

## Swift Observation of GRB 110319A

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### 1 Introduction

At 02:16:41 UT, the *Swift* BAT triggered and located GRB 110319A (Trigger 449578, Melandri, *et al.*, *GCN Circ.* 11807). *Swift* slewed immediately to the burst. The BAT on-board calculated location is RA, Dec = (356.401, -66.017) deg, which is

$$\begin{aligned} \text{RA}(J2000) &= 23^h 45^m 36^s \\ \text{Dec}(J2000) &= -66^\circ 01' 01'' \end{aligned}$$

with an uncertainty of 3 arcmin (radius, 90% containment, including systematic uncertainty). The BAT light curve showed a double-peaked structure with a duration of about 30 sec. The peak count rate was  $\sim 3800$  counts/s (15 – 350 keV), at  $\sim 5$  s after  $T_0$ .

The XRT began observing the field at  $T + 55.9$  s after the BAT trigger, finding a bright, fading, uncatalogued X-ray source with an enhanced position RA, Dec = (356.5017, -66.0114) deg, which is equivalent to:

$$\begin{aligned} \text{RA}(J2000) &= 23^h 46^m 0.43^s \\ \text{Dec}(J2000) &= -66^\circ 00' 40.1'' \end{aligned}$$

with an uncertainty of 1.8" (radius, 90% containment) (Goad, *et al.*, *GCN Circ.* 11808).

UVOT took a finding chart exposure of 150 s with the White filter starting  $T + 66$  s after the BAT trigger. An afterglow candidate has been found in the optical filters. The  $2.7' \times 2.7'$  sub-image covers 100% of the XRT error circle. The typical  $3\sigma$  upper limit has been about 19.6 mag. No correction has been made for the expected extinction corresponding to  $E_{(B-V)}$  of 0.03.

### 2 BAT Observation and Analysis

Using the data set from  $T - 239$  to  $T + 963$  s further analysis of BAT GRB 110319A has been performed by *Swift* team (Barthelmy, *et al.*, *GCN Circ.* 11811). The BAT ground-calculated position is RA( $J2000$ ) = 356.510 deg ( $23^h 46^m 02.4^s$ ), Dec( $J2000$ ) = -66.008 deg ( $-66^\circ 00' 28.7''$ )  $\pm 1.0'$  (radius, sys+stat, 90% containment). The partial coding was 100%.

The mask-weighted light curve (Fig.1) shows two overlapping peaks starting at  $\sim T + 0$ , peaking at  $\sim T + 5$  and  $\sim T + 13$  s, and ending at  $\sim T + 30$  s.  $T_{90}(15 - 350 \text{ keV})$  is  $19.3 \pm 1.6$  s (estimated error including systematics).

The time-averaged spectrum from  $T - 0.3$  to  $T + 31.3$  s is best fit by a power law with an exponential cutoff. This fit gives a photon index  $1.31 \pm 0.43$  and  $E_{peak}$  of  $21.9 \pm 7.0$  keV (chi squared 54.2 for 56 d.o.f.). For this model the total fluence in the 15 – 150 keV band is  $(1.4 \pm 0.1) \times 10^{-6}$  ergs/cm<sup>2</sup> and the 1-sec peak flux measured from  $T + 13.1$  s in the 15 – 150 keV band is  $2.2 \pm 0.2$  ph/cm<sup>2</sup>/sec. A fit to a simple power law gives a photon index of  $2.55 \pm 0.08$  (chi squared 86.5 for 57 d.o.f.). All the quoted errors are at the 90% confidence level.

### 3 XRT Observations and Analysis

We have analysed 9.9 ks of XRT data for GRB 110319A (Melandri, *et al.*, *GCN Circ.* 11807); the data comprise 33 s in Windowed Timing (WT) mode (the first 7 s were taken while *Swift* was slewing) with the remainder in Photon Counting (PC) mode. The enhanced XRT position for this burst was given by Goad, *et al.*, *GCN Circ.* 11808.

The light curve (Fig.2) can be modelled with a series of power-law decays. The initial decay index is  $\alpha_1 = 3.1_{-0.2}^{+0.2}$ . At  $T + 169$  s the decay flattens to an  $\alpha_2 = 0.65_{-0.08}^{+0.06}$ . The light curve breaks again at  $T + 7816$  s to a decay with  $\alpha_3 = 1.24_{-0.09}^{+0.10}$ .

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of  $3.4_{-0.3}^{+0.4}$ . The best-fitting absorption column is  $2.4_{-0.6}^{+0.7} \times 10^{21} \text{ cm}^{-2}$ , in excess of the Galactic value of  $2.6 \times 10^{20} \text{ cm}^{-2}$  (Kalberla *et al.* 2005). The PC mode spectrum has a photon index of  $2.33_{-0.14}^{+0.13}$  and a best-fitting absorption column of  $1.16_{-0.18}^{+0.32} \times 10^{21} \text{ cm}^{-2}$ . The counts to observed (unabsorbed) 0.3 – 10 keV flux conversion factor deduced from this spectrum is  $3.3 \times 10^{-11} (5.0 \times 10^{-11}) \text{ erg cm}^{-2} \text{ count}^{-1}$ .

