Swift Observations of GRB 090418A

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1 Introduction

BAT triggered on GRB 090418A at 11:07:40 UT (trigger 349510, Mangano *et al.*, *GCN Circ.* 9149). This was a 1.024 s rate-trigger on a long burst with $T_{90} = 56$ s. Swift slewed immediately to this burst and XRT [UVOT] began follow-up observations at $T+96.1$ s [$T+84$ s]. Our best position is the UVOT location RA($J2000$) = 269.31321 *deg* (17^h 57^m 15.17^s), Dec($J2000$) = +33.40585 *deg* ($+33^d$ $24'$ $21.1''$) with an estimated uncertainty of 0.5 arcsec (radius, 90% confidence, statistical + systematic).

GRB 090418A has also been seen by Konus Wind (Pal'shin *et al.*, *GCN Circ.* 9196), and by INTEGRAL/SPI-ACS, confirming the multi peak structure of the prompt emission reported in Mangano *et al.*, *GCN Circ.* 9149 (Volodymyr Savchenko, private communication).

The optical afterglow was detected by a number of ground based telescopes, e.g.: the Katzman Automatic Imaging Telescope (KAIT) at Lick Observatory (Chornock *et al.*, *GCN Circ.* 9148); by ROTSE-IIIb, located at McDonald Observatory, Texas, 19.0 s after the burst (Yuan *et al.*, *GCN Circ.* 9150 and Yuan, *GCN Circ.* 9152); with Shajn telescope of CrAO, after 0.5484 days (Pavlenko *et al.*, *GCN Circ.* 9179); with Russian-Turkish 1.5-m telescope (RTT150, Bakirlitepe, TUBITAK National Observatory, Turkey) 0.52 days after the burst (Kumar *et al.*, *GCN Circ.* 9199).

IR detection have been given by the 1.3-m Peters Automated Infrared Imaging Telescope (PAIRITEL) 26 minutes after the Swift trigger (Cobb & Bloom *et al.*, *GCN Circ.* 9152).

A redshift estimate z = 1.608 was provided using the Kast spectrograph on the Lick 3-meter telescope (Chornock & Cenko *et al.*, *GCN Circ.* 9151) after the detection of metal absorption lines in spectra collected only 816s after the burst trigger.

The POSS2 galaxy (Pavlenko *et al.*, *GCN Circ.* 9179) located approximately 4 arcsec northwest of the afterglow of GRB 090418A is unlikely to be the host galaxy of GRB 090418A since its UVOT detection in the uvw2 filter suggests it has a redshift of less than approximately 1.3 (Holland *GCN Circ.* 9183).

2 BAT Observation and Analysis

Using the data set from $T-240$ to $T+705$ s, refined analysis of BAT GRB 090418A was performed by the Swift team and reported in Fenimore *et al.*, *GCN Circ.* 9157. The BAT ground-calculated position is RA($J2000$) = 269.320 *deg* (17^h 57^m 16.8^s), Dec($J2000$) = 33.407 *deg* ($+33^d$ $24'$ $24.4"$) with an uncertainty of 1.4 arcmin, (radius, sys+stat, 90% containment). The partial coding was 31%.

The mask-weighted light curve (Fig.1) shows two clusters of peaks. The first starts at $\sim T-8$ s, peaks at $\sim T+1$ s, and reaches a minimum at $T+15$ s. The second cluster peaks at around $T+40$ s and returns to background at $\sim T+70$ s. T_{90} (15−350 keV) is 56±5 s (estimated error including systematics).

The time-averaged spectrum from $T-8.5$ to $T+61.1$ s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.48±0.07. The fluence in the $15-150$ keV band is $4.6\pm0.2\times10^{-6}$ erg cm^{-2}. The 1−sec peak photon flux measured from $T+0.06$ s in the $15-150$ keV band is 1.9±0.3 ph cm^{-2} s^{-1}.

The results of the batgrbproduct analysis are available at http://gcn.gsfc.nasa.gov/notices_s/349510/BA/.

The joint spectral analysis of the Konus-Wind and the Swift/BAT data enables to derive the broad-band spectral parameters of this burst (Pal'shin *et al.*, *GCN Circ.* 9196). To perform this analysis the time interval of the spectral data for each instrument is chosen from $T-6.7$ to $T+58.1$ s, referred to the BAT trigger time. The energy ranges used in the joint spectral analysis are 20-1200 keV and 14-150 keV for the Konus-Wind and the Swift/BAT respectively.

