

## Swift Observation of GRB 130609B

*H. A. Krimm (CREST/GSFC/USRA), A. Maselli (INAF-IASFPA)  
and M. H. Siegel (PSU), for the Swift Team*

### 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) =  $-40^{\circ}.168$  ( $-40^{\circ} 10' 04''.0$ )  $\pm 1.0$  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  $210.6 \pm 15.1$  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  $8.5 \pm 0.4$  ph cm $^{-2}$  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  $\alpha$  of 2.36 (+0.38, -0.22).

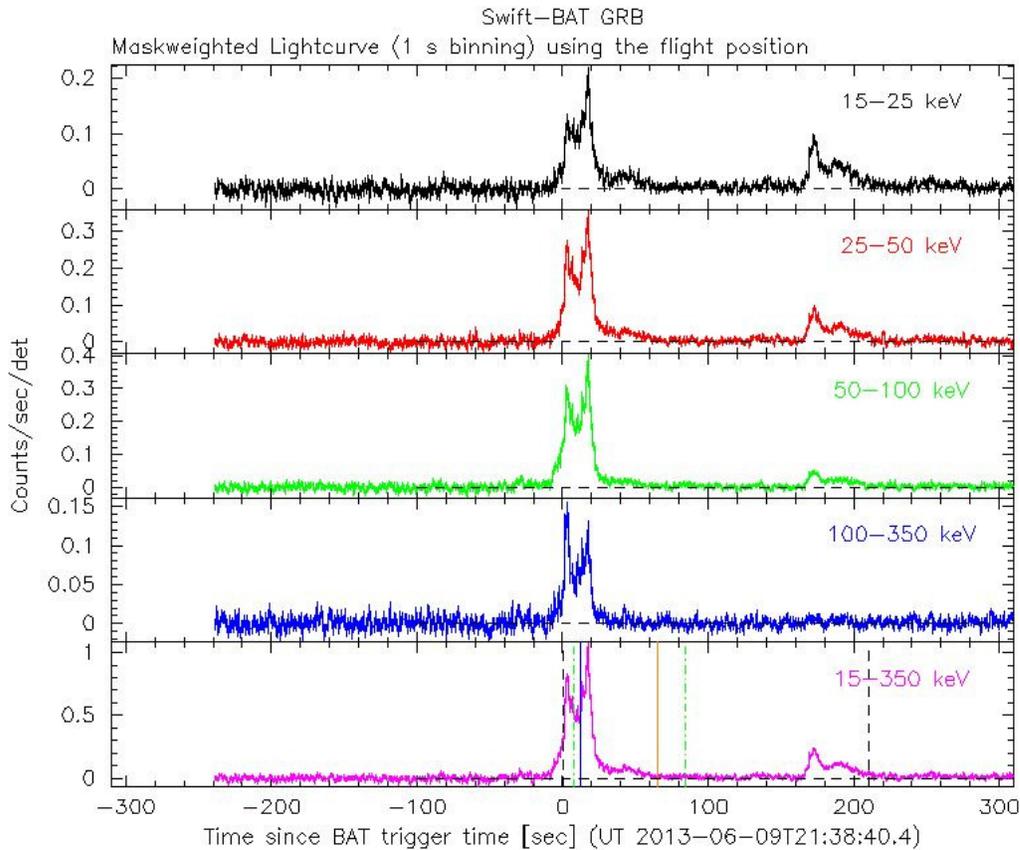


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector (note illum-det =  $0.16 \text{ cm}^2$ ) and  $T_0$  is 21:38:40.4 UT.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of  $1.84 \pm 0.029$ . 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  $2.01 \pm 0.10$  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  $3\sigma$  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).

