Swift Observation of GRB 070508

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0   Revisions

This is the final report on GRB 070508. This report has an update of the XRT light curve and a new analysis of the Windowed Timing and Photon Counting mode light curves and spectral analysis of the Photon Counting mode data of the first two segments. At the end we summarize also observations from other observatories.

1   Introduction

BAT triggered on GRB 070508 at 04:18:17 UT (Trigger 278854) (Grupe, *et al.*, *GCN Circ.* 6383). This burst is a long burst with an observed $T_{90} = 21\pm1$ s. Swift slewed to this burst immediately and XRT began follow-up observations at $T + 76$ s, and UVOT at $T + 68$ s. Our best position is the UVOT White-Filter location RA($J2000$) = 312.7987 *deg* ($20h51m11.68s$), Dec($J2000$) = -78.3847 *deg* ($-78d23'05.0''$) with a 90% confidence statistical error of $0.5''$ as given in Marshall & Grupe (*GCN Circ.* 6392). This position is $2.5''$ away from the optical position reported by Berger & Burgasser (*GCN Circ.* 6386).

2   BAT Observation and Analysis

Using the data set from $T-240$ s to $T+962$s, further analysis of BAT GRB 070508 has been performed by the Swift team (Barthelmy, *et al.*, *GCN Circ.* 6390). The BAT ground-calculated position is RA($J2000$) = 312.832deg ($20h51m19.8s$), Dec($J2000$) = -78.382 *deg* ($-78d22'54.8''$) ± 0.4 *arcmin*, (radius, systematic and statistical, 90% containment). The partial coding was 62%.

The masked-weighted light curves (Fig.1) consists of 20 main peaks (between T+0 and T+20 sec). The emission starts at T-20 s and clearly extends out to T+30 s and at a lesser level extends out past T+800 s. $T_{90}(15 - 350keV)$ is 21 ± 1 s (estimated error including systematics).

The time-averaged spectrum from $T - 13.8$s to $T + 33.1$s is best fitted by a power law model with exponential cutoff. This fit gives a photon spectral index of $\Gamma = 1.14\pm0.12$ and $E_{\mathrm{peak}} = 258\pm134$ keV, ($\chi^2 = 27.7$ for 56 d.o.f.). For this model the total fluence in the $15-150$ *keV* band is $(2.0\pm0.0)\times10^{-5}$ ergs cm^{-2} and the 1-s peak flux measured from $T + 10.84$s in the $15 - 150$ *keV* band is 24.7 ± 0.6 photons cm^{-2} s^{-1}. A fit to a simple power law gives a photon index of $\Gamma = 1.36 \pm 0.03$ (χ^2 38.4 for 57 d.o.f.). All the quoted errors are at the 90% confidence level.

3   XRT Observations and Analysis

Using the Photon Counting mode data from segment 001 the starting 7.7 ks after the burst of XRT data of GRB 070508 the refined XRT position is RA($J2000$) = 312.7974 *deg* ($20h51m11.38s$), Dec($J2000$) =

$-78.3850\ deg$ ($-78d23'06.11''$) ($3.7''$ error circle ,90% confidence) This position is $1.1''$ away from the initial XRT position reported by Grupe *et al.*, *GCN Circ.* 6383 and $2.4''$ from the optical position reported by Berger & Burgasser (*GCN Circ.* 6386). Note that the source during the first two orbits was positioned on one of the dead columns. This was not the case during the segment 001 observations.

The $0.3 - 10\ keV$ light curve (Fig.2) shows bright decaying afterglow with an initial decay slope of $\alpha = 1.30 \pm 0.09$ and a break at about 50ks after the burst. The decay slope after the break is $\alpha = 1.84 \pm 0.09$. We do not see a canonical light curve that is typically seen in GRB afterglows (Nousek et al 2006, Zhang et al. 2006). The light curve of the afterglow of GRB 070508 is very similar to GRBs 060105 (Tashiro et al., 2007, PASJ, 59, 361) and GRB 060813. Detailed light curves in both count rate and flux units are available in both graphical and ASCII formats at http://www.swift.ac.uk/xrt_curves/ (Evens et al. 2007, A&A submitted, astro-ph/0704.0128).

The Windowed Timing mode spectrum can be fitted by an absorbed single power law with a photon spectral index $\Gamma = 2.05 \pm 0.04$ and an absorption column density of $N_{\rm H} = (3.8 \pm 0.2) \times 10^{21}$ cm^{-2} which is in excess of the Galactic value ($N_{\rm H,gal} = 8.60 \times 10^{20}$; Dickey & Lockman 1990). The spectrum of the Photon Counting mode data from the first two orbits and segment 001 are consistent with this result. Following the relation given in Grupe et al. 2007 (AJ, 133, 2216) the excess absorption column density suggests that the redshift of this burst is less than 2.6.

