Swift Observations of GRB 090530

J. K. Cannizzo (NASA/UMBC), M. Stamatikos (NASA/ORAU),
V. Mangano (INAF-IASFPA), P. Schady (MSSL-UCL), for the Swift Team

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 ~ 5000 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 (1.78×10^{20} cm^{-2}, Kalberla et al. 2005), with an excess column of $2.1(+2.01/-1.71) \times 10^{21}$ cm^{-2} (90% confidence). The initial flux in the 2.5 s image was 6.42×10^{-10} erg cm^{-2} 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'×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 ± 0.14. No correction has been made for the expected extinction corresponding to $E(B-V) = 0.02$. *INTEGRAL*/SPI-ACS also weakly detected this GRB.[1]

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 ± 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 ± 0.17. The fluence in the $15-150$ keV band is $1.1(\pm 0.1) \times 10^{-6}$ erg cm^{-2}. The 1 s peak photon flux measured from $T+0.0$ s in the $15-150$ keV band is 2.5 ± 0.3 ph cm^{-2} s^{-1}. All the quoted errors are at the 90% confidence level.

[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 ± 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 2.0×10^{-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} (3σ 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 1.78×10^{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 5.4×10^{-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 ± 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:

Filter	T_start(s)	T_stop(s)	Exp(s)	Mag
white	83	233	147	17.43 +/- 0.03
v	624	644	19	17.69 +/- 0.29
b	550	570	19	18.60 +/- 0.27
u	295	545	246	17.46 +/- 0.05
uvw1	5735	5935	197	20.15 +/- 0.37
uvm2	5530	11687	1082	20.31 +/- 0.22
uvw2	5121	17468	1279	21.31 +/- 0.32

The values quoted above are not corrected for the Galactic extinction due to the reddening of

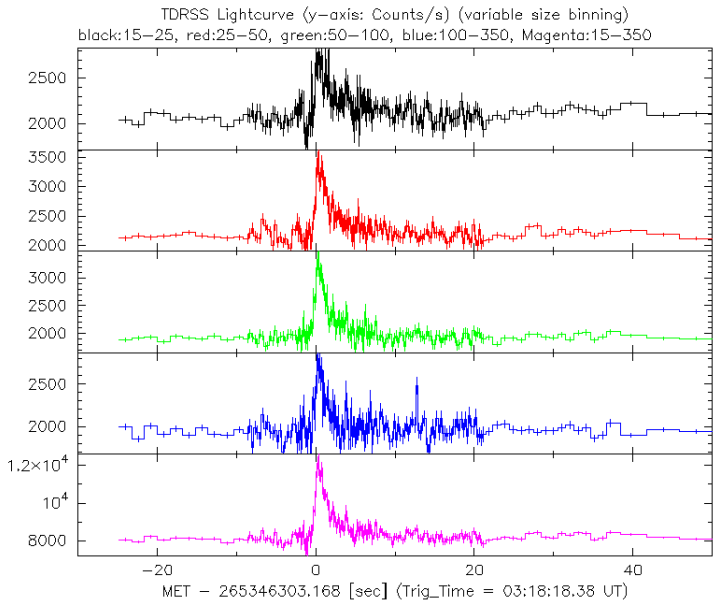

Figure 1: BAT Lightcurve. The light curve in the 4 individual plus total energy bands ($15-25$ keV, $25-50$, $50-100$, $100-350$, and $15-350$).

$E(B-V) = 0.02$ 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).

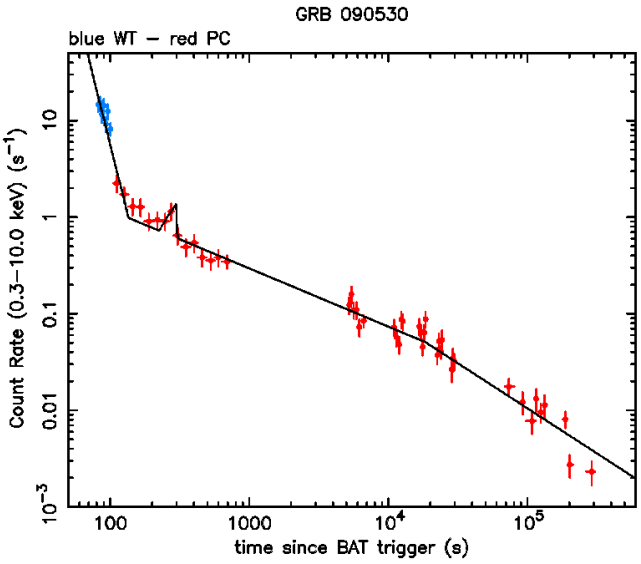

Figure 2: XRT Lightcurve. A broken powerlaw fit gives: $\alpha_1 = 5.7$, $t_{\rm break,\ 1} = 135 \pm 10$ s, $\alpha_2 = 0.60 \pm 0.04$, $t_{\rm break,\ 2} = 18.5 \pm 1$ ks, $\alpha_3 = 0.93 \pm 0.15$.

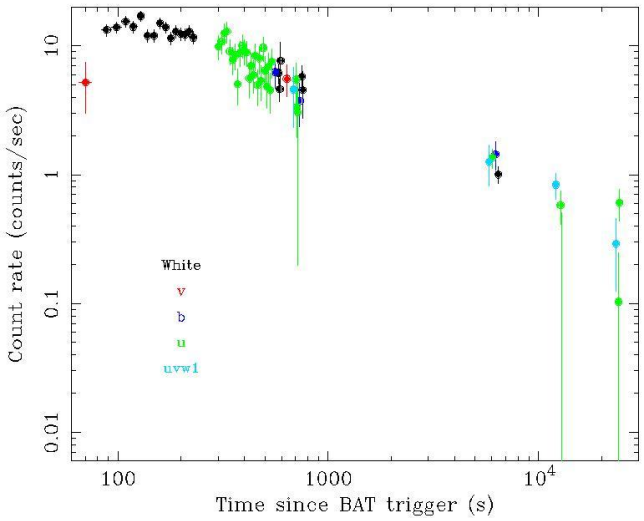

Figure 3: UVOT Lightcurve. A broken powerlaw fit gives $\alpha = 0.66 \pm 0.02 (1\sigma)$.