The spectrum is well fitted with a power-law with exponential cutoff model:
$\mathrm{dN/dE} \sim \mathrm{E}^{\alpha} \exp\left(-(2+\alpha)\ \mathrm{E/E}_{peak}\right)$. The best fit spectral parameters are: $\alpha = -1.30 \pm 0.09$ and $\mathrm{E}_{peak} = 610^{+530}_{-164}$ keV ($\chi^2/\mathrm{dof} = 37.0/57$). The best fit spectral parameters for the GRB (Band) model fixing $\beta = -2.5$ are: $\alpha = -1.30 \pm 0.09$, and $\mathrm{E}_{peak} = 601^{+554}_{-215}$ keV ($\chi^2/\mathrm{dof} = 37.1/57$). The energy fluence in the $15-1200$ keV band calculated by a power-law with exponential cutoff model for this 64.8 s interval is $(1.79\pm0.21)\times10^{-5}$ erg cm^{-2}.

All the quoted errors are at the 90% confidence level.

3 XRT Observations and Analysis

Swift-XRT began follow-up observations of the field of GRB 090418A (trigger 349510, Mangano *et al.*, *GCN Circ.* 9149) on date 2009 May 18, 11:09:26 UT, 102 s after the BAT trigger.

The whole dataset consists of 116 s in Windowed timing mode (from $T+102$ s to $T+218$ s) and ~ 43.7 ks in Photon Counting mode (starting 219 s after the trigger to the end of the observation at $T+475$ ks).

Using 2594 s of XRT Photon Counting mode data and 5 UVOT images for GRB 090418A, 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 = 269.31329, +33.40607 which is equivalent to:

RA (J2000): $17^h\ 57^m\ 15.19^s$
Dec (J2000): $+33^d\ 24'\ 21.8"$

with an uncertainty of 1.7 arcsec (radius, 90% confidence; Goad *et al.*, *GCN Circ.* 9154).

This position is within 2.4 arcsec of the initial XRT position reported by Mangano *et al.*, *GCN Circ.* 8762, and 1.6 arcsec from the optical afterglow candidate reported by Holland *et al.*, *GCN Circ.* 9175.

The $0.3-10$ keV X-ray light curve (Fig.2) is well fitted by a doubly broken power law, with a initial decay slope alpha1=4.79±0.56, a first break at about $T+133$ s, an intermediate decay slope alpha2=0.68±0.01, a second break at about $T+5.6\pm0.6$ ks and a final decay slope alpha3=1.63±0.04.

The average WT spectrum (Mangano *et al.*, *GCN Circ.* 9163) is best fitted by an absorbed power-law model, with photon index 2.0±0.2, and intrinsic $\mathrm{N_H}=(6\pm3)\times10^{21}$ cm^{-2} (at the redshift z=1.608, Chornock *et al.*, *GCN Circ.* 9151) in excess with respect to the Galactic absorption value of 3.6×10^{20} cm^{-2} (Kalberla et al. 2005). The average observed [unabsorbed] flux in the $0.3-10$ keV band is 3.5×10^{-10} [4.6×10^{-10}] ph cm^{-2} s^{-1}.

The average PC spectrum of the first orbit (covering the intermediate slowly decaying phase) is well fitted by an absorbed power-law model, with photon index 2.1±0.1, intrinsic $\mathrm{N_H}=(1.2\pm0.3)\times10^{22}$ cm^{-2} and average observed [unabsorbed] flux in the $0.3-10$ keV band of 1.5×10^{-10} [2.2×10^{-10}] ph cm^{-2} s^{-1}.

Finally, the average PC spectrum from $T+4.2$ ks to $T+18$ ks (orbits 2-4) is well fitted by an absorbed power-law model, with photon index 2.0±0.1, intrinsic $\mathrm{N_H}=(1.1\pm0.2)\times10^{22}$ cm^{-2} and average observed [unabsorbed] flux in the $0.3-10$ keV band of 1.3×10^{-11} [1.8×10^{-11}] ph cm^{-2} s^{-1}. The average count-rate to observed [unabsorbed] flux conversion factor is 4.5×10^{-11} [6.5×10^{-11}] erg cm^{-2} counts^{-1}. All quoted errors are at 90% confidence level.

