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A Statistical Study of XBLs, RBLs and FSRQs at 1.5 GHz *

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Abstract BL Lac objects are similar to the flat spectrum radio quasars in many aspects except regarding the emission lines. In order to study their relationship, we selected 56 BL Lacertae objects (33 X-ray-selected, 23 radio-selected) and 45 flat spectrum radio quasars, analyzed their radio luminosities and core-dominance parameters. We found that the radio luminosities of the radio selected BL Lac objects located in between the X-ray selected BL Lac objects and the flat spectrum radio quasars. However, this intermediate position does not hold for the core-dominance parameter: the RBLs have the largest core-dominance parameters. This suggests that the core-dominance parameter can not be taken as a sequencing criterion. We also investigated the correlation between the luminosity and the core-dominance parameter for the three subclasses. We concluded that, here, the sequence XBL–RBL—FSRQ still exists.

Key words: techniques: statistical studies — blazars: general — luminosity: radio

1 INTRODUCTION

Blazars consist of two subclasses, namely BL Lacertae objects and flat spectrum radio quasars (FSRQs). BL lacerate objects are highly variable, polarized active galactic nuclei (AGNs) with a non-thermal radio-X-ray continuum where only very weak emission lines or no any emission lines can be observed (Kollgaard 1994). BL Lac objects can be further classified, according to the surveys, into two subclasses: X-ray-selected BL Lac objects (XBLs) and radio-selected BL Lac objects (RBLs). Previous work showed that XBLs are different from RBLs in many aspects. For example, XBLs often have lower redshifts than RBLs (Laurent-Muehleisen et al. 1993). In the radio band, XBLs tend to have weaker cores and are less core-dominated than RBLs (Perlman & Stocke 1993), and in the optical band, XBLs are less variable and less polarized than RBLs (Jannuzi et al. 1994), XBLs show close mutual correlation while RBLs do not (Fan et al. 1993, 1994; Xie et al. 1991, 1993), but XBLs often show higher polarization than RBLs in the radio band (Fan et al. 2006). The peaks of the radio-X-ray SED of most XBLs are in the ultraviolet-X-ray band, while RBLs peaks are in the infrared-optical band (Kollgaard 1996). They occupy different regions in the effective spectrum index plot, which was explained by the beaming effect (Fan & Xie 1996). Up to now almost all the identified TeV emitters are XBLs rather than RBLs (Bottcher 2006) and the relationship between XBLs and RBLs is still not well examined.

FSRQs are similar to BL Lac objects in many aspects. FSRQs are quasars with spectral index $\alpha \leq 0.5$ ($F_\nu \propto \nu^{-\alpha}$) at frequencies of a few GHz and almost all FSRQs are core dominated. FSRQs and BL Lac objects are both highly polarized and rapidly variable (Fugmann 1988; Impey & Tapia 1990). There is a great difference in emission lines, however, FSRQs have strong emission lines while BL Lac objects seldom have emission lines. Vagnetti et al. (1991) put forward an evolutionary unified scheme, which regards FSRQs to evolve into BL Lacs and the optical continuum is dominated by a beamed component

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which swamps the emission lines. Another completely different explanation for the BL Lac phenomenon is proposed by Ostriker et al. (1985), in terms of gravitational microlensing. They argued that BL Lac objects can be gravitationally microlensed radio quasars with continuum emission greatly amplified by stars in a foreground galaxy. Padovani (1992) proposed that either microlensing or evolutionary model are not available to unit BL Lacs and FSRQs and he explained some observed differences between BL Lacs and FSRQs with the beaming model, which is also discussed by Xie et al. (2001, 2007), Cao (2002) and Ma et al. (2007). Recently, based on the superluminal sources we proposed that the difference in the ratio of the core luminosity to the extended luminosity in the co-moving frame can explain the different behaviors of the emission lines between BL Lacs and FSRQs (Fan et al. 2003).

Any model concerning the relation between BL and FSRQs should account for their similarities in the continuum emissions and their differences in the emission lines. Sambruan et al. (1996) found that there is a continuous distribution of bolometric luminosity from XBLs to FSRQs with RBLs in between. Thus, luminosity is an important parameter here. Also, the core-dominance parameter, $R = \frac{L_c}{L_e}$ (L_c, the emission from the core; L_e, that from the extended component) is perhaps an indicator of the orientation of the jet, and even the boosting effect, so it is also an important observational parameter. Therefore, we shall focus on these two parameters in our discussion.

In this paper, we study their relationship by analyzing the luminosity distribution and the relationship between the relevant parameters at 1.5 GHz. The data and results are given in Section 2, a discussion and the conclusions are given in Section 3.

Throughout this paper, we adopt $H_0 = 50\,\mathrm{km\ s^{-1}\ Mpc^{-1}}$, $q_0 = 0.5$ and the spectral index α is as defined in $F_\nu \propto \nu^{-\alpha}$.

