

## Swift Observations of GRB 091029

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### 1 Introduction

At 03:53:22 UT on 2009-10-29, the Swift Burst Alert Telescope (BAT) triggered and located GRB 091029 (trigger=374210). Swift slewed immediately to the burst and found X-ray and optical counterparts of the burst in the XRT and UVOT (Grupe et al. *GCN Circ.* 10097)

The best *Swift* position of this burst is the UVOT position given in Marshall & Grupe (*GCN Circ.* 10108) with RA-2000 = 04h 00m 42.59s, and Dec-2000 =  $-55^{\circ} 57' 20.0''$  with an uncertainty of  $0.55''$ .

One interesting aspect of this burst was that we saw a brightening in the UVOT which seem to coincide with a flare seen in X-rays. The optical afterglow had several observatories following it including GROND (Filgas et al., *GCN Circ.* 10098). A Gemini-South spectroscopic redshift for this burst of  $z=2.752$  was reported by Chornock et al. (*GCN Circ.* 10100).

### 2 BAT Observation and Analysis

At 03:53:22 UT on 2009-10-29, the Swift Burst Alert Telescope (BAT) triggered and located GRB 091029 (trigger=374210, Grupe et al. *GCN Circ.* 10097). Using the data set from T-240 to T+962 s, the BAT ground-calculated position is RA, Dec = 60.166, -55.954 deg which is

$$\text{RA(J2000)} = 04\text{h } 00\text{m } 40.0\text{s}$$

$$\text{Dec(J2000)} = -55^{\circ} 57' 12.7''$$

with an uncertainty of 1.0 arcmin, (radius, sys+stat, 90% containment). The partial coding was 99% (Barthelmy et al. *GCN Circ.* 10103).

The mask-weighted light curve shows three overlapping peaks, the first starting at T-10 s, peaking at T+2, +20, and +26 s, and ending at T+70 s.  $T_{90}$  (15-350 keV) is  $39.2 \pm 5$  s (estimated error including systematics).

The time-averaged spectrum from T-1.8 to T+60.2 s is best fit by a power law with an exponential cutoff. This fit gives a photon index  $1.46 \pm 0.27$ , and  $E_{\text{peak}}$  of  $61.4 \pm 17.5$  keV ( $\chi^2 = 49.9$  for 56 d.o.f.). For this model the total fluence in the 15-150 keV band is  $2.4 \pm 0.1 \times 10^{-6}$  ergs  $\text{cm}^{-2}$ . The 1s peak photon flux measured from T+19.12 s in the 15-150 keV band is  $1.8 \pm 0.1$  photons  $\text{s}^{-1} \text{cm}^{-2}$ . A fit to a simple power law gives a photon index of  $1.88 \pm 0.06$  ( $\chi^2 = 57.4$  for 57 d.o.f.). All the quoted errors are at the 90% confidence level.

The results of the batgrbproduct analysis are available at [http://gcn.gsfc.nasa.gov/notices\\_s/374210/BA/](http://gcn.gsfc.nasa.gov/notices_s/374210/BA/)

### 3 XRT Observations and Analysis

Using 4524 s of XRT Photon Counting mode data and 7 UVOT images for GRB 091029, Goad et al. (*GCN Circ.* 10102) found an astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA, Dec = 60.17793, -55.95556 which is equivalent to:

RA (J2000): 04h 00m 42.70s

Dec (J2000): -55° 57' 20.0''

with an uncertainty of 1.7'' (radius, 90% confidence). The latest position can be viewed at [http://www.swift.ac.uk/xrt\\_positions](http://www.swift.ac.uk/xrt_positions). Position enhancement is described by Goad et al. (2007, *A&A*, 476, 1401) and Evans et al. (2009, *MNRAS*, 397, 1177).

A spectrum formed from the WT mode data (69s exposure) can be fitted with an absorbed power-law with a photon spectral index of  $2.30 \pm 0.08$  with an absorption column density consistent with the Galactic value of  $1.14 \times 10^{20} \text{ cm}^{-2}$  (Kalberla et al. 2005). The PC mode spectrum (using 15727 s of data, excluding the flare around 300 s after the burst) results in a slightly flatter X-ray spectrum with  $\Gamma = 2.00 \pm 0.07$ .