4   UVOT Observation and Analysis

The UVOT began observing the field of GRB 070508 68 s after the BAT trigger (Marshall & Grupe, *GCN Circ.* 6391). The afterglow is clearly detected in White with 19.8±0.1 mag in the first exposure and V with 19.7±0.2 mag. The White and V detections and upper limits of the other filters are summarized in Table 1 and the UVOT light curves are displayed in Figure 3. These magnitudes are not corrected for Galactic extinction E(B-V) = 0.14 (Schlegel et al. 1998).

5   Other Observations

GRB 070508 was observed by several observatories. The most important measurements are the tentative redshift z=0.82 as reported by Jacobsson et al. (*GCN Circ.* 6398) and the peak energy and hard X-ray spectral slopes by the Suzaku WAM, RHESSI, and Konus-Wind. Table 2 summarizes the results from these observations.

The afterglow was detected with the 6.5m Magellan/Clay telescope as reported by Berger & Burgasser (*GCN Circ.* 6386) who also gave an optical position of the afterglow at RA(*J*2000) = 312.8003 deg (20h51m12.07s), Dec(*J*2000) = $-78.3853\ deg$ ($-78d23'07.0''$) with an uncertainty of $0.5''$. The afterglow was also detected by the Danish 1.5m telescope in La Silla with I=20.5±0.2 and R=21.5±0.2 (Thoene et al., *GCN Circ.* 6389) and by the 1.3m SMARTS telescope at CTIO with I=20.7±0.3 (Cobb, *GCN Circ.* 6391). Upper limits were also reported by Klotz et al. (*GCN Circ.* 6384) from TAROT observations, Covino et al. (*GCN Circ.* 6385) using the 60cm REM telescope, and Gilmore & Kilmartin (*GCN Circ.* 6387) from the 0.6m Mt. John Observatory in New Zealand.
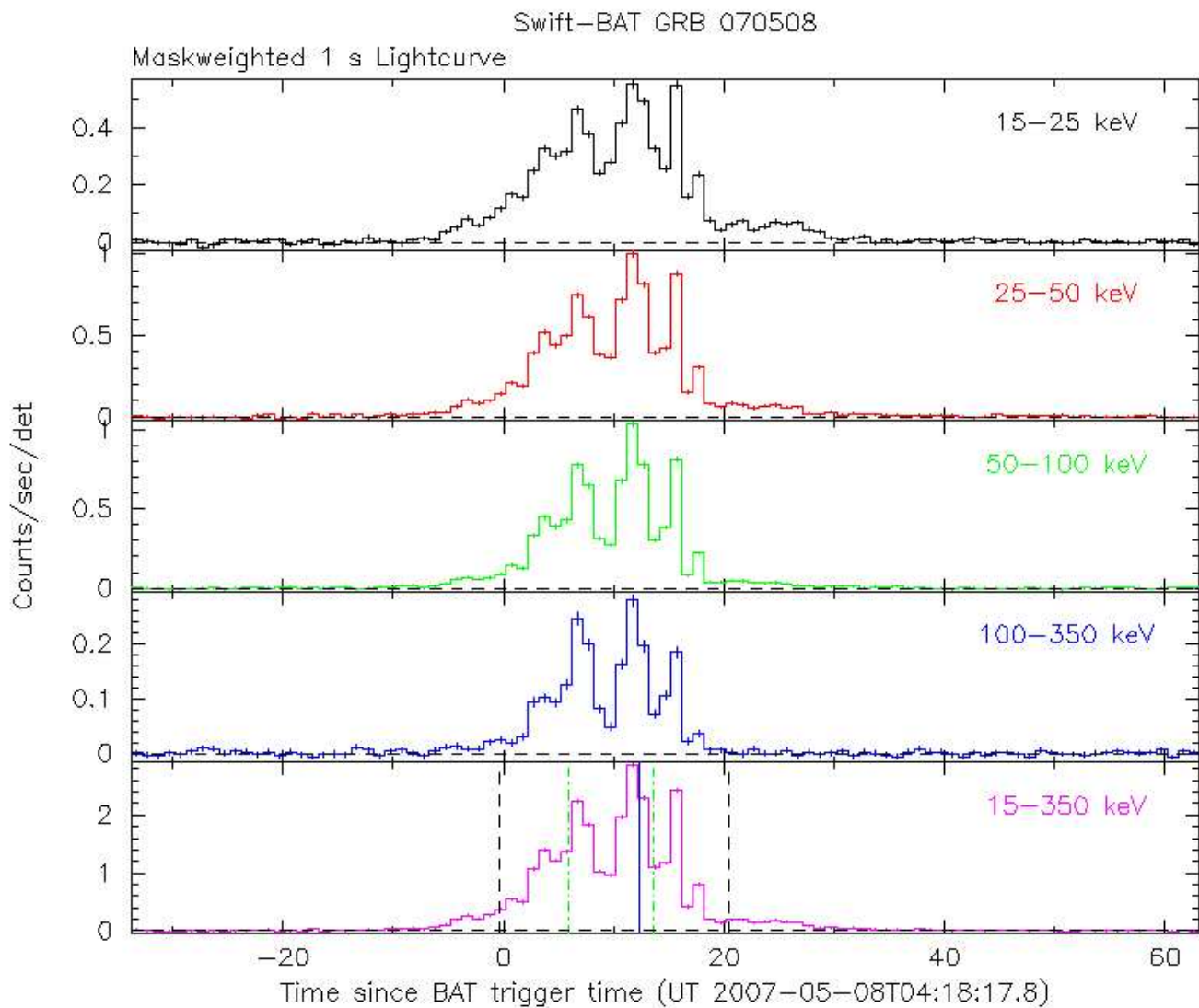
Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector^{-1} and T_0 is 2007-May-08 04:18:17 UT.
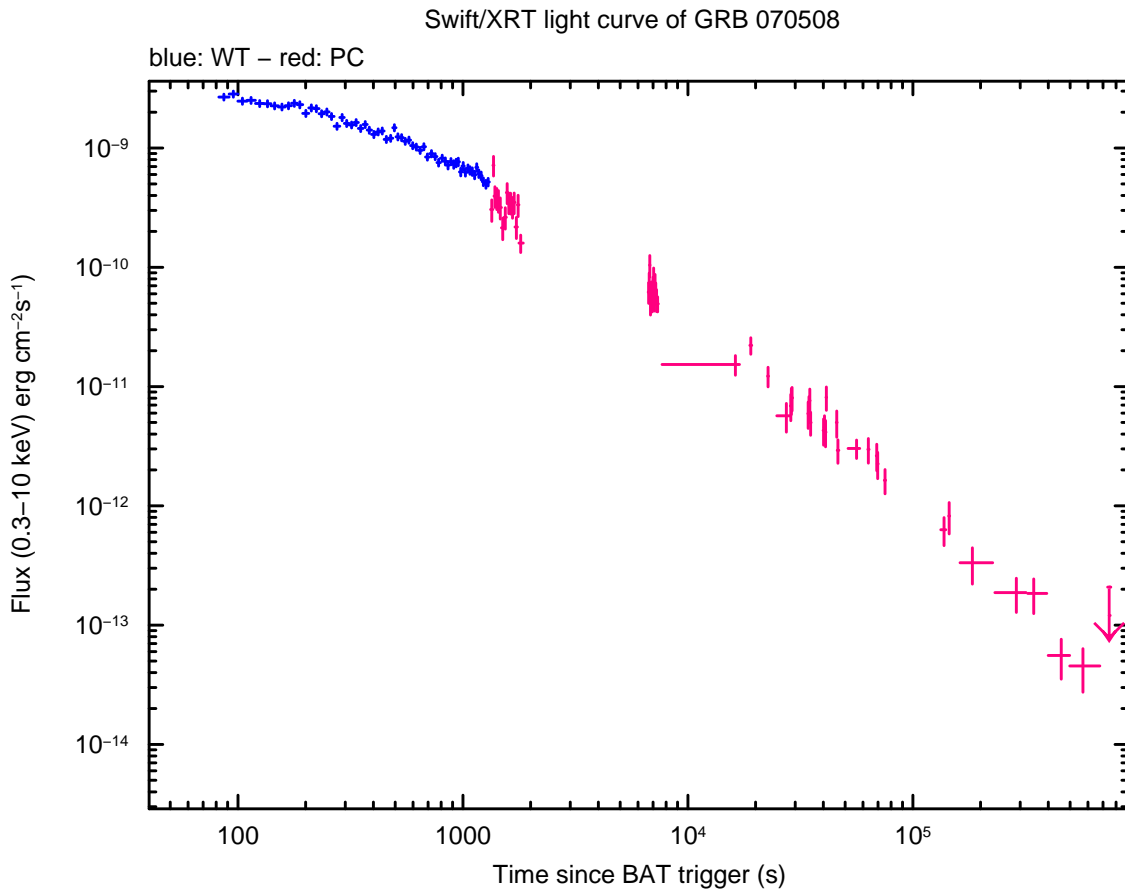
Figure 2: XRT 0.3-10 keV band flux light curve: Windowed Timing mode is blue and Photon Counting mode is red. Windowed Timing mode data were rebinned with 200 photons per bin and Photon Counting mode data with 25 photons per bin. The approximate conversion is 1 count s^{-1} = $\sim$ 7.67 $\times 10^{-11}$ $ergs$ $s^{-1}cm^{-2}$ for an unabsorbed flux corrected for photon pileup.

