# Swift Observations of GRB 110106A

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## 1 Introduction

BAT triggered on GRB 110106A at 15:25:16 UT, (trigger 441664, Mangano *et al.*, *GCN Circ.* 11520). This was a 1.024 s rate-trigger on a long burst with $T_{90} = 4.3 \pm 1.1$ s. Swift slewed immediately to the burst and found an X-ray counterpart to the burst in XRT. XRT began follow up observations at $T + 91$ s, and UVOT observations began at $T + 92$ s.

Our best position is the enhanced XRT position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA($J2000$) = 79.30578 *deg* ($05^h$ $17^m$ $13.39^s$) Dec($J2000$) = +64.17349 *deg* ($+64^d$ $10'$ $24.6"$) with an uncertainty of 1.8 arcsec (radius, 90% confidence, Osborne *et al.*, *GCN Circ.* 11526).

The field of GRB 110106A has been observed by some ground based optical telescopes:

the Xinglong Tsinghua-NAOC Telescope (TNT) telescope in the R band 10 min after the trigger (Xin *et al.*, *GCN Circ.* 11521); the MASTER II robotic telescope located in Kislovodsk 41 s after the trigger (Gorbovskoy *et al.*, *GCN Circ.* 11523); the 3.6m TNG telescope, located in the Canary Islands in the R and I band 4.41 hr after the trigger (Malesani *et al.*, *GCN Circ.* 11524) and then in the K band 10.33 hr after the GRB (Malesani *et al.*, *GCN Circ.* 11539); the MITSuME 50cm telescope of Okayama Astrophysical Observatory in the g', Rc and Ic filters 65 s after the trigger (Kuroda *et al.*, *GCN Circ.* 11535); the 1.3m ISAS-Kanazawa telescope, located at Sagamihara in the Rc band 1.3 min after the trigger (Yatsu *et al.*, *GCN Circ.* 11536). None of these telescopes could detect an optical afterglow inside the XRT error circle, but a galaxy at z=0.093 (Piranomonte *et al.GCN Circ.* 11530) was found just outside the error circle, and suggested for possible association with the GRB (Malesani *et al.*, *GCN Circ.* 11524 and *GCN Circ.* 11539, Gorbovskoy *et al.*, *GCN Circ.* 11542).

## 2 BAT Observation and Analysis

Using the data set from $T - 61$ to $T + 242$ s refined analysis of BAT GRB 110106A was performed by the Swift team and reported in Stamatikos *et al.*, *GCN Circ.* 11527.

The BAT ground-calculated position is RA($J2000$) = 79.295 *deg* ($05^h$ $17^m$ $10.8s^s$), Dec($J2000$) = +64.199 *deg* ($+64^d$ $11'$ $56.4"$) with an uncertainty of 2.0 arcmin, (radius, sys+stat, 90% containment). The partial coding was 34%.

The mask-weighted light curve (Fig.1) shows shows a pulse starting at $\sim T - 1$ s and lasting about 6 s. $T_{90}$ (15−350 keV) is 4.3±1.1 s (estimated error including systematics).

The time-averaged spectrum from $T - 1.0$ to $T + 3.9$ s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.71±0.28. The fluence in the 15−150 keV band is $3.0 \pm 0.5 \times 10^{-7}$ erg cm$^{-2}$. The 1−s peak photon flux measured from $T + 0.32$ s in the 15−150 keV band is 1.9±0.3 ph cm$^{-2}$ 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/441664/BA/

## 3 XRT Observations and Analysis

Swift-XRT began follow-up observations of the field of GRB 110106A (trigger 441664, Mangano *et al.*, *GCN Circ.* 11520) 91 s after the BAT trigger.

The whole dataset consists of about 22.9 ks of data from 91 s to 92.2 ks after the BAT trigger. The data comprise 8 s in Windowed Timing (WT) mode (taken while Swift was slewing), with the remainder in Photon Counting (PC) mode. (Mangano *et al.*, *GCN Circ.* 11526).

Using 3088 s of XRT Photon Counting mode data and 6 UVOT image for GRB 110106A, we find an astrometrically corrected X-ray position (using the XRT−UVOT alignment and matching UVOT field sources to the USNO−B1 catalogue): RA($J2000$), Dec($J2000$) = 79.30578, +64.17349 which is equivalent to:

RA($J2000$) = $05^h\ 17^m\ 13.39^s$
Dec($J2000$) = $+64^d\ 10^{'}\ 24.6^{"}$

with an uncertainty of 1.8 arcsec (radius, 90% confidence; Osborne *et al.*, *GCN Circ.* 11526).

This position is within 2.9 arcsec of the initial XRT position reported by Mangano *et al.*, *GCN Circ.* 11520.

The late-time 0.3−10 keV XRT light curve (from $T + 3.5$ ks, Fig.2) is well fitted by a power-law with a decay index of $1.2^{+0.4}_{-0.3}$.

