Swift Observation of GRB 090404

H. Ziaeepour (UCL/MSSL), D.M. Palmer (LANL), J. Tueller (GSFC), K. L. Page (U Leicester), S.R. Oates (UCL/MSSL) for the Swift Team

1 Introduction

BAT triggered on GRB 090404 at 15:56:30.44 UT (Trigger 348428) (Ziaeepour, et al., *GCN Circ.* 9086). This was a 2.048 sec rate-trigger with significance of 16.34 sigma on a long multi-peak and relatively soft burst with $T_{90} = 84 \pm 14$ sec in $15-350$ keV band. Swift slewed to this burst immediately. The XRT began its observations at $T + 87.3$ sec and found a very bright varying afterglow (Page & Ziaeepour, *GCN Circ.* 9091). UVOT started its finding chart exposure at $T + 96$ sec. No optical source was found in the XRT error circle (Oates & Ziaeepour, *GCN Circ.* 9094). The best available position for this burst is the enhanced XRT position:RA ($J2000$) = 239.239875 deg ($15h56d57.57s$), Dec($J2000$) = 35.516139 deg ($+35d30'58.1$").

This burst has been also observed in optical and IR by TNT (Xin et al., *GCN Circ.* 9090, BOOTES-3 (Yock, et al., *GCN Circ.* 9092), NOT (Malesani, et al., *GCN Circ.* 9093, *GCN Circ.* 9095), GROND (Afonso, et al., *GCN Circ.* 9096), and Calar Alto (Jelinek, et al., *GCN Circ.* 9099). No new source has been found in these observations. Nonetheless, the observations by Plateau de Bure Interferometer (Castro-Tirado, et al., *GCN Circ.* 9100) detected a new source inside the XRT position circle in 108 GHz at $\sim T + 30$ hr that makes this burst one of the few GRBs detected in this frequency band.

2 BAT Observation and Analysis

Using the data from $T - 239$ to $T + 963$ sec, further analysis of BAT GRB 090404 has been performed by Swift team (Tueller, et al., *GCN Circ.* 9089). The BAT ground-calculated position is RA($J2000$) = 239.233 deg ($15h56m55.8s$), Dec($J2000$) = 35.518 deg ($+35d31'03.4$")$\pm$1.0 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 89% (the offset angle was 19.7 deg).

The mask-weighted 1-sec binned light curves (Fig.1) show at least 7 overlapping peaks starting at about $\sim T - 50$ sec with highest overlapped double peak from $\sim T + 17$ sec to $\sim T + 35$ sec. T_{90} in $(15 - 350$ keV) is 84 ± 14 sec (estimated error including systematics).

The time-averaged spectrum from $T - 35.2$ to $T + 94.6$ sec is best fit by a simple power law with a photon index of 2.32 ± 0.08 ($\chi^2 = 61.18261$ for 57 d.o.f.). For this model the total fluence in the $15 - 150$ keV band is $(3.0 \pm 0.1) \times 10^{-6}$ergs cm^{-2}and the 1-sec peak flux measured from $T + 17.32$ sec in the $15 - 150$ keV band is 1.9 ± 0.2 ph cm^{-2} sec^{-1}. All the quoted errors are at 90% confidence level.

3 XRT Observations and Analysis

Using 989 sec Photon Counting (PC) mode data and 2 UVOT images (Beardmore, et al., *GCN Circ.* 9088 and *http://www.swift.ac.uk/xrt_positions/*), the astrometrically corrected (enhanced) X-ray position is RA($J2000$) = 239.23986 deg ($15h56m57.57s$), Dec($J2000$) = +35.51615 deg ($+35d30'58.1$") with an uncertainty of 1.8 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 begins at $\sim T + 87$ with a large count rate of ~ 1200 count/sec^{-1} that decays quickly and becomes shallow at $\sim T + 500$ sec. A faint flare is visible between $\sim T + 300$ and $T + 600$ before the shallow regime begins.

The light-curve can be approximately modelled with 3 broken power-laws: It begins with $\alpha_1 = 3.2 \pm 0.3$

until $\sim T + 119$ sec at which point the decay steepened to a slope of $\alpha_2 = 9.2 \pm 0.3$. After $\sim T + 275$ sec the decay is much more gradual with $\alpha_3 = 0.10 \pm 0.06$. This shallow regime breaks to a steeper slope of $\alpha_4 = 1.26 \pm 0.05$ at ~ 15 ksec until the end of XRT observations. The data show significant softening until at least $T + 150$ sec (Page & Ziaeepour, *GCN Circ.* 9091). A spectrum extracted from the first orbit of PC data can be fitted with a power-law of $\Gamma = 3.0 \pm 0.5$ and a total absorbing column $N_H = 5.1 \times 10^{21}$ cm^{-2} which is in excess of the Galactic value of 2.0×10^{20} cm^{-2} (Kalberla et al.2005). The counts to observed (unabsorbed) $0.3 - 10$ keV flux conversion factor deduced from this spectrum is $3.1 \times 10^{-11}(1.4 \times 10^{-10})$ ergs cm^{-2} count^{-1}.

