

Swift Observations of GRB 080721

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1. INTRODUCTION

At 10:25:16 UT, the Swift Burst Alert Telescope (BAT) triggered and located GRB 080721 (trigger 317508; Marshall *et al.* GCN Circ. 7988). Swift slewed immediately to the burst. A bright afterglow was discovered in both the X-ray and optical bands (Marshall *et al.* GCN Circ. 7988). Holland, Ward, and Marshall (GCN Circ. 7991) and Ward, Holland, and Marshall (GCN Circ. 7996) estimated a photometric redshift between 2.3 and 2.8 using the UVOT data. D'Avanzo *et al.* (GCN Circ. 7997) determined a spectroscopic redshift of 2.602, and Jakobsson *et al.* (GCN Circ. 7998) confirmed this value. UVOT data provide (Ward, Holland, and Marshall GCN Circ. 7996) the most accurate Swift position of RA (J2000) = 14h 57m 55.855s and Dec (J2000) = $-11^{\circ} 43' 24.54''$ with an estimated 90% confidence error of 0.5".

The burst was also detected with Konus-Wind (Golenetskii *et al.* GCN Circ. 7995). The time-integrated spectrum is well fit with a Band model with a peak energy of 485 (-59, +67) keV.

2) BAT OBSERVATION AND ANALYSIS

The BAT ground-calculated position (Cummings *et al.* GCN Circ. 7992) is RA (J2000) = 14h 57m 55.4s and Dec (J2000) = $-11^{\circ} 42' 33.3''$ with an uncertainty of 1.3' (90% containment radius including both statistical and systematic errors). The partial coding was 4%.

The mask-weighted light curve (Figure 1) shows approximately six peaks. The first starts at $\sim T-11$ sec and rises to a peak at $\sim T-7$ sec. The second and third peaks at $\sim T+1$ and $\sim T+7$ sec. respectively are much brighter. The remaining peaks are much smaller and stretch out to $\sim T+370$ sec. T_{90} (15-350 keV) is 16.2 \pm 4.5 sec (estimated error including systematics).

The time-averaged spectrum from T-2.6 to T+25.8 sec is well fit by a simple power-law model with an index of 1.11 ± 0.08 . The fluence in the 15-150 keV band is $1.2 \pm 0.1 \times 10^{-5}$ erg-cm⁻². The 1-sec peak photon flux measured from T-0.16 sec in the 15-150 keV band is 20.9 ± 1.8 photons-cm⁻²-sec⁻¹. All the quoted errors are at the 90% confidence level.

3. XRT OBSERVATIONS AND ANALYSIS

The XRT began observing GRB 080721 in Windowed Timing (WT) mode 113 sec. after the BAT trigger. Using 2.7 ks of XRT Photon Counting (PC) mode data and 6 UVOT images, Osborne *et al.*, (GCN Circ. 7993) found a UVOT-enhanced XRT position of RA (J2000) = 14h 57m 55.75s, Dec (J2000) = $-11^{\circ} 43' 25.1''$ with an uncertainty of 1.5 arc sec. (radius, 90% confidence).

The light curve (Fig. 2) can be modeled with a triple broken power law with the following best-fitting parameters (90% confidence):

$$\begin{aligned} \alpha_1 &= 0.72 (-0.06, +0.04), t_{b1} = 277 (-14, +11) \text{ s,} \\ \alpha_2 &= 0.0 \text{ (fixed, to reproduce the step), } t_{b2} = 316 (-5, +2) \text{ s,} \\ \alpha_3 &= 0.94 \pm 0.02, t_{b3} = 3199 \pm 1 \text{ s,} \\ \alpha_4 &= 1.60 \pm 0.02, \chi^2/\text{dof} = 1401/1364, \text{ null hypotheses probability of 24\%.} \end{aligned}$$

A spectrum extracted from T+113 to T+1370 sec. (the first orbit of data) can be modeled with an absorbed power-law with $\Gamma = 1.90 \pm 0.02$ and $N_H = 1.10 \pm 0.05 \times 10^{21}$ cm⁻² in excess of the Galactic column density in this direction of 6.9×10^{20} cm⁻². We found no evidence for spectral evolution during this time interval. The observed (unabsorbed) flux over this time interval is 2.2×10^{-9} erg-cm⁻²-s⁻¹ (2.7×10^{-9} erg-cm⁻²-s⁻¹) (Guidorzi *et al.*, GCN Circ. 7994).

Detailed light curves in both count rate and flux units are available in both graphical and ASCII formats at http://www.swift.ac.uk/xrt_curves/.

4. UVOT OBSERVATIONS AND ANALYSIS

UVOT observed the field of GRB 080721 starting about 118 sec. after the BAT trigger. The afterglow is detected in white, V, B, and U filters at the position given in Section 1. The measured magnitudes are presented in Table 1, and the light curve in the white filter is shown in Fig 3. No corrections have been made for the expected extinction in the Milky Way corresponding to E_{B-V} of 0.10 (Schlegel *et al.* 1998). The photometry uses the UVOT photometric system described in Poole *et al.* (MNRAS 383, 627 (2008)).

