Swift Observations of GRB 090628

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1 Introduction

BAT triggered on GRB 090628 at 21:20:12 UT (trigger 355942, Mangano *et al.*, *GCN Circ.* 9585). This was a 1.024 s rate-trigger on a long burst with $T_{90} = 20$ s. Due to an Earth limb constraint, a prompt slew was not possible. Swift executed a delayed slew and XRT [UVOT] began follow-up observations at $T + 2796$ s [$T + 2791$ s].

Our best position is the UVOT enhanced Swift-XRT position RA($J2000$) = 237.05272 *deg* ($15^h\ 48^m\ 12.65^s$), Dec($J2000$) = -15.98489 *deg* ($-15^d\ 59'\ 05.6''$) with an estimated uncertainty of 1.9 arcsec (radius, 90% confidence, statistical + systematic).

The field of GRB 090628 have been observed by some ground based optical telescopes: the Calar Alto telescope (Kubanek *et al.*, *GCN Circ.* 9589), the GROND (Kruehler *et al.*, *GCN Circ.* 9591), the Zeiss-1000 telescope of SAO RAS (Moskvitin *et al.*, *GCN Circ.* 9594), but no candidate optical afterglow was detected.

2 BAT Observation and Analysis

Using the data set from $T - 240$ to $T + 649$ s refined analysis of BAT GRB 090628 was performed by the Swift team and reported in Markwardt *et al.*, *GCN Circ.* 9593. The BAT ground-calculated position is RA($J2000$) = 237.038 *deg* ($15^h\ 48^m\ 09.0s^s$), Dec($J2000$) = -15.969 *deg* ($-15^d\ 58'\ 09.0"$) with an uncertainty of 1.7 arcmin, (radius, sys+stat, 90% containment). The partial coding was 63%.

The mask-weighted light curve (Fig.1) shows a weak $1-$sec wide precursor peak at $\sim T - 7.5$ s that then returns almost to background levels, and the main peak starting at $\sim T - 0.3$ s, peaking at $\sim T + 1$ s, and ending at $\sim T + 6$ s. T_{90} ($15 - 350$ keV) is 20.1±4.6 s (estimated error including systematics).

The time-averaged spectrum from $T - 25.0$ to $T + 4.0$ s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.36±0.20. The fluence in the $15 - 150$ keV band is $7.0\pm0.8\times10^{-7}$ erg cm^{-2}. The $1-$sec peak photon flux measured from $T + 0.05$ s in the $15 - 150$ keV band is 1.5 ± 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/355942/BA/

3 XRT Observations and Analysis

Swift-XRT began follow-up observations of the field of GRB 090628 (trigger 355942, Mangano *et al.*, *GCN Circ.* 9585) on date 2009 June 28, 22:06:52 UT, 2796 s after the BAT trigger.

The whole dataset consists of ~ 34.5 ks in Photon Counting mode (starting 2796 s after the trigger to the end of the observation at $T + 223.9$ ks).

Using 3973 s of XRT Photon Counting mode data and 2 UVOT images for GRB 090628, we find an astrometrically corrected X-ray position (using the XRT$-$UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA($J2000$), Dec($J2000$) = 237.05272, -15.98489 which is equivalent to:

RA($J2000$) = 15^h 48^m 12.65^s
Dec($J2000$) = -15^d $59^{'}$ $05.6^{"}$

with an uncertainty of 1.9 arcsec (radius, 90% confidence; Goad *et al.*, *GCN Circ.* 9590). This position is within 4.3 arcsec of the initial XRT position reported by Sbarufatti *et al.*, *GCN Circ.* 9586.

The $0.3-10$ keV XRT light curve Fig.2) is well fitted by a broken power-law with an initial flat or rising phase followed by a steep decay. The fit is insensitive to the initial rise slope, of the order of 0.4, possibly consistent with zero, and provides a break at 17±3 ks after the trigger and a post-break decay slope of -1.6±0.4.

The average spectrum of the initial 19 ks of data (from $T + 2796$ s to $T + 101.7$ ks) can be fitted by an absorbed power-law model with Cash statistics. Best fit spectral parameters are the absorption column $N_H < 2.0 \times 10^{21}$ cm^{-2} (consistent with Galactic absorption of 8.7×10^{20} cm^{-2}, Kalberla *et al.*, 2005) and photon index $\Gamma = 1.4 \pm 0.3$ [Cstat(dof): 87.6(113)]. The $0.3-10$ keV observed(unabsorbed) average flux is $5.0 \times 10^{-13} (5.5 \times 10^{-13})$ erg cm^{-2} s^{-1}.

