

## Swift Observation of GRB 070330

*D. Grupe (PSU), C. Markwardt (U.Md. & NASA/GSFC), Hans Krimm (GSFC), S. D. Barthelmy (GSFC), Paul Kuin (UCL-MSSL), Patricia Schady (UCL-MSSL), Peter Brown (PSU), M. Chester (PSU), Jamie Kennea (PSU), D.N. Burrows (PSU), P. Roming (PSU), and N. Gehrels (GSFC) for the Swift Team*

### 0 Revisions

This is the final report on GRB 070330. This report has an undated of the XRT light curve and a new analysis of the Windowed Timing and Photon Counting mode light curves. Due to its relatively low sun angle at the time of the observations and that the afterglow had become relatively faint, it was decided to drop this burst after 2007 April 03. This report also has a summary about ground-based observations of this burst.

### 1 Introduction

BAT triggered on GRB 070330 at 22:51:31 UT (Trigger 273180) (Grupe, *et al.*, *GCN Circ.* 6232). This burst is a long burst with an observed  $T_{90} = 9 \pm 1$  s. Swift slewed to this burst immediately and XRT began follow-up observations at  $T + 68$  s, and UVOT at  $T + 54$  s. Our best position is the UVOT V-Filter location  $RA(J2000) = 269.5426$  deg (17h58m09.94s),  $Dec(J2000) = -63.7930$  deg ( $-63d47'36.1''$ ) with an error of  $0.5''$  as reported in Kuin *et al.* *GCN Circ.* 6238. This position is  $0.5''$  away from the preliminary UVOT position reported in the first GCN Circular (Grupe, *et al.*, *GCN Circ.* 6232).

### 2 BAT Observation and Analysis

Using the data set from  $T - 240$  s to  $T + 963$ s, further analysis of BAT GRB 07330 has been performed by the Swift team (Fenimore, *et al.*, *GCN Circ.* 6237). The BAT ground-calculated position is  $RA(J2000) = 269.5333$ deg (17h58m07.9s),  $Dec(J2000) = -63.799$  deg ( $-63d47'54.7''$ )  $\pm 1.9$  arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 80%.

The masked-weighted light curves (Fig.1) shows a single FRED-like peak.  $T_{90}(15 - 350$ keV) is  $9 \pm 1$  s (estimated error including systematics).

The time-averaged spectrum from  $T - 1.1$ s to  $T + 8.9$ s is best fitted by a power law model with exponential cutoff. This fit gives a photon spectral index of  $\Gamma = -0.33 \pm 1.76$  and  $E_{\text{peak}} = 36.3 \pm 6.1$  keV, ( $\chi^2 = 56.1$  for 56 d.o.f.). For this model the total fluence in the 15 – 150 keV band is  $(1.8 \pm 0.3) \times 10^{-7}$  ergs  $\text{cm}^{-2}$  and the 1-s peak flux measured from  $T - 0.06$ s in the 15 – 150 keV band is  $0.9 \pm 0.1$  photons  $\text{cm}^{-2} \text{s}^{-1}$ . A fit to a simple power law gives a photon index of  $\Gamma = 2.06 \pm 0.22$  ( $\chi^2 = 66.7$  for 57 d.o.f.). All the quoted errors are at the 90% confidence level.

### 3 XRT Observations and Analysis

Using the data from the first 127 ks after the burst of XRT data of GRB 070330 (34.5 ks in Photon Counting mode), the refined XRT position is  $RA(J2000) = 269.5407$  deg (17h58m09.8s),

$\text{Dec}(J2000) = -63.7934 \text{ deg } (-63d47'36.1'')$  ( $3.6''$  error circle ,90% confidence, including boresight uncertainties) as reported by Grupe *GCN Circ.* 6234. This position is within  $0.4 \text{ arcsec}$  of the initial XRT position reported by Grupe *et al.*, *GCN Circ.* 6232.

The  $0.3 - 10 \text{ keV}$  light curve (Fig.2) shows a flare with a peak at about 210s after the burst and an initial decline after the peak with a slope of  $\alpha_1 = 3.49 \pm 0.26$ , following by a shallow slope of  $\alpha_2 = 0.53 \pm 0.20$ , beginning at  $T + 1000 \pm 200\text{s}$ . After a third break at about 20ks after the burst the decay steepens again with a decay slope  $\alpha_3 = 1.37 \pm 0.16$ .

The initial Photon Counting mode spectrum can be fitted by an absorbed single power law with an absorption column density consistent with the Galactic value ( $N_{\text{H,gal}} = 7.14 \times 10^{20}$ ; Dickey & Lockman 1990) and a photon spectral index  $\Gamma = 1.85 \pm 0.16$ . Following the relation given in Grupe *et al.* 2007 (AJ in press, astro-ph/0612104) the consistency of the absorption parameter with the Galactic absorption column density suggest a burst possibly at high redshift.

