

Morphological properties of short duration Gamma Ray Bursts

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Abstract. In this paper, we study a sample of short duration bursts contained in the 3B BATSE catalogue. We fit the time profiles of these GRBs with lognormal functions and study various temporal properties of these objects. In most of the mutipeaked bursts, we find that the temporal asymmetry of individual pulses evolves with time i.e. subsequent pulses tend to be more symmetric.

Key words : GRBs, lognormal functions, rise and decay times

1. Introduction

With the detection of afterglows in radio, optical and X-ray from several gamma ray burst events as well as with the measurement of redshifts corresponding to a few of these transient sources, there has been a tremendous enhancement in the understanding of GRBs (e.g. Metzger et al., 1997; Waxman, 1997; Kulkarni et al., 1998). In particular, if the redshift estimates are correct, the extragalactic nature of GRBs stands confirmed, settling a three decade old controversy. However, as far as gamma emission is concerned, the diversity in time-profiles, spectral variability, duration etc. observed with regard to GRBs still poses a major challenge to the theoretical models. For most GRBs, the gamma-ray time history shows complex structures with several peaks. A proper understanding of the origin of peaks is still lacking, although many ideas have been proposed in the literature (e.g. Shaviv & Dar, 1995; Fenimore, Madras & Nayakshin, 1996; Sari & Piran, 1997). As a step to study such peaks in a systematic manner we direct our attention, in this paper, to short duration GRBs (T_{90} less than 2 seconds) and analyse their temporal properties after fitting the gamma ray time-history of each burst with a collection of lognormal functions.

2. Lognormal fits and data analysis

Table 1. Value of r_{rd} of subsequent pulses averaged over bursts with same Complexity Index. $\langle r_{rd} \rangle_i$ is the average r_{rd} of i^{th} peak in a burst, $i=1$ to 5.

burst sample	$\langle r_{rd} \rangle_1$	$\langle r_{rd} \rangle_2$	$\langle r_{rd} \rangle_3$	$\langle r_{rd} \rangle_4$	$\langle r_{rd} \rangle_5$
$CI = 1$	$.29 \pm .14$				
$CI = 2$	$.46 \pm .24$	$.57 \pm .27$			
$CI = 3$	$.44 \pm .21$	$.76 \pm .14$	$.77 \pm .18$		
$CI = 4$	$.41 \pm .24$	$.79 \pm .19$	$.85 \pm .06$	$.69 \pm .15$	
$CI = 5$	$.48 \pm .23$	$.63 \pm .23$	$.73 \pm .10$	$.85 \pm .08$	$.84 \pm .12$

Individual peaks in most GRBs exhibit a rapid rise and slow decay, and therefore, it is convenient to fit each such peak with a lognormal function,

$$C(t) = \frac{N}{t\sqrt{2\pi\sigma}} \exp\{-(\log t - \mu)^2/2\sigma^2\}, \quad (1)$$

where $C(t)$ is the photon counts in the peak at time t while N , μ and σ are the associated free parameters that are fixed after obtaining a best fit. To begin with, the position of a peak is taken to be the point at which the first differential of the time history goes from positive to negative. A low pass filter is applied several times to eliminate spurious peaks arising out of background noise. Having identified the genuine burst peaks, a reduced χ_v^2 is calculated after making an initial estimate of free parameters for each peak, and then these parameters are changed slowly from their initial values till χ_v^2 comes down to 0.1 percent of its original value. The fit is accepted only if the final χ_v^2 is close to 1 (for details, see Gupta et al. 1999). The best fit parameters are then used to calculate the following quantities associated with a given burst :

(1) Burst Complexity Index (CI) : This is defined as the number of peaks detected in a given burst. We find that bursts with higher CI are less in number, and that average value of CI is 2.48 implying that on an average the bursts have 2 to 3 peaks.

(2) Risetime (t_r) : Risetime of a peak is taken to be the time interval during which the value of the fitted lognormal function increases from 5% to 95% of its maximum value.

(3) Decaytime (t_d) : Decaytime is the time interval during which the fitted counts in the peak falls from 95% to 5% of its maximum value.

(4) r_{rd} : r_{rd} is defined as the ratio of t_r to t_d . Since, most GRBs lack redshift information, use of this ratio in the analysis has a merit in the sense that because of the cancellation of stretching of t_r and t_d due to cosmological expansion, r_{rd} is independent of burst redshift. We compute this ratio for the first peak, second peak and so on for all bursts with a given CI, and then consider the average value of r_{rd} corresponding to first, second and so on. Since, r_{rd} does not depend on the distance of the GRB event, any systematic trend exhibited by the value of

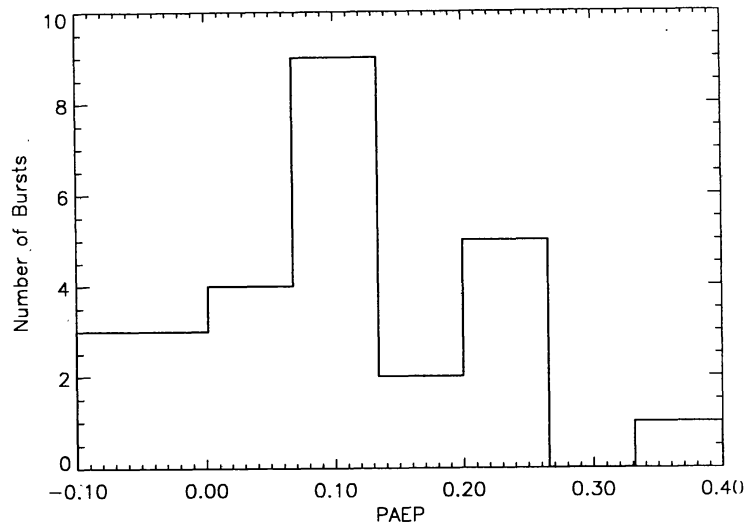


Figure 1. Histogram of PAEP shows that 24 out of 27 bursts are associated with a positive PAEP, reinforcing the conclusion that peaks tend to become more symmetric with time

r_{rd} averaged over different bursts with a given CI has a physical significance. The results have been summarized in Table 1. It is evident from the table that later peaks tend to be more symmetric than the earlier ones in a monotonic fashion.

(5) **Peak Asymmetry Evolution Parameter (PAEP)** : In order to study the evolution of r_{rd} within a burst, we plot r_{rd} against the peak number for bursts with $CI \geq 3$ (27 of them) and fit with a straight line. PAEP is defined to be the slope of the fitted line - a positive value indicates that the peaks in the corresponding burst tend to become more symmetric as time evolves. In our analysis, we find that PAEP is positive in 24 cases out of 27 bursts, while only 3 bursts show negative values for PAEP. We provide a histogram of PAEP in Fig. 1 The average PAEP observed for bursts with $CI \geq 3$ is $.127 \pm .116$ while the histogram attains its maximum value when $PAEP \sim 0.1$.

3. Conclusion

Short duration GRBs exhibit a strong evolutionary trend - later peaks tend to assume a more symmetric time profile. This is seen both on an average in bursts with any CI (as is apparent from table 1) as well as in individual bursts, evident from the first fact that PAEP is positive in 90% of the cases studied.

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