Swift Observations of GRB 090102

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1 Introduction

BAT triggered on GRB 090102 at 02:55:45 UT (Trigger 338895) (Mangano *et al.*, *GCN Circ.* 8762). This was a 2.048 s rate-trigger on a long burst with $T_{90} = 27$ s. Swift slewed to this burst after a wait time of 271 s due to Earth limb constraint and XRT [UVOT] began follow-up observations at $T+387.2$ s [$T + 395$ s]. Our best position is the UVOT location RA($J2000$) = 128.24391 *deg* (08^h 32^m 58.54^s), Dec($J2000$) = +33.11421 *deg* ($+33^d$ $06^{'}$ $51.2^{''}$) with an error of 1.1 arcsec (90% confidence, including systematic uncertainties).

GRB 090102 has also been seen by Konus Wind (Golenetskii *et al.*, *GCN Circ.* 8776), and by INTEGRAL/SPI-ACS, confirming the bright, multi peak structure of the prompt emission reported in Mangano *et al.*, *GCN Circ.* 8762 (Beckmann, private communication).

The MAGIC Imaging Atmospheric Cherenkov Telescope performed a follow-up observation about 20 min after the trigger but found no evidence for VHE gamma-ray emission above a (preliminary) analysis threshold of 89 GeV (Gaug *et al.*, *GCN Circ.* 8816).

The optical afterglow was detected by a number of ground based telescopes, e.g.: by TAROT 40.8s after the GRB trigger (Klotz *et al.*, *GCN Circ.* 8761) and later on (Klotz *et al.*, *GCN Circ.* 8764), by REM 35s after the trigger (Covino *et al.*, *GCN Circ.* 8763), by the NOT 38 minutes after the burst onset (de Ugarte Postigo *et al.*, *GCN Circ.* 8766) and between 0.1 and 3 days after the burst (Malesani *et al.*, *GCN Circ.* 8780), by GROND 2.50 h after the burst (Afonso *et al.*, *GCN Circ.* 8771), by the IAC80 19.2h after the burst (de Ugarte Postigo *et al.*, *GCN Circ.* 8772), and by the Palomar 60-inch telescope 50 min after the burst and later on (Cenko *et al.*, *GCN Circ.* 8773).

Upper limits in radio were set by VLT 8.46 GHz (Chandra *et al.*, *GCN Circ.* 8779) and by WSRT at 4.9 GHz (van der Horst *et al.*, *GCN Circ.* 8792).

A redshift estimate z = 1.547 was provided by the NOT (de Ugarte Postigo *et al.*, *GCN Circ.* 8766) from several metal lines in a 45-min low-resolution spectrum, and then confirmed by the Palomar 200" Hale telescope (Cenko *et al.*, *GCN Circ.* 8773) and by the Hobby-Eberly Telescope (Cucchiara *et al.*, *GCN Circ.* 8774).

Based on its bright multiwavelength emission and good sun angle, the Swift team declared GRB 090102 to be a burst of interest to be followed by Swift to late time (Mangano *et al.*, *GCN Circ.* 8768).

2 BAT Observation and Analysis

Using the data set from $T - 239$ to $T + 963$ s, further analysis of BAT GRB 090102 was performed by the Swift team (Sakamoto *et al.*, *GCN Circ.* 8769). The BAT ground-calculated position is RA($J2000$) = 128.248 *deg* (08^h 32^m 59.5^s), Dec($J2000$) = 33.107 *deg* ($+33^d$ $06^{'}$ $25.7^{"}$) with an uncertainty of 1.4 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 6%.

The mask-weighted light curves (Fig.1) shows approximately 4 overlapping peaks starting at $T - 14$ s, peaking at $T + 2$ s, and ending at $T + 15$ s. T_{90} (15−350 keV) is 27.0±2.2 s (estimated error including systematics).

The time-averaged spectrum from $T - 13.9$ to $T + 18.7$ s is best fit by a simple power-law model. The

power law index of the time-averaged spectrum is 1.36±0.08. The fluence in the 15−150 keV band is $(6.8 \pm 0.3) \times 10^{-6}$ erg cm^{-2}. The 1-sec peak photon flux measured from $T + 1.68$ s in the 15−150 keV band is 5.5 ± 0.8 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/338895/BA/

3 XRT Observations and Analysis

Swift-XRT began follow-up observations of the field of GRB 090102 (trigger 338895, Mangano *et al.*, *GCN Circ.* 8762) on date 2009 January 02, 03:02:21 UT, 396 s after the BAT trigger. The whole dataset consists of 230 s in Windowed timing mode (from $T + 396$ *sec* to $T + 626$ *sec*) and $\sim$ 112 ks in Photon Counting mode (starting 635 s after the trigger).

