Swift Observations of GRB 090424

J. K. Cannizzo (NASA/UMBC), T. N. Ukwatta (GWU), D. M. Palmer (LANL),
R. Margutti (Univ Bicocca & OAB), M. De Pasquale (MSSL/UCL), for the Swift Team

1 Introduction

BAT triggered on a long burst, GRB 090424, at 14:12:09 UT (Trigger 350311) (Cannizzo, et al., *GCN Circ.* 9223). *Swift* slewed immediately to the burst. The BAT light curve shows several bright peaks in the first 5 s, and then several smaller peaks at $T + 8$, +15, and +50 s. Total duration of about 60 s. The peak count rate was $\sim 5 \times 10^4$ c s^{-1} ($15 - 350$ keV), at $\sim T + 3$ s. XRT began observing at $T + 84.5$ s and found a bright, uncatalogued X-ray source at RA, Dec = (189.5213, +16.8364) deg, or { 12h 38m 05.11s +16d 50' 11.0"} (J2000) with $\sigma = 4.8$ arcsec (radius, 90% containment). UVOT began observing at $T + 91$ s, taking a 150 s exposure in the White filter. It found a candidate afterglow $m = 15.29 \pm 0.14$ (1σ) at RA, Dec = (189.52128, +16.83753) deg, which is { 12h 38m 05.11s +16d 50' 15.1"} (J2000) with $\sigma = 0.74$ arcsec (radius, 90%-confidence). This position is 4.1 arcsec from the center of the XRT error circle. The estimated magnitude is 15.29 ± 0.14 (1σ). No correction has been made for the expected extinction corresponding to $E(B - V) \simeq 0.03$. With a simultaneous detection, *INTEGRAL*/SPI-ACS observed a multi-peak structure[1] as did *Fermi* GBM (Connaughton et al., *GCN Circ.* 9230) and *Suzaku* WAM (Hanabata et al., *GCN Circ.* 9270). A redshift $z = 0.544$ was determined by Gemini-South and the William Herschel Telescope.

This burst has been also observed in the optical and IR by ROTSE-IIIa (Yuan et al., *GCN Circ.* 9224), TNT (fading $\Delta m \simeq 3.5$ mag from $\sim T + 100$ s to $\sim T + 1000$ s; Xin et al., *GCN Circ.* 9225), 1.23m CAHA (Gorosabel et al., *GCN Circ.* 9236), 2m Liverpool Telescope (Guidorzi et al., *GCN Circ.* 9238), 0.4m RC telescope (Oksanen *GCN Circ.* 9239), 0.5m & 1m TAOS/Lulin (Urata et al., *GCN Circ.* 9240, 9247), 8.1m Gemini-South ($z = 0.544$; Chornock et al., *GCN Circ.* 9243), 2.2m GROND La Silla (Olivares et al., *GCN Circ.* 9245), 0.35m THO (Nissinen & Hentunen, *GCN Circ.* 9246), 4.2m WHT ($z = 0.544$; Wiersema et al., *GCN Circ.* 9250), 1m Mt. Lemmon (Park et al., *GCN Circ.* 9248, 9253; Im et al., *GCN Circ.* 9275), 1.04m Sampurnanand (Roy et al., *GCN Circ.* 9278), 2.4m Gao-Mei-Gu (Mao et al., *GCN Circ.* 9305), 1.3m ANDICAM (Cobb et al., *GCN Circ.* 9313), AZT-11 CrAO (Rumyantsev et al., *GCN Circ.* 9320), and in the radio (VLA bright 673 ± 39 μJy; Chandra et al., *GCN Circ.* 9260). These observations are summarized in Figure 1.

2 BAT Observation and Analysis

Using the data set from $T - 60$ to $T + 243$ s, further analysis of BAT GRB 090424 was performed by the *Swift* team (Sakamoto et al., *GCN Circ.* 9231). The BAT ground-calculated position is RA, Dec = (189.531, 16.829) deg, or {12h 38m 07.4s +16d 49' 45.9"} (J2000) with $\sigma = 1.0$ arcmin, (radius, sys+stat, 90% containment). The partial coding was 12%.

