Swift Observations of GRB 110928A

E. A. Hoversten (PSU), C. A. Wolf (PSU), S. D. Barthelmy (GSFC), D. N. Burrows, (PSU), M. H. Siegel (PSU), & N. Gehrels (GSFC) for the Swift Team

1 Introduction

At 01:51:31 UT on 28 September 2011 BAT triggered on and located GRB 110928A (Hoversten *et al.*, *GCN Circ.* 12394, Trigger #504215). Due to an Earth limb constraint Swift was unable to slew to this burst until 55 minutes after the trigger. XRT and UVOT began follow up observations at $T + 3.3$ ks. Our best position is the UVOT-enhanced XRT position at RA($J2000$) = 257.73295 deg ($17h10m55.91s$), Dec($J2000$) = +36.53571 deg ($+36d32'08.5''$) with an uncertainty of 2.2 arcsec (radius, 90% confidence).

Ground-based observations of GRB 110928A were reported by numerous observatories, however all of these observations yielded upper limits. Optical limits were reported by ROTSE-III (Schaefer *et al.*, *GCN Circ.* 12395), Palomar 60 inch telescope (Cenko, *GCN Circ.* 12401), RAPTOR (Wren *et al.*, *GCN Circ.* 12407, and Skynet (Haislip *et al.*, *GCN Circ.* 12408, 12409). Near infrared upper limits were reported by PAIRITEL (Morgan *et al.*, *GCN Circ.* 12400).

2 BAT Observation and Analysis

Using the data set from $T - 60$ to $T + 243$ s further analysis of GRB 110928A (trigger #504215) was performed by the Swift team (Barthelmy, *et al.*, *GCN Circ.* 12399). The BAT ground-calculated position is RA($J2000$) = 257.745 deg ($17h10m58.7s$), Dec($J2000$) = 36.547 deg ($+36d32'49.3$"), with an uncertainty of 2.3 arcmin, (radius, sys+stat, 90% containment). The partial coding was 37%.

The mask-weighted light curve shows a single FRED-like peak starting at $\sim T_0$ and ending at $\sim T + 30$ s. $T_{90}(15 - 350keV)$ is 26.7 ± 4.8 s (estimated error including systematics).

The time-averaged spectrum from $T - 0.53$ to $T + 27.88$ s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.09 ± 0.30. The fluence in the 15-150 keV band is $6.9 \pm 1.1 \times 10^{-7} erg\ cm^{-2}$. The 1-second peak photon flux measured from $T + 6.84$ s in the 15-150 keV band is 0.9 ± 0.3 $photon\ cm^{-2}\ s^{-1}$. All the quoted errors are at the 90% confidence level.

The BAT light curve is shown in Figure 1.

3 XRT Observations and Analysis

XRT observations began 3.3 ks after the BAT trigger. Analysis of 12 ks of XRT data from 3.3 to 44.3 s after the BAT trigger was performed (Wolf *et al.*, *GCN Circ.* 12404). The data was collected in Photon Counting (PC) mode. The UVOT-enhanced XRT position of GRB 110928A is RA($J2000$) = 257.73295 deg ($17h10m55.91s$), Dec($J2000$) = +36.53571 deg ($+36d32'08.5''$) with an uncertainty of 2.2 arcsec (radius, 90% confidence, Osborne *et al.*, *GCN Circ.* 12402).

The light curve can be modelled with a power-law decay with a decay index of $\alpha = 0.55^{+0.17}_{-0.19}$. A spectrum formed from the PC mode data can be fitted with an absorbed power-law with a photon spectral index of $2.07^{+0.34}_{-0.27}$. The best-fitting absorption column is $4.8^{+2.5}_{-1.7} \times 10^{21}$ cm^{-2}, in excess of the

Galactic value of 3.1×10^{20} cm^{-2} (Kalberla et al. 2005). The counts to observed (unabsorbed) 0.3-10 keV flux conversion factor deduced from this spectrum is 4.4×10^{-11} (8.1×10^{-11}) $erg\ cm^{-2}\ counts^{-1}$.

The XRT light curve is shown in Figure 2.

4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 110928A 3.3 ks after the BAT trigger (Hoversten *GCN Circ.* 12406). No optical afterglow consistent with the XRT position (Osborne *et al.*, *GCN Circ.* 12402) is detected in the initial UVOT exposures. The 3-sigma upper limits using the UVOT photometric system (Poole et al. 2008) for the first finding chart (FC) exposure and subsequent exposures are given in Table 1. The magnitudes are not corrected for Galactic extinction which is $E(B-V) = 0.03$ along the line of sight to the burst (Schlegel, Finkbeiner, & Davis, 1998).

