Beaming Effect in Blazars

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Abstract

From the view point of observation, the orientation of a jet can be expressed by a so called core-dominance parameter, $R = S_{core}/S_{Ext.}$, where S_{core} is core emission while $S_{Ext.}$ is extended emission, the R, to some extent, is also associated with the beaming effect. In this work, we compiled 1338 blazars with available core-dominance parameter, out of which 172 blazars are known to have γ-ray emissions (from 3FGL). We compared the log R between the 172 Fermi-detected blazars (FDBs) and the rest non-Fermi-detected blazars (non-FDBs), and found that the averaged values are $< \mathrm{logR} >= 1.268 \pm 0.88$ for FDBs and $< \mathrm{logR} >= -0.521 \pm 0.94$ for non-FDBs. A K-S test shows that the probability for the distributions of FDBs and non-FDBs to come from the same parent distribution is $P = 2.38 \times 10^{-7}$. Secondly, we also investigated the variability index (VI) in γ-ray band for FDBs, and found a tendency for source with higher log R to have larger VI value for FDBs, namely, $VI = (0.095 \pm 0.045)logR + (2.275 \pm 0.058)$. Meanwhile, we also studied the relationship between the apparent velocity and the γ-ray luminosity, and found the γ-ray brighter sources have higher apparent velocities. A correlation between spectrum index and the core-dominance parameter is also found implying a two-component model for γ-ray emissions as we discussed in our previous work (Wu, Fan, Yang, et al. 2014).

Keywords. galaxies: active galactic nuclei (AGNs)-galaxies:jets-galaxies:quasars

Introduction

Active galactic nuclei (AGNs) consist of quasars, Seyfert galaxies, radio galaxies, BL Lac objects, optically violent variable (OVVs), and LINER. Blazars are a extreme sub-class of AGNs, which can be divided into two sub-classes, BL Lac Objects (BLs) and flat spectrum radio quasars (FSRQs). Blazars show extreme observation properties, such as high and variable luminosity, high and variable polarization, no emission line or emission lines being very strong, superluminal motions in their radio components, and high γ-ray emission, and attracted much attention of astronomers in the world to search for its emission mechanism, the central structure, and the evolution amongst different types of subclasses of AGNs (see, e.g., Adbo et al. 2010; Aller et al. 2003; Andruchow et al. 2005; Cellone et al. 2007; Ciprini et al. 2007; Dai et al. 2009; Efimov et al. 2002; Fan 2003; Fan et al. 1997; 2008, 2009, 2010; Gupta et al. 2004; Kurtanidze et al. 2007; Romero et al. 2000, 2002; Wagner 1996; Wills et al. 1992; Wu et al. 2005; Xie et al. 2005; Zhang & Fan 2008; Fan et al. 2013). Observations show that high energy γ-rays maybe strongly beamed. In radio bands, emissions are assumed to consist of two components, namely the core and the extended emissions. The ratio of core to extended emission is called a core-dominance parameter, $R = S_{core}/S_{Ext.}$.

In our previous paper (Fan et al. 2011), we compiled 1223 radio sources with radio observations including core and extended emissions and calculated their core-dominance parameters at 5 GHz. In our calculation, if radio observations were not made at 5 GHz, then they were transferred into 5 GHz by adopting $\alpha_{core} = 0$ and $\alpha_{Ext} = 0.75$ (Fan et al. 2011). Based on that paper, we investigated the correlation between radio and γ-ray emissions, and found that it is possible that γ-ray emissions are composed two components (Wu, Fan, Liu, et al. 2014). In a recent paper, we also compiled a sample of about 800 radio sources (Pei et al. 2014). Combining those two papers, we can get a sample of 1342 blazars with available log R, out of which 172 are in the 3FGL sample. From the detections from Fermi mission, blazars are variable which can be described by a parameter, Variability Index (VI). The Variability Index (VI) is defined as following(see Abdo , 2011),

$$w_i = \frac{1}{\sigma_i^2 + (f_{rel}F_i)^2}$$

$$F_{wt} = \frac{\Sigma_i w_i F_i}{\Sigma_i w_i}$$

$$VI = \Sigma_i w_i (F_i - F_{wt})^2$$

where i runs over the 11 intervals (11 months), F_i means flux density, σ_i is the statistical uncertainty in F_i, F_{wt} stands for weighted averaged and $f_{rel} = 0.03$, which is defined as a simple x^2 criterion. In this work, we will use the available sample to investigate the difference in core-dominance parameter between FDB and non-FDBs, the relationship between the core-dominance parameter and VI, that between radio and γ-ray spectral indices, and that between γ-ray spectral index and core-dominance parameter.

