Swift Observation of the possibly short GRB 100816A

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1 Introduction

BAT detected GRB 100816A at 19:12:41 UT on the 16^{th} August 2010 (Oates, *et al.*, *GCN Circ.* 11102). Current analysis indicates that this GRB is consistent with being either a short GRB, a short GRB with extended emission or a long GRB. Classification of this GRB is uncertain since the $T_{90}(15-350$ keV$) = 2.9 \pm 0.6$ s (estimated error including systematics) (Markwardt, *et al.*, *GCN Circ.* 11111) and the spectral lag analysis is inconclusive (Norris, *et al.*, *GCN Circ.* 11113).

Swift BAT slewed immediately to this burst and XRT observations and UVOT settled observations began ~ 83 s and 91 s respectively, after the BAT trigger (Target ID 431764). A source was detected by both the XRT and the UVOT (Oates, *et al.*, *GCN Circ.* 11102). Our best position is the UVOT location RA($J2000$) = 351.73983 *deg* ($23h$ $26m$ $57.56s$), Dec($J2000$) = 26.5785 *deg* ($26d$ $34'$ $42.6''$) with an error of 0.5 arcsec (radius, 90% containment). Observations were also performed by ROTSE-III (Pandy, *GCN Circ.* 11103), TNG (Antonelli, *et al.*, *GCN Circ.* 11104), MASTER (Gorbovskoy, *et al.*, *GCN Circ.* 11105), TAROT (Klotz, *et al.*, *GCN Circ.* 11106), CQUEAN (Im, *et al.*, *GCN Circ.* 11108), Gemini-N (Tanvir, *et al.*, *GCN Circ.* 11109), CAHA (Terron, *et al.*, *GCN Circ.* 11112), Lulin (Urata, *et al.*, *GCN Circ.* 11117), NOT (Malesani , *et al.*, *GCN Circ.* 11120), VLT (Tanvir, *et al.*, *GCN Circ.* 11123), Fermi (Fitzpatrick, *et al.*, *GCN Circ.* 11124), GTC (Gorosabel, *et al.*, *GCN Circ.* 11125), MITSuME (Kuroda, *et al.*, *GCN Circ.* 11126) and Konus-Wind (Golenetskii, *et al.*, *GCN Circ.* 11127).

A redshift of $z = 0.8035$ is provided from Gemini-N afterglow spectroscopy (Tanvir, *et al.*, *GCN Circ.* 11127) and was confirmed by GTC ($z = 0.8049$, Gorosabel, *et al.*, *GCN Circ.* 11125).

2 BAT Observation and Analysis

Using the data set from T-119 to T+263 s we report on the BAT refined analysis of BAT GRB 100816A (trigger 431764) (Oates, *et al.*, *GCN Circ.* 11102). The BAT ground-calculated position is RA, Dec = 351.738, 26.568 deg, which is:

RA(J2000) = $23h$ $26m$ $57.1s$
Dec(J2000) = $+26d$ $34'$ 04.4"

with an uncertainty of 1.0 arcmin, (radius, sys+stat, 90% containment). The partial coding was 33%.

The mask-weighted light curve, see Fig. 1, shows a single symmetric peak. There is low-level ongoing emission out to about T+100 s. The $T_{90}(15-350$ keV) is 2.9 ± 0.6 s (estimated error including systematics).

The time-averaged spectrum from T-0.7 to T+4.5 s is best fit by a power law with an exponential cutoff. This fit gives a photon index 0.73 ± 0.24, and E_{peak} of 170.7 ± 79.7 keV (χ^2 50.79 for 56 d.o.f.). For this model the total fluence in the 15-150 keV band is $2.0 \pm 0.1 \times 10^{-6}$ erg cm^{-2} and the 1 s peak flux measured from T+0.10 s in the 15-150 keV band is 10.9 ± 0.4 ph cm^{-2} sec^{-1}. A fit to a simple power law gives a photon index of 1.16 ± 0.06 (χ^2 61.72 for 57 d.o.f.). All the quoted errors are at the 90% confidence level.

The results of the batgrbproduct analysis are available at:
`http://gcn.gsfc.nasa.gov/notices_s/431764/BA/`

3 XRT Observations and Analysis

The XRT began observations of GRB 100816A 88 s after the BAT trigger (Oates, *et al.*, *GCN Circ.* 11102). The XRT found a bright, uncatalogued X-ray source located at RA, Dec = 351.74001, 26.57858 deg which is equivalent to:

RA (J2000): $23h\ 26m\ 57.60s$
Dec (J2000): $+26d\ 34'\ 42.9$"

with an uncertainty of 1.6 arcsec (radius, 90% confidence).

We have analyzed 4.4 ks of XRT data for GRB 100816A from 89 s to 12.2 ks after the BAT trigger. The data comprise 144 s in Windowed Timing (WT) mode with the remainder in Photon Counting (PC) mode.

