

Swift Observation of GRB 130609B

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1 Introduction

BAT triggered on GRB 130609B at 21:38:40 UT (Trigger 557828) (Krimm, *et al.*, *GCN Circ.* 14841). This was a 1.024 sec rate-trigger on a long, bright burst with $T_{90} = 210.6$ sec. Swift slewed to this burst immediately and XRT began follow-up observations at $T + 76$ sec, and UVOT at $T + 85$ sec. Our best position is the UVOT location RA(J2000) = $53^{\circ}.77128$ (03h 35m 5.11s), Dec(J2000) = $-40^{\circ}.17409$ ($-40^{\circ} 10' 26''.7$) with an error of 0.5 arcsec (90% confidence, including boresight uncertainties).

GRB 130609B was also detected by Konus-Wind (Golenetskii, *et al.*, *GCN Circ.* 14856) who report a fit to a Band function with $E_p = 397 \pm 26$ keV, Fermi-GBM (Pelassa, *GCN Circ.* 14869) and Suzaku WAM (Takaki, *et al.*, *GCN Circ.* 14915). Ground-based observations were reported from GROND (Schmidl, Rossi & Greiner, *GCN Circ.* 14866)

2 BAT Observation and Analysis

Using the data set from $T - 239$ to $T + 963$ sec, further analysis of Swift GRB 130609B has been performed by the Swift/BAT team (Lien, *et al.*, *GCN Circ.* 14862; Krimm & Cummings *GCN Circ.* 14867). The BAT ground-calculated position is RA(J2000) = $53^{\circ}.776$ (03h 35m 06.2s), Dec(J2000) = $-40^{\circ}.168$ ($-40^{\circ} 10' 04''.0$) ± 1.0 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 43% (the bore sight angle was $32^{\circ}.04$).

The mask-weighted light curve (Fig.1) shows an initial complex of two main overlapping peaks with numerous subsidiary peaks, with strong emission between $T - 10$ and $T + 50$ sec and low-level emission between $T - 30$ and $T + 120$ sec. The highest points are at $T + 4$ and $T + 18$ sec. Then there is a second, weaker and softer pair of overlapping peaks between $T + 160$ sec and $T + 220$ sec, and finally a third small peak at around $T + 270$ sec. The second and third sets of peaks are consistent with the two very large flares seen in the Swift-XRT (Fig.2). $T_{90}(15 - 350$ keV) is 210.6 ± 15.1 sec (estimated error including systematics).

The time-averaged spectrum from $T - 7.8$ to $T + 307.6$ sec is best fit by a simple power-law model. The power law index of the time-averaged spectrum is $1.32 + -0.04$ ($\chi^2 = 55.59$ for 57 d.o.f.). The fluence in the 15 - 150 keV band is $1.6 \pm 0.03 \times 10^{-5}$ erg cm^{-2} . The 1-sec peak photon flux measured from $T + 16.78$ sec in the 15 - 150 keV band is 8.5 ± 0.4 ph $\text{cm}^{-2} \text{s}^{-1}$. All the quoted errors are at the 90% confidence level.

3 XRT Observations and Analysis

Using the first 7.0 ksec of the XRT data of GRB 130609B (Goad, *et al.*, *GCN Circ.* 14847, Paganini *et al.*, *GCN Circ.* 14852), (1.4 ks in Windowed Timing mode and the remainder in Photon Counting mode), the refined XRT position is RA(J2000) = $53^{\circ}.77097$ (03h 35m 5.03s), Dec(J2000) = $-40^{\circ}.17407$ ($-40^{\circ} 10' 26''.7$) with an error of 1.7 arcsec (90% confidence, including boresight uncertainties).

The late-time light curve (Figure 2; from $T_0 + 5.4$ ks) can be modeled with an initial power-law decay with an index of $\alpha = 1.42 (+0.14, -0.56)$, followed by a break at $T + 13.6$ ks to an α of 2.36 (+0.38, -0.22).

