

Swift Observation of GRB 080916a

H. Ziaepour (UCL/MSSL), S.R. Oates (UCL/MSSL), T. Sakamoto (GSFC/UMBC), W. Baumgartner (GSFC/UMBC), R.L.C. Starling (U Leicester), S. T. Holland (CRESST/USRA/GSFC) for the Swift Team

0 Revisions

The UVOT light curve is added. Version 3: The name of the telescope used by Fugazza et al. for the follow-up is corrected.

1 Introduction

BAT triggered on GRB 080916a at 09:45:20.61 UT (Trigger 324895) (Ziaepour, et al., *GCN Circ.* 8237). This was a 1.024 sec rate-trigger with significance of 59.92 sigma on a mildly bright burst with two overlapping peaks and $T_{90} = 60$ sec in 15 – 350 keV band. Swift slewed to this burst immediately. The XRT began its observations at $T + 70$ sec, and UVOT started its finding chart exposure at $T + 78$ sec. They both found a varying afterglow (Starling & Ziaepour, *GCN Circ.* 8244, Oates & Ziaepour, *GCN Circ.* 8249). The optical counterpart was also mildly bright. It had a flare coincident with an X-ray flare observed by the XRT. The UVOT position of this source is: RA ($J2000$) = 336.27583 deg (22h25m06.20s), Dec($J2000$) = -57.02303 deg (-57d01'22.9").

This burst has been also observed by Integral/SPI-ACS (Volker Beckmann), by Konus-Wind (Golenetskii, et al., *GCN Circ.* 8259), by Fermi (Bissaldi, et al., *GCN Circ.* 8263), and by Suzaku (Suzuki, et al., *GCN Circ.* 8284). The optical/IR afterglow was also detected by the REM (Fugazza, et al., *GCN Circ.* 8238, Antonelli, et al., *GCN Circ.* 8239), by PROMPT (Holmes, et al., *GCN Circ.* 8264), and by GROND (Rossi, et al., *GCN Circ.* 8266). A spectroscopic observation by the VLT (Fynbo, et al., *GCN Circ.* 8254) measured the redshift of the burst $z = 0.689$ leading to an $E_{iso} = 7 \times 10^{51}$ erg.

2 BAT Observation and Analysis

Using the data from $T - 240$ to $T + 962$ sec, further analysis of BAT GRB 080916a has been performed by Swift team (Baumgartner, et al., *GCN Circ.* 8243). The BAT ground-calculated position is RA($J2000$) = 336.289 deg (22h25m09.3s), Dec($J2000$) = -57.026 deg (-57d01'33.7") ± 1.0 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 82% (the offset angle was 10.56 deg).

The mask-weighted 1-sec binned light curves (Fig.1) show two overlapping FRED peaks starting at about $\sim T - 3$ sec, peaking at $\sim T + 2$ sec and at ~ 17 sec, and ending at $\sim T + 100$ sec. T_{90} in (15 – 350 keV) is 60 ± 7 sec (estimated error including systematics).

The time-averaged spectrum from $T - 2.4$ to $T + 88.6$ sec is best fit by a power law with an exponential cutoff. This gives a photon index of 1.17 ± 0.21 and $E_{peak} = 94.6 \pm 23.0$ keV ($\chi^2 = 48.0$ for 56 d.o.f.). For this model the total fluence in the 15 – 150 keV band is $(4 \pm 0.1) \times 10^{-6}$ ergs cm^{-2} and the 1-sec peak flux measured from $T + 1.25$ sec in the 15 – 150 keV band is 2.7 ± 0.2 ph $\text{cm}^{-2} \text{sec}^{-1}$. A fit to a simple power-law model gives a photon index of 1.63 ± 0.05 ($\chi^2 = 64.5$ for 57 d.o.f.) and total fluence in the 15 – 150 keV band $(4.19 \pm 0.1) \times 10^{-6}$ ergs cm^{-2} . All the quoted errors are at the 90% confidence level.

3 XRT Observations and Analysis

Using 3292 sec of the XRT Photon Counting (PC) mode data, from $T + 70$ sec to $T + 7440$ sec, and 4 UVOT images (Evans, et al., *GCN Circ.* 8241 and http://www.swift.ac.uk/xrt_positions/), the astrometrically corrected (enhanced) X-ray position is RA($J2000$) = 336.27621 deg (22h25m6.29s), Dec($J2000$) = -57.02300 deg ($-57d01'22.8''$) with an uncertainty of 2.0 arcsec (radius, 90% confidence). This position is within 0.74 arcsec of the UVOT position (Oates & Ziaepour, *GCN Circ.* 8249).

