

Swift Observation of GRB 070406

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0 Revisions

Version 2 contains a 3-sigma upper limit on the brightness of any X-ray afterglow. Updated light curves of the two candidate X-ray afterglow sources, neither of which was found to be fading up to nine days post trigger, are also presented.

1 Introduction

BAT detected GRB 070406 at 00:50:40 UT (Trigger 274153) (Cummings *et al.*, *GCN Circ.* 6247). This was a sub-threshold (6.4 sigma) peak in a 0.256 second image trigger on a short burst with $T_{90} = 0.7 \pm 0.2$ sec. Swift did not automatically slew to the GRB location because the burst was below the on-board threshold. Ground analysis optimized the detection to a confident 8.3 sigma.

Swift monitored the field of GRB 070406 for nine days, starting 20.6 hr after the burst. From the analysis of the full data set, consisting of 121 ks of total exposure in XRT/Photon Counting mode, no X-ray afterglow is detected within the BAT refined error circle (Krimm *et al.*, *GCN Circ.* 6261). There are two faint uncatalogued X-ray sources in the BAT circle, but they do not show evidence of fading. The non-detection in the first follow-up observation (from 20.6 to 41.9 hr post trigger) implies an X-ray afterglow fainter than 7.5×10^{-4} cts/s (3-sigma upper limit). Our best position is the BAT location RA(J2000) = 198.956 deg (+13h 15m 49.3s), Dec (J2000) = +16.530 deg (+16d 31' 46") with an error of 2.5 arcmins (radius, 90% containment, including systematic uncertainty).

2 BAT Observation and Analysis

Using the data set from $T = -2.3$ to $T + 7.7$ sec, a further analysis of BAT GRB 070406 (trigger 274153) has been performed by the Swift team (Krimm *et al.*, *GCN Circ.* 6261).

The BAT ground-calculated position is RA, Dec = 198.956, 16.530 deg which is RA(J2000) = 13h 15m 49.3s, Dec(J2000) = 16d 31' 46" with an uncertainty of 2.5 arcmin (radius, 90% containment, including systematic uncertainty). The partial coding was 92% (the bore sight angle was 24 deg).

The mask weighted light curves shows two peaks at $T + 0$ and $T + 0.7$ sec (Fig. 1). The burst was very faint in BAT, and additional peaks may be hidden in the noise. T_{90} is 0.7 ± 0.2 sec (15-350 keV) (estimated error including systematics).

The time-averaged spectrum from $T + 0.0$ to $T + 0.7$ is best fit by a simple power-law model. The photon index of the time-averaged spectrum is 0.9 ± 0.4 . The fluence in the 15-150 keV band is $(4.5 \pm 1.0) \times 10^{-8}$ ergs/cm². The 1-sec peak photon flux measured from $T + 0.00$ sec in the 15-150 keV band is 0.7 ± 0.1 ph/cm²/sec. All the quoted errors are at the 90% confidence level.

3 XRT Observations and Analysis

In the first 56 ksec of data, taken between 20.6 hr and 3.5 day post burst in Photon Counting (PC) mode, two faint uncatalogued X-ray sources are detected at the 3 sigma level within the BAT error

circle (Krimm *et al.*, *GCN Circ.* 6261): S1 and S2 (Troja *et al.*, *GCN Circ.* 6255 and *GCN Circ.* 6265).

The astrometrically-corrected position of the X-ray source S1 is: RA (J2000) = 13h 15m 51.59s, Dec(J2000) = +16d 30' 46.6" with an estimated error radius of 4.7" (90% containment). This position lies 1.9 arcsec from the position quoted in Butler & Bloom (*GCN Circ.* 6263) and 1.7 arcsec from the bright optical source reported by Kann (*GCN Circ.* 6256).

The final light curve of S1 covering all nine days of Swift observations (121 ks in PC mode) is shown in Fig. 2. The X-ray source displays a steady behaviour with a fairly constant count rate of 1.5×10^{-3} cts/s (Fig. 2). S1 is not identified as the X-ray counterpart of GRB 070406, as noted by Butler & Bloom, (*GCN Circ.* 6263), and it is instead likely to be associated with AGN activity (Berger *et al.*, *GCN Circ.* 6262).

