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Flux-depending X-ray Spectrum Index of Blazars

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Abstract Based on a sample of 69 blazars, relationships between flux density and spectral index, and distributions of redshift and spectral index have been investigated for highly frequency peaked BL Lac (HBLs), lowly frequency peaked BL Lac (LBLs) and flat spectrum radio quasars (FSRQs) respectively. Our result shows that (1) an anti-correlation between flux density and spectral index is found for HBLs, there is no clear relation for LBLs or FSRQs, which suggest that the X-ray emission in HBLs are from synchrotron process while that for LBLs and FSRQs from synchrotron self-Compton process, (2) the X-ray spectral index has a consequence for the three subclasses with HBLs showing the softest X-ray spectrum and FSRQs the hardest X-ray spectrum and with LBLs the middle of HBLs and FSRQs.

Key words: Active Galactic Nuclei — BL Lacertae objects — X-rays

1 INTRODUCTION

Blazars were classified as BL Lacertae objects, optically violently variable quasars (OVVs), highly polarized quasars (HPQs), and core-dominant radio quasars (CDQs). When the line emissions are taken into account, blazars have two very different subclasses as BL Lacertae objects with no or very weak emission line, and FSRQs with strong emission lines. For BL Lacertae objects, their spectral energy distributions show two separate types by their peak energy frequency, therefore BL Lac objects are divided into high-frequency peaked (HBL) and low frequency peaked (LBL) objects (Padovani & Giommo 1995), generally HBLs correspond to the X-ray selected BL Lacertae objects (XBLs) while LBLs to the radio selected BL Lacertae objects(RBLs). In this case, we have FSRQs, LBLs, and HBLs for blazar.

The classification of RBLs and XBLs, which is based on the survey result, has no physics, but the distinction of XBLs and RBLs is clear (Maccagni 1989; Fan et al. 1993), which was explained based on the relativistic beaming model (Fan et al. 1993, 1994, 1997; Fan & Xie 1996). The classification of HBL and LBL is based on a physical difference between the two classes and not on the selection band. The change of perspective from XBL/RBL to HBL/LBL has important implications for the jet model and has spurred a strong interest in the study of the physical parameters underlying the emission process in BL Lacs.

As for the relationship between BLs and FSRQs, it is still unclear. The whole magnetic wavelength non-thermal continuum and properties such as rapid variability and polarization are common to both FSRQs and BL Lacs, however, they differ in their emission line properties. An evolutionary link between BL Lacs and FSRQs may explain the correlation of broad-band properties with redshift (Vagnetti, Cavaliere, & Giallongo 1991), continuity of the radio and X-ray luminosity functions also suggests a continuity of some kind between BLs and FSRQs (Maraschi & Rovetti 1994). Very recently, we proposed that the both subclasses have no evolution effect, the emission lines difference is from the fact that the ratio of the de-beamed emissions to the unbeamed emissions in the co-moving frame is not the same. The ratio in BLs is larger than that in FSRQs, this difference results in the observation difference in emission lines between BLs and FSRQs (see Fan 2003).

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It is obvious that the relationship is interesting for BLs and FSRQs. In this paper, the X-ray data from Donato et al. (2001) are used to investigate the relationship between BLs and FSRQs. Here, we considered the relationship between the flux density and the spectral index. In the 2nd section the analysis results are given, in the 3th section, we give some discussions and a brief conclusion.

2 SAMPLE AND RESULTS

2.1 Sample

In this paper, a sample including 69 blazars were compiled from the paper by Donato et al. (2001), of which, 30 are HBLs, 17 are LBLs, and 22 are FSRQs.There were two or more than two observational data of each Blazar in the sample.

2.2 Method and Results

Blazars are variable and strong X-ray emitters. Observations show that the spectrum changes with the brightness of the source. For a single source, different epoch observations can be used to discuss the relationship between the spectrum index and the flux density. Generally the spectrum becomes harder when the source brightens and the spectrum softens when the source dims. But for a sample of sources, the above method is not useable since different source has different brightness, one can not put all the spectrum and flux density points in one plot. Otherwise, the points are very scattering and will dilute the relationship for a sample. In this case, we proposed to use the normalized spectrum index and flux density to investigate the relationship.

If a source has m sets of observations with spectrum indexes and flux densities. we normalize the two values by following calculations.

Firstly, we calculate the weighted averaged values with the uncertainties of flux densities and spectrum indexes.

$$\langle \alpha_{\rm X} \rangle = \frac{\sum \frac{\alpha_i}{\Delta \alpha_i}}{\sqrt{n \sum (\frac{1}{\Delta \alpha_i})^2}}; \qquad \langle F_{\rm X} \rangle = \frac{\sum \frac{F_{\rm X_i}}{\Delta F_{\rm X_i}}}{\sqrt{n \sum (\frac{1}{\Delta F_{\rm X_i}})^2}} ,$$

where $i = 1, 2, 3, ..., m$.

