GRB OBSERVATIONS WITH THE FERMI GBM

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The Fermi GBM is performing on orbit as expected. We have triggered on over 100 gamma-ray bursts, with four or so in common with the LAT. GBM covers the energies 8 keV to 40 MeV using two sets of overlapping detectors, with moderate energy resolution. I discuss the on-orbit performance of GBM, as well as the GRB global properties we are collecting, with an emphasis on burst spectroscopy.

1 Introduction

The *Fermi* Gamma-ray Burst Monitor (GBM) was designed for gamma-ray burst (GRB) spectroscopy, localization, and other analyses especially to support the Large Area Telescope (LAT). As such, it is not as sensitive as other, currently operating instruments, such as the Swift Burst Alert Telescope, nor is it required to pinpoint burst localizations for large ground-based telescopes. What it is designed for, to work in tandem with the LAT to identify interesting events and to provide continuum spectroscopy in the energies below the LAT threshold, it has done quite well.

The GBM consists of two type of detectors, 12 sodium iodide (NaI) detectors, placed around the *Fermi* spacecraft to preferentially cover the sky above the Earth's limb (assuming zenith pointing, on the average), plus two bismuth germanate (BGO) detectors, one each on opposite sides of the spacecraft. The NaI detectors cover the low-energy regime, 8 – 1000 keV, while the BGO detectors cover the energies in the middle regime between the NaI range up to the LAT threshold, 200 keV – 40 MeV. The placement and energy coverage of the NaI detectors make them suitable for coarse-grained GRB localization, with an estimated systematic error of roughly 3 degrees to be combined in quadrature with the statistical error. In Table 1, we present the average location errors for the different stages of the location process, as of February 2009: done on-board by the GBM Flight Software (FSW), done automatically on the ground using FSW generated background and source data selections, and performed by a human using their best judgement for data selection. This last method also includes a much better determination of the scattering of gamma-rays from the Earth's atmosphere than is possible on-board, as well as a one-degree grid of fluxes for each detector mapped onto the sky. The on-board grid has five degree resolution. The FSW localizations provide the basis for the LAT decision to repoint the spacecraft autonomously; with a fairly large field of view, the LAT needs only to know whether the trigger is on or out of the field of view. The requirement for GBM is 15° for this case.

Table 1: GBM Localizations.

Type of localization	Average Error (deg.)
FSW (on-board)	8.6
Ground (auto)	8.3
Human in-the-loop	4.4

2 Calibration

Extensive validation of our energy calibration has been done both before launch and also during flight. The flight electronics have been verified to be highly linear, so it becomes important to map out the non-linear light output of the NaI detectors, especially at the low energy end. We used several radioactive sources at various stages in the assembly and integration of the instrument, as well as accelerators in Germany (BESSY) and Stanford University [1]. In orbit, there are a number of lines at known energies in the background spectra that may be used both to validate the calibration as well as to serve as features to lock in the automatic gain control (AGC) function of the GBM FSW. For the NaI detectors, we use the 511 keV annihilation line for AGC, which is nearly always visible, as in Figure 1. As another valuable reference point, each spectrum exhibits a shoulder below the 32 keV Iodine K-shell electron escape feature. The BGO background spectrum is rich and varying, with spectral features due to activation from the hard radiation that the observatory passes through in the South Atlantic Anomaly, as well as persistent atmospheric features. The GBM team has settled on a line at 2.2 MeV for the AGC, which is also present nearly all the time (see Figure 1).