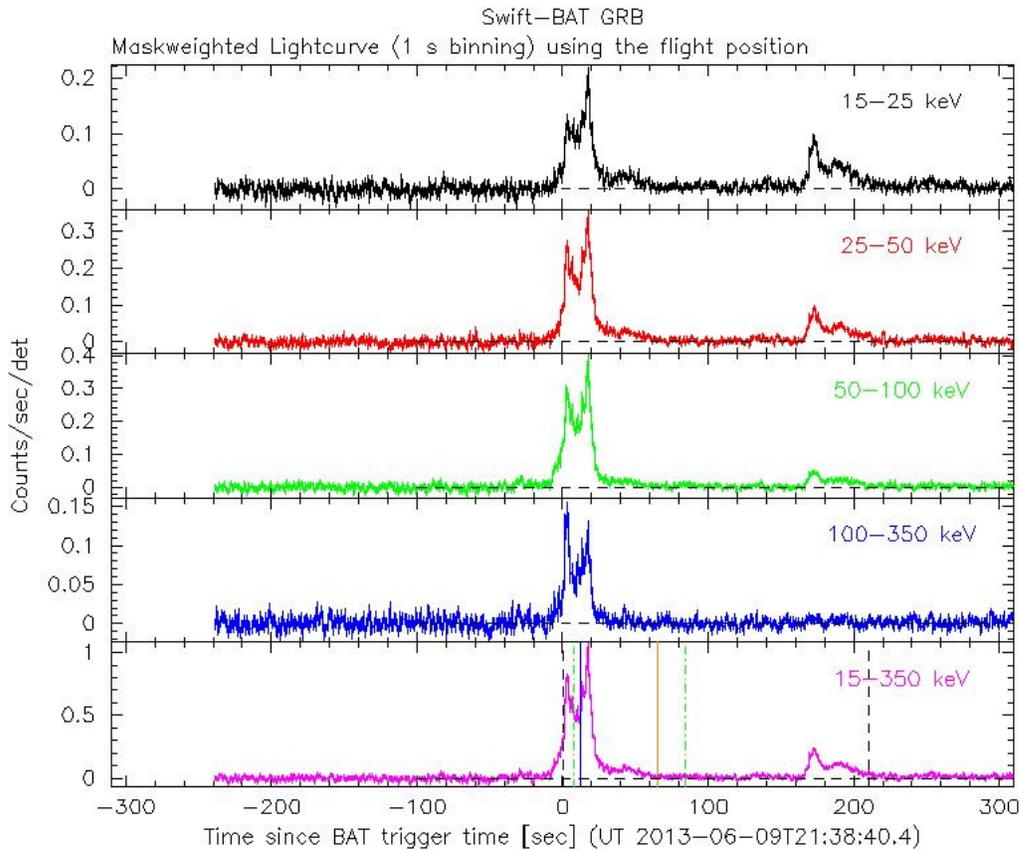


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector (note illum-det = 0.16 cm^2) and T_0 is 21:38:40.4 UT.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of 1.84 ± 0.029 . The best-fitting absorption column is $1.40 \pm 0.08 \times 10^{21} \text{ cm}^{-2}$, in excess of the Galactic value of $1.4 \times 10^{20} \text{ cm}^{-2}$ (Kalberla et al. 2005). The PC mode spectrum has a photon index of 2.01 ± 0.10 and a best-fitting absorption column of $1.28 \pm 0.25 \times 10^{21} \text{ cm}^{-2}$. The counts to observed (unabsorbed) 0.3 – 10 keV flux conversion factor deduced from this spectrum is $3.7 \times 10^{-11} (5.0 \times 10^{-11}) \text{ erg cm}^{-2} \text{ count}^{-1}$.

4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 130609B, 85 sec after the initial BAT trigger (Siegel & Krimm, *GCN Circ.* 14857). A fading source consistent with the XRT position is detected in the initial UVOT exposures (see Figure 3). Preliminary detections and 3σ upper limits using the UVOT photometric system (Breeveld et al. 2011, AIP Conf. Proc. 1358, 373) for the first and second orbit exposures are presented in Table 1 and in Figure 4. These magnitudes are not corrected for the expected extinction due to the Galactic reddening of $E(B-V) = 0.01 \text{ mag}$ (Schlegel, Finkbeiner & Davis, 1998, ApJ 500, 525).

