SWIFT and BATSE Bursts' Classification

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Abstract: Two classes of gamma-ray bursts were identified in the BATSE catalogs characterized by their durations. There were also some indications for the existence of a third type of gamma-ray bursts. Swift satellite detectors have different spectral sensitivity than pre-Swift ones for GRBs. Therefore we reanalyze their duration distribution. In this poster we analyze the bursts' duration distribution and also the duration-hardness bivariate distribution, published in The First BAT Catalog. Similarly to the BATSE data, to explain the BAT GRBs' duration distribution three components are needed. Although, the relative frequencies of the groups are different than they were in the BATSE GRB sample, the difference in the instrument spectral sensitivities can explain this bias in a natural way. This means theoretical models may have to explain three different type of gamma-ray bursts.

Introduction

It has been a great challenge to classify gamma-ray bursts (GRBs). Mazets et al. (1981) and Norris et al. (1984) suggested there might be a separation in the duration distribution. Using The First BATSE Catalog, Kouveliotou et al. (1993) found a bimodality in the distribution of the logarithms of the durations. In that paper they used the parameter T90 (the time in which 90% of the fluence is accumulated) to characterize the duration of GRBs. Today it is widely accepted that the physics of these two groups are different, and these two kinds of GRBs are different phenomena (Norris et al. 2001, Balázs et al. 2003, Fox et al. 2005, Zhang et al. 2007). Zhang et al. 2009 uses Type I. and II. classification based on the progenitor models. In the Swift database the measured redshift distribution for the two groups are also different, for short burst the median is **0.4** and for the long ones it is **2.4** (Bagoly et al. 2006).

In a previous paper using the Third BATSE Catalog Horváth (1998) have shown that the duration (T_{90}) distribution of GRBs observed by BATSE could be well fitted by a sum of three log-normal distributions. We find it statistically unlikely (with a probability 10^{-4}) that there are only two groups. Simultaneously, Mukherjee et al. (1998) report the finding (in a multidimensional parameter space) of a very similar group structure of GRBs. Somewhat later several authors (Hakkila et al. 2000, Balastegui et al. 2001, Rajaniemi & Mahonen 2002, Hakkila et al. 2003, Borgonovo 2004, Chattopadhyay et al. 2007) included more physical parameters into the analysis of the bursts (e.g. peak-fluxes, fluences, hardness ratios, etc.). A cluster analysis in this multidimensional parameter space suggests the existence of the third ("intermediate") group as well (Mukherjee et al. 1998, Hakkila et al. 2000, Balastegui et al. 2001). The physical existence of the third group is, however, still not convincingly proven. However, the celestial distribution of the third group is anisotropic (Mészáros et al. 2000, Litvin et al. 2001, Maglioccetti et al. 2003, Vavrek et al. 2008). All these results mean that the existence of the third intermediate group in the BATSE 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 the HETE-II database (Vanderspek et al. 2004) there are only 104 GRBs and in the Swift first BAT database (Sakamoto et al. 2008) there are 237 GRBs. Therefore, in this poster we use the Swift data because of its better statistics.

