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THE FIRST *SWIFT* BAT GAMMA-RAY BURST CATALOG

T. Sakamoto,[1,2] S. D. Barthelmy,[1] L. Barbier,[1] J. R. Cummings,[3,4] E. E. Fenimore,[5] N. Gehrels,[1]
D. Hullinger,[6] H. A. Krimm,[4,7] C. B. Markwardt,[4,8] D. M. Palmer,[5] A. M. Parsons,[1]
G. Sato,[1,9] M. Stamatikos,[1,2] J. Tueller,[1] T. N. Ukwatta,[1,10] and B. Zhang[11]
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ABSTRACT

We present the first *Swift* Burst Alert Telescope (BAT) catalog of gamma-ray bursts (GRBs), which contains bursts detected by the BAT between 2004 December 19 and 2007 June 16. This catalog (hereafter the BAT1 catalog) contains burst trigger time, location, 90% error radius, duration, fluence, peak flux, and time-averaged spectral parameters for each of 237 GRBs, as measured by the BAT. The BAT-determined position reported here is within 1.75′ of the *Swift* X-Ray Telescope (XRT)-determined position for 90% of these GRBs. The BAT T_{90} and T_{50} durations peak at 80 and 20 s, respectively. From the fluence-fluence correlation, we conclude that about 60% of the observed peak energies, $E_{\rm peak}^{\rm obs}$, of BAT GRBs could be less than 100 keV. We confirm that GRB fluence to hardness and GRB peak flux to hardness are correlated for BAT bursts in analogous ways to previous missions' results. The correlation between the photon index in a simple power-law model and $E_{\rm peak}^{\rm obs}$ is also confirmed. We also report the current status for the on-orbit BAT calibrations based on observations of the Crab Nebula.

Subject headings: gamma rays: bursts

Online material: color figures, machine-readable tables

1. INTRODUCTION

The *Swift* mission (Gehrels et al. 2004) has revolutionized our understanding of gamma-ray bursts (GRBs). Because of the sophisticated on-board localization capability of the *Swift* Burst Alert Telescope (BAT; Barthelmy et al. 2005a) and the fast spacecraft pointing of *Swift*, more than 90% (30%) of *Swift* GRBs have an X-ray (optical) afterglow observation from the *Swift* X-Ray Telescope (XRT; Burrows et al. 2005a) or the *Swift* UV/Optical Telescope (UVOT; Roming et al. 2005) within a few hundred seconds after the trigger. *Swift* opens a new opportunity to study the host galaxies and the distance scale of the mysterious short-duration GRBs.[12] (e.g., Gehrels et al. 2005; Barthelmy et al. 2005b) *Swift* allows us to use GRBs as a tool for investigation of the early universe (see detection of GRB 050904 at a redshift of 6.29; Cusumano et al. 2006). *Swift* found the fourth GRB, GRB 060218, which is securely associated with a supernova (Campana et al. 2006). Furthermore, *Swift* is providing X-ray afterglow data (e.g., Zhang et al. 2006) that give us insight into details of the fireball model and to the nature of the central engine.

Here we present the first BAT GRB catalog, including 237 GRBs detected by BAT from 2004 December 19 to 2007 June 16. In § 2, we describe the BAT instrument. In § 3, we show the current status of the on-orbit calibration of the BAT based on the Crab observations. In § 4, we describe the analysis methods for the catalog. In § 5, we describe the content of the tables of the catalog and show the results of the prompt emission properties of the BAT GRBs based on the catalog. Our conclusions are summarized in § 6. All quoted errors in this work are at the 90% confidence level.

2. INSTRUMENTATION

The BAT is a highly sensitive, large field of view (FOV) (1.4 sr for >50% coded FOV and 2.2 sr for >10% coded FOV), coded-aperture telescope that detects and localizes GRBs in real time. The fast and accurate BAT GRB positions with 1′–3′ error radii are the key to autonomously slewing the spacecraft to point the XRT and the UVOT. The BAT GRB position, light curves, and the detector plane image (BAT scaled map) are transmitted through TDRSS to the ground within 20–200 s after the burst trigger. The BAT detector plane is composed of 32,768 pieces of CdZnTe (CZT: $4 \times 4 \times 2$ mm), and the coded-aperture mask is composed of ~52,000 lead tiles ($5 \times 5 \times 1$ mm) with a 1 m separation between mask and detector plane. The energy range is 15–150 keV for imaging or mask-weighting[13] with a noncoded response up to 350 keV.

