PROCEEDINGS OF SCIENCE

Spectral classification and variation of Fermi GRBs

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The Fermi GBM catalog contains general physical quantities of the observed objects and also estimated parameters (peak energy, spectral indices, intensity) from four fitted spectral models (Band, smoothly broken power law, Comptonized, power law) for the peak flux and the fluence. We studied the nature of the errors of the peak flux, the fluence, and duration parameters. We have found a linear correlation between the logarithm of the measured quantities and their error bars. We interpret our results as an indication that the peak flux, fluence and duration follow a Poissonic distribution.

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1. Introduction

Gamma-ray bursts (GRBs) are the most powerful bursts in the far Universe. The timescale of these bursts varies on a wide range – from tens of milliseconds to thousands of seconds [1]. On the other hand, the phenomenological classification scheme would remain an open question. From the 80s we distinguish them on the basis of the burst duration: there are short and long GRBs [2]. It seems that short GRBs are caused by the collision of two massive stars, and hypernovas can explain long GRBs. Nowadays using multi-and uni-variate statistical analysis techniques an intermediate group was found [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. Moreover, more huge structures have been published recently which were created by GRBs: the Hercules-Borealis great wall at $z \approx 2$ [13, 14] and the GRB ring at $z \approx 0.8$ [15, 16]. The genesis of these structures is not known yet.

2. Data & Mathematical summary

The Fermi Gamma-ray Space Telescope (FGST) is a space observatory being used to perform gamma-ray astronomy observations from low Earth orbit since 2008. It has two instruments, the Large Area Telescope (LAT), and the Gamma-ray Burst Monitor (GBM). The GBM is used to study gamma-ray bursts; the data received by its 14 detectors (12 NaI and 2 BGO) are collected by a central Data Processing Unit (DPU) [17]. The database from the Fermi GBM detectors, the FERMIGBRST[1] catalog [18, 19] contains more than 2000 GRBs with several parameters such as position, durations, flux, fluences and spectral properties. These parameters were calculated from the light curves and spectral fitting. In the catalog the best fit model for both the peak flux of the burst ('pflx') and for the entire burst duration ('flnc') is also found. This model can belong in the power law, Comptonized, smoothly broken power law or Band spectral class.

Linear discriminant analysis (LDA) finds k – 1 canonical coordinates (k being the number of classes) that best separate the categories [20]. These functions – which are called discriminant functions – are uncorrelated and defined in effect, an optimal k – 1 space through the p-dimensional cloud of data separates (the projections in that space of) the k groups best. The biggest difference between the groups are shown by the first discriminant function. The subsequent functions show in order of relevance the maximum distance between the groups in the parametric space. We used LDA with Jackknifed Prediction from *'MASS'* package in R. Finally, we analyzed the errors of the parameters.

3. Results

We studied the relationship between the best fit spectral model and the GRB's model independent physical parameters – duration, flux, fluence – using LDA method [21] on the 'GOOD sample' (published by [18]). Taking into account all the data where the best model was available we found that at least the first discriminate function was significant on both the 'pflx' and 'flnc' spectral types ($sign.level < 2.2 \cdot 10^{-16}$). From the correlations between the discriminant functions and the input variables, the structure matrix we found that the flux and fluence were important parameters for the separation of the spectral classes but the durations were not. According to LDA the strongest

[1] https://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermigbrst.html

separator variable at the 'pflx' type is the Flux and at the 'flnc' type the Fluence. We found that the 'pflx' types could be separated better, even though the 'flnc' spectra has more photons.

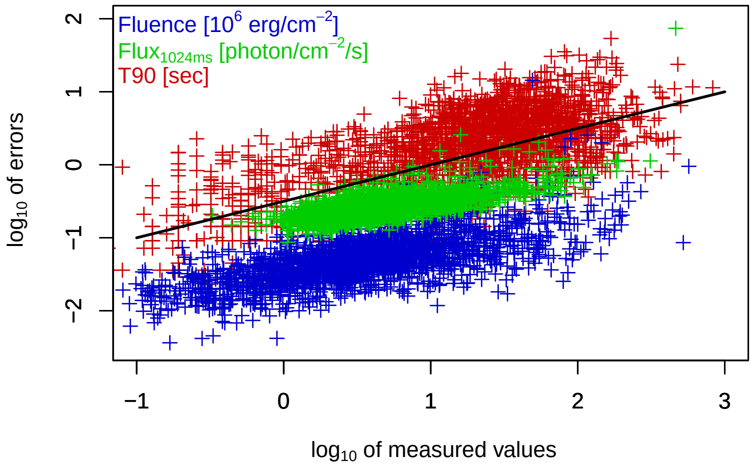

Figure 1: We examined the errors of the main physical parameters and found strong correlation – 0.68 ± 0.037 – between the errors and the measured values on logarithmic scale. The significant slope is $\approx 2:1$ which can be explained as a result of natural Poissonic noise.

For these anomalies we examined the errors of the main physical parameters because we thought that there is some kind of a systematic error in the examined parameters. Finally, we found a strong a significant correlation (0.68 ± 0.037) between the errors and the measured values on logarithmic scale Fig. 1. The significance was less than 10^{-5}. The property of the Poissonic distribution is that its expected value and its variance is equal [22], from which it follows that the standard deviation equals the square of the signal. The slope of this correlation was found at ≈ 0.5 which can be explained as a result of natural Poissonic noise.

4. Summary

We found that there is a strong linear correlation between the Fermi GBM parameters and the errors of the main physical parameters. We interpreted these results as a Poissonic noise because the expected value equal the variance for the Poissonic distribution. We showed that these physical parameters (fluxes, fluences and durations) could discriminate between the spectral classes and the peak flux type spectra was better separable.

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