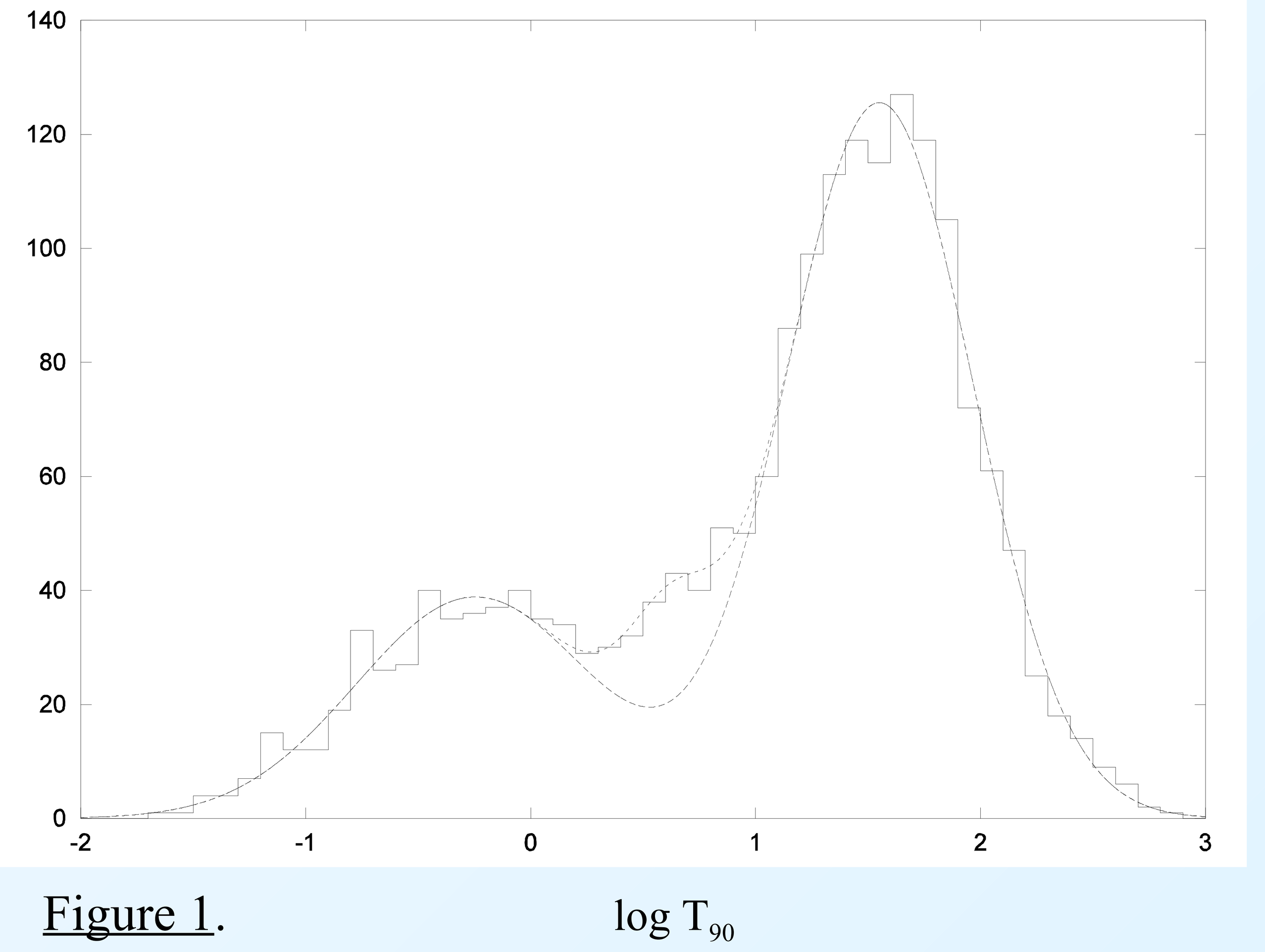

Figure 1.   log T_{90}

LOG-NORMAL FITS FOR DURATION DISTRIBUTIONS

Similarly to Horváth 2002 we fit the log T_{90} distribution using Maximum Likelihood (ML) method with a superposition of *k* log-normal components, each of them having 2 unknown parameters to be fitted with N=**222** measured points in our case (In the Swift First BAT Catalog there are 237 GRBs, of which 222 have duration information(Sakamoto et al. 2008). For the distribution see Fig. 2.). Our goal is to find the minimum value of *k* suitable to fit the observed distribution. Assuming a weighted superposition of *k* log-normal distributions one has to maximize the following likelihood function:

$$L_k = \sum_{i=1}^{N} \log\left(\sum_{l=1}^{k} w_l f_l\left(x_i, \log T_l \sigma_l\right)\right) \quad (1)$$

where w_l is a weight, f_l a log-normal function with log T_l mean and σ_l standard deviation having the form of

$$f_l = \frac{1}{\sigma_l \sqrt{2\pi}} \exp\left(-\frac{\left(x - \log T_l\right)^2}{2\sigma_l^2}\right) \quad (2)$$

and due to a normalization condition.

The three-Gaussian fit is shown in Figure 2. The best parameters were published in Horváth et al. 2008. For the comparison of this result Figure 1. shows the best two and three-Gaussian fits for the BATSE data (1929 GRB).

