

Swift and INTEGRAL SPI-ACS Observations of GRB 080602

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1 Introduction

The Swift Burst Alert Telescope (BAT) triggered on GRB 080602 (trigger 312958) at 01:30:28 UT, (Beardmore *et al.*, *GCN Circ.* 7781). This was a 2.048 s rate-trigger on a long burst which showed two well separated main peaks with a $T_{90} = 74 \pm 7$ s. Swift slewed immediately to this burst and XRT began follow-up observations at $T + 118$ s, and UVOT at $T + 124$ s. Our best position is the UVOT-enhanced XRT location RA(J2000) = 19.17574 deg ($01^h 16^m 42.18^s$), Dec(J2000) = -9.23207 deg ($-09^d 13' 55.4''$), with an error of 1.7 arcsec (90% confidence).

The second peak was also detected by Konus-Wind (Golenetskii *et al.*, *GCN Circ.* 7784) and the SPI-ACS on INTEGRAL (see below).

The source was not detected in the optical by the UVOT or by a ground based observation at the NOT (Malesani *et al.*, *GCN Circ.* 7783) to a limiting R-band magnitude of 22.3.

2 BAT Observation and Analysis

Using the data set from $T - 296$ to $T + 302$ s, further analysis of BAT GRB 080602 has been performed by the Swift team (Sato *et al.*, *GCN Circ.* 7786). The BAT ground-calculated position is RA(J2000) = 19.177 deg ($01^h 16^m 42.6^s$), Dec(J2000) = -9.239 deg ($-09^d 14' 19.8''$) with an uncertainty of 1.7 arcmin, (radius, 90% containment, systematic and statistical). The partial coding was 19%.

The mask-weighted light curve (Fig. 1) shows 4 or 5 peaks, the first starting at $\sim T - 25$ s, the second at $\sim T - 15$ s, the 3rd at $\sim T - 5$ s, peaking at $\sim T + 1$ s and ending at $\sim T + 15$ s; the 4th starts at $\sim T + 55$ s and ends at $\sim T + 65$ s. T_{90} (15-350 keV) is 74 ± 7 s (estimated error including systematics).

The time-averaged spectrum from $T - 11.5$ to $T + 69.3$ s is best fit by a simple power-law model. The power law index of the time-averaged spectrum is 1.43 ± 0.13 . The fluence in the 15–150 keV band is $(3.2 \pm 0.2) \times 10^{-6}$ erg cm^{-2} . The 1-sec peak photon flux measured from $T + 59.60$ s in the 15–150 keV band is 2.9 ± 0.2 ph $\text{cm}^{-2} \text{s}^{-1}$. All the quoted errors are at the 90% confidence level.

3 INTEGRAL SPI-ACS Observations

GRB 080602 has also been detected by SPI-ACS on-board INTEGRAL. The initial burst on which Swift-BAT triggered is not visible in the ACS light curve, but four prominent peaks are detected at $T + 58.5$ s, $T + 60.5$ s, $T + 62$ s, and $T + 64$ s, with a duration of 1 s, 2 s, 1.5 s, and 2 s, respectively (Fig. 2). Between these peaks the count rate drops to the noise level. These peaks are consistent with substructure seen in the BAT data at this time. Because the ACS is derived from 91 independent detectors with different lower energy thresholds (in the range 50–150 keV) and because the response varies as a function of the GRB incident angle, the count rates cannot be easily translated into physical flux units.

4 XRT Observations and Analysis

The Swift-XRT observed GRB 080602 for one orbit which consisted of 71 s of Windowed Timing mode data starting 118 s after the trigger and 1.23 ks of Photon Counting mode data, 193 s after the trigger (Beardmore *et al.*, *GCN Circ.* 7785.)

Using 930 s of overlapping XRT Photon Counting mode and UVOT data, 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) = 19.17574 deg (01^h 16^m 42.18^s), Dec(J2000) = −9.23207 deg (−09^d 13′ 55.4″) with an uncertainty of 1.7 arcsec (radius, 90% confidence). The position is 6.3 arcsec from the on-board position reported in Beardmore *et al.* (*GCN Circ.* 7781) and 0.4 arcsec from the initial refined XRT position reported in Beardmore *et al.* (*GCN Circ.* 7782).