2 DATA AND RESULTS

2.1 Data

We collected 33 XBLs, 23 RBLs, with values of both L_e and L_c both available from Kollgaard et al. (1996), and 45 FSRQs from Browne et al. (1987). The relevant data are listed in Tables 1 and 2 for the XBLs and RBLs, respectively. In the tables, column (1) gives the name of the source, column (2) the redshift, columns (3) and (4) the core and extend luminosity at 1.5 GHz in units of W Hz $^{-1}$, and column (5) the core-dominance parameter. The data for FSRQs are listed in Table 3, in which column (1) gives the name of the source, column (2), the redshift, columns (3) and (4) the core and extend luminosity at 5 GHz in units of W Hz^{-1}, and column (5) the core-dominance parameters converted to 1.5 GHz. All the data come from Browne et al. (1987) except for the core-dominated parameter R, which was calculated at 1.5 GHz from the translated luminosities.

In our following analysis, we have converted all the FSRQ data at 5 GHz into the data at 1.5 GHz band, adopting a core and an extended spectral index of 0 and 1.0 (Browne et al. 1987) since the data in Kollgaard et al. samples (1996) are given at 1.5 GHz. The K-correction was applied to all the data assuming a spectral index of 1 for the extended emission and 0 for the core emission of FSRQs (Browne et al. 1987), and 0.7 and 0 for the lobe and core emissions of the BL Lac objects, respectively (Kollgaard et al. 1996).

2.2 Results

2.2.1 Distribution of Luminosity

From the data listed in Tables 1, 2, and 3 for XBLs, RBLs and FSRQs, we obtain the average values for each subclass as follows:

$$\begin{aligned}
\langle \log L_\mathrm{c}(\mathrm{W\ Hz^{-1}}) \rangle &= 24.77 \pm 0.69, \\
\langle \log L_\mathrm{e}(\mathrm{W\ Hz^{-1}}) \rangle &= 24.40 \pm 0.83, \\
\langle \log L_\mathrm{t}(\mathrm{W\ Hz^{-1}}) \rangle &= 24.99 \pm 0.69, \\
\langle \log R \rangle &= 0.38 \pm 0.10, \quad \text{for the 33 XBLs;} \\
\langle \log L_\mathrm{c}(\mathrm{W\ Hz^{-1}}) \rangle &= 26.57 \pm 0.75, \\
\langle \log L_\mathrm{e}(\mathrm{W\ Hz^{-1}}) \rangle &= 25.26 \pm 0.96, \\
\langle \log L_\mathrm{t}(\mathrm{W\ Hz^{-1}}) \rangle &= 26.61 \pm 0.76,
\end{aligned}$$

Table 1 Data of XBLs from Kollgaard et al. (1996)

Source (1)	z (2)	log $L_{\rm c}$ (3)	log $L_{\rm e}$ (4)	R (5)	Source (1)	z (2)	log $L_{\rm c}$ (3)	log $L_{\rm e}$ (4)	R (5)
0158.5+0019	0.299	24.5	24.1	1.7	1221.8+2452	0.218	24.7	23.5	14.3
0219–164	0.698	26.7	26.1	3.0	1229.2+6430	0.164	24.7	23.6	9.6
0257.9+3429	0.245	24.5	23.1	20.2	1402.3+0416	0.200	24.5	24.3	1.6
0317.0+1834	0.190	24.2	23.4	5.2	1407.9+5954	0.465	25.1	25.2	0.5
0323+022	0.147	24.7	23.8	7.0	1443.5+6349	0.299	24.5	24.4	0.9
0414+009	0.287	25.3	25.1	1.3	1458.8+2249	0.235	24.8	23.8	8.3
0506–039	0.304	25.0	24.9	0.9	1534.2+0148	0.312	25.0	25.0	0.8
0521–365	0.055	25.7	26.2	0.3	1552.1+2020	0.222	24.8	24.5	1.8
0548–322	0.069	24.2	24.9	0.2	1652+398	0.034	24.8	23.6	18.0
0607.9+7108	0.267	24.6	24.6	0.8	1722+119	0.018	23.0	22.2	6.4
0706+592	0.124	24.6	24.8	0.6	1727+502	0.055	24.2	23.8	2.6
0737.9+7441	0.315	25.0	23.6	18.4	1807+698	0.0512	25.2	25.0	1.3
0829+046	0.180	25.9	24.9	8.3	2007+777	0.342	26.5	25.1	23.0
1011+496	0.200	25.8	24.8	7.9	2143.4+0704	0.237	25.0	24.8	1.3
1101+384	0.031	24.0	24.1	1.6	2155–304	0.117	25.1	25.1	1.1
1101–232	0.186	24.8	25.0	0.5	2356–309	0.165	24.7	24.1	3.5
1133+704	0.046	24.0	24.3	0.5					