The CZT pixels are biased to −200 V with a nominal operating temperature of 20°C. The energy scale calibration is performed automatically on the front-end electronics (XA1) by injecting calibration pulses. This electronic calibration task is executed every ~5000 s during spacecraft slews. In addition to the electronic calibration, there are two ^{241}Am tagged sources mounted below the mask for calibrating the absolute energy scale and the detector efficiency for each CZT pixel in-flight.

[1] NASA Goddard Space Flight Center, Greenbelt, MD 20771.
[2] Oak Ridge Associated Universities, P.O. Box 117, Oak Ridge, TN 37831-0117.
[3] Joint Center for Astrophysics, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250.
[4] Center for Research and Exploration in Space Science and Technology (CRESST), NASA Goddard Space Flight Center, Greenbelt, MD 20771.
[5] Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545.
[6] Moxtek, Inc., 452 West 1260 North, Orem, UT 84057.
[7] Universities Space Research Association, 10211 Wincopin Circle, Suite 500, Columbia, MD 21044-3432.
[8] Department of Astronomy, University of Maryland, College Park, MD 20742.
[9] Institute of Space and Astronautical Science, JAXA, Kanagawa 229-8510, Japan.
[10] Center for Nuclear Studies, Department of Physics, George Washington University, Washington, DC 20052.
[11] Department of Physics and Astronomy, University of Nevada, Las Vegas, NV 89154.
[12] The short burst GRB 050709, which was observed and promptly localized by *HETE-2*, is also a good example of a short GRB observation (Villasenor et al. 2005).

[13] Mask-weighting is a background-subtraction technique based on the modulation resulting from the coded mask.

TABLE 2
BAT GRB Energy Fluence

GRB Name	Spectral Model	Fluence (10^{-8} ergs cm^{-2})					Start (s)	Stop (s)
		S(15–25)	S(25–50)	S(50–100)	S(100–150)	S(15–150)		
041217	CPL	30.6 ± 3.4	73.2 ± 3.4	109.0 ± 5.6	64.4 ± 8.3	277.0 ± 12.3	+0.8	+8.2
041219A	...	...	...	...	...	...	...	...
041219B	...	...	...	...	...	...	...	...
041219C	PL	29.6 ± 2.6	39.7 ± 2.1	39.2 ± 3.1	22.7 ± 2.9	131.0 ± 7.3	+6.7	+14.2
041220	PL	6.2 ± 0.7	10.2 ± 0.7	12.9 ± 1.2	9.1 ± 1.3	38.3 ± 2.8	−0.2	+6.8
041223	PL	143.0 ± 6.1	334.0 ± 8.3	617.0 ± 10.6	581.0 ± 16.4	1670.0 ± 27.9	−10.5	+145.9
041224	CPL	134.0 ± 12.2	261.0 ± 10.7	316.0 ± 14.6	162.0 ± 21.5	873.0 ± 34.8	−109.6	+116.3
041226	PL	3.9 ± 1.6	7.5 ± 1.8	11.4 ± 3.4	9.2 ± 4.4	32.1 ± 8.3	−1.3	+93.4
041228	PL	52.5 ± 4.6	90.5 ± 4.5	119.0 ± 6.2	86.7 ± 7.4	349.0 ± 15.2	−0.4	+70.6

Note.—Table 2 is available in its entirety in the electronic edition of the *Supplement*. A portion is shown here for guidance regarding its form and content.

The next four columns give the locations by the ground process in equatorial (J2000.0) coordinates, the signal-to-noise ratio of the BAT image at the location, and the radius of the 90% confidence region in arcmin. The 90% error radius is calculated based on the signal-to-noise ratio of the image using the following equation, which is derived from the BAT hard X-ray survey process,[23,24]

$$r_{90\%} = 10.92\ ;\ \mathrm{SNR}^{-0.7}\ (\mathrm{arcmin}),$$

where SNR is the signal-to-noise ratio of the BAT image. However, due to the limitation of the BAT point-spread function, we decided to quote the minimum allowed value of $r_{90\%}$ as $1'$ in the catalog. The next two columns specify the burst durations that contain from 5% to 95% (T_{90}) and from 25% to 75% (T_{50}) of the total burst fluence. These durations are calculated in the 15–350 keV band.[25] The next two columns are the start and stop time from the BAT trigger time of the event data. The last column is the comments.