Filter	T_{Start}	T_{Stop}	Exposure	Mag
White	86	185	98	19.8+/-0.12 (1σ)
V	192	571	393	19.7+/-0.22 (1σ)
B	669	1946	86	>19.6 (90% confidence)
U	644	1933	117	>18.4 (90% confidence)
UVW1	620	7389	283	>18.2 (90% confidence)
UWM2	1705	7215	236	>17.8 (90% confidence)
UVW2	698	6806	294	>18.6 (90% confidence)

Table 1: Magnitude from UVOT observations. The start, stop, and exposure times are given in s. Start and stop times are referenced to the BAT trigger time.
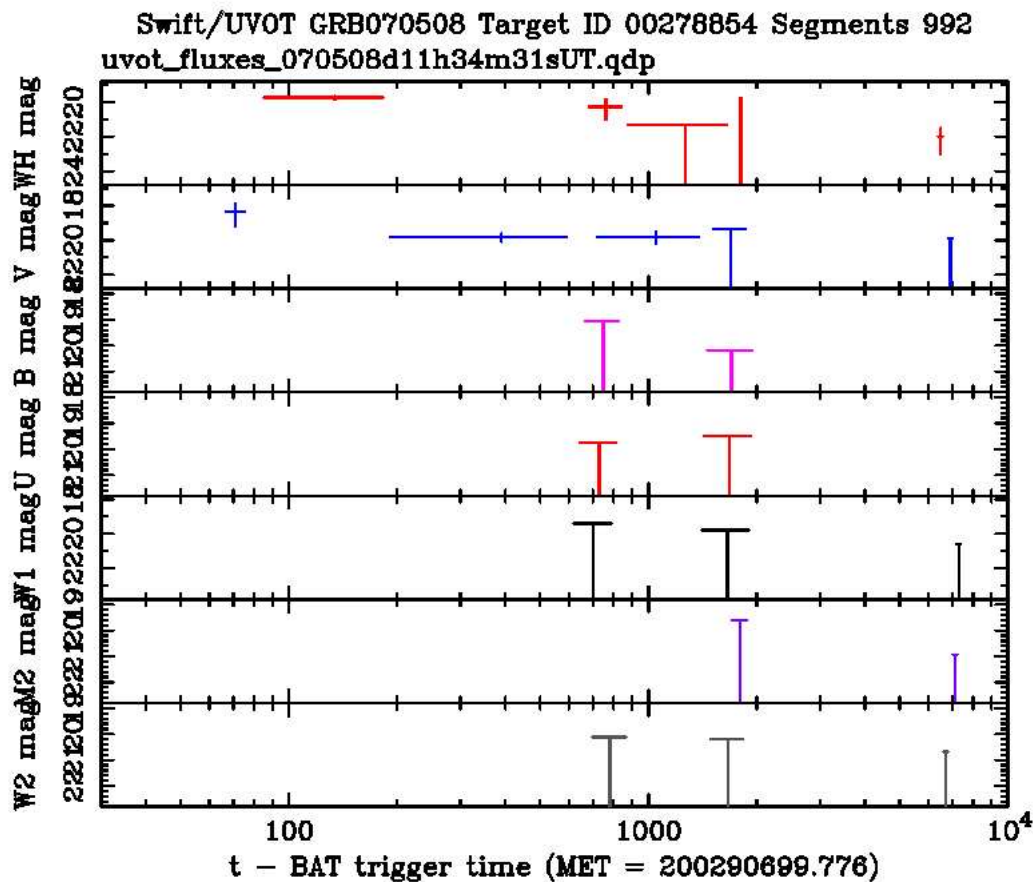
Figure 3: UVOT Lightcurve

Mission	Energy range	E_{peak}	β	Reference
Suzaku WAM	50 keV - 5 MeV	233±12	0.96±0.21	Uehara et al., *GCN Circ.* 6396
RHESSI	30 keV - 10 MeV	254±45	0.76±0.52	Bellm et al., *GCN Circ.* 6399
Konus-Wind	20 keV - 1 MeV	188±8	0.81±0.07	Golenetskii et al., *GCN Circ.* 6403

Table 2: High Energy measurements by Suzaku, RHESSI and Konus-Wind. The peak energies E_{peak} are given in units of keV. The high energy spectral slope β is defined as dN/dE$\propto E^{-\beta}$.