HTML ABSTRACT + LINKS

Are Short GRBs Really Hard?

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Abstract. Thanks to the rapid position notice and response by HETE-2 and Swift, the X-ray afterglow emissions have been found for four recent short gamma-ray bursts (GRBs; GRB 050509b, GRB 050709, GRB 050724, and GRB 050813). The positions of three out of four short GRBs are coincident with galaxies with no current or recent star formation. This discovery tightens the case for a different origin for short and long GRBs. On the other hand, from the prompt emission point of view, a short GRB shows a harder spectrum comparing to that of the long duration GRBs according to the BATSE observations. We investigate the prompt emission properties of four short GRBs observed by Swift/BAT. We found that the hardness of all four BAT short GRBs is in between the BATSE range for short and long GRBs. We will discuss the spectral properties of short GRBs including the short GRB sample of Konus-Wind and HETE-2 to understand the hard nature of the BATSE short GRBs.

Keywords: Prompt gamma-ray emission, short GRBs
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INTRODUCTION

In the year of 2005, there is a major progress in understanding of the nature of short GRBs. *Swift* X-Ray Telescope (XRT) found the X-ray afterglows from the short GRBs; GRB 050509B [1], GRB 050724 [2] and GRB 050813 [3, 4] detected by *Swift* Burst Alert Telescope (BAT). This discovery allows us to pinpoint the location of the short GRBs within $10''$ for the first time. And also the short GRB, GRB 050709, observed by *HETE*-2 allows us to determine the position less then $1''$ thanks to the follow-up observations by HST and *Chandra* [5]. Because of these accurate position measurements, we start to understand that the environment and/or the progenitor of short GRBs might be different from the long GRBs (e.g. [6]).

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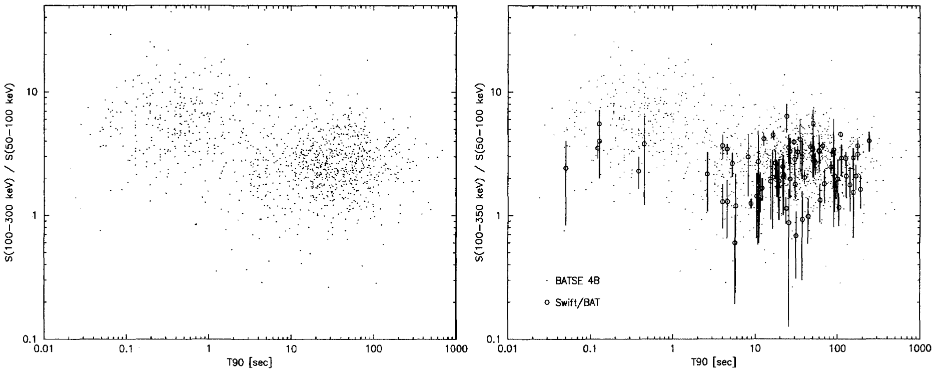

FIGURE 1. T_{90} - Hardness plot (left: BATSE and right: BAT). The error bar in the BAT sample is 90% confidence level.

From the prompt emission point of view, one of the most popular characteristic of short GRBs is the spectral hardness of these bursts. The left of figure 1 shows the T_{90} duration versus the fluence ratio between 100–300 (BATSE channel 3) and 50–100 (BATSE channel 2) keV band (hereafter HR32) for the BATSE GRBs [7]. As see in this figure, the short GRBs ($T_{90} < 2$ s) have a significantly larger hardness ratio comparing to that of the long GRBs. About 48% and 26% of the BATSE short GRBs having HR32 grater than 6 and 8 respectively.

In this paper, we will focus on the prompt emission spectral properties of short GRBs observed by *Swift*/BAT, *HETE*-2, and *Konus-Wind* to investigate the hardness of the short GRBs.

T_{90} - HARDNESS RATIO

Figure 1 and 2 show T_{90} vs. HR32 for the GRB sample of BATSE, BAT, *HETE*-2, and *Konus-Wind*. Although the HR32 for the long GRBs are consistent with the BATSE GRB sample, HR32 for the short GRBs observed by BAT, *HETE*-2 and *Konus-Wind* is not as hard as the BATSE short GRBs. There are about a quarter of the BATSE short GRBs having the HR32 grater than 8. However, none of the short GRBs observed by BAT, *HETE*-2 and *Konus-Wind* having the similar amount of HR32.

HR32 of the short GRBs of all four GRB instruments is summarized in figure 3. Although the number of the sample is limited for BAT and *HETE*-2, the distribution of HR32 for short GRBs observed by *Konus-Wind*, *HETE*-2, and BAT are all consistent. However, the BATSE HR32 distribution is spread over to much wider range, especially for the larger value of HR32.

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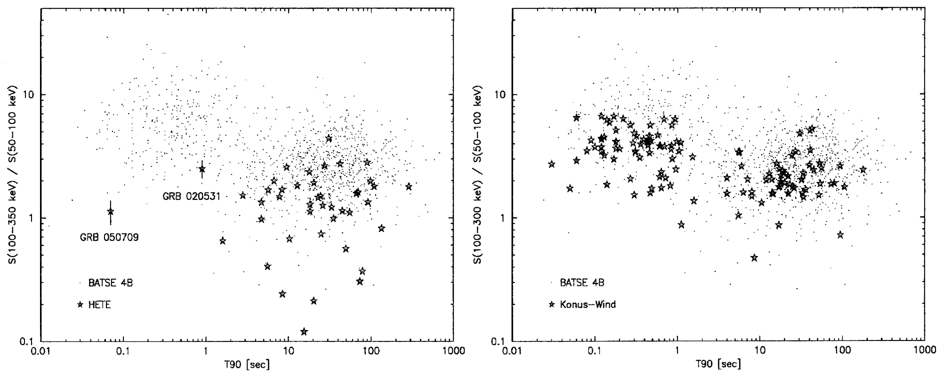

FIGURE 2. T_{90} - Hardness plot (left: HETE and right: Konus-Wind). Note that the reason for many long GRBs showing the smaller number of HR32 in the *HETE*-2 GRB sample is that *HETE*-2 is observing large number of "soft" GRBs, so called XRFs [8].

