CORRELATIONS BETWEEN RADIO EMISSION OF THE PARSEC-SCALE JET AND OPTICAL NUCLEAR EMISSION OF HOST AGN

J. Torrealba, T. G. Arshakian, V. Chavushyan, and I. Cruz-González

1. INTRODUCTION

One approach to investigate the physical processes in active galactic nuclei (AGN) at scales not reachable by present-day telescopes is to study the correlation between radiative energy in different frequencies. Arshakian et al. (2010) (hereafter A10) investigated the radio-optical correlation between the VLBA core emission at 15 GHz and the optical nuclear emission at 5100 Å for a statistically complete sample of 135 compact jets to test a single production mechanism for radio and optical continuum emission on scales of submilliarcseconds. The present study is an extension of that research with a sample of 250 compact extragalactic radio sources at 15 GHz compiled by Kovalev et al. (2005), which includes 135 compact AGN from the flux-density limited MOJAVE-1 sample (Lister et al. 2009). The sample comprises 188 quasars, 36 BL Lacs, 20 radio galaxies, and 6 sources with no optical identification. The majority of AGN in the sample have relativistic jets oriented to the line of sight and have an unprecedented resolution of 0.5 milliarcseconds at 15 GHz. Note that this sample is not complete by the limiting radio flux.

2. RADIO-OPTICAL CORRELATIONS: ANALYSIS AND SUMMARY

The total luminosity of the VLBA component ($L_{\text{VLBA}}$), the unresolved core ($L_{\text{un}}$) and the jet luminosity ($L_{\text{jet}}$) at 15 GHz were estimated as described in A10 § 3. Optical nuclear luminosities at 5100 Å ($L_{5100}$) corrected for stellar contribution (Equation (10) in A10) were estimated for 233 AGN of our sample from an homogeneous calibration using the B-band in the standard Johnson’s photometric system.

The partial Kendall’s $\tau$ test (Akritas & Siebert 1996) is used to check the correlation between the

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TABLE 1
KENDALL’S $\tau$ CORRELATION ANALYSIS BETWEEN RADIO AND OPTICAL LUMINOSITIES $^a$

|       | All          | Quasars      | BL Lac       |
|-------|--------------|--------------|--------------|
|       | $A1$         | $A2$         | $A3$         | $\tau$ $P$    | $\tau$ $P$    | $\tau$ $P$    |
| $L_{5100}$ | $L_{VLBA}$ $z$ | 0.259        | 3.95E-14     | 0.237        | 7.67E-10      | 0.140        | 0.173        |
| $L_{5100}$ | $L_{un}$ $z$  | 0.242        | 6.14E-12     | 0.198        | 9.02E-07      | 0.150        | 0.149        |
| $L_{5100}$ | $L_{jet}$ $z$ | 0.246        | 2.07E-12     | 0.218        | 6.53E-08      | 0.389        | 9E-04        |

$^a$The columns are arranged as follows: $A1$ and $A2$ are the independent variables for which the Kendall’s $\tau$ correlation analysis is performed, and $A3$ is the dependent variable, in this case the redshift, “All” refers to the 233 sources in the sample, also were analyzed separately 181 quasars and 31 BL Lacs, $\tau$ is the correlation coefficient, and $P$ is the probability of a chance correlation. The correlations considered to be significant are marked in bold face.

Fig. 1. The total radio luminosity of the VLBA jet at 15 GHz against optical continuum luminosity at 5100 Å (left panel), and radio luminosity of the jet (unresolved core subtracted) against optical continuum luminosity at 5100 Å (right panel) for quasars, BL Lacs and radio galaxies.

radio luminosities of the unresolved core and the jet and the optical nuclear luminosity. We consider the correlations to be significant for the samples of all 233 AGN and 181 quasars if the chance probability of the correlation $P < 0.02$ (or confidence level > 98%), and $P < 0.05$ (or confidence level > 95%) for the sample of 31 BL Lacs. The outcome of the statistical analysis is summarized in Table 1 and they are in agreement with the results reported in A10. There is a significant positive correlation for 233 AGN between optical nuclear emission and radio emission originated in the jet at milliarcsecond scales (Figure 1; Table 1). For quasars, correlations hold also between optical nuclear luminosity and radio luminosities of the unresolved core (at sub-milliarcseconds scales) and the whole jet. For BL Lacs, the optical luminosity correlates positively only with the jet luminosity at the high confidence level of $\sim 99.9\%$ (Figure 1). The dispersion of the radio-optical correlation can be caused by non-simultaneous observations, distributions of intrinsic luminosities, and Doppler factors. The larger dispersion for BL Lacs could be a result of stronger variability in the radio and optical bands as well as a wider range of intrinsic luminosities, while for radio galaxies the deeming of optical continuum emission by an obscuring dusty torus can vary significantly.

Our results, together with the apparent speed – optical luminosity diagram and the aspect curves derived from the relativistic beaming theory (see Figure 9 of A10), support the idea that the optical emission is generated in the relativistic jet. In particular, the optical emission in quasars with superluminal jets originates in the innermost part of the jet at sub-parsec scales, while in the BL Lacs it is generated in the parsec-scale jet.

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