

# Swift Observations of GRB 140709B

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## 1. Introduction

At 15:15:45 UT, the Swift Burst Alert Telescope (BAT) triggered and located GRB 140709B (trigger=603866) (Swenson *et al.* GCN Circ. [16551](#)). Swift slewed immediately to the burst. At the time of the trigger, the initial BAT position was 48° from the Sun (2.5 hours East) and 111° from the 89%-illuminated Moon. **Table 1** contains the best reported positions from Swift, and the latest XRT position can be viewed at [http://www.swift.ac.uk/xrt\\_positions](http://www.swift.ac.uk/xrt_positions).

**Table 2** is a summary of GCN Circulars about this GRB from observatories other than Swift.

Standard analysis products for this burst are available at [http://gcn.gsfc.nasa.gov/swift\\_gnd\\_ana.html](http://gcn.gsfc.nasa.gov/swift_gnd_ana.html).

## 2. BAT Observations and Analysis

As reported by Palmer *et al.* (GCN Circ. [16560](#)), the BAT ground-calculated position is RA, Dec = 146.040, 63.536 deg which is RA(J2000) = 09<sup>h</sup>44<sup>m</sup>09.5<sup>s</sup> Dec(J2000) = +63°32'10.0" with an uncertainty of 1.1 arcmin, (radius, sys+stat, 90% containment). The partial coding was 99%.

The mask-weighted light curve (**Figure 1**) shows a complex structure. The first peak has a broad, symmetrical shape, starting at T-20 s, peaking at T+25 s and ending at T+60 s. Then the second episode begins at T+80 s, with multiple short (~1-2 second) peaks extending to T+140 s, before cutting off. The highest of these short peaks is at T+125 s. T<sub>90</sub> (15-350 keV) is 155.0 ± 22.3 s (estimated error including systematics).

The time-averaged spectrum from T-13.94 to T+197.51 s is best fit by a power law with an exponential cutoff. This fit gives a photon index 0.79 ± 0.30, and E<sub>peak</sub> of 152.6 ± 111.0 keV ( $\chi^2$  48.15 for 56 d.o.f.). For this model the total fluence in the 15-150 keV band is 4.2 ± 0.2 × 10<sup>-6</sup> erg cm<sup>-2</sup> and the 1-s peak flux measured from T+123.63 s in the 15-150 keV band is 0.9 ± 0.1 ph cm<sup>-2</sup> s<sup>-1</sup>. This fluence is larger than that of 78% of the long GRBs in the Second BAT GRB Catalog (Sakamoto *et al.* 2011). A fit to a simple power law gives a photon index of 1.22 ± 0.07 ( $\chi^2$  54.91 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/603866/BA/](http://gcn.gsfc.nasa.gov/notices_s/603866/BA/).

## 3. XRT Observations and Analysis

Analysis of the initial XRT data was reported by de Pasquale *et al.* (GCN Circ. [16562](#)). We have analysed 11 ks of XRT data for GRB 140709B, from 85 s to 34.6 ks after the BAT trigger. The data comprise 207 s in Windowed Timing (WT) mode (the first 4 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. [16556](#)).

The late-time light curve (**Figure 2**) (from T0+4.8 ks) can be modelled with a power-law decay with a decay index of  $\alpha=1.00 \pm 0.11$ .

A spectrum formed from the WT mode data can be fitted with an absorbed power-law with a photon spectral index of 1.14 ± 0.07. The best-fitting absorption column is 2.2 (+0.5, -0.4) × 10<sup>21</sup> cm<sup>-2</sup>, in excess of the Galactic value of 4.3 × 10<sup>20</sup> cm<sup>-2</sup> (Willingale *et al.* 2013). The PC mode spectrum has a photon index of 2.05 (+0.14, -0.13) and a best-fitting absorption column of 1.8 ± 0.4 × 10<sup>21</sup> cm<sup>-2</sup>. The counts to observed (unabsorbed) 0.3-10 keV flux conversion factor deduced from this spectrum is 3.4 × 10<sup>-11</sup> (4.7 × 10<sup>-11</sup>) erg cm<sup>-2</sup> count<sup>-1</sup>.