Table 2 Data of RBLs from Kollgaard et al. (1996)

Source (1)	z (2)	log $L_{\rm c}$ (3)	log $L_{\rm e}$ (4)	R (5)	Source (1)	z (2)	log $L_{\rm c}$ (3)	log $L_{\rm e}$ (4)	R (5)
0118–272	0.559	26.9	25.6	14.7	1514–241	0.049	25.4	23.5	77.4
0235+164	0.940	27.7	25.7	61.4	1538+149	0.605	27.2	26.3	6.4
0426–380	1.030	27.3	26.1	8.6	1652+398	0.033	24.8	23.6	18.0
0537–441	0.894	28.0	26.0	63.2	1749+701	0.770	27.1	25.9	10.2
0735+178	0.424	27.1	25.1	72.6	1803+784	0.684	27.4	26.0	15.9
0814+425	0.258	26.6	25.2	20.4	1807+698	0.051	25.2	25.0	1.3
0820+225	0.951	27.6	27.2	1.7	1823+568	0.664	27.1	26.8	1.7
0823+033	0.506	27.1	24.6	242.6	2007+777	0.342	26.5	25.1	23.0
0851+202	0.306	26.8	24.8	83.9	2131–021	0.557	27.3	25.7	30.5
0954+658	0.367	26.8	25.0	52.0	2200+420	0.069	25.8	23.9	79.0
1308+326	0.996	27.2	26.2	18.4	2254+074	0.190	25.8	24.4	23.6
1418+546	0.152	26.0	24.2	48.9					

$$\langle \log R \rangle \ = \ 1.31 \pm 0.12, \quad \text{for the 23 RBLs;}$$

and

$$\begin{aligned} \langle \log L_{\rm c}({\rm W\ Hz^{-1}}) \rangle \ &= \ 27.68 \pm 0.54, \\ \langle \log L_{\rm e}({\rm W\ Hz^{-1}}) \rangle \ &= \ 26.98 \pm 0.82, \\ \langle \log L_{\rm t}({\rm W\ Hz^{-1}}) \rangle \ &= \ 27.79 \pm 0.57, \\ \langle \log R \rangle \ &= \ 0.70 \pm 0.07, \qquad \text{for the 45 FSRQs.} \end{aligned}$$

To compare these three subclasses, in Figure 1 we show their distributions of core luminosities (left panels) and the corresponding cumulative distribution functions for use in the K-S test (right panels); the same for the extended luminosities in Figure 2, for the total luminosities in Figure 3, and for the core dominance parameter in Figure 4. The K-S test consists in identifying the largest distance d between two given cumulative distributions, then reading out (from a known theoretical distribution bearing the name of Kolmogorov) the probability p that a value as large as d could have resulted by chance if the two given distributions come from the same parent distribution. A small p means that the two samples are significantly different, i.e., they are not likely to have come from the same parent.