The results of the XRT-team automatic analysis are available at http://www.swift.ac.uk/xrt_products/00349510.

4 UVOT Observation and Analysis

The UVOT began settled observations of the Swift localised GRB 090418A 160 s after the BAT trigger. The optical afterglow position detected by UVOT is RA($J2000$) = 269.31321 *deg* (17^h 57^m 15.17^s), Dec($J2000$) = +33.40585 *deg* ($+33^d$ $24^{'}$ $21.1^{''}$) with an error of 0.5 arcsec (90% confidence, including systematic uncertainties) (Holland *et al.*, *GCN Circ.* 9175).

UVOT light curves are shown in Fig. 3. The afterglow is not detected at approximately 2.6 days (220 ks) after the BAT trigger. The estimated late-time power-law decay index is alpha = 0.5 between about 6.4 and 122 ks after the BAT trigger. There is weak evidence that the afterglow light remained constant between approximately 122 ks and 205 ks s after the BAT trigger. There is no detection in any filter after this time.

The initial magnitudes (or 3 sigma limits), reported in Holland *et al.GCN Circ.* 9175, are give 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
u (fc)	160	410	246	17.31 ± 0.09
v	466	485	19	17.31 ± 0.24
b	415	435	19	18.22 ± 0.25
u	539	559	19	18.55 ± 0.39
uvw1	515	835	19	> 18.1
uvm2	490	510	19	> 17.6
uvw2	441	461	19	> 18.1
uvw1	515	11,831	1337	20.82 ± 0.26
	114,115	131,895	2064	> 22.0
uvm2	490	18,413	2109	> 21.8
uvw2	441	16,709	1357	> 21.8

Table 1: Magnitudes and Upper Limits from UVOT observations

The detection in the uvw1 filter, combined with the lack of a detection in the uvm2 filter, is consistent with this source having a redshift of z = 1.608 (Charnock *et al.*, *GCN Circ.* 9151).

The quoted magnitudes have not been corrected for the expected Galactic extinction along the line of sight corresponding to a reddening of E(B-V) = 0.04 mag (Schlegel, et al., 1998, ApJS, 500, 525). All photometry is on the UVOT flight system described in Poole et al. (2008, MNRAS, 383, 627).

