Swift Observation of GRB 070406

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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 ± 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. Follow-up observations are currently being conducted.

At present there is no secure fading X-ray or optical counterpart identified. There are faint X-ray sources in the BAT circle, but they do not show strong evidence of fading. 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 lightcurves 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 power law index of the time-averaged spectrum is 0.9 ± 0.4. The fluence in the 15-150 keV band is (4.5 ± 1.0) $\times 10^{-8}$ ergs/cm^2. The 1-sec peak photon flux measured from T+0.00 sec in the 15-150 keV band is 0.7 ± 0.1 ph/cm^2/sec. All the quoted errors are at the 90% confidence level.

3 XRT Observations and Analysis

Using the XRT data from 20.6 hr and 3.5 day post burst (56 ksec in Photon Counting 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 astrometric 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). Using all data from 20.6 hr to 6 day post trigger (85 ksec) the X-ray source displays a steady behavior with a fairly constant count rate of 1.5×10^{-3} cts/s (Fig. 2). It is very unlikely that S1 is the X-ray counterpart of GRB 070406, as noted by Butler & Bloom, (*GCN Circ.* 6263), and it is more likely associated with AGN activity (Berger et al., GCN Circ. 6262).

Examining the observations performed between 2 and 3.5 day after the burst, another faint source (S2) is detected within the refined BAT error circle (Krimm *et al.*, *GCN Circ.* 6261). Its astrometric corrected position 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.

A lightcurve of S2 using all available data from 20.6 hr to 6.9 day post trigger (91 ksec) 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 limits of 1.5×10^{-3} cts/s. It is still unclear whether the source is fading. Swift follow-up observations are being performed.

4 UVOT Observation and Analysis

The UVOT began observing the field of GRB 070604 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 are not corrected for Galactic extinction E(B-V) = 0.027 (Schlegel et al. 1998).

The blue galaxy found in pre-burst SDSS images (Kann, GCN 6256) within the tentative XRT error circle (S1) (Troja et al., GCN 6255) is found from the UVOT observations to be unusually bright in the UV filters.