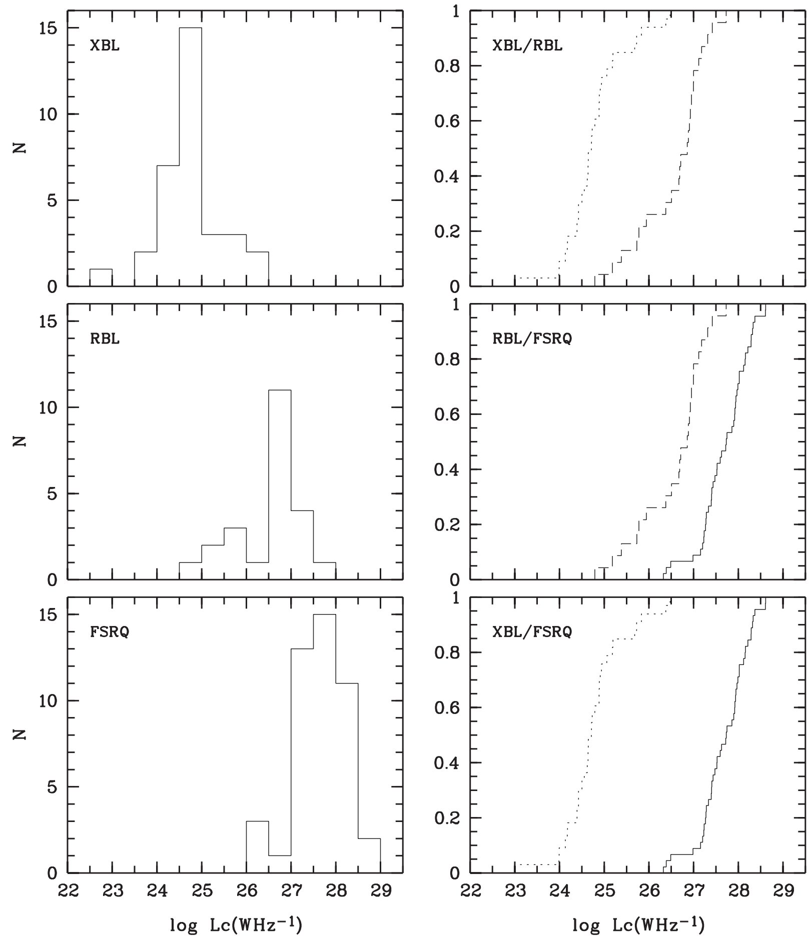

Fig. 1 Left: Core luminosity distributions of XBLs (top), RBLs (middle) and FSRQs (bottom). Right: Corresponding cumulative distributions in pairs for use in the K-S test, with dotted line for XBLs dashed line for RBLs and solid line for FSRQs.

For the core luminosity, the probability for the distribution of XBLs and RBLs to come from the same parent distribution is $p = 3.72 \times 10^{-8}$, while that for RBLs and FSRQs is $p = 1.28 \times 10^{-8}$, and that for XBLs and FSRQs is $p = 1.51 \times 10^{-16}$.

For the extended luminosity, we have $p = 3.02 \times 10^{-3}$ for XBLs and RBLs, $p = 4.17 \times 10^{-9}$ for RBLs and FSRQs, and $p = 1.44 \times 10^{-14}$ for XBLs and FSRQs.

For the total luminosity, $p = 1.72 \times 10^{-7}$ for XBLs and RBLs, $p = 4.17 \times 10^{-9}$ for RBLs and FSRQs, and $p = 1.51 \times 10^{-16}$ for XBLs and FSRQs.

For the core-dominance parameter, $p = 5.0 \times 10^{-5}$ for XBLs and RBLs, $p = 3.21 \times 10^{-4}$ for RBLs and FSRQs, and $p = 1.24 \times 10^{-2}$ for XBLs and FSRQs.

2.2.2 *Correlations*

We now investigate the correlation between, on one hand, the three varieties of radio luminosity ($L_{\rm e}$, $L_{\rm c}$, and $L_{\rm t}$ for the extended, core and total luminosities), and, on the other, the core-dominance parameter R, respectively for 33 XBLs, 23 RBLs and 45 FSRQs. The relevant linear regression analysis gives the results

Table 3 The FSRQ Data

Source (1)	z (2)	log L_c (3)	log L_e (4)	R (5)	Source (1)	z (2)	log L_c (3)	log L_e (4)	R (5)
0106+013	2.107	29.1	28.2	0.76	1127–145	1.187	28.5	26.8	6.87
0112–017	1.365	28.0	27.0	1.26	1226+023	0.158	27.5	26.7	1.63
0119+041	0.637	27.2	26.0	2.90	1237–101	0.753	27.4	26.2	2.71
0135–247	0.831	27.5	26.3	2.59	1252+119	0.871	27.5	26.0	5.07
0229+131	2.065	28.7	27.4	1.95	1522+155	0.628	26.7	25.8	1.46
0234+285	1.207	28.2	26.2	13.50	1611+343	1.401	28.4	27.0	3.13
0237+040	0.978	27.5	25.7	9.56	1633+382	1.814	28.6	26.7	8.46
0237–027	1.116	27.8	25.8	14.10	1641+399	0.594	28.1	26.6	5.95
0333+321	1.258	28.3	26.8	4.20	1725+044	0.293	26.5	24.4	29.20
0336–019	0.852	28.0	26.5	5.12	1730–130	0.908	28.3	26.5	9.92
0403–132	0.571	27.6	26.9	0.95	1739+522	1.375	27.9	26.2	6.33
0420–014	0.915	28.2	25.8	39.30	2037+511	1.686	28.8	27.4	2.80
0438–436	2.860	29.2	28.0	1.23	2121+053	1.878	28.4	26.0	26.18
0440–003	0.844	27.6	26.3	3.24	2131–021	0.560	27.6	25.6	19.23
0458–020	2.286	28.8	28.1	0.45	2201+171	1.067	27.6	26.6	1.45
0528–250	2.812	28.7	27.1	3.13	2216–038	0.901	27.8	26.7	1.98
0537–286	3.110	28.9	27.0	5.79	2223–052	1.404	28.7	27.2	3.94
0537–441	0.894	28.2	25.9	31.60	2230+114	1.037	28.3	26.9	3.69
0736+017	0.191	26.4	24.3	31.70	2234+282	0.795	28.0	25.6	41.98
0827+243	2.046	28.2	26.7	3.11	2251+158	0.859	28.6	27.4	2.55
0906+015	1.018	27.9	26.1	9.37	2344+092	0.677	27.5	25.5	17.88
0923+392	0.699	28.2	27.0	2.79	2345–167	0.600	27.6	26.2	4.70
0953+254	0.712	27.5	25.4	22.06					