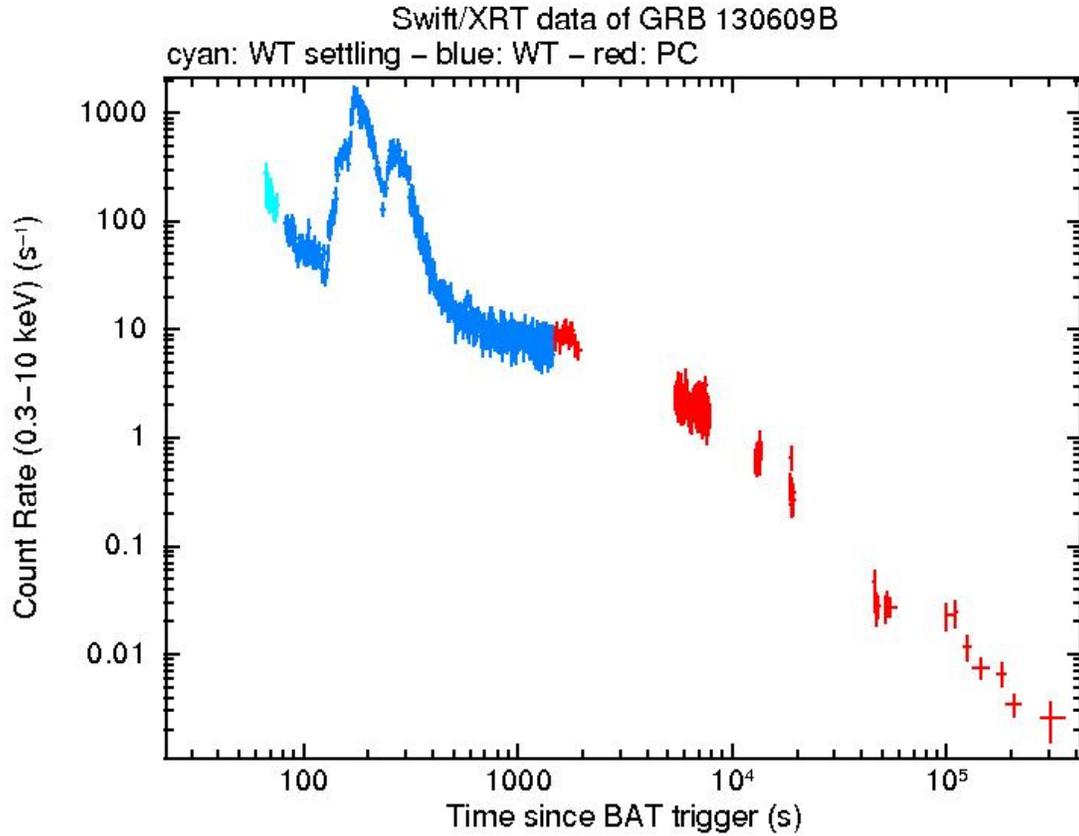


Figure 2: XRT Lightcurve. Counts/sec in the 0.3-10 keV band: Settling mode (cyan), Window Timing mode (blue), Photon Counting mode (red). The approximate conversion is 1 count/sec =  $\sim 3.7 \times 10^{-11}$  *ergs/cm<sup>2</sup>/sec*.