The 0.3 – 10 keV light curve given below (Fig.2) can be modelled with a multiple broken power-law model with the following decay slopes and break times:

$$\alpha_1 = 3.76_{-0.05}^{+0.10}$$

$$T_{\text{break1}} = 310_{-5}^{+12} \text{ s}$$

$$\alpha_2 = 0.22 \pm 0.03$$

$$T_{\text{break2}} = 10450_{-665}^{+560} \text{ s}$$

$$\alpha_3 = 1.00_{-0.03}^{+0.04}$$

$$T_{\text{break3}} = 100 \text{ ks}$$

$$\alpha_4 = 1.25 \pm 0.10$$

There is a flattening of the light curve at the end of the observations which is most likely due to a random background source. A visual inspection of the data shows no obvious X-ray afterglow for the observations with  $T > 1.2 \text{ Ms}$ .

### 4 UVOT analysis

The Swift/UVOT began settled observations of the field of GRB 091029 91 s after the BAT trigger (Grupe et al., *GCN Circ.* 10097). Marshall & Grupe (*GCN Circ.* 10108) reported on the detection of the optical afterglow at the refined UVOT position RA, Dec 60.17745, -55.95557, which is

RA(J2000) = 04h 00m 42.59s

DEC(J2000) = -55°57'20.0''

with a 90%-confidence error radius of about 0.55''. This position is consistent with the enhanced XRT

Filter	$T_{\text{start}}$	$T_{\text{stop}}$	Exposure	Mag
white	91	240	147	20.22±0.13
white	584	603	19	18.75±0.14
v	635	654	19	17.81±0.26
b	559	578	19	19.04±0.28
u	303	552	19	18.42±0.08
uvw1	684	1280	58	> 19.32
uvm2	1930	1949	19	> 18.74
uvw2	611	1206	58	> 20.45

Table 1: Magnitudes from UVOT observations of GRB 091029. The quoted upper limits have not been corrected for the expected Galactic extinction along the line of sight of  $E_{B-V} = 0.02$  mag. All photometry is on the UVOT photometric system described in Poole et al. (2008, MNRAS, 383, 627).

position (Goad et al., *GCN Circ.* 10102). The detection in the white, v, b and u filters and not in the UV filters is consistent with the redshift of 2.752 (Chornock et al., *GCN Circ.* 10053).

The magnitudes and  $3\sigma$  upper limits for the summed images are listed in Table 1.

The afterglow brightened by a factor of 4 between the first two observations in the white filter, which had mean observing times of T+166 s. and T+594s. The afterglow then decayed following an approximately power law form with a decay index of -0.45. This decay form lasted until at least T+8231 s. A similar optical light curve was reported by LaCluze et al. (GCN Circ. 10099 and 10107).