as follows:

$$\left.\begin{array}{lll}\log L_{\rm e} &=& -(0.83\pm0.21)\log R+(24.73\pm0.15), \qquad r=-0.576\\ \log L_{\rm c} &=& (0.17\pm0.22)\log R+(24.79\pm0.15), \qquad r=0.14\\ \log L_{\rm t} &=& -(0.12\pm0.22)\log R+(25.10\pm0.15), \qquad r=-0.097\end{array}\right\}\text{for 33 XBLs,}$$

$$\left.\begin{array}{lll}\log L_{\rm e} &=& -(0.93\pm0.30)\log R+(26.60\pm0.43), \qquad r=-0.583\\ \log L_{\rm c} &=& (0.01\pm0.32)\log R+(26.73\pm0.46), \qquad r=0.007\\ \log L_{\rm t} &=& -(0.07\pm0.32)\log R+(26.88\pm0.46), \qquad r=-0.051\end{array}\right\}\text{for 23 RBLs,}$$

$$\left.\begin{array}{lll}\log L_{\rm e} &=& -(1.29\pm0.16)\log R+(27.89\pm0.13), \qquad r=-0.773\\ \log L_{\rm c} &=& -(0.29\pm0.16)\log R+(27.89\pm0.14), \qquad r=-0.264\\ \log L_{\rm t} &=& -(0.48\pm0.16)\log R+(28.13\pm0.13), \qquad r=-0.411\end{array}\right\}\text{for 45 FSRQs,}$$

where r is the linear regression correlation coefficient.

3 DISCUSSION AND CONCLUSIONS

Blazar is an extreme class of AGNs. Its further subdivision into XBLs, RBLs and FSRQs is important for understanding the nature of AGNs, results of their research could shed light on the emission mechanism of blazars and even on the evolutionary process of AGNs. Understanding the connections among XBLs, RBLs, and FSRQs will substantially advance our understanding of the fundamental nature of blazars. In this paper, we study the luminosity and the core-dominance parameters for samples of XBLs, RBLs and FSRQs at 1.5 GHz and check their correlations. For the luminosity distribution, the p value (given by the K-S test) between XBLs and FSRQs is smaller than that between RBLs and FSRQs, which is again smaller than that between XBLs and RBLs. On average, the core, extended and even the total luminosities in XBLs are smaller than those in RBLs, which in turn are smaller than those in FSRQs. Thus, the XBLs, RBLs and FSRQs seem to follow a continuous sequence, which supports the argument that RBLs are intermediate between XBLs and FSRQs, and accord with the results of Sambruna et al. (1996), Fossati et al. (1997, 1998), Mao et al. (2005), and Yang et al. (2006).

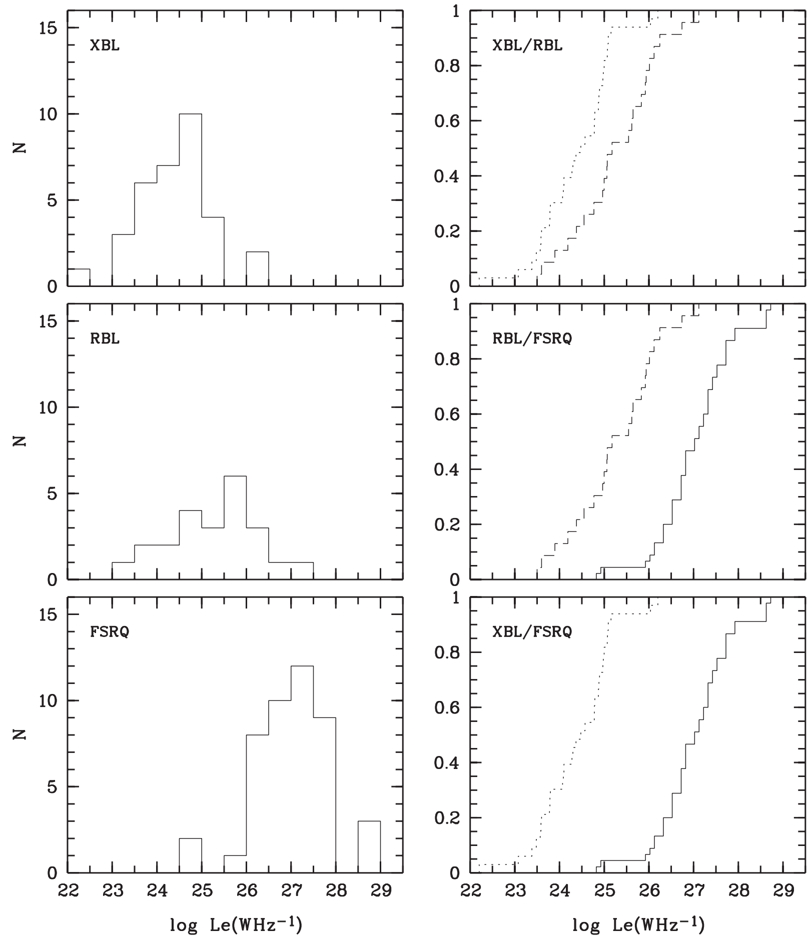

Fig. 2 Left: Extended luminosity distributions of XBLs (top), RBLs (middle) and FSRQs (bottom). Right: Corresponding cumulative distributions in pairs for use in the K-S test, with dotted line for XBLs dashed line for RBLs and solid line for FSRQs.