The PC mode spectrum (extracted from $T+113$ s to $T+21.8$ ks, 8.65 ks exposure) has a photon index of $2.7^{+0.4}_{-0.5}$ and a best-fitting absorption column of $4.0^{+1.6}_{-1.4} \times 10^{21}$ cm$^{-2}$, in excess of the Galactic value of $1.3{\times}10^{21}$ cm$^{-2}$ (Kalberla et al. 2005) with a significance of 4.8 sigma. The counts to observed (unabsorbed) 0.3−10 keV flux conversion factor deduced from this spectrum is $3.4{\times}10^{-11}(1.0{\times}10^{-10})$ erg cm$^{-2}$ s$^{-1}$.

The results of the XRT-team automatic analysis are available at
http://www.swift.ac.uk/xrt_products/00441664.

## 4 UVOT Observation and Analysis

The UVOT began settled observations of the field of GRB 110106A 92 s after the BAT trigger (Mangano *et al.*, *GCN Circ.* 11520). Settled observations started at 110 s. We do no detect an optical afterglow in any of the UVOT filters.

3-sigma upper limits for the finding charts (FC) and co-added exposures are given in the following Table 1 where $T_{start}$ and $T_{stop}$ are the start and stop time of the observation.

The above upper limits are not corrected for the Galactic extinction corresponding to a reddening of E(B-V) = 0.05 (Schlegel et al., 1998, ApJS, 500, 525). The photometry is on the UVOT photometric system described in Poole et al. (2008, MNRAS, 383, 627).

| Filter | $T_{start}$(s) | $T_{stop}$(s) | Exp(s) | 3-sigma upper limit |
|---|---|---|---|---|
| white_FC | 110 | 162 | 52 | >20.2 |
| | 3530 | 3680 | 150 | >20.3 |
| v | 3687 | 16046 | 1278 | >20.3 |
| b | 4508 | 10281 | 1082 | >21.1 |
| u | 4302 | 5939 | 393 | >20.4 |
| uvw1 | 4097 | 5734 | 393 | >20.2 |
| uvm2 | 3892 | 5529 | 393 | >20.1 |
| uvw2 | 4918 | 11717 | 706 | >20.9 |
| white | 110 | 11194 | 1280 | >22.0 |

