The Fermi Gamma-Ray Burst Monitor: Results from the first year+

Elisabetta Bissaldi

*Max-Planck-Institute for Extraterrestrial Physics*

*Member of the Fermi-GBM Team*
1) The Gamma-Ray Burst Monitor
The GBM Collaboration

University of Alabama in Huntsville

NASA Marshall Space Flight Center

Los Alamos National Laboratory

Max-Planck-Institut für extraterrestrische Physik

Bill Paciesas (PI)
Jochen Greiner (Co-PI)
The Fermi Gamma-Ray Burst Monitor

**NaIs** (location & low-E spectrum)

**BGOs** (mid-E spectrum)

**LAT** (high-E spectrum)

**NaIs**: 8 keV – 1 MeV

**BGOs**: 150 keV – 40 MeV

**LAT**: 20 MeV – >300 GeV

"Typical" Prompt GRB Spectrum

- GBM
- NaIs
- BGOs
- LAT

Photon Energy (MeV)
The Fermi Gamma-Ray Burst Monitor

- 12 Sodium Iodide NaI(Tl) scintillation detectors
  - Ø: 12.7 cm (5” x 5”)
  - Thickness: 1.27 cm (0.5”)
  - Energy range: 8 keV – 1 MeV
  - Wide Field of View
  - Burst Trigger

- 2 Bismuth Germanate (BGO) scintillation detectors
  - Ø: 12.7 cm (5” x 5”)
  - Thickness: 12.7 cm (5”)
  - Spectral overlap with the LAT: 200 keV – 40 MeV

- 1 Power Box (PB)
- 1 Digital Processing Unit (DPU)
The Fermi Gamma-Ray Burst Monitor

On-axis effective area \( \approx 120 \text{ cm}^2 \)

The Fermi Gamma-Ray Burst Monitor

NaI and BGO crystals are used in the monitor to detect gamma rays. The effective area versus source angle for NaI and BGO crystals is shown in the graphs. The NaI FM 04 graph includes data for $^{137}$Cs at 32.89 keV, $^{203}$Hg at 279.2 keV, and $^{137}$Cs at 661.66 keV. The BGO EQM graph includes data for $^{88}$Y at 898.04 keV and $^{88}$Y at 1836.06 keV.

E. Bissaldi et al. 2009, ExpAstr, 24, 47
2) GBM Science
GBM Science

- **Techniques**
  - Short transients detected by on-board trigger algorithm
    - trigger timescales 16 ms – 16 s (currently longest is 8 s)
  - Pulsed sources detected by power spectral analysis and/or epoch folding
  - Longer-term transients and persistent sources detected by Earth occultation

- **Triggered Sources**
  - Gamma-ray bursts (GRBs)
  - Soft Gamma Repeaters (SGRs)
  - Terrestrial Gamma Flashes (TGFs)
  - Solar flares

- **Non-triggered Sources**
  - AGNs
  - X-ray binaries: HMXBs, LMXBs, Be binaries, microquasars
GBM triggering

- GBM triggers when 2 or more detectors exceed background by \( n \) \textit{sigma} over \( t \) timescale in \( e \) energy band

- 62 algorithms operating simultaneously:
  - \( 4.5 \leq n \leq 7.5 \)
  - \( 16 \text{ ms} \leq t \leq 8.096 \text{ s} \)
  - \( E \)
    - 25 - 50 keV
    - 50 - 300 keV
    - 100 - 300 keV
    - > 300 keV

- What happens when GBM triggers?
- What does GBM trigger on?
GBM Actions on Triggering

LAT  ARR
2 s

On-board

Localize

Classify

Make data

Automated location

Human location & class.

Spectra etc.

GCN (World)

Ground software

Quick-look
5 s - 600 s

1-4 hr

10 s

10 min - hrs

1 day

1 day

All GBM Data are public at the FSSC:
http://fermi.gsfc.nasa.gov/ssc/data/access/
GBM First Year Trigger Summary

- 253 GRBs
  - 242 between 50–300 keV
    - 11 between 25–50 keV
    - No GRB triggered on hard energy ranges
    - i.e. 212 BATSE-like GRBs in 1 year
- 62 commanded (test)
- 168 SGRs – most on soft, short trigger algorithms.
- 14 TGFs – all on hard, short trigger algorithms.
- 1 solar flare
- Others are Cyg X-1 rises, accidentals, and particle events
Localization Accuracy

- Determined using GBM GRBs which have accurate locations from other instruments
  - Swift, IPN, Integral and ground-based
  - Bayesian method (Briggs et al., ApJSS, 1999)

- Systematic error (to be added to the stat. error):
  - FSW automatic: 3 degrees, consistent with zero
  - Human-in-the-loop: 3.8 +/- 0.5 degrees

- FSW and ground-automatic locations are sent as GCN Notices
  - Ground-automatic more accurate!
  - Recent improvement (by ~20 s) in the speed of the ground-automatic locations

- Human-in-the-loop locations are currently sent within GCN Circulars.
  - Plan to switch to Notices & speed to make these locations more accessible to robotic telescopes!

