Swift Observation of GRB 100413A

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1 Introduction

BAT triggered on GRB 100413A on 2010 April 13 at 17:33:28 UT (Trigger 419404) (Holland et al. 2010, GCN Circ. 10581). This was a long burst with $T_{90} = 191$ s (Stamatikos et al. 2010, GCN Circ. 10600). *Swift* slewed immediately to this burst and follow-up observations started with the XRT at 140 s and UVOT at 150 s. Our best position is the UVOT-enhanced XRT location, RA, Dec (J2000.0) = 266°.22175, +15°.83400, which corresponds to

$$\begin{aligned} \text{RA (J2000.0)} &= 17^{\text{h}}44^{\text{m}}53^{\text{s}}.22 \\ \text{Dec (J2000.0)} &= +15^\circ 50' 02''.4 \end{aligned}$$

with an uncertainty of 1″.8 (radius, 90% containment, including systematics). No optical afterglow was detected by UVOT or by ground-based observatories.

GRB 100413A was detected by *Konus–Wind* (Golenetskii et al. 2010, GCN Circ. 10590). The light curve had multiple peaks with a total duration of ≈2 s. The spectrum was best fit with a power law with an exponential cutoff with $\alpha = -1.01 \pm 0.06$ and $E_{\text{peak}}(\text{obs}) = 446 \pm 123$ keV. It was also detected by *Suzaku*/WAM (Sugita et al. 2010, GCN Circ. 10604). Their light curve showed a multipeak structure with a duration of $T_{90} \approx 160$ s. The spectrum was best fit by a power law with an exponential cutoff with $\alpha = -0.59^{-1.64}_{+1.27}$ and $E_{\text{peak}} = 364^{+98}_{-55}$ keV. EVLA detected a radio afterglow at 8.5 GHz (Frail & Fox 2010, GCN Circ. 10611).

2 BAT Observation and Analysis

Using the data set from $T - 239$ to $T + 963$ s we find the following. The BAT ground-calculated position is RA, Dec (J2000.0) = 266°.223, +15°.835, which corresponds to

$$\begin{aligned} \text{RA (J2000.0)} &= 17^{\text{h}}44^{\text{m}}53^{\text{s}}.6 \\ \text{Dec (J2000.0)} &= +15^\circ 50' 05'' \end{aligned}$$

with an uncertainty of 1′.5, (radius, systematic + statistical errors, 90% containment). The partial coding was 48%.

The mask-weighted light curves (Figure 1) shows multiple overlapping peaks in two main clusters of peaks. It starts at about $T - 45$ s, with the first cluster ending at about $T + 40$ s. The second cluster starts at about $T + 90$ s, peaks at around $T + 100$ s, and ends at about $T + 250$ s. The emission does not return to background between the two clusters of peaks. T_{90} (15–350 keV) is 191 ± 14 s.

The time-averaged spectrum from $T - 3.4$ to $T + 227.4$ s is best fit by a simple power-law model. The power-law index of the time-averaged spectrum is 1.25 ± 0.07. The fluence in the 15–150 keV band is $(6.2 \pm 0.2) \times 10^{-6}$ erg cm^{-2}. The 1-s peak photon flux measured from $T + 116.78$ s in the 15–150 keV band is 0.7 ± 0.1 ph cm^{-2} s^{-1}. All the quoted errors are at the 90% confidence level.

