Swift Observations of GRB 110422A

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1 Introduction

BAT triggered on GRB 110422A at 15:41:55 UT, (trigger 451901, Mangano *et al.*, *GCN Circ.* 11957). This was a 1.024 s rate-trigger on a long burst with $T_{90} = 25.9 \pm 0.6$ s. Swift slewed to the burst after a 12 minute observing constraint delay and found an X-ray counterpart to the burst in XRT. XRT began follow up observations at $T + 814.5$ s, and UVOT observations began at $T + 822$ s.

Our best position is the enhanced XRT position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA($J2000$) = 112.04671 *deg* (07^h 28^m 11.21^s) Dec($J2000$) = +75.10666 *deg* ($+75^d$ $06'$ $24.0"$) with an uncertainty of 1.7 arcsec (radius, 90% confidence, Evans *et al.*, *GCN Circ.* 11965).

GRB 110422A has been detected also by Konus Wind (Golenetskii *et al.*, *GCN Circ.* 11971) at 15:41:42.948 UT, with a multipeaked light curve duration of ∼40 s and a time-integrated spectrum well fitted (in the 20−500 keV range) by a Band model with lower energy photon index alpha = -0.65 ± 0.06, higher energy photon index beta = $2.96^{+0.14}_{-0.19}$, and peak energy Ep = 152 ± 5 keV.

GRB 110422A has also been detected by the Suzaku Wide-band All-sky Monitor (WAM) (Iwakiri *et al.*, *GCN Circ.* 11976) at 15:41:45 UT, with a multipeaked light curve of T_{90} ∼22 s and a time-integrated spectrum well fitted (in the 50 keV−5 MeV range) by a single power-law with a photon index of 2.83 ± 0.11.

The field of GRB 110422A has been observed by some ground based optical telescopes: the AZT-33IK telescope of Sayan observatory (Mondy), on April 22 at 15:58 UT (Klunko *et al.*, *GCN Circ.* 11958); the MASTER II robotic telescope, 53 sec after GRB time (Gres *et al.*, *GCN Circ.* 11960 and Gres *et al.*, *GCN Circ.* 12007); the Nordic Optical Telescope (NOT) equipped with ALFOSC with a median time 21:11:33.3 UT (i.e., 5.49397 hr after the BAT trigger) (Xu *et al.*, *GCN Circ.* 11961), 29.4 hr after the BAT trigger (Xu *et al.*, *GCN Circ.* 11970) and 77.6 hr after the BAT trigger (Xu *et al.*, *GCN Circ.* 11974); the Zeiss-1000 telescope of SAO RAS, Russia, ∼3 hours after the trigger (Moskvitin *et al.*, *GCN Circ.* 11962); the 3.6m TNG equipped with the Dolores camera, starting ∼5.7 hours after the burst event (Melandri *et al.*, *GCN Circ.* 11963); the Taurus Hill Observatory's (A95) Celestron C-14 (OTA) telescope ∼5 hours after the trigger (Hentunen *et al.*, *GCN Circ.* 11966); the 2.1m telescope at the McDonald observatory, TX, using CQUEAN camera with griz filters, about 11.19 hours after the BAT trigger (Yiseul Jeon *et al.*, *GCN Circ.* 11967); the Murikabushi 1m telescope of Ishigakijima Astronomical Observatory ∼21 hours after the burst (Kuroda *et al.*, *GCN Circ.* 11972); the AZT-11 telescope of CrAO between April 22 19:13 and 20:11 UT (Rumyantsev *et al.*, *GCN Circ.* 11973), April 24 (Rumyantsev *et al.*, *GCN Circ.* 11979) and April 28 (Rumyantsev *et al.*, *GCN Circ.* 11986). The best position of the optical counterpart is given in Xu *et al.*, *GCN Circ.* 11961.

Spectroscopic observations have been done by the TNG (Malesani *et al.*, *GCN Circ.* 11977) and the GTC telescope telescope located in La Palma (de Ugarte Postigo *et al.*, *GCN Circ.* 11978), and the measured value for the redshift is z=1.770 ± 0.001.

The field of GRB 110422A has been observed in the Optical/FIR with Herschel on May 4 and the source has been detected (Huang *et al.*, *GCN Circ.* 12006).

