Bright High-Energy GRBs detected with the Gamma-ray Burst Monitor on Fermi

Andreas von Kienlin (⇒ Elisabetta Bissaldi) on behalf of the Fermi GBM Collaboration

Collaborators at MPE: J. Greiner, D. Gruber, S. Foley, A. Rau, R. Diehl

I. BGO bright bursts ➔ Sample selection

II. Predictability of LAT-detected events

III. High-energy temporal analysis

IV. High-energy spectral analysis and comparisons
The GBM-BGO detectors

GBM

12 NaIs
(location & low-E spectrum)

2 BGOs
(mid-E spectrum)

LAT
(high-E spectrum)

Andreas von Kienlin
Fermi Symposium • Rome • May 10th, 2011
The GBM-BGO detectors

**12 NaIs** (location & low-E spectrum)
- Diameter: 12.7 cm (5” x 5”)
- Thickness: 12.7 cm (5”)
- Energy range: ~200 keV – ~40 MeV

**2 BGOs** (mid-E spectrum)

**2 Bismuth Germanate Detectors**
- Diameter: 12.7 cm (5” x 5”)
- Thickness: 12.7 cm (5”)
- Energy range: ~200 keV – ~40 MeV
BGO bright bursts selection criteria (1)

- Selection from the set of 253 GRBs collected during the first year of GBM operation

1. First (coarser+automated!) selection
   - Bursts with more than 80 counts/s over background in at least one BGO detector over its full energy range (250 keV–40 MeV)

2. Second (refined!) burst selection
   - Bursts with signal above 3σ in the BGO CTIME light curves
     - [CTIME data have a 64 ms temporal resolution during burst-mode and spectral resolution of 8 energy channels]

Example of BGO CTIME energy channel boundaries for GRB 090227B

<table>
<thead>
<tr>
<th>BGO Ch. #</th>
<th>Energy Interval Start (keV)</th>
<th>Energy Interval Stop (keV)</th>
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<tbody>
<tr>
<td>0</td>
<td>113.25</td>
<td>451.60</td>
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<tr>
<td>1</td>
<td>451.60</td>
<td>973.33</td>
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<td>2</td>
<td>973.33</td>
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<td>3</td>
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<td>5</td>
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<td>6</td>
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<tr>
<td>7</td>
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</table>

150-500 keV
0.5-1 MeV
1-2 MeV
2-5 MeV
5-10 MeV
10-20 MeV
20-40 MeV
Overflow
Further subdivision according to the detection significance in different energy channels

- 52 GRBs in Ch.1 (~0.5 – 1 MeV)
- 19 GRBs in Ch.2 (~1 – 2 MeV)
- 10 GRBs in Ch.3 (~2 – 5 MeV)
- 6 GRBs in Ch.4 (~5 – 10 MeV)

GRB 081215A: Example light curve

- Top panel: 8–200 keV band (NaI detector)
- Other four panels: BGO light curves in different energy ranges
- Marginally detected by the LAT (86° to the boresight)
- No directional nor energy info
BGO bright bursts selection criteria (2)

- Total number of GRBs included in this analysis: 52
  - ~20% of all bursts detected during the first year of GBM operation
  - All LAT detected burst (in the first year!) are in the sample

<table>
<thead>
<tr>
<th>GBM Trig. #</th>
<th>GRB Name</th>
<th>Trig. Time (T0, MET)</th>
<th>NaI Det.</th>
<th>BGO Det.</th>
<th>LAT Angle (deg)</th>
<th>Data Type</th>
<th>Time Interval Start</th>
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<td>238512142</td>
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</table>
I. BGO bright bursts ➔ Sample selection

II. Predictability of LAT-detected events

III. High-energy temporal analysis

IV. High-energy spectral analysis and comparisons
LAT predictability

- BGO peak count rate measured in channel 1 (~500 keV - ~1 MeV)
  - 15 GRBs inside the LAT FoV
  - 11 GRBs at the edge of the LAT FoV
  - Green circles, orange stars and red squares represent firm, marginal or missing LAT detections
  - Blue dotted line marks a “detection limit” which was arbitrarily placed at 30 and 100 counts per second in the measured peak count rate.

