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 \([T+84] \). Our best position is the UVOT location RA(J2000) = 269.31321 deg (17\(^h\) 57\(^m\) 16.8s), Dec(J2000) = +33.4075 deg (+33\(^d\) 24\(^′\) 24.4\(^″\)) 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 \( 1.48\pm0.07 \). 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 \( 1.9\pm0.3 \) 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 for the Konus-Wind and the Swift/BAT respectively.

The spectrum is well fitted with a power-law with exponential cutoff model:
\[
dN/dE \sim E^\alpha \exp\left(-\frac{E}{E_{\text{peak}}}ight).
\]
The best fit spectral parameters are: \(\alpha = -1.30 \pm 0.09\) and \(E_{\text{peak}} = 610^{+530}_{-164}\) keV (\(\chi^2/\text{dof} = 37.0/57\)). The best fit spectral parameters for the GRB (Band) model fixing \(\beta = -2.5\) are: \(\alpha = -1.30 \pm 0.09\), and \(E_{\text{peak}} = 601^{+554}_{-215}\) keV (\(\chi^2/\text{dof} = 37.1/57\)). 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 \((1.79 \pm 0.21) \times 10^{-5}\) 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 \(\sim 43.7\) 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\(^m\) 21.8\(^s\)

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 an initial decay slope alpha1=4.79\(\pm\)0.56, a first break at about \(T + 133\) s, an intermediate decay slope alpha2=0.68\(\pm\)0.01, a second break at about \(T + 5.6\pm 0.6\) ks and a final decay slope alpha3=1.63\(\pm\)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\(\pm\)0.2, and intrinsic \(N_H=(6\pm3) \times 10^{21}\) 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\(\times\)10\(^{20}\) cm\(^{-2}\) (Kalberla et al. 2005). The average observed [unabsorbed] flux in the 0.3 – 10 keV band is 3.5\(\times\)10\(^{-10}\) [4.6\(\times\)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\(\pm\)0.1, intrinsic \(N_H=(1.2\pm0.3) \times 10^{22}\) cm\(^{-2}\) and average observed [unabsorbed] flux in the 0.3 – 10 keV band of 1.5\(\times\)10\(^{-10}\) [2.2\(\times\)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\(\pm\)0.1, intrinsic \(N_H=(1.1\pm0.2) \times 10^{22}\) cm\(^{-2}\) and average observed [unabsorbed] flux in the 0.3 – 10 keV band of 1.3\(\times\)10\(^{-11}\) [1.8\(\times\)10\(^{-11}\)] ph cm\(^{-2}\) s\(^{-1}\). The average count-rate to observed [unabsorbed] flux conversion factor is 4.5\(\times\)10\(^{-11}\) [6.5\(\times\)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 (17h 57m 15.17s), Dec(J2000) = +33.40585 deg (+33° 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.

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<th>$T_{stop}$</th>
<th>Exp</th>
<th>Magnitude/3-sig UL</th>
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<td>410</td>
<td>246</td>
<td>17.31 ± 0.09</td>
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<tr>
<td>v</td>
<td>466</td>
<td>485</td>
<td>19</td>
<td>17.31 ± 0.24</td>
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<tr>
<td>b</td>
<td>415</td>
<td>435</td>
<td>19</td>
<td>18.22 ± 0.25</td>
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<tr>
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<td>19</td>
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</table>

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 $\approx 6.5 \times 10^{-11}$ ph cm$^{-2}$ s$^{-1}$. 
Figure 3: UVOT light curves. Upper limits from Table 1 are not included.