

Swift Observations of GRB 111016A

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1 Introduction

BAT triggered on GRB 111016A at 18:37:04 UT, (trigger 505646, Mangano *et al.*, *GCN Circ.* 12439). This was an image trigger on a long burst with $T_{90} = 550 \pm 105$ s. Swift slewed immediately to the burst and found an X-ray counterpart to the burst in XRT (Osborne *et al.*, *GCN Circ.* 12440). XRT began follow up observations at $T + 180$ s, and UVOT observations began at $T + 187$ 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($J2000$) = 153.83400 *deg* ($10^h 15^m 20.16^s$) Dec($J2000$) = +27.46235 *deg* ($+27^d 27' 44.5''$) with an uncertainty of 1.5 arcsec (radius, 90% confidence, Evans *et al.*, *GCN Circ.* 12441).

The field of GRB 111016A has been observed by some ground based optical telescopes: the MITSuME 50 cm telescope of Akeno Observatory, ~ 15 min after the BAT trigger (Usui *et al.*, *GCN Circ.* 12443); the robotic Palomar 60 inch telescope, ~ 16.9 hours after the initial Swift trigger (Cenko *et al.*, *GCN Circ.* 12444); the 0.5m robotic telescope D50 in Ondrejov observatory, ~ 5.5 hours after the Swift trigger (Blazek *et al.*, *GCN Circ.* 12448); the WIYN High Resolution Infrared Camera (WHIRC) on the WIYN 3.5m telescope, about 17 hours post-burst (Kamble *et al.*, *GCN Circ.* 12451); the 40-cm telescope ORI-40 of Kitab ISON observatory, on October 16 at 22:07:26 UT (Volnova *et al.*, *GCN Circ.* 12486). A position for marginally detected optical afterglow candidate is given in Cenko *et al.*, *GCN Circ.* 12444.

The field of GRB 111016A has been observed in the Optical/NIR with the Near-Infrared Imager and Spectrometer (NIRI) mounted on the 8 m Gemini North telescope (Cenko *et al.*, *GCN Circ.* 12447).

2 BAT Observation and Analysis

Using the data set from $T-239$ to $T+963$ s from telemetry downlinks, the refined analysis of BAT GRB 111016A was performed by the Swift team and reported in Barthelmy *et al.*, *GCN Circ.* 12445.

The BAT ground-calculated position is RA($J2000$) = 153.826 *deg* ($10^h 15^m 18.2^s$) Dec($J2000$) = +27.474 *deg* ($+27^d 28^m 26.7^s$) with an uncertainty of 2.2 arcmin, (radius, sys+stat, 90% containment). The partial coding was 64%.

The mask-weighted light curve (Fig.1) shows a series of slightly overlapping peaks starting at $\sim T-5$ s, peaking at $T+58$, $T+118$, $T+160$, $T+210$, $T+255$ s, then returning to baseline, followed by smaller peaks at $T+410$, $T+540$, $T+600$ s, and possible peaks at $T+700$ and $T+800$ s. The burst location goes out of the BAT FOV at $T+960$ s. T_{90} (15–350 keV) is 550 ± 105 s (estimated error including systematics).

The time-averaged spectrum from $T+35.41$ to $T+614.48$ s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.95 ± 0.12 . The total fluence in the 15–150 keV band is $(4.0 \pm 0.3) \times 10^{-6}$ erg cm^{-2} . The 1-sec peak photon flux measured from $T+115.23$ s in the 15–150 keV band is 0.9 ± 0.2 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/505646/BA/

3 XRT Observations and Analysis

The whole Swift-XRT dataset for GRB 111016A (trigger 505646, Mangano *et al.*, *GCN Circ.* 12439), consists of 81.2 ks of data from 168.38 s to 710.5 ks after the BAT trigger. The data comprise ~ 9 s in Windowed Timing (WT) mode taken while Swift was slewing (from T+168.4 to T+178 s), ~ 689 s in Windowed Timing (WT) mode (from T+185 to T+ 873.7 s), with the remainder in Photon Counting (PC) mode (from T+4055.8 s). Using the initial 5089 s of PC mode data and 11 UVOT images, we find an enhanced XRT position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA(*J*2000), Dec(*J*2000) = 153.83400, +27.46235 which is equivalent to RA(*J*2000) = $10^h 15^m 20.16^s$ Dec(*J*2000) = $+27^d 27' 44.5''$ with an uncertainty of 1.5 arcsec (radius, 90% confidence, Evans *et al.*, *GCN Circ.* 12441).