The astrometrically-corrected position for source S2 is: RA (J2000) = 13h 15m 43.42s, Dec(J2000) = +16d 31' 09.3" with an estimated error radius of 5.7" (90% containment). This position lies 92 arcsec from the BAT refined position. According to the SDSS catalogue, two galaxies lie 3.7 and 13.6 arcsec from the X-ray position of S2, respectively. A third object, classified as a star, is 1.3 arcsec from the X-ray source. Berger (*GCN Circ.* 6266) reports that the latter source is embedded within an extended source and that this is either the result of chance superposition, or more likely, that it is an AGN.

The final light curve of S2 using all nine days of Swift observations (121 ks in PC mode) is presented in Fig. 3. The source is only marginally detected in the first 20 ksec (20.6 to 41.9 hours post burst) yielding a 3 sigma upper limit of 1.5×10^{-3} cts/s and the following four detections are not consistent with a fading source. It is likely that the X-ray source is associated with the extended object noted by Berger (*GCN Circ.* 6266).

The non-detection of a fading X-ray source in the first follow-up observation (from 20.6 to 41.9 hr post trigger) implies a X-ray afterglow fainter than 7.5×10^{-4} cts/s (3-sigma upper limit). Assuming a power-law spectral shape with photon index 2 and a Galactic absorption of 1.8×10^{20} cm⁻² (Dickey & Lockman, 1990), it corresponds to an observed (unabsorbed) limiting flux of 2.7×10^{-14} (2.9×10^{-14}) erg/cm²/s in the 0.3-10 keV band.

4 UVOT Observation and Analysis

The UVOT began observing the field of GRB 070406 starting 20.6 h after the initial BAT trigger (Landsman *et al.*, *GCN Circ.* 6258).

Comparison with pre-burst DSS and SDSS images show no new source within the BAT error circle with the following 3 sigma upper limits in the co-added frames in all filters. Upper limits are summarized in Table 1. These upper limits not corrected for the Galactic extinction corresponding to a reddening of $E(B-V) = 0.027$ mag (Schlegel *et al.* 1998).

A point source on the UVOT images is identified with the blue galaxy discovered in pre-burst SDSS images (Kann, *GCN Circ.* 6256) within the tentative XRT error circle (Troja *et al.*, *GCN Circ.* 6255). The galaxy is found to be unusually bright in the UV filters (Table 2). The magnitudes were measured with a 5 arcsec radius aperture.

However, there is no compelling evidence of variability of this source within the individual UVOT frames.