### 4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 110319A  $T + 65$  s (Siegel, *et al.*, *GCN Circ.* 11812) after the BAT trigger (Melandri, *et al.*, *GCN Circ.* 11807). We identify an optical afterglow near the enhanced XRT position given by Melandri, *et al.*, *GCN Circ.* 11810. The transient is only detected in the optical filters and shows fading between the first and second orbits.

The UVOT position is:

$$\begin{aligned} \text{RA(J2000)} &= 23^{\text{h}} 46^{\text{m}} 00.69^{\text{s}} = 356.50287 \text{ deg} \\ \text{Dec(J2000)} &= -66^{\circ} 00' 40.4'' = -66.01122 \text{ deg} \end{aligned}$$

with an estimated uncertainty of 0.44'' (radius, 90% confidence, statistical + systematic). Preliminary  $3\sigma$  upper limits and magnitudes using the UVOT photometric system (Poole *et al.* 2008, MNRAS, 383, 627) for the exposures are:

Filter	Start	Stop	Exposure	Mag / $3\sigma$ UL
white (fc)	65	215	147	$18.3 \pm 0.07$
white	3924	5560	393	$20.32 \pm 0.22$
v	4336	5971	393	$> 19.56$
b	3719	5355	393	$19.51 \pm 0.21$
b	11317	11950	615	$> 20.63$
u	277	395	115	$18.13 \pm 0.13$
u	4950	11310	1081	$19.76 \pm 0.18$
uvw1	4745	4945	196	$> 19.72$
uvw1	9497	10397	885	$> 20.58$
uvm2	4540	4740	196	$> 19.64$
uvm2	5976	6172	193	$> 19.69$
uvw2	4131	4330	196	$> 19.91$
uvw2	5566	5766	196	$> 19.91$

Table 1: Magnitude and  $3\sigma$  limits from UVOT observations . The values quoted above are not corrected for the Galactic extinction due to the reddening of  $E_{(B-V)} = 0.03$  in the direction of the burst (Schlegel *et al.* 1998)