Preliminary refined analysis has been reported in Mangano *et al.*, *GCN Circ.* 12442. After the first orbit of WT data where flaring activity occurs, the 0.3–10 keV XRT light curve (Fig.2) can be modelled with a broken power-law with the following best fit parameters:

$$\alpha_1 = 3.582_{-1.103}^{+0.2421}, T_{break1} = T + 5701_{-451}^{+972} \text{ s } \alpha_2 = 0.9838_{-0.0706}^{+0.06023}$$

A spectrum formed from the 689 s WT mode data can be fitted with an absorbed power-law with a photon spectral index of $1.801_{-0.024}^{+0.025}$. The best-fitting intrinsic absorption column is $1.597_{-0.072}^{+0.074} \times 10^{21} \text{ cm}^{-2}$, in excess of the Galactic value of $2.5 \times 10^{20} \text{ cm}^{-2}$ (Kalberla *et al.*, 2005). A spectrum formed from the initial 28.6 ks of PC mode data (from T+4055.8 s to T+73.5 ks) can be fitted with an absorbed power-law with a photon spectral index of $2.26_{-0.16}^{+0.16}$. The best-fitting intrinsic absorption column is $5.0_{-2.9}^{+3.1} \times 10^{20} \text{ cm}^{-2}$. The counts to observed (unabsorbed) 0.3–10 keV flux conversion factor deduced from this spectrum is 3.2×10^{-11} (4.2×10^{-11}) $\text{erg cm}^{-2} \text{ s}^{-1}$.

The results of the XRT-team automatic analysis are available at http://www.swift.ac.uk/xrt_curves/00505646.

4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 111016A approximately 188 s after the BAT detection (Mangano *et al.*, *GCN Circ.* 12439). No optical afterglow consistent with the Enhanced Swift-XRT position (Evans *et al.*, *GCN Circ.* 12441) is detected in the initial UVOT exposures, however a marginal source is detected in followup observations in the UVOT white filter. This position is consistent with the source observed by Cenko *et al.*, *GCN Circ.* 12444. Preliminary 3-sigma upper limits/magnitudes for the first finding chart (FC) exposure and subsequent exposures are given in the following Table 1 where T_{start} and T_{stop} are the start and stop time of the observation (Pritchard *et al.*, *GCN Circ.* 12446).

The above magnitudes 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).

The final UVOT light curves are shown in figure 3.

Filter	$T_{start}(s)$	$T_{stop}(s)$	Exp(s)	Magnitude/Upper Limit
white (FC)	188	337	147	>20.3
u (FC)	345	595	246	>19.3
white	188	23781	1926	>21.5
white	27360	45216	4662	21.56
v	4468	16602	1278	>20.5
b	5288	23264	1967	>21.6
u	345	22351	1328	>20.4
uvw1	724	18207	1095	>20.5
uvm2	700	17507	1298	>20.8
uvw2	651	12429	1135	>20.7

Table 1: Magnitudes or 3-sigma upper limits from UVOT observations. (FC) stands for Finding Chart.