2 BAT Observation and Analysis

Using the data set from T−61 to T+195 s from telemetry downlinks, the refined analysis of BAT GRB 110422A was performed by the Swift team and reported in Palmer *et al.*, *GCN Circ.* 11959.

The BAT ground-calculated position is RA($J2000$) = 112.057 *deg* (07^h 28^m 13.7^s) Dec($J2000$) = +75.100 *deg* ($+75^d$ 05^m 58.8^s) with an uncertainty of 1.0 arcmin, (radius, sys+stat, 90% containment). The partial coding was 22%.

The mask-weighted light curve (Fig.1) shows several overlapping peaks starting at ∼T−15 s, peaking at ∼T+8 s, and ending at ∼T+60 s. At the 3-sigma level, there is another peak from T+70 to T+115 s. T_{90} (15−350 keV) is 25.9±0.6 s (estimated error including systematics).

The time-averaged spectrum from T−11.2 to T+40.3 s is best fit by a power law with an exponential cutoff. This fit gives a photon index 0.86 ± 0.10 and Epeak of 149.4 ± 18.5 keV (chi squared 46.5 for 56 d.o.f.). The total fluence in the 15−150 keV band is $(4.1\pm0.1)\times10^{-5}$ erg cm^{-2}. The 1−sec peak photon flux measured from T+6.90 s in the 15−150 keV band is 30.7±1.0 ph cm^{-2} s^{-1}. A fit to a simple power law gives a photon index of 1.35 ± 0.00 (chi squared 118.3 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/451901/BA/

3 XRT Observations and Analysis

The whole Swift-XRT dataset for GRB 110422A (trigger 451901, Mangano *et al.*, *GCN Circ.* 11957), consists of 67 ks of data from 820 s to 976.6 ks after the BAT trigger. The data comprise 394 s in Windowed Timing (WT) mode (from T+820 to T+1238 s) with the remainder in Photon Counting (PC) mode (from T+1243 s). Using the initial 1328 s of PC mode data and 3 UVOT images, we find an enhanced XRT position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA($J2000$), Dec($J2000$) = 112.04671, +75.10666 which is equivalent to RA($J2000$) = 07^h 28^m 11.21^s Dec($J2000$) = $+75^d$ $06^{'}$ $24.0^{"}$ with an uncertainty of 1.7 arcsec (radius, 90% confidence, Evans *et al.*, *GCN Circ.* 11965).

Preliminary refined analysis has been reported in Mangano *et al.*, *GCN Circ.* 11968. The 0.3−10 keV XRT light curve (Fig.2) can be modelled with a broken power-law with a smooth break, with the following best fit parameters:
α_1=0.74 ± 0.08, T_{break1}=T+5552±2032 s, α_2=1.69±0.05.

A spectrum formed from the 394 s WT mode data can be fitted with an absorbed power-law with a photon spectral index of $1.811^{+0.073}_{-0.071}$. The best-fitting intrinsic absorption column at redshift z=1.77 is $1.27^{+0.22}_{-0.20} \times 10^{22}$ cm^{-2}, in excess of the Galactic value of 4.2×10^{20} cm^{-2} (Kalberla *et al.*, 2005). A spectrum formed from the initial 12.5 ks of PC mode data (from T+1243 s to T+59.1 ks) can be fitted with an absorbed power-law with a photon spectral index of $1.886^{+0.071}_{-0.069}$. The best-fitting intrinsic absorption column is $1.04^{+0.19}_{-0.18}\times10^{22}$ cm^{-2}. The counts to observed (unabsorbed) 0.3−10 keV flux conversion factor deduced from this spectrum is 3.9×10^{-11} (5.2×10^{-11}) erg cm^{-2} s^{-1}.

The results of the XRT-team automatic analysis are available at
http://www.swift.ac.uk/xrt_curves/00451901.

4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 110422A approximately 822 s after the BAT detection (Mangano *et al.*, *GCN Circ.* 11957). An optical afterglow consistent with the optical position found by Klunko *et al.*, *GCN Circ.* 11958 and others is found in the UVOT, and is clearly fading. It is detected in initial exposures in both *white* and *b*, and also in *v* and *u* when the initial exposures are summed up.

Preliminary magnitudes and/or 3-sigma upper limits for the initial *white*, *u*, *v*, *b*, *uvw*1, *uvm*2 and *uvw*2 optimally co-added exposures are given in the following Table 1 where T_{start} and T_{stop} are the start and stop time of the observation (Breeveld *et al.*, *GCN Circ.* 11969).