4 UVOT Observation and Analysis

The UVOT began settled observations of the field of GRB 090404 about $T+96$ sec (Oates & Ziaeepour, *GCN Circ.* 9094). No optical afterglow is detected in the initial UVOT exposures at the refined position of the X-ray afterglow (Beardmore et al., *GCN Circ.* 9088). 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	96	246	147	< 20.92
White	591	1189	206	< 20.82
White	5121	18611	1084	< 21.80
U fc	310	559	246	< 20.17
U	715	1140	39	< 18.60
U	4710	35856	3049	< 21.56
V	641	1239	78	< 18.58
V	5531	11198	1150	< 20.37
B	565	1164	58	< 19.35
B	4915	35968	2078	< 21.50
UVW1	691	1116	39	< 18.45
UVW1	4504	45467	3237	< 21.47
UVM2	665	1091	58	< 18.54
UVM2	5736	41754	2695	< 21.42
UVW2	616	1214	78	< 19.09
UVW2	5326	6965	393	< 20.28

Table 1: Magnitude upper limits from the UVOT observations.

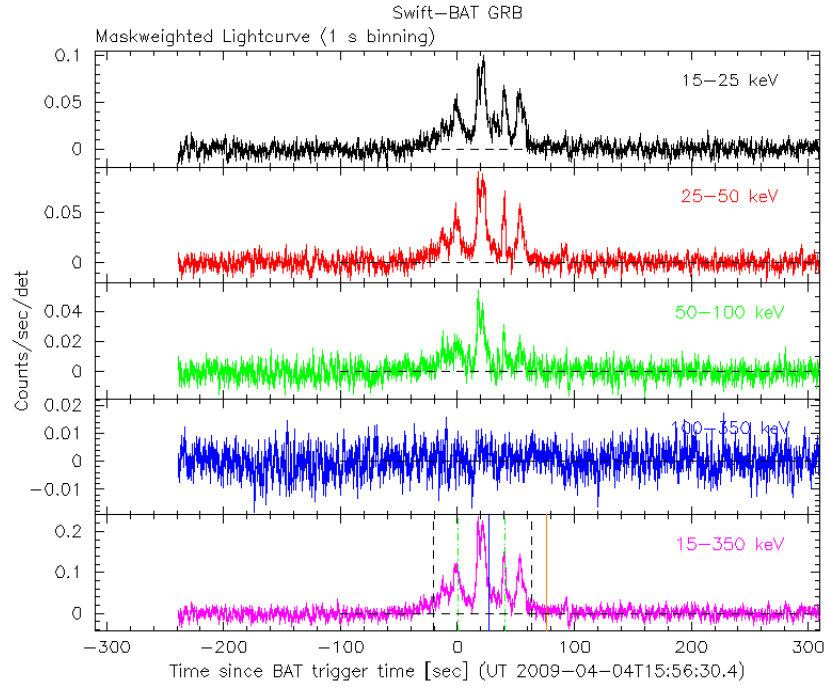

Figure 1: BAT light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector.

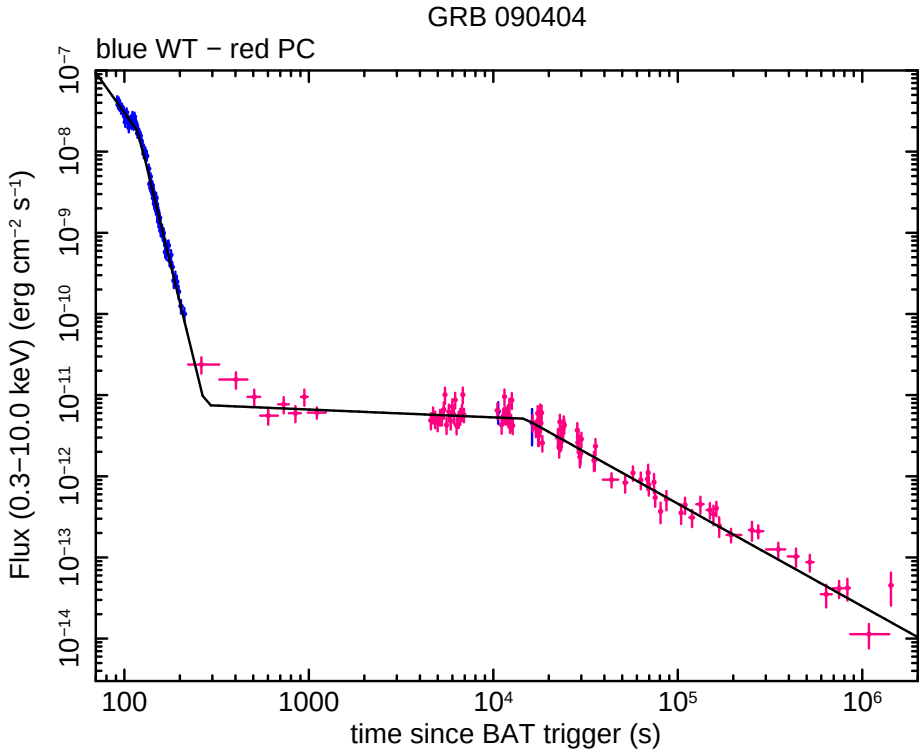

Figure 2: XRT light curve in the $0.3 - 10$ keV band. The conversion factor from count rate to absorbed flux is 1 count/sec $\sim 3.1 \times 10^{-11}$ ergs cm^{-2} sec^{-1}and to unabsorbed flux 1 count/sec $\sim 1.4 \times 10^{-10}$ ergs cm^{-2} sec^{-1}.