Swift Observation of GRB 090709A

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1   Introduction

BAT triggered on GRB 090709A at 07:38:34 UT (Trigger 356890) (Morris, *et al.*, *GCN Circ.* 9625). This was a 1.024 sec rate-trigger and the burst has T_{90} = 88.7 sec. Swift slewed to this burst immediately and XRT began follow-up observations at $T + 67.8$ sec, and UVOT at $T + 76$ sec. The XRT identified a fading, uncatalogued point source in an initial 2.5 sec image. The best Swift position derived from UVOT and XRT data is the RA($J2000$) = 289.92664 deg (19h19m42.39s), Dec($J2000$) = +60.72764 deg (+60d43′39.5″) with an error of 1.5 arcsec (90% confidence, including boresight uncertainties).

Though not detected by UVOT, the optical afterglow was detected in the NIR by Subaru (Aoki, *et al.*, *GCN Circ.* 9634), PAIRITEL (Morgan, *et al.*, *GCN Circ.* 9635). Later re-analysis of early visible observations (in r' and z') revealed marginal detections. A deep optical observation with the 10.4m Gran Telescopio Canarias to search for a host galaxy (Castro-Tirado *et al.*, *GCN Circ.* 9655) reveals no host to a limit of i'=25.2.

2   BAT Observation and Analysis

Using the data set from $T - 239$ to $T + 505$ sec, further analysis of BAT GRB 090709A has been performed by the Swift team (Sakamoto, *et al.*, *GCN Circ.* 9640). The BAT ground-calculated position is RA($J2000$) = 289.944 deg (19h19m46.7s), Dec($J2000$) = +60.728 deg (+60d43′40.8″) ± 1.0 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 75%.

The mask-weighted light curve (Fig.1) shows a complex structure. A faint precursor starts at $T-80$ sec, peaks at $T - 70$ sec, and returns to almost background at $T - 20$ sec. Then a series of overlapping peaks starts with the brightest centered at $T + 22$ sec. Then begins an exponential decay with a series of decreases eventually returning to background level at $T + 270$ sec. There are two more peaks at $T + 330$ and $T + 400$ sec. A third peak is chopped off while still rising when the source went out of the BAT FOV at $T + 490$ sec due to the spacecraft slewing because of an observing constraint. T90 (15-350 keV) is 89 ±3 sec (estimated error including systematics).

The time-averaged spectrum from $T - 66.7$ to $T + 101.5$ sec is well fit by simple power law. The power law index of the time-averaged spectrum is 1.22 ± 0.03. The fluence in the $15 - 150$ keV band is $(2.57 \pm 0.03) \times 10^{-5} ergs/cm^2$. The 1-sec peak photon flux measured from $T + 21.80$ sec in the $15 - 150 \ keV$ band is $7.8 \pm 0.3 \ ph/cm^2/sec$. All the quoted errors are at the 90% confidence level.

3   XRT Observations and Analysis

Using 9.4 ksec of data from T+74 sec to T+27.3 ksec of GRB 090709A (26.9 ksec in Photon Counting mode), the refined XRT position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue) is RA($J2000$) = 289.92664 deg (19h19m42.39s), Dec($J2000$) = +60.72764 deg (+60d43′39.5″) ± 1.5 arcsec (90% confidence, including boresight uncertainties). This position is within 4.8 arcsec of the initial XRT position, and 2.4 arcsec from the optical afterglow candidate, reported by Morgan *et al.*(*GCN Circ.* 9635).

The $0.3 - 10\,keV$ light curve (Fig.2) can be modeled with a broken power-law decay. The initial decay index is 0.77 ± 0.1. At T+7918 sec the light curve breaks to a decay with 1.51 ± 0.06.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of 1.78 ± 0.04. The best-fitting absorption column is $2.14^{+0.13}_{-0.12} \times 10^{21} cm^{-2}$, in excess of the Galactic value of $6.6 \times 10^{20} cm^{-2}$ (Kalberla *et al.*2005). The PC mode spectrum has a photon index of 2.05 ± 0.08 and a best-fitting absorption column of $2.68^{+0.26}_{-0.25} \times 10^{21} cm^{-2}$. The counts to observed (unabsorbed) 0.3-10 keV flux conversion factor deduced from this spectrum is $4.2 \times 10^{-11} (6.7 \times 10^{-11})\ erg/cm^2/count$.