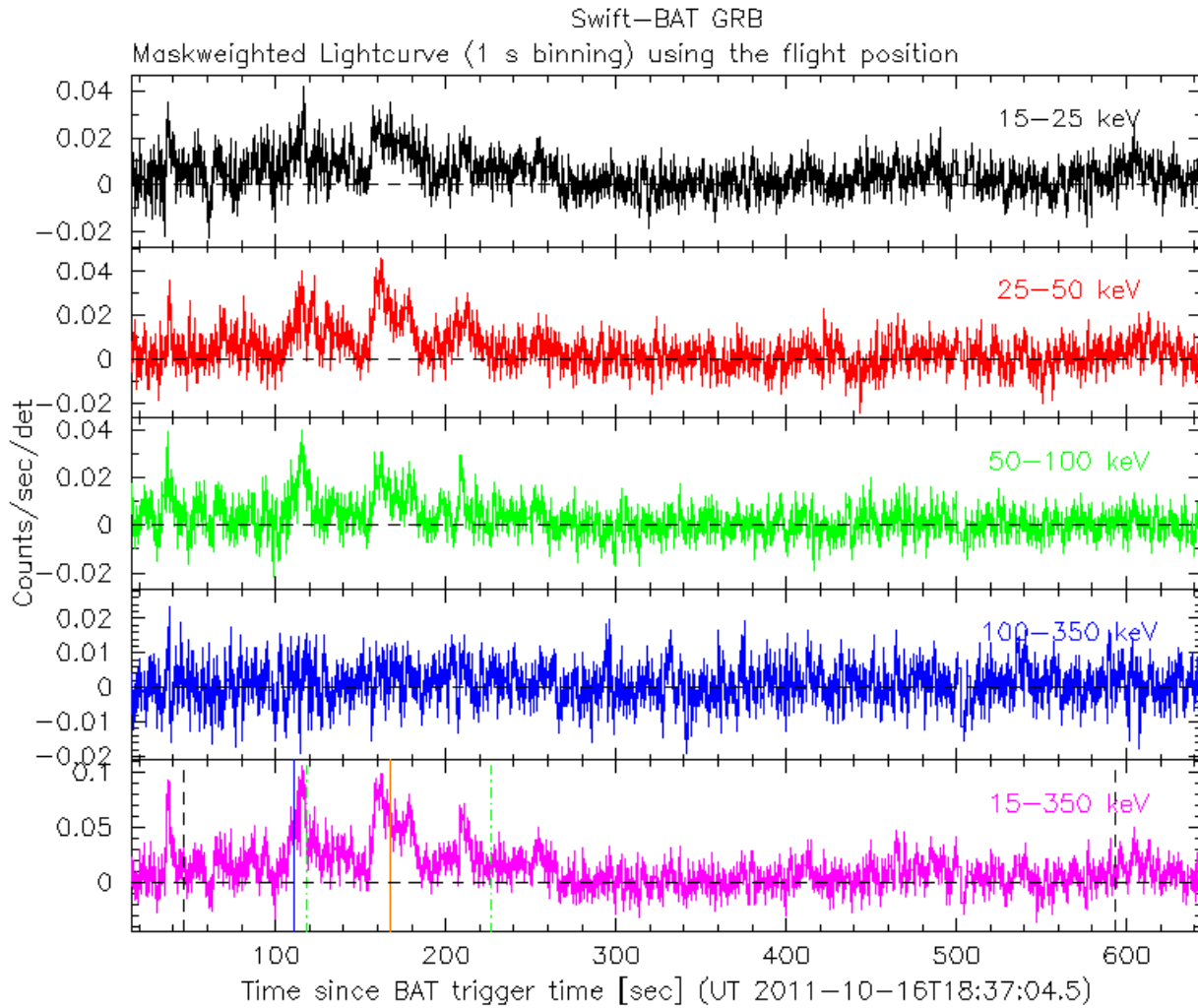


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector $^{-1}$ (note illum-det = 0.16 cm^2) and T_0 is 2011 Oct 16 18:37:04 UT.

