X-RAY FLARES IN THE EARLY *SWIFT* OBSERVATIONS OF THE POSSIBLE NAKED BURST GRB 050421

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ABSTRACT

We present the *Swift* observations of the faint burst GRB 050421. The X-ray light-curve shows two flares: the first flare peaking at $\sim$ 110 s after the BAT trigger (T_0) and the second one peaking at $\sim$ 154 s. We argue that the mechanism producing these flares is probably late internal shocks. The X-ray light-curve shows a rapid decline with a temporal index $\alpha \sim 3.1$. The X-ray source disappears completely less than 1 hour after the trigger. An X-ray spectral softening is also observed with time from $\beta \sim 0.1$ to ~ 1.2. A good joint fit to the BAT and XRT spectra indicates that the early X-ray and Gamma-ray emissions are produced by the same mechanism. The X-ray spectral softening is likely due to a shift down to lower energies of the peak of the prompt emission, and the rapid decline of the X-ray emission is probably the tail of the prompt emission. This suggests that the X-ray emission is completely dominated by high latitude radiation and the external shock, if any, is below the detection threshold.

Key words: Gamma-ray: bursts - Gamma-rays, X-rays: individual (GRB 050421).

1. INTRODUCTION

The *Swift* Gamma-Ray Burst (GRB) Explorer was launched on 20th November 2004 (Gehrels et al. 2004). It is a multi-wavelength observatory covering the Gamma-ray, X-ray and UV/optical bands. After the detection of a GRB by the Burst Alert Telescope (BAT, Barthelmy et al. 2005), the observatory slews automatically and rapidly to point the narrow field instruments: the X-ray Telescope (XRT, Burrows et al. 2005a), and the UV/Optical Telescope (UVOT, Roming et al. 2005). Due to its rapid pointing capability and high sensitivity, *Swift* is ideal for studying the properties of the early afterglow, in particular the transition between prompt and forward shock emissions.

We report here the *Swift* observations of the GRB discovered at 04:11:52 UT on 21st April 2005 by the BAT (Godet et al. 2005). The XRT started to observe 89 s after the BAT trigger (T_0) and observed an X-ray fading source at (J2000) RA=$20^{h}29^{m}02.44^{s}$ and Dec= $+73^{o}39'17.8''$ with a total uncertainty radius of 3.7 arc-seconds (90% containment). This XRT position is corrected for the effect of the boresight offset (Moretti et al. 2005). The UVOT started to observe 112 s after the BAT trigger, but detected no new source. No radio, infra-red or optical counterpart was detected by ground-based instruments (e.g. Bloom et al., Jelinek et al. 2005). By convention, we note the flux as $F_\nu \propto \nu^{-\beta} t^{-\alpha}$, where β is the energy spectral index and α is the temporal index.

2. SUMMARY OF THE MAIN SPECTRAL AND TEMPORAL RESULTS

- The BAT light-curve displays a FRED peak with a duration $T_{90} \sim 10.3$ s, a spectral slope of $\beta = 0.7 \pm 0.5$, and a tail extending to $\sim$ 100 s after the trigger. A faint burst with a fluence of 1.1×10^{-7} erg cm^{-2} s^{-1} in the 15-150 keV band, it is in the bottom 10% of GRBs detected by the BAT.
- A rapid decline ($\alpha = 3.1 \pm 0.1$) of the XRT light-curve with 2 flares peaking at $T_0 + 110$ s and $T_0 + 154$ s (Fig. 1). The X-ray emission decayed from $\sim 10^{-9}$ erg cm^{-2} s^{-1} at $T_0 + 100$ s to $< 7 \times 10^{-13}$ erg cm^{-2} s^{-1} at $T_0 + 1000$ s, and was no longer detected beyond $T_0 + 1000$s.
- A spectral softening from the early $T_0 + 115 \rightarrow T_0 + 171$ s data with $\beta = 0.1 \pm 0.3$ to the later $\sim T_0 + 180 \rightarrow T_0 + 771$ s with $1.2^{+0.3}_{-0.1}$.