Using 1798 s of XRT Photon Counting mode data and 4 UVOT images for GRB 090102, we find an astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA, Dec = 128.2442, +33.1145 deg which is equivalent to:

RA (J2000) = $08^h\ 32^m\ 58.60^s$
Dec (J2000) = $+33^d\ 06'\ 52.1"$

with an uncertainty of 1.7 arcsec (radius, 90% confidence) (Beardmore *et al.*, *GCN Circ.* 8765). This position is within 5.8 arcsec of the initial XRT position, and 1.4 arcsec from the optical afterglow candidate, reported by Mangano *et al.*, *GCN Circ.* 8762.

The $0.3 - 10$ keV XRT light curve (Fig.2) is well fitted by a single power-law with slope -1.36±0.01.

The WT spectrum (Mangano *et al.*, *GCN Circ.* 8767) is well fitted by an absorbed power-law with photon index 1.7±0.1, Galactic N_H=4.0×10^{20} cm^{-2} (Kalberla et al. 2005) and intrinsic absorption column of $(3.8\pm2.0)\times10^{21}$ cm^{-2} at the measured redshift z=1.547 (De Ugarte Postigo *et al.*, *GCN Circ.* 8766). The average observed [unabsorbed] flux during the WT observation is 6.2×10^{-10} [7.2×10^{-10}] ph cm^{-2} s^{-1}.

The PC spectrum, extracted from about $T+630$ s to $T+25$ ks, is also well fitted by an absorbed power law with photon index 1.8±0.1, Galactic N_H=4.0×10^{20} cm^{-2} and and intrinsic N_H=$(7.0\pm2.0)\times10^{21}$ cm^{-2} at z=1.547. The average observed [unabsorbed] flux during the PC observation is 2.8×10^{-11} [3.5×10^{-11}] ph cm^{-2} s^{-1}.

The rate to flux conversion factor is 1.3×10^{-10} erg cm^{-2} counts^{-1}.

4 UVOT Observation and Analysis

The UVOT began settled observations of the Swift localised GRB 090102 395 s after the BAT trigger. The optical afterglow position detected by UVOT is RA($J2000$) = 128.24391 *deg* ($08^h\ 32^m\ 58.54^s$), Dec($J2000$) = +33.11421 *deg* ($+33^d\ 06'\ 51.2''$) with an error of 1.1 arcsec (90% confidence, including systematic uncertainties) (Mangano *et al.GCN Circ.* 8762).

The source is detected in the initial optical observations but quickly fades (with alpha ∼0.9±0.2 in white filter) below detection limits. The initial magnitudes (or 3 sigma limits), reported in Curran *et al.GCN Circ.* 8770, are give in Table 1, where T_{mid} is the weighted mid time of the observation. UVOT light curves are shown in Fig. 3.

The detection in u along with the limits in uvw1 and bluer is consistent with a redshift of approximately $1.8 < z < 2.5$ and with the spectroscopic redshift suggested by de Ugarte Postigo *et al.GCN Circ.* 8766.

The values quoted above are in the UVOT photometric system (Poole et al. 2008, MNRAS, 383,

Filter	T_{mid}(s)	Exp(s)	Magnitude/3-sig UL
wh	470.	147.	18.04 ± 0.04
	684.	19.	18.43 ± 0.15
	857.	19.	18.61 ± 0.17
v	382.	10.	17.02 ± 0.29
b	660.	19.	18.35 ± 0.27
	6893.	197.	20.10 ± 0.33
u	635.	19.	17.89 ± 0.26
	807.	19.	18.07 ± 0.28
uvw1	3547.	255.	> 19.99
uvm2	6278.	197.	> 19.67
uvw2	1035.	388.	> 20.45

Table 1: Magnitudes and Upper Limits from UVOT observations

627). They are not corrected for the expected Galactic extinction corresponding to a reddening of E(B-V)=0.047 mag in the direction of the burst (Schlegel et al. 1998).

