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Relativistic beaming and central components of radio galaxies

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Abstract. We present results of our study of the parsec-scale components of radio galaxies as observed at radio and optical wavelengths, in the framework of the Unified Scheme.

Key words : galaxies: active – BL Lacertae objects: general – galaxies: nuclei – quasars: general

1. Introduction

Radio Galaxies are radio-loud ($S(\nu)_{5GHz}/S(\nu)_B$ > 10) Active Galactic Nuclei (AGN) found in hosts that are elliptical galaxies. Their radio structure is made up of two lobes of radio-emitting plasma situated on either side of an unresolved radio core and connected to the core by plasma jets. The radio structures fall in two distinct sub-classes: the Fanaroff-Riley type I (FR I) with extended plumes and tails having $L_{178} < 2 \times 10^{26}$ WHz^{-1} and the Fanaroff-Riley type II (FR II) with narrow jets and hotspots having $L_{178} > 2 \times 10^{26}$ WHz^{-1} at 178 MHz. Within the *unification scheme* for radio-loud AGN, FR I and FR II radio galaxies are thought to represent the parent populations of BL Lac objects and radio-loud quasars, respectively. BL Lacs and quasars show clear evidence for relativistic beaming resulting from the bulk relativistic motion of the plasma moving close to the line of sight. If FR I and FR II radio galaxies are the plane-of-sky counterparts of BL Lacs and radio-loud quasars respectively, FR I and FR II jets should also have bulk relativistic motion. The *radio core prominence parameter* R_c, which is the ratio between core and extended radio flux density, is a beaming indicator. This is because if the core is the unresolved relativistically beamed jet and the lobes are unbeamed then R_c becomes a statistical measure of orientation.

The *primary motivation* for our work comes from the discovery of unresolved optical nuclear components in radio galaxies of both FR types, by the Hubble Space Telescope (Chiaberge et al. 1999). The optical flux density of these Central Compact Cores (CCC), show a striking linear correlation with the radio core flux density. On the basis of the correlation between CCC luminosity and radio core luminosity, and also of the fact that the optical spectral index is ~ 0.7, Chiaberge et al. suggest that the CCCs are the optical counterparts of the relativistic radio jet. We study the relationship between the CCC luminosities of FR Is and FR IIs and the radio core prominence parameter, R_c (calculated using the total and core radio flux densities at 5 GHz). We further consider, for comparison, a set of BL Lacs and radio-loud quasars along with the radio galaxies.

2. The sample and the data

The sample of 27 3CR FR Is with their CCC flux density data comes from Chiaberge et al. (1999); the CCC flux densities for the FR Is NGC 7052 and NGC 6251 are from Capetti & Celotti (1999) and Hardcastle & Worral (2000) respectively. The sample and the data of 26 3CR FR II radio galaxies comes from Chiaberge et al. (2000). The set of BL Lacs and their optical core flux densities are from Perlman & Stocke (1993) and Padovani & Giommi (1995), while the data for the radio-loud quasars comes from Vermeulen & Cohen (1994).

