# Swift Observation of GRB 130606A

*T. N. Ukwatta (MSU), M. Stamatikos (OSU/NASA/GSFC), A. Maselli (INAF-IASFPA), T. A. Pritchard (PSU), S. D. Barthelmy (GSFC), D. N. Burrows (PSU), M. H. Siegel (PSU), and N. Gehrels (GSFC) for the Swift Team*

## 1 Introduction

BAT triggered (Trigger 557589) on GRB 130606A at 21:04:39 UT (Ukwatta et al., 2013). Swift slewed immediately to the burst. This was a $15.09\,\sigma$ rate-trigger on a burst with $T_{90} = 276.58 \pm 19.31$ sec. The XRT began observing the field at 21:05:51.4 UT, 72.4 seconds after the BAT trigger and found a uncatalogued X-ray source. The UVOT started settled observations 80 seconds after the trigger and no optical afterglow was detected. Our best position is the enhanced XRT position at RA($J2000$) = 249.39633 deg (16h 37m 35.12s), Dec($J2000$) = +29.79622 deg (+29d 47′ 46.4″) with an uncertainty of 1.5 arcsec (90% confidence).

Subsequent ground based optical and NIR observations have identified a fading optical/NIR afterglow outside the XRT error circle located at RA($J2000$) = $16h\,37m\,35.188s$, $Dec$(J2000) = +29d 47' 47.03" (Xu et al., 2013; Nagayama et al., 2013; Virgili et al., 2013; Sonbas et al., 2013; Butler et al., 2013). The XRT uncertainty was effected by the pointing instability of the Swift spacecraft at the time of the trigger. Optical spectroscopic studies have determined that this is a high-redshift burst with $z = 5.913$ (Castro-Tirado et al., 2013; Lunnan et al., 2013).

## 2 BAT Observation and Analysis

Using the data set from $T - 240$ to $T + 962$ sec, further analysis of BAT GRB 130606A has been performed by BAT team (Barthelmy et al., 2013). The BAT ground-calculated position is RA($J2000$) = 249.390 deg (16h 37m 33.6s), Dec($J2000$) = 29.796 deg (+29d 47′ 44.5″) ± 2.0 arcmin, (radius, systematic and statistical, 90% containment). The partial coding was 96% (the bore sight angle was 22.7 deg).

The BAT mask-weighted light curve (Fig. 1) shows multiple peaks. The first peak starts around $T - 5$ secs and last for 15 seconds, a cluster of weak peaks can be seen from $T + 80$ sec to $T + 110$ sec, bright two peak structure is seen from $T + 150$ sec to $T + 170$ sec, finally very weak extended multi-peak structure is observed beyond $T + 200$ sec up to $T + 500$ sec. T90 (15-350 keV) is $276.58 \pm 19.31$ sec (estimated error including systematics).

The time-averaged spectrum from $T - 1.34$ to $T + 297$ sec is best fit by a simple power-law model. The power law index of the time-averaged spectrum is $1.52 \pm 0.12$. The fluence in the 15-150 keV band is $2.9 \pm 0.2 \times 10^{-6}$ erg cm$^{-2}$. The 1-sec peak photon flux measured from $T + 160.36$ sec in the $15 - 150$ keV band is $2.6 \pm 0.2$ ph cm$^{-2}$sec$^{-1}$. 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/557589/BA/`