The results of the XRT-team automatic analysis are available at
http://www.swift.ac.uk/xrt_products/00355942.

4   UVOT Observation and Analysis

The UVOT began settled observations of the Swift localised GRB 090628 2791 s after the BAT trigger. Data summed from the first orbit does not reveal a source at the refined position of the X-ray afterglow (Goad *et al.*, *GCN Circ.* 9590).

The 3-sigma upper limits for the finding chart (fc; Hoversten *et al.*, *GCN Circ.* 9587) and following single exposures are reported in Table 1, where T_{start} and T_{stop} are the start and stop time of the observation.

Filter	T_{start}(s)	T_{stop}(s)	Exp(s)	Magnitude/3-sig UL
white (fc)	2791	2941	147	> 20.26
white	3361	3560	196	> 20.72
v	3771	3971	196	> 19.23
b	3155	3355	196	> 20.16
b	4591	4672	79	> 19.64
u	2950	3149	196	> 19.63
u	4386	4586	196	> 19.82
uvw1	4181	4381	196	> 19.65
uvm2	3976	4176	196	> 19.33
uvw2	3566	3766	196	> 19.62

Table 1: Magnitudes and Upper Limits from UVOT observations

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).
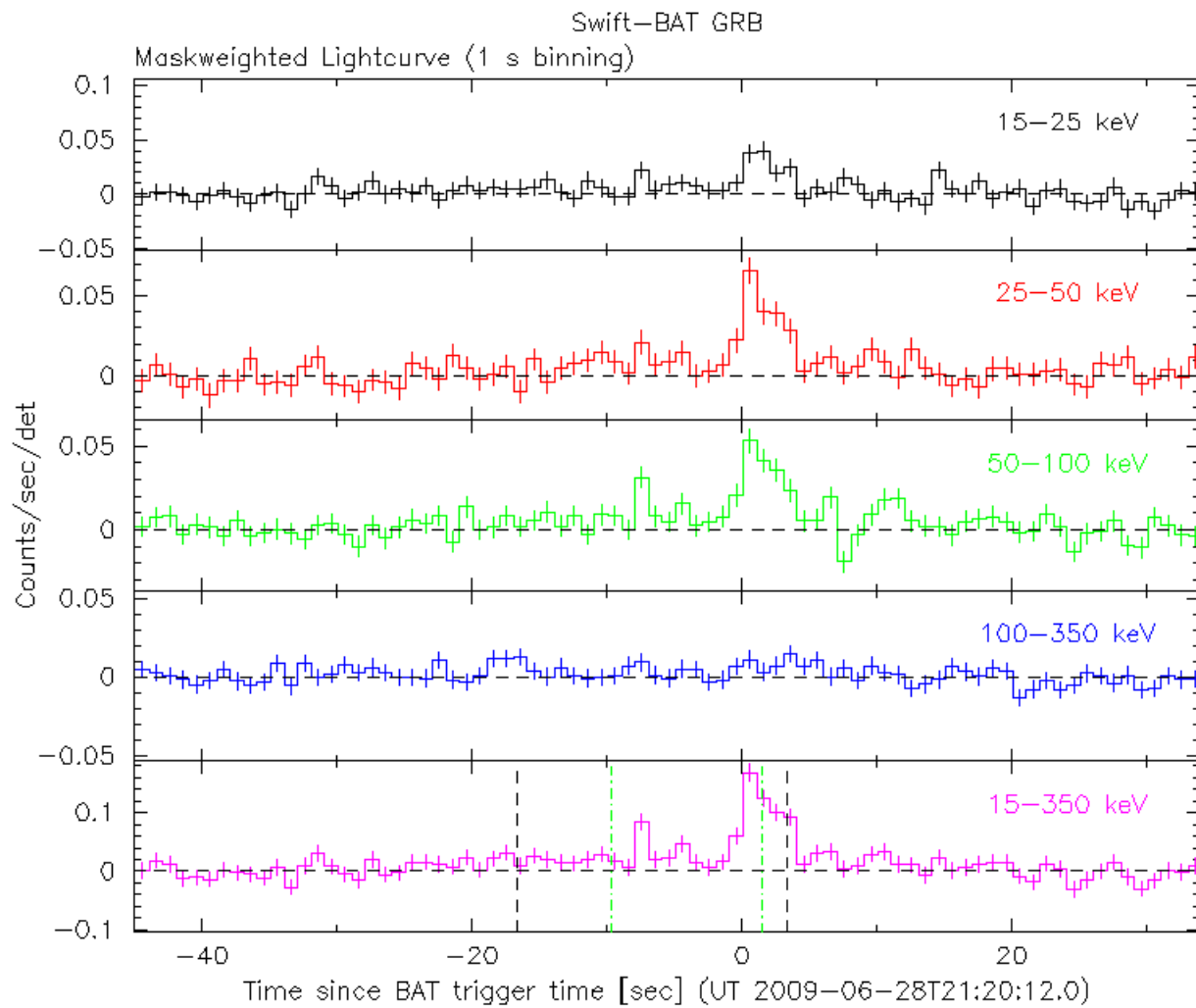
Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector^{-1} (note illum-det = 0.16 cm^2) and T_0 is 2009 June 28, 21:20:12 UT
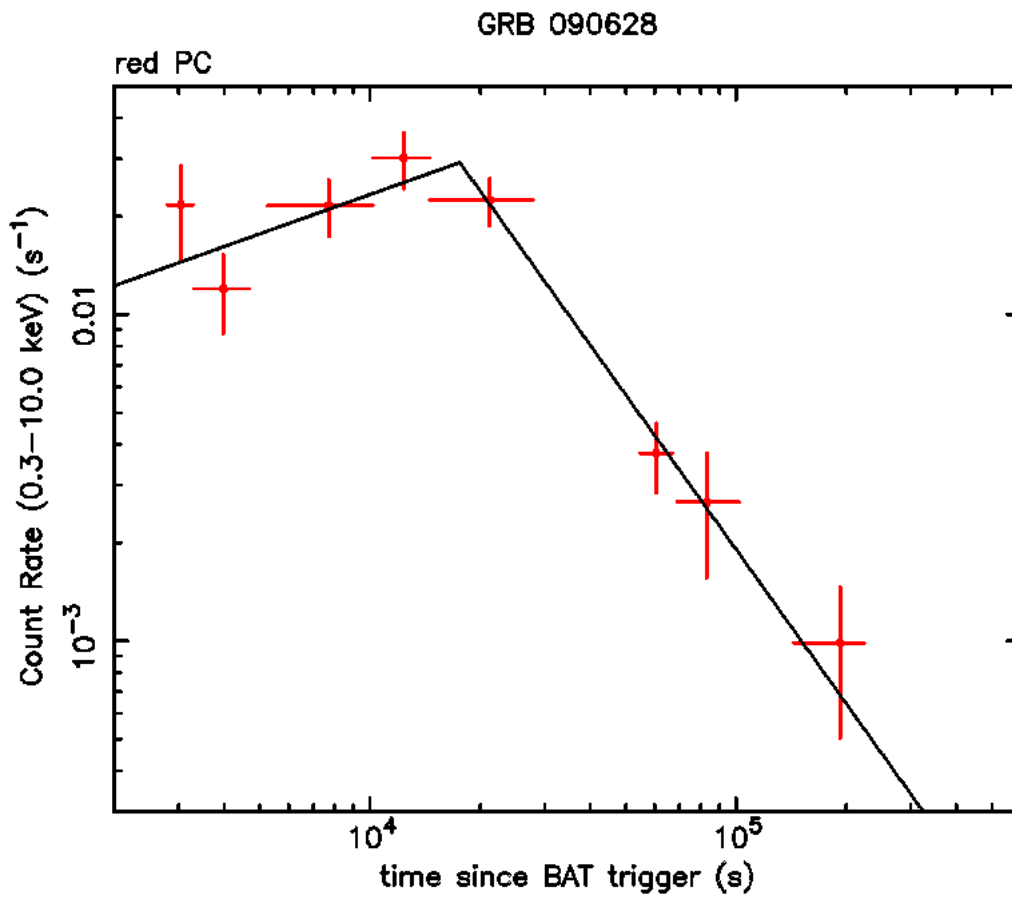
Figure 2: XRT Light curve. Counts/s in the $0.3-10$ keV band, Photon Counting mode. The approximate conversion is 1 count/s $= \sim 8.0 \times 10^{-11}$ erg cm^{-2} s^{-1}.