The 0.3–10 keV light curve (Fig.2) begins from $\sim T + 70$ sec with a shallow decay slope of $\alpha_1 = 1.3_{-0.6}^{+0.4}$, probably from a peak before the beginning of the XRT observations. It breaks at $T = 102_{-6}^{+4}$ sec to a steep decay of $\alpha_2 = 3.5 \pm 0.3$ until $T = 381 \pm 25$ sec. There may be a *bump* due to flaring between $\sim T + 250$ sec and $\sim T + 1000$ and centered at ~ 500 sec. From $T = 1270_{-220}^{+240}$ sec until the last break at $\sim T + 30$ ksec the decay is shallow again with $\alpha_3 = 0.5 \pm 0.2$. From the last break until the end of observations the slope is $\alpha_6 = 1.29 \pm 0.1$. A number of small flares are visible in the last two sections of the light curve.

The spectrum from 3.2 ksec of Photon Counting (PC) mode data can be fit with an absorbed power law with a photon index $\Gamma = 2.1 \pm 0.2$ and an intrinsic absorption $N_H = 2.6_{-0.6}^{+0.7} \times 10^{21}$ cm $^{-2}$, in excess of the Galactic value of 1.8×10^{20} cm $^{-2}$ (Kalberla et al.2005). This is consistent with the spectrum formed from the initial 170 sec of Windowed Timing (WT) mode data.

4 UVOT Observation and Analysis

The UVOT began settled observations of the field of GRB 080916a about $T + 78$ sec (Oates & Ziaepour, *GCN Circ.* 8249). A quickly fading candidate afterglow was found in the XRT error circle in all filters. The UVOT position of the optical afterglow is: RA ($J2000$) = 336.27583 deg (22h25m06.20s), Dec($J2000$) = -57.02303 deg ($-57d01'22.9''$) with a 1-sigma error radius of about 0.5 arcsec. The observed magnitudes are given in Table 1. They are not corrected for the Galactic extinction in the line of sight, corresponding to a reddening of E(B-V)= 0.798 mag (Schlegel et al., *ApJS.* **500** (1998) 525). The photometry is based on the UVOT photometric system (Poole, et al., *MNRAS* **383** (2008) 627).

Fig.3 shows the UVOT light curve in White filter. The brightening of the optical afterglow coincides with the flare in the XRT light curve between $\sim T + 250$ sec and $\sim T + 1000$ sec.

Filter	T_{start} (sec)	T_{stop} (sec)	Exposure (sec)	Mag
White (fc)	78	178	98	18.33 ± 0.06
White	872	972	98	18.47 ± 0.06
V (fc)	182	582	393	17.55 ± 0.06
V	978	1378	393	18.39 ± 0.11
B	1458	1477	19	18.90 ± 0.35
U	538	658	19	17.53 ± 0.19
UVW1	613	633	19	18.25 ± 0.39
UVM2	741	1565	39	18.42 ± 0.40
UVW2	692	864	39	18.75 ± 0.37

Table 1: Magnitude and upper limits from the UVOT observations.

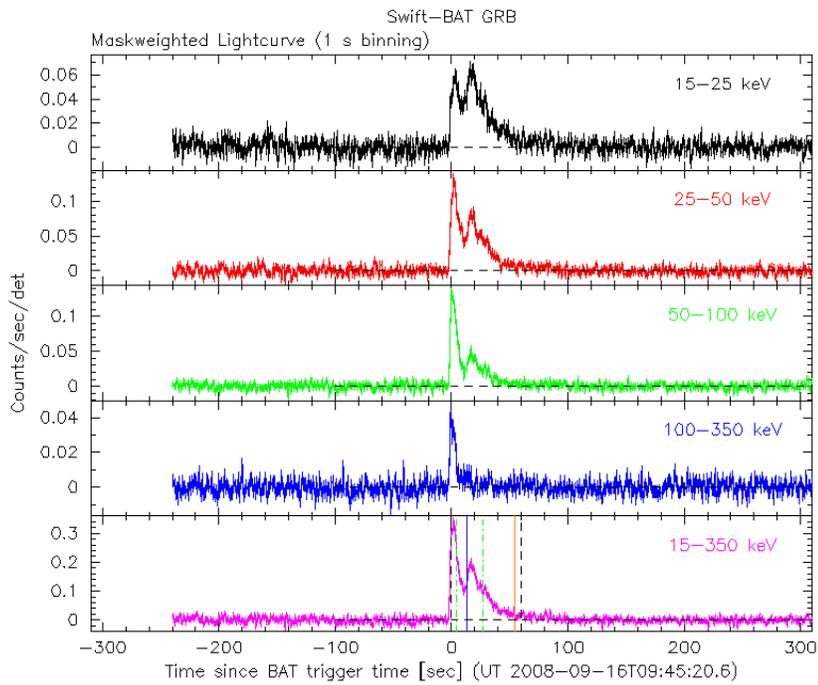


Figure 1: BAT light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector.