The light curve can be modeled with a broken power-law decay with an initial decay index of $\alpha_1 = 1.57 \pm 0.10$, a break at $t = 795^{+485}_{-288}$ s, which is followed by a decay with an index $\alpha_2 = 1.01 \pm 0.06$. There is also some flaring activity during the first decay segment.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of $2.18^{+0.19}_{-0.18}$. The best-fitting absorption column is $3.1^{+1.3}_{-1.2} \times 10^{21}$ cm^{-2}, in excess of the Galactic value of 4.5×10^{20} cm^{-2} (Kalberla, *et al.*, 2005). The PC mode spectrum has a photon index of $2.03^{+0.12}_{-0.16}$ and a best-fitting absorption column of $3.0 \pm 1.1 \times 10^{21}$ cm^{-2}. The counts to observed (unabsorbed) 0.3-10 keV flux conversion factor deduced from this spectrum is $3.8 \times 10^{-11}(5.2 \times 10^{-11})$ erg cm^{-2} count^{-1}.

The results of the XRT-team automatic analysis are available at:
`http://www.swift.ac.uk/xrt_products/00431764`

4 UVOT Observation and Analysis

The Swift/UVOT began observing the field of GRB 100816A 91 s after the BAT trigger (Oates, *et al.*, *GCN Circ.* 11102). We detected the optical afterglow significantly in the white and u filters and marginally in the v, b and uvw1 filters. The best UVOT position is RA(J2000) = 351.73983 deg, Dec(J2000) = 26.5785 deg, which is equivalent to:

RA (J2000): $23h\ 26m\ 57.56s$,
Dec (J2000):$+26d\ 34'\ 42.6''$

with an error of 0.5 arcsec (radius, 90% containment) and this position is consistent with the XRT enhanced position (Evans,*et al.*, *GCN Circ.* 11110).

The results of the UVOT-team automatic analysis are available at:
`http://gcn.gsfc.nasa.gov/swift_gnd_ana.html`

The 3-sigma upper limits for the finding chart exposures (FC) and summed images provided in Table 1 and the UVOT white filter light curve is provided in Fig. 3.

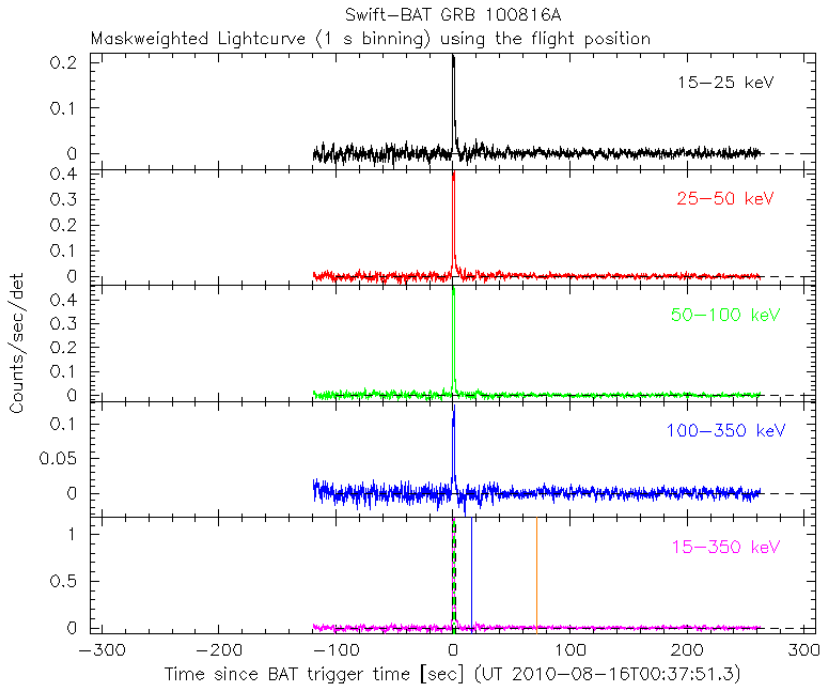

Figure 1: BAT light curve. The mask-weighted light curve in the 4 individual plus total energy bands: 15 - 25 keV (black), 25 - 50 keV (red), 50 - 100 keV (green), 100 - 350 keV (blue), 15 - 350 keV (magenta)

