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Possible Lognormal Distribution of Fermi-LAT Data of OJ 287

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Abstract. OJ 287 is a BL Lac object at redshift $z = 0.306$ that has shown double-peaked bursts at regular intervals of 12 yr during the last 40 yr according to previous research. Some of the AGN γ ray power density shows a white noise process, while some others shows a red noise process. Some AGN flux presents normal or log-normal distribution. The two processes have an intrinsic relationship with centre black hole emission mechanism. We present the results of the analysis of the Fermi-LAT data. We review some problems concerning the random process.

Key words. Galaxies: blazar: gamma-ray: Fermi-LAT: data analysis.

1. Introduction

The variability time scales of blazar range from a few minutes to several years (Ulrich 1995). Variability may contain random noises and possible periodic signals. Timing analysis of variability has been a highly visible part of blazar research for several decades (Scargle 1981, 1990). It was claimed that some blazars show possible periodicity in their light curves (Fan *et al.* 2002; Xie *et al*. 2002). Studying the random noise is helpful in the search for periodicity and provides implication of the physical process in the jet or the accretion disk. OJ 287 was also monitored in the γ-ray band by Fermi telescope. The observations provide us an opportunity to study the nature of the variability in the gamma-ray band, which is the main purpose of this paper.

2. Data analysis

Since the light curve is unevenly sampled, we use a method of unevenly sampled time series analysis. The flux I_i is sorted by the time t_i , namely,

$$I_i = I(t_i)\ (i = 0, 1, 2, \ldots, n),\ t_0 < t_1 < \cdots < t_n, \tag{1}$$

where t_i is the measurement data. The Auto Covariance Function (ACF) is defined as

$$\mathrm{ACF}(\tau) = \langle x(t)x(t+\tau)\rangle \lim_{N\to\infty} = \sum_{T=1}^{N-\tau} x(t)x(t+\tau). \tag{2}$$

The spectrum is defined as the Fourier transform of the ACF

$$S(\omega) = \sum_{T=1}^{N} \mathrm{ACF}(\tau)\mathrm{e}^{-i\omega t} = S\left(\frac{1}{2\pi f}\right) = f^{\beta}. \tag{3}$$

3. The relations of the black hole mass and radiation area, as well as luminosity

Blazar luminosity is generated by the central black hole mass accretion. The relationship between the luminosity and mass of the black hole is as follows:

$$L \sim \frac{GM_H\dot{M}}{r}. \tag{4}$$

$\dot{M}$ is the mass accretion rate, the relationship between the light variability time scale and black hole mass is (Xie *et al*. 2002)

$$\Delta t_{\min} = \tau\frac{r_G}{c} = 0.98\times 10^{-5}\left(\frac{M_H}{M_\theta}\right), \tag{5}$$

$$\tau = \pi(r_{o^{1.5}} + a)r_o = \frac{r}{r_G}. \tag{6}$$

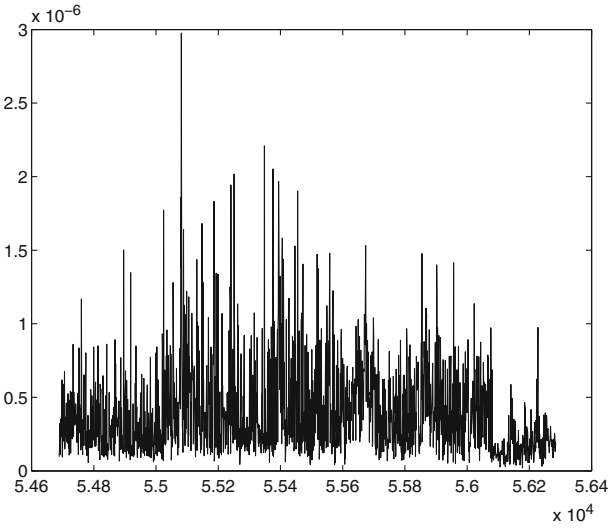

Figure 1. The Feimi-LAT daily light curve of OJ 287.