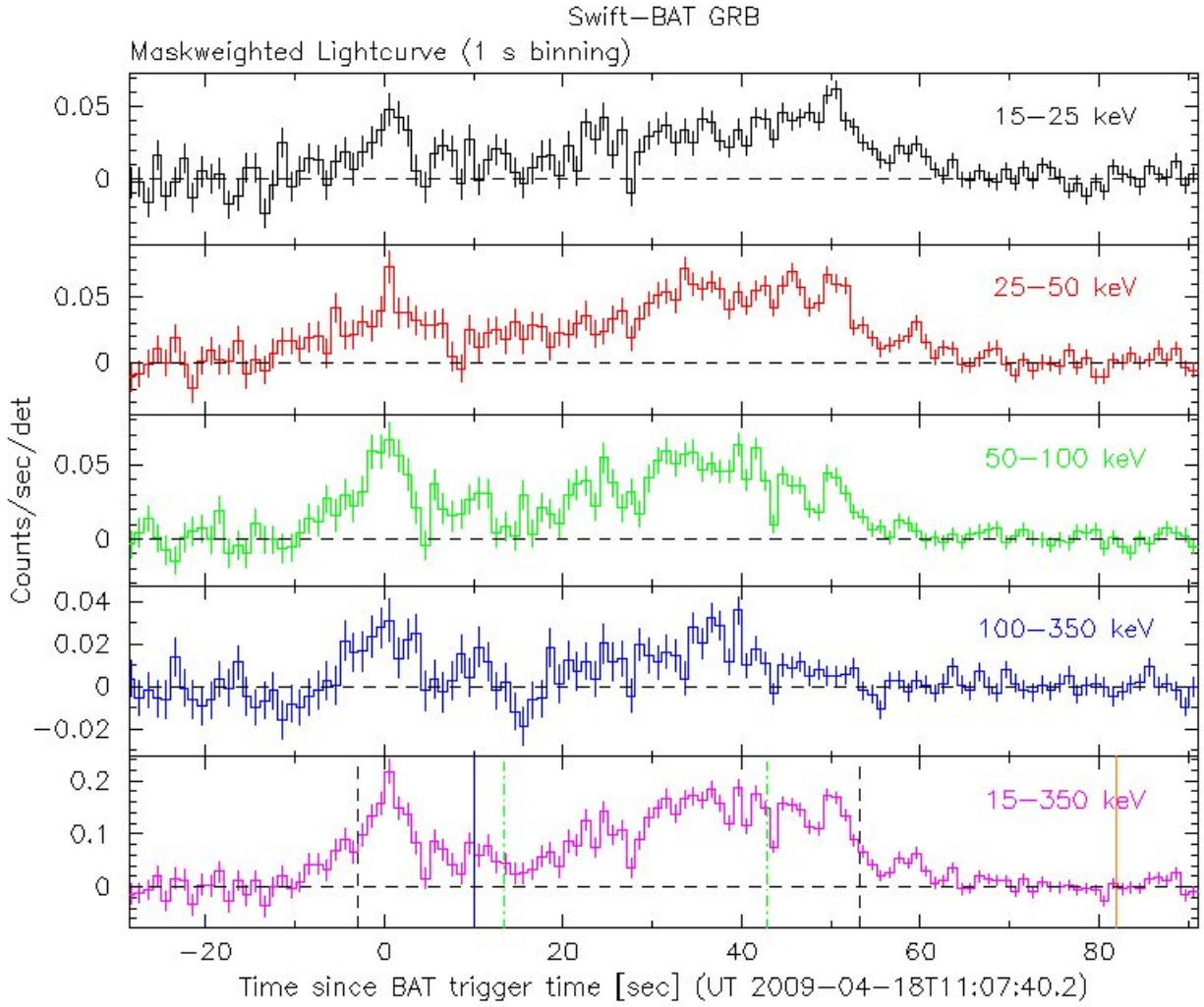

Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector^{-1} (note illum-det = 0.16 cm^2) and T_0 is 2009 April 18, 11:07:40 UT