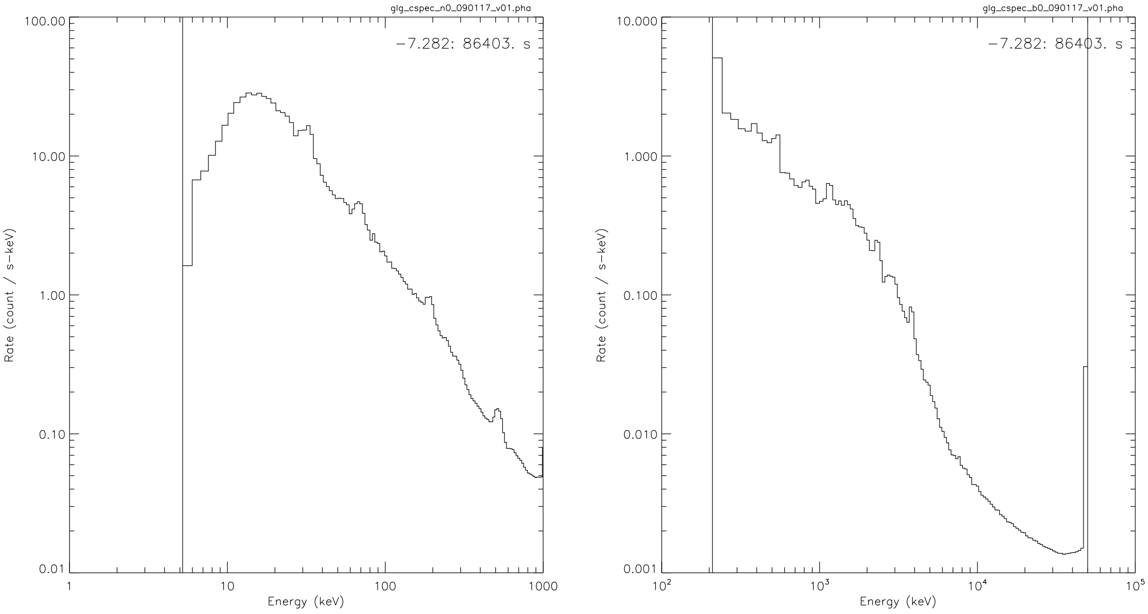

Figure 1: Typical GBM background spectra. *left*: NaI *right*: BGO

3 Data Products

As a service to the GRB community, the GBM team will provide a series of successively more refined data products, all in FITS (Flexible Image Transport System) format. The first, of course, will be the data themselves, which consist of three types: CPSEC, fully energy resolved (128 channel) spectroscopy data, one file for each detector, at medium time resolution (0.256 s during a trigger), spanning T ± 4000 s. CTIME data consists of 8 energy channels at 0.064 s time resolution, spanning T ± 1000 s. Both of these data products are delivered as a time series of spectra, FITS PHA Type-II. Finally, Time-Tagged Event files consist of FITS EVENT data, 128 energy channels, spanning T $-20+300$ s. Detector response matrices are provided for each data type (the TTE data share responses with CSPEC).

At a higher level of abstraction, the GBM team will be performing several global catalog tasks for each trigger and publishing the catalog results. First of all, the human-in-the-loop ground localization of each trigger will provide consistency checks on the on-board performance, as well as serving as the input for the response matrix generation, when localizations derived externally to GBM can not be obtained. Next, the burst duration calculation determines the T90 and T50 values, the peak flux value and integration interval and the total fluence, both in photon and energy units. The duration calculation uses a spectral deconvolution in each time interval in order to take out the effects of bandpass and spacecraft slew. Essentially, a spectral model is fit to each of a series of background subtracted spectra, over a time span that includes many of the background spectra themselves. In calculating the cumulative fluence, the background subtracted background fitted spectra should more or less sum to zero, and only those portions of the time history where count from the trigger itself are present should contribute to the sum. The cumulative fluence plot over time can be seen in Figure 2, with a plateau before any emission begins, a rising portion as the trigger progresses, followed by another flat plateau after the end of the emission. As it is difficult to determine exactly where the emission begins or ends in any given trigger, the T90 statistic marks where the 5th and 95th percentile of the emission fall on the time axis.