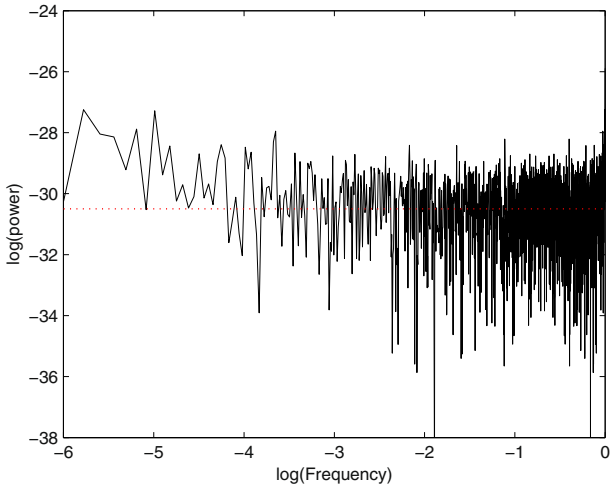

Figure 2. The power spectrum of the Fermi-LAT light curve of OJ 287. The linear fit is the red dashed line.

G is the gravitational constant, c is the speed of light, a is the rotational constant when t is equal to $t_{\min}$ which is equal to 2π. Taking into account the relativistic jet effect, AGNs minimum intrinsic time scale is (Xie *et al*. 2002)

$$\Delta t_{\min}(\text{in}) = \left[\frac{\sigma}{1+z}\right] \Delta t_{\min}(\text{ob}), \tag{7}$$

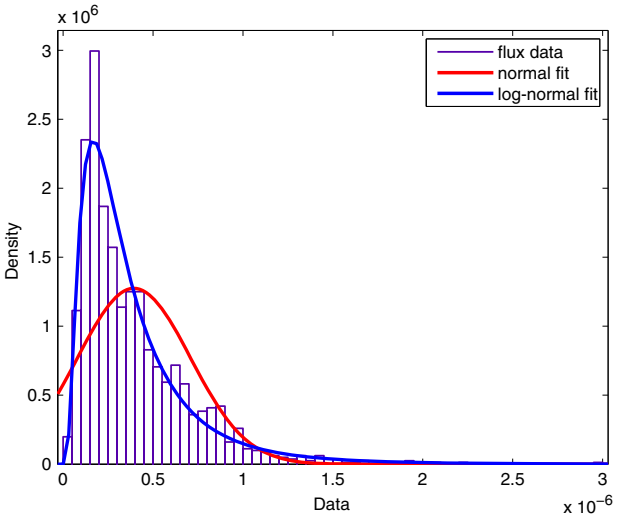

Figure 3. The histogram depicts the flux distribution of Fermi-LAT data. The blue line shows the case of log-normal fit. The red line is the normal fit of the flux.

which is known as the Doppler factor, the size of the region of the celestial radiation is

$$R \leq 0.2ct = c\left(\frac{\sigma}{1+z}\right)\Delta t_{\min}. \tag{8}$$

4. Summary

By using the method of Fourier transform for the unevenly sampled time series, we analysed the four-year Fermi-LAT γ-ray data of OJ 287. It is found that the variability is non-periodical and the γ-ray data neither belong to the red noise or the white noise. The statistical analysis reveals that the gamma-ray flux data follow a log-normal distribution well. Li and Fenimore (1996), found log-normal distributions for the peak fluence and peak time intervals of GRBs. Li and Gaskell (2004) also found the log-normal X-ray flux variation in an extremely narrow-line Seyfert 1 galaxy. A log-normal distribution of γ-ray fluxes suggests that the emitting regions could have a log-normal distribution, potentially any of the generating mechanisms could produce the required driving log-normal distributions. Although its physical meaning is not obvious, it is expected that this feature may contain an important clue to understanding the central engine of a blazar (Figures 1, 2 and 3).

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