

Swift Observations of GRB 110102A

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report for the Swift Team

1 Introduction

BAT detected GRB 110102A at 18:52:25 UT on the 2nd January 2011 (Oates, *et al.*, *GCN Circ.* 11509). A precursor triggered BAT producing an image rate trigger at a significance of 11.29σ . Emission was detected from $\sim T-50$ s to $\sim T+340$ and the $T_{90}(15 - 350 \text{ keV})$ is 264 ± 8 s (estimated error including systematics).

Swift BAT slewed immediately to this burst and XRT observations and UVOT settled observations began ~ 139 s and 156 s respectively, after the BAT trigger (Target ID 441454). A source was detected by both the XRT and the UVOT (Oates, *et al.*, *GCN Circ.* 11509,11514; D'Elia, *et al.*, *GCN Circ.* 11517). Our best position is the UVOT location $RA(J2000) = 245.88087 \text{ deg}$ ($16h 23m 31.41s$), $Dec(J2000) = 7.61383 \text{ deg}$ ($07d 36' 49.8''$) with an error of 0.5 arcsec (radius, 90% containment). Observations were also performed by Fermi (Lin, *GCN Circ.* 11512), INTEGRAL/SPI-ACS (Beckmann, private communication), Konus-Wind (Golenetskii, *et al.*, *GCN Circ.* 11515) and MITSuME (Kuroda, *et al.*, *GCN Circ.* 11513).

2 BAT Observation and Analysis

Using the data set from T-239 to T+963 sec, we report on the BAT refined analysis of GRB 110102A (trigger 441454) (Oates, *et al.*, *GCN Circ.* 11509). The BAT ground-calculated position is RA, Dec = $245.877, 7.617 \text{ deg}$, which is:

$$\begin{aligned} RA(J2000) &= 16h 23m 30.5s \\ Dec(J2000) &= +07d 37' 00.1'' \end{aligned}$$

with an uncertainty of 1.8 arcmin, (radius, sys+stat, 90% containment). The partial coding was 66%.

The mask-weighted light curve, see Fig. 1, shows a pair of small precursor peaks starting at $\sim T-50$ sec and ending at $\sim T+50$ sec. The main emission occurs with four peaks that start at $\sim T+100$ s and ending at $\sim T+340$ s with the maximum at $\sim T+210$ s. The $T_{90}(15 - 350 \text{ keV})$ is 264 ± 8 s (estimated error including systematics).

The time-averaged spectrum from T-49.2 to T+294.9 s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.60 ± 0.04 . The fluence in the 15-150 keV band is $(1.65 \pm 0.03) \times 10^{-5} \text{ erg cm}^{-2}$. The 1-sec peak photon flux measured from T+208.76 s in the 15-150 keV band is $8.4 \pm 0.3 \text{ ph cm}^{-2} \text{ s}^{-1}$. All the quoted errors are at the 90% confidence level.

The results of the batgrbproduct analysis are available at:

http://gcn.gsfc.nasa.gov/notices_s/441454/BA/

3 XRT Observations and Analysis

The XRT began observations of GRB 110102A 139 s after the BAT trigger.

The XRT found a bright, uncatalogued X-ray source located at RA, Dec = $245.88117, +7.61377 \text{ deg}$

which is equivalent to:

RA (J2000): 16h 23m 31.48s
Dec (J2000): +07d 36' 49.6"

with an uncertainty of 1.7 arcsec (radius, 90% confidence).

We analyzed 154.61 ks of XRT data for GRB 110102A, from 139 s to 1.4×10^6 s after the BAT trigger. The data comprise 375 s in Windowed Timing (WT) mode with the remainder in Photon Counting (PC) mode.

The light curve shows an initial flaring activity, superimposed on a canonical 4 segment light curve, which can be modeled with triple broken power-law decay. The initial decay index is $\alpha_1 \sim 8.6$. At 457 ± 5 s the decay flattens to an $\alpha_2 = 0.51 \pm 0.03$. At 11.08 ± 0.01 ks the decay steepens again to $\alpha_3 = 1.40 \pm 0.03$ and breaks to a final decay $\alpha_4 = 2.2 \pm 0.4$ at $(2.4 \pm 0.7) \times 10^5$ s.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of 1.50 ± 0.04 . The best-fitting absorption column is $7.8 \pm 1.1 \times 10^{20} \text{cm}^{-2}$, in excess of the Galactic value of $4.8 \times 10^{20} \text{cm}^{-2}$ (Kalberla et al. 2005). The PC mode spectrum has a photon index of 2.26 ± 0.06 and a best-fitting absorption column of $1.29 \pm 0.16 \times 10^{21} \text{cm}^{-2}$. The counts to observed (unabsorbed) 0.3-10 keV flux conversion factor deduced from this spectrum is $3.6 \times 10^{-11} (5.8 \times 10^{-11}) \text{ erg cm}^{-2} \text{ count}^{-1}$.