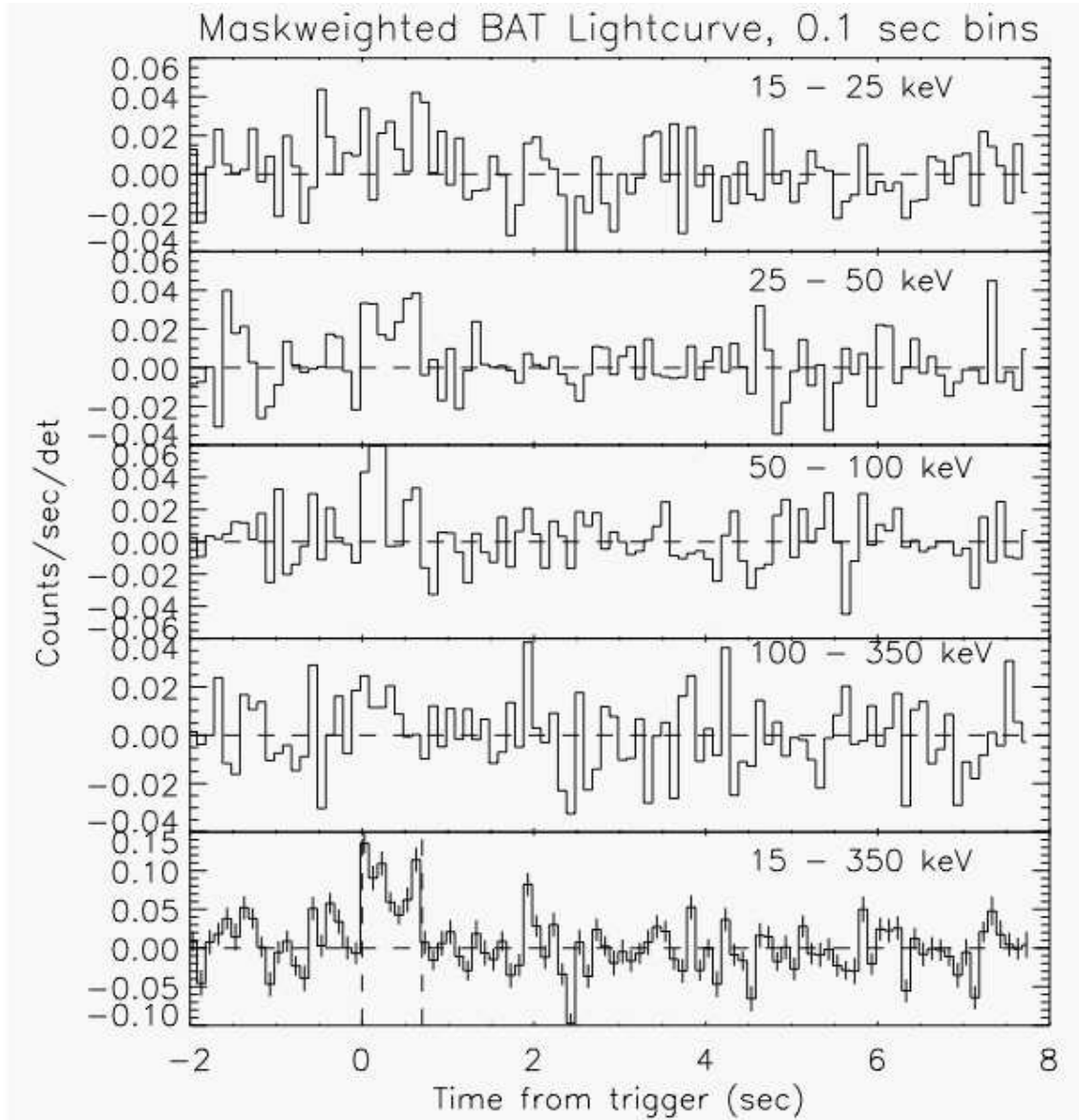


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector (note illum-det = 0.16cm^2) and T_0 is 00:50:40 UT.

Filter	Start	Stop	Exposure	3-Sigma UL
V	84712	132829	1407	21.6
B	74251	139272	3360	23.0
U	102871	138592	2539	22.4
UVW1	98648	137680	3666	24.3
UVM2	90394	133486	2845	23.5
UVW2	80549	131916	2626	23.9
WHITE	75162	115280	1318	22.6