- First optical afterglow detection using GBM automatic location:
  - GRB090902B using ROTSE-IIIa & IIIc (Pandey et al, GCNC 9878); 15.9 mag after ~1.4 hours

- Algorithm improvements are under development to improve the localization accuracy of the ground-automatic and human-in-the-loop locations
GBM Gamma-Ray Bursts
Fermi Gamma-ray Bursts – First Year+

Detections as of 090904

GRB 090323 $\Rightarrow z = 3.6$

GRB 090510 $\Rightarrow z = 0.9$

GRB 090328 $\Rightarrow z = 0.7$

GRB 090328 $\Rightarrow z = 0.7$

GRB 090510 $\Rightarrow z = 0.9$

291 GBM GRBs

10 LAT GRBs

* In Field-of-view of LAT (154)

* Out of Field-of-view of LAT (137)
What can GBM GRBs add?

- Source of $E_{\text{Peak}}$ for Swift bursts
  - Spectroscopy from 8 keV - 40 MeV
- Time-resolved spectra for understanding central engine of GRBs
- Trigger for LAT $\Rightarrow$ Joint spectral fits

**GRB 090227B**
Short GRB
$E_{\text{Peak}} \approx 2$ MeV
GBM Observation of Short GRBs

- **Short & Bright GRB Sample:**
  - $t_{50} < 1 \text{ s}$
  - Fluence $> 2 \times 10^{-6} \text{ erg/cm}^2$ (8-1000 keV)
  - 3 GRBs: 090227B, 090228, 090510

- **GBM Results:**
  - Short GRBs have very high $E_{\text{peak}}$ values, with modestly steep $\beta$ values
  - Band function preferred in 2 of the 3 GRBs over cutoff power law

GRB 090323 and GRB 090328
Items in common

- Long duration GRBs
  - Detection up to much, much later times than GBM duration
  - Careful evaluation of the LAT background as a function of time
- ARR issued
  - Significant impact on the Fermi analysis (especially for GBM)
  - Responses change while the observatory is slewing
- Superb afterglow observations from X-ray to radio
- Spectroscopic redshifts were determined

GRB 090323 is at $z = 3.6$

GRB 090328 is at $z = 0.736$
GRB 090323: GBM detectors

- First quick-look data analysis of the NaI detectors (50-300 keV band)
- Temporal resolution:
  - Blue line: 1 s resolution
    - 70 s, covering ~8 s pre-burst and ~60 s post-burst.
  - Black line: 8 s resolution
Autonomous Repoint Recommendation (ARR)

- The high energy emission detected by the LAT was made possible by the ARR sent from GBM
  - Otherwise GRB would have been out of FOV!

LAT 6 hour automated science processing

GRB 090323
In GBM, the effect of the ARR is particularly visible after T0+60 s, where the detectors orientation changes with incredible rapidity, making the spectral analysis a delicate issue.
NaI background subtraction

GRB 090323

NaI 9

8 – 900 keV

Time Since TSTART (s)

Rate (count / s)

2500
2000
1500
1000
500
1000
1500
2000
2500

Time Since TSTART (s)

8 – 900 keV

Rate (count / s)
Because of the slewing due to the ARR, we need to select the best NaI detector combination for each time interval!

**GRB 090323**

- **T90** \( \sim 140 \text{ s} \)
- **Fluence** = \((1.23 \pm 0.02) \times 10^{-4} \text{ erg/cm}^2\)
- **1-sec Peak Flux** = \(12.3 \pm 0.4 \text{ ph/s/cm}^2\)
Time interval selection

GRB 090328

- **T90**: ~60 s
- **Fluence**: $(5.2 \pm 0.7) \times 10^{-5}$ erg/cm$^2$
- **1-sec Peak Flux**: $22.6 \pm 0.8$ ph/s/cm$^2$

Spectral analysis of the brightest interval

GRB 090323

GRB 090328
Spectral results brightest interval

GBM only Band fit

GRB 090323

- \( E_{\text{peak}} = 536 (\pm 25 - 24) \) keV
- alpha = \(-0.80 (\pm 0.02)\)
- beta = \(-2.8 (+0.2 - 0.4)\)

GRB 090328

- \( E_{\text{peak}} = 479 (\pm 58) \) keV
- alpha = \(-1.08 (+0.04 - 0.03)\)
- beta = \(-2.3 (+0.2 - 0.3)\)

PRELIMINARY

Spectral parameter evolution

GRB 090323


GRB 090328

LAT extended emission

GRB 090323

- LAT detections above 100 MeV:
  - During GBM time (0 – 160 s): ~25 events
  - From 0 to 400 s: ~60 events
  - From 0 to 17 ks: ~80 events
    - High detection significance

LAT extended emission

GRB 090328

- Binsize: 60 s
- 15 deg ROI
- blue line: GRB within 98 deg of Earth limb
- black line: (SAA)

- LAT detections above 100 MeV:
  - During GBM time (0 – 70 s): ~18 events
  - From 0 to 6.8 ks: ~60 events
    - High detection significance!

Conclusions

- GBM is healthy!
  - More than 300 GRBs up to now
  - Flexible triggering
    - SGRs
    - TGFs
    - Extra GRBs that are long but weak
  - Better localization
    - More follow-up observations
  - Good spectral capabilities for short burst
  - Source of $E_{\text{Peak}}$ for Swift bursts
    - Spectroscopy from 8 keV - 40 MeV!

- LAT observations are providing surprises!
  - Fermi analysis of two long bursts
    - $\sim$150 s and $\sim$60 s in GBM
    - Extended emission is detected to much longer time in the LAT
    - ARR enabled the detection!
  - ...Papers coming soon!