- This analysis enables selection of good candidates for potential LAT detections
  - Information added to the GBM Ground Location GCN notices (GCN/FERMI_GBM_GND_POSITION)
  - alerts observers that a bright, hard burst has occurred in the LAT field-of-view.

Bissaldi et al. (2011)
I. BGO bright bursts → Sample selection

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Duration distributions

- 17 short, 35 long bursts in the sample
- Duration bimodality in the 50-300 keV distribution is clear
- $T_{90}$ (50–300 keV): Short bursts: $\sim$1.2 s, Long bursts: $\sim$33 s
- $T_{90}$ (300 keV–10 MeV): Short bursts: $\sim$1.0, Long bursts: $\sim$25 s
  - Narrower distribution
  - Bursts at higher energies tend to be shorter

Bissaldi et al. (2011)
Followed the approach described by Richardson et al. (1996)
- BATSE 3B, 72 bursts, 25-50 keV, 50-100 keV, 100-300 keV, and >300 keV.
- Utilized broader BGO energy coverage: adding 5 energy channels from 300 keV to 10 MeV
- Power law fit ($T_{90} = AE^{\alpha/90}$)
  - Central energy value used to represent each energy channel in the fit
- Results for long and short bursts computed separately
- Fit performed for the mean T90 values computed from subsets of bursts detected in 3–5 energy channels

Evolution of duration with energy

<table>
<thead>
<tr>
<th>Subsamples:</th>
<th>0.3 – 2 MeV</th>
<th>0.3 – 5 MeV</th>
<th>0.3 – 10 MeV</th>
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<tbody>
<tr>
<td>$\langle \alpha_{90} \rangle$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-0.41 ± 0.04</td>
<td>-0.42 ± 0.17</td>
<td></td>
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<tr>
<td>-0.38 ± 0.04</td>
<td>-0.42 ± 0.17</td>
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<tr>
<td>-0.32 ± 0.02</td>
<td>-0.40 ± 0.12</td>
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</tbody>
</table>
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Comp results

- Time-integrated spectra of 25 bursts are best fit with a Comp model!

- Comptonized (Comp) model
  - Low-energy power-law with an exponential high-energy cutoff, which is $\beta \rightarrow -\infty$

$\Rightarrow$ 75% of all short bursts in the sample are best fit by a Comp model (13 out of 17)

Bissaldi et al. (2011)
Band results

- Time-integrated spectra of 27 bursts are best fit with a Band function

- Only 4 out of 17 short GRBs are best fit by Band (+evidence for extra component!)
  - Softer beta values
  - Higher Epeak values

Bissaldi et al. (2011)
GBM vs. BATSE comparison

- Comparison with BATSE bright bursts results (Kaneko et al. 2006)
- Increasing the space of study towards short and hard bursts with higher $E_{\text{peak}}$ values (by selection!)
  - 30% of the sample are short bursts, unlike the Kaneko sample (only 4%!)
  - See Guiriec et al., Ghirlanda et al., Nava et al. (2010)
• GBM is an excellent tool to study in detail bright shorter and harder GRBs as well as longer ones (1st year bright BGO sample: 52 GRBs)

• We can use the GBM data to predict LAT detections
  • Peak count rate measured between 500 keV and 1 MeV with the mostly illuminated BGO detector

• We have extended the duration vs energy relationship up to ~10 MeV; we confirm the earlier trend of T90 ~ E^-0.4

• Most integrated spectra of bright short GRBs are best fit with a comptonized model. We find that the ones associated with an extra component are best fit with a Band function

• The hardness selected sample of GBM differs from the BATSE bright burst sample
I. Predictability of LAT-detected events

II. High-energy temporal analysis

III. High-energy spectral analysis and comparisons
I. Predictability of LAT-detected events

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