Table 1: Magnitude limits from UVOT observations

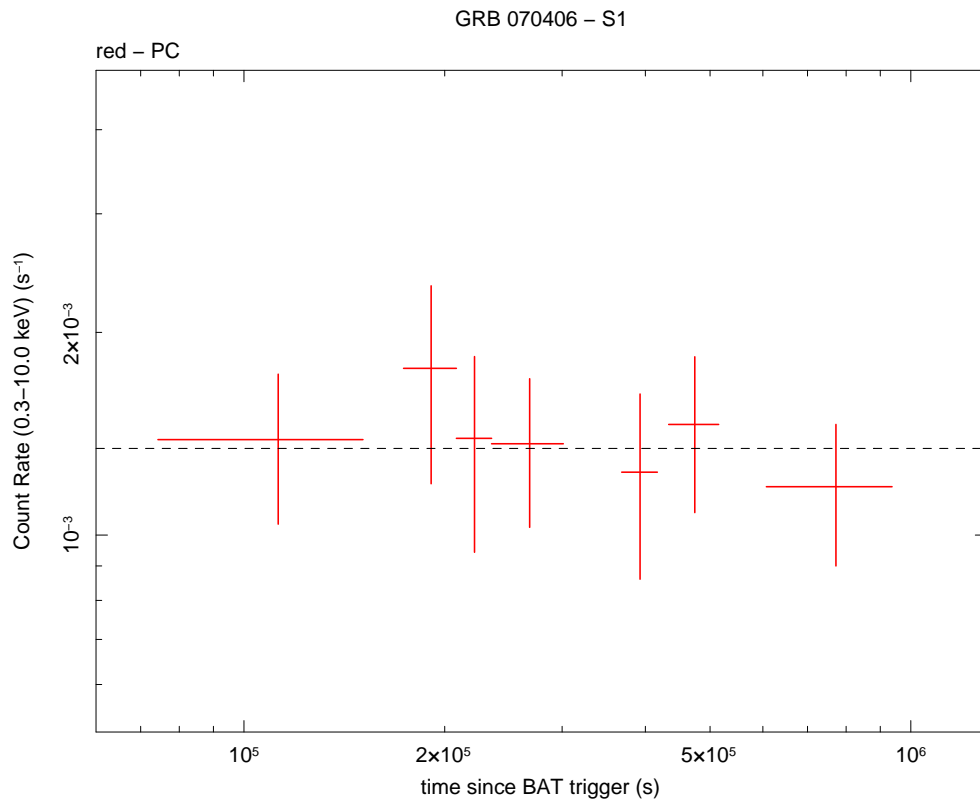


Figure 2: XRT Light curve of Source 1. Counts/sec in the 0.3-10 keV band. Photon Counting mode (red).

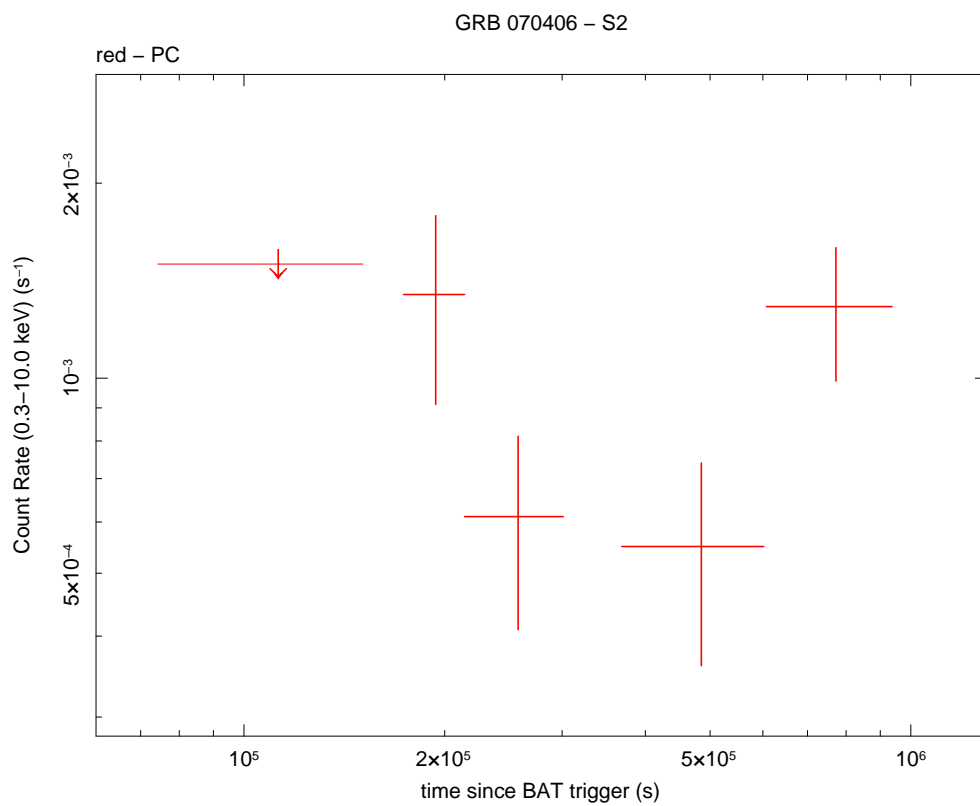


Figure 3: XRT Light curve of Source 2. Counts/sec in the 0.3-10 keV band. Photon Counting mode (red).

Filter	Magnitude	Error
V	20.05	0.15
B	20.06	0.05
U	19.11	0.04
UVW1	18.83	0.04
UVM2	18.52	0.05
UVW2	18.67	0.04

Table 2: Magnitude and errors from UVOT observations of the blue galaxy found in pre-burst SDSS images (Kann, GCN 6256).