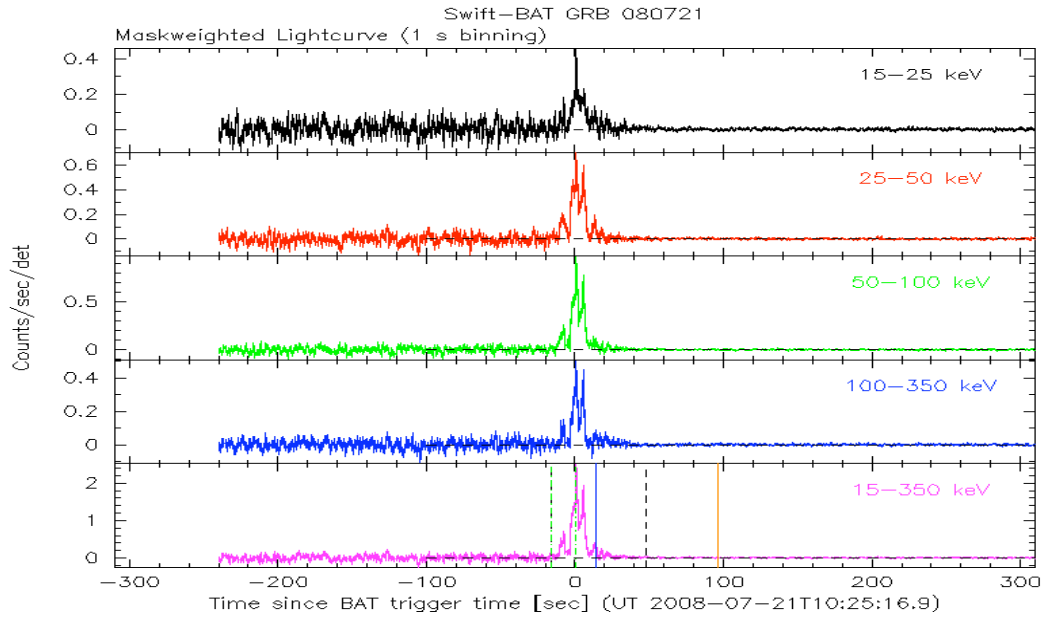


Fig.1: The BAT mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector $^{-1}$. Each illuminated detector has an area of 0.16 cm^2 .