4 UVOT Observation and Analysis

The UVOT began observing the field of GRB 090709A 77 sec after the initial BAT trigger (Morris *et al.*, *GCN Circ.* 9625). No new source was detected within the XRT error circle in the white (150 sec) finding exposure or in the co-added images in any filter down to 3-sigma magnitude. Upper limits are summarized in Table 1. These upper limits are not corrected for Galactic extinction E(B-V) = 0.09.
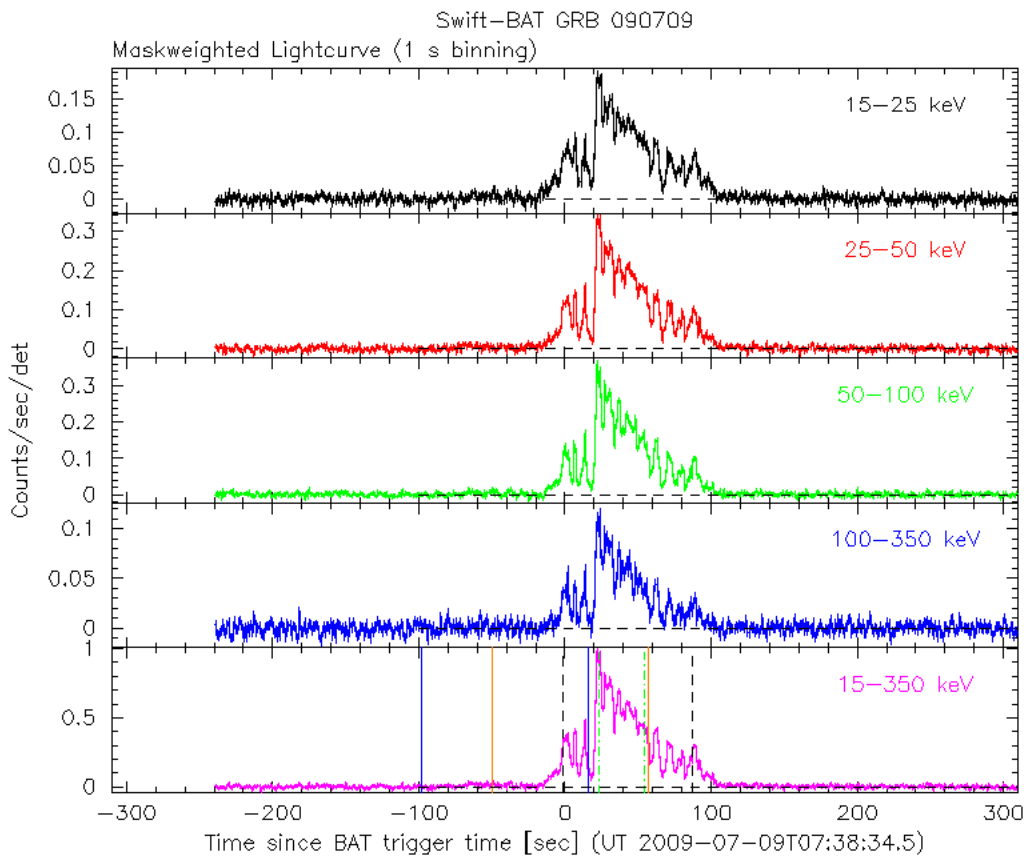

Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector and T_0 is 07:38:34 UT.
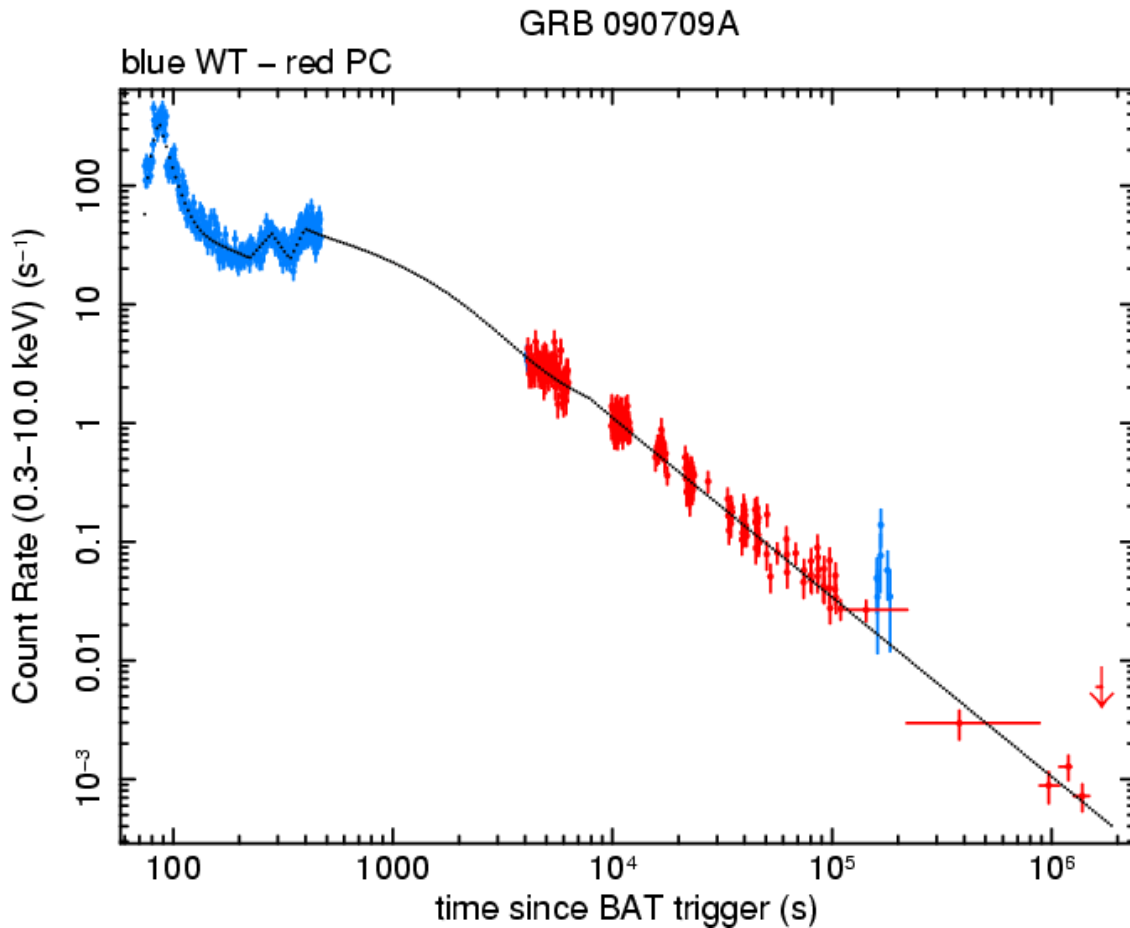
GRB 090709A

blue WT – red PC

Figure 2: XRT Lightcurve. Counts/sec in the 0.3-10 keV band: Window Timing mode (blue), Photon Counting mode (red). The approximate conversion is 1 count/sec $= \sim 4.2 \times 10^{-11}\ ergs/cm^2/sec$.

Filter	Start	Stop	Exposure	3-Sigma UL
WHITE (finding)	77	227	150	> 21.03
V	4697	4897	200	> 19.59
B	4081	4281	200	> 20.01
U	290	471	181	> 20.09
UVW1	5107	5307	200	> 19.83
UVM2	4902	5102	200	> 19.63
UVW2	4492	4692	200	> 19.85

Table 1: Magnitude limits from UVOT observations