A summary of the PC-mode spectrum is thus:

Total column: 1.8 ± 0.4 × 10<sup>21</sup> cm<sup>-2</sup>  
 Galactic foreground: 4.3 × 10<sup>20</sup> cm<sup>-2</sup>  
 Excess significance: 5.7  $\sigma$   
 Photon index: 2.05 (+0.14, -0.13)

The results of the XRT team automatic analysis are available at [http://www.swift.ac.uk/xrt\\_products/00603866](http://www.swift.ac.uk/xrt_products/00603866).

#### 4. UVOT Observations and Analysis

The Swift/UVOT began settled observations of the field of GRB 140709B 97 s after the BAT trigger (Swenson GCN Circ. [16622](#)). No optical afterglow consistent with the XRT position (Goad *et al.* GCN Circ. [16556](#)) is detected in the initial UVOT exposures. **Table 3** gives preliminary magnitudes using the UVOT photometric system (Breeveld *et al.* 2011, AIP Conf. Proc., 1358, 373). No correction has been made for the expected extinction in the Milky Way corresponding to a reddening of  $E_{B-V}$  of 0.04 mag. in the direction of the GRB (Schlegel *et al.* 1998).

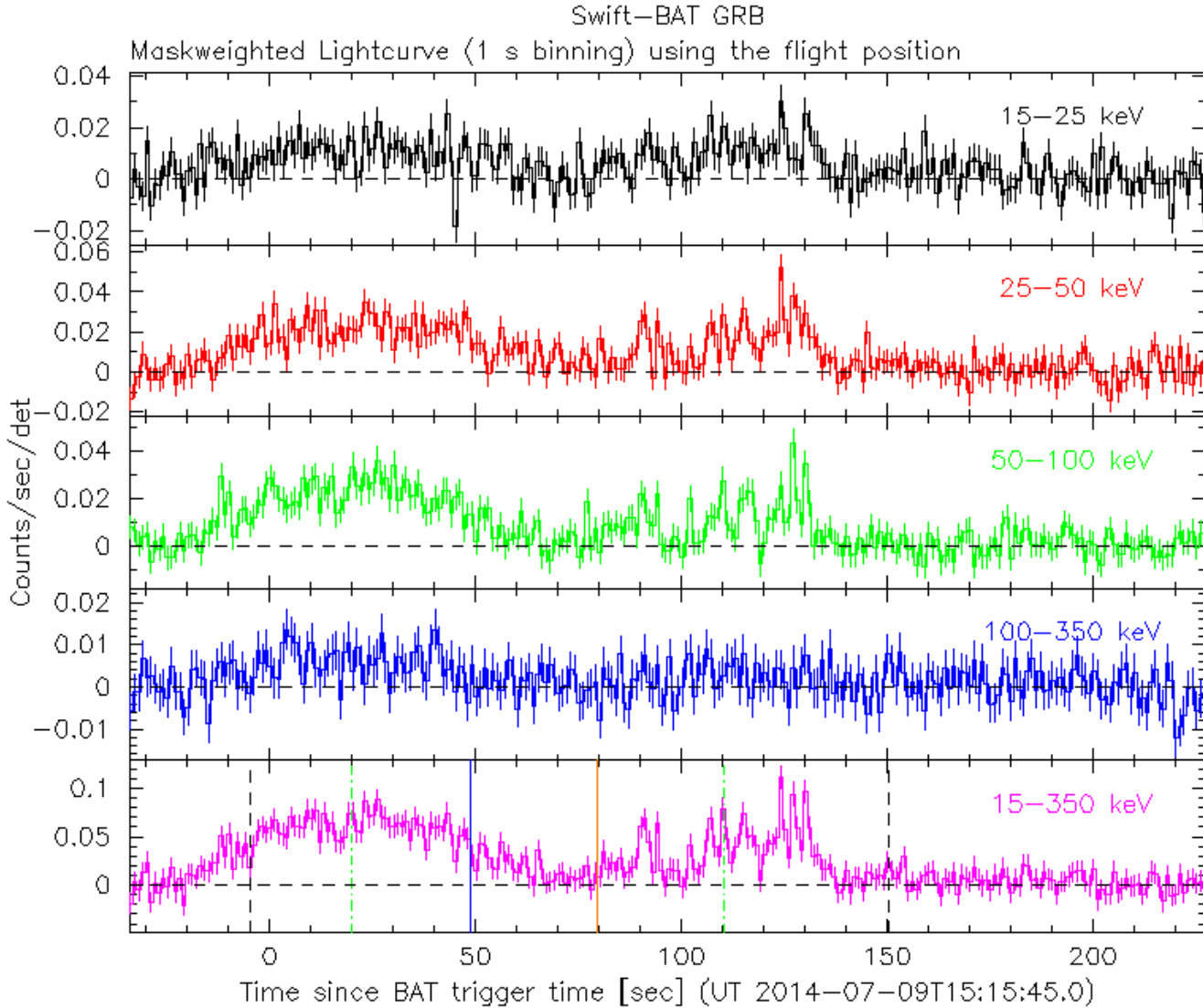


Figure 1. The BAT mask-weighted light curve in the four individual and total energy bands. The units are counts  $s^{-1}$  illuminated-detector $^{-1}$ .