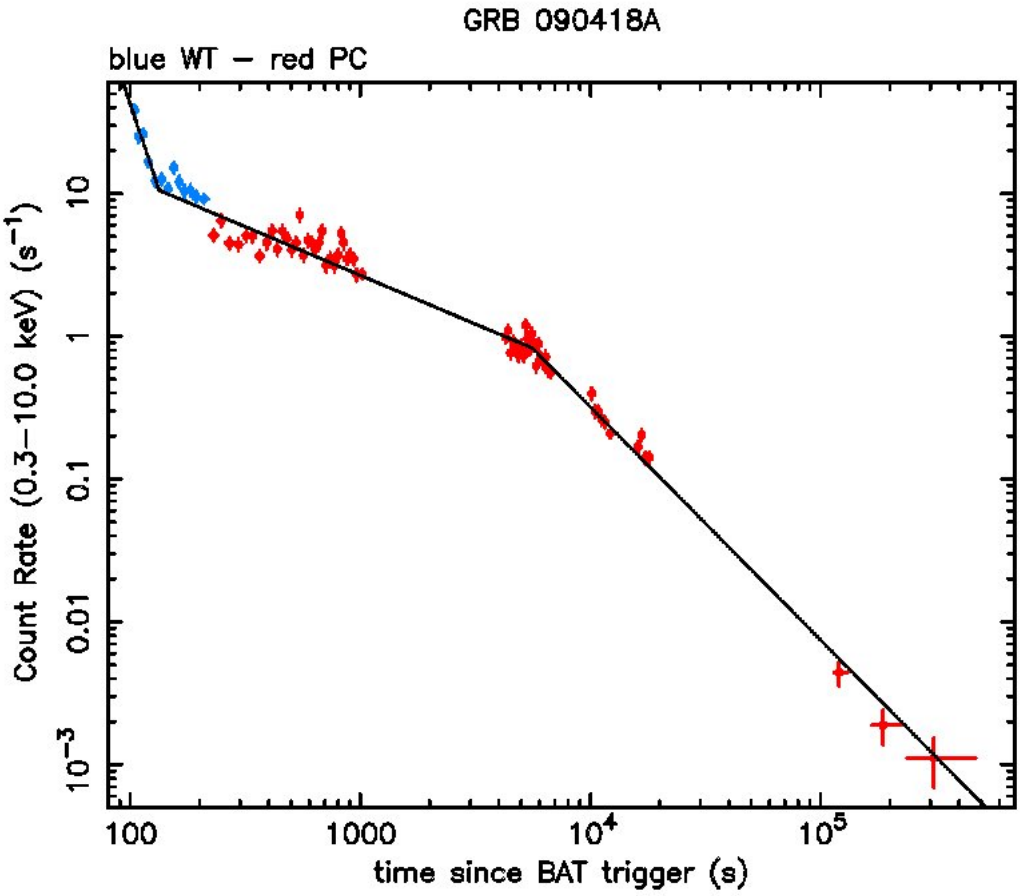

Figure 2: XRT Light curve. Counts/s in the 0.3−10 keV band: Window Timing mode (blue), Photon Counting mode (red). The approximate conversion is 1 count/s = $\sim 6.5 \times 10^{-11}$ ph cm^{-2} s^{-1}.

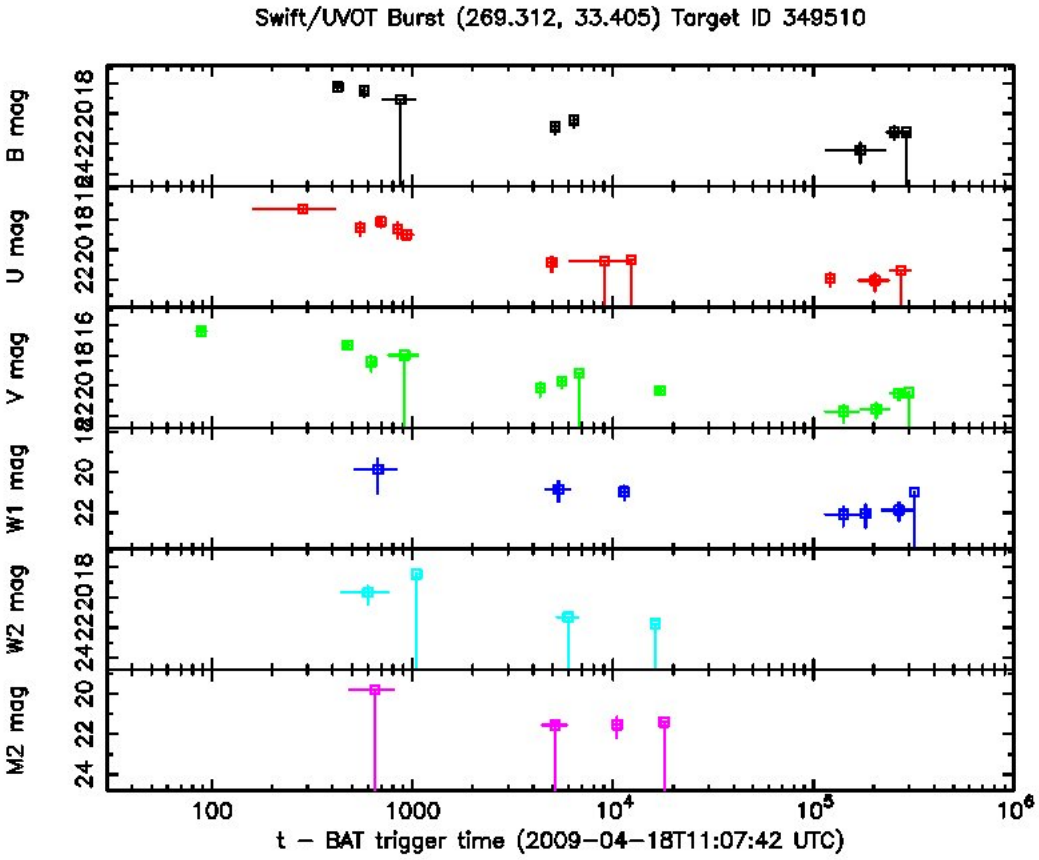

Figure 3: UVOT light curves. Upper limits from Table 1 are not included.