Observations of GRBs with the Large Area Telescope

Elena Moretti
KTH & CIFS
On behalf of the Fermi GBM/LAT Collaborations
High-Energy Emissions from GRB (Past)

EGRET observations of delayed HE gamma-ray emissions
- It is not straightforward to explain by conventional electron synchrotron models
- Proton acceleration?
  • Extra components?
  • 5 EGRET bursts with >50 MeV observations in 7 years
- No evidence of cutoff or extra HE component in the summed spectrum

Hurst et al. 1994

Gonzalez, Nature 2003 424, 749
The Fermi observatory instruments

Improved performance of Fermi LAT (Large Area Telescope)
- Larger FOV (>2.4 sr): more GRB samples
- Larger effective area: better statistics
- Less dead time: detailed lightcurve, time-resolved analysis
- Wider energy coverage: up to >300 GeV

Fermi Gamma-ray Burst Monitor
- Views entire unocculted sky
- NaI: 8keV-1MeV
- BGO: 200 keV - 40 MeV
GBM-LAT synergy for GRB studies

Both LAT and GBM can independently trigger
✔ Spectral coverage of more than 7 decades (8keV->300GeV)
  - Bright burst: study of the cut-off, if any.
✔ Detailed temporal/spectral resolution:
  - Is there any “extra component”?
  - How common is the extended/delayed GeV emission?
  - Intrinsic lag because cosmological effects?
The GBM detects ~250 GRBs/year (~540 total)
~18% short
~50% in the LAT FoV
The LAT detects ~10 GRBs/year: 20 total as of today
Properties: Delayed Onset

**GRB 090510 (short)**
- Delay: ~0.5s
- 8-260keV
- 0.26-5MeV
- LAT all events
- >100 MeV
- >1GeV

**GRB 080916C (long)**
- Delay: ~5s
- 8-260keV
- 0.26-5MeV
- LAT all events
- >100 MeV
- >1GeV

Almost all GRBs show a delayed onset!!!
Properties: Extra HE spectral component

GRB 090510 (short)

GRB 090902B (long)

First extra component by Fermi
At > 5 sigma level

3 LAT GRBs show extra PL component
(090510, 090902B, 090926A)

First time a low-energy extension of the PL component has been seen

T0+4.6s to T0+9.6s
Properties: Long lived HE component

GRB 090510 (short GRB)

*De Pasquale et al., ApJL 709, 146 (2010)*

- Forward shock model can reproduce the spectrum from the optical up to GeV energies
- Extensions needed to arrange the temporal properties

Several GRBs show this long lived component as 090816C, 090902B, and 090926A

**LAT emission until 200 s**

No spectral evolution (photon index $-2.1 \pm 0.1$)
compactness problem: large luminosity + small emitting region = large optical depth ($\gamma-\gamma \rightarrow e^+e^-$ large)

Possible solution: relativistic motion ($\Gamma \gg 1$)

$$
\tau_{\gamma\gamma}(E) = \frac{3}{4} \frac{\sigma_T d_L^2}{t_v \Gamma} \frac{m_e^4 c^6}{E^2 (1+z)^3} \int_0^{\infty} \frac{d\epsilon'}{\epsilon'^2} n \left( \frac{\epsilon' \Gamma}{1+z} \right) \varphi \left( \frac{\epsilon' E (1+z)}{\Gamma} \right)
$$

$\Gamma_{\min}$ calculation from highest energy photon

$$
\Gamma_{\min}(E_{\max}) = \left[ 4 d_L^2 A \frac{m_e^2 c^4}{c^2 t_v (1+z)^2 E_{\max}} g \sigma_T \right]^{\frac{1}{2}} \left[ \frac{(\alpha-\beta) E_{pk}}{(2+\alpha)100 \text{ keV}} \right]^{\frac{2}{2+2\beta}} \\
\times \exp \left( \frac{\beta-\alpha}{2-2\beta} \right) \left[ \frac{2m_e^2 c^4}{E_{\max}(1+z)^2 100 \text{ keV}} \right]^{\frac{2}{2-2\beta}};
$$

for $\Gamma_{\min} > \sqrt{\frac{(1+z)^2 E_{\max} E_{pk}(\alpha-\beta)}{2m_e^2 c^4 (2+\alpha)}}$

$\Gamma_{\min} \sim 1000$ for short and long GRBs
A constraint on the quantum gravity mass ($M_{QG}$) can be derived by direct measurement of photon arrival time (assuming the emitted time is the same for all photons):

$$\frac{M_{QG,1}}{M_{\text{plank}}} > 1.19$$

This value disfavors quantum gravity models which linearly alters the speed of light ($n=1$).
Properties: cut-off on HE spectral component

- Extra component shows at $>5\sigma$
- spectral break at $\sim 1.4$ GeV
- First direct measurement of $\Gamma \sim 630$ (if cutoff due to $\gamma-\gamma$ absorption)

8-14.3 keV
14.3-260 keV
0.26-5 MeV
LAT all event
$>100$ MeV
$>1$ GeV
The GRBs emits less in the 100 MeV-10 GeV band respect to the 20 keV-2MeV band! (HE emission not common)

Long GRBs seem to emit ~5-20 times less at HE than at LE respect to short GRBs
Only ~52% of Fermi GRBs are in LAT field of view

- ~80% of “Gold” sample do not predict LAT counts;
- ~20% do show discrepancies and hint at spectral curvature;