## 4 UVOT Observation and Analysis

The UVOT began observing the field of GRB 070330 54 s after the initial BAT trigger (Kuin *et al.*, *GCN Circ.* 6238). The afterglow is clearly detected in V with  $V = 18.69 \pm 0.24 \text{ mag}$  in the first exposure, but was not detected in the following V exposures or in any of the other UVOT filters. Due to a 7th mag bright star no observations were obtained in White and UVW2. The non-detection in all following V exposures suggests a decay slope  $\alpha_V > 0.8$ . The V detection and upper limits are summarized in Table 1. These magnitudes are not corrected for Galactic extinction  $E(B-V) = 0.063$  (Schlegel *et al.* 1998).

## 5 Ground-based observations

There were a few ground-based follow-up observations of the optical afterglow of GRB 070330. French *et al.*, *GCN Circ.* 6233 reported of observations by the Watcher 40cm automated telescope at the Boyden Observatory, South Africa. They found a  $3\sigma$  upper limit of 18.2 mag in a 848s exposure image with a central time of 23:06:40 UT, 915s after the burst.

Klotz *et al.*, *GCN Circ.* 6235 reported of observations with the 25cm TAROT robotic telescope at ESO La Silla starting 2.5 hours after the burst. They found an upper limit of 17.4 in R.

Cobb *GCN Circ.* 6236 reported of I and J observations with ANDICAM at the 1.3m telescope at CTIO. These observations were performed about 7.6 hours after the burst. The total summed exposure times were 36 and 30 minutes in I and J, respectively. Only upper limits were found with  $I > 20.5$  and  $J > 18.6$ .

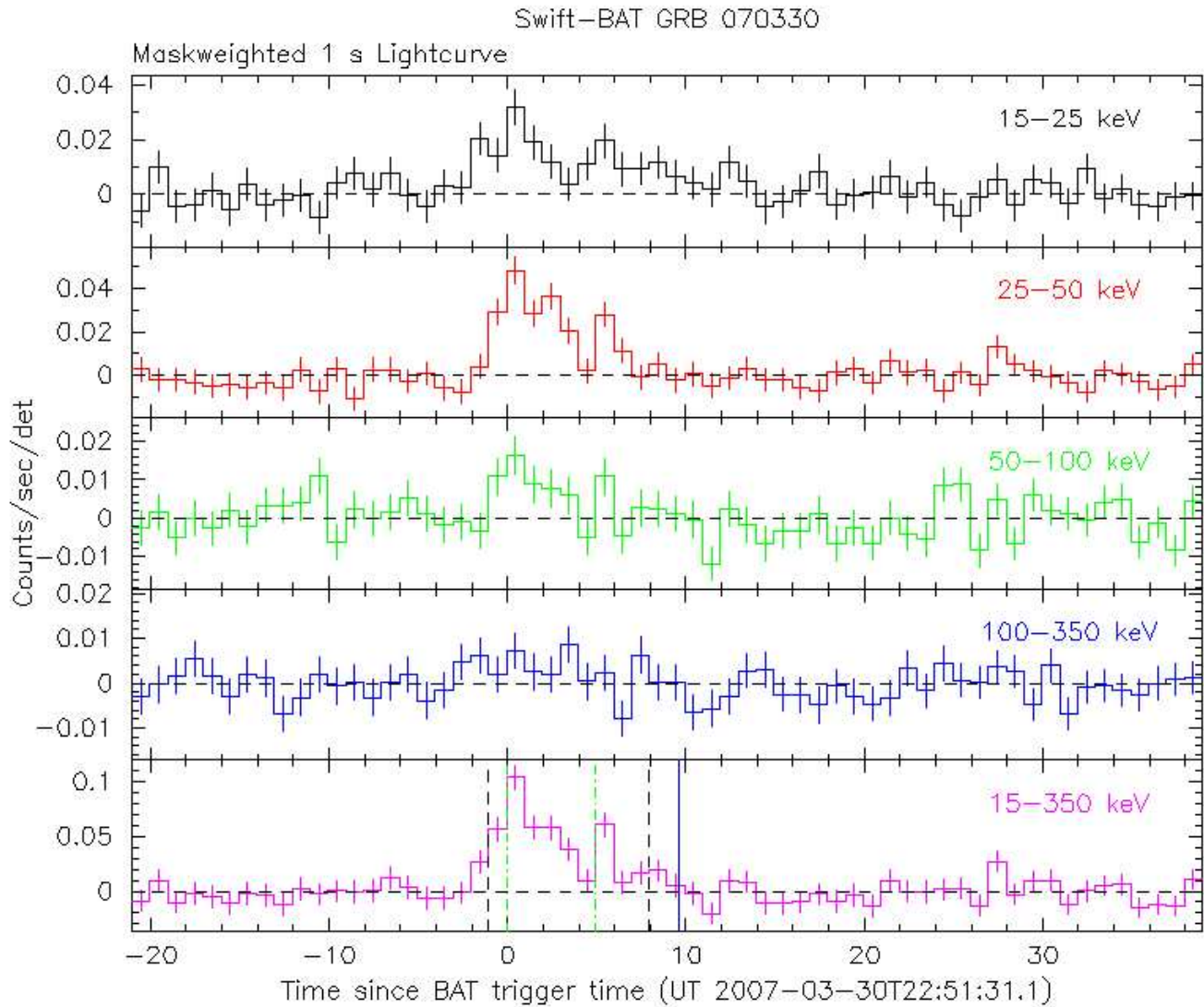


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts  $\text{s}^{-1}$  illuminated-detector $^{-1}$  and  $T_0$  is 2007-March-30 22:51:31 UT.