Sample and Results

After the launch of Fermi/LAT, many blazars have been detected to show γ-ray emissions(see Abdo et al. 2010; Ackermann et al. 2011; Nolan et al. 2012; Lott 2014), it has provided good chance to study γ-ray emission mechanism of γ-rays and beaming effect. Basing on the third catalog of Fermi γ-ray large area telescope (LAT)-3FGL, the largest Blazar catalogue (Massaro et al. 2011), and the radio source sample with core-dominance parameters (Fan et al. 2011, Pei, et al. 2015), We compiled 1342 blazars with available core-dominance parameter, log R, out of which 176 are Fermi-detected blazars (FDBs) (105 FSRQ , 62 BL Lac , 4 Bcu , 4 G and 1 Sy 1) and 1166 are non-Fermi-detected blazars (non-FDBs). In this work, we only considered Fermi-detected blazars and the non-Fermi-detected blazars.

2.1 Comparison for log R:

From the available FDBs and the non-FDBs, we can get the averaged values of $< \mathrm{logR} >= 1.268 \pm 0.88$ for FDBs and $< \mathrm{logR} >= -0.521 \pm 0.94$ for non-FDBs. A K-S test shows that the probability for the distributions of FDBs and non-FDBs to come from the same parent distribution is $P = 2.38 \times 10^{-7}$. The histogram and the accumulative result are shown in Fig. 1. If we considered the Flat Spectrum Radio Quasars (FSRQs) and BL Lac Objects (BL Lacs) separately, we can get the averaged values of logR for FSRQs is 1.127 ± 0.34 and 1.527 ± 0.12 for BL Lacs. BL Lacs have on average, higher log R than FSRQs.

2.2 Correlation between logR and Variability Index:

From the 3FGL (Ackermann et al. 2015), we can get γ-ray variability index (VI) for the 172 FDBs, a relationship between logR and variability index (VI) is found: $VI = (0.095 \pm 0.045)logR + (2.275 \pm 0.058)$. It is shown that there is a positive tendency between core dominance parameter and variability index. We also investigated the relationship for FSRQs and BL Lacs separately, we have $VI_{FSRQs} = 0.093logR + 2.382$ for FSRQs and $VI_{BLLacs} = 0.140logR + 2.034$ for BL Lacs. The results are shown in Fig. 2.

2.3 Correlation between logR and γ-ray Spectrum Index:

For the 172 sources, we did study about the relationship between logR and spectrum index (α_γ), and found $\alpha_\gamma = 0.056logR + 0.2271$. the corresponding result is shown in Fig.3.

2.4 Relationship between Apparent Velocity and γ-Ray Luminosity: Combing the superluminal sources with the FDBs we can get a sample of γ-ray superlumnal sources. Our analysis shows that there brighter sources tend to have higher apparent velocity as shown in Fig. 4.