The core-dominance parameter R is a measure of relative orientation (Orr & Browne 1982; Kollgaard et al. 1996), i.e., a larger R means a smaller viewing angle in the blazar. Is this true? To check this, we considered three samples and compared their R. From the relevant data listed in the tables, we found that the average R of RBLs is the largest among the three groups, which does not follow the sequence XBLs–RBLs–FSRQs. It seems to be inconsistent with the point of view obtained from the luminosities of RBLs being the intermediate class between XBLs and FSRQs. What does this tell us? Ghisellini et al. (1993) and Valtaoja (1999) showed that the viewing angle of BL Lacs is larger than that of FSRQs, and the Doppler factor of BL Lacs is smaller than that of FSRQs, while R of RBLs is larger than that of FSRQs. Therefore, viewing angle alone can not explain the difference in R between BL Lacs and FSRQs.

Moreover, the beaming model (Laurent-Muehleisen et al. 1993) shows that the apparent monochromatic luminosity of a moving source (jet) $L_{\rm j}(\theta)$, as seen by an observer at angle θ to the direction of motion, is related to the intrinsic luminosity $\psi_{\rm j}$ by the formula $L_{\rm j}(\theta) = \delta^p \psi_{\rm j}$, where δ is the Doppler factor. The value of p depends on the jet model. The total luminosity of the source, $L_{\rm t}$, is the sum of two components, the angle-dependent beamed luminosity $L_{\rm j}$ and an unbeamed part $\psi_{\rm u}$; assuming $\psi_{\rm j} = f\psi_{\rm u}$, we obtain $L_{\rm t} = \psi_{\rm u} + L_{\rm j} = \psi_{\rm u}(1 + f\delta^p)$ and the core-dominance parameter $R = \frac{L_{\rm j}}{\psi_{\rm u}} = f\delta^p$. Fan (2003) found that

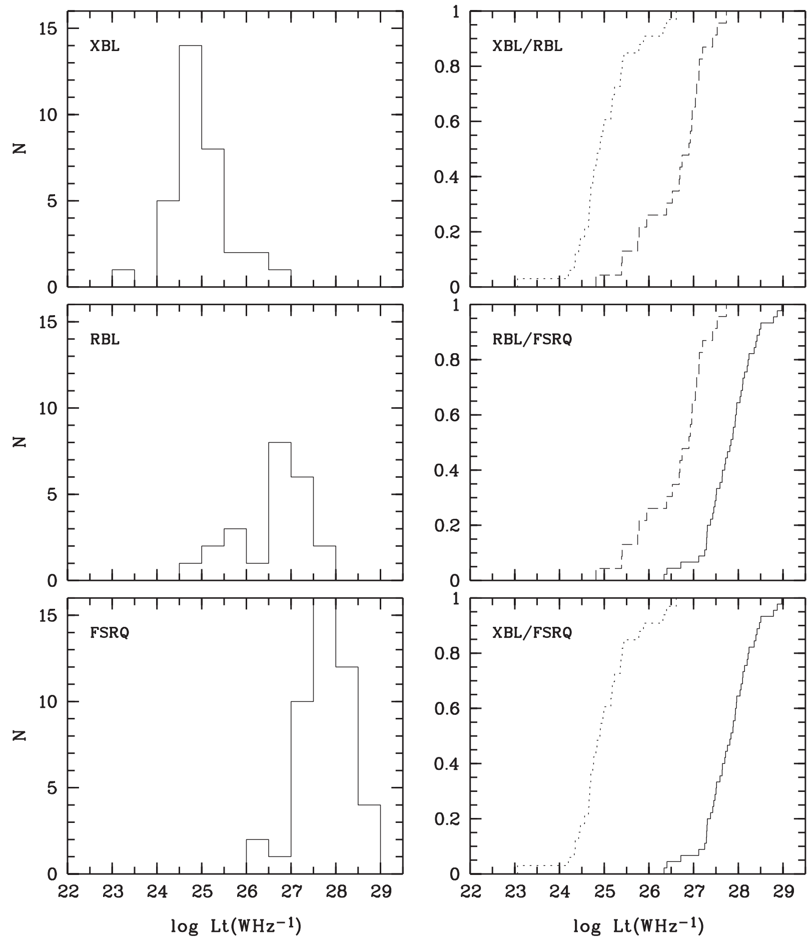

Fig. 3 Left: Total luminosity distributions of XBLs (top), RBLs (middle) and FSRQs (bottom). Right: Corresponding cumulative distributions in pairs for use in the K-S test, with dotted line for XBLs dashed line for RBLs and solid line for FSRQs.

