Spectral Analysis of the 3 Brightest Short GRBs Observed with GBM

by

Sylvain Guiriec

National Space Science and Technology Center
University of Alabama in Huntsville
NASA Marshall Space Flight Center

On behalf of the Fermi/GBM Collaboration

See also poster P3-233 by Erin Kara (Wed- Thurs)
(Guiriec et al. In preparation)
Why is GBM unique for short and hard GRBs?

• GBM has an effective area 1/36 of its famous predecessor BATSE
  => GBM required bright events

BUT

• Even if smaller, GBM/BGO detectors are much thicker with higher z.
  => Much better photo-peak efficiency and effective area above 1 MeV:
    - BATSE maximal energy ~10 MeV.
    - GBM maximal energy ~40 MeV.
  => Spectroscopy of hard bursts possible with GBM.

• GBM has:
  ✓ much more available on-board memory.
  ✓ a much higher telemetry downlink budget.
  ✓ a better data design for Time Tag Events (TTE).
  => Data available with a time resolution down to 2 μs,
    128 spectral channels from 8 keV to 40 MeV and from -30 to 300 s.
  => Ideal for the study of short events like short GRBs,
    TGFs (see Michael Briggs talk and Jerry Fishman poster on TGFs) and SGRs (see Chryssa Koveliotou and Ersin Gogus talks)

12 Iodine Sodium detectors (NaI: 8 keV to 1 MeV)

2 Germanate Bismuth detectors (BGO: 200 keV to 40 MeV)
• About 68 short GRBs detected with GBM since since July, 2008.

• Short GRBs correspond to ~20% of the total GRBs detected with GBM

Sample criteria for this analysis

• $T_{50} < 1s$

• Fluence $> 2e^{-6}$ erg/cm$^2$ => bright enough for time-resolved spectroscopy with GBM

=> This selection results in 3 brightest and hardest short GRBs detected with GBM so far:

• GRB 090227B
• GRB 090228
• GRB 090510

In all the following, spectral analysis performed from 8 keV to 40 MeV.
Time-integrated spectra of the 3 GRBs

- Various model tested:
  - Power-law with exponential decay (comptonized)
  - Band function
  - Comptonized+PL
  - Band+PL

- Fit performed with the analysis package Rmfit

- Choice of the best model: statistical improvement of the Castor Cstat value between models according to the additional degree of freedom
Time-integrated spectra of the 3 GRBs
Case of GRB 090227B

Band (Cstat: 699/607 dof)  Comptonized + PL (Cstat: 689/606 dof)

