Swift Observation of GRB 090407

H. Ziaeepour (UCL/MSSL), S.D. Barthelmy (GSFC), T.N. Ukwatta (GWU), A.P. Beardmore (U Leicester), S.R. Oates (UCL/MSSL) for the Swift Team

1 Introduction

BAT triggered on GRB 090407 at 10:28:25.63 UT (Trigger 348650) (Ziaeepour, et al., *GCN Circ.* 9101). This was a 2.048 sec rate-trigger with significance of 12.44 sigma on a long multi-peak burst with $T_{90} = 310 \pm 70$ sec in $15 - 350$ keV band. Swift slewed to this burst immediately. The XRT began its observations at $T + 96.7$ sec and found a bright flaring afterglow (Beardmore & Ziaeepour, *GCN Circ.* 9107). UVOT started its finding chart exposure at $T + 98$ sec. No optical source was found in the XRT error circle (Oates & Ziaeepour, *GCN Circ.* 9106). The best available position for this burst is the enhanced XRT position:RA ($J2000$) = 68.97908 deg ($04h35m54.98s$), Dec($J2000$) = -12.67929 deg ($-12d40'45.5$") (Evans, et al., *GCN Circ.* 9105).

This burst has been also observed in optical and IR by ROTSE-III (Schaefer & Yuan, *GCN Circ.* 9102), VLT (Malesani & Fynbo, *GCN Circ.* 9108), and GROND (Afonso, et al.., *GCN Circ.* 9109). No new source has been found in these observations. The deepness of these observations shows that this is a very dark burst.

2 BAT Observation and Analysis

Using the data from $T - 239$ to $T + 627$ sec, further analysis of BAT GRB 090407 has been performed by Swift team (Ukwatta, et al., *GCN Circ.* 9104). The BAT ground-calculated position is RA($J2000$) = 68.979 deg ($04h35m54.9s$), Dec($J2000$) = -12.684 deg ($-12d41'02.4$") $\pm$ 2.2 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 84% (the offset angle was 27.3 deg).

The mask-weighted 1-sec binned light curves (Fig.1) show two clusters of peaks. The first cluster starts at $\sim T - 15$ sec, peaks at $\sim T + 2$ sec, and returns to baseline at $\sim T + 10$ sec. The second cluster starts at $\sim T + 130$ sec, peaks at $\sim T + 140$ sec, and returns to baseline at $\sim T + 340$ sec. T_{90} in ($15 - 350$ keV) is 310 ± 70 sec (estimated error including systematics).

The time-averaged spectrum from $T - 17.7$ to $T + 368.6$ sec is best fit by a simple power law with a photon index of 1.73 ± 0.29 ($\chi^2 = 53.26$ for 57 d.o.f.). For this model the total fluence in the $15 - 150$ keV band is $(1.0 \pm 0.2) \times 10^{-6}$ ergs cm^{-2}and the 1-sec peak flux measured from $T + 0.45$ sec in the $15 - 150$ keV band is 0.6 ± 0.1 ph cm^{-2} sec^{-1}. All the quoted errors are at 90% confidence level.

3 XRT Observations and Analysis

Using 8297 sec Photon Counting (PC) mode data and 13 UVOT images (Evans, et al., *GCN Circ.* 9105 and *http* : *//www.swift.ac.uk/xrt_positions/*), the astrometrically corrected (enhanced) X-ray position is RA($J2000$) = 68.97908 deg ($04h35m54.98s$), Dec($J2000$) = -12.67929 deg ($-12d40'45.5$") with an uncertainty of 1.4 arcsec (radius, 90% confidence). The $0.3 - 10$ keV light curve of this burst including all the XRT observations is shown in Fig.2. It shows a number of flares in the first 400 sec of observations, the largest occurring from $\sim T + 120$ sec to $\sim T + 180$ sec, reaching a peak rate of 90 count sec^{-1} at $\sim T + 140$ sec. This flare is also seen by the Swift-BAT (Ukwatta, et al., *GCN Circ.* 9104). Further flaring is seen from $\sim T + 200$ sec to $\sim T + 350$ sec, ending with a steep decay. After

$\sim T + 1027$ sec the X-ray light curve becomes much flatter until $\sim T + 7$ ksec when it breaks to a steeper slope and then at $\sim T + 120$ ksec it breaks again (Beardmore & Ziaeepour, *GCN Circ.* 9107).

The PC model observations after the end of flaring epoch can be approximately modelled with multiple broken power-laws: From $\sim T + 400$ sec until $\sim T + 1027$ sec the decay slope is $\alpha_1 = 3.9$. Then a shallow regime begins with a slope of $\alpha_2 = 0.01 \pm 0.15$. It breaks at $\sim T + 7 \pm 2.9$ ksec to a steeper slope of $\alpha_3 = 0.63 \pm 0.06$ until $\sim T + 120$sec when another break and steepening happens. The slope at this epoch until the end of the XRT observations is $\alpha_4 = 1.93 \pm 0.24$.