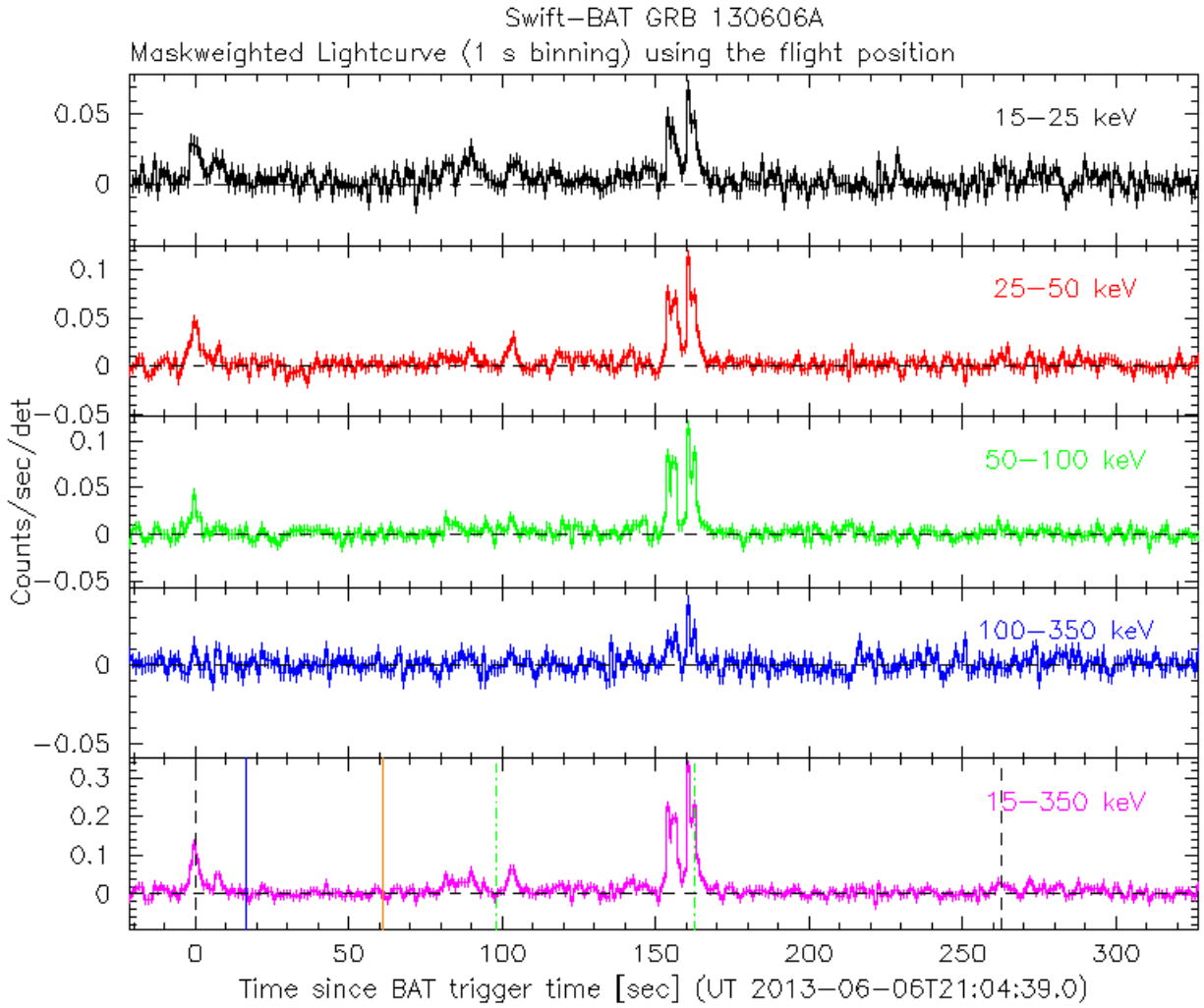


Figure 1: The mask-weighted light curve in the 4 individual plus total energy bands. The units are counts/sec/illuminated-detector and $T_0$ is 21:04:39 UT.

## 3 XRT Observations and Analysis

We have analysed 7.6 ks of XRT data for GRB 130606A, from 62 s to 58.7 ks after the BAT trigger (Burrows et al., 2013). The data comprise 499 s in Windowed Timing (WT) mode (the first 9 s were taken while Swift was slewing) with the remainder in Photon Counting (PC) mode. The enhanced XRT position (Osborne et al., 2013) for this burst is: RA, Dec = 249.39633, +29.79622 which is equivalent to:

RA (J2000): 16h 37m 35.12s
Dec (J2000): +29d 47' 46.4"

with an uncertainty of 1.5 arcsec (radius, 90% confidence).