**GRB 090620 PRELIMINARY**

\[
\begin{align*}
E_{pk} &= 149.5 \pm 3.69 \\
\alpha &= -0.21 \pm 0.04 \\
\beta &= -2.65 \pm 0.11
\end{align*}
\]

LAT Flux Limit = 3.6x10^{-5}

Expected LAT Flux = 9.2x10^{-8}
<table>
<thead>
<tr>
<th>GRB1</th>
<th>Angle from LAT (or class)</th>
<th>Duration</th>
<th># of events &gt; 100 MeV</th>
<th># of events &gt; 1 GeV</th>
<th>Delayed HE onset</th>
<th>Long-lived HE emission</th>
<th>Extra spectral comp.</th>
<th>Highest photon Energy</th>
<th>Redshift</th>
</tr>
</thead>
<tbody>
<tr>
<td>080825C</td>
<td>~ 60° long</td>
<td>~ 10</td>
<td>0</td>
<td>?</td>
<td>X</td>
<td>~ 600 MeV</td>
<td>~ 1 GeV</td>
<td>~ 6.0</td>
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</tr>
<tr>
<td>081024B</td>
<td>21° short</td>
<td>~ 10</td>
<td>2</td>
<td>?</td>
<td>?</td>
<td>3 GeV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>081215A</td>
<td>~ 86° long</td>
<td>~ 10</td>
<td>~ 10</td>
<td>?</td>
<td>?</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>090217</td>
<td>~ 34° long</td>
<td>~ 10</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>~ 1 GeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>090323</td>
<td>~ 55° long</td>
<td>~ 20</td>
<td>&gt; 0</td>
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<td>?</td>
<td>?</td>
<td>3.57</td>
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<td></td>
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<tr>
<td>090328</td>
<td>~ 64° long</td>
<td>~ 20</td>
<td>&gt; 0</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>0.736</td>
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<td></td>
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<tr>
<td>090510</td>
<td>~ 14° short</td>
<td>&gt; 150</td>
<td>&gt; 20</td>
<td>?</td>
<td>?</td>
<td>~ 31 GeV</td>
<td>0.903</td>
<td></td>
<td></td>
</tr>
<tr>
<td>090626</td>
<td>~ 15° long</td>
<td>~ 20</td>
<td>&gt; 0</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>090902B</td>
<td>51° long</td>
<td>&gt; 200</td>
<td>&gt; 30</td>
<td>?</td>
<td>?</td>
<td>~ 33 GeV</td>
<td>1.822</td>
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<tr>
<td>090926</td>
<td>~ 52° long</td>
<td>&gt; 150</td>
<td>&gt; 50</td>
<td>?</td>
<td>?</td>
<td>~ 20 GeV</td>
<td>2.1062</td>
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<tr>
<td>091003A</td>
<td>~ 13° long</td>
<td>~ 20</td>
<td>&gt; 0</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>0.8969</td>
<td></td>
<td></td>
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<tr>
<td>091031</td>
<td>~ 22° long</td>
<td>~ 20</td>
<td>&gt; 0</td>
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<td>?</td>
<td>?</td>
<td>~ 1.2 GeV</td>
<td></td>
<td></td>
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<tr>
<td>100116A</td>
<td>~ 29° long</td>
<td>~ 10</td>
<td>3</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>~ 2.2 GeV</td>
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<tr>
<td>100225A</td>
<td>~60 long</td>
<td>~10</td>
<td>1</td>
<td>?</td>
<td>?</td>
<td>~9.5 GeV</td>
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<tr>
<td>100325A</td>
<td>~10 long</td>
<td>~5</td>
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<td>?</td>
<td>?</td>
<td>?</td>
<td>800 MeV</td>
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<td>&gt; 0</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>4 GeV</td>
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What's up? Low Energy Events

TITLE: GCN CIRCULAR
NUMBER: 11155
SUBJECT: GRB100826A: Fermi-LAT Observations
DATE: 10/08/30 20:52:22 GMT
FROM: Julie McEnery at NASA/GSFC <julie.e.mcenery@nasa.gov>

Julie McEnery (NASA/GSFC) and Nicola Omodei (Stanford) report on behalf of the Fermi-LAT collaboration.
The Fermi Large Area Telescope (LAT) detected emission from GRB 100826A also detected by GBM (trigger 304556304) at 22:58:22.89 on August 26, 2010.

The GBM location was at a very large angle of (~70 degrees) to the LAT boresight, and no significant excess is seen using standard analysis procedures.

Using a non-standard data selection, over 350 counts above background were detected within a 50 s interval coinciding with the first GBM broad peak. The LAT light curve has a very similar structure to this GBM peak, with the maximum count rate occurring at ~22 s post-trigger. A preliminary study of the instrument performance at such a large inclination suggests that these events are likely to be low energy gamma-rays, with energies less than 200 MeV. This data selection has insufficient spatial resolution to provide a reliable LAT localization.
Summary

• Some observed properties
  - High energy emission (>100 MeV) observed in both long and short bursts
  - Delayed onset between LAT and GBM (“the missing peak”)
    • Characteristic Spectral evolution
    • Separate region from initial GBM emission (Internal Shocks?)
    • Not seen in 090217
    • Both in long and short bursts
• Single Band-function dominates 6 decades of energy band
  - Extra component dominates in few cases (both in long and shorts)
• Long lived high-energy emission detected both in Long and Short bursts
• Cut-off observed in the HE spectral component
• Fundamental physics tested (LIV, Gamma min)
• HE emission not a common propriety of GRBs
Thanks