At first, the X-ray light curve shows signs of a steep decay with a slope of $4.7_{-0.9}^{+2.1}$, breaking to a shallower decay of 0.21 ± 0.16 at a time of 145_{-6}^{+11} s after the trigger. This is followed by a further steepening to a slope of $0.76_{-0.23}^{+0.41}$ at a time of 561_{-201}^{+276} s (Fig. 3).

A spectrum of the Windowed Timing data can be well fit by an absorbed power-law, with a photon index 1.63 ± 0.21 and a column density $(1.0 \pm 0.5) \times 10^{21}$ cm^{−2}, compared with the Galactic column density in this direction of 3.5×10^{20} cm^{−2}. The observed (unabsorbed) 0.3-10 keV flux is 3.13×10^{-10} (3.61×10^{-10}) erg cm^{−2} s^{−1}.

The Photon Counting mode spectrum is also well fit by an absorbed power-law, with column density $(2.1 \pm 0.4) \times 10^{21}$ cm^{−2} and photon index 2.12 ± 0.15 . The observed (unabsorbed) 0.3-10 keV flux is 1.66×10^{-10} (2.59×10^{-10}) erg cm^{−2} s^{−1}. The observed count to flux conversion factor for this data is 3.5×10^{-11} erg cm^{−2} count^{−1}.

5 UVOT Observation and Analysis

The UVOT began observing the field of GRB 080602 124.3 s after the initial BAT trigger. No new source was detected within the XRT error circle in the white (196.4 s) finding exposures, or in the co-added *v*-band images down to 3-sigma magnitude limits. The upper limits are summarized in Table 1. These upper limits are quoted on the UVOT photometric system (Poole *et al.*, 2008 MNRAS 383 627) and are not corrected for Galactic extinction $E(B-V) = 0.370$ (Schlegel *et al.*, 1998 ApJ 500 525).

Filter	Start	Stop	Exposure	3-Sigma UL
wh	124.3	963.5	196.4	21.16
v	230.2	1369.5	786.9	20.3