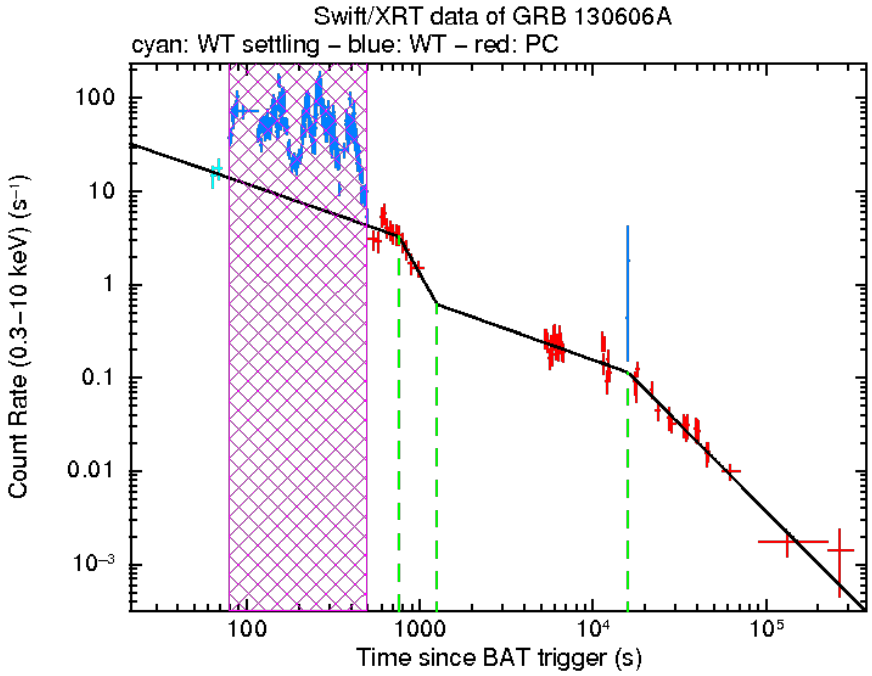


Figure 2: XRT Lightcurve. Count rate in the $0.3-10$ keV band is plotted with Window Timing (WT) mode data in blue, WT Settling data in light blue and Photon Counting (PC) mode data in red. The approximate conversion is 1 count/sec = $\sim 3.7 \times 10^{-11}$ ergs/cm$^2$/sec.

The X-ray light curve (Fig. 2) can be modelled with a series of broken power law decays with following parameters (ignoring the flaring activity early in the light curve): $\alpha_1 = 0.64^{+0.12}_{-0.16}$, $T_{\rm break1} = 758.6^{+71.3}_{-102.9}$ sec, $\alpha_2 = 3.3^{+2.3}_{-1.3}$, $T_{\rm break2} = 1.26^{+0.78}_{-0.26} \times 10^3$ sec, $\alpha_3 = 0.66^{+0.24}_{-0.21}$, $T_{\rm break3} = 1.60^{+0.44}_{-0.25} \times 10^4$ sec, and $\alpha_4 = 1.86^{+0.21}_{-0.16}$.

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of $1.55 \pm 0.04$. The best-fitting absorption column is $8.4 \pm 1.0 \times 10^{20}$cm$^{-2}$, in excess of the Galactic value of $2.0 \times 10^{20}$cm$^{-2}$ (Kalberla et al., 2005). The PC mode spectrum has a photon index of $1.84^{+0.15}_{-0.14}$ and a best-fitting absorption column of $4.5^{+3.1}_{-2.5} \times 10^{20}$cm$^{-2}$. The counts to observed (unabsorbed) $0.3-10$ keV flux conversion factor deduced from this spectrum is $3.8 \times 10^{-11}(4.2 \times 10^{-11})$ erg cm$^{-2}$count$^{-1}$.

A summary of the PC-mode spectrum is thus:
Total column: $4.5^{+3.1}_{-2.5} \times 10^{20}\mathrm{cm}^{-2}$
Galactic foreground: $2.0 \times 10^{20}\mathrm{cm}^{-2}$
Excess significance: <1.6 sigma
Photon index: $1.84^{+0.15}_{-0.14}$

The results of the XRT-team automatic analysis are available at
`http://www.swift.ac.uk/xrt_products/00557589`.

## 4 UVOT Observation and Analysis

The Swift/UVOT began settled observations of the field of GRB 130606A 84 s after the BAT trigger (Pritchard et al., 2013). No optical afterglow consistent with the optical position (Xu et al., 2013) is detected in the initial UVOT exposures. Aspect correction was lost in a number of sub-exposures resulting in image streaks, rough aspect corrections and larger apertures have been used to calibrate the field, although with a lower sensitivity. Preliminary 3-sigma upper limits using the UVOT photometric system (Breeveld et al., 2011) for the first finding chart (FC) exposure and subsequent exposures are:

| Filter | Tstart (s) | Tstop (s) | Exposure (s) | Magnitude |
|---|---|---|---|---|
| white_FC | 84 | 231 | 144 | >21.1 |
| u_FC | 293 | 543 | 246 | >20.3 |
| white | 84 | 6539 | 361 | >22.1 |
| v | 5314 | 12245 | 1148 | >20.6 |
| b | 549 | 6334 | 236 | >20.7 |
| u | 293 | 18354 | 561 | >20.4 |
| w1 | 672 | 18247 | 1102 | >21.1 |
| m2 | 5519 | 15930 | 625 | >20.5 |
| w2 | 1028 | 6744 | 216 | >20.1 |

Table 1: Magnitudes and limits from UVOT observations

The magnitudes in the table are not corrected for the Galactic extinction due to the reddening of E(B-V) = 0.02 in the direction of the burst (Schlegel et al., 1998).

## References

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