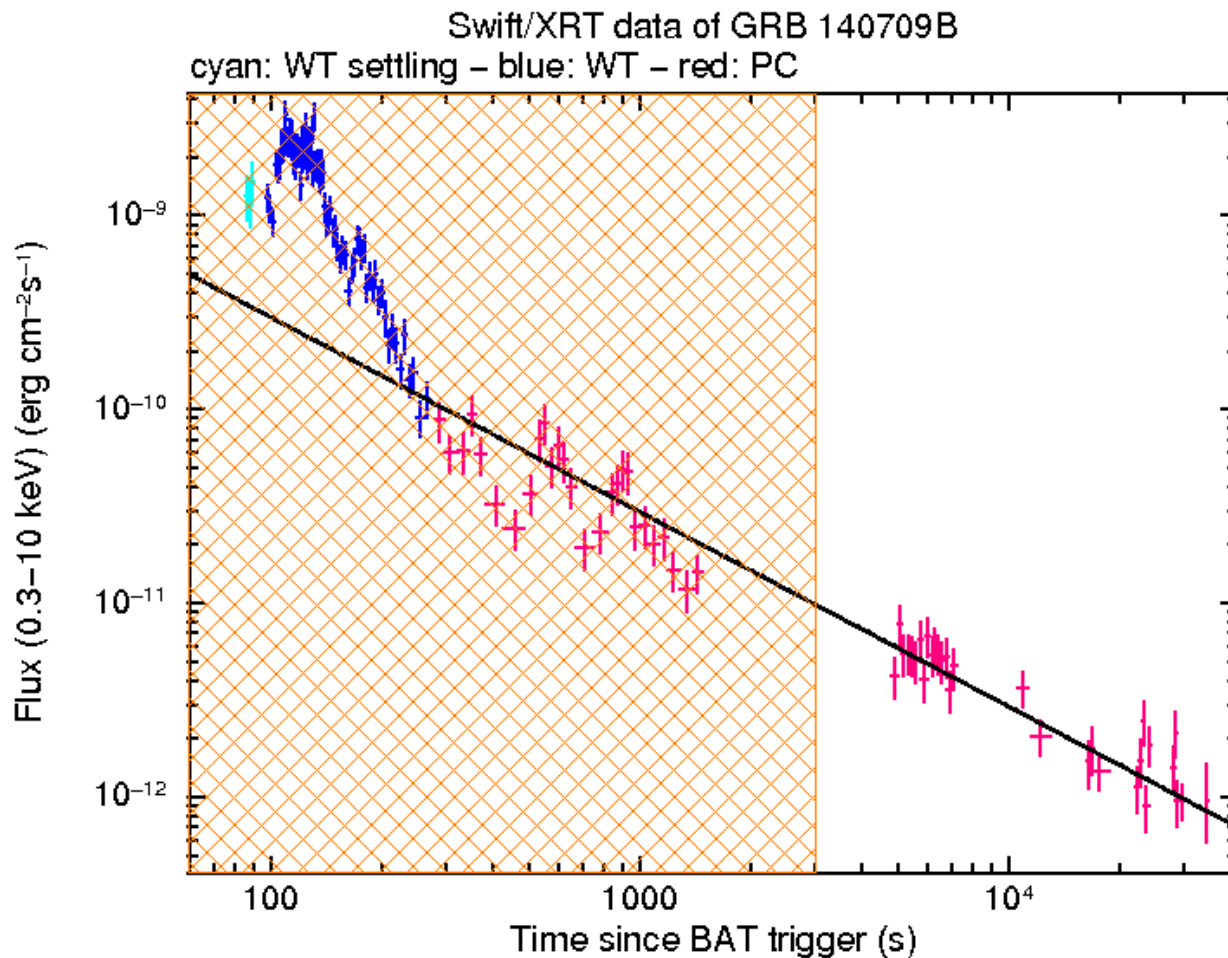


Figure 2. The XRT light curve. Any data from a crosshatched region are not included in the fit.

| RA (J2000)   | Dec (J2000)  | Error | Note         | Reference  |
|--|--------------|-------|--------------|--|
| 09 <sup>h</sup> 44 <sup>m</sup> 13.20 <sup>s</sup> | +63°31'46.5" | 1.5"  | XRT-final    | <a href="#">UKSSDC</a>                               |
| 09 <sup>h</sup> 44 <sup>m</sup> 13.02 <sup>s</sup> | +63°31'45.6" | 2.1"  | XRT-enhanced | Goad <i>et al.</i> GCN Circ. <a href="#">16556</a>   |
| 09 <sup>h</sup> 44 <sup>m</sup> 09.5 <sup>s</sup>  | +63°32'10.0" | 1.1'  | BAT-refined  | Palmer <i>et al.</i> GCN Circ. <a href="#">16560</a> |

Table 1. Positions from the Swift instruments.

| Band      | Authors               | GCN Circ.             | Subject                                   | Observatory          | Notes  |
|-----------|-----------------------|-----------------------|---|----------------------|--|
| Optical   | Ivanov <i>et al.</i>  | <a href="#">16552</a> | MASTER optical observation                | MASTER               | upper limits   |
| Optical   | Sota <i>et al.</i>    | <a href="#">16557</a> | OSN optical limit                         | Obs.de Sierra Nevada | upper limits   |
| Optical   | Volnova <i>et al.</i> | <a href="#">16558</a> | Khureltogot optical upper limit           | Khureltogot          | upper limits   |
| Optical   | Volnova <i>et al.</i> | <a href="#">16571</a> | update of Khureltogot optical upper limit | Khureltogot          | upper limits   |