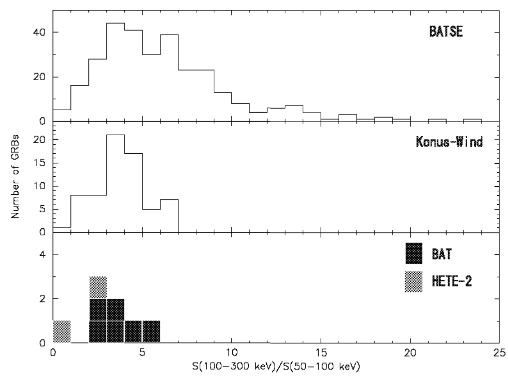

FIGURE 3. The histogram of HR32 for the short GRBs observed by BATSE, Konus-Wind, HETE-2, and Swift/BAT.

WHY BATSE SHORT GRBS LOOK HARDER?

To investigate the origin of the hardness seen in the BATSE short GRBs, we calculate HR32 with a power-law times exponential cutoff model[1] as a function of the power-law index, α, and the cutoff energy, E_0. The result is shown in the left panel of figure 4. To archive HR32 > 6 in a cutoff power-law model, α has to be grater than 0. If E_0 is less than 500 keV, α should increase rapidly when E_0 goes smaller. Thus, we may conclude that a large value of HR32 seen in the BATSE short GRBs is as a result of $\alpha > 0$, but not of a large E_0 energy.

To check our hypothesis, we made the comparison of α distribution between BATSE

[1] dN/dE $\sim E^{\alpha} \exp(-E/E_0)$

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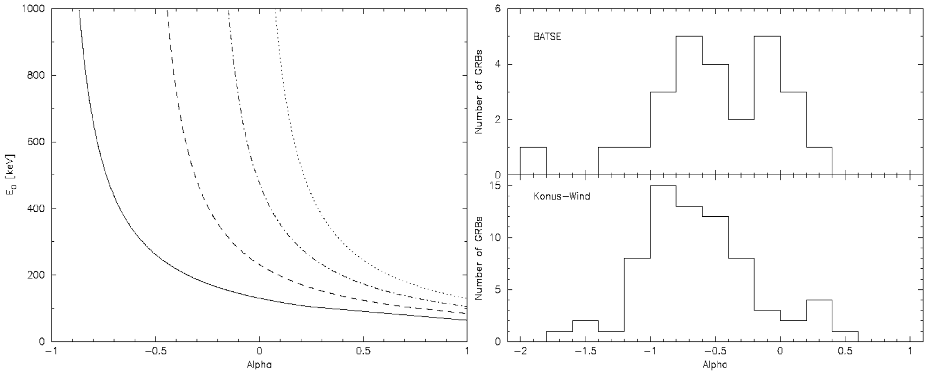

FIGURE 4. Left: The calculated α and E_0 as a function of HR32 (solid, dashed, dash-dotted, and dotted lines are HR32 of 4, 6, 8, and 10 respectively. Right: The photon index α distribution of the BATSE [9] and the Konus-Wind [10] short GRB sample.

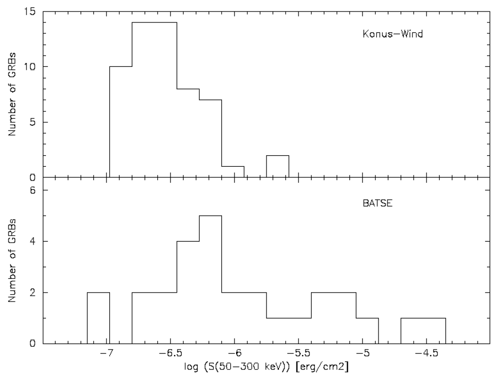

FIGURE 5. The 50-300 keV fluence distribution of the Konus-Wind and BATSE short GRB sample. Note that in the Konus-Wind short GRB sample of this figure, we only include the short GRBs with the time interval of the spectrum less than 256 ms. Thus, we are not including the large fluence bursts due to the difficulty in calculating the fluence in the 50-300 keV band.

[9] and Konus-Wind [10] sample. The right panel of figure 4 shows the comparison. The α distribution of the Konus-Wind short GRB sample has a tight distribution which is centroid around -0.8. On the other hand, as mentioned by Ghirlanda et al. [9], a large fraction of the BATSE short GRBs has $\alpha > 0$. This result tightens our conclusion that the hardness of the BATSE short GRBs are coming from the extremely flat photon index α.

As shown in figure 5, the BATSE short GRBs studied by Ghirlanda et al. [9] are the bright short GRBs. Since the Konus-Wind short GRBs studied by Mazets et al. [10] are well covering the fluence range of the BATSE short GRB sample, it is difficult to understand the systematic difference in α distribution between Konus-Wind and BATSE by the selection effect of the sample. However, we need the complete spectral

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information of the BATSE short GRBs to confirm our conclusion.

We study the hardness of the prompt emission of short GRBs observed by four different GRB instruments. We found that the hardness ratios of the short GRBs observed by BATSE have a systematically larger value than the short GRBs observed by other instruments. We also confirmed that the hardness of the BATSE short GRBs is as a result of the extremely flat power-law index α ($\alpha > 0$) which is not a dominant population in the *Konus-Wind* short GRB sample.

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