Extended Emission of Short Gamma-Ray Bursts

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Abstract

Preliminary results of our analysis on the extended emission of short/medium duration GRBs observed with Swift/BAT are presented. The Bayesian blocks algorithm is used to analyze the burst durations and the temporal structure of the lightcurves in different energy bands. We show here the results of three bursts (GRBs 050724, 061006 and 070714B) that have a prominent soft extended emission component in our sample. The extended emission of these bursts is a continuous, flickering-liked component, lasting ~ 100 seconds post the GRB trigger at 15-25 keV bands. Without considering this component, the three bursts are classified as short GRBs, with \( T_{90} \approx 2 \sim 3 \) seconds. GRB 060614 has an emission component similar to the extended emission, but this component has pulse-liked structure, possibly indicating that this emission component is different from that observed in GRBs 050724, 061006, and 070714B. Further analysis on the spectral evolution behavior of the extended emission component is on going.

Keywords: Gamma-ray bursts

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Introduction

The Swift satellite now is leading a new era in the short GRB study, and rapid progress has been made. The precise localization led to redshift measurement and host galaxy connection for this class of GRBs, favoring mergers of compact object binaries as the progenitors of the short GRBs [5][11]. However, a soft, extended emission component following early hard spikes observed in the light curves of some short GRBs challenges the models and blurs the clear picture of long-short classification of GRBs with a division line at \( T_{90} = 2 \) seconds. The extended emission lasts tens of seconds[10]. It was observed by CGRO/BATSE [6] and HETE-2 [2]. We present a systematic analysis of this emission component with Swift/BAT observation from both spectral and temporal features, focusing on the issue if the extended emission is a distinguished component from the hard spikes. The Bayesian blocks (BB) method [7] is used to analyze the BAT light curves and to calculate the duration of the burst in different energy bands. The time-resolved spectral analysis for this emission component is also on going.

Data and Method

The Swift/BAT data are downloaded from the NASA Swift Archive. We deduce the BAT data with our code by using the standard BAT tool[4]. Since the energy band of BAT is 15-150 keV, we derive the BAT lightcurve in four energy bands, i.e., 15-25 keV 25-50 keV, 50-100 keV and 100-150 keV, and fit the observed spectrum with a simple power (\( F \propto \nu^{-\Gamma} \)).
We search for the soft, extended emission component based on both the observed lightcurves and the spectra. We first pick up candidates based on their lightcurves in different energy bands by eye, and then analyze the structure measure the burst duration in different energy bands with the Bayesian block algorithm [7]. The BB method is a time-domain algorithm for detecting temporal structures of a pulse, revealing pulse shapes, and generally characterizing intensity variations. It rebuilds the raw counting data into time intervals during which the photon arrival rate is a perceptible constant. A change point of count rate is obtained by the Bayesian statistics, and a simple iterative procedure is used to generate a light curve. Shown in Figure 1 is a test for extracting a signal that is contaminated with Poisson noise by this method.

Results of Temporal Analysis with the BB Method

We search for the candidates with the BB method, and a sample of 50 GRBs is obtained. Among the bursts in the sample, GRBs 050724, 061006 and 070714B are the most prominent cases. We present our preliminary results for these cases in this section. We show the light curves of GRB 050724 in the four energy bands as an example in figure 2. The extended emission component is observed in the 15-25 keV band, and its duration become shorter at higher energy bands. It was not detected at the energy band of 100-150 keV. We calculate the $T_{90}$ without/with considering the extended emission component, and the results are shown in Table 1. The extended emission of these bursts are continuously flickering-like. Considering only the hard peaks, these three bursts are classified as short GRBs. The soft, extended emission component is also observed in GRBs 060614[10] and 070220. It is bright, and also detected in the energy band of 100-150 keV, as shown in Figure 3. It is difficult to define a rigorous criterion to separate this component from the main spikes at early time. Zhang et al. (2007) argued that time-resolved spectral analysis is an approach to identify it. With the BB method, we find that this component is pulse-like, significantly different from that observed in GRBs 050724, 061006, and 070714B.

Conclusions

We have searched for the extended emission of the short GRBs with the BB method. We first search for the candidates with the BB method, and a sample of 50 GRBs is obtained. Among the bursts in the sample, GRBs 050724, 061006 and 070714B are the most prominent cases. The extended emission from these bursts is a continuous, flickering-liked component, and is observed only in the low energy bands. We calculate the $T_{90}$ without/with considering the extended emission component. Without Considering the extended emission component the three bursts are classified as short GRBs.

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| GRB    | 15-25 | 25-50 | 50-100 | 100-150 | 15-25 | 25-50 | 50-100 | 100-150 |
|--------|-------|-------|--------|---------|-------|-------|--------|---------|
| 050724 | 136.96| 91.39 | 38.14  | 0.20    | 1.34  | 1.28  | 1.09   | 0.20    |
| 061006 | 108.10| 133.67| 51.46  | 0.58    | 2.49  | 2.36  | 0.77   | 0.39    |
| 070714B| 112.19| 61.25 | 2.3    | 2.3     | 2.56  | 2.43  | 2.3    | 2.3     |
| 060614 | 104.83| 95.81 | 95.36  | 86.27   |       |       |        |         |
| 070220 | 72.52 | 106.69| 63.23  | 37.18   |       |       |        |         |

$^a$column 2 – 5 are $T_{90}$ (s) of the whole burst
$^b$column 6 – 9 are $T_{90}$ (s) of peak only
Figure 1: Test for extracting a signal that is contaminated by Poisson noise with the BB method: 
*Top*: original signal; *Middle*: signal contaminated with Poisson noise. *Bottom*: the extracted signal.
Figure 2: The extended emission component observed in GRB 050724: Left: original lightcurves; right: subtracted lightcurves.

Figure 3: The extended emission component observed in GRB 060614: Left: original lightcurves; right subtracted lightcurves.
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