Swift Observation of GRB 111228A

T. N. Ukwatta (MSU), P. D'Avanzo (INAF-OAB), N. P. M. Kuin (MSSL/UCL), H. A. Krimm (CRESST/GSFC/USRA), J. R. Cummings (GSFC/UMBC), S. D. Barthelmy (GSFC), D. N. Burrows (PSU), M. H. Siegel (PSU), and N. Gehrels (GSFC) for the Swift Team

1 Introduction

BAT triggered (Trigger 510649) on GRB 111228A at 15:44:43 UT (Ukwatta et al., 2011). Swift slewed immediately to the burst. This was a $16.82\,\sigma$ rate-trigger on a burst with $T_{90} = 101.20 \pm 5.42$ sec. The XRT began observing the field at 15:47:08.5 UT, 145.1 seconds after the BAT trigger. XRT found a fading, uncatalogued X-ray source (Ukwatta et al., 2011; Goad et al., 2011). The UVOT started settled observations at $\sim T + 155$ sec and detected an optical afterglow consistent with the XRT position. Our best position is the UVOT location at RA($J2000$) = 150.06684 deg (10h 00m 16.04s), Dec($J2000$) = +18.297834 deg (+18d 17′ 52.2″) with an uncertainty of 0.56 arcsec (90% confidence, including boresight uncertainties).

The spectroscopic redshift of the burst is ~ 0.714 (Dittman et al., 2011; Cucchiara et al., 2011; Palazzi et al., 2011; Xu et al., 2011; Schulze et al., 2011). In addition, GRB 111228A was detected by KonusWind (Golenetskii et al., 2011) and also by the Fermi GBM (Briggs et al., 2011).

2 BAT Observation and Analysis

Using the data set from $T - 239$ to $T + 963$ sec, further analysis of BAT GRB 111228A has been performed by BAT team (Cummings et al., 2011). The BAT ground-calculated position is RA($J2000$) = 150.063 deg (10h 00m 15.0s), Dec($J2000$) = 18.284 deg (+18d 17′ 02.2″) ± 1.4 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 39% (the bore sight angle was 41.3 deg).

The mask-weighted light curve (Fig. 1) shows multiple peaks in several clusters. The first set of peaks is at a low level from $\sim T - 12$ s to $\sim T + 12$ s. There is another low level set from $\sim T + 32$ to $\sim T + 42$ s, followed by a much brighter set of three overlapping peaks from $\sim T + 45$ to $\sim T + 60$ s. The final cluster is broad and relatively soft from $\sim T + 85$ to $\sim T + 110$ s. T90 (15-350 keV) is 101.20 ± 5.42 sec (estimated error including systematics).

The time-averaged spectrum from $T - 12.82$ to $T + 115.43$ sec is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 2.27 ± 0.06. The fluence in the $15 - 150$ keV band is $8.5 \pm 0.2 \times 10^{-6}$erg cm^{-2}. The 1-sec peak photon flux measured from $T + 54.56$ sec in the $15 - 150$ keV band is 12.4 ± 0.5 ph cm^{-2} sec. 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/510649/BA/`.