Table 1: Magnitude limits from UVOT observations

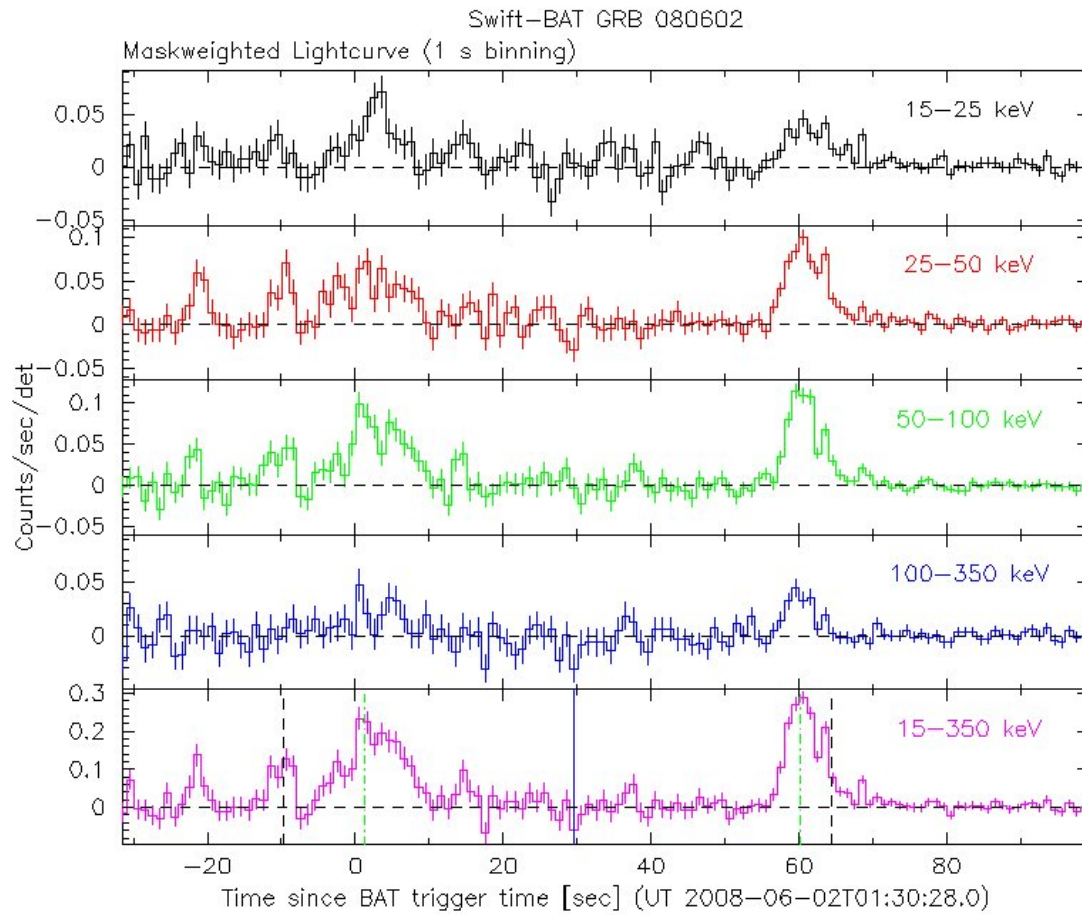


Figure 1: The mask-weighted BAT light curve in the 4 individual plus total energy bands. The units are $\text{count s}^{-1} \text{ illuminated-detector}^{-1}$ (note $\text{illum-det} = 0.16 \text{ cm}^2$) and T_0 is 01:30:28.0 UT.

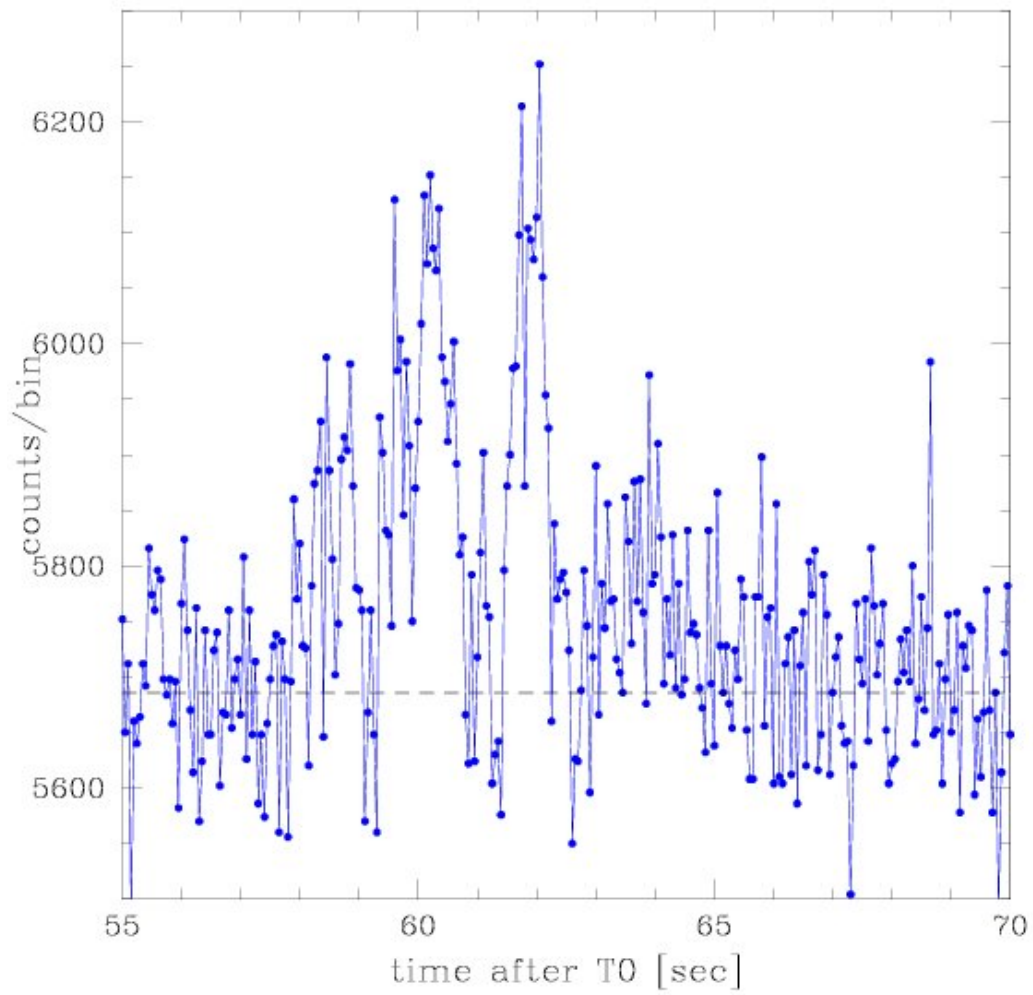


Figure 2: INTEGRAL SPI-ACS light curve of the time interval covering the second main peak. The units are count/50 – msec bin over the energy range 50-150 keV.