The mask-weighted light curve shows several overlapping bright peaks starting at about $T - 2$s and ending at about $T + 5$ s. There are 3 much weaker, and broader, peaks at $T + 7$, +15, and +50 s. The emission returns to background at around $T + 150$ s. T_{90} ($15 - 350$ keV) is 48 ± 3 s (estimated error including systematics). The BAT light curve is shown in Figure 2.

[1] http://isdc.unige.ch/Soft/ibas/results/triggers/spiacs/2009-04/2009-04-24T14-12-07.4257-22473-00007-0.png

The time-averaged spectrum from $T-0.7$ to $T+103.2$ s is best fit by a power law with an exponential cutoff. This fit gives a photon index 1.19 ± 0.15, and $E_{\rm peak}$ of 108.6 ± 20.3 keV ($\chi^2 = 45.8$ for 56 d.o.f.). For this model the total fluence in the $15-150$ keV band is $2.13 \pm 0.04 \times 10^{-5}$ erg cm^{-2} and the 1−s peak flux measured from $T-0.1$ s in the $15-150$ keV band is 71 ± 2 ph cm^{-2} s^{-1}. A fit to a simple power law gives a photon index of 1.62 ± 0.03 ($\chi^2 = 72.0$ for 57 d.o.f.). All the quoted errors are at the 90% confidence level.

3 XRT Observation and Analysis

Using 564 s of PC data and 2 UVOT images for GRB 090424 (Goad et al., *GCN Circ.* 9232), the astrometrically corrected X-ray position (using the XRT-UVOT alignment and matching UVOT field sources to the USNO-B1 catalogue): RA, Dec = (189.52107, +16.83773), or {12h 38m 5.06s; +16d 50' 15.8"} (J2000) with $\sigma = 1.7$ arcsec (radius, 90% confidence). The light-curve can be modelled by a double broken power-law, with a first decaying index $\alpha_1 = 1.29 \pm 0.05$ and a first break time of about 260 s. The decay then flattens to $\alpha_2 = 0.74 \pm 0.02$. After 1450 s the decay is best modelled by a power-law index $\alpha_3 = 1.15 \pm 0.05$ (Margutti et al., *GCN Circ.* 9237). The XRT light curve is shown in Figure 3.

The very good statistics allows us to observe spectral evolution in WT data before the first break, with the simple power law photon index evolving from 2.6 to 2.1. A spectrum extracted from WT mode data in the time interval $0.4-1.4$ ks can be modelled with an absorbed power-law with a photon index $\Gamma = 2.13 \pm 0.05$ and best-fitting absorption column $N_H = (0.20 \pm 0.01) \times 10^{22}$ cm^{-2}, in excess of the Galactic value of 1.9×10^{20} cm^{-2}.

The spectrum extracted from PC data in the time interval $6.1-8$ ks can be modelled with an absorbed power-law, with $\Gamma = 2.06 \pm 0.09$ and a column density of $N_H = (0.27 \pm 0.03) \times 10^{22}$ cm^{-2}. The observed (unabsorbed) 0.3 -10 keV flux over this time interval is 4.2×10^{-11} (6.7×10^{-11}) erg cm^{-2} s^{-1}. Uncertainties are given at 90% confidence.

If the light-curve continues to decay with $\alpha \simeq 1.15$, the count rate at $T + 24$ hr is estimated to be 0.10 c s^{-1}, which corresponds to an observed (unabsorbed) flux of 4.2×10^{-12} (6.7×10^{-12}) erg cm^{-2} s^{-1}.

4 UVOT Observation and Analysis

The Swift/UVOT started settled observations of the burst GRB090424 (Schady et al., *GCN Circ.* 9234), with the finding chart (fc) exposure in white light at $T + 167$ s. The afterglow is detected in the all filters, placing an upper limit on the redshift of ~ 1.3. The combined UVOT data indicates that the afterglow is fading with a decay index of $\alpha \simeq 0.9$.