The data show spectral evolution during the flaring intervals, after which the PC mode spectrum can be modelled by an absorbed power-law with a photon index of 2.43 ± 0.13 and a total absorbing column density $N_H = 2.51 \pm 0.35 \times 10^{21}$ cm^{-2}, which is in excess of the Galactic value of 3.7×10^{20} cm^{-2} (Kalberla et al.2005) in the direction of the burst. The observed $0.3 - 10$ keV flux at this time $\sim T + 6.2$ ksec is $6.29^{+0.41}_{-0.56} \times 10{-}12$ ergs cm^{-2} sec^{-1}, which corresponds to an unabsorbed flux of 1.3×10^{-11} ergs cm^{-2} sec^{-1}. The counts to observed $0.3 - 10$ keV flux conversion factor deduced from this spectrum is 3.5×10^{-11} ergs cm^{-2} count^{-1}.

4 UVOT Observation and Analysis

The UVOT began settled observations of the field of GRB 090407 about $T+98$ sec (Oates & Ziaeepour, *GCN Circ.* 9106). No optical afterglow is detected in the initial UVOT exposures at the refined position of the X-ray afterglow (Evans, et al., *GCN Circ.* 9105). The 3 sigma upper limits for the finding chart (fc) and summed exposures 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)= 0.02 mag (Schlegel et al., *ApJS.* **500** (1998) 525). The photometry is based on the UVOT photometric system (Poole, et al., *MNRAS* **383** (2008) 627).

Filter	T_{start} (sec)	T_{stop} (sec)	Exposure (sec)	Mag.Lim.
White fc	98	248	147	< 20.50
U fc	310	559	246	< 19.89
White	590	2050	303	< 21.04
V	640	5550	352	< 19.25
U	713	2001	136	< 19.61
B	565	2026	156	< 19.99
UVW1	689	1977	136	< 19.35
UVM2	664	5607	207	< 19.49
UVW2	615	2071	170	< 19.74

Table 1: Magnitude upper limits from the UVOT observations.

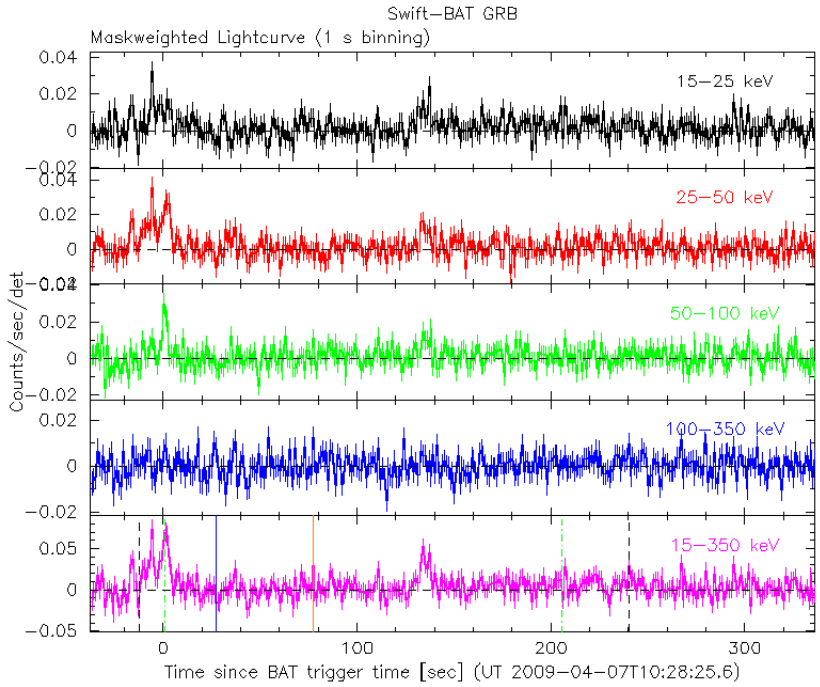

Figure 1: BAT light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector.

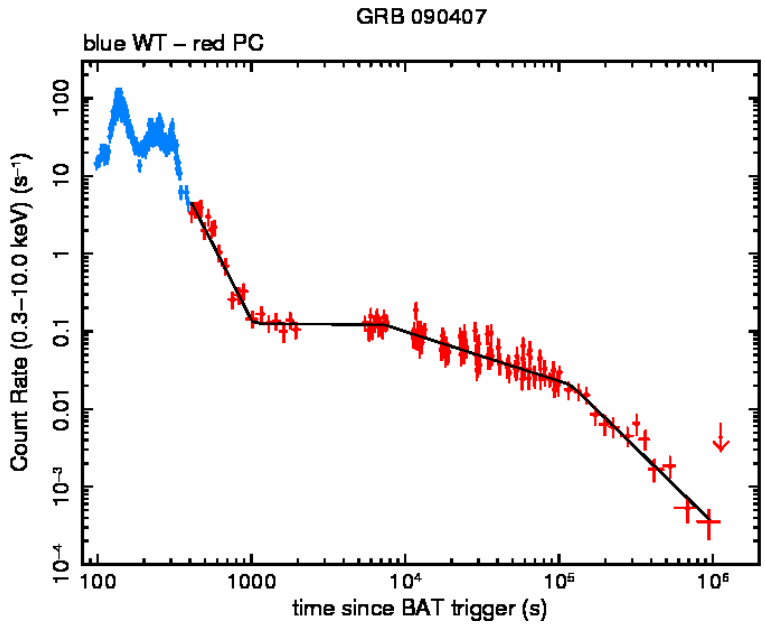

Figure 2: XRT light curve in the $0.3-10$ keV band. The conversion factor from count rate to absorbed flux is 1 count/sec $\sim 3.5 \times 10^{-11}$ ergs cm^{-2} sec^{-1}.