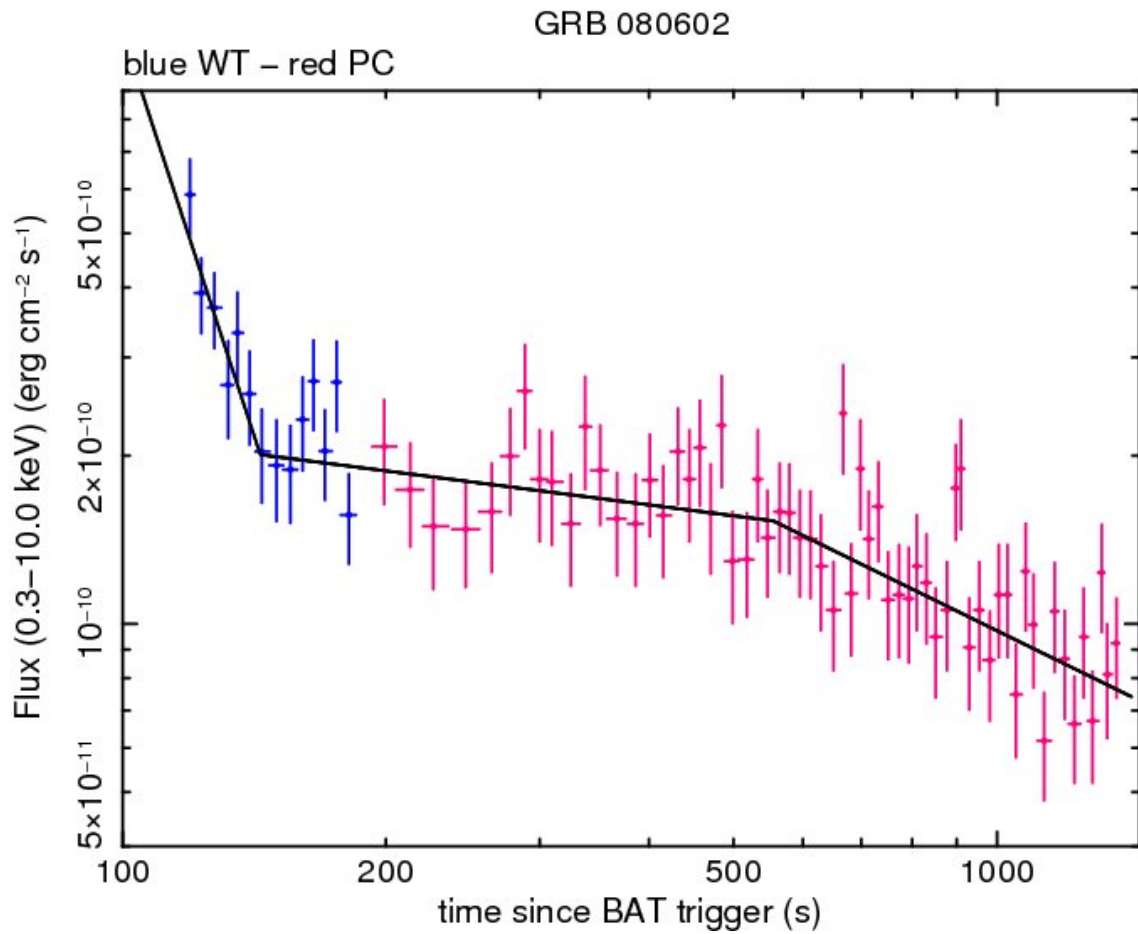


Figure 3: XRT lightcurve showing flux ($\text{erg cm}^{-2} \text{s}^{-1}$) in the 0.3-10 keV band, modelled with a doubly broken power-law (see text for the parameters). Windowed Timing mode is shown in blue, Photon Counting mode is red.