The UVOT magnitudes are:

Filter	Tmid(s)	Exp(s)	Magnitude
white (fc)	167	147.4	15.27 +/- 0.01
u (fc)	429	245.8	16.40 +/- 0.03
white	594	19.4	16.99 +/- 0.07
v	644	19.5	16.86 +/- 0.19

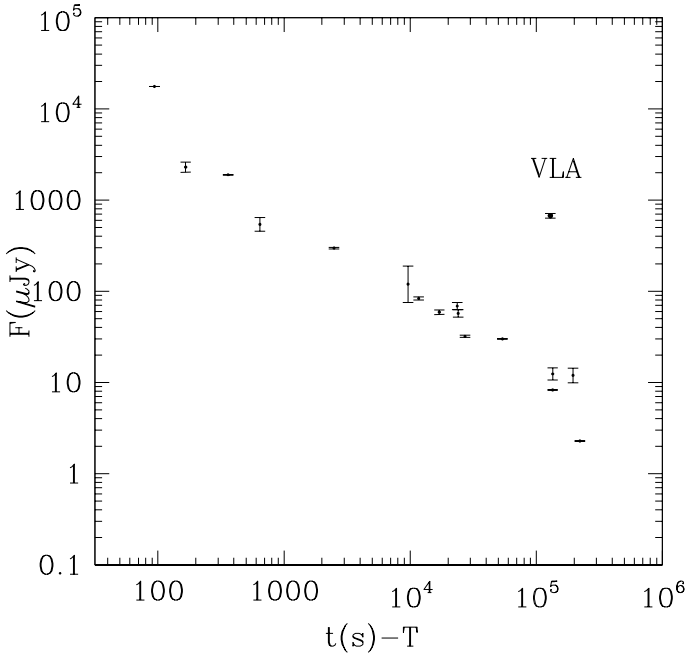

Figure 1: Optical/IR/Radio observations as summarized in section 1.

b	570	19.5	17.27 +/- 0.13
u	1122	19.5	17.44 +/- 0.20
uvw1	695	19.5	16.81 +/- 0.19
uvm2	670	19.4	17.39 +/- 0.34
uvw2	793	19.4	17.51 +/- 0.27

The values quoted above are in the UVOT photometric system (Poole et al. 2008, MNRAS, 383, 627) and are not corrected for the expected Galactic extinction corresponding to a reddening of $E(B-V) = 0.025$ mag in the direction of the burst (Schlegel et al. 1998).

The UVOT combined light curve, normalised to the white band filter, is shown in Figure 4. The afterglow is detected in all filters out to $\sim T + 40000$s, and the light curve is best fit by a broken power-law model with $\alpha_1 = 1.45 \pm 0.05$, $t_{\rm bk} = 329 + 42/-40$s, and $\alpha_2 = 0.95 \pm 0.02$.