Secondly, we calculate the normalized flux density and spectrum index values,

$$R_{F_i} = \frac{F_{X_i}}{\langle F_{\rm X} \rangle}; \qquad R_{\alpha_i} = \frac{\alpha_{X_i}}{\langle \alpha_{\rm X} \rangle} ,$$

and the normalized uncertainty values

$$\Delta R_{F_i} = \frac{\Delta F_i}{\langle F_{\rm X} \rangle}; \qquad \Delta R_{\alpha_i} = \frac{\Delta \alpha_i}{\langle \alpha \rangle} .$$

When the process is adopted to the present sample, we obtained the values for $R_{F_{X_i}}$, R_{α_i}, and ΔR_{α_i} for each source. Since the uncertainty for the flux density is not available in the literature (Donta et al. 2001), we calculated the $R_{F_{X_i}}$ by assuming the same uncertainty, and we did not calculate the $\Delta R_{F_{X_i}}$. When the linear regression analysis is performed to the $R_{F_{\rm X}}$ and R_α with their uncertainties on $\langle \alpha \rangle$, following results were obtained.

1) For 30 HBLs,

$$R_{F_{\rm X}} = -(0.824 \pm 0.293) R_\alpha + (1.917 \pm 0.330),$$

there is an anti-correlation between flux density and spectrum index. Namely, when X-ray emission flux will decline, the X-ray photon spectral index increase, with correlation coefficient $r = -0.287$, and a chance probability $P = 0.604\%$. (see Table 1 and Figure 1(a)).

2) For 17 LBLs and 22 FSRQs, there are not clearly correlations between flux and spectrum index (see Table 1).

Table 1 Linear Regression Analysis Results

Subclass	A	ΔA	B	ΔB	r	SD	N	$P/\%$
HBLs	1.917	0.330	–0.824	0.293	–0.287	0.393	90	0.604
LBLs	0.656	0.364	0.300	0.312	0.150	0.437	42	34.219
FSRQs	0.570	0.408	0.376	0.354	0.146	0.397	54	29.235

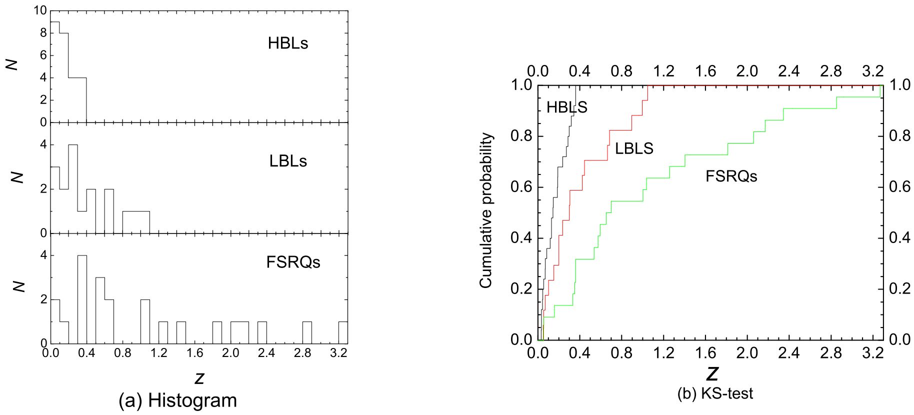

Fig. 1 Comparison of three subclass in their redshift.

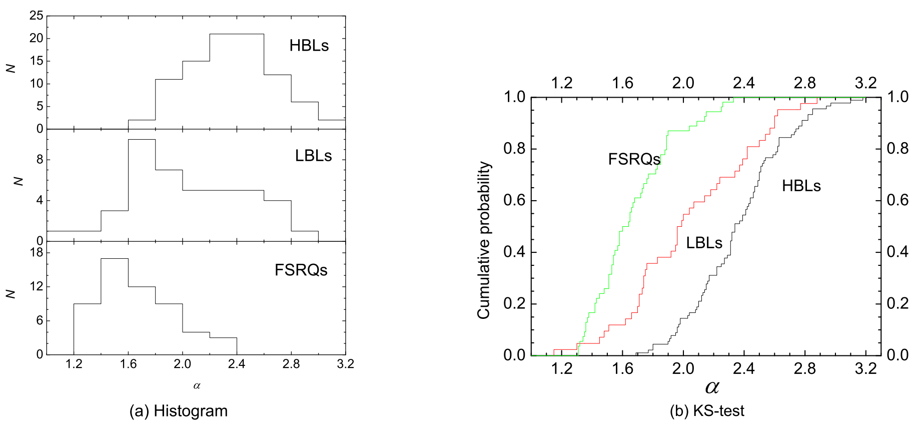

Fig. 2 Comparison of three subclass in their spectral index.

2.3 Results of the Distributions for Redshift and Spectrum Index

The histogram distributions of redshift for 30 HBLs, 17 LBLs, and 22 FSRQs are shown in Figure 1(a), and distributions for spectrum index are in Figure 2(a). Their Kolmogolov-Smirnov (KS) tests are in Figure 1(b) and Figure 2(b) for HBLs, LBLs, and FSRQs.