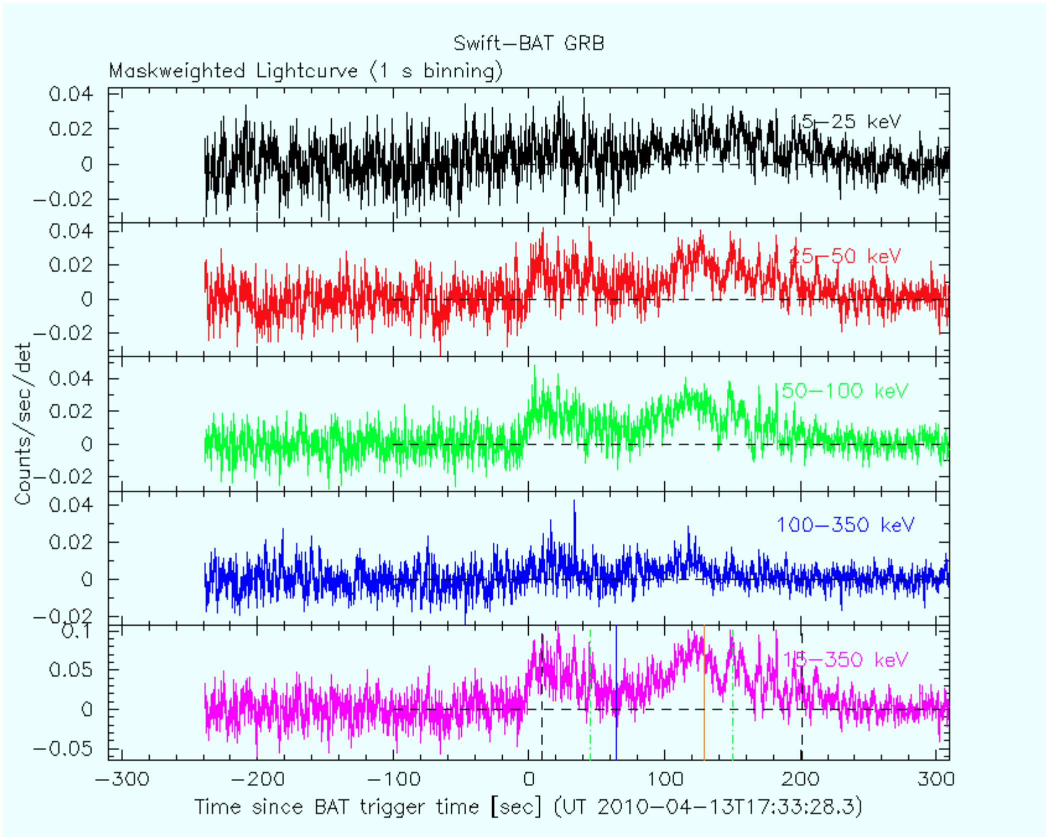

Figure 1: BAT light curves. The mask-weighted 1 s light curves in the four individual plus total energy bands. The units are count s^{-1} illuminated-detector^{-1} and T_0 is 17:33:28.3 UT.

3 XRT Observation and Analysis

The *Swift*/XRT began observing GRB 100413A at 17:35:48.4, 140.0 s after the BAT trigger. Using 952 s of Photon Counting (PC) mode data and one UVOT image we find an astrometrically-corrected X-ray position (using the XRT–UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue) of RA, Dec (J2000.0) = 266.°22175, +15.°834000, which corresponds to

$$\begin{aligned} \text{RA (J2000.0)} &= 17^{\text{h}}44^{\text{m}}53\overset{\text{s}}{.}22 \\ \text{Dec (J2000.0)} &= +15^\circ 50' 02\overset{''}{.}4 \end{aligned}$$

with an uncertainty of 1.″8, (radius, 90% containment).

The X-ray light curve (Figure 2) can be modelled with a series of power-law decays. The initial decay index is $\alpha_1 = 2.53 \pm 0.07$. At $T + 433^{+34}_{-25}$ s the decay flattens to $\alpha_2 = 1.21^{+0.04}_{-0.13}$. The light curve breaks again at $T + 6193^{+1559}_{-2927}$ s to $\alpha_3 = 1.59 \pm 0.08$.

A spectrum formed from the Window Timing (WT) mode data can be fitted with an absorbed power-law with a photon spectral index of 1.83 ± 0.06. The best-fitting absorption column is $2.42^{+0.19}_{-0.18} \times 10^{21}$ cm^{-2}, in excess of the Galactic value of 7.3×10^{20} cm^{-2} (Kalberla et al. 2005). The PC mode spectrum has a photon index of $2.06^{+0.13}_{-0.12}$ and a best-fitting absorption column of $(3.1 \pm 0.4) \times 10^{21}$ cm^{-2}.