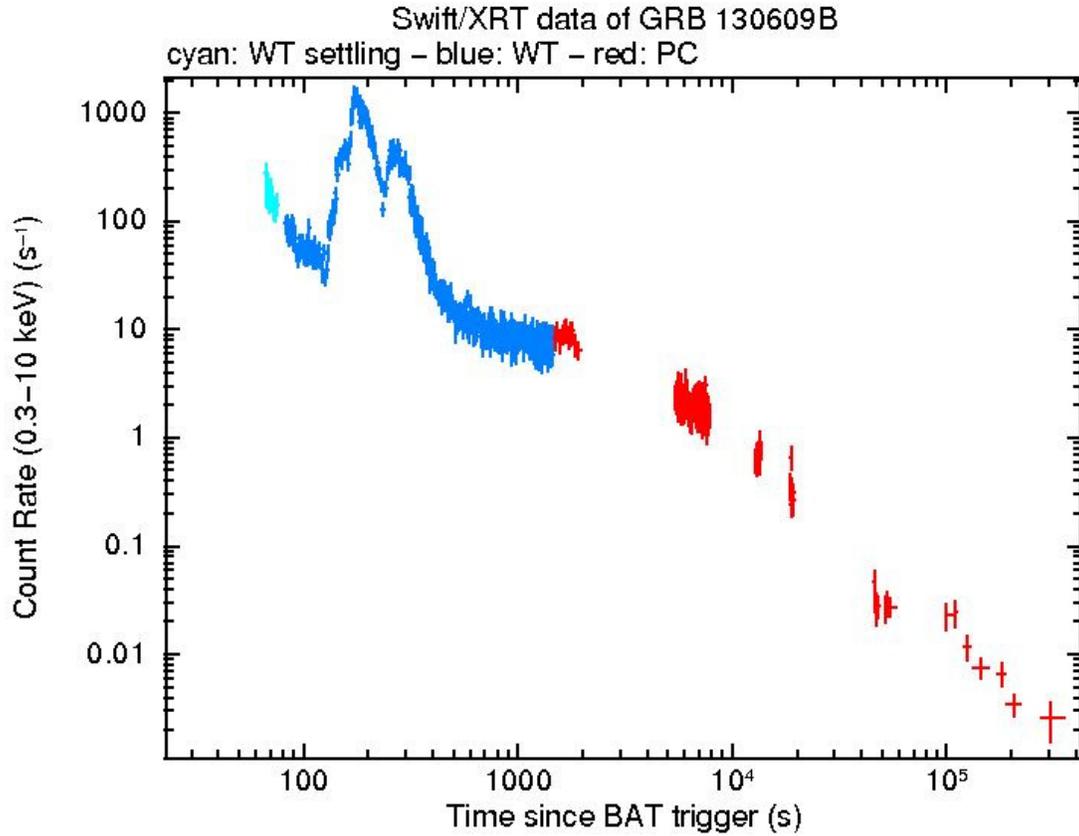


Figure 2: XRT Lightcurve. Counts/sec in the 0.3-10 keV band: Settling mode (cyan), Window Timing mode (blue), Photon Counting mode (red). The approximate conversion is 1 count/sec = $\sim 3.7 \times 10^{-11}$ *ergs/cm²/sec*.

Filter	Start	Stop	Exposure (s)	Magnitude (or 3σ limit)
white (finding chart)	84	234	147	15.47 ± 0.02
white	577	1891	283	17.36 ± 0.03
white	6046	7681	393	18.39 ± 0.05
v	799	1941	136	16.89 ± 0.09
v	6457	6657	196	18.00 ± 0.15
b	552	1866	136	17.32 ± 0.06
b	5841	7476	393	18.46 ± 0.09
u (fc)	297	546	245	16.31 ± 0.04
u	700	1841	116	17.15 ± 0.08
u	5636	7271	393	18.15 ± 0.09
uvw1	676	1816	136	17.61 ± 0.12
uvw1	5432	7067	393	18.75 ± 0.15
uvm2	823	1791	116	19.12 ± 0.35
uvm2	6662	6861	196	> 19.66
uvw2	603	1916	116	> 19.51
uvw2	6252	7855	362	> 20.39

Table 1: Magnitudes and limits from UVOT observations. Start and stop times are relative to the trigger time.