The results of the XRT-team automatic analysis are available at:
http://www.swift.ac.uk/xrt_products/00441454

4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 110102A 156 s after the BAT trigger (Oates, *et al.*, *GCN Circ.* 11509). The optical afterglow is detected in the *white*, *v*, *b* and *u* filters at the refined UVOT position RA(J2000) = 245.88087 deg, DEC(J2000) = +7.61383 deg, which is:

RA (J2000): 16h 23m 31.41s,
Dec (J2000):+07d 36' 49.8"

with an estimated uncertainty of 0.5 arcsec (radius, 90% confidence). This position is consistent with the enhanced XRT position (Goad, *et al.*, *GCN Circ.* 11510). The detection in *u* suggests a redshift of < 2.5 .

The results of the UVOT-team automatic analysis are available at:
http://gcn.gsfc.nasa.gov/swift_gnd_ana.html

The 3-sigma upper limits for the finding chart exposures (FC) and summed images provided in Table 1 and the UVOT *white* filter light curve is provided in Fig. 3.

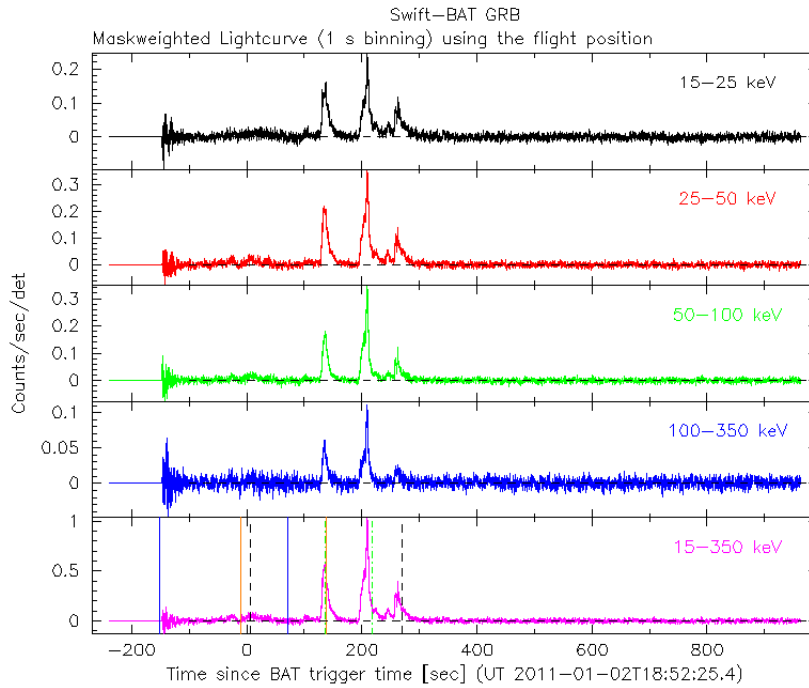


Figure 1: BAT light curve. The mask-weighted light curve in the 4 individual plus total energy bands: 15 - 25 keV (black), 25 - 50 keV (red), 50 - 100 keV (green), 100 - 350 keV (blue), 15 - 350 keV (magenta)

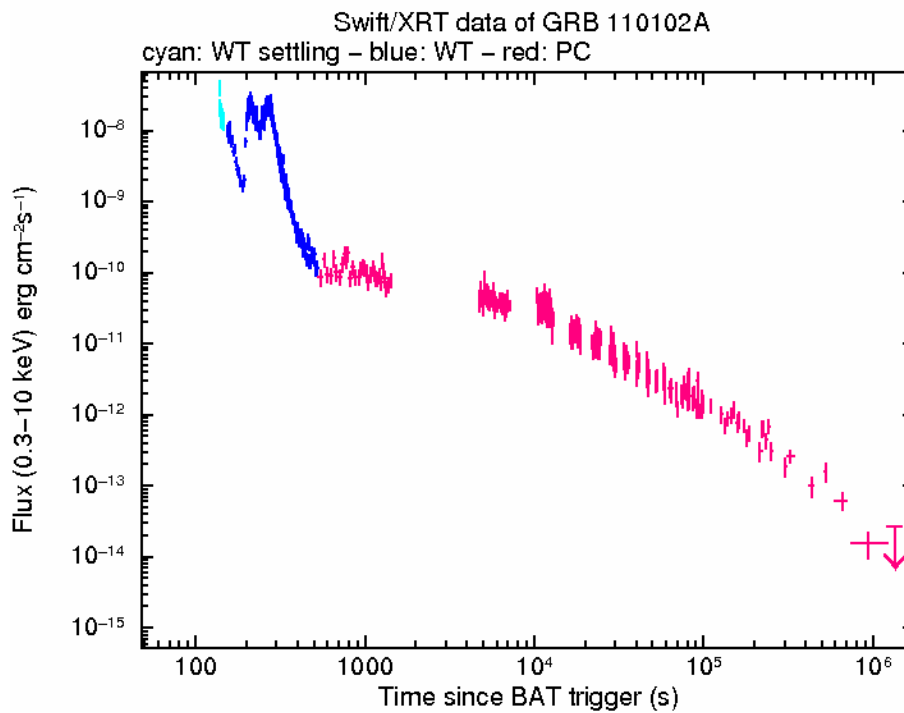


Figure 2: XRT light curve in the 0.3-10 keV band. The counts-to-observed-flux conversion factor is 1 count = 3.6×10^{-11} erg cm⁻².

