Investigation on the Bimodal Distribution of the Duration of Gamma-ray Bursts from BATSE Light Curves

Wenfei Yu, Tipei Li, and Mei Wu
Laboratory for Cosmic Ray and High Energy Astrophysics
Institute of High Energy Physics
Chinese Academy of Sciences
P.O.Box: 918-3
Beijing, 100039
P. R. China

Email: yuwf@astrosv1.ihep.ac.cn

Abstract. We have investigated the bimodal distribution of the duration of BATSE gamma-ray bursts (GRBs) by analyzing light curves of 64 ms time resolution. We define the average pulse width of GRBs from the auto-correlation function of GRB profiles. The distribution of the average pulse width of GRBs is bimodal, suggesting that GRBs are composed of long-pulse GRBs and short-pulse GRBs. The average pulse width of long-pulse GRBs appears correlated with the peak flux, consistent with the time dilation effect anticipated from the cosmological origin of GRBs. However, the correlation between the average pulse width and the peak flux for the short-pulse GRBs doesn’t show such a tendency, which needs further study with higher time resolution data.

1. Introduction

The distribution of the duration of gamma-ray bursts shows an indication of two distinct groups from earlier experiments[^1].[^2][^3][^4]. Data from Burst and Transient Source Experiment (BATSE) have confirmed the bimodal distribution of the duration of gamma-ray bursts. In terms of the parameter T90, which is the time interval during which the integrated counts of a burst go from 5% to 95% of the total integrated counts, the bursts are separated into two groups around T90 ∼ 2 s[^5]. Time dilation, an evidence for the cosmological origin of GRBs, was found in the long GRBs[^6]. It is not yet known whether the two kinds of bursts are different or not.

A recent study on the pulses in GRBs suggests that the duration of the equivalent width of each pulse and the mean duration of individual pulse are bimodal[^7]. In this paper, we present a different approach to investigate the average pulse width of GRBs.

2. Data Preparation and Pulse Width Definition

Light curves of the BATSE GRBs in 4B catalogue are studied. The light curves are from concatenated DISCLA, PREB and DISCSC data, and were obtained from
Compton Observatory Science Support Center (COSSC). They have been arranged into 64 ms time bins. First we subtract BATSE background from GRB light curves. The BATSE background were estimated by a 5-degree polynomial. The total number of GRBs with visually acceptable background estimate is 1186. Then we calculate the average pulse width $T_P$ of each GRB as follows.

![Figure 1](image_url)

**Figure 1.** The auto-correlation coefficients of BATSE trigger 143. The shaded area corresponds to the data used to calculate $T_P$.

First we calculate the auto-correlation of the light curve of each GRB. The auto-correlation coefficients of the GRB, $A(i)$, are defined as follows:

$$A(i) = \frac{\sum_{k=0}^{N-i-1} (X_k - \bar{X})(X_{k+i} - \bar{X})}{\sum_{k=0}^{N-1} (X_k - \bar{X})^2}$$

where $A(i)$ ($i = 0, ..., N - 1$) the auto-correlation coefficient at $i \delta t$. We define the average pulse width $T_P$ as

$$T_P = 2.0 \times \sqrt{\frac{\sum_{k=1}^{M} k^2A(k) + (0.25)^2A(0)}{\sum_{k=0}^{M} A(k)}} \delta t$$

where 0.25 represents the average time shift of the central bin of the auto-correlation coefficient $A(0)$, and $M$ the maximum of $i$ with $A(i-1)+A(i)$ no less than 0.0 in the main peak of the auto-correlation.

The auto-correlation coefficients of BATSE trigger No.143 is shown in Fig.1. The data in the shaded region is used to calculate $T_P$. We calculate $T_P$ of each GRB and study the distribution of the average pulse width of the 1186 GRBs.

3. Results

We have obtained the following results from the study of the average pulse width $T_P$
• The distribution of $T_P$ of GRB is bimodal. This suggests that the average pulse width is bimodally distributed, and GRBs can be divided into two groups, namely shot-pulse bursts and long-pulse bursts. The distribution of $T_P$ is peaked at about 0.5 s and 14 s for the two groups, respectively. They are roughly separated around 2 s. This is shown in Fig.2.

• The average pulse width of the dim long-pulse bursts are longer than the bright long-pulse bursts. However, the average pulse width of the short-pulse bursts does not show a simple relation with GRB peak flux. This is shown in Fig.3.

4. Summary

We have presented our preliminary analyses of 1186 BATSE GRB light curves in order to study the bimodal distribution of the duration of GRBs. We conclude

• The duration of the average pulse width in GRBs are bimodally distributed. This is consistent with a different approach (Mitrofanov et al. 1998).

• Long-pulse bursts show the evidence for the time dilation effect. This isn’t shown for the short-pulse bursts. Further study of the short-pulse bursts is need, and probably need to include correction of the BATSE selection effect and to study short GRBs with high time resolution TTE data.

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References

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Figure 3. \( T_P \) vs. Peak Flux of long-pulse bursts \((T_P > 2 \text{ s})\) (bottom) and short-pulse bursts \((T_P < 2 \text{ s})\) (top). Both short-pulse GRBs and long-pulse GRBs are divided into 4 groups according to their peak fluxes. The median, instead of the mean, of \( T_P \) of each group, is shown in the figure. The error on the median is derived from bootstrap method.

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