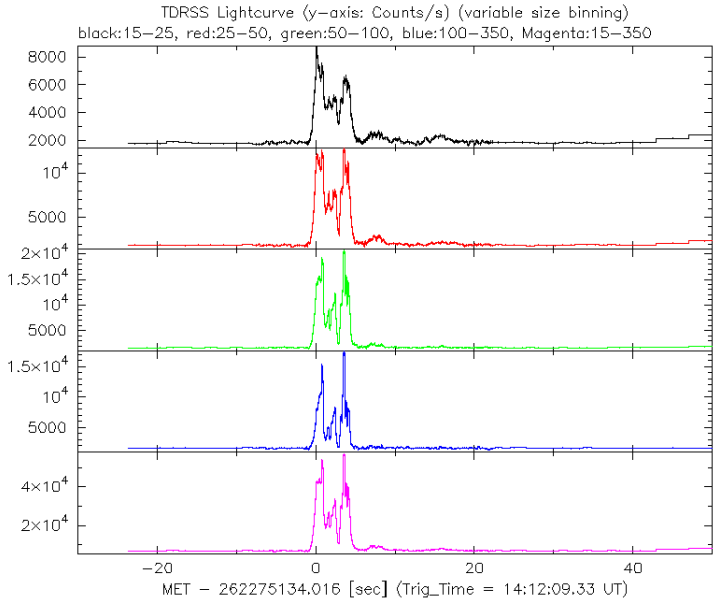

Figure 2: BAT Lightcurve. The light curve in the 4 individual plus total energy bands ($15-25$ keV, $25-50$, $50-100$, $100-150$, and $15-150$).

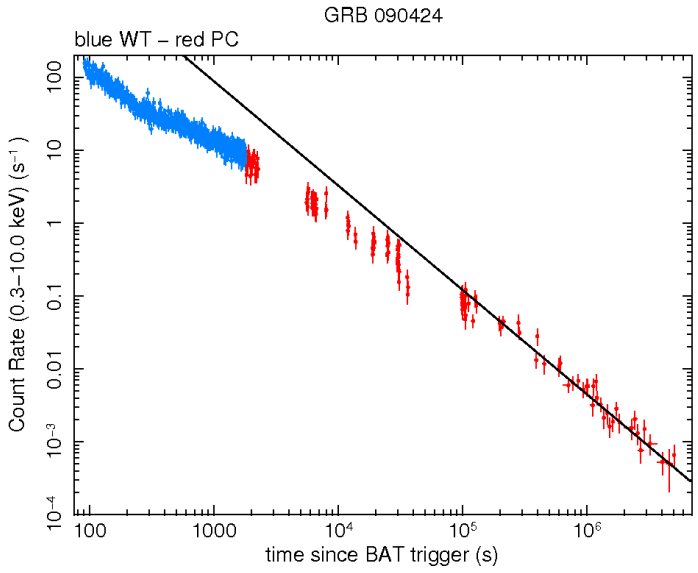

Figure 3: XRT Lightcurve. A broken powerlaw fit gives: $\alpha_1 = 1.29 \pm 0.05$, $t_{\rm break,\ 1} = 260$s, $\alpha_2 = 0.74 \pm 0.02$, $t_{\rm break,\ 2} = 1450$s, $\alpha_3 = 1.16 \pm 0.01$. Fitting with a SPL starting at $T + 2 \times 10^5$ s yields $\alpha = -1.4 \pm 0.1$.

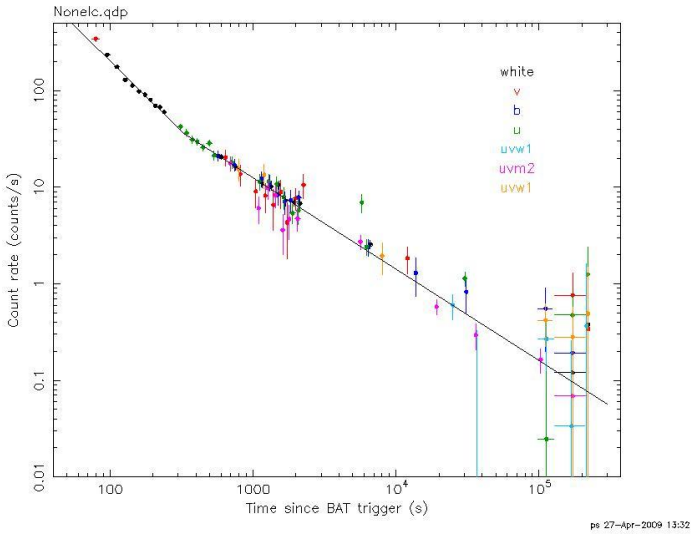

Figure 4: UVOT Lightcurve. A broken powerlaw fit gives: $\alpha_1 = 1.45 \pm 0.05$, $t_{\rm break} = 329 + 42/-40$s, $\alpha_2 = 0.95 \pm 0.02$.