Table 1: 3-sigma upper limits from UVOT observations

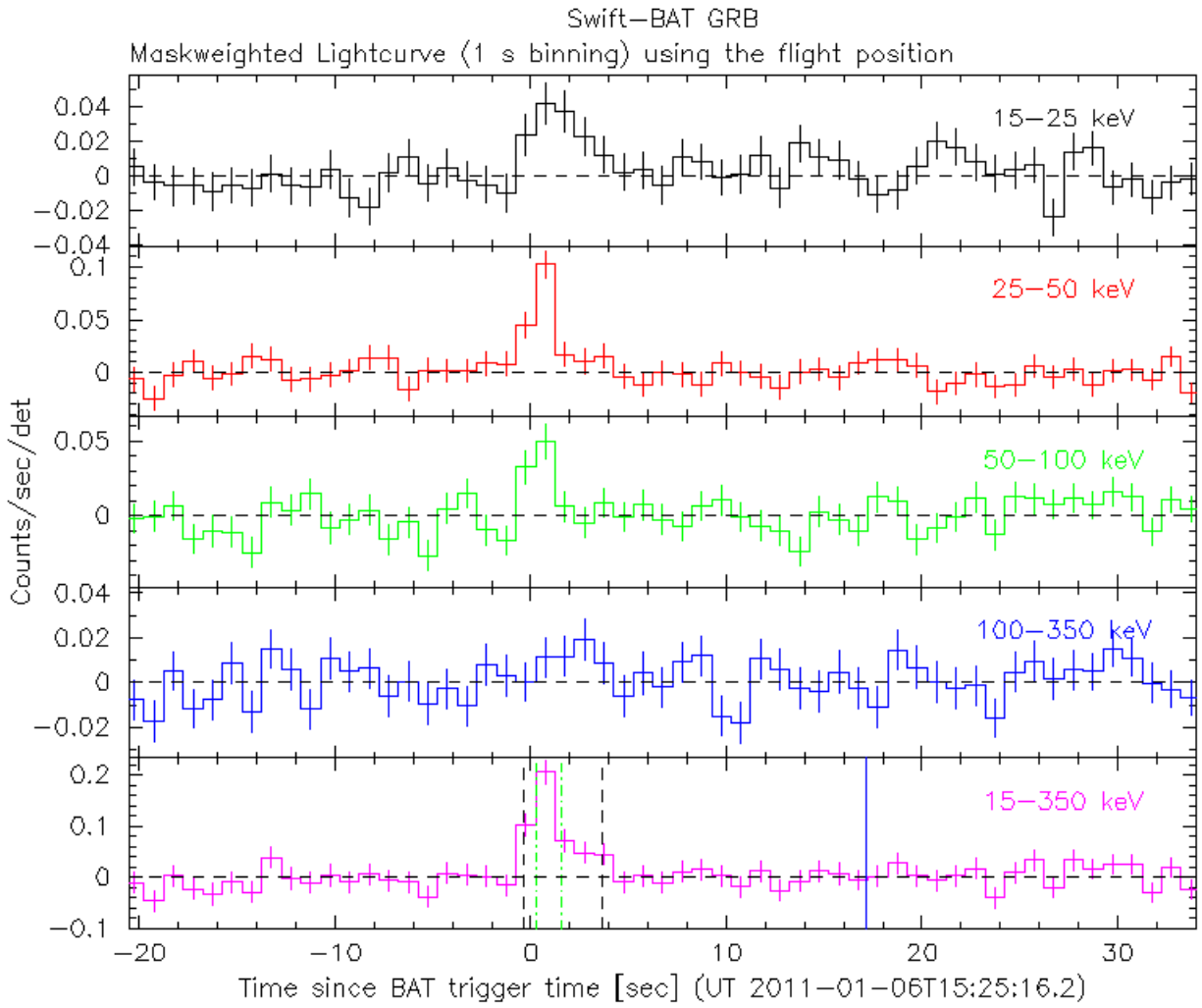


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts $s^{-1}$ illuminated-detector$^{-1}$ (note illum-det = 0.16 $cm^2$) and $T_0$ is 2011 Jan 06 15:25:16 UT.

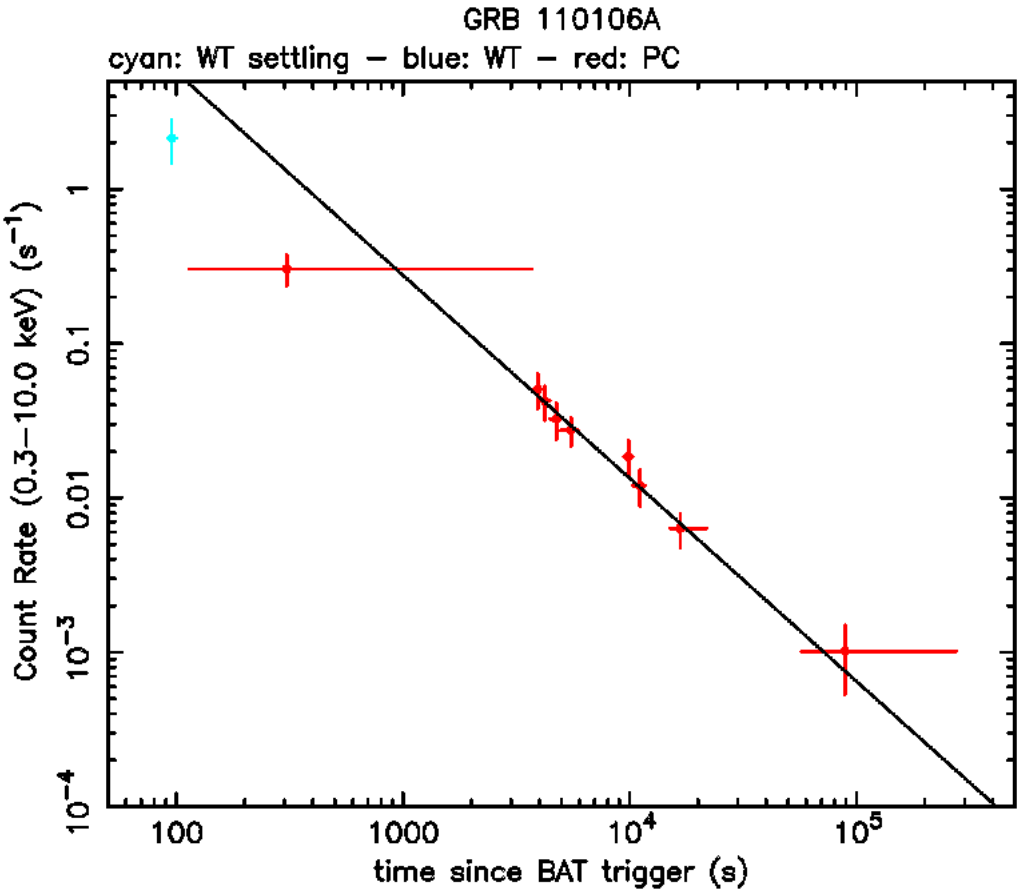


Figure 2: XRT Light curve. Counts/s in the 0.3−10 keV band: Window Timing mode (cyan for settling and blue for settled observation), Photon Counting mode (red). The approximate conversion is 1 count/s = $\sim 1.1 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$.