the ratios f are greater in the RBLs than in the FSRQs. If this is true, then R in BL Lacs should be greater than that in FSRQs because they differ little in δ. In addition, since f is bigger for BL Lacs, the emission from the jet can dominate over the unbeamed emission lines, and non-emission lines can be observed in BL Lacs. For FSRQs, f is not large enough, so that both the line emission and the beamed emission can be observed (Fan 2003). In this sense, R can not be taken as the criterion for the relation amongst XBLs, RBLs, and FSRQs, and the continuous sequence of XBLs, RBLS, and FSRQs still exits.

The core luminosity of blazars is usually dominated by the beamed emission with Doppler-boosted flux while the extended luminosity is not Doppler-enhanced. In this sense, one can expect that the core luminosity is correlated with the core-dominance while the extended luminosity is not. However, the corresponding data in the tables do not show the expected results, i.e., the data show that the core luminosity is almost uncorrelated with the core-dominance parameter. However, the extended luminosity is strongly anti-correlated with the core-dominance parameter. The result obviously contradicts the common inference. A possible explanation for this unexpected result is that the cores emissions may not be dominated by the beamed emission and the extended emission may not be isotropic (Qin et al. 1996). However, this idea seems to contradict the conventional idea. From the definition of $R = \frac{L_c}{L_e}$, we have $R + 1 = \frac{L_t}{L_e}$. If L_t is distributed in a narrow range and R is far larger than 1, one can expect that $\log R$ will be anticorrelated with

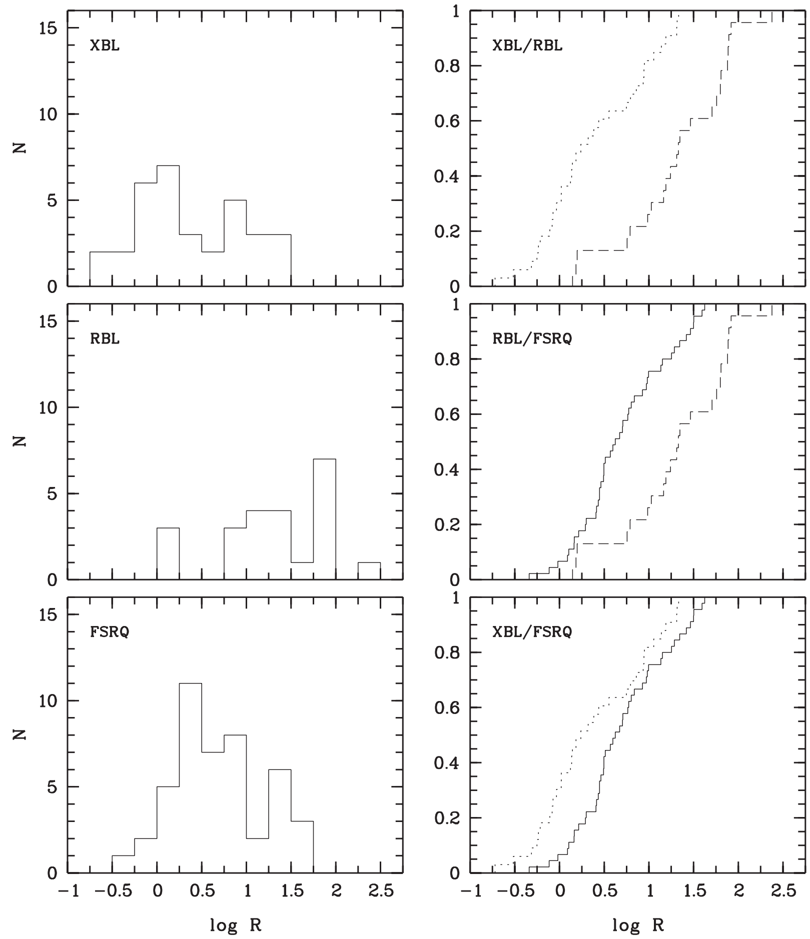

Fig. 4 Left: Core dominance parameter distributions of XBLs (top), RBLs (middle) and FSRQs (bottom). Right: Corresponding cumulative distributions in pairs for use in the K-S test, with dotted line for XBLs dashed line for RBLs and solid line for FSRQs.

