBL-HBL offset appear.

References

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