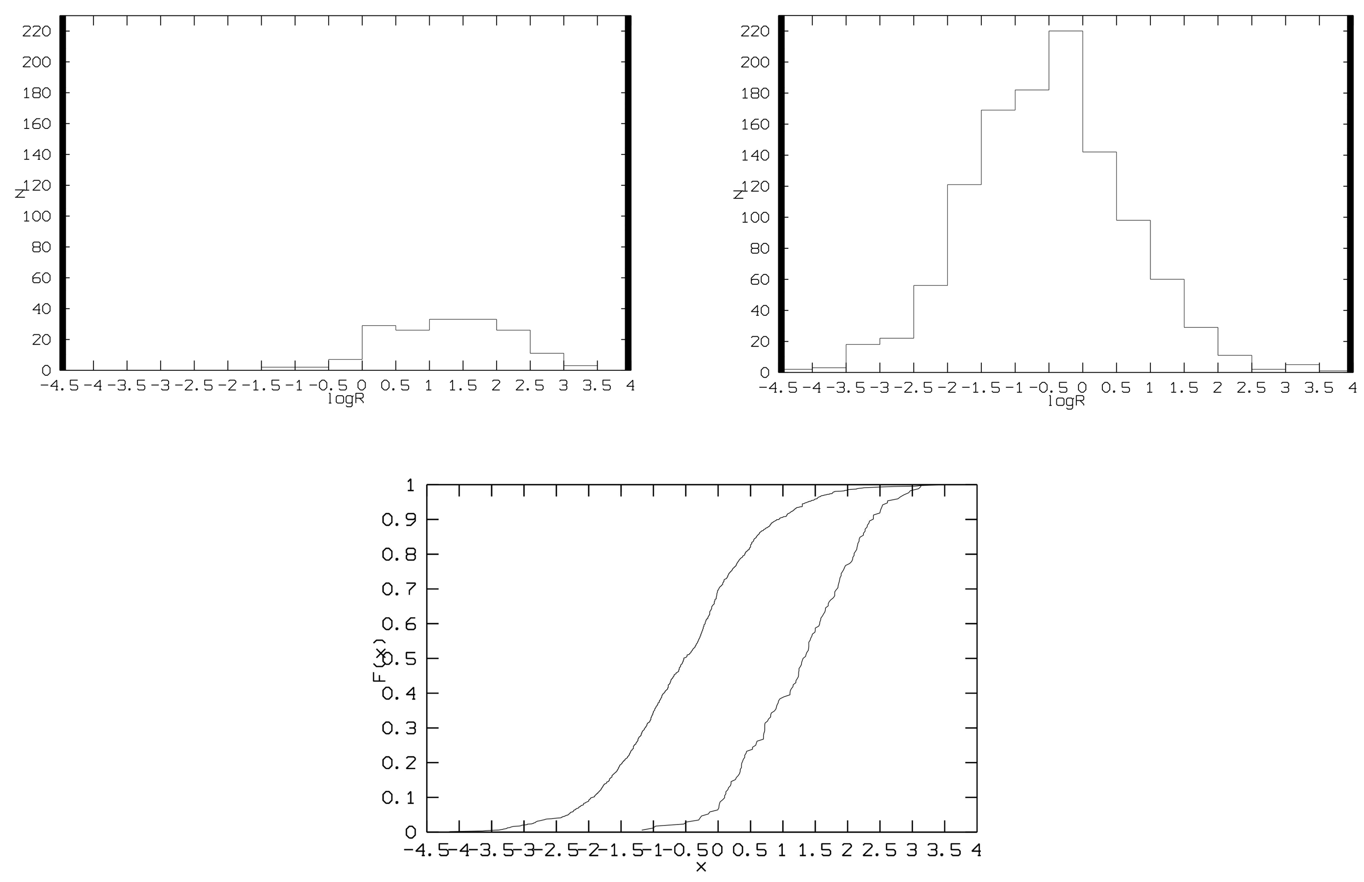

Figure 1: logR between the blazars who have the γ-ray(FDBs) and not have the γ-ray(non-FDBs)