References

[1] Barthelmy, S. D., et al. 2011, *GCN Circ.* 12399

[2] Cenko, S. B., et al. 2011, *GCN Circ.* 12401

[3] Haislip, J., et al. 2011, *GCN Circ.* 12408

[4] Haislip, J., et al. 2011, *GCN Circ.* 12409

[5] Hoversten, E. A. 2011, *GCN Circ.* 12406

[6] Hoversten, E. A., et al. 2011, *GCN Circ.* 12394

[7] Kalberla, P. M. W., et al. 2005, *A.& A.*, 440, 775

[8] Morgan, A. N., et al. 2011, *GCN Circ.* 12400

[9] Osborne, J. P., et al. 2011, *GCN Circ.* 12402

[10] Poole, T. S., et al. 2008, *MNRAS*, 383, 627

[11] Schaefer, B. E., et al. 2011, *GCN Circ.* 12395

[12] Schlegel, D. J., Finkbeiner, D., & Davis, M. 1998, *ApJ.*, 500, 525

[13] Wolf, C. A., et al. 2011, *GCN Circ.* 12404

[14] Wren, J., et al. 2011, *GCN Circ.* 12407

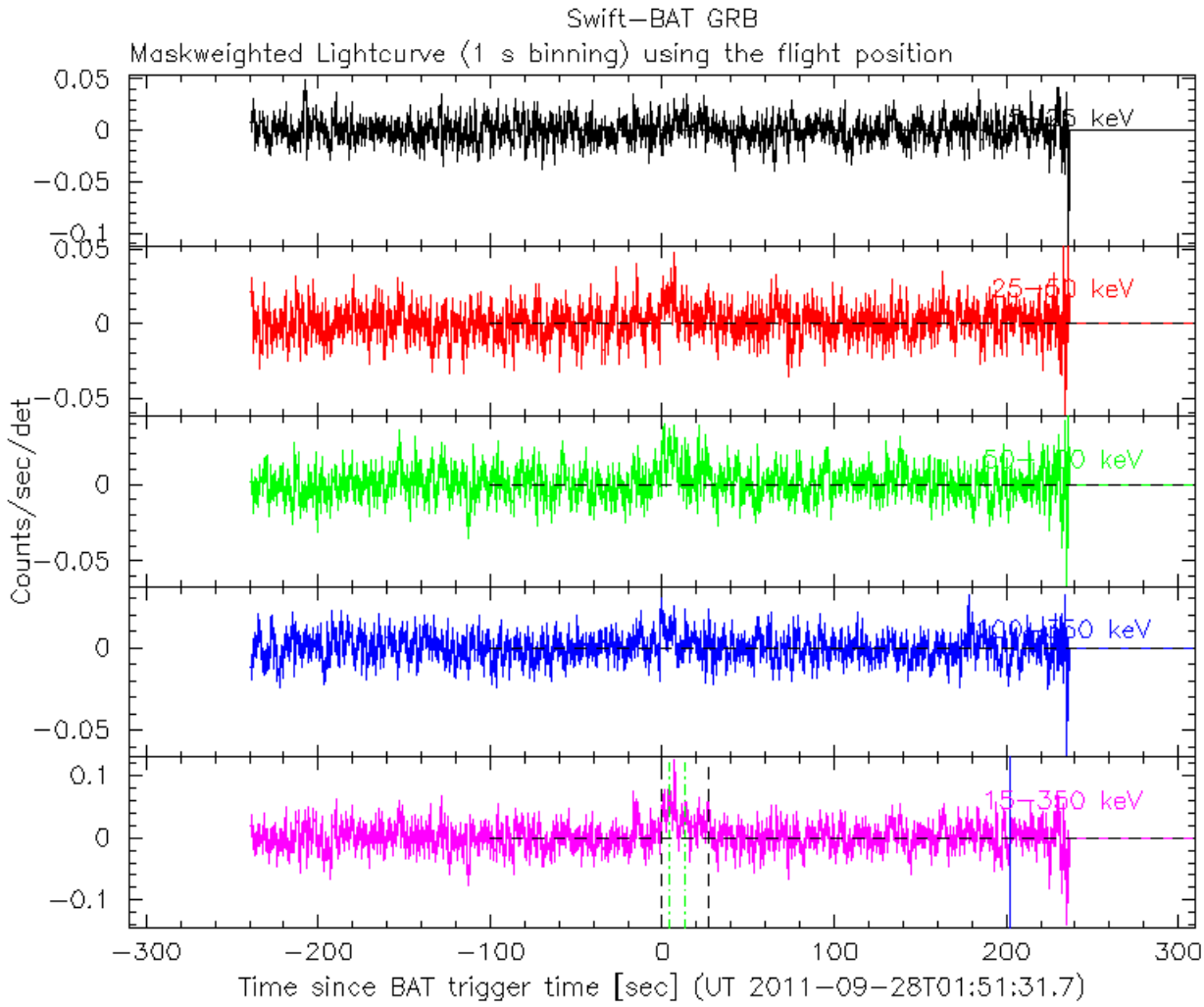

Figure 1: BAT Light curve. The mask-weighted light curve over all energy bands. The units are counts/s/illuminated-detector (note illum-det = 0.16 cm^2) and T_0 is 01:51:31.7 UT.