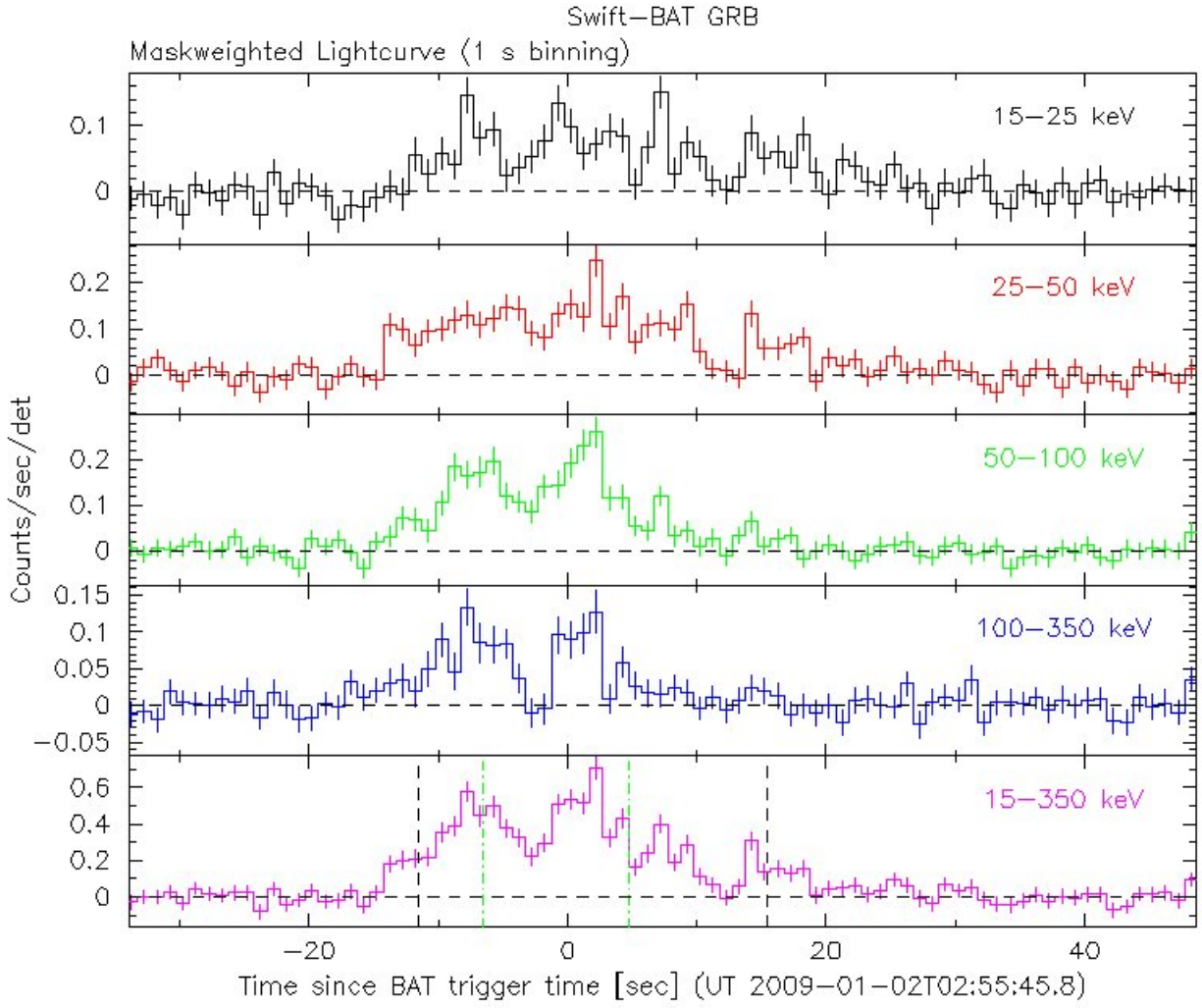

Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector^{-1} (note illum-det = 0.16 cm^2) and T_0 is 2009 Jan 02, 02:55:45 UT