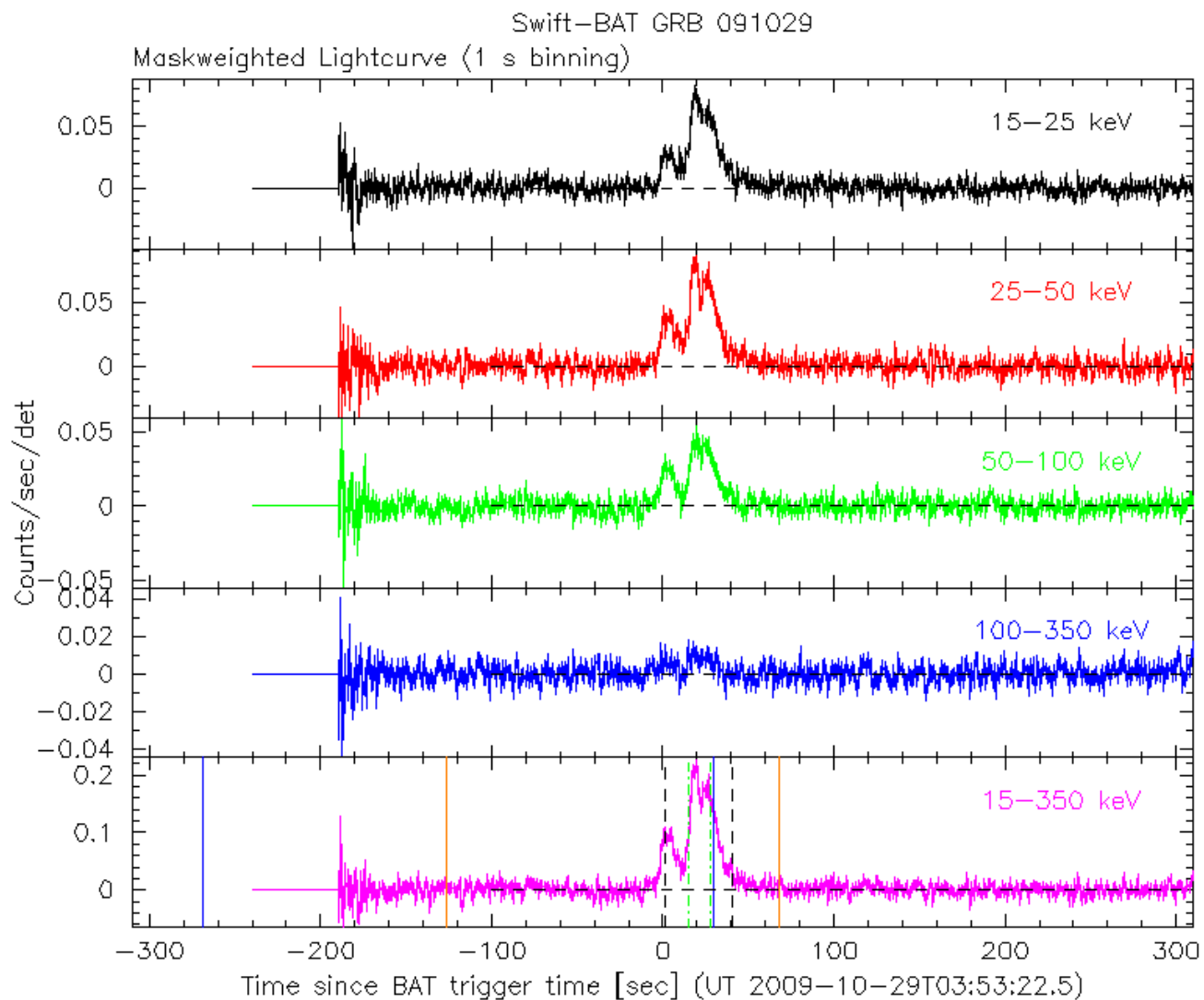


Figure 1: BAT Light curve of GRB 091029.

