

## Swift Observation of GRB 090516

*A. Rowlinson (University of Leicester), W. H. Baumgartner (GSFC/UMBC), M. H. Siegel (PSU),  
for the Swift Team*

### 1 Introduction

BAT triggered on GRB 090516 at 08:27:50 UT (Trigger 352190) (Rowlinson, *et al.*, *GCN Circ.* 9374). This was a 26.880 sec rate-trigger on a long burst with  $T_{90} = 210 \pm 65$  sec. Swift slewed to this burst immediately and XRT began follow-up observations at  $T+170$  sec, and UVOT at  $T+171$  sec. Our best position is the astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue) of  $RA(J2000) = 138.26050deg$  (09h13m2.52s),  $Dec(J2000) = -11.85442deg$  ( $-11d51'15.9''$ ) with an error of 1.5 arcsec (90% confidence).

GRB 090516 was also detected by Konus Wind (Sakamoto, *et al.*, *GCN Circ.* 9415) and Fermi GBM (McBreen, *et al.*, *GCN Circ.* 9422).

The optical afterglow was detected by several ground based telescopes. The first observations were by Faulkes Telescope South 17 minutes after the burst (Guidorzi, *et al.*, *GCN Circ.* 9375) and the Stardome Observatory at 80 minutes (Christie, *et al.*, *GCN Circ.* 9396). RIMOTS provided an upper limit for the optical afterglow at 1.8 hours (Ohmori, *et al.*, *GCN Circ.* 9391). At 12.9 hours the optical afterglow was detected by NOT (Gorosabel, *et al.*, *GCN Circ.* 9379) and, at 14.6 hours, by GROND (Rossi, *et al.*, *GCN Circ.* 9382).

A redshift of  $4.109 \pm 0.002$  was calculated using the spectrum of the afterglow detected by the VLT and also showed an intervening system at  $z=2.697 \pm 0.002$  (de Ugarte Postigo, *et al.*, *GCN Circ.* 9383).

### 2 BAT Observation and Analysis

Using the data set from  $T - 240$  to  $T + 963$  sec, further analysis of BAT GRB 090516 has been performed by Swift team (Baumgartner, *et al.*, *GCN Circ.* 9384). The BAT ground-calculated position is  $RA(J2000) = 138.246deg$  (09h12m59.1s),  $Dec(J2000) = -11.848deg$  ( $-11d50'51.4''$ )  $\pm 1.5$  arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 9%.

The mask-weighted light curve (Fig.1) shows several overlapping peaks starting at  $T - 20$  sec with the last peak at  $T + 180$  sec, and then decaying to background at  $T + 330$  sec.  $T_{90}(15 - 350keV)$  is  $210 \pm 65$  (estimated error including systematics).

The time-averaged spectrum from  $T - 15.5$  to  $T + 288.5$  sec is best fitted by a simple power law model. This fit gives a photon index of  $1.84 \pm 0.11$ . For this model the total fluence in the 15 – 150 keV band is  $(9.0 \pm 0.6) \times 10^{-6} ergs/cm^2$  and the 1-sec peak flux measured from  $T + 7.98$  sec in the 15 – 150 keV band is  $1.6 \pm 0.2 ph/cm^2/sec$ . 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/352190/BA/>

### 3 XRT Observations and Analysis

The XRT began observing the burst 170 s after the BAT trigger (Rowlinson & Evans, *GCN Circ.* 9378). Using 2534 s of XRT Photon Counting (PC) mode data and 5 UVOT images for GRB 090516, we find an astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue) of  $RA(J2000) = 138.26050deg$  (09h13m2.52s),  $Dec(J2000) = -11.85442 deg$  ( $-11d51'15.9''$ )  $\pm 1.5$  arcsec (90% confidence).

The  $0.3 - 10$  keV light curve (Fig.2) shows an initial steep decline with a slope of  $3.28 \pm 0.07$ , following by a shallow slope of  $0.87_{-0.09}^{+0.08}$ , beginning at  $T + 632_{-56}^{+65}$  sec. At  $(1.7_{-0.1}^{+0.3}) \times 10^4$  sec the light curve breaks with a slope of  $1.78_{-0.07}^{+0.10}$ .