For redshift, the average value $\langle z\rangle_{\rm HBLs} = 0.167 \pm 0.021$, $\langle z\rangle_{\rm LBLs} = 0.402 \pm 0.084$, and $\langle z\rangle_{\rm FSRQs} = 1.088{\pm}0.203$. KS-test shows that the probabilities are respectively as follows: For HBLs and LBLs, $D_{\rm H,L} = 0.412$ and $p = 4.597 \times 10^{-2}$; for HBLs and FSRQs, $D_{\rm H,F} = 0.744$ and $p = 1.475 \times 10^{-6}$; for LBLs and FSRQs, $D_{\rm F,L} = 0.452$ and $p = 2.661 \times 10^{-2}$. For spectrum index, the average value $\langle\alpha\rangle_{\rm HBLs} = 2.362 \pm 0.057$, $\langle\alpha\rangle_{\rm LBLs} = 2.035 \pm 0.104$, $\langle\alpha\rangle_{\rm FSRQs} = 1.670 \pm 0.058$. And we have $D_{\rm H,L} = 0.429$ and $p = 3.086 \times 10^{-5}$ for HBLs and LBLs, $D_{\rm H,F} = 0.815$ and $p = 7.873 \times 10^{-21}$ for HBLs and FSRQs, and $D_{\rm F,L} = 0.489$ and $p = 1.239 \times 10^{-5}$ for LBLs and FSRQs.

3 DISCUSSION AND CONCLUSIONS

Blazars consist of two subclasses with quite different emission line features (BLs and FSRQs). Their relation is still an open question. Observations indicate that blazars show the relation between source brightness and the spectrum (Gear et al. 1986; Brown et al. 1989; Fan et al. 1998; Fan & Lin 1999).

In this paper, we have studied the correlations between X-ray flux densities and spectrum indices at 1 keV for subclass HBL, LBL, and FSRQs. We found that for HBLs, the flux densities are anti-correlated with their spectrum indices suggesting that the spectrum flattens when the source brightens, but for LBLs and FSRQs there are no clearly correlations. This difference is from the fact that the emissions in HBLs is different from that in LBLs and FRSQs. For the former, the peak synchrotron emission locates in the UV/X-ray bands, the X-ray emission is mainly duo to the synchrotron process. When new relativistic electrons injected into the jets, the emissions make the source brighten, and the spectrum is determined by the background electrons and the injected ones (Fan 2002). The steepening of the spectrum with the source dimming is attributed to the radiative energy losses, and effect the higher energy electron before effecting the lower energy ones (Fan 1999).

For LBLs and FSRQs, their peak synchrotron emissions locates in the IR/Opt. bands, the X-ray emission in LBLs is dominated by inverse Compton scattering the same photons of synchrotron emission and the synchrotron process while for FSRQs, the situation is even more complex than LBLs. In this case, the emission mechanisms for the X-ray bands in LBLs and FSRQs make their X-ray spectrum complex and the correlation between the flux density and the spectrum diluted. Our analysis indicates that there is no clear correlation between flux and spectrum index for LBLs and FSRQs. Similar phenomenon was also found in other AGNs(Fan & Lin 1999).

In the histograms for redshift and spectrum indices, the K-S test indicates that HBLs and FSRQs have different parent distribution while LBLs and FSRQs have quite possible parent distribution. It is also clear that the LBLs is the bridge connecting HBLs to FSRQs as found by Sambruna et al. (1996) and Mao et al. (2005). From our investigation and above discussions, we can get some conclusions. The physical properties of HBLs are significantly different from those of FSRQs, but LBLs are not significantly different from FSRQs, it seems that the LBLs is the middle state of HBLs and FSRQs. The X-ray emissions in HBLs is different from that in FSRQs and LBLs, HBLs emission is produced by the synchrotron process, and LBLs and FSRQs emission are consist of several components.

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References

Brown L. M. J. et al., 1989, ApJ, 340, 150
Donato D. et al., 2001, A&A, 375, 739
Fan J. H., et al., 1993, ApJ, 415, 113
Fan J. H., et al., 1994, Ap&SS, 213, 305
Fan J. H., Xie G. Z., 1996, A&A, 306, 55
Fan J. H., et al., 1997, Ap&SS, 246, 119
Fan J. H., et al., 1998, ApJ, 507, 173
Fan J. H., Lin R. G., 1999, ApJS, 121, 131
Fan J. H., 2003, ApJ, 585, 23
Gear W. K. et al., 1986, Nature, 324, 546
Maccagni D., et al., 1989, in BL Lacertae Objects, ed L. Maraschi, T. Maccacaro, M. H. Ulirich, Lecture Notes in Physics 334, Berlin: Springer, p.281
Mao L. S., Xie, G. Z., Bai, J. M., Liu, H. M. 2005, Chin. J. Astron. Astrophys. (ChJAA), 5, 471
Maraschi L., Rovetti F., 1994, ApJ, 436, 79
Padovani P., Giommi P., 1995, ApJ, 444, 567
Sambruna R. M. et al., 1996, ApJ, 463, 444
Vagnetti F., Cavaliere A., Giallongo E., 1991, ApJ, 368, 366