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Article

The similarity of light curves of Fermi Blazars

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Abstract: Blazars show rapid and high amplitude variability. In this work , Fermi daily light curve of 130 sources are analyzed, distribution of daily variability are compared with each other by using Kolmogorov-Smirnov (K-S) test. results show: 1)Some pairs of the distributions are similar; 2) In most cases, the distributions are not Gaussian.

Keywords: galaxies:blazar; light curve; simulation

1. Introduction

Active galactic nuclei(AGNs) is a special object causing many astronomers' attention. As a very extreme subclass of AGN , blazars show many properties: rapid and high amplitude variability, high polarization, superluminal motion. Blazars are subdivided in two class,the Flat Spectrum Radio Quasars(FSRQS) and BL Lacertae objects (BL Lacs).FSRQS show strong emission line ,but BL Lacs show very weak emission lines or no emission lines. A more reasonable classification of blazars is based on the distribution of their peak frequency ν_p in the spectral energy distribution (SEDs) [1,2]. Abdo et al. extended the classication to all non-thermal dominated AGNs using new acronyms as low synchrotron peaked blazars (LSP, $\log \nu_p < 14$ Hz), intermediate synchrotron peaked blazars (ISP, $\log \nu_p = 14 \sim 15$ Hz), and high synchrotron peaked blazars (HSP, $\log \nu_p > 15$ Hz) [3]. Quite Recently, Fan et al. calculated the SEDs for a sample of 1425 Fermi blazars and obtained new results, LSP with $\log \nu_p < 14.0$ Hz; ISP with $\log \nu_p = 14.0 \sim 15.3$ Hz; HSP with $\log \nu_p > 15.3$ Hz [4].

2. Data and Methods

2.1. Daily light curves of Fermi sources

Data of sources could be downloaded from the website of LAT Monitored Source List Light Curves. Commonly, Fluxes of Fermi source is highly variable. Here, $F(t)$ denotes the flux at time t. Because the time interval of the flux F(t) is one day, the daily variable intensity of flux could be calculated by the formula

$$V_i = F(t_{i+1}) - F(t_i), \ \ i = 1, \dots N.$$

Here V_i is the daily variable intensity of flux. All V_i of a Fermi souce are gotted, then the mean μ and the standard deviation σ can be obtained by

$$\mu = \frac{1}{N}\sum_{i=1}^{N} V_i, \ \ i = 1, 2, \dots, N,$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(V_i - \mu)^2}{N}}, \ \ i = 1, 2, \dots, N.$$

Then , V_i are normalized,

$$X_i = \frac{(V_i - \mu)}{\sigma}, i = 1, 2, \dots, N$$

Here X_i is the normalized daily variable intensity of flux.

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2.2. Pairwise Comparison

When the new data set X_i is gotted, the cumulative distribution function (CDF) of X_i could be calculated. $SN(x)$ denote the CDF. $SN(x)$ is a function giving the fraction of data points to the left of a given value x. $SN(x)$ is constant between consecutive X_i , and add a constant $\frac{1}{N}$ at each X_i. (See Figure 1)

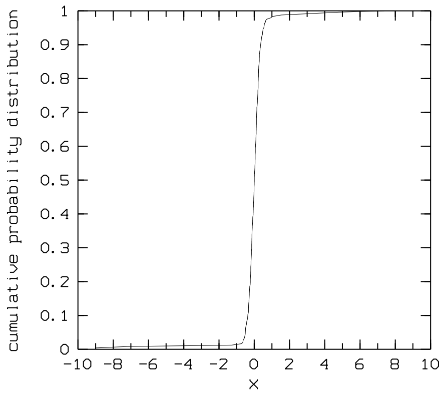
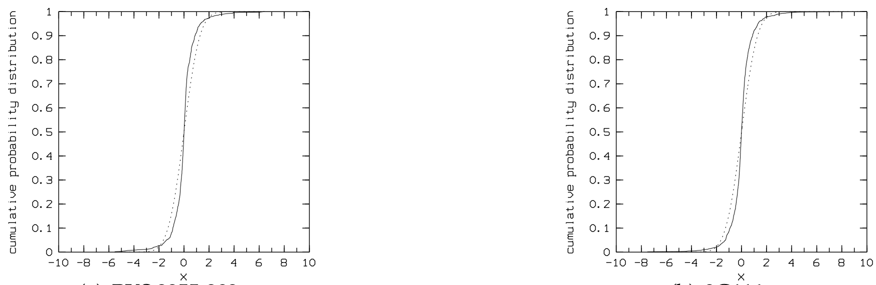