Filter	T_{start}(s)	T_{stop}(s)	Exp(s)	Magnitude/Upper Limit
white (FC)	822	972	147	18.80 ± 0.12
white (summed)	1054	1766	97.2	19.50 ± 0.23
white	7837	8037	197	>20.4
v (summed)	1104	2336	156	18.72 ± 0.35
b	1029	1049	19.4	18.02 ± 0.3
b (summed)	1202	2435	156	18.97 ± 0.22
u (summed)	1004	2410	175	18.80 ± 0.26
uvw1 (summed)	980	2385	175	>19.4
uvm2 (summed)	1128	2360	156	>19.4
uvw2 (summed)	1079	2310	156	>19.6

Table 1: Magnitudes or 3-sigma upper limits from UVOT observations. (FC) stands for Finding Chart.

The above magnitudes are not corrected for the Galactic extinction corresponding to a reddening of E(B-V) = 0.05 (Schlegel et al., 1998, ApJS, 500, 525). The photometry is on the UVOT photometric system described in Poole et al. (2008, MNRAS, 383, 627).

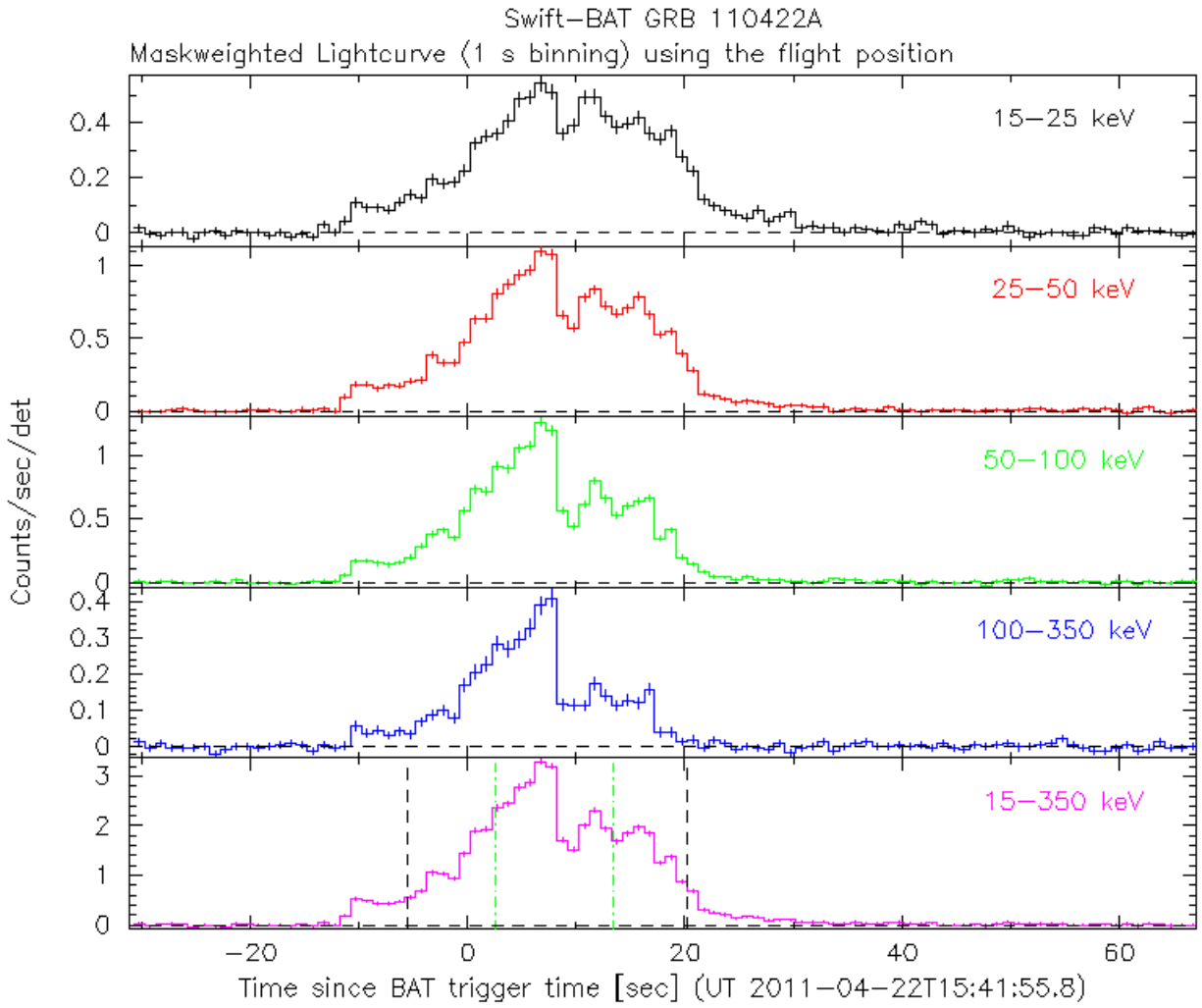

Figure 1: BAT Light curve. The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts s^{-1} illuminated-detector^{-1} (note illum-det = 0.16 cm^2) and T_0 is 2011 Apr 22 15:41:55 UT.

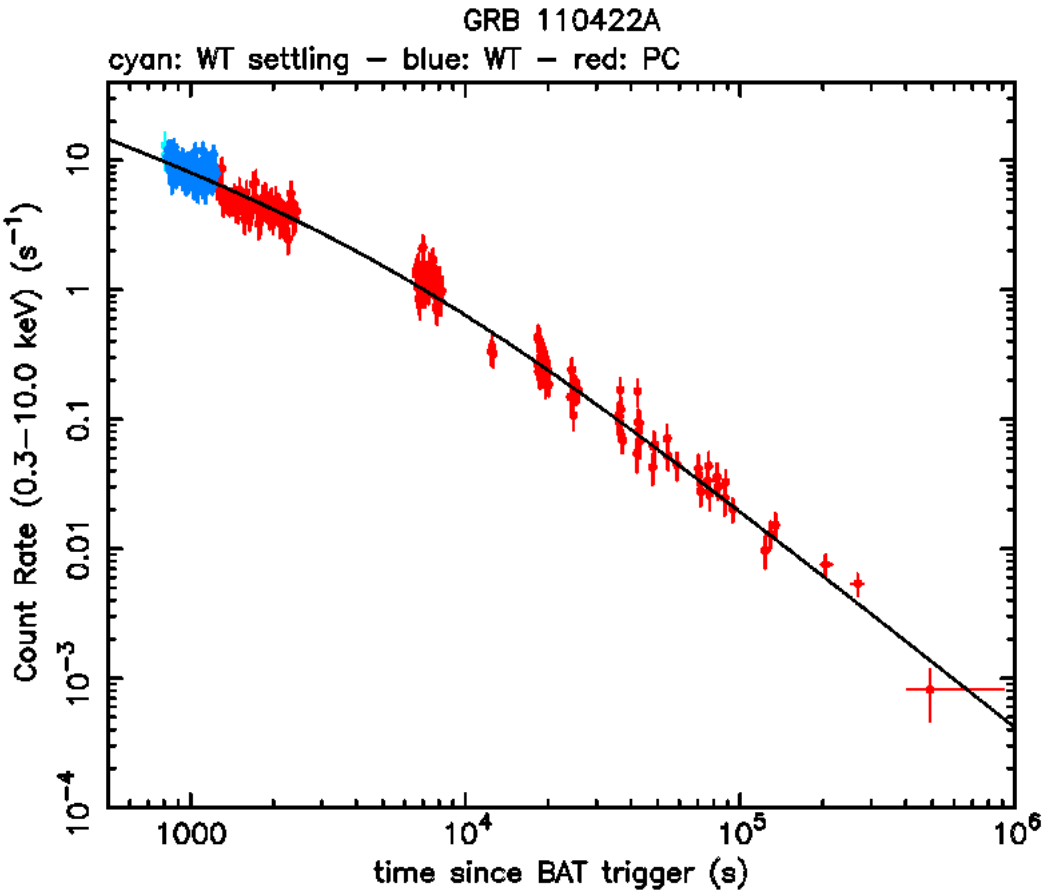

Figure 2: XRT Light curve. Counts/s in the 0.3−10 keV band: Windowed Timing mode (blue), and Photon Counting mode (red). The approximate conversion is 1 count/s = $\sim 5.2 \times 10^{-11}$ erg cm^{-2} s^{-1}.