log $L_{\rm e}$ as shown by the results in Figure 5. However, in our consideration (see Fig. 3), the total luminosity is distributed mainly in a 1.5 dex range while the extended luminosity is in more than 2.0 dex, and even 3 dex for RBLs (see Fig. 2). Because the total luminosity has a spread, that the regression correlation coefficient is only moderate is reasonable. Besides, the relation of the core luminosity and the core-dominance parameter obtained in this work can also be explained from the definition of R: $R = \frac{L_{\rm c}}{L_{\rm e}}$. It follows that $\frac{R}{1+R} = \frac{L_{\rm c}}{L_{\rm c}+L_{\rm e}} = \frac{L_{\rm c}}{L_{\rm t}}$, if R is large, then the left hand side is about 1.0, and there is no correlation between log $L_{\rm c}$ and log R. Therefore, if the total luminosity of a sample is limited, then we can expect an anti-correlation between the extended luminosity and the core-dominance parameter when R is large, however, there is no correlation between the core luminosity and the core-dominance parameter.

From the evolutional point of view, if FSRQs evolve into XBLs through RBLs, then we can expect a luminosity sequence with the XBLs showing lowest luminosity, since with not much matter to feed the central black hole, the accretion ratio will be smaller at this evolutionary stage. Furthermore, there should be no emission lines or only weak emission lines in XBLs. Our analysis shows that there is a luminosity sequence of XBLs, RBLs and FSRQs, which supports the evolution idea. However, it is also possible that the ratio of the core luminosity to the extended luminosity in the co-moving frame is greater in the BLs than in the FSRQs (Fan 2003), this idea can explain not only the similarity in the continuum but also the

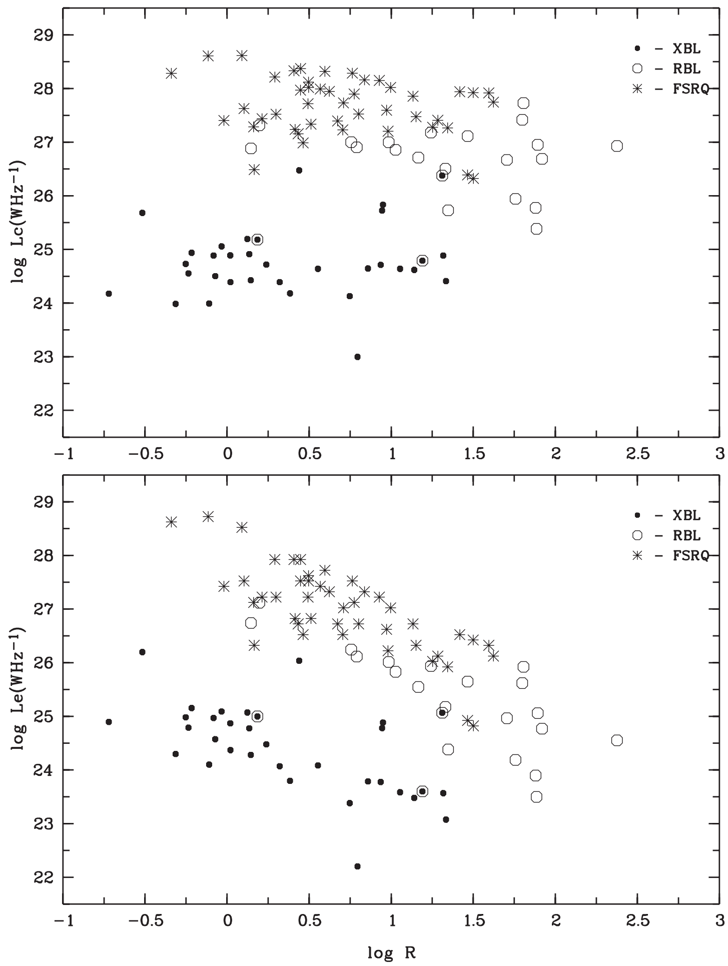

Fig. 5 A plot of $\log L_{\rm c} - \log R$ (top graph) and $\log L_{\rm e} - \log R$ (bottom graph) for the total sample.

difference in the emission lines between BLs and FSRQs. It is clear the relation between BLs and FSRQs needs to be analyzed further with more data.

From the regression of $\log L_{\rm e} - \log R$ for XBLs, RBLs and FSRQs, we have that the value of the slope for RBLs is located in between those of XBLs and FSRQs (the values of the slope for XBLs, RBLs and FSRQs are respectively –0.83±0.21, –0.97±0.30 and –1.29±0.13), which is consistent with the result of the luminosity distributions.

In the paper, we analyzed the distribution of luminosity and core-dominance parameter for XBLs, RBLs and FSRQs, and found that RBLs are located in between XBLs and FSRQs in the luminosity distribution and the slope of the relation between the luminosity and the core dominance parameter. For the core-dominance parameter, RBLs show the largest average value among all blazars. The core-dominance parameter can not be used to discuss the relationship amongst XBL, RBLs and FSRQs.

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