Figure 1. The step-function cumulative probability distribution $SN(x)$. $SN(x)$ rises a constant $\frac{1}{N}$ at each measured point.

The Kolmogorov-Smirnov (KS) test is used to make a comparison between each distribution of X_i with Gaussian distribution . The Kolmogorov-Smirnov D and the significance level can be obtained. As an example, for PKS 2255-282, D is 0.141579 ,the significance is 2.91×10^{-11}. For 3C 446, D is 0.136177 ,the significance is 4.63×10^{-24}. For PKS 2320-035, D is 0.192385 ,the significance is 1.56×10^{-29}. For CGRaBS J0211+1051, D is 0.190047 ,the significance is less than 10^{-45}. The cumulative probability distribution, shows in the bottom panel in Figure 2 and 3.



(a) PKS 2255-282 (b) 3C446

Figure 2. The cumulative probability distributions of PKS 2255-282 and 3C446.The solid line is the cumulative probability distributions of sources, the dotted line is the cumulative probability distributions of Gaussian distribution. The distribution of PKS 2255-282 and Gaussian distribution are same at the 2.91×10^{-11} level ,and the distribution of 3C446 and Gaussian distribution are same at the 4.63×10^{-24} level.

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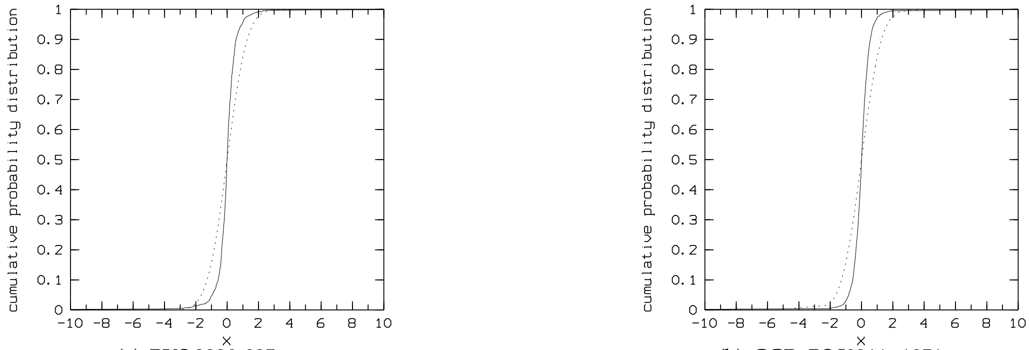

(a) PKS 2320-035 (b) CGRaBS J0211+1051

Figure 3. The cumulative probability distributions of PKS 2320-035 and CGRaBS J0211+1051.The solid line is the cumulative probability distributions of sources, the dotted line is the cumulative probability distributions of Gaussian distribution. The distribution of PKS 2320-035 and Gaussian distribution are same at the 1.56×10^{-29} level ,and the distribution of CGRaBS J0211+1051 and Gaussian distribution are same at the level less than 4.63×10^{-24} .

Then, the pairwise comparison is made between any two sources by using KS test. Figure 4 shows the cumulative probability distributions of PKS 2255-282 and 3C446. The distributions of PKS 2255-282 and 3C446 are similar at 94.3 percent level according to a KS test.

