

Final Swift Observation of GRB 090417B

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1 Introduction

BAT triggered on GRB 090417B at 15:20:03 UT (Trigger 349450) (Sbarufatti, *et al.*, *GCN Circ.* 9135). This was a 320 sec image-trigger on a very long burst with $T_{90} > 260$ sec. Swift slewed to this burst immediately and XRT began follow-up observations at $T + 393$ sec, and UVOT at $T + 378$ sec. Our best position is the XRT-UVOT enhanced location $\text{RA}(J2000) = 209.6942\text{deg}$ ($13h58m46.62s$), $\text{Dec}(J2000) = +47.0182\text{deg}$ ($+47d01'05.4''$) with an error of 1.4 arcsec (90% confidence, including boresight uncertainties).

2 BAT Observation and Analysis

Using the data set from $T - 239$ to $T + 2100$ sec, further analysis of BAT GRB 090417B has been performed by Swift team (Cummings, *et al.*, *GCN Circ.* 9139, Barthelmy, *et al.*, *GCN Circ.* 9153). The BAT ground-calculated position is $\text{RA}(J2000) = 209.687\text{deg}$ ($13h58m44.8s$), $\text{Dec}(J2000) = +47.015\text{deg}$ ($+47d00'55''$) ± 1.0 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 94%.

The mask-weighted light curve (Fig.1) shows that this burst started before $T - 200$ sec (where we start collecting event data on each trigger), slowly rises to a peak around $T + 400$ sec to a minimum around $T + 1100$ sec, then increases to a second maximum around $T + 1650$ sec, and then decreases again with continuing emission past $T + 2100$ sec (where the data stops). The amplitudes of the two peaks are 0.09 ± 0.01 and 0.060 ± 0.006 $\text{ph}/\text{cm}^2/\text{sec}$, respectively.

The time-averaged spectrum from $T+278.7$ to $T+617.1$ sec is best fitted by a simple power law model. This fit gives a photon index of 1.85 ± 0.14 . For this model the total fluence in the $15 - 150$ keV band is $(2.3 \pm 0.2) \times 10^{-6} \text{ergs}/\text{cm}^2$ and the 1-sec peak flux measured from $T+434.93$ sec in the $15 - 150$ keV band is $0.3 \pm 0.1 \text{ ph}/\text{cm}^2/\text{sec}$. All the quoted errors are at the 90% confidence level.

3 XRT Observations and Analysis

Using 6972 sec of XRT Photon Counting mode data and 9 UVOT images, we find an astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching to the USNO-B1 catalogue): $\text{RA}(J2000) = 209.6942$ ($13h58m46.62s$), $\text{Dec}(J2000) = +47.0182(+47d01'05.4'')$ with an uncertainty of 1.4 arcsec (90% confidence). This position lies 0.35 arcmin from the BAT refined position, inside the quoted error circle (Barthelmy, *et al.*, GCN circ. 9153).

The $0.3 - 10$ keV light curve (Fig.2) of the first orbit is dominated by flaring activity, with 3 major peaks at $T + 530$, $T + 1410$ and $T + 1560$ sec respectively. After the flares, the light-curve decays with a slope 0.88 ± 0.02 until $T + 8700$ sec, when it steepens to an index 1.38 ± 0.04 . A second break is observed at $T + 410$ ksec, followed by a decay index of $2.4^{+0.5}_{-0.9}$.

The average Windowed Timing spectrum of the first orbit is best fitted by an absorbed power-law model with a high energy cutoff. The best fit parameters are photon index 0.40 ± 0.17 , cutoff energy 3.1 ± 0.4 keV and NH $(9.2 + / - 0.6) \times 10^{21} \text{cm}^{-2}$, in large excess with respect to the galactic value $1.6 \times 10^{20} \text{cm}^{-2}$ (Kalberla *et al.* 2005). The average observed(unabsorbed) flux in the $0.3 - 10$ keV band is $1.6(2.1) \times 10^{-9} \text{ ergs}/\text{cm}^2/\text{sec}$. The average spectrum of the large double peaked flare between