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of  $2.09 \pm 0.04$ . The best-fitting absorption column is  $1.57_{-0.09}^{+0.10} \times 10^{21} \text{cm}^{-2}$ , in excess of the Galactic value of  $4.5 \times 10^{20} \text{cm}^{-2}$  (Kalberla et al. 2005). The PC mode spectrum has a photon index of  $2.09_{-0.12}^{+0.13}$  and a best-fitting absorption column of  $9.6_{-2.5}^{+2.6} \times 10^{20} \text{cm}^{-2}$ . The counts to observed flux conversion factor is  $1 \text{ count s}^{-1} = 3.6 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$ .

Detailed light-curves (in both count rate and flux units) and spectra are available from [http://www.swift.ac.uk/xrt\\_products/00352190/](http://www.swift.ac.uk/xrt_products/00352190/)

## 4 UVOT Observation and Analysis

The UVOT began observing the field of GRB 090516 171 sec after the initial BAT trigger (Siegel *et al.*, *GCN Circ.* 9377). Data summed from the first and second orbits does not reveal a source at the refined position of the X-ray afterglow (Beardmore *et al.*, *GCN Circ.* 9376). Upper limits are summarized in Table 1. The magnitudes are not corrected for the Galactic extinction corresponding to a reddening of  $E_{B-V} = 0.05$  (Schlegel et al., 1998, *ApJS*, 500, 525). The photometry is on the UVOT photometric system described in Poole et al. (2008, *MNRAS*, 383, 627).

Filter	Start	Stop	Exposure	3-Sigma UL
white (finding)	176	326	147	>20.85
v	4259	5895	393	>21.06
b	590	606	15	>18.74
b	5079	5278	196	>20.32
u	334	584	245	>20.12
u	4873	6390	274	>20.20
uvw1	4669	6306	393	>20.36
uvm2	4464	6101	393	>20.18
uvw2	4054	5690	393	>20.41
white	3848	5483	393	>21.06