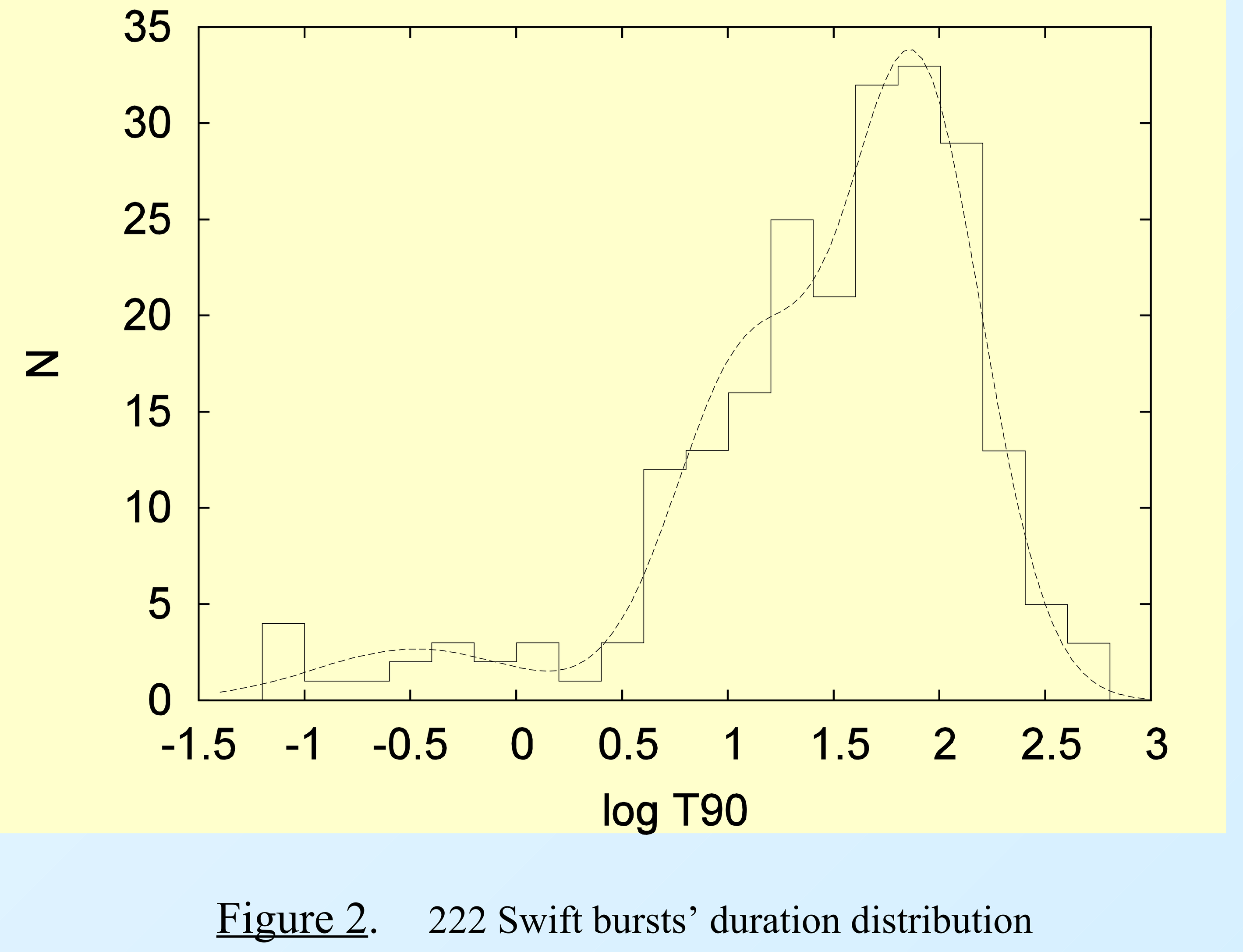

Figure 2.   222 Swift bursts' duration distribution and the best 3-Gaussian fit

One can use more parameters for classification. The analysis of the clustering properties of GRBs in the BATSE 3B Catalog Mukherjee et al. (1998) identified the following measured quantities relevant for classification: duration, total fluence and hardness. Fitting the observed distribution with the superposition of Gaussian components one had to keep the number of estimated parameters as small as possible to ensure the stability of the Maximum Likelihood procedure, therefore we decided to use two dimensional Gaussians with the logarithmic duration and hardness. This work for the BATSE data was done by Horváth et al (2006) (Figure 3. shows the result).

