Spectral Analysis of Three Short GRBs Observed with GBM

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Plenary Session: "Fermi GBM Observations of Three Intense Short GRBs" by S. Guiriec (Tues., 4:45pm)

Summary: We performed Spectral Analysis of the 3 brightest short GBM GRBs. The time-integrated spectra are best fit with Band + Power Law, which suggests an extra component dominating at low and high energies, possibly due to hadronic emission mechanisms. The time-resolved spectra are similar to long GRBs, except contracted in time and shifted to higher energies.

Abstract

We investigate the spectral properties of the three brightest short gamma-ray bursts observed thus far by GBM (GRB 090227B, GRB090228 and GRB 090510). GBM, with its combination of NaI and BGO detectors, covers a broad range of energies from 8 keV to 40 MeV, and can resolve spectra with timescales as small as a few milliseconds. These three bursts have E_{peak} values much higher than what has been previously observed for long bursts[1], and are best fit with a standard Band function plus a Power Law (PL) dominating at low and high energies, suggesting an additional component, which could be interpreted as hadronic emission[2]. Moreover, with the improved capabilities of GBM, it is possible to do fine time-resolved spectroscopy of these short GRBs. Like in long bursts, E_{peak} is clearly tracking the structure of the light curve[1], but also exhibits some peculiar features. E_{peak} is spread over a wide energy range, and the light curve is similar to long GRBs, except contracted in time, and shifted to higher energy.

Data and Analysis Tools

- GBM has detected ~70 short GRBs corresponding to ~18-20% of the total.
- The short GRBs 090227B, 090228 and 090510 have t_{50} less that 1s and have fluences above 2.10^{-6} erg/cm^2 over an energy range from 8-1000 keV, which assures that we can perform fine time-resolved spectroscopy with good statistics.
- Combination of data from the Sodium Iodide detectors (12 NaI detectors positioned peripherally around spacecraft ranging in energy from 8 keV to 1 MeV) and the Bismuth Germanate detectors (two BGO detectors positioned on opposite ends of the spacecraft ranging from 200 keV to 40 MeV)
- Detectors used:
  - GRB 090227B (NaI 0, 1, 2, 5, BGO 0)
  - GRB 090228 (NaI 0, 1, 2, 3, 5, BGO 0)
  - GRB 090510 (NaI 3, 6, 7, 8, 9, BGO 0, 1)
- Spectral analysis performed with GBM analysis software, RMFit
  - Best fit optimizing the Castor Cstat statistic

Time-Integrated Spectra

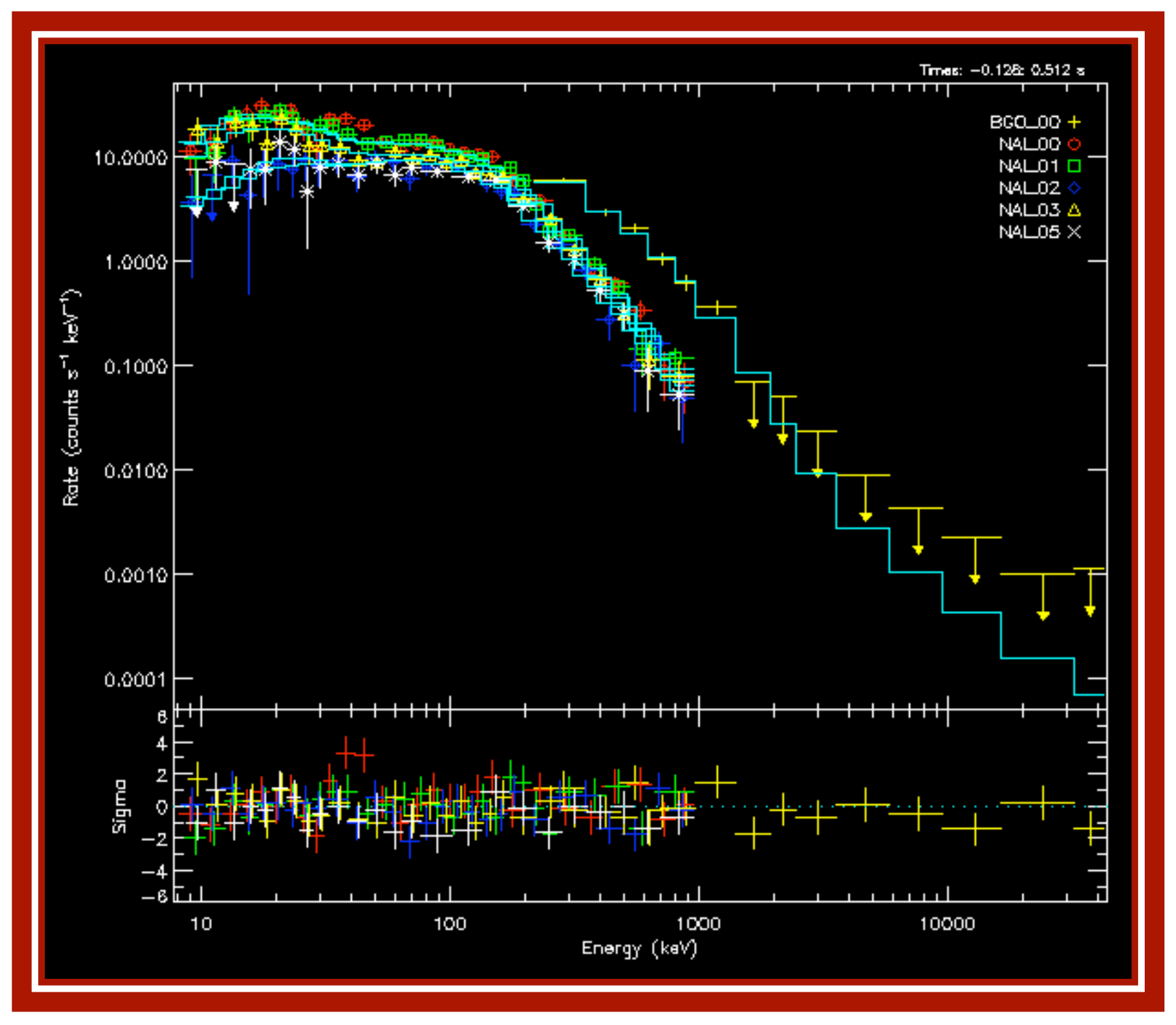

Fig. 1: Count Spectrum (Band +PL) GRB 090228