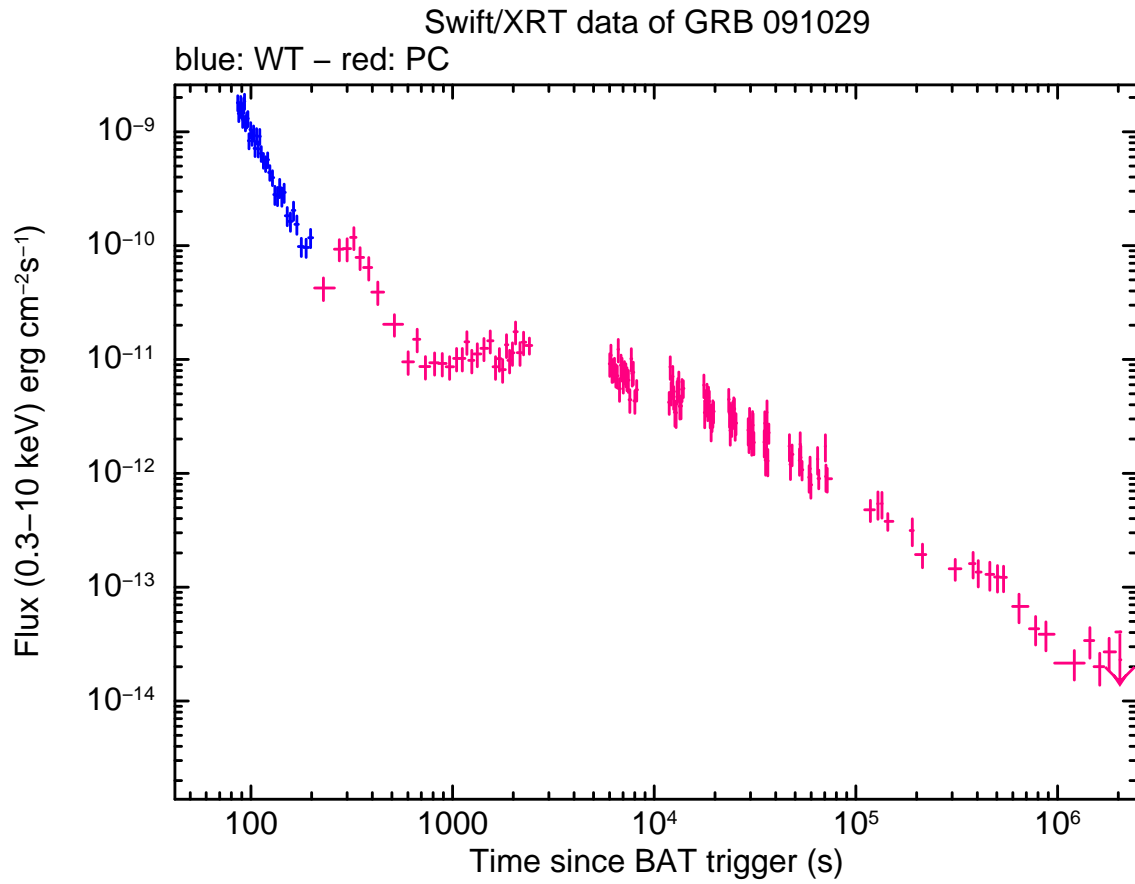


Figure 2: XRT flux light curve of GRB 091029 in the 0.3–10 keV band. The approximate conversion is  $1 \text{ count s}^{-1} = \sim 3.4 \times 10^{-11} \text{ ergs s}^{-1}\text{cm}^{-2}$ .

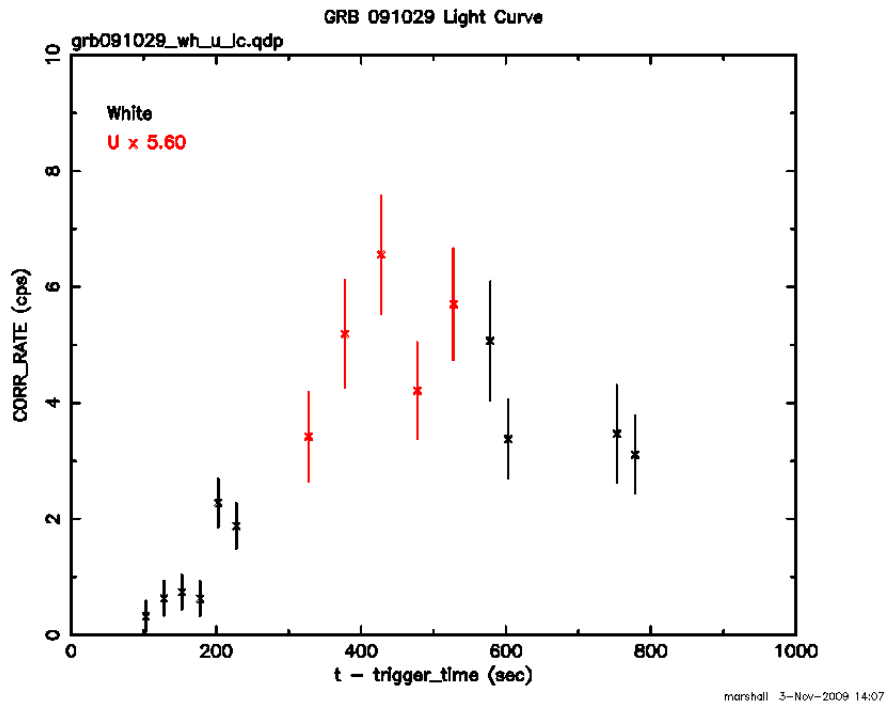


Figure 3: Observed UVOT light curve of GRB 091029