The additional component dominates the standard Band function at both low and high Energy.
<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>Parameters of the Band function</th>
<th>PL</th>
<th>Castor Cstat / dof</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$E_{\text{peak}}$ (keV)</td>
<td>$\alpha$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>GRB 090227B</td>
<td>Compt</td>
<td>2227$^{+90}_{-85}$</td>
<td>-0.52$^{+0.02}_{-0.02}$</td>
<td>-3.35$^{+0.27}_{-0.39}$</td>
</tr>
<tr>
<td></td>
<td>Band</td>
<td>2116$^{+97}_{-95}$</td>
<td>-0.50$^{+0.02}_{-0.02}$</td>
<td>-3.44$^{+0.58}_{-0.80}$</td>
</tr>
<tr>
<td></td>
<td>Compt+PL</td>
<td>1995$^{+96}_{-91}$</td>
<td>-0.36$^{+0.05}_{-0.05}$</td>
<td>-3.44$^{+0.58}_{-0.80}$</td>
</tr>
<tr>
<td></td>
<td>Band+PL</td>
<td>1947$^{+205}_{-98}$</td>
<td>-0.36$^{+0.05}_{-0.13}$</td>
<td>-3.44$^{+0.58}_{-0.80}$</td>
</tr>
<tr>
<td>GRB 090228</td>
<td>Compt</td>
<td>862$^{+52}_{-47}$</td>
<td>-0.59$^{+0.03}_{-0.03}$</td>
<td>-3.77$^{+0.64}_{-0.64}$</td>
</tr>
<tr>
<td></td>
<td>Band</td>
<td>860$^{+50}_{-49}$</td>
<td>-0.59$^{+0.03}_{-0.03}$</td>
<td>-3.77$^{+0.64}_{-0.64}$</td>
</tr>
<tr>
<td></td>
<td>Compt+PL</td>
<td>722$^{+47}_{-42}$</td>
<td>-0.23$^{+0.11}_{-0.10}$</td>
<td>-4.74$_{-\infty}$</td>
</tr>
<tr>
<td></td>
<td>Band+PL</td>
<td>723$^{+45}_{-41}$</td>
<td>-0.24$^{+0.10}_{-0.10}$</td>
<td>-4.74$_{-\infty}$</td>
</tr>
<tr>
<td>GRB 090510</td>
<td>Compt</td>
<td>4797$^{+255}_{-237}$</td>
<td>-0.77$^{+0.02}_{-0.02}$</td>
<td>-2.80$^{+0.20}_{-0.28}$</td>
</tr>
<tr>
<td></td>
<td>Band</td>
<td>4383$^{+290}_{-278}$</td>
<td>-0.75$^{+0.02}_{-0.02}$</td>
<td>-2.80$^{+0.20}_{-0.28}$</td>
</tr>
<tr>
<td></td>
<td>Compt+PL</td>
<td>3731$^{+265}_{-246}$</td>
<td>-0.51$^{+0.08}_{-0.07}$</td>
<td>-3.65$_{-\infty}$</td>
</tr>
<tr>
<td></td>
<td>Band+PL</td>
<td>3695$^{+284}_{-265}$</td>
<td>-0.51$^{+0.08}_{-0.08}$</td>
<td>-3.65$_{-\infty}$</td>
</tr>
<tr>
<td></td>
<td>(GBM+LAT)</td>
<td>Band+PL</td>
<td>3936$^{+280}_{-260}$</td>
<td>-0.58$^{+0.06}_{-0.05}$</td>
</tr>
</tbody>
</table>

- **Comp + PL is systematically preferred** => Existence of an additional component in these 3 GRBs
- Value of the index of the additional PL similar in all these bursts
- Higher $E_{\text{peak}}$ values than for long GRBs (=> question during Ehud talk: short vs long GRBs with GBM)
- Steep $\beta$ values (which confirm the comment from Guido to Nicola in the previous talk)
- GBM only results and GBM+LAT fits are consistent for GRB 090510
The existence of additional components in these 3 GRBs is consistent with LAT data

See Poster Valerie Connaughton P3-171 (Wed-Thur)
Similar to what we observed in long GRBs but contracted in time and shifted to higher energy (Ford et al.).

- $E_{\text{peak}}$ tracks the light curves like for the long burst.
- The hardest part is not always at the beginning.
- The most intense peaks are not always the hardest.
• $\alpha < -3/2$ : $e^-$ synchrotron emission valid for fast cooling
• $\alpha > -2/3$ : $e^-$ synchrotron emission valid for slow cooling

$\alpha < -3/2$:
• $e^-$ synchrotron emission valid for fast cooling

$\alpha < -2/3$:
• $e^-$ synchrotron emission valid for slow cooling

$\alpha$ nearly systematically violates the synchrotron line of death of $-2/3$.

$E_{\text{peak}}$ evolves over an incredible broad range of energy.
Conclusion

Time-integrated spectra

- **Time-integrated spectra** are best fit with **Band+Power law model**

  => **Additional component** : electron SSC or hadronic emission

- The **additional power law** dominates the standard Band spectrum at low and high energy

  => **low energy extension of the PL challenges all the models**

- The **hardest short GRBs** have Epeak values well above those of the hardest long GRBs.

  Additional component: electron SSC or hadronic emission

Fine time-resolved spectroscopy

- **Short GRBs** have similar light curves than long GRBs but contracted in time and shifted towards higher energy, and appear to have steeper β.

- Epeak tracks the light curves and spreads over a broad energy range

  => consistent with the electron synchrotron models in the internal shocks context (Acceleration and cooling of the electrons leading to a hardening with the peak rise then a softening of the burst during the pulse decay)

- α in the time resolved spectroscopy **violates the synchrotron limits** (Frederic Daigne talk: possible answer with IC ?)

Poster P3-233 by Erin Kara (Wed-Thurs)
Poster P3-171 by Valerie Connaughton (Wed-Thurs)
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