3.1 Spectral Catalog

At the highest level, the GBM team will produce a Spectral Catalog, similar to the series produced while BATSE was operating [2]. As much as possible, a time-integrated plus a peak flux spectrum for every GRB trigger will be fitted with a standard set of spectral models, with increasing numbers of spectral shape parameters: power-law, exponentially attenuated power law, Band 'GRB' function [3], and smoothly broken power law. For brighter events, these models will be used in time series of spectral fits to determine the characteristics of the spectral evolution through the burst. Most importantly for corellation studies, several of these models produce parameters that are either identical to, or comparable to, $E_{\rm peak}$.

The catalog will consist of a series of model fit result FITS files for each trigger, where the fit parameters are stored in a data extension, which may be read by any FITS reader, including FV. In most cases, where it makes sense, the data from the brightest detectors, both NaI and BGO, will be jointly fitted. The temporal history will be constructed to obtain equal significance in each time bin (using the signal to noise ratio) and each spectrum will be entirely independent. Typically, CSPEC or binned TTE data will be used.

3.2 GRB Trigger Properties

As of the time of the Moriond Meeting in February 2009, GBM had triggered on 109 GRBs. Based upon preliminary spectral analyses of the time-integrated spectra, these break down as follows:

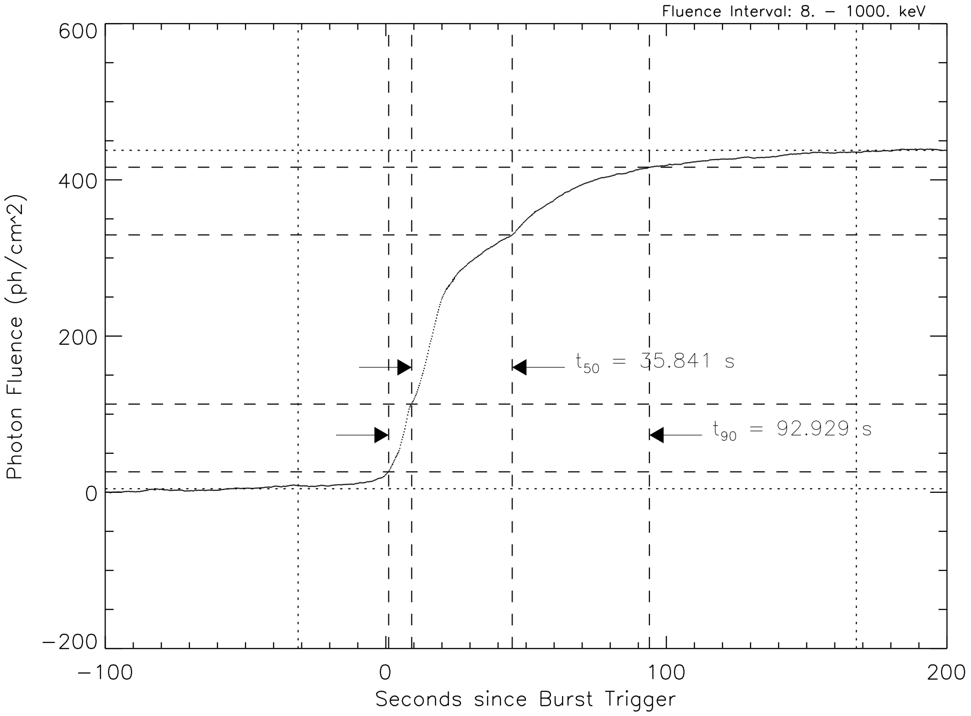

Figure 2: GRB080817: Burst Duration.

- 20 consistent with single Power Law (all of these had low fluence $< 1 \times 10^{-6}$ erg/cm^2),
- 43 consistent with Exponentially attenuated Power Law,
- 47 consistent with Band GRB model,
- 9 more are too weak to make much of a guess for the spectrum.

In addition, joint fits with spectral data obtained from the LAT for the burst in common so far give us confidence in our energy calibration.

References

1. E. Bissaldi, et al. *Experimental Astronomy* **24**, 47 (2009).
2. Y. Kaneko, et al. *ApJS* **166**, 298 (2006).
3. D. L. Band, et al. *ApJ* **413**, 281 (1993).