The energy fluences calculated in various energy bands are summarized in Table 2. The first column is the GRB name. The next column specifies the spectral model that was used in deriving the fluences (PL: simple power-law model, eq. [1]; CPL: cutoff power-law model, eq. [2]). The next five columns are the fluences in the 15–25, 25–50, 50–100, 100–150, and 15–150 keV bands. The unit of the fluence is 10^{-8} ergs cm^{-2}. The last two columns specify the start and the stop time from the BAT trigger time that was used to calculate the fluences. Note that since our analysis is based on the available event data, 6 bursts with the incomplete data (see the twelfth column of Table 1) might not include the whole burst emission.

Tables 3 and 4 summarize the 1 s peak photon and energy fluxes in various energy bands. The first column is the GRB name. The next column specifies the spectral model used in deriving the 1 s peak flux. The next five columns are the 1 s peak photon and energy fluxes in the 15–25, 25–50, 50–100, 100–150, and 15–150 keV bands. The unit of the flux is photons cm^{-2} s^{-1} for the peak photon flux and 10^{-8} ergs cm^{-2} s^{-1} for the peak energy flux. The last two columns specify the start and the stop time from the BAT trigger time that were used to calculate the peak fluxes.

The time-averaged spectral parameters are listed in Table 5. The first column is the GRB name. The next three columns are the photon index, the normalization at 50 keV, and χ^2 of the fit for a PL model. The degree of freedom is 57 for all bursts in a PL fit. The next four columns are the photon index, $E^{\rm obs}_{\rm peak}$, the normalization at 50 keV, and χ^2 of the fit in a CPL model. The degree of freedom is 56 for all bursts for a CPL fit. The spectral parameters in a CPL are only shown for the bursts that meet the criteria described in the § 4.

[23] See http://heasarc.gsfc.nasa.gov/docs/swift/analysis/bat_digest.html.
[24] SWIFT-BAT-CALDB-CENTROID-v1, http://swift.gsfc.nasa.gov/docs/heasarc/caldb/swift/docs/bat/index.html.
[25] The coded mask is transparent to photons above 150 keV. Thus, photons above 150 keV are treated as background in the mask-weighted method. The effective upper boundary is ∼150 keV.

TABLE 3
BAT GRB 1 s Peak Photon Flux

GRB Name	Spectral Model	Flux (photons cm^{-2} s^{-1})					Start (s)	Stop (s)
		$F^{\rm p}_{\rm ph}$(15–25)	$F^{\rm p}_{\rm ph}$(25–50)	$F^{\rm p}_{\rm ph}$(50–100)	$F^{\rm p}_{\rm ph}$(100–150)	$F^{\rm p}_{\rm ph}$(15–150)		
041217	PL	2.11 ± 0.28	2.25 ± 0.18	1.71 ± 0.14	0.80 ± 0.11	6.86 ± 0.52	+3.3	+4.3
041219A	...	...	...	...	...	...	...	...
041219B	...	...	...	...	...	...	...	...
041219C	PL	0.96 ± 0.15	0.82 ± 0.09	0.48 ± 0.06	0.18 ± 0.04	2.45 ± 0.25	+8.1	+9.1
041220	PL	0.52 ± 0.04	0.58 ± 0.03	0.47 ± 0.02	0.23 ± 0.02	1.81 ± 0.14	0.0	+1.0
041223	PL	1.45 ± 0.14	2.12 ± 0.12	2.32 ± 0.10	1.45 ± 0.10	7.35 ± 0.32	+35.0	+36.0
041224	PL	0.80 ± 0.15	0.94 ± 0.11	0.79 ± 0.04	0.41 ± 0.03	2.94 ± 0.30	−0.1	+0.9
041226	PL	0.09 ± 0.02	0.11 ± 0.02	0.10 ± 0.02	0.05 ± 0.01	0.35 ± 0.05	+3.3	+4.3
041228	PL	0.60 ± 0.16	0.54 ± 0.04	0.33 ± 0.03	0.13 ± 0.02	1.61 ± 0.25	+22.0	+23.0

Notes.—Table 3 is available in its entirety in the electronic edition of the *Supplement*. A portion is shown here for guidance regarding its form and content. Dagger (†) signifies that the signal-to-noise ratio of the peak spectrum is too low to perform a spectral fit.

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