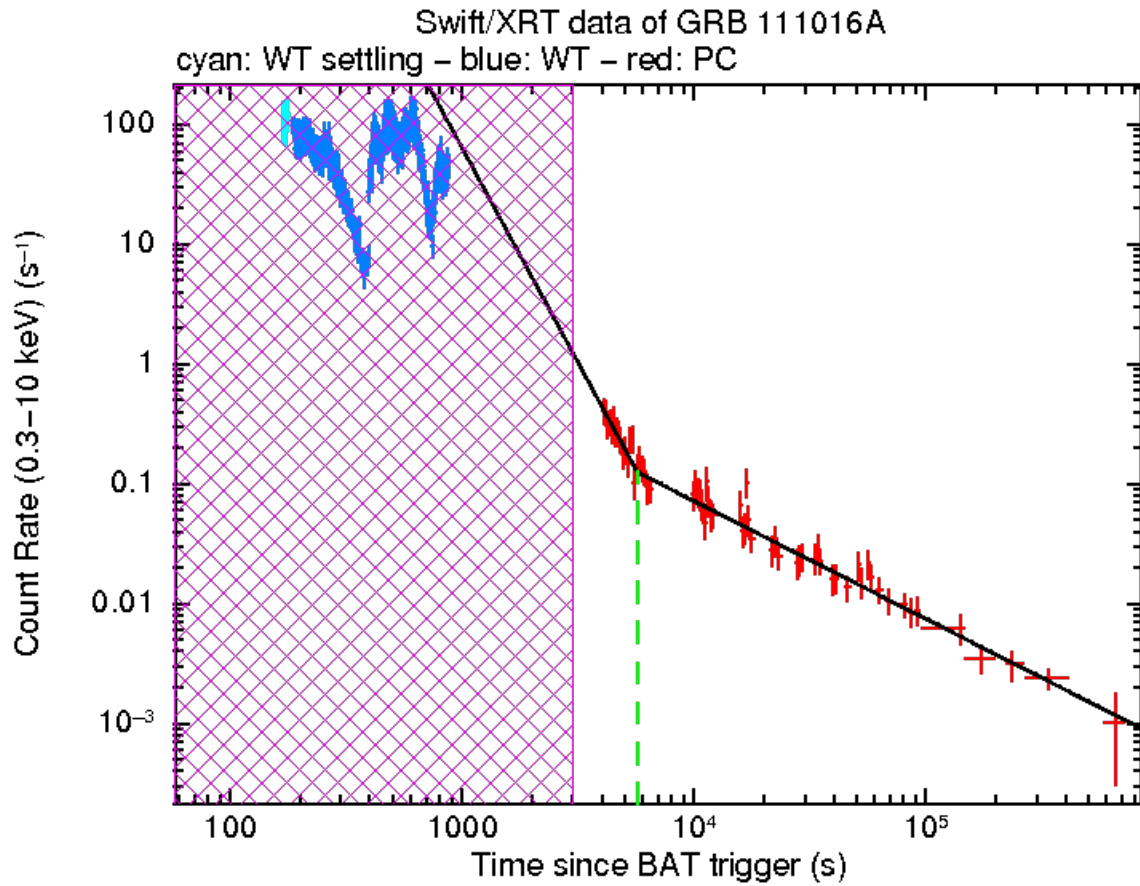


Figure 2: XRT Light curve. Counts/s in the 0.3–10 keV band: Windowed Timing mode (cyan for settling and blue for settled observation), and Photon Counting mode (red). The approximate conversion is 1 count/s = $\sim 4.2 \times 10^{-11}$ erg cm⁻² s⁻¹.

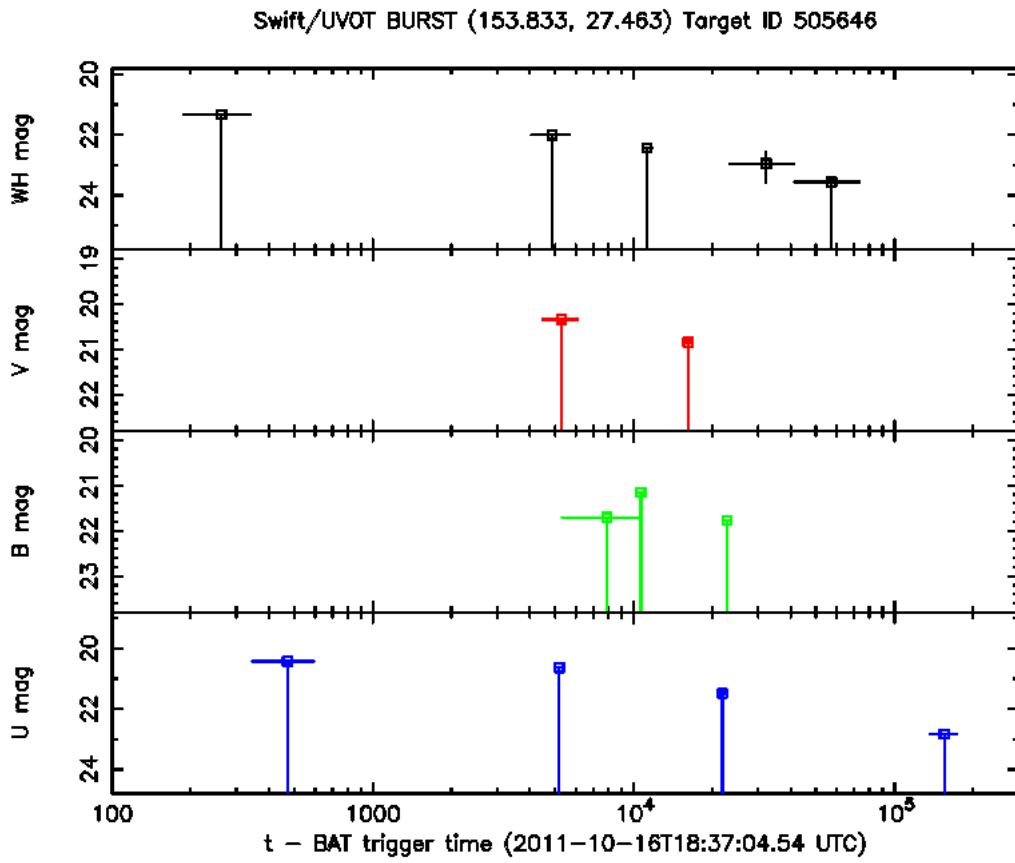


Figure 3: Final UVOT light curves, including upper limits from Table 1.