Swift Observations of GRB 090530

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1 Introduction

BAT triggered on a long burst, GRB 090530, at 03:18:18 UT (Trigger 353567) (Cannizzo, et al., GCN Circ. 9438). Swift slewed immediately to the burst. The BAT light curve shows a single peak with a duration of about 10 s. The peak count rate was \( \sim 5000 \, \text{c s}^{-1} \) (15 \(-\) 350 keV), at \( \sim T + 0 \) s. XRT began observing the field at 03:19:33.1 UT, at \( T + 74.7 \) s, and found a bright, fading, uncatalogued X-ray source located at RA, Dec = (179.41927, 26.59282) deg, or \{11h 57m 40.62s, +26d 35' 34.2"\} (J2000) with \( \sigma = 3.9 \) arcsec (radius, 90\% containment). This is 84 arcsec from the BAT position. A power-law fit to a spectrum gives a column density in excess of the Galactic value \( (1.78 \times 10^{20} \, \text{cm}^{-2}) \), Kalberla et al. 2005), with an excess column of \( 2.1(+2.01/ -1.71) \times 10^{21} \, \text{cm}^{-2} \) (90\% confidence). The initial flux in the 2.5 s image was \( 6.42 \times 10^{-10} \, \text{erg cm}^{-2} \, \text{s}^{-1} \) (0.2 \(-\) 10 keV).

UVOT took a finding chart exposure of 150 s with the White filter starting at \( T + 83 \) s. There is a candidate afterglow in the rapidly available 2.7' \times 2.7' sub-image at (179.41876, 26.59405) deg, or \{11:57:40.50; +26:35:38.6\} (J2000) with \( \sigma = 0.75 \) arc sec (90\% containment). This is 4.7 arc sec from the XRT position. The estimated magnitude is 17.39 \( \pm 0.14 \). No correction has been made for the expected extinction corresponding to \( E(B-V) = 0.02 \).

This burst has been also observed in the optical and NIR by ROTSE-IIIb (Flewelling et al., GCN Circ. 9439), 1.3m PAIRITEL (Morgan et al., GCN Circ. 9440), 0.3m GRAS002 (Nissinen & Hentunen, GCN Circ. 9441, 9442), MOSCA (Malesani et al., GCN Circ. 9452), 2.2m GROND (Rossi et al., GCN Circ. 9458), 1.0m Mt. Lemmon (Im & Urata, GCN Circ. 9459), 0.4m GRT (Sakamoto et al., GCN Circ. 9466), and RAPTOR (Wren et al., GCN Circ. 9478).

2 BAT Observation and Analysis

Using the data set from \( T - 60 \) to \( T + 243 \) s, further analysis of GRB 090530 was performed by the Swift team (Palmer et al., GCN Circ. 9443). The BAT ground-calculated position is RA, Dec = (179.400, 26.590) deg, or \{11h 57m 36.0s, +26d 35' 23.0"\} (J2000) with \( \sigma = 1.9 \) arcmin, (radius, sys+stat, 90\% containment). The partial coding was 41\%.

The mask-weighted light curve shows a FRED-like peak starting at \( \sim T - 0.3 \) s, peaking at \( \sim T + 0.2 \) s, and returning almost to background. Then a second and much smaller peak starts at \( \sim T + 35 \) s, peaks at \( \sim T + 45 \) s, and ends at \( \sim T + 50 \) s. There is a \( \sim 3 \sigma \) precursor peak at \( T - 4 \) s. \( T_{90} \) (15 \(-\) 350 keV) is 48 \( \pm 36 \) s (estimated error including systematics).

The time-averaged spectrum from \( T - 12.2 \) to \( T + 51.8 \) s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.61 \( \pm 0.17 \). The fluence in the 15 \(-\) 150 keV band is \( 1.1(\pm0.1) \times 10^{-6} \, \text{erg cm}^{-2} \). The 1 s peak photon flux measured from \( T + 0 \) s in the 15 \(-\) 150 keV band is \( 2.5 \pm 0.3 \) ph cm\(^{-2}\) s\(^{-1}\). All the quoted errors are at the 90\% confidence level.

