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The De-beamed γ-Ray Emissions in Blazars

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Abstract. Blazars (BL Lacertae objects and flat spectrum radio quasars) are strong γ-ray emitters, the γ-ray emissions are strongly beamed. In this work, we compiled a sample of Fermi blazars with available beaming factors, δ_R, to investigate the correlation between the γ-ray flux density, $\log f_\gamma$, and redshift, $\log z$ for the whole sample and the subclasses of the present sample. The analysis shows that there is no correlation between $\log f_\gamma$ and $\log z$ for the observed γ-ray flux density, but there are strong correlations between the de-beamed flux densities, $\log f_\gamma^{db}$ and $\log z$ for the whole sample and the subclasses. Our results confirm that the γ-ray emissions are strongly beamed and imply that it is possible for one to use the radio beaming factor, δ_R for the beaming effect discussions in the γ-ray bands for Fermi blazars.

Keywords. galaxies:active-galaxies:BL Lacertae objects-galaxies:quasars-galaxies:jets

1. Introduction

Blazars are a very extreme subclass of active galactic nuclei(AGNs) showing rapid and high amplitude variability, high and variable polarization, strong and variable γ-ray emissions, and even superluminal motions etc. (Fan *et al.* 2013a, and reference therein). The strong γ-ray emissions in blazars suggest the existence of a relativistic beaming effect, which is discussed in the papers (see Kovalev *et al.* 2009; Arshakian *et al.* 2010; Savolainen *et al.* 2010; Pushkarev *et al.* 2010; Fan *et al.* 2013b,c; Giovannini, 2013; Giroletti *et al.* 2012; Massaro, *et al.* 2013a,b).

In a relativistic beaming model, the observed emission, $f^{\rm ob}$, is strongly boosted, namely, $f^{\rm ob.} = \delta^p f^{\rm in}$, here $f^{\rm in}$ is the intrinsic emission in the source frame, δ is the Doppler factor, $p = 3+\alpha$ for a moving compact source or $p = 2+\alpha$ for a continuous jet (Lind & Blandford 1985), and α is the spectral index ($f_\nu \propto \nu^{-\alpha_\nu}$). The Doppler factor, δ is an important parameter, which was estimated in some papers (Ghisellini *et al.*, 1993; Lahteenmaki & Valtaoja, 1999; Fan *et al.*, 2009; Hovatta *et al.* 2009).

In this work, we compiled a sample of 73 Fermi blazars with available Doppler factors, and investigated the correlations between the flux density and the redshift.

2. Results and Conclusion

For the γ-ray sources, the integral flux, f, in units of $\mathrm{GeV \cdot cm^{-2} \cdot s^{-1}}$, can be expressed in the form (Fan *et al.* 2013b,c)

$$f = N_{(E_{\rm L} \sim E_{\rm U})} \left(\frac{E_{\rm L} E_{\rm U}}{E_{\rm L} - E_{\rm U}} \right) \ln \frac{E_{\rm U}}{E_{\rm L}}, \text{if} \quad \alpha_{\rm ph} = 2, \text{otherwise}$$

$$f = N_{(E_{\rm L} \sim E_{\rm U})} \frac{1 - \alpha_{\rm ph}}{2 - \alpha_{\rm ph}} \frac{(E_{\rm U}^{2-\alpha_{\rm ph}} - E_{\rm L}^{2-\alpha_{\rm ph}})}{(E_{\rm U}^{1-\alpha_{\rm ph}} - E_{\rm L}^{1-\alpha_{\rm ph}})}$$

here $N_{(E_L \sim E_U)}$ is the integral photons in the energy range of E_L and E_U. In this work, E_L and E_U correspond to 1 GeV and 100 GeV respectively.

From the integral flux, we can get

$$logf = -(0.30 \pm 0.15)logz + (0.28 \pm 0.07),$$

with a correlation coefficient $r = -0.23$ and a chance probability of $p = 5.4\%$.

However, when we use the de-beamed integral flux densities to deal with the correlation, we have following results.

$$logf^{db^{\alpha+3}} = -(2.58 \pm 0.38)logz - (4.3 \pm 0.17), \text{and}$$

$$logf^{db^{\alpha+2}} = -(2.08 \pm 0.30)logz - (3.24 \pm 0.13),$$

with correlation coefficients and the probabilities being r =-0.63, $p < 10^{-4}$ for both cases.

If the Fermi blazars belong to a group, then we can expect that the flux density should follow a theoretical result as $logf = -2.0logz + const$. Our investigation for a Fermi sample with available radio Doppler factors suggests that the observed flux density does not follow that relationship, but the de-beamed ones follow that relationship with the slopes being –2.58 ± 0.38 and -2.08 ± 0.30 for α+3 and α+2 cases respectively. Our result suggests that 1) the γ-ray emissions are strongly beamed; 2) the de-beamed flux density follow the theoretical relationship for Fermi blazars; 3) the radio Doppler factors can be used to deal with the relativistic beaming effect in the γ-ray band. This is consistent with the result in our previous work, which showed that the estimated γ-ray Doppler factors are correlated with the radio Doppler factors (Fan *et al.* 2013d).

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