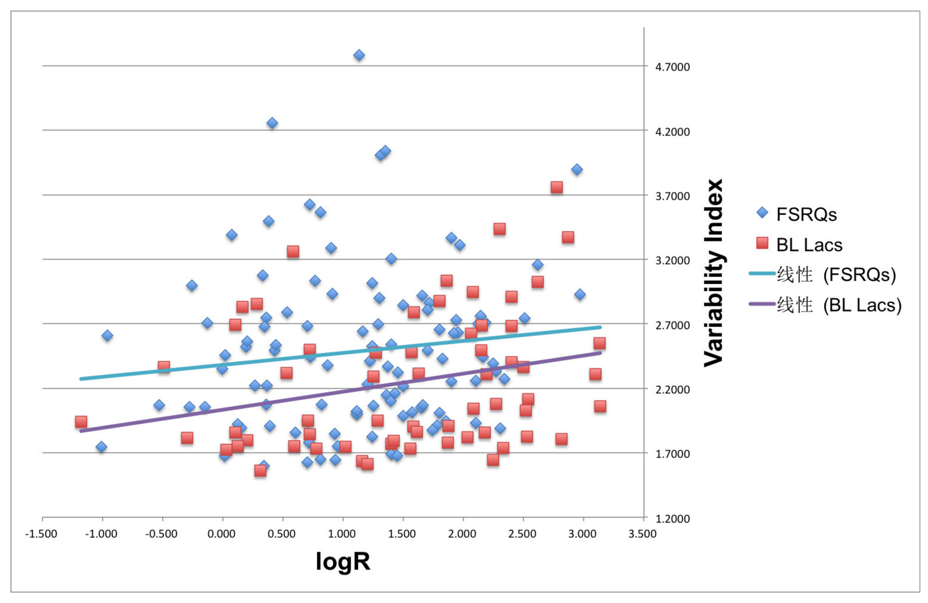

Figure 2: The correlation between logR and Variability Index for FDBs

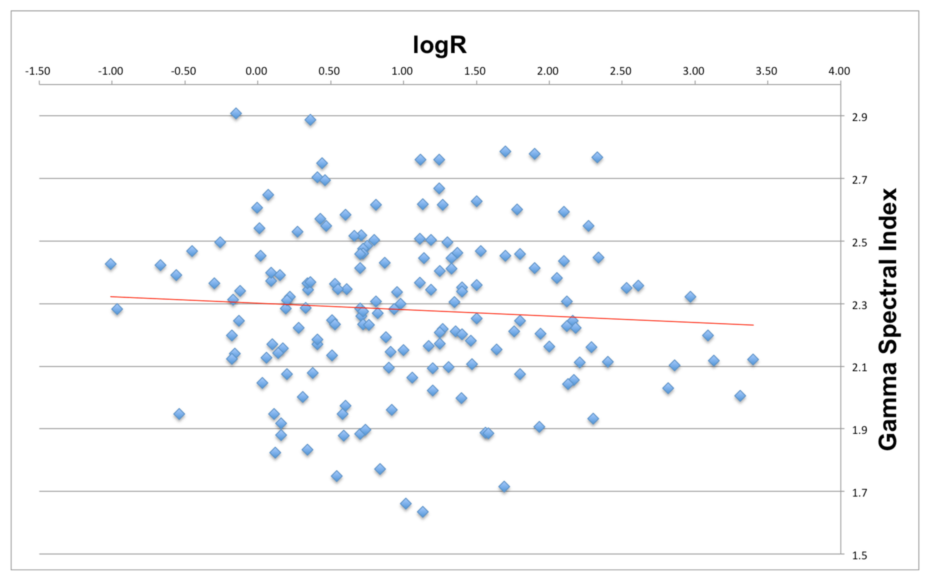

Figure 3: The correlation between logR and γ-ray Spectrum Index

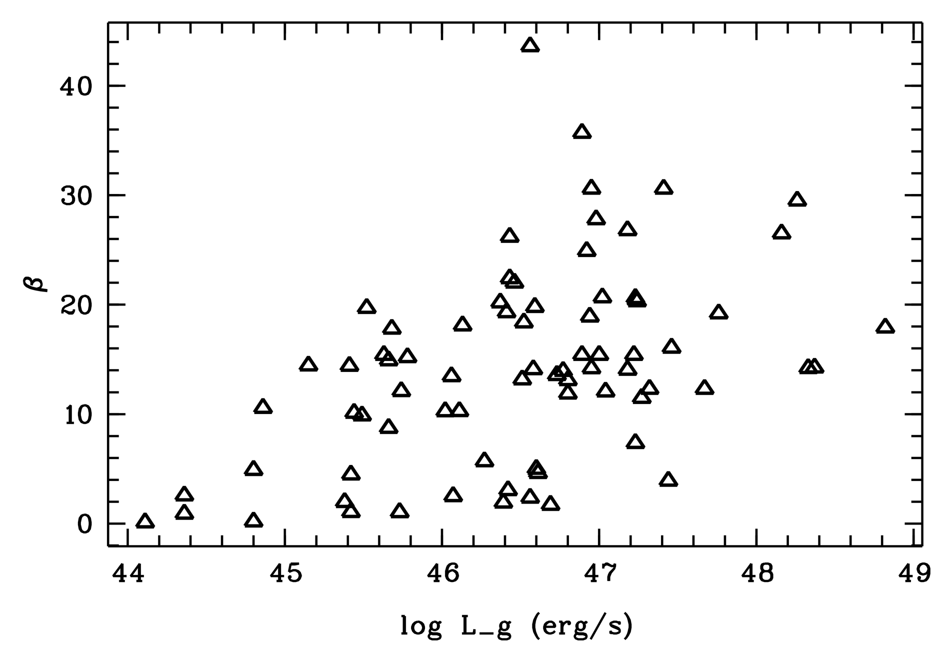

Figure 4: The correlation between log L_g and β

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