$T + 1.3 \text{ ksec}$ and $T + 2.0 \text{ ksec}$ is also fitted by an absorbed power-law model with a high energy cutoff with best fit parameters photon index 0.46 ± 0.2 , cutoff energy 3.2 ± 0.5 and NH $(9.5 \pm -0.7) \times 10^{21} \text{ cm}^{-2}$. The average Photon Counting spectrum in the $T + 5.4 \text{ ksec} - T + 30 \text{ ksec}$ interval is well fitted by an absorbed power-law with photon index 2.0 ± 0.1 and NH $(9.6 \pm 0.10) \times 10^{21} \text{ cm}^{-2}$. The average observed(unabsorbed) flux in the $0.3 - 10 \text{ keV}$ band is $2.8(5.6) \times 10^{-11} \text{ ergs/cm}^2/\text{sec}$. The count-rate to flux conversion factor is $1.0 \times 10^{-10} \text{ ergs/cm}^2/\text{sec}$. All quoted errors are at 90% confidence level.

4 UVOT Observation and Analysis

The UVOT began observing the field of GRB 090417B at 15:26:38 UT, 378 sec after the initial BAT trigger (Sbarufatti *et al.*, *GCN Circ.* 9135). No new source was detected within the XRT error circle in the white (147 sec) finding exposure, or in the co-added images in any filter down to 3-sigma magnitude. Upper limits are summarized in Table 1. These upper limits are not corrected for the Galactic extinction corresponding to a reddening of $E(B-V) = 0.02$ mag

Filter	Start	Stop	Exposure	3-Sigma UL
white (finding)	395	545	147	21.7
v	552	13098	1237	21.3
b	651	19457	862	21.9
u	1300	25241	1376	22.0
uvw1	601	25174	2300	22.2
uvm2	750	24268	1878	21.8
uvw2	700	29604	1331	22.0
white	395	7823	841	22.6