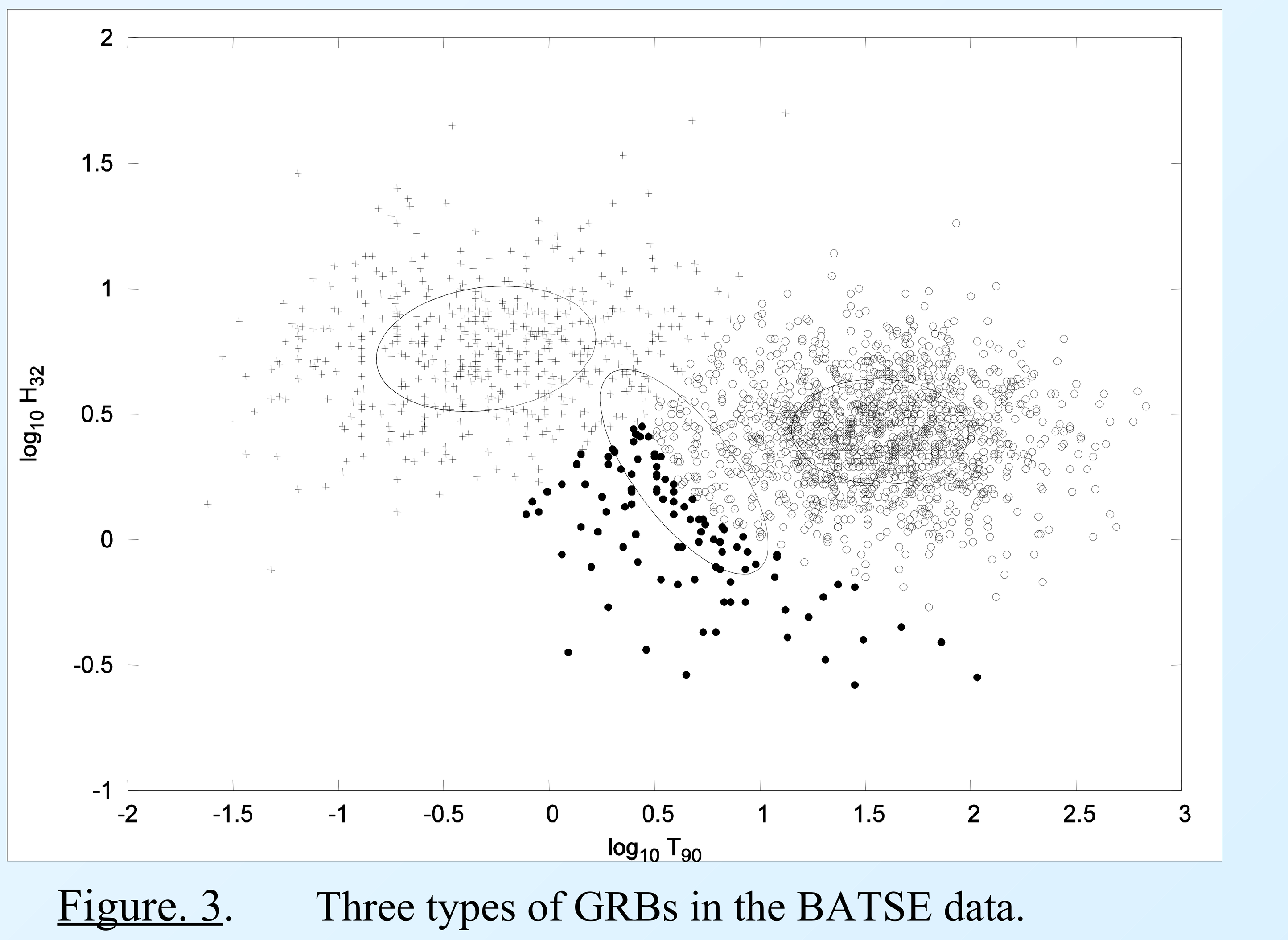

Figure. 3.   Three types of GRBs in the BATSE data.

Table 1.