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

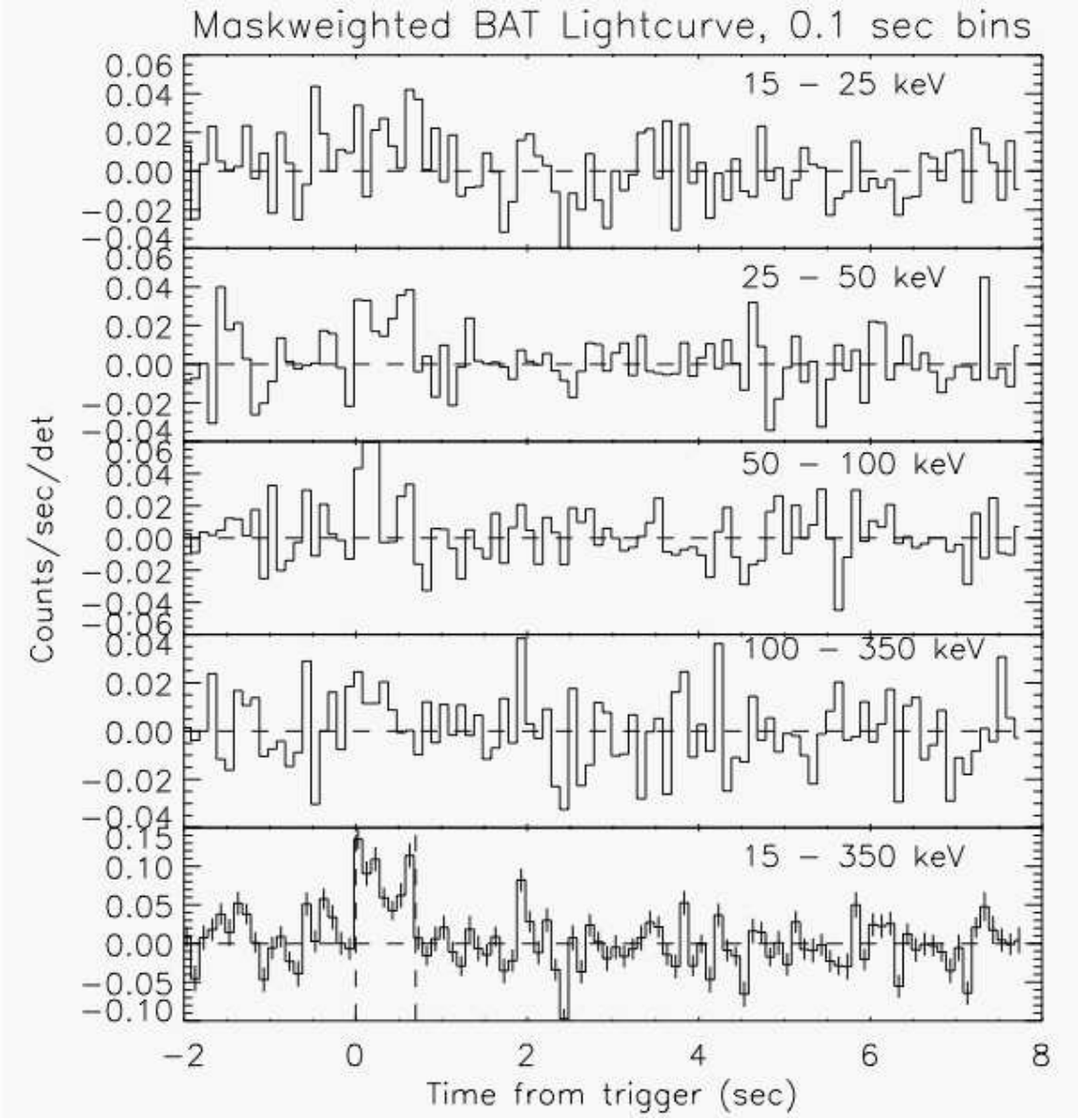

Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector (note illum-det = $0.16cm^2$) and T_0 is 00:50:40 UT.