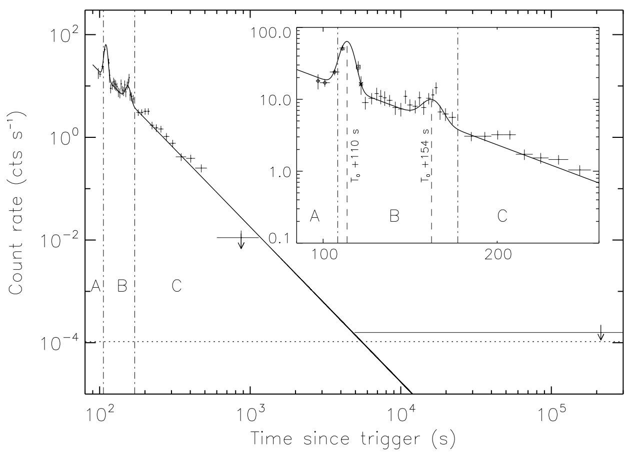

Figure 1. Background subtracted XRT light-curve of GRB 050421 over the energy band 0.3-10 keV: A) Low-rate Photo-Diode (LrPD) slew and settling data (diamonds); B) Image Mode (triangle), Piled-up Photo-Diode (PuPD) (square), LrPD (star) and Windowed Timing (WT) pointing data; C) Photon Counting (PC) pointing data. The best fit to the light-curve is plotted by the solid line. The dotted line corresponds to the background level in the PC data. The upper limits are 3 σ limits. The times of the two X-ray flares are also shown in the plot.

- The joint fit of the BAT and early XRT data shows that they are likely produced by the same mechanism which is consistent with an absorbed power-law with a slope $\beta = 0.2 \pm 0.2$. Fig. 2 shows the combined light-curves of the BAT data extrapolated in the 0.3-10 keV band and the XRT data in the same band.
- Excess absorption $\Delta N_H(z = 0) \sim 4.4 \times 10^{21}$ cm^{-2}, over that due to the Galaxy is seen in the XRT spectra. No variation in absorption with time is seen.

3. DISCUSSION & CONCLUSION

GRB 050421 was one of the faintest bursts observed by *Swift*. It showed a rapid temporal decline in X-rays on which were superposed at least two X-ray flares. The short rise and decay times and the amplitude of the flares indicate that the flares are probably produced by late internal shocks (e.g. Burrows et al. 2005b and Zhang et al. 2005). Simple kinematic arguments also support this interpretation (Ioka et al. 2005). The spectral softening seen in the XRT is likely due to the shift, in the XRT energy band, of the peak of the prompt spectrum with time (Ford et al. 1995). The temporal decline and the spectral results can not be explained by invoking the current afterglow models (e.g. Zhang et al. 2005). A natural explanation for the steep temporal decay and the spectral slopes seen in the previous section is then to invoke a "high latitude emission" model (e.g. Kumar & Panaitescu 2000). In this model, the tail of the prompt emission is produced

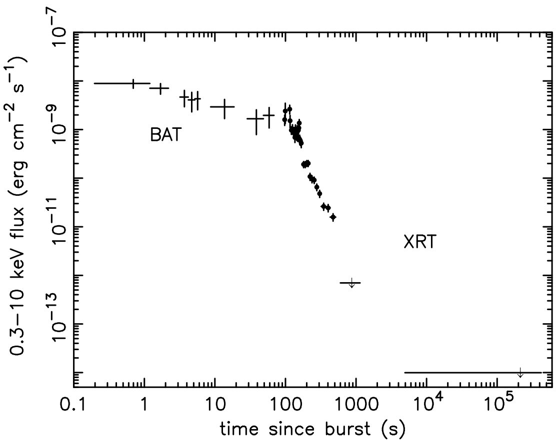

Figure 2. Combined light-curves of the BAT data (crosses) extrapolated in the 0.3-10 keV band and the XRT data (circles) in the 0.3-10 keV energy range. The unabsorbed fluxes are given in units of erg cm^{-2} s^{-1}. The BAT and XRT fluxes were derived from the spectral slopes given in Section 2.

at high angles relative to the observer line of sight (with angles $\theta > \Gamma^{-1}$ where Γ is the Lorentz factor).

GRB 050421 would then be the first burst for which the XRT slewed promptly, for which no forward shock emission was observed. Therefore, GRB 050421 would be the first "naked burst" (Kumar & Panaitescu 2000) discovered by *Swift*.

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