

γ -Ray Doppler Factors for Fermi Blazars

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Abstract. In this paper, we compiled the X-ray observations for 138 Fermi blazars and calculated their Doppler factors, δ_γ . The calculated Doppler factors, δ_γ , are found strongly correlated with the γ -ray luminosity.

Keywords. Galaxies:active-galaxies:BL Lacertae objects-galaxies:quasars-galaxies:jets-Fermi (LAT)

1. Introduction

Blazars are an extreme subclass of active galactic nuclei (AGNs), and show rapid and large variability, high and variable polarization, superluminal motions in their radio components, and strong γ -ray emissions, etc (Abdo *et al.* 2010; Nolan *et al.* 2012; Fan 2012).

Since the launch of the new generation of γ -ray detector, Fermi has detected a lot of blazars (Abdo *et al.* 2010; Nolan *et al.* 2012). The relativistic beaming effect has been discussed for the Fermi blazars (see Savolainen *et al.* 2010, and references therein). But the γ -ray Doppler factors have not been estimated for those Fermi blazars. It is known that the Doppler factors are important in the discussion of blazars, therefore, we will estimate the factors for the Fermi detected blazars with available X-ray emission data. We adopt $H_0 = 73 \text{ km s}^{-1} \text{ Mpc}^{-1}$ through this paper.

2. Doppler Factor Estimation and Conclusion

The extreme observation properties of blazars, such as rapid variability, high and variable polarization, and superluminal motion can be explained using a relativistic beaming model. The strong γ -rays detected from blazars imply that the beaming effect is presented in those sources, otherwise, the γ -rays should have been absorbed due to pair-production on collision with the lower energetic photons. In 1993, Mattox, *et al.* considered the pair-production optical depth, they assumed that (1) the X-ray is produced in the same region as the γ -rays, and that a similar X-ray intensity was extant at the time of the γ -ray observation, (2) the emission region is spherical, (3) the emission is isotropic, and the size of the emission region is constrained by time variation to be less than $R = c\Delta T/(1+z)$, here ΔT is the timescale of variability, c is the speed of light, z is the redshift. Based on those assumptions and that the optical depth does not exceed unity, one can obtain a lower limit for the γ -ray Doppler factor, δ_γ , namely

$$\delta \geq \left[1.54 \times 10^{-3} (1+z)^{4+2\alpha} \left(\frac{d_L}{\text{Mpc}} \right)^2 \left(\frac{\Delta T}{\text{hr}} \right)^{-1} \left(\frac{F_{\text{KeV}}}{\mu\text{Jy}} \right) \left(\frac{E_\gamma}{\text{GeV}} \right)^\alpha \right]^{\frac{1}{4+2\alpha}}, \quad (2.1)$$

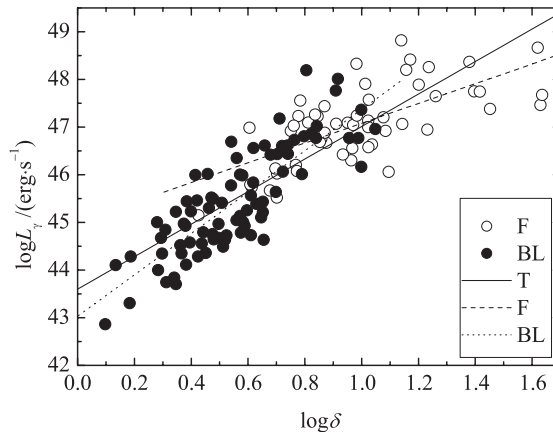


Figure 1. Plot of the γ -ray luminosity, $\log \nu L_\nu$ (ergs/s) against the γ -Doppler factor, $\log \delta_\gamma$ for the Fermi blazars. The open circles stand for FSRQs, the filled points for BLs. The solid line stands for the best fitting result for the whole sample, the broken line for FSRQs, and the dotted line for BLs.

where α is the X-ray spectral index ($F_{\nu_X} \propto \nu_X^{-\alpha}$), F_{KeV} is the flux density at 1 KeV, E_γ is the energy at which the γ -rays are detected, and d_L is the luminosity distance, which can be expressed in the form $d_L = \frac{c}{H_0} \int_1^{1+z} \frac{1}{\sqrt{\Omega_M x^3 + 1 - \Omega_M}} dx$ from the $\Lambda - \text{CDM}$ model with $\Omega_\Lambda \simeq 0.7$, $\Omega_M \simeq 0.3$ and $\Omega_K \simeq 0.0$.

Estimation of δ_γ When the relation is adopted to 138 Fermi blazars with available X-ray data, the γ -ray Doppler factors, δ_γ 's are obtained by assuming that $\Delta T = 24$ hours, the plot of δ_γ 's vs the γ -ray luminosity is shown in Fig. 1.

Discussions and Conclusion From the Fermi mission, we can see that most of the identified detected point sources are blazars (Nolan *et al.* 2012). So, we can take γ -ray emissions as one of the observational properties of blazars. From the obtained δ_γ 's, and the calculated γ -ray luminosities (see Fan *et al.* 2012), we have $\log L_\gamma$ (erg/s) = $(3.41 \pm 0.18)\log \delta + (43.60 \pm 0.14)$ for the whole sample, which confirms that the γ -rays are strongly beamed. However, the slope and constant ($\log L_\gamma$ (erg/s) = $(2.07 \pm 0.31)\log \delta + (45.00 \pm 0.32)$) for FSRQs are different from those ($\log L_\gamma$ (erg/s) = $(4.34 \pm 0.33)\log \delta + (43.03 \pm 0.19)$) for BL Lacs. Do flat spectrum radio quasars have different γ -ray origin than BL Lacs? Or they have different dependence on the γ -ray Doppler factors? or they have different ΔT ?

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