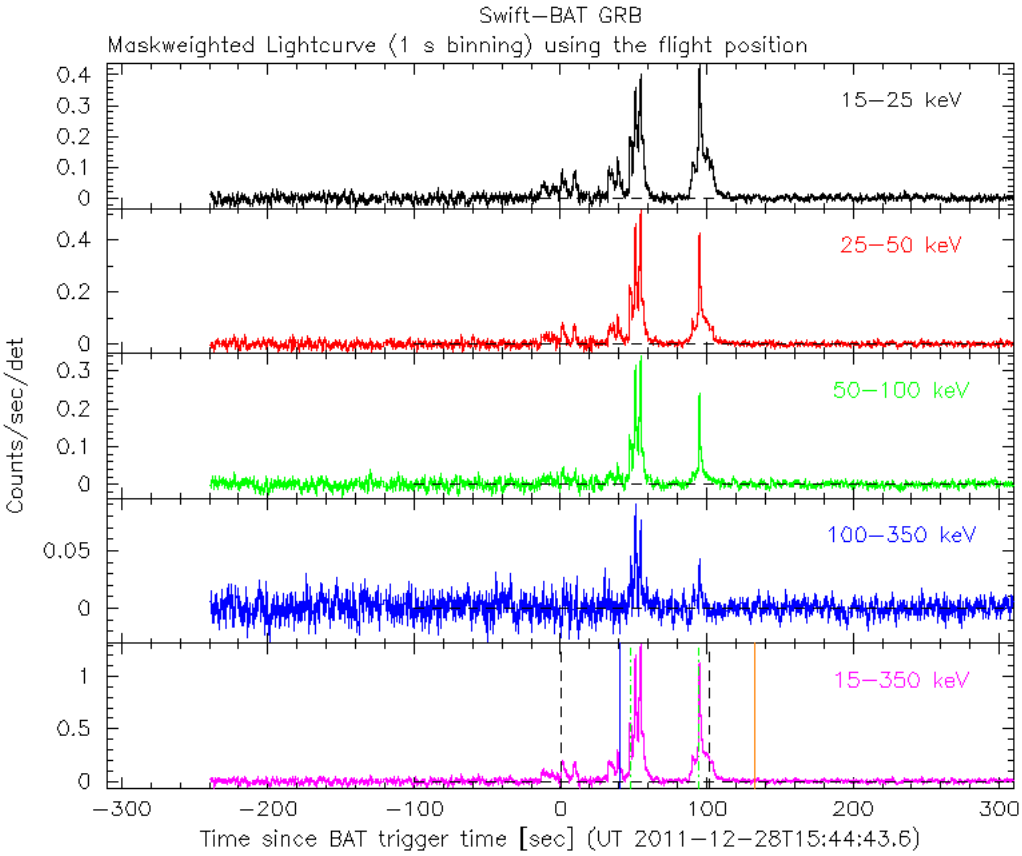

Figure 1: The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector and T_0 is 15:44:43 UT.

3 XRT Observations and Analysis

XRT data were collected from $T+135$ s to $T+2946$ ks. The data comprise 331 s in Windowed Timing (WT) mode (the first 9 s were taken while Swift was slewing) with the remainder in Photon Counting (PC) mode. The enhanced XRT position for this burst is:

RA(J2000) = 10h 00m 16.10s
Dec(J2000)= +18d 17' 52.2"

with an uncertainty of 1.4 arcsec (radius, 90% confidence).

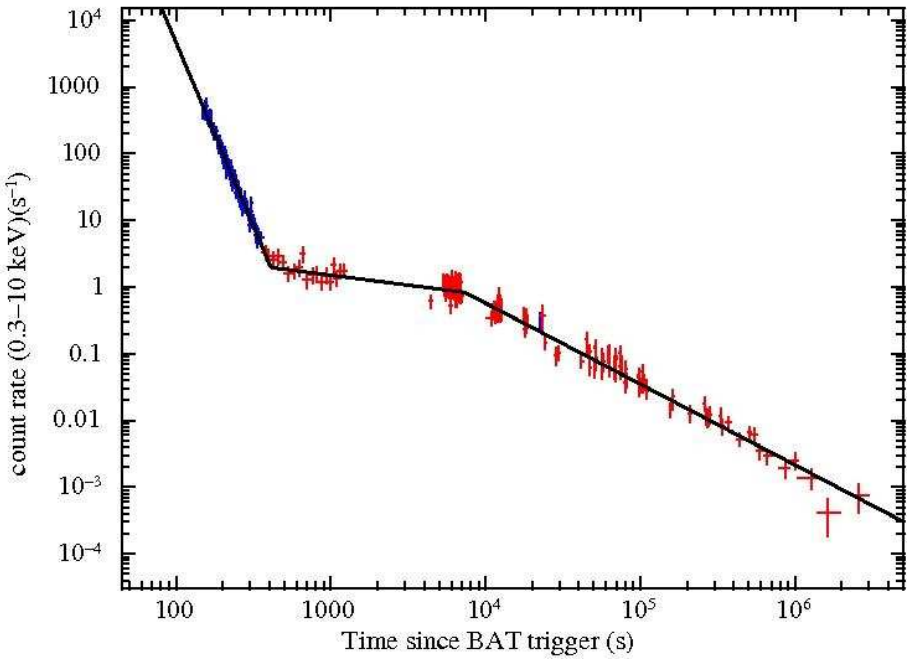

Figure 2: XRT Lightcurve. Flux in the $0.3-10$ keV band with Window Timing (WT) mode data in blue and Photon Counting (PC) mode data in red. The approximate conversion is 1 count/sec $= \sim 3.5\times10^{-11}$ ergs/cm^2/sec.