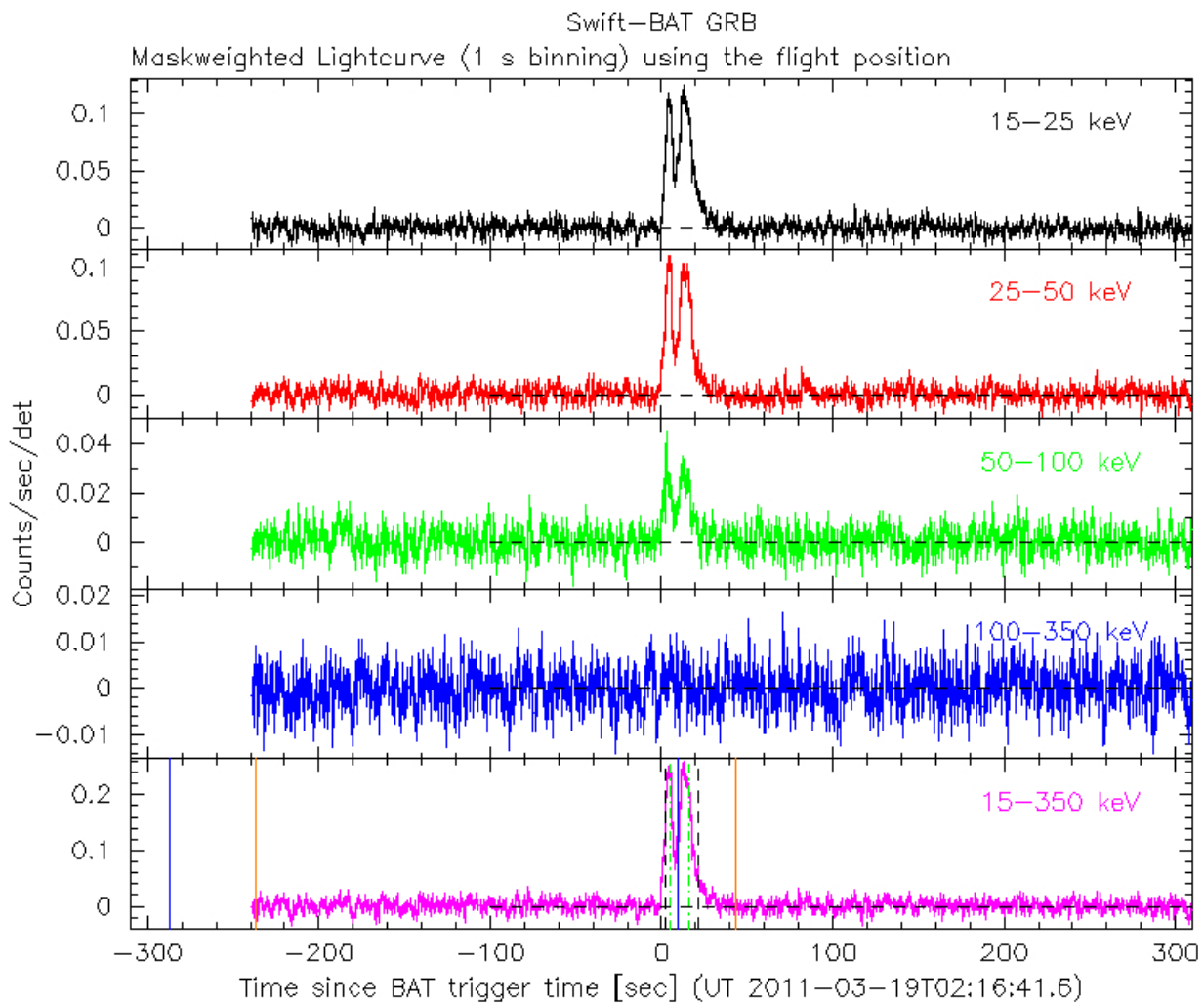


Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands (15 - 25, 25 - 50, 50 - 100, 100 - 350 and 15 - 350 keV).

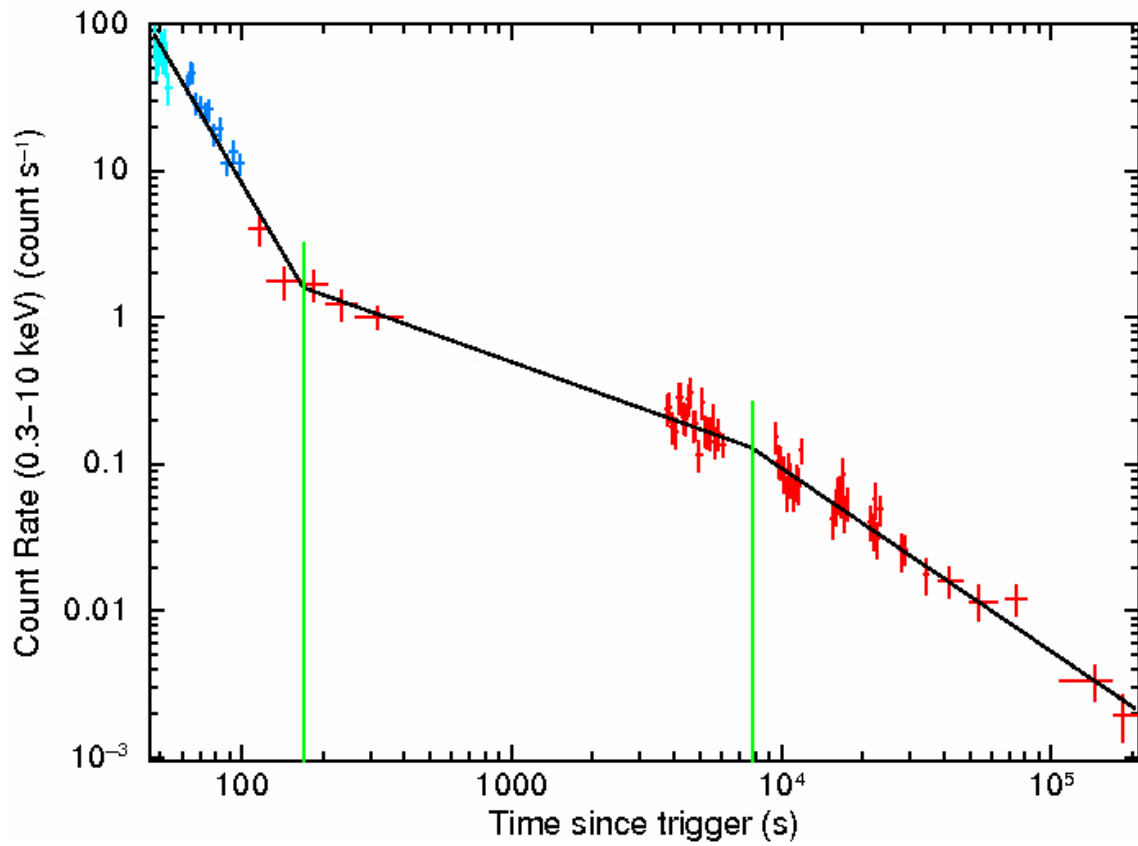


Figure 2: XRT Lightcurve. It can be modelled by a series of power-laws. Data are from WT mode (blue) and PC mode (red); green vertical lines mark the times where the power-law decay changes.