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

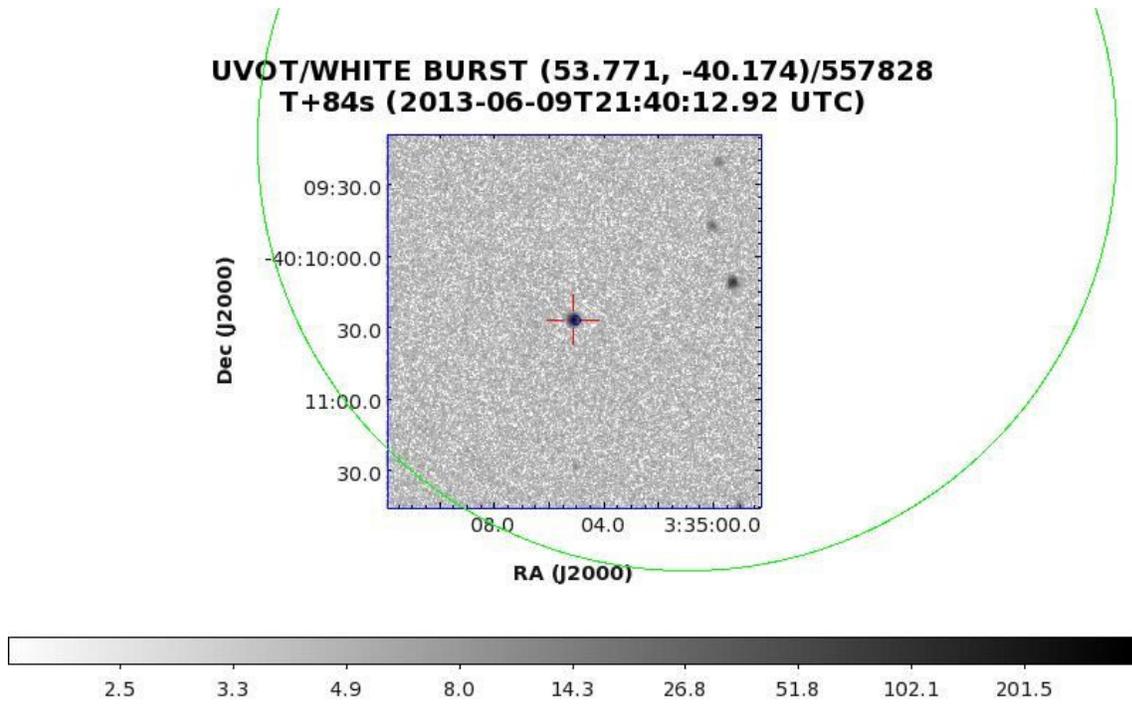


Figure 3: UVOT Finding chart for GRB 130609B

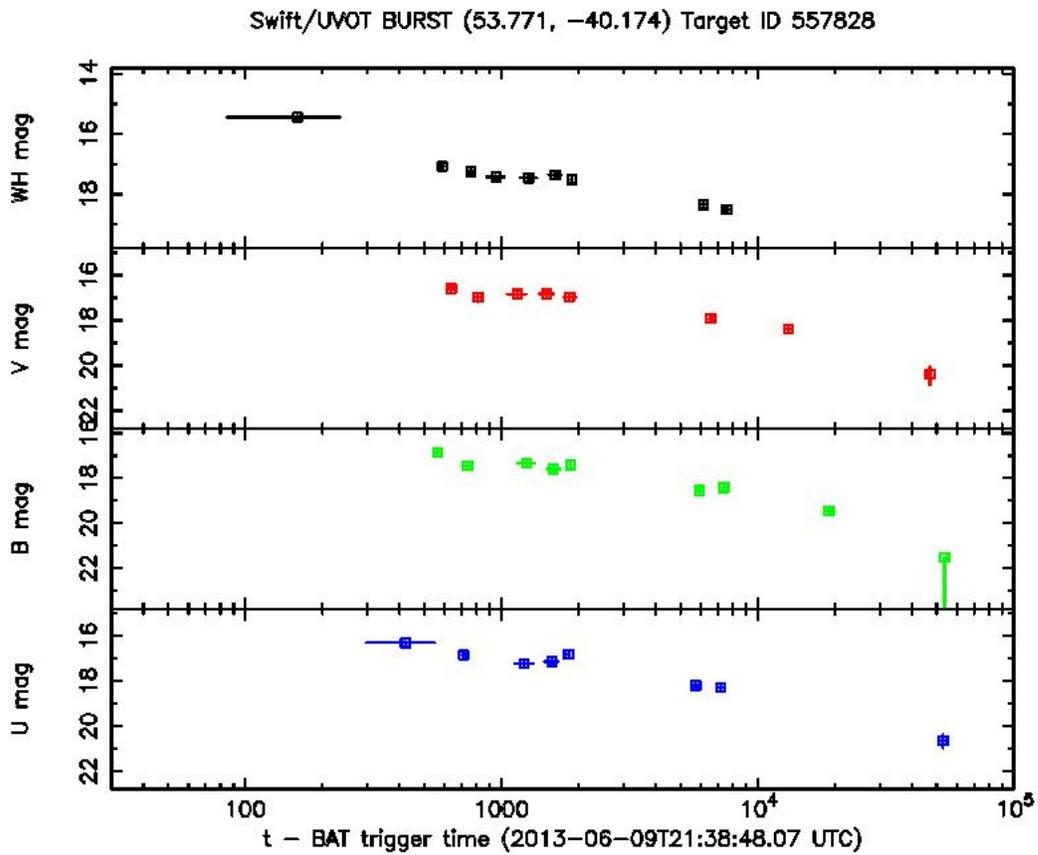


Figure 4: UVOT Lightcurve in the white, v, b and u bands.