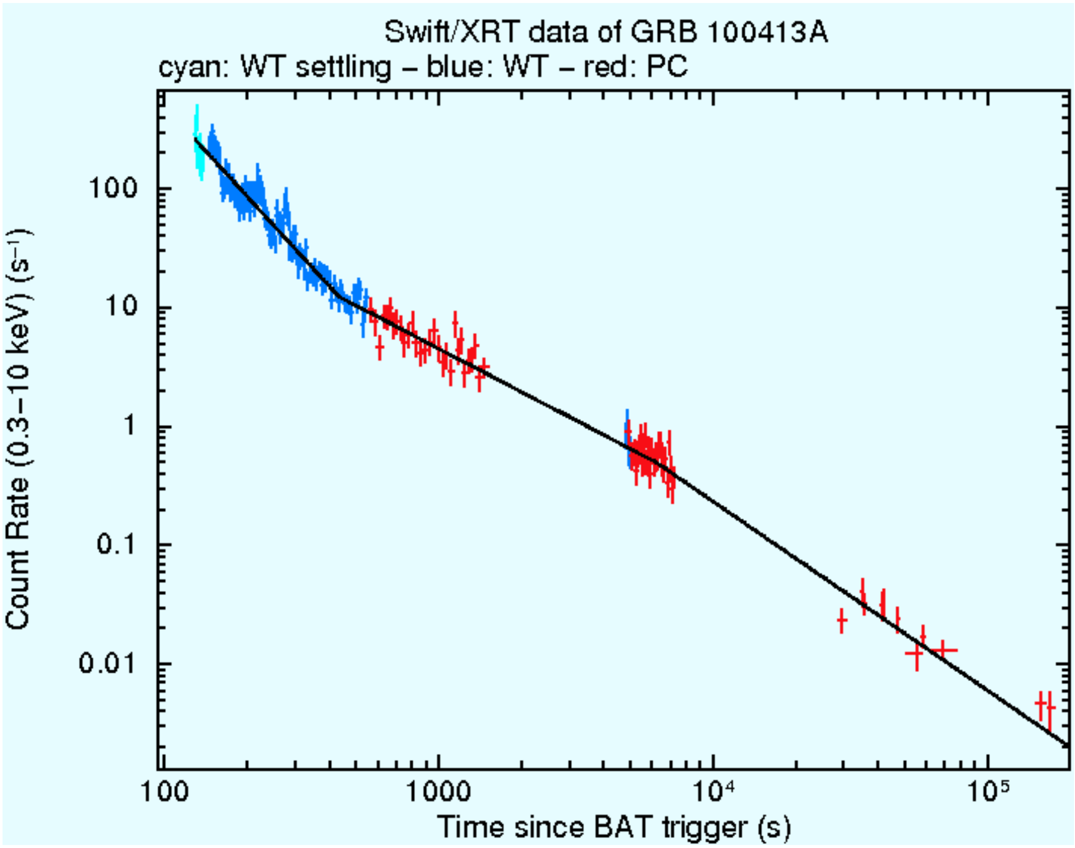

Figure 2: XRT flux light curves in counts s^{-1} in the 0.3–10 keV band: Window Timing (settling) mode (cyan), Window Timing mode (blue), and Photon Counting mode (red). The conversion factor to observed (unabsorbed) flux is 4.5×10^{-11} (7.4×10^{-11}) erg cm^{-2} $count^{-1}$.

Fitting an absorbed cutoff power-law model to the WT data between $T + 146$ s and $T + 550$ s yields a tentative redshift of $z = 3.9^{+1.7}_{-0.7}$ and a column density of $N_H(z) = 5.5^{+9.8}_{-2.1} \times 10^{22}$ cm^{-2}.

4 UVOT Observation and Analysis

The *Swift*/UVOT began settled observations of the field of GRB 100413A at $T + 150$ s. No optical afterglow consistent with the UVOT-enhanced XRT position (Goad et al. 2008) is detected in the initial UVOT exposures. Preliminary 3-σ upper limits using the UVOT photometric system (Poole et al. 2008) for the first finding chart (FC) exposures and subsequent exposures are given in Table 1.

The values quoted above are not corrected for the Galactic extinction due to the reddening of $E_{B\text{–}V} = 0.11$ mag in the direction of the burst (Schlegel et al. 1998).

Filter	$T_{\rm start}$	$T_{\rm stop}$	Exp(s)	Mag	
white$_{\rm FC}$	150	300	147	> 20.5	3-σ UL
$u_{\rm FC}$	308	558	246	> 20.5	3-σ UL
white	150	6231	589	> 21.8	3-σ UL
v	639	6641	490	> 20.4	3-σ UL
b	564	7321	353	> 20.7	3-σ UL
u	308	7256	717	> 20.7	3-σ UL
uvw1	688	7051	471	> 20.5	3-σ UL
uvm2	663	6846	490	> 20.4	3-σ UL
uvw2	614	6436	491	> 20.8	3-σ UL

Table 1: UVOT 3-σ upper limits for GRB 100413A. $T_{\rm start}$ and $T_{\rm stop}$ are the times, in seconds since the BAT trigger, of the start and stop of the observations. Exp is the total exposure time during the observation.

References

Goad, M. R., et al., 2008, A&A, 492, 873

Kalberla, P. M. W., et al., 2005, A&A, 440, 775

Poole, T. S., et al., 2008, MNRAS, 383, 627

Schlegel, D. J., et al., 1998, ApJS, 500, 525