The light curve can be modelled with a series of power-law decays (Fig. 2). The initial decay index is $\alpha_1 = 5.500^{+0.093}_{-0.091}$. At $T+411^{+11}_{-10}$ s the decay flattens to an $\alpha_2 = 0.298^{+0.051}_{-0.054}$ before breaking again at $T+7355^{+806}_{-755}$ s to a final decay with index $\alpha_3 = 1.214^{+0.029}_{-0.029}$.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of $3.85^{+0.08}_{-0.08}$. The best-fitting total absorption column is $5.20^{+0.26}_{-0.25}\times10^{21}$ cm^{-2}, in excess of the Galactic value of 3.0×10^{20} cm^{-2} (Kalberla et al., 2005). The PC mode spectrum has a photon index of $2.06^{+0.08}_{-0.08}$ and a best-fitting total absorption column of $2.81^{+0.49}_{-0.47}\times10^{21}$ cm^{-2}. The counts to observed (unabsorbed) 0.3-10 keV flux conversion factor deduced from this spectrum is $3.5\times10^{-11}(4.7\times10^{-11})$ erg cm^{-2} count^{-1}.

The results of the XRT-team automatic analysis are available at
`http://www.swift.ac.uk/xrt_products/00510649`.

4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 111228A, 155 seconds after the BAT trigger. A new source was found, consistent with the enhanced Swift XRT position, at

RA(J2000) = 150.06684 deg
Dec(J2000) = +18.297834 deg.

Preliminary magnitudes and 3-sigma upper limits using the UVOT photometric system (Breeveld et al., 2011) for the first finding chart (FC) exposure and subsequent exposures have been given in Table1. UVOT continued detecting the optical emission until 31 Jan 2012, giving very good multicolor light curves.

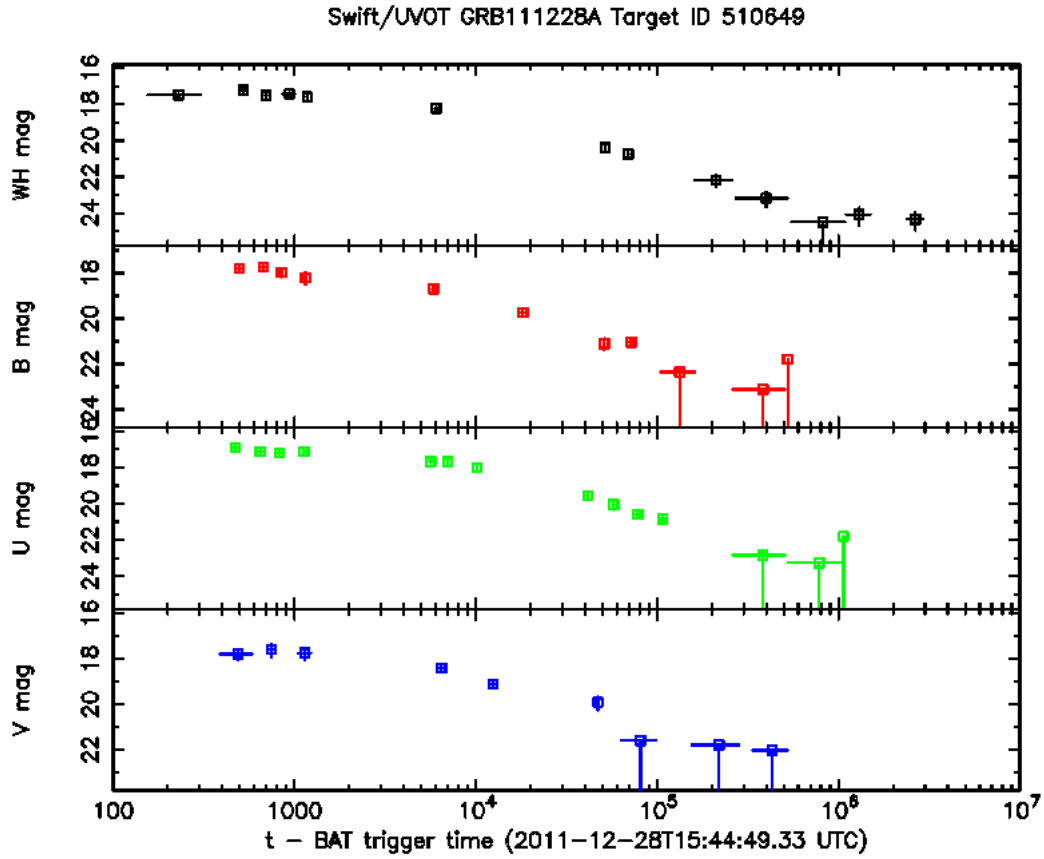

Figure 3: UVOT light curve in the white, b, u, and v filters.