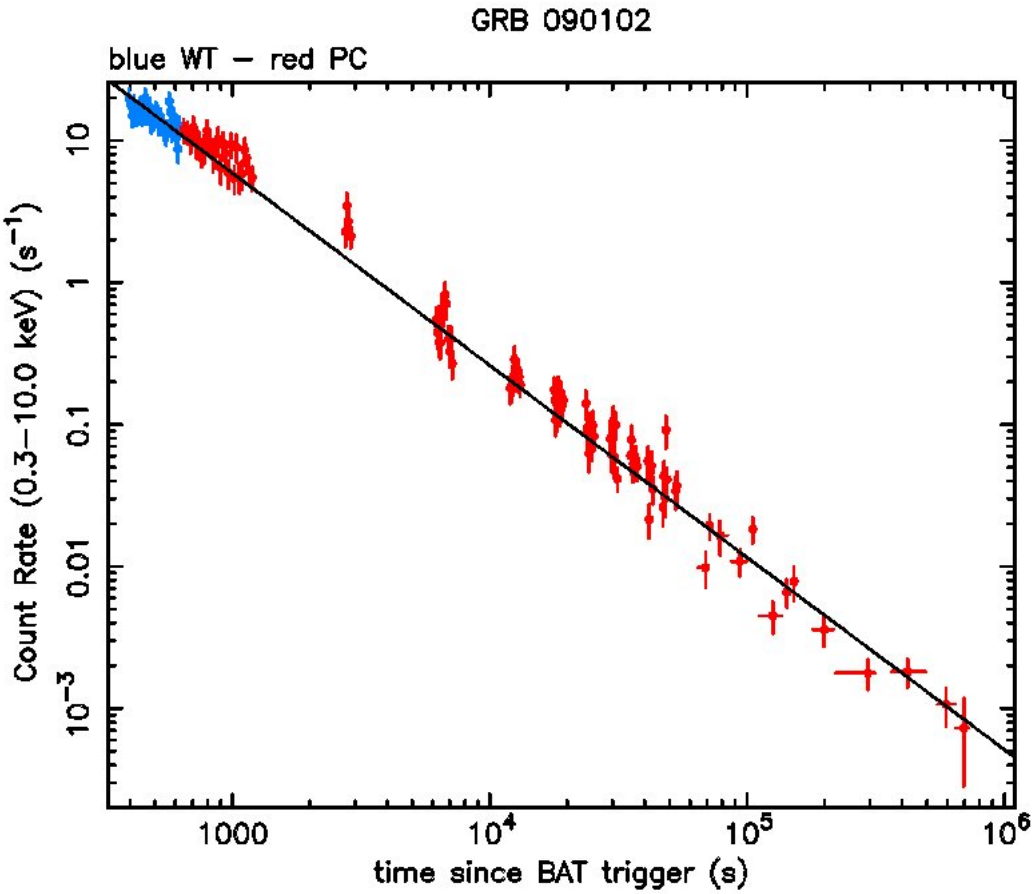

Figure 2: XRT Lightcurve. Counts/s in the 0.3−10 keV band: Window Timing mode (blue), Photon Counting mode (red). The approximate conversion is 1 count/s = $\sim 1.3 \times 10^{-10}$ ph cm^{-2} s^{-1}.

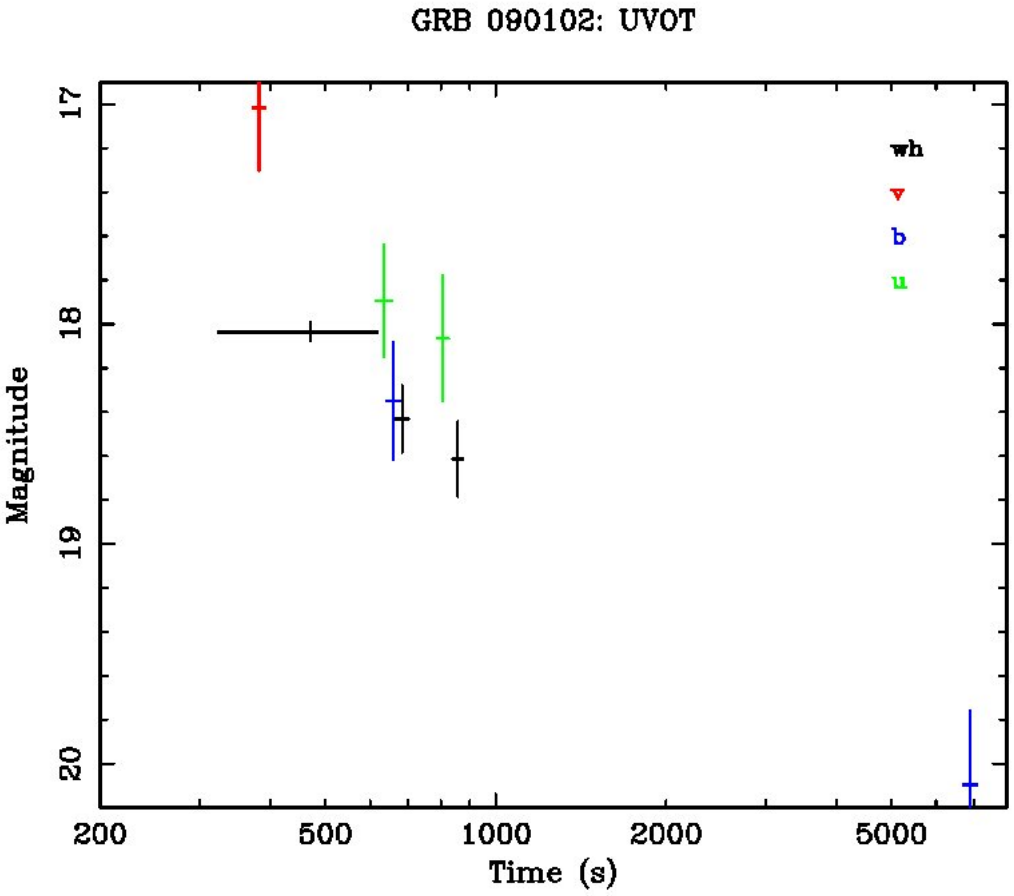

Figure 3: UVOT light curves. Upper limits from Table 1 are not included.