Filter	Start (s)	Stop (s)	Exposure (s)	Magnitude/ 3σ UL
<i>white</i> (FC)	156	306	147	17.97 +/- 0.06
<i>u</i> (FC)	314	564	246	17.98 +/- 0.09
<i>white</i>	868	1018	147	18.39 +/- 0.08
<i>v</i>	816	835	19	17.86 +/- 0.53
<i>u</i>	1122	1315	39	18.89 +/- 0.62
<i>b</i>	597	589	19	17.60 +/- 0.20
<i>uvw1</i>	693	6331	452	>20.09
<i>uvm2</i>	668	6126	292	>19.87
<i>uvw2</i>	619	7152	471	>20.35

Table 1: Magnitude limit from UVOT observations. The values quoted above are not corrected for the expected Galactic extinction corresponding to a reddening of $E(B-V) = 0.08$ mag in the direction of the burst (Schlegel, Finkbeiner & Davis, 1998).

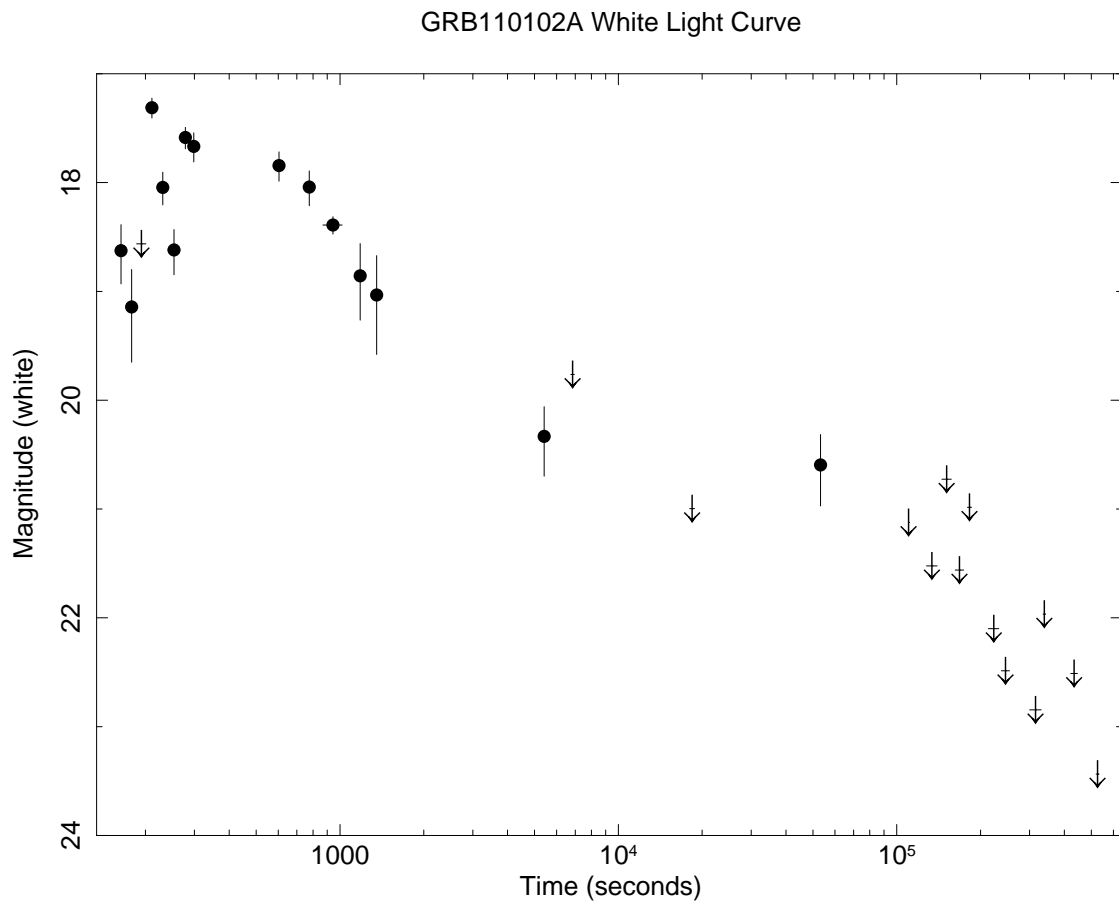


Figure 3: UVOT *white* filter light curve. Arrows are 3σ upper limits.