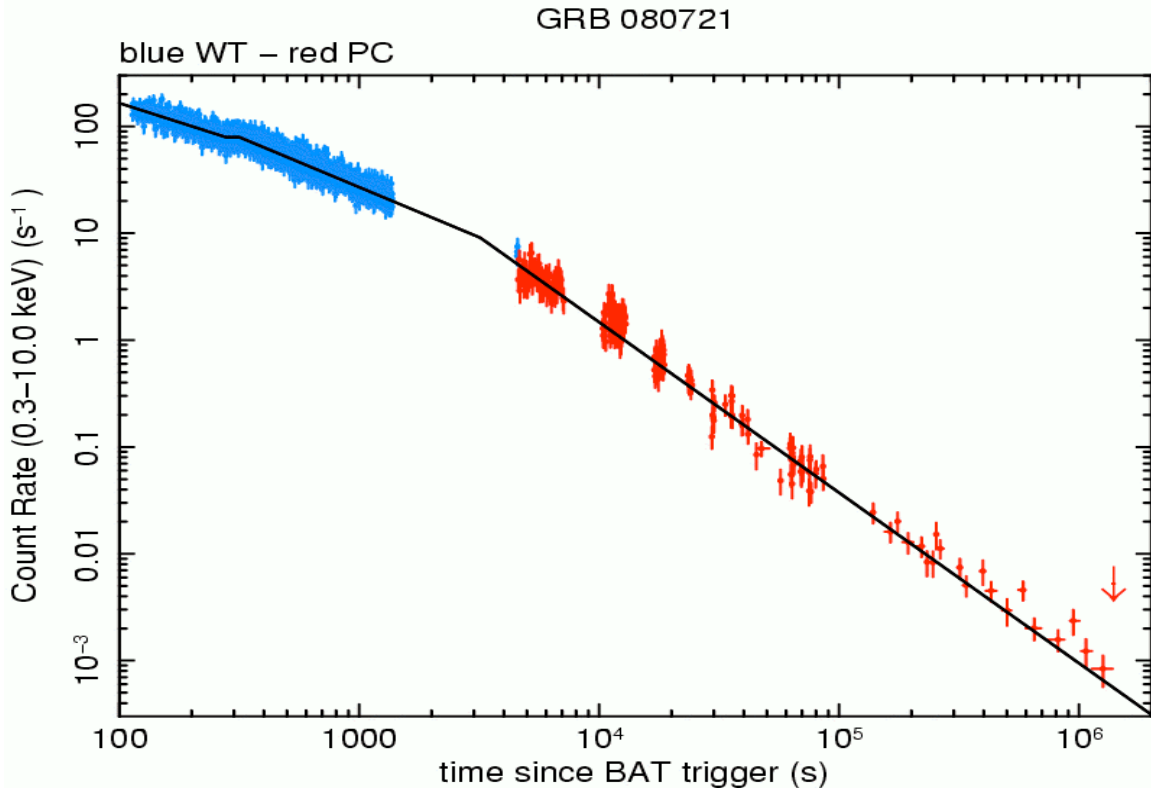


Fig.2: The XRT light curve plotted as a function of the time since the BAT trigger. One count- s^{-1} is about $4.3 \times 10^{-11} \text{ erg-cm}^{-2}\text{-s}^{-1}$ (absorbed) in the 0.3-10 keV band.

| Filter | T_{start} | T_{stop} | Exposure | Magnitude | Uncertainty |
|---------------|--------------------------|-------------------------|------------------|------------------|--------------------|
| | (seconds) | (seconds) | (seconds) | | |
| white | 118 | 217 | 98 | 14.58 | 0.00 |
| white | 858 | 959 | 98 | 16.94 | 0.03 |
| white | 5173 | 5372 | 197 | 19.12 | 0.08 |
| white | 6609 | 6808 | 197 | 19.43 | 0.11 |
| v | 225 | 624 | 393 | 14.98 | 0.01 |
| v | 964 | 1363 | 393 | 16.47 | 0.03 |
| v | 5583 | 5782 | 197 | 18.27 | 0.17 |
| v | 7020 | 7157 | 136 | 18.40 | 0.23 |
| b | 704 | 7703 | 403 | 16.56 | 0.12 |
| u | 680 | 6398 | 432 | 16.58 | 0.12 |
| uvw1 | 655 | 6192 | 432 | >18.01 | |
| uvm2 | 631 | 5987 | 236 | >17.58 | |
| uvw2 | 734 | 7014 | 393 | >18.03 | |

Table 1: UVOT Observations. The start and stop times of the exposures are given in seconds since the BAT trigger. No corrections have been made for the expected extinction in the Milky Way corresponding to $E_{B,V}$ of 0.10 (Schlegel *et al.* 1998)

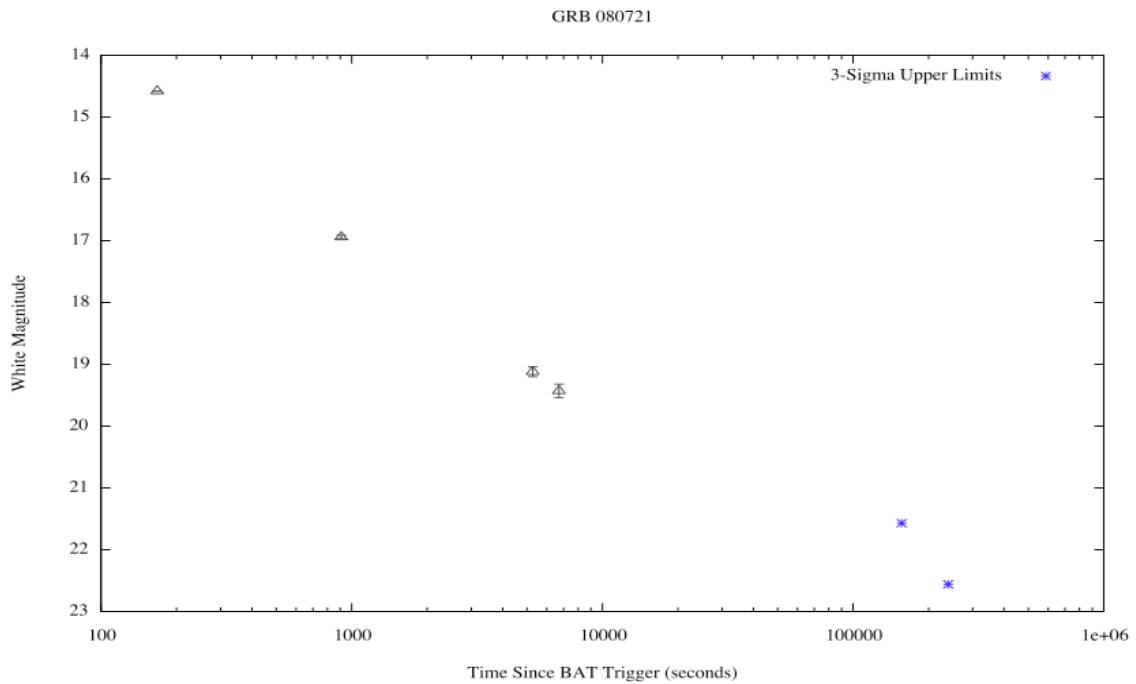


Fig.3: The light curve in the UVOT white filter.