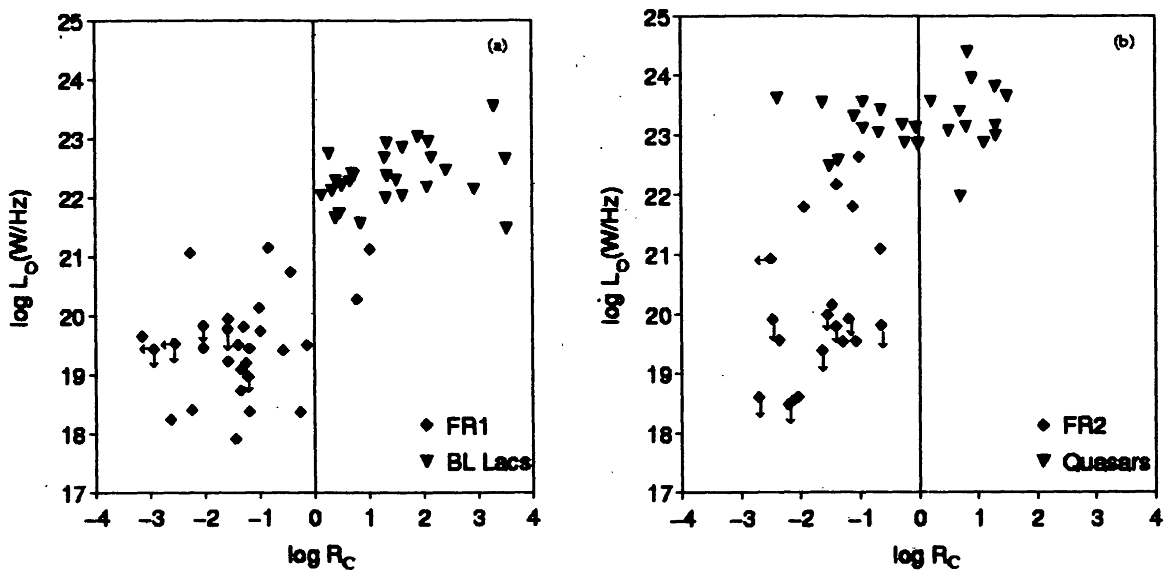

Figure 1. Optical core luminosity L_o (WHz^{-1}), versus radio core prominence parameter R_c, for (a) FR I radio galaxies and BL Lac objects and (b) Fr II radio galaxies and radio-loud quasars (arrows indicate upper limits).

3. Results

For FR I radio galaxies, the CCC optical luminosities are correlated with R_c at the 0.10 significance level (excluding 3C 386 which has a broad Hα line, atypical of FR I radio galaxies). See Figure 1a. The correlation supports the suggestion that the CCC optical flux density is orientation-dependent in the same way as the core radio emission and it may thus constitute the optical counterpart of the radio synchrotron jet. In Figure 1a, we have included for comparison, a set of BL Lacs. The BL Lacs extend the correlation to higher R_c (the formal statistical significance level > 0.0005, Spearman rank correlation test). The slopes of the regression are similar for FR Is and BL Lacs (FR Is: slope ≈ 0.3; BL Lacs: slope ≈ 0.14). This is as would be expected if FR Is are the parent population of BL Lacs.

The optical core luminosity for the sample of FR II radio galaxies also shows a correlation with radio core prominence (significance level > 0.10; Spearman rank correlation test; Figure 1b). The slope of the correlation is steeper w.r.t. the optical core luminosity, as compared to FR Is and also the BL Lacs (FR IIs: regression slope ≈ 0.8). This could be an indication of obscuration in the central regions of FR IIs as compared to FR Is. Furthermore, the plot (Figure 1b) suggests that the radio-loud quasars seem to extend the FR II correlation to higher R_c (significance level > 0.0005); which is as would be predicted by the radio-loud Unification Scheme.

The regressions of FR Is, BL Lacs and FR IIs separately, and the plots when extended to higher values of R_c by including BL Lacs and quasars, is consistent with the idea that FR Is and BL Lacs on the one hand and FR IIs and quasars on the other, form distinct populations. It must be noted that the number of FR II radio galaxies is small. Also, if all the upper limits indeed result in lower values of optical core luminosities for FR Is and FR IIs, the correlation with BL Lacs and radio-loud quasars respectively, will get better.

References

Capetti A., Celotti A., 1999, MNRAS, 304, 434
Chiaberge M., Capetti A., Celotti A., 1999, A & A, 349, 77
Chiaberge M., Capetti A., Celotti A., 2000, A & A, 355, 873
Hardcastle M.J., Worrall D.M., 2000, MNRAS, 314, 359
Padovani P., Giommi P., 1995, MNRAS, 277, 1477
Perlman E.S., Stocke J.T., 1993, ApJ, 406, 430
Vermeulen R.C., Cohen M.H., 1994, ApJ, 430, 467