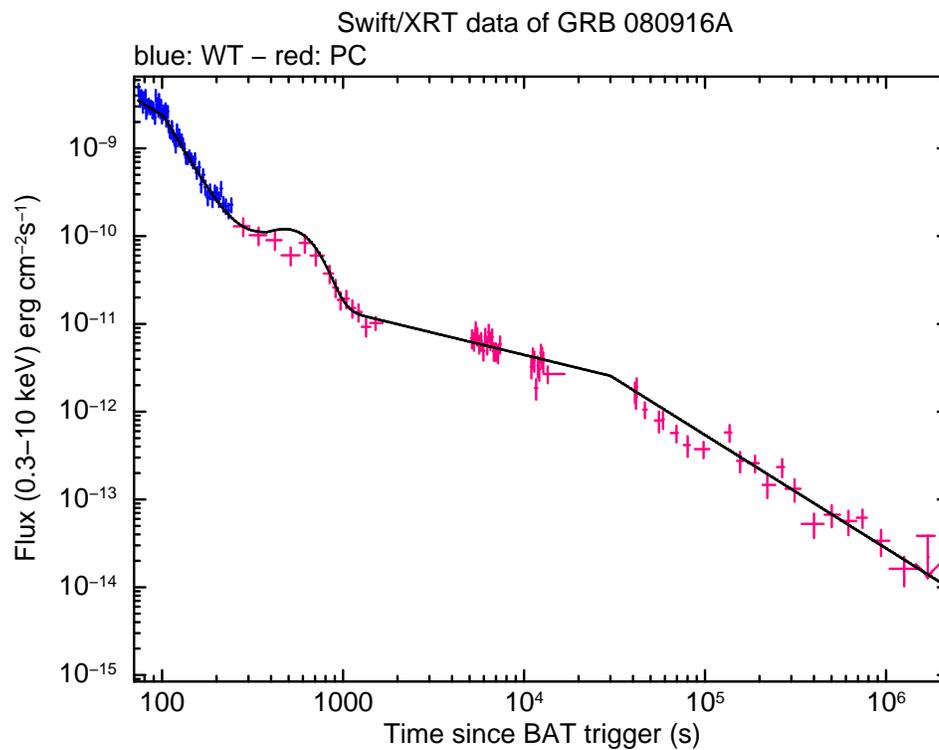


Figure 2: XRT light curve in the 0.3 – 10 keV band. The conversion factor from count rate to absorbed flux is 1 count/sec $\sim 4.0 \times 10^{-11}$ ergs cm^{-2} sec^{-1} and to unabsorbed flux 1 count/sec $\sim 6.8 \times 10^{-11}$ ergs cm^{-2} sec^{-1} .

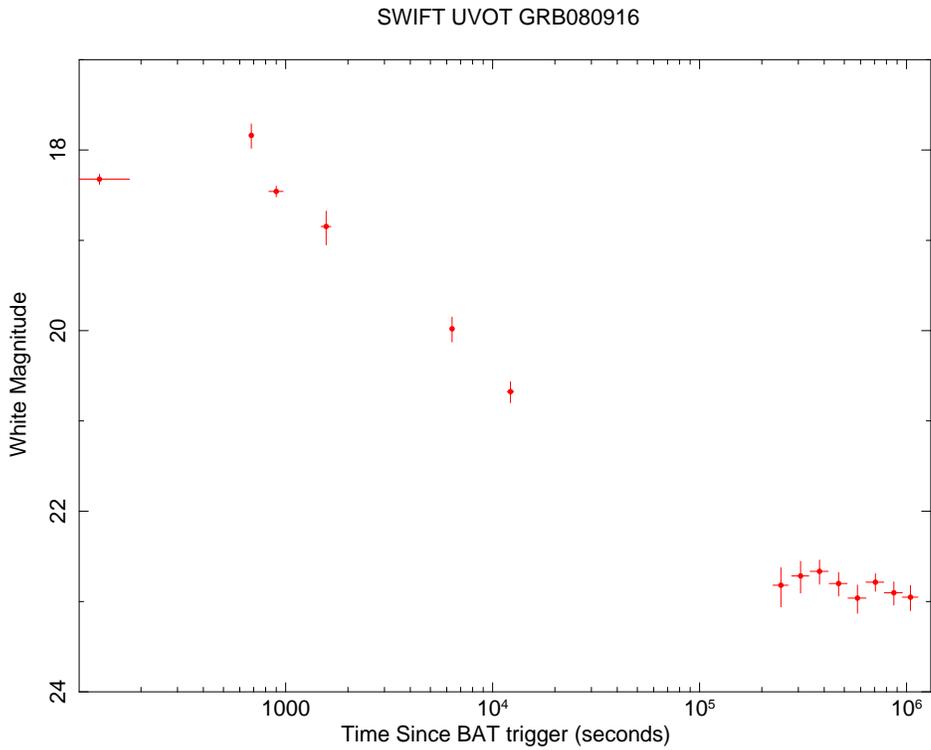


Figure 3: UVOT light curve in White filter.