Indication of Two Classes in the Swift Short Gamma-Ray Bursts from the XRT X-Ray Afterglow Light Curves

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Abstract. We present the discovery of two distinct classes in the Swift short duration gamma-ray bursts (S-GRBs) from the X-Ray Telescope (XRT) X-ray afterglow light curve. We find that about 40% of the Swift S-GRBs have an X-ray afterglow light curves which only lasts less than 10^4 seconds after the burst trigger (hereafter short-lived S-GRBs). On the other hand, another 60% of S-GRBs have a long lasting X-ray afterglow light curve which resembles the long duration gamma-ray bursts. We also find that none of the short-lived S-GRBs shows the extended emission in the Burst Alert Telescope (BAT) energy range. We compare the burst properties for both the prompt emission and the afterglow, and discuss the possibility of different progenitors for the Swift short GRBs.

Keywords: gamma ray: bursts

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INTRODUCTION

The distinct class in short duration GRBs (S-GRBs) has been claimed based on the prompt emission properties, namely a S-GRB with an extended emission (E.E.) [1] (see Figure 1). The initial short spike of a S-GRB with an E.E. shows a negligible spectral lag which is one of the strong indications that the burst is indeed classified as a S-GRB [2]. The E.E. emission tends to be softer than the initial short spike [e.g., 3, 4].

On the other hand, there is an indication for two different populations in S-GRBs based on the afterglow and the host galaxy properties. For instance, the afterglow has been found only in X-rays for GRB 050509B. The host galaxy of GRB 050509B is very likely to be an elliptical galaxy with no star formation [5]. Whereas, in the case of GRB 051221A, the afterglow has been detected in all of frequencies (X-ray, optical and radio). And its host galaxy is a star forming galaxy [6].

In this paper, we present the discovery of two distinct classes in the S-GRB X-ray afterglows observed by Swift X-ray Telescope (XRT). We will discuss these two S-GRB classes comparing with their prompt emission properties, afterglows, and host galaxies.

SAMPLE

The samples of S-GRBs in our study include the bursts detected by Swift in 2005-2007. We have 26 S-GRB samples in total; 19 of them have the X-ray afterglows; 9 of them have the optical afterglows; 17 of them have the redshift measurements (including 8 S-GRBs with host galaxy identifications only by the XRT position). Note that all of the redshifts of S-GRBs are from their host galaxy. In this study, we will focus on 19 S-GRBs with X-ray afterglows (see Table 1).

The XRT light curves are collected from Swift/XRT GRB light curve repository [7]. The analysis of the Swift Burst Alert Telescope (BAT) data has been performed using the standard BAT ftools.

SHORT-LIVED AND LONG-LIVED X-RAY AFTERGLOW

Figure 2 show the overlaid XRT X-ray light curve of S-GRBs. We notice that the X-ray light curves can be grouped into two classes. The first class is “short-lived (SL)” X-ray afterglow; the X-ray flux is < 10^{-13} erg cm^{-2} s^{-1} at 10^4 sec
FIGURE 1. The BAT light curve of GRB 060313 as an example of S-GRBs without E.E. (left) and GRB 061006 as an example of S-GRBs with E.E. (right) The insert of GRB 061006 is the BAT light curve around the initial short spike in 16 msec binning.

FIGURE 2. The XRT X-ray afterglow light curves of the short-lived (SS; left) and the long-lived (LL; right) class. After the trigger. The second class is “long-lived (LL)" X-ray afterglow; the X-ray flux is $>10^{-13}$ erg cm$^{-2}$ s$^{-1}$ at $10^4$ sec after the trigger. About 40% of our S-GRB samples belongs to the SL X-ray afterglow class. They have very faint X-ray afterglow lasting only a few hours after the trigger making them distinct compared to that of X-ray afterglow of L-GRBs. On the other hand, the X-ray afterglow light curves of LL class are similar to the L-GRBs. Table 1 shows whether 1) there is an E.E. detection in BAT (“E.E.” column), 2) the optical afterglow (OA) has been detected (“OA” column), and 3) the redshift has been measured (“redshift” column). It is interesting to note that none of the SL S-GRBs have an E.E. and also an OA detection. When we take into account that the redshifts of GRB 060502B and GRB 061217 are questionable, most of the S-GRB redshifts are from the LL S-GRB class.

Figure 3 shows the BAT peak count rate in 64 msec window versus the burst duration. The peak count rate of all of the SL S-GRB class is small ($< 0.5$ counts s$^{-1}$ det$^{-1}$). The LL S-GRB class has a mixture of a small and a large peak count rate. We also notice that a peak count rate of a short spike varies even with or without an E.E. Troja et al. [8] found that all S-GRBs without E.E. lie far from the center of the host galaxy. Figure is the same figure in Troja et al. [8] by having different marks for the SL and the LL class. Although it is not surprising because none of the SL class has an E.E. emission, most of the SL S-GRBs lie far from the center of the host galaxy.

Based on the fact that the LL S-GRBs show 1) similar X-ray afterglow light curve properties to L-GRBs, 2) are closer to the center of the host galaxy which is the characteristics of the L-GRB hosts, and 3) have detection of optical
afterglows, the progenitor of S-GRBs with E.E. might be closer to L-GRBs.

**SUMMARY**

There is an indication of two classes in S-GRBs based on their X-ray afterglow properties. There are the classes of S-GRBs with SL X-ray afterglows and LL X-ray afterglows. The SL S-GRBs show 1) no E.E. and a small peak count rate in the prompt emission, 2) no optical afterglow, 3) a very small number of a redshift measurement, and 4) a larger offset from the center of the host galaxy. Based on their characteristics, the afterglows and their host properties of the SL S-GRBs should provide a unique prove to understand the nature of S-GRBs.

**TABLE 1.** The S-GRB sample in this work. See text for the details.

| GRB   | Class | E.E. | OA | Redshift | GRB   | Class | E.E. | OA | Redshift |
|-------|-------|------|----|----------|-------|-------|------|----|----------|
| 050509B | SL    | N    | N  | Y        | 050724 | LL    | Y    | Y  | Y        |
| 050813  | SL    | N    | N  | N        | 051221A | LL    | N    | Y  | Y        |
| 051210  | SL    | N    | N  | N        | 051227  | LL    | Y    | Y  | N        |
| 060502B | SL    | N    | N  | Y(?)     | 060313  | LL    | N    | Y  | N        |
| 060801  | SL    | N    | N  | N        | 061006  | LL    | Y    | Y  | Y        |
| 061217  | SL    | N    | N  | Y(?)     | 061201  | LL    | N    | Y  | N        |
| 070429B | SL    | N    | N  | N        | 061210  | LL    | Y    | N  | N        |
| 070729  | SL    | N    | N  | N        | 070714B | LL    | Y    | Y  | Y        |
| 070724A | LL    | N    | N  | Y        | 070724A | LL    | N    | Y  | N        |
| 070809  | LL    | N    | Y  | N        | 071227  | LL    | Y    | Y  | Y        |

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