Duration ($\log T_{90}$)	*w* (Swift)		Duration ($\log T_{90}$)	*w* (BATSE)
-0.479	7.5 %	Short	- 0.301	24.5 %
1.754	65 %	Long	1.565	64.5 %
0.991	27.5 %	Intermediate	0.637	11 %

Now we use the Swift First BAT catalog and made 2D Gauusian fits in the duration hardness plane. Figure 4 shows the result (black=short, red=interm. green=long bursts). In Table 1. we compare the results of the Swift and BATSE data.

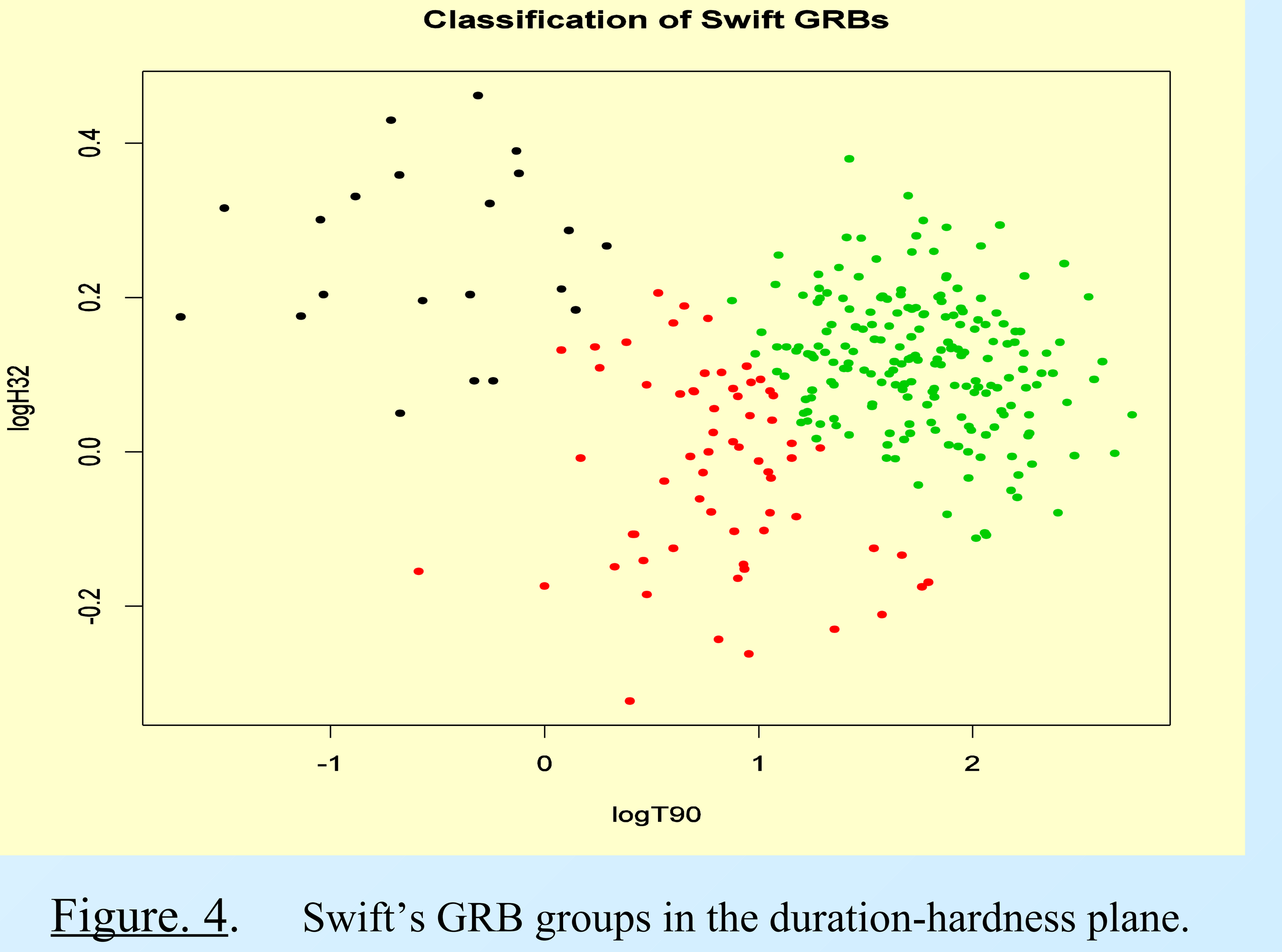

Figure. 4.   Swift's GRB groups in the duration-hardness plane.

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