Filter	$T_{\text{mid}}$	Exposure	Mag
V	462	393	$18.69 \pm 0.24$
V	33978	1632	$> 21.45$ ( $3\sigma$ upper limit)
UVM2	25521	2814	$> 18.35$ ( $3\sigma$ upper limit)
UVW1	20282	1998	$> 18.36$ ( $3\sigma$ upper limit)
U	25521	2814	$> 21.60$ ( $3\sigma$ upper limit)
B	30318	3305	$> 18.15$ ( $3\sigma$ upper limit)

Table 1: Magnitude from UVOT observations

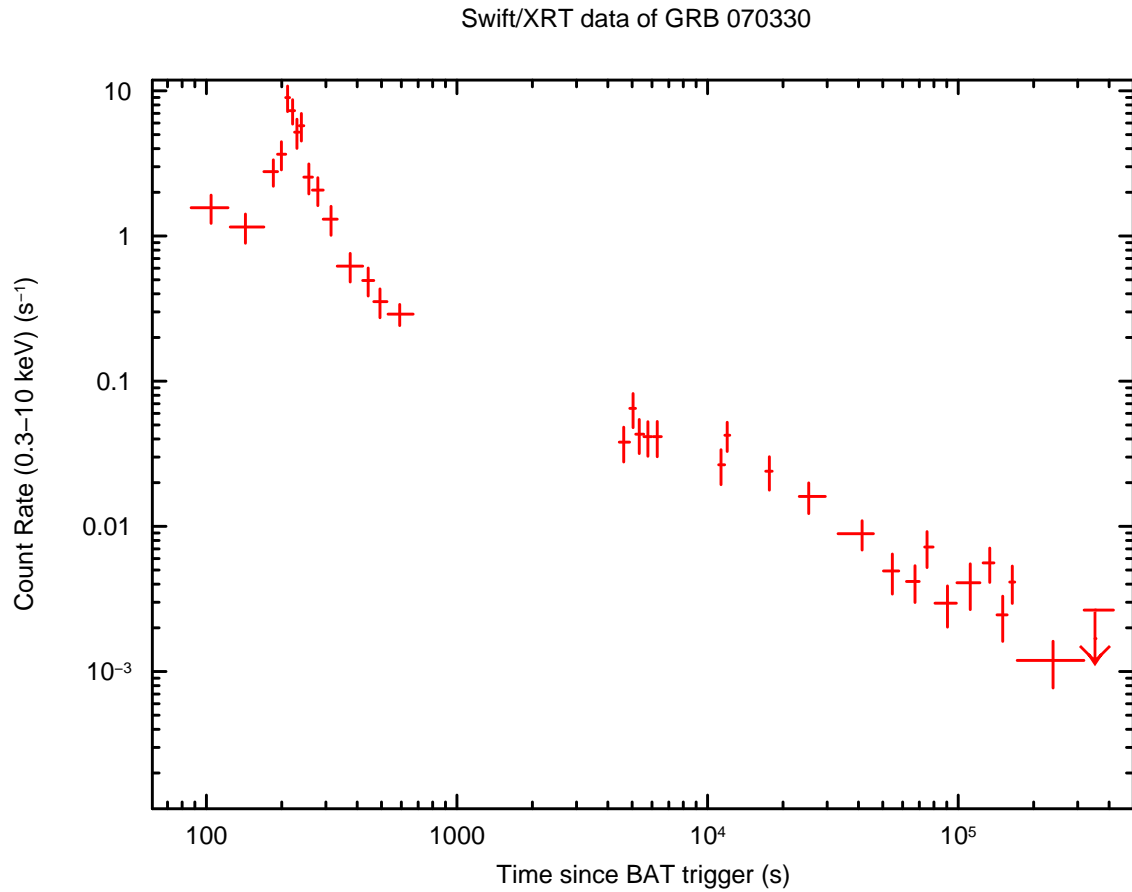


Figure 2: XRT Lightcurve. Counts  $s^{-1}$  in the 0.3-10 keV band: Photon Counting mode (red). The approximate conversion is  $1 \text{ count } s^{-1} = \sim 1.16 \times 10^{-10} \text{ ergs } s^{-1} \text{ cm}^{-2}$  for an unabsorbed flux corrected for photon pileup.