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\(^1\)http://isdc.unige.ch/Soft/ibas/results/triggers/spiacs/2009-05/2009-05-30T03-18-18.00-00000-00000-0.png
### 3 XRT Observation and Analysis

Using 646 s of XRT Photon Counting mode data and 1 UVOT images for GRB 090530 (Beardmore et al., *GCN Circ.* 9445), the astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA, Dec = (179.41846, +26.593410) deg, or {11h 57m 40.43s; +26d 35’ 36.3”} (J2000) with $\sigma = 1.5$ arcsec (radius, 90% confidence).

Subsequent analysis was carried out from the first five orbits of Swift-XRT data (Mangano et al., *GCN Circ.* 9451) consisting of 22 s WT data from $T + 81$ to $T + 103$ s and 9 ks in PC data from $T + 105$ s to $T + 24.4$ ks.

The $0.3 – 10$ keV X-ray light curve is best fitted by a broken powerlaw with early decay index of about $-5.7$, late decay index $-0.60 \pm 0.04$ and a break at $\sim T + 140$ s. In the first orbit a small amplitude flare is detected at $T + 300$ s. Flaring activity is also visible along the later decay. If decaying at the present rate, the predicted rate after 24h from the trigger is $2.0 \times 10^{-2}$ c s$^{-1}$.

The average initial WT spectrum (covering the initial steep decay) can be modeled as an absorbed power-law with index 2.3(+0.5 – 0.4), absorbing column $N_H < 1.1 \times 10^{21}$ cm$^{-2}$ (3$\sigma$ UL) and observed (unabsorbed) average flux in the $0.3 – 10$ keV energy range of $2.9(3.6) \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$. The average PC spectrum (roughly covering the flatter part of the afterglow) is best fitted by an absorbed power-law with index 2.00 ± 0.15 The absorbing column is $N_H = (8.2 – 2.9 + 3.6) \times 10^{20}$ cm$^{-2}$ in excess with respect to the Galactic value of $1.78 \times 10^{20}$ cm$^{-2}$ (Kalberla et al. 2005). The average observed (unabsorbed) flux is $4.0(4.9) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$. The count-rate to flux conversion factor is $5.4 \times 10^{-11}$. All quoted errors are at 90% confidence level.

### 4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 090530 at $T + 158$ s (Schady et al., *GCN Circ.* 9438) and a decaying source was detected in all UVOT filters within the XRT error circle (Beardmore et al., *GCN Circ.* 9445), putting an upper limit on the redshift of $z < 1.7$.

The source initially rises, and at $\sim T + 100$ s, and decays at a constant rate of $0.73 \pm 0.03$ for the duration of intial UVOT observations, to $\sim T + 20$ ks. The best UVOT position is RA, Dec = (179.41873, +26.59400) deg, or {11:57:40.50; +26:35:38.4} (J2000) with $\sigma = 0.5$ arcsec (radius, 90% confidence, statistical + systematic), consistent with the ROTSE-IIIb afterglow position (Flewelling et al., *GCN Circ.* 9439).

The UVOT magnitudes are:

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<th>Filter</th>
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<th>T_stop(s)</th>
<th>Exp(s)</th>
<th>Mag</th>
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<td>233</td>
<td>147</td>
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<tr>
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<td>644</td>
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<td>17.69 +/- 0.29</td>
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<td>570</td>
<td>19</td>
<td>18.60 +/- 0.27</td>
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<td>21.31 +/- 0.32</td>
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</tbody>
</table>

The values quoted above are not corrected for the Galactic extinction due to the reddening of
Figure 1: BAT Lightcurve. The light curve in the 4 individual plus total energy bands (15 – 25 keV, 25 – 50, 50 – 100, 100 – 350, and 15 – 350).

$E(B-V) = 0.02$ in the direction of the burst (Schlegel et al. 1998). The photometry is on the UVOT photometric system described in Poole et al. (2008, MNRAS, 383, 627).
Figure 2: XRT Lightcurve. A broken powerlaw fit gives: $\alpha_1 = 5.7$, $t_{\text{break}, 1} = 135 \pm 10$ s, $\alpha_2 = 0.60 \pm 0.04$, $t_{\text{break}, 2} = 18.5 \pm 1$ ks, $\alpha_3 = 0.93 \pm 0.15$.

Figure 3: UVOT Lightcurve. A broken powerlaw fit gives $\alpha = 0.66 \pm 0.02(1\sigma)$.