Table 1: Magnitude limits from UVOT observations

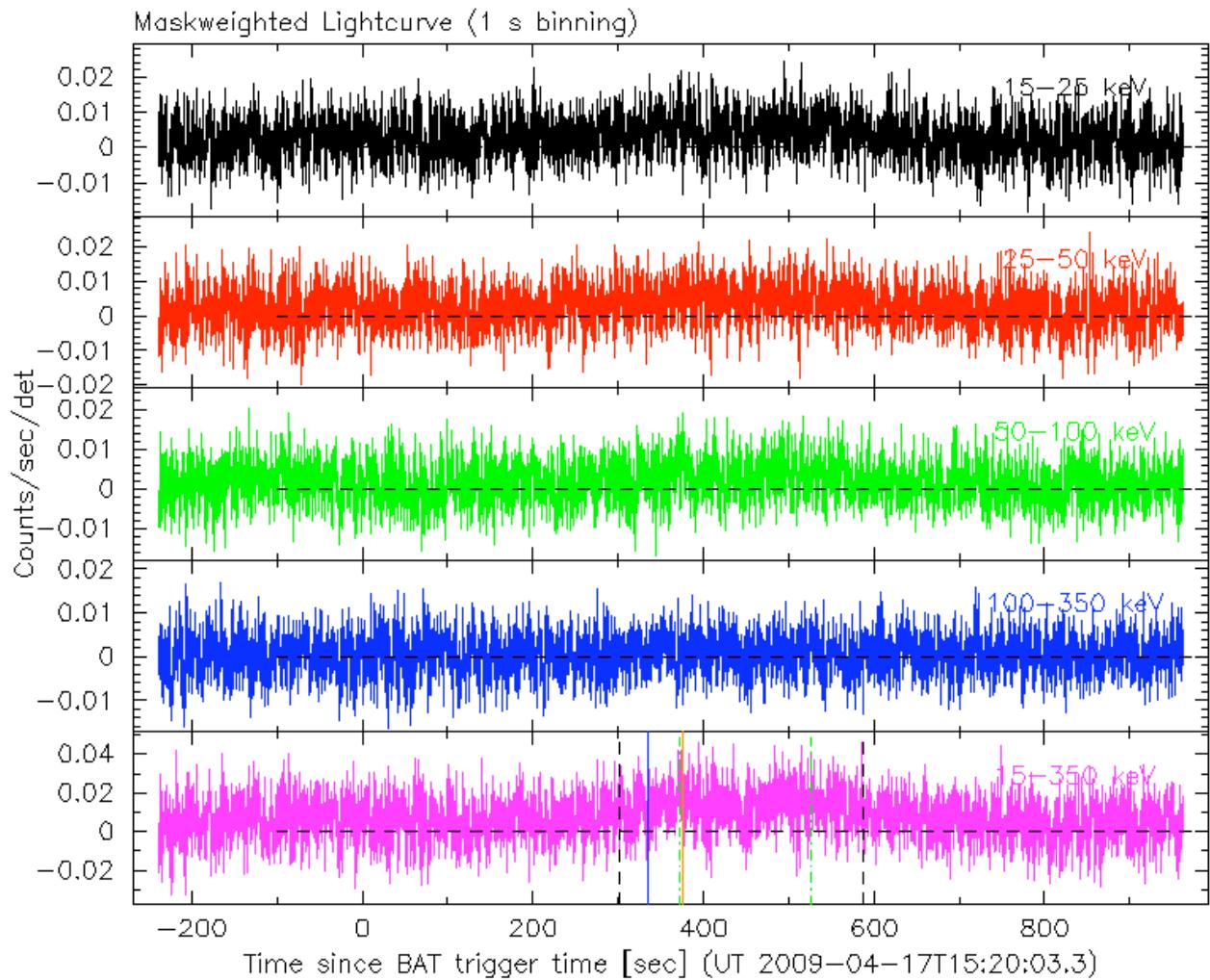


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector.

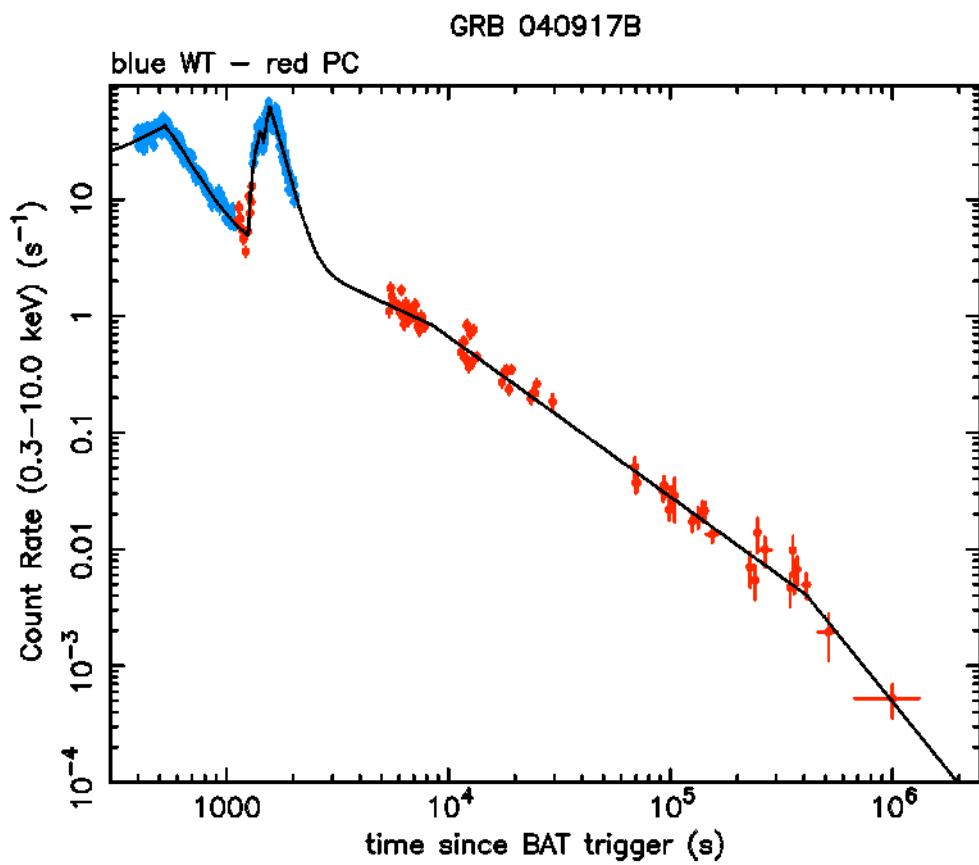


Figure 2: XRT Lightcurve. Counts/sec in the 0.3-10 keV band: Window Timing mode (blue), Photon Counting mode (red). The approximate conversion is 1 count/sec = $\sim 1.0 \times 10^{-10} \text{ ergs/cm}^2/\text{sec}$.