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

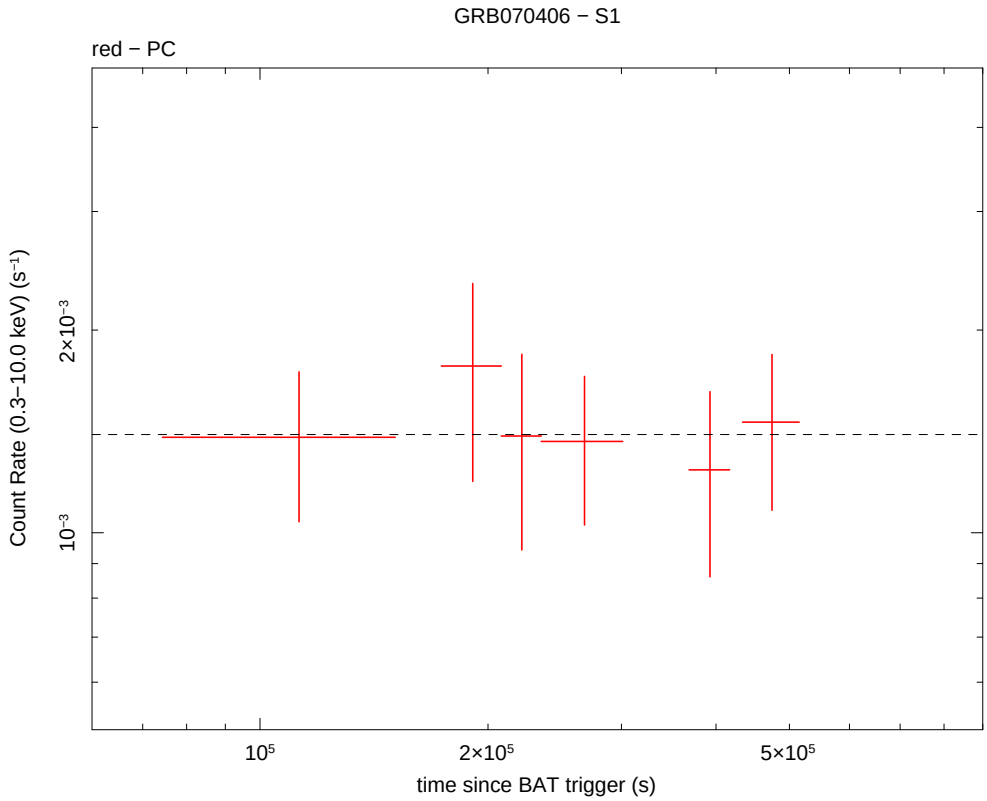

Figure 2: XRT Lightcurve of Source 1. Counts/sec in the 0.3-10 keV band. Photon Counting mode (red).

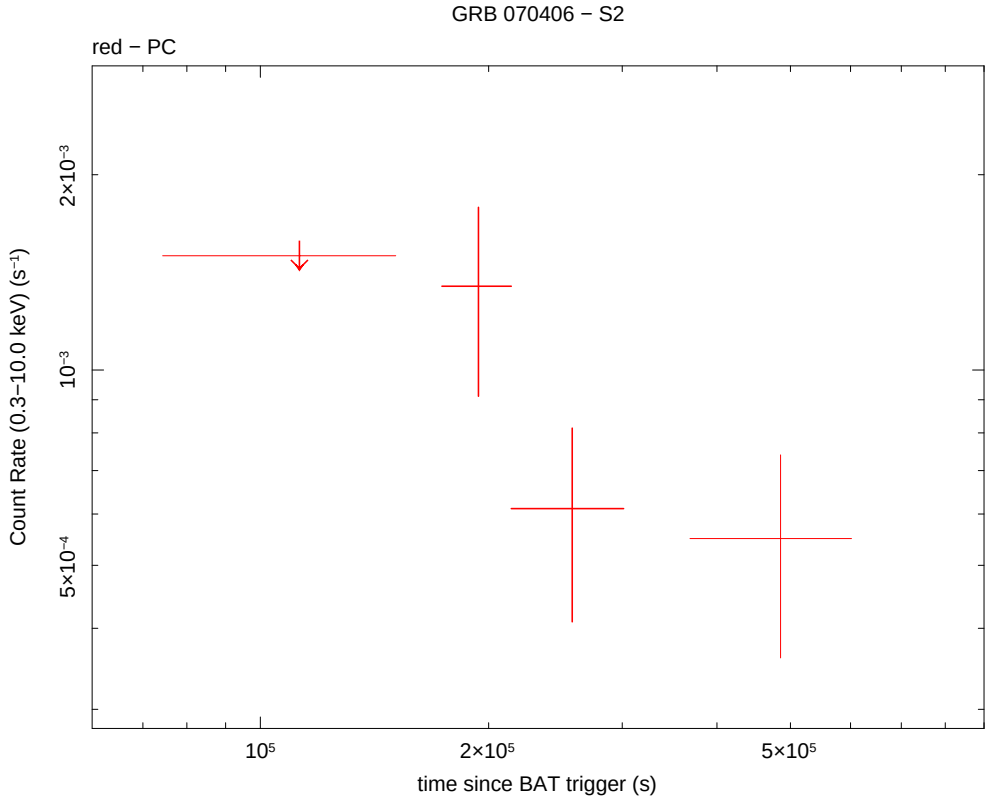

Figure 3: XRT Lightcurve of Source 2. Counts/sec in the 0.3-10 keV band. Photon Counting mode (red).

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).