| Gamma-ray | Zhang                 | <a href="#">16561</a> | Fermi GBM detection                       | Fermi GBM            | $E_{\text{peak}}=530\pm 232$ keV<br>Fluence= $1.6\pm 0.1\times 10^{-5}$ erg cm <sup>-2</sup> |

Table 2. Summary of GCN Circulars from other observatories sorted by band and then circular number.

| Filter              | T <sub>start</sub> (s) | T <sub>stop</sub> (s) | Exp(s) | Mag   |
|---------------------|------------------------|-----------------------|--------|-------|
| white <sub>FC</sub> | 4835                   | 4985                  | 147    | >20.8 |
| u <sub>FC</sub>     | 97                     | 346                   | 246    | >20.6 |
| white               | 4835                   | 6626                  | 541    | >21.7 |
| v                   | 633                    | 7037                  | 491    | >20.5 |
| b                   | 352                    | 6422                  | 534    | >20.9 |
| u                   | 97                     | 6216                  | 668    | >21.2 |
| w1                  | 683                    | 11259                 | 922    | >20.8 |
| m2                  | 1087                   | 7230                  | 440    | >21.2 |
| w2                  | 758                    | 6832                  | 471    | >20.6 |

Table 3. UVOT observations reported by Swenson (GCN Circ. [16622](#)). The start and stop times of the exposures are given in seconds since the BAT trigger. The preliminary 3- $\sigma$  upper limits are given. No correction has been made for extinction in the Milky Way.

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