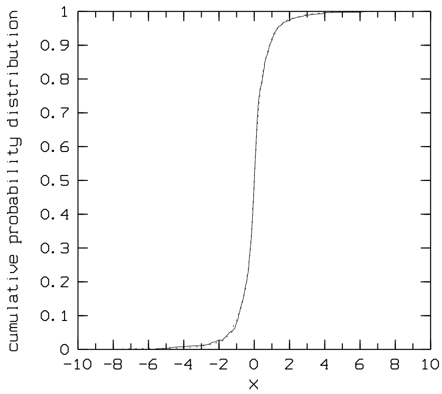

Figure 4. The cumulative probability distributions of PKS 2255-282 and 3C446.The solid line is the cumulative probability distribution of PKS 2255-282, the dotted line is the cumulative probability distribution of 3C446. The distribution of PKS 2255-282 and 3C446 are similar at 94.3 percent level according to a KS test.

The cumulative probability distributions of PKS 2320-035 and CGRaBS J0211+1051 ,is plotted in Figure 5, are also similar at 94.9 percent level according to a KS test.

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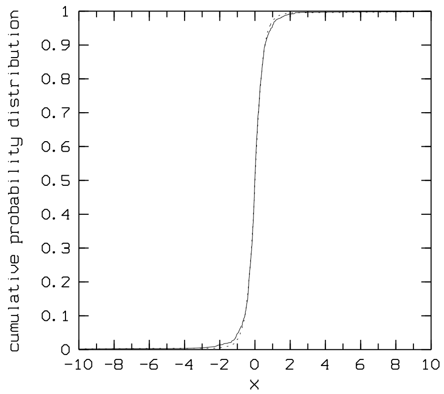

Figure 5. The cumulative probability distributions of PKS 2320-035 and CGRaBS J0211+1051.The solid line is the cumulative probability distribution of KS 2320-035, the dotted line is the cumulative probability distribution of CGRaBS J0211+1051. The distribution of PKS 2320-035 and CGRaBS J0211+1051 are similar at 94.9 percent level according to a KS test.

Based on the former results, the cumulative probability distribution of most sources is not Gaussian. The distribution of large deviation should be examined. Now we consider those measured data which belong to the top 20% and the last 20% of the sample X_i. $SN(x)$ could be approximated by the power function, respectively,

$$\begin{cases} SN(x) \propto (-x)^{-\alpha_{down}} & \text{x<0} \\ SN(x) \propto 1 - x^{-\alpha_{up}} & \text{x>0} \end{cases} \tag{1}$$

By using linear fitting, we can get the α_{dowm} and α_{up}. Totally 130 sources in the set, so we have 130 α_{dowm} and α_{up}. We plot all the α_{dowm} and α_{up}.(See Figure 6)

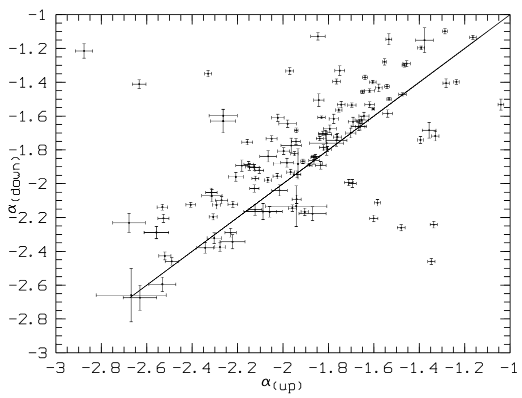

Figure 6. The comparation between α_{dowm} and α_{up}. The solid line indicates the locus of points with $\alpha_{dowm} = \alpha_{up}$.

3. Discussion

As we all know ,the flux measured is variable. We may think the variability is random. But the KS test tells us the distribution of the sample is not similar with the Gaussian distribution. So the variability of flux should connect with the internal physical mechanism.

When we make a comparison between any two samples ,we find that some groups of sources are very similar. Also, They are different from Gaussian distribution. So we think the same sources may have some same physical mechanism.

The distribution of sample is different from Gaussian distribution. so the probability density function is also different. In Figure6, most of the data points are up the line y=x. This means the absolute value of α_{up} is larger than α_{dowm}. So we can realize that the probability to get a positive value x is larger than the probability to get a negative value x' ($|x| = |x'|$). A positive value x means the flux rised, and a negative value x' means the flux fell, we can get a statistical result that the flux increase rapidly, but decrease slowly.

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Conflicts of Interest: The authors declare no conflict of interest.

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