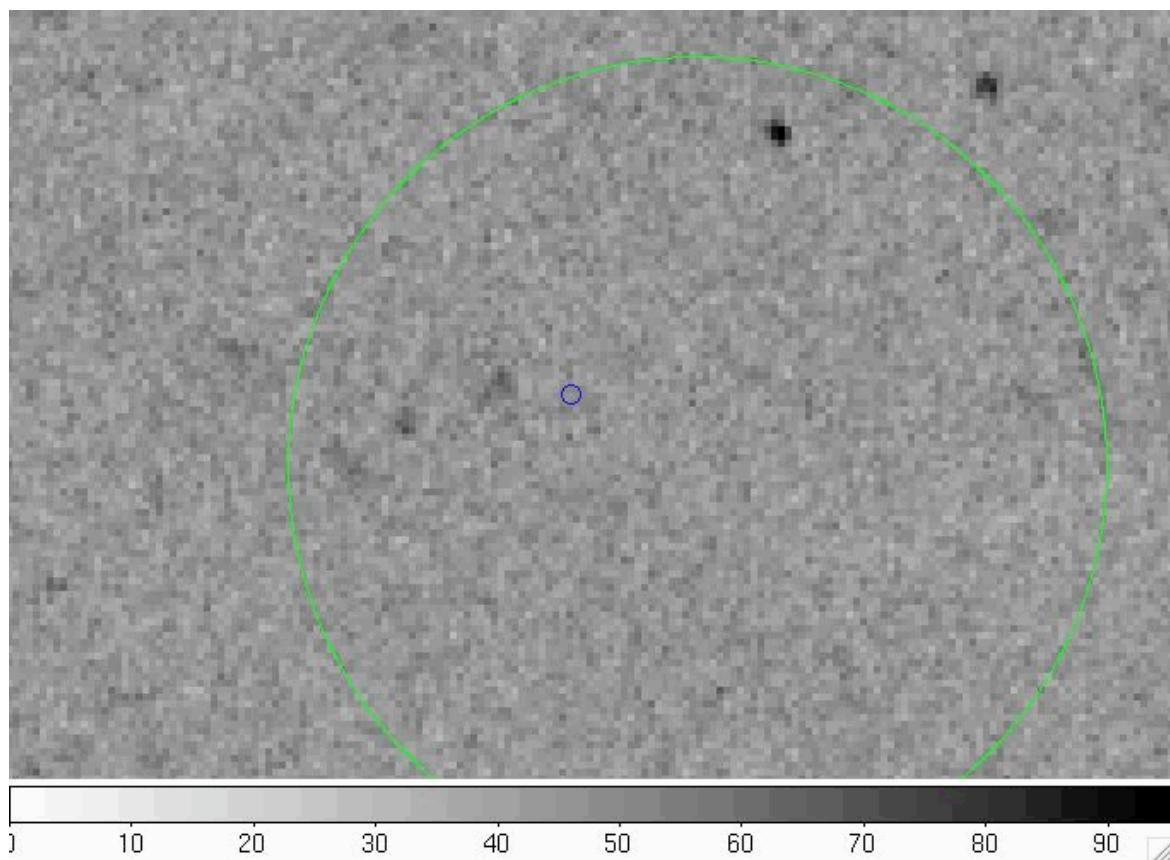


Figure 3: 841 sec coadded white image of the field of GRB 090417B starting 395 sec after the BAT trigger. The refined BAT error circle is shown in green. The UVOT-enhanced XRT error circle is shown in blue..