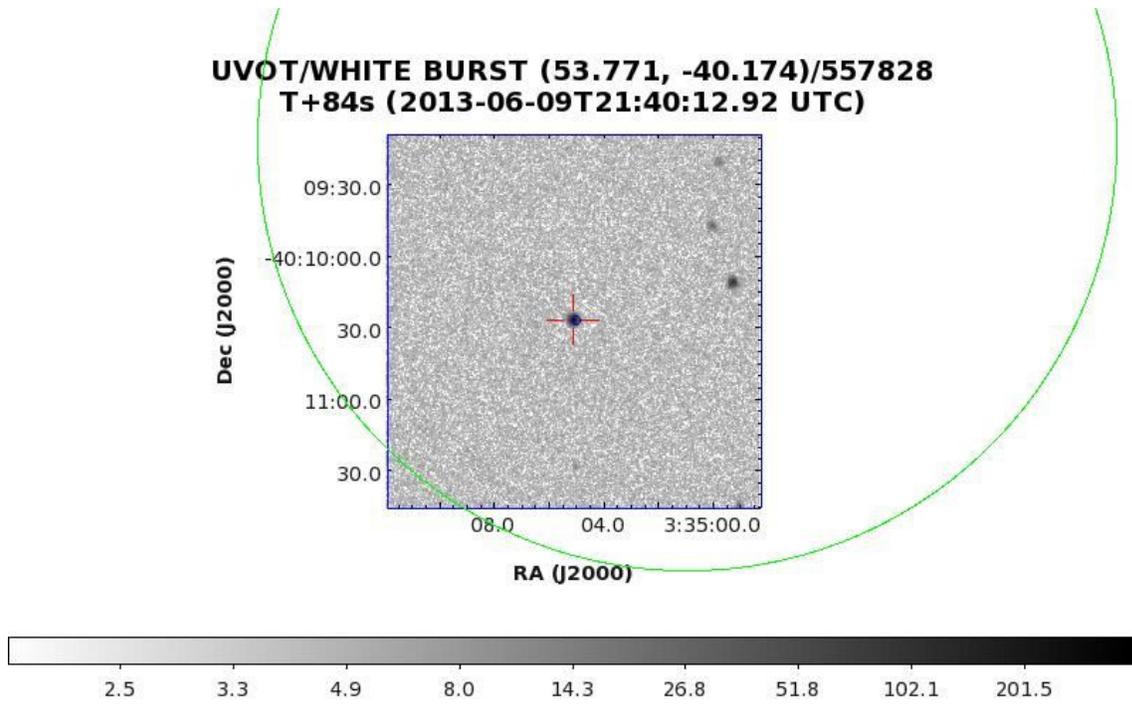


Figure 3: UVOT Finding chart for GRB 130609B

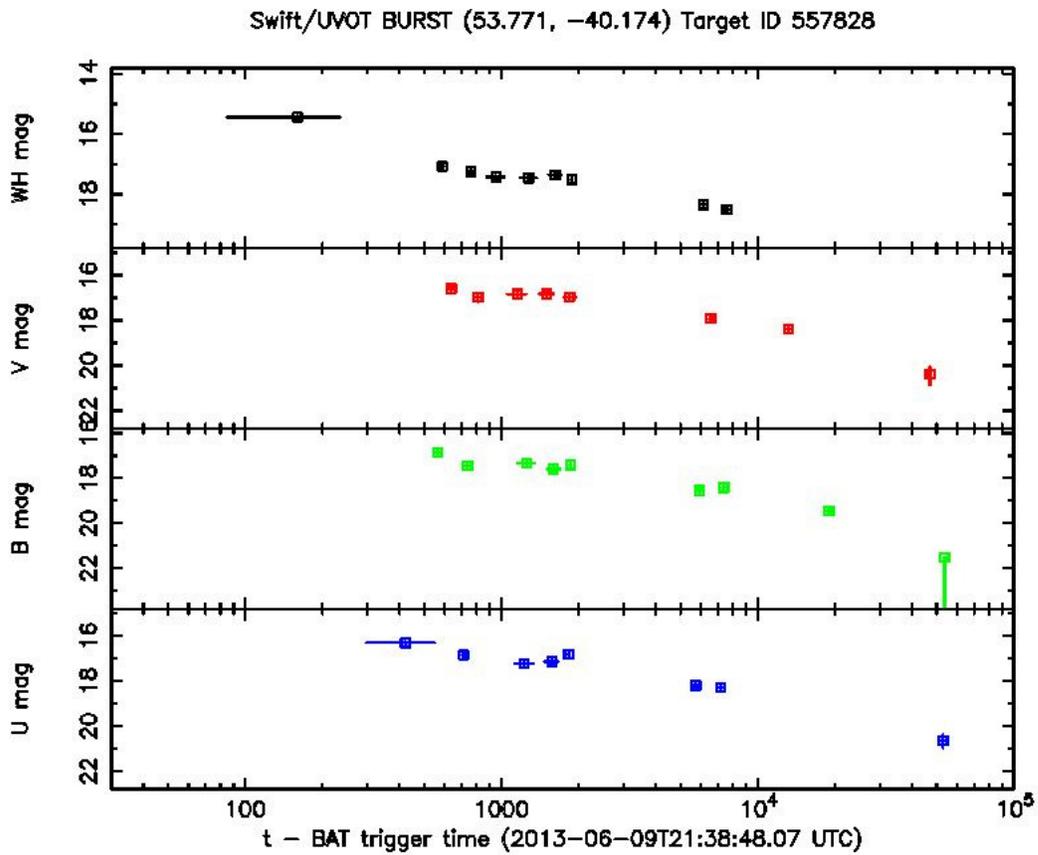


Figure 4: UVOT Lightcurve in the white, v, b and u bands.