



## Classification of Fermi Gamma-RAY Bursts

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The Fermi GBM Catalog has been recently published. Previous classification analyses of the BATSE, RHESSI, BeppoSAX, and Swift databases found three types of gamma-ray bursts. Now we analyzed the GBM catalog to classify the GRBs. PCA and Multiclustering analysis revealed three groups. Validation of these groups, in terms of the observed variables, shows that one of the groups coincides with the short GRBs. The other two groups split the long class into a bright and dim part, as defined by the peak flux. Additional analysis is needed to determine whether this splitting is only a mathematical byproduct of the analysis or has some real physical meaning.

*Gamma-Ray Bursts 2012 Conference -GRB2012,*

*May 07-11, 2012*

*Munich, Germany*

## 1. Introduction

Accumulating evidence indicates that GRBs represent a mixture of objects of different physical natures. Classification of GRBs in the parameter space of their observable properties may give information on the number and physical nature of types of these objects. Mazets et al. [16] and Norris et al. [19] suggest that there might be a separation in the duration distribution. In the First BATSE Catalog, a bimodality was found in the logarithmic duration distribution [12]. Today it is widely accepted that the physics of these two groups (*long* and *short* GRBs) are different, and these two kinds of GRBs represent different phenomena ([2], [4], [20], [27]). Zhang et al. [28] uses Type I. and II. classification based on the progenitor models.

In a previous paper using the Third BATSE Catalog Horváth [7] has shown that the duration ( $T_{90}$ ) distribution of GRBs observed by BATSE could be well fitted by a sum of three log-normal distributions. Simultaneously, Mukherjee et al. [18] reported the finding (in a multidimensional parameter space) of a very similar group structure of GRBs. Somewhat later several authors ([1], [3], [5], [6], [14], [22], [25]) included more physical parameters into the analysis of the bursts (e.g. peak-fluxes, fluences, hardness ratios, etc.). The physical existence of the third group is, however, still not convincingly proven. However, the celestial distribution of the third group is anisotropic ([13], [15], [17], [26]). All these results mean that the existence of the third *intermediate* group in the BATSE [9], RHESSI [23], BeppoSAX [8] and Swift [10] [11] sample is acceptable, but its physical meaning, importance and origin is less clear than those of the other groups. Hence, it is worth to study new samples if their size is large enough for statistics. In this paper we use the new Fermi catalog [21] data for this analysis.

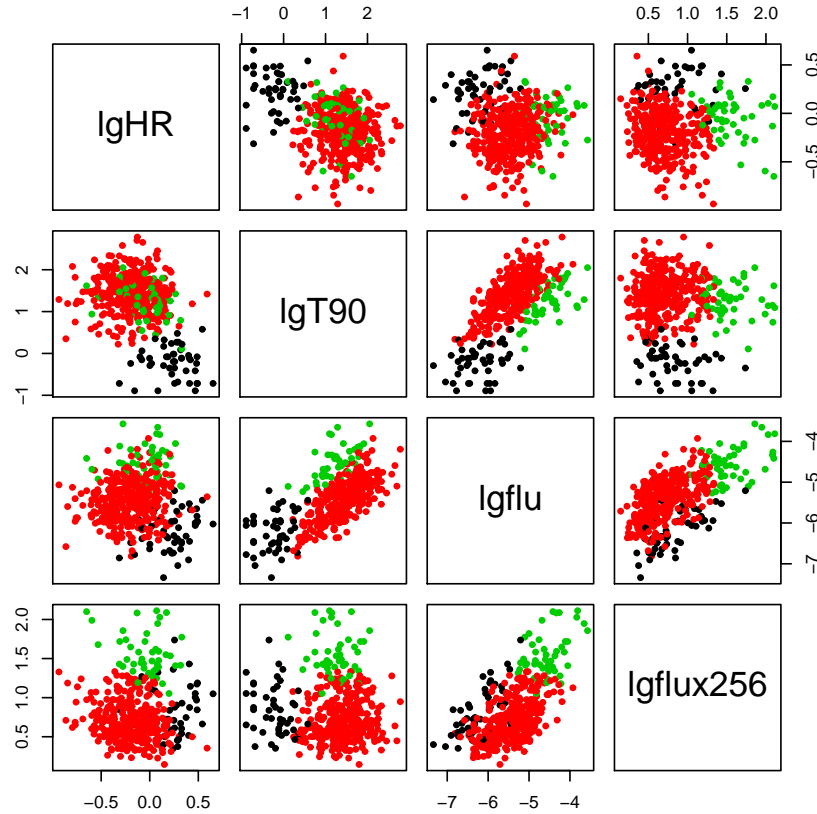
## 2. Analysis of the Fermi GMB data

The Fermi GRB catalog [21] contains 490 GRBs, we used 425 GRBs which had no huge errors in the observed parameters. From the Catalog we used the following variables  $T_{90}$ , total fluence, hardness ratio and peakflux256. Using the correlation matrix we made a Principal Component Analysis (PCA). The eigenvalues are 1.915, 1.305, 0.725 and 0.055. The computations were made with the R statistical package.

After PCA we used *Mclust*, the clustering algorithm fitting of a functional model superposed from Gaussian components. Optimizing the number of the components and their parameters is the task of the procedure. Since the first 3 PC represent 98.8 % of the total variance of the Fermi data, respectively, we kept 3 PCs as input variables for the Mclust procedure. This choice is reasonable because the first 3 PCs account for the vast majority of the variances of the observed variables, used in the analysis (PC1 accounts mainly for  $\lg T_{90}$  and  $\lg$ fluence, PC2, PC3 do it for  $\lg$ HR and  $\lg$ p256). The best fitting model is a three component Gaussian, coded by 'EEE', meaning equal volumes, equal shapes and parallel axes of the error ellipses. To study the impact of classifications on the input data we computed cluster membership of the bursts and used as a color code in a matrix plot displaying the dependencies among the observed variables (Figure 1.).

## 3. Conclusion

The logarithmic duration, fluence, hardness and peakflux variables can be well represented



**Figure 1:** The color coded three groups in the Fermi data. The black circles are the short, the red and green ones are the long GRBs. Green circles are the brighter bursts among the long ones.

by three PCs obtained from PCA of the correlation matrix. The PC1 accounts for the duration and fluence while PC2, PC3 do it for the hardness and peakflux. The best fit of a model family of superposed multivariate Gaussian functions revealed three groups. Validation of these groups, in terms of the observed variables, showed that one of the groups coincides with the short GRBs. The other two ones split the long group into a bright and dim part according to the peak flux; a result similar to this has been found previously for BATSE data [24]. Further analysis is needed to determine whether this splitting is only a mathematical byproduct of the analysis or whether it has some real physical meaning.

## Acknowledgments

This work was supported by the Hungarian OTKA-77795 grant. JH acknowledges support from NASA-AISRP NNX09AK60G and NASA-ADAP NNX09AD03G.

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