The late time observations in the white filter flatten indicating that a possible host is detected. The position of the late time emission of the possible host is:

RA(J2000) = 150.06643 deg
Dec (J2000) = +18.297903 deg.

The position of the late time emission is offset from the early emission by 0.9" which is significantly larger than the position error for a single uvot image of 0.5", and a possibly smaller position error when comparing between summed uvot images. Given that the flattening of the light curve suggests an underlying source, and the apparent offset, the late time emission may come from a different source, possibly the host.

Filter	Tstart (s)	Tstop (s)	Exposure (s)	Magnitude
white	155	305	147	17.30 ± 0.03
v	389	759	58	17.73 ± 0.16
b	488	508	19	17.71 ± 0.15
u	463	483	19	16.70 ± 0.12
w1	439	459	19	16.59 ± 0.17
m2	764	784	19	16.84 ± 0.24

Table 1: Magnitudes and limits from UVOT observations

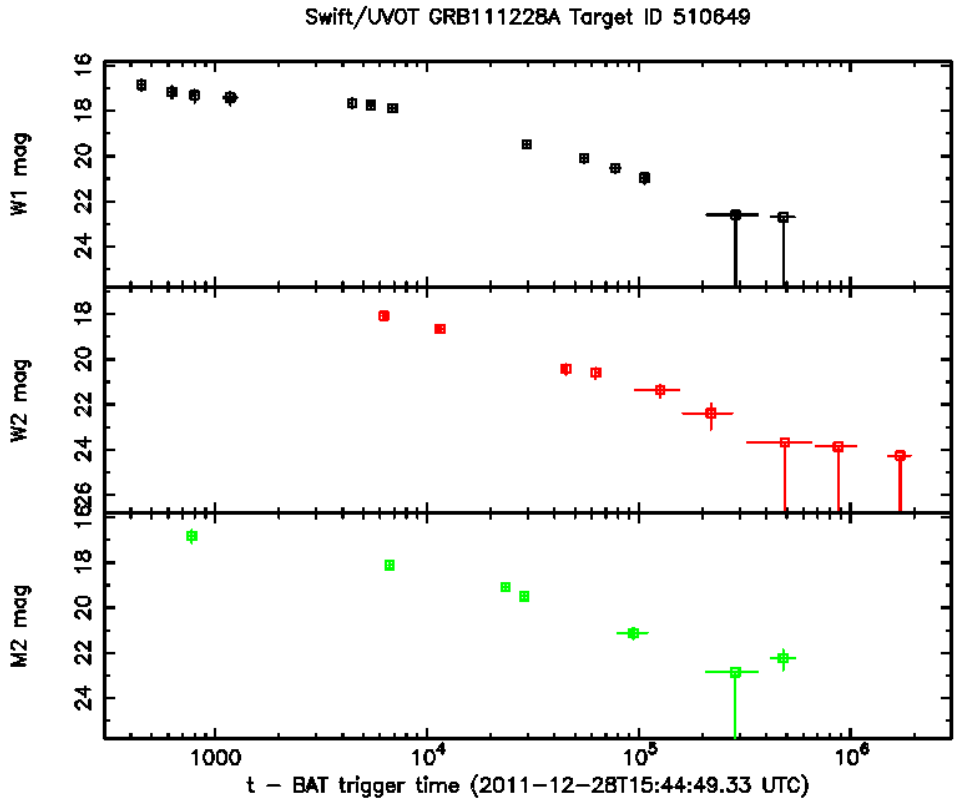

Figure 4: UVOT light curve in the W1, W2, and M2 filters

The count rate between 20ks and 700ks decays with a power index $\sim$ -1.3 in nearly all bands. Taking that as the decay rate, the light curves in white and uvw2 deviate from the power law decay rate at times more than 800ks after the trigger. We subtracted the extrapolated power law decay to obtain the underlying emission.

The current best estimate host magnitudes are: white=$24.6^{+0.4}_{-0.6}$ mag, and uvw2 = 24.9 mag; host fluxes are white: $(2.05 \pm 0.8) \times 10^{-7}$ Jy (3471 Å broadband), and with a S/N just over 1: uvw2 = 9×10^{-8} Jy at 2030 Å.

References

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