Filter	Start	Stop	Exposure	Mag 3σ UL
white (FC)	3342	3492	147	> 20.2
white	3342	4723	344	> 21.0
v	3499	3698	197	> 19.1
b	4319	4518	197	> 21.0
u	4114	4313	197	> 20.8
uvw1	3909	4108	197	> 20.3
uvm2	3704	3903	197	> 19.9
uvw2	4729	4929	197	> 21.6

Table 1: UVOT observations

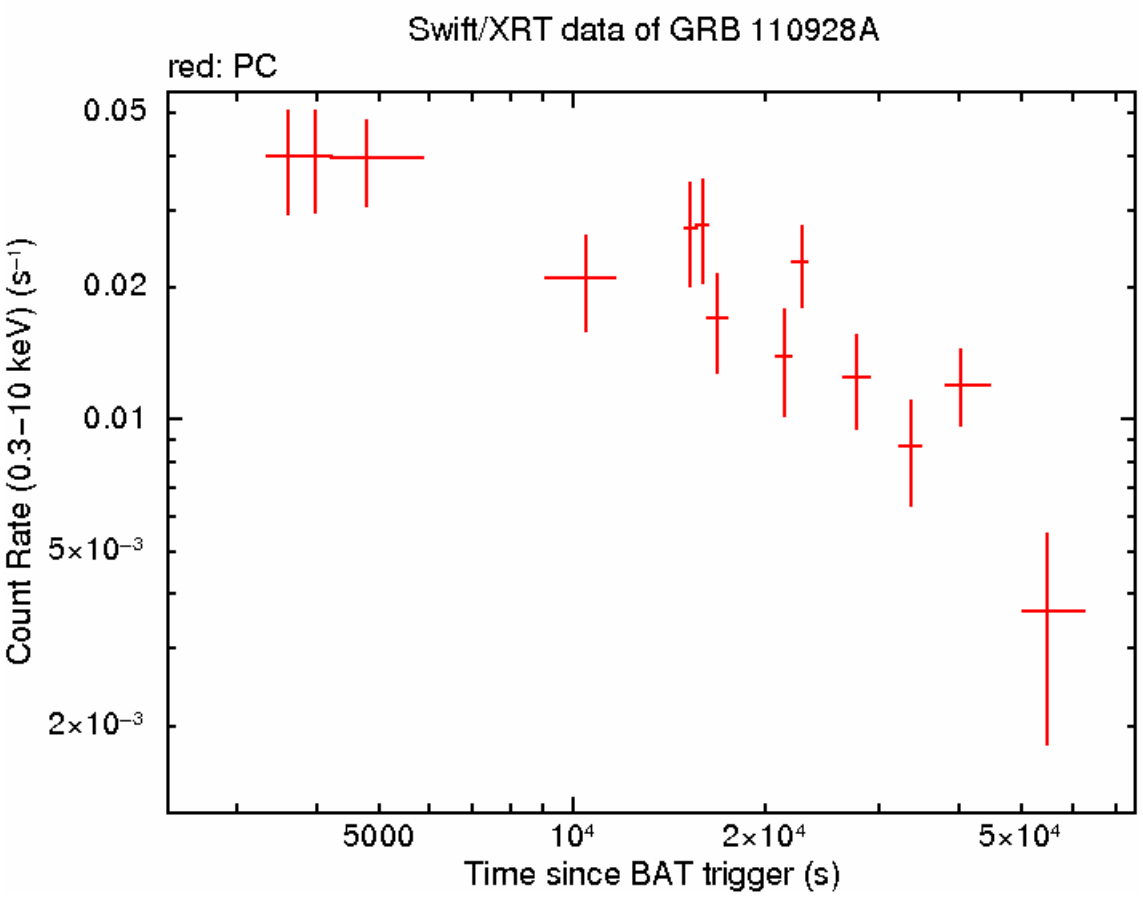

Figure 2: XRT Light curve. Flux in the 0.3-10 keV band: in Photon Counting mode (red). The approximate conversion is 1 count $s^{-1} \simeq 4.14 \times 10^{-11}$ $ergs$ cm^{-2} s^{-1}.