Table 1: Magnitude limits from UVOT observations

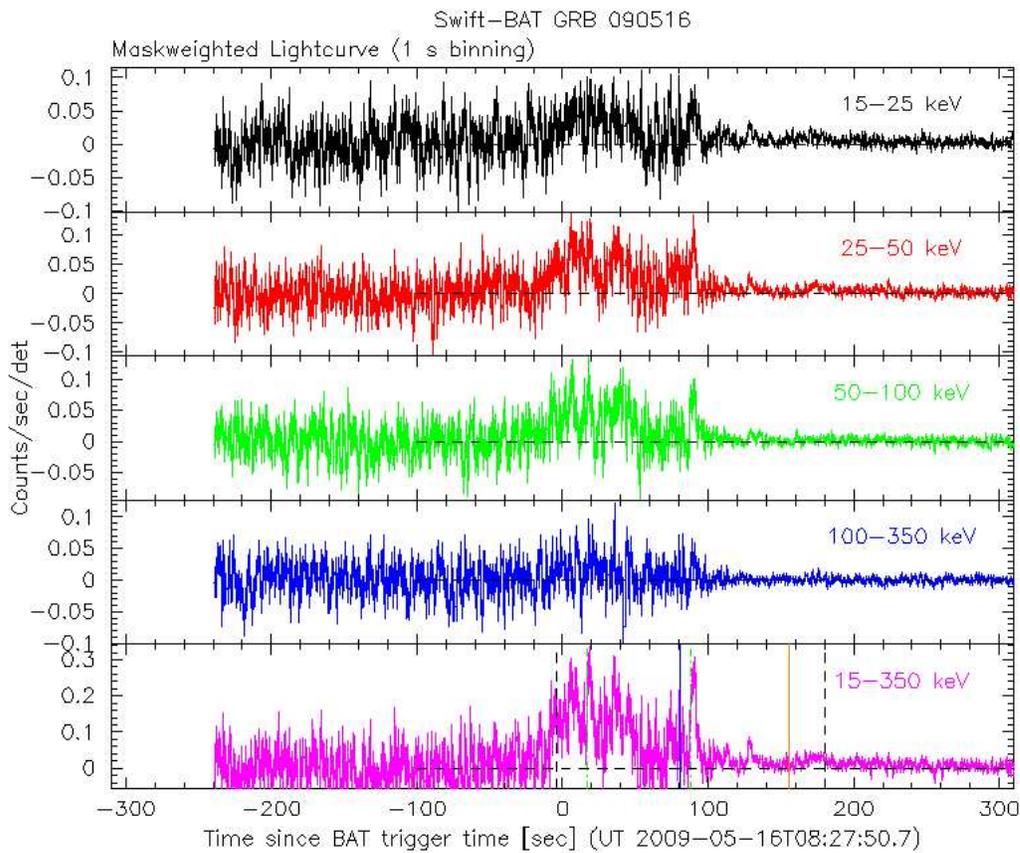


Figure 1: BAT light-curve. The mask-weighted light-curve in the 4 individual plus total energy bands. The units are counts/s/illuminated-detector (note illum-det = 0.16 cm<sup>2</sup>).

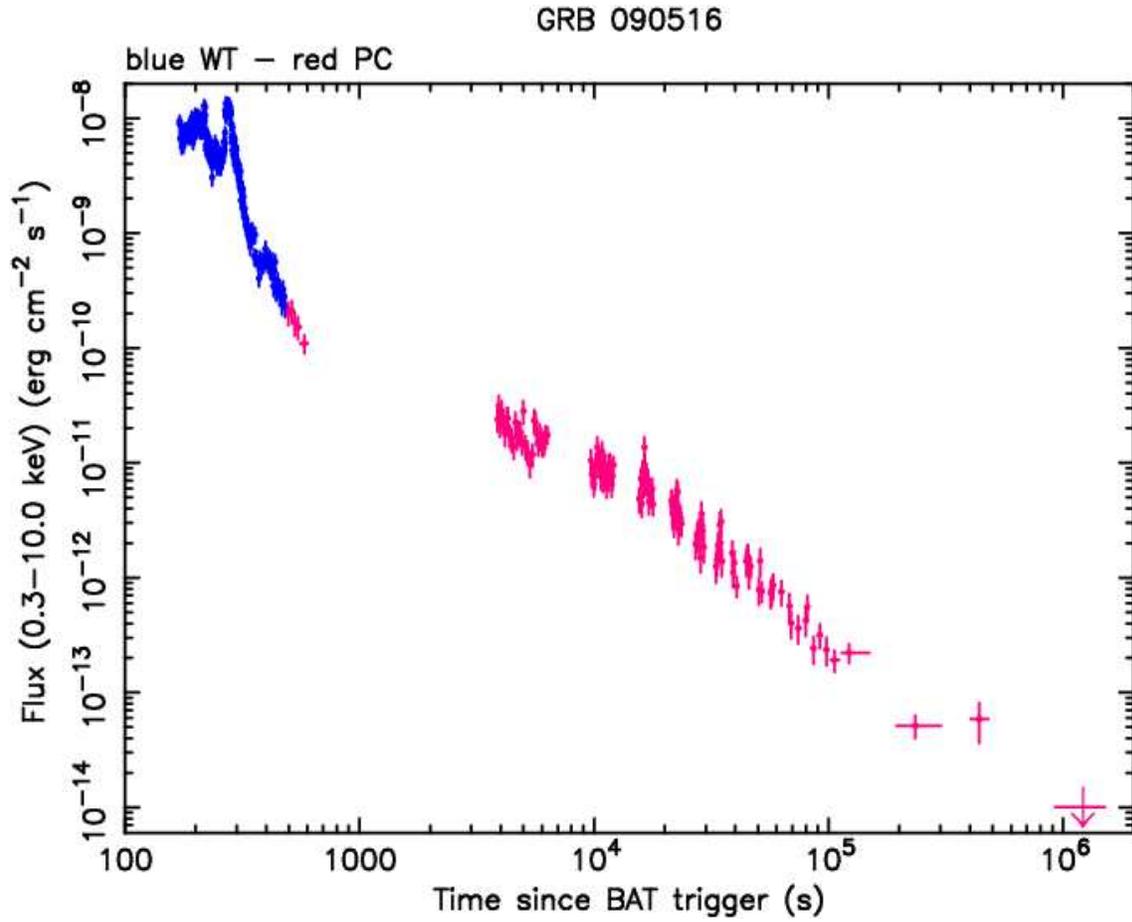


Figure 2: XRT flux light-curve; all data were collected in Photon Counting mode. The approximate counts to flux conversion is  $1 \text{ count s}^{-1} = 3.6 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$ .