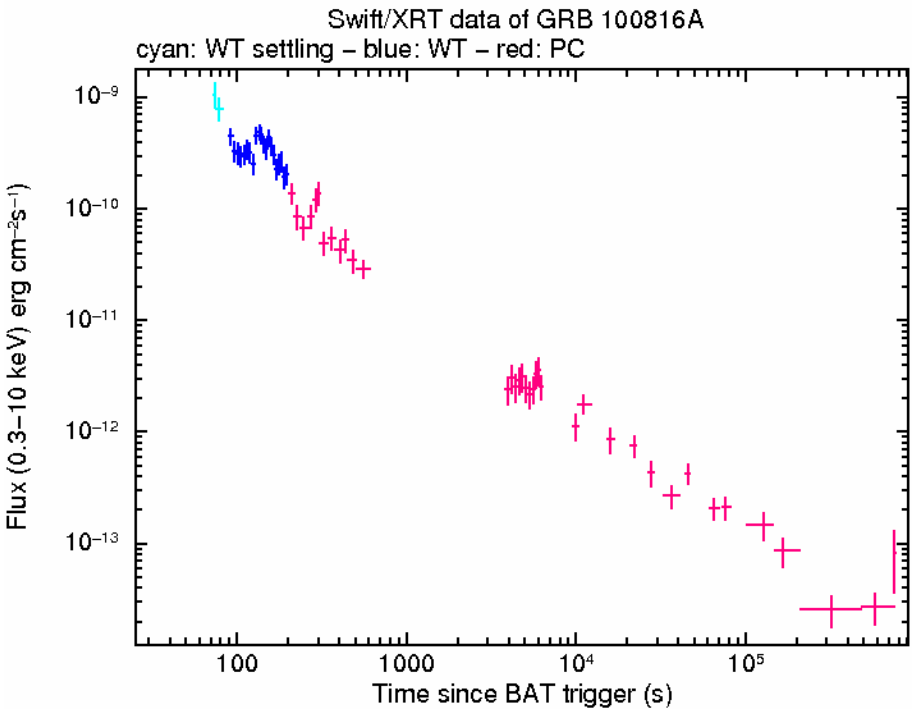

Figure 2: XRT light curve in the 0.3-10 keV band. The counts-to-observed-flux conversion factor is 1 count $= 3.8 \times 10^{-11}$ erg cm^{-2}.

Filter	Start (s)	Stop (s)	Exposure (s)	Magnitude/3σ UL
white (FC)	91	241	147	17.01 +/- 0.05
white	586	606	19	18.90 +/- 0.19
v	3991	5626	393	21.56 +/- 0.94
b	4811	6393	341	21.07 +/- 0.35
u (FC)	305	555	246	18.02 +/- 0.08
u	4606	4806	197	20.39 +/- 0.35
uvw1	4401	6036	393	20.98 +/- 0.44
uvm2	4196	34516	1279	>21.42
uvw2	3787	28671	2475	>22.19

Table 1: Magnitude limit from UVOT observations. The values quoted above are not corrected for the expected Galactic extinction corresponding to a reddening of E(B-V) = 0.09 mag in the direction of the burst (Schlegel, Finkbeiner & Davis, 1998).

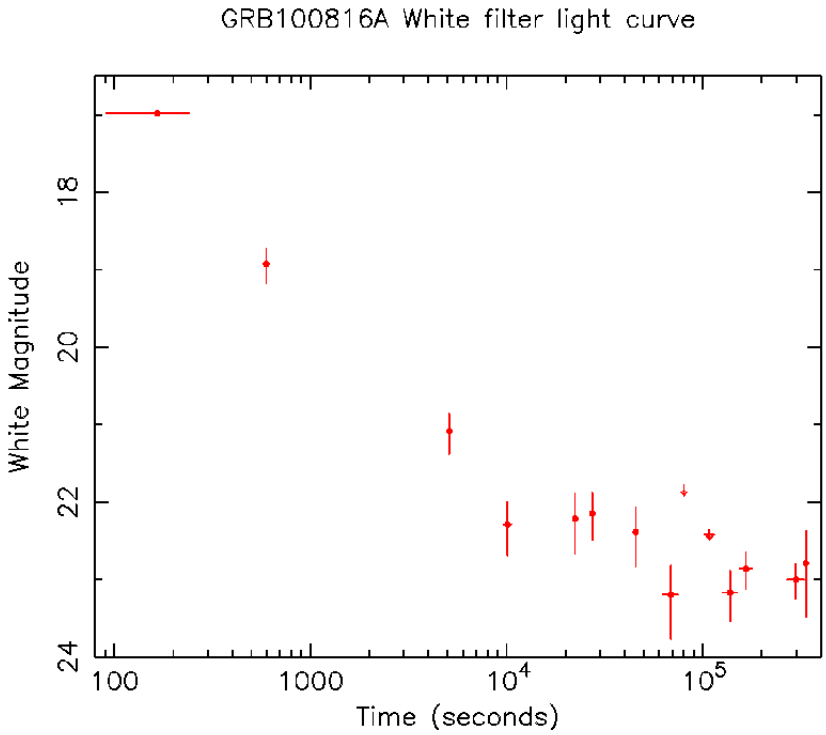

Figure 3: UVOT white filter light curve. Arrows are 3σ upper limits.