Temporal properties of the short gamma-ray bursts

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A temporal analysis has been performed on a sample of 100 bright gamma-ray bursts (GRBs) with $T_{90} < 2$s from the BATSE Current Catalog. The GRBs were denoised using a median filter and subjected to an automated pulse selection algorithm as an objective way of identifying the effects of neighbouring pulses. The rise times, fall times, FWHM, pulse amplitudes and areas were measured and the frequency distributions are presented here. All are consistent with lognormal distributions. The distribution of time intervals between pulses is not random but consistent with a lognormal distribution. The time intervals between pulses and pulse amplitudes are highly correlated with each other. These results are in excellent agreement with a similar analysis that revealed lognormal distributions for pulse properties and correlated time intervals between pulses in bright GRBs with $T_{90} > 2$s. The two sub-classes of GRBs appear to have the same emission mechanism which is probably caused by internal shocks. They may not have the same progenitors because of the generic nature of the fireball model. Gamma rays – bursts: Gamma rays – observations: Methods – data analysis: Methods – statistical

Introduction

It has been recognised that GRBs may occur in two sub-classes based on spectral hardness and duration with $T_{90} > 2$s and $T_{90} < 2$s kmf:1993, dbt:1995, paciessas:2001. The bimodal distribution can be fit by two Gaussian distributions in the logarithmetic durations mhln:1994. There is significant evidence for a third subgroup as part of the long duration GRBs mfb:1998, horv:1998 but this has been questioned because of a possible BATSE selection effect hhp:2000. It has been suggested cmo:1999 that the small group of GRBs with $T_{90} < 0.1$ s form an additional category. The short GRBs have a higher value of $\langle V/V_{\text{max}} \rangle$ kc:1996, a much smaller value of the spectral lag nsb:2000, a pulse shape that depends on position in the burst gunpta:2000 and a smaller space density than long GRBs schmidt:2001.

A variety of statistical methods have been applied to the temporal properties of GRBs with $T_{90} > 2$s. It is important to compare the temporal profiles of the long and short GRBs to determine the similarities and differences between the two classes in an objective way. A detailed objective analysis has been performed on the temporal profiles of a large sample of 319 bright GRBs with $T_{90} > 2$s quillig:2001, hmq:1998. The properties of the pulses in GRBs and the time intervals between them were found to be consistent with lognormal distributions. These results can be used as templates for comparison with a similar analysis of GRBs with $T_{90} < 2$s.

The analysis method is presented in section 2 and the results in section 3. In section 4 the results are discussed and compared with the long GRBs.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median</th>
<th>$\sigma$</th>
<th>$\pm50%$</th>
<th>KS ($\tau_\sigma \geq 8$, $\tau_i \geq 80%$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time</td>
<td>0.035</td>
<td>-3.31</td>
<td>0.94</td>
<td>0.012-0.11 0.48 0.16</td>
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Data Preparation

The parameters of the pulse properties in GRBs include the median value for the data, the median $\mu$ and the standard deviation $\sigma$ expressed as natural logarithms, the width of the lognormal distributions at the $\pm 50\%$ level in normal space, the KS probability that properties of pulses selected at different levels of $\tau_\sigma$ and $\tau_i$ were drawn from the same distribution as those selected at $\tau_\sigma \geq 5$, $\tau_i \geq 50\%$. All pulses with $\tau_\sigma \geq 5$ were used for the time intervals and not just isolated pulses. The values for the pulse areas and amplitudes were obtained from 55 GRBs that were summed over two BATSE Large Area Detectors. 0.3cm tabular|b|ccccccc 0.1cm Property Median $\mu$ $\sigma$ Width ($\pm50\%$) KS ($\tau_\sigma \geq 3$, $\tau_i \geq 20\%$) KS ($\tau_\sigma \geq 8$, $\tau_i \geq 80\%$)

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Data Preparation

The dataset was taken from the BATSE current catalog. The time tagged event data at 5 ms resolution was used. The data from the four energy channels were combined into a single channel to maximize the signal-to-noise ratio. These GRBs were ordered according to their peak flux in 256 ms ($P_{256\text{ms}}$) and the first 100 bursts without data gaps and with 5 ms audio available for the complete burst were selected. All GRBs in the sample had $P_{256\text{ms}} > 1.6$ photons cm$^{-2}$s$^{-1}$.

Background subtraction

The first step in the data preparation involved selecting the appropriate background for subtraction. The start and end times for each burst were identified. A background section was then identified which was usu-
ally after the main section of the GRB. If 5 ms was available for the background level estimation, it was used, otherwise a median filter was used to denoise the GRBs. This denoises a signal by finding the median of each bin. The best denoised signal was found by varying the bin size and the value of $\sigma$. The wavelet method quillig:2001 was not used because the short durations of the GRBs produced a smaller number of data points than that required for our wavelet method.

The pulse selection method was described elsewhere quillig:2001. The pulses selected had a threshold of 5 $\sigma$ ($\tau_\sigma \geq 5$) and isolated from adjacent pulses by at least 50% ($\tau_\iota \geq 50\%$). A value of $\tau_i \geq 50\%$ implies that the two minima on either side of the pulse maximum must be at or below half the maximum value. A total of 313 pulses were selected with $\tau_\sigma \geq 5$ and 181 of these had $\tau_i \geq 50\%$.

Results

Distributions of $t_r$, $t_f$, FWHM, pulse area, pulse amplitude and $\Delta T$ The distribution of the number of pulses with $\tau_\sigma \geq 5$ is given in Fig. 1. The median value of the number of pulses per GRB is 2.5 and is smaller than the value of 6 for long GRBs quillig:2001. The distributions of rise time $t_r$, fall time $t_f$ and full width at half maximum (FWHM) for the isolated pulses are presented in Fig. 2 along with the lognormal fits to the data. The distributions of pulse amplitudes and areas are presented in Fig. 3 for the isolated pulses. The distribution of time intervals between pulses with $\tau_\sigma \geq 5$ is given in Fig. 4.

figure[hbp] xlab[Number of Pulses] ylab[Number of GRBs] 2em [width=0.85]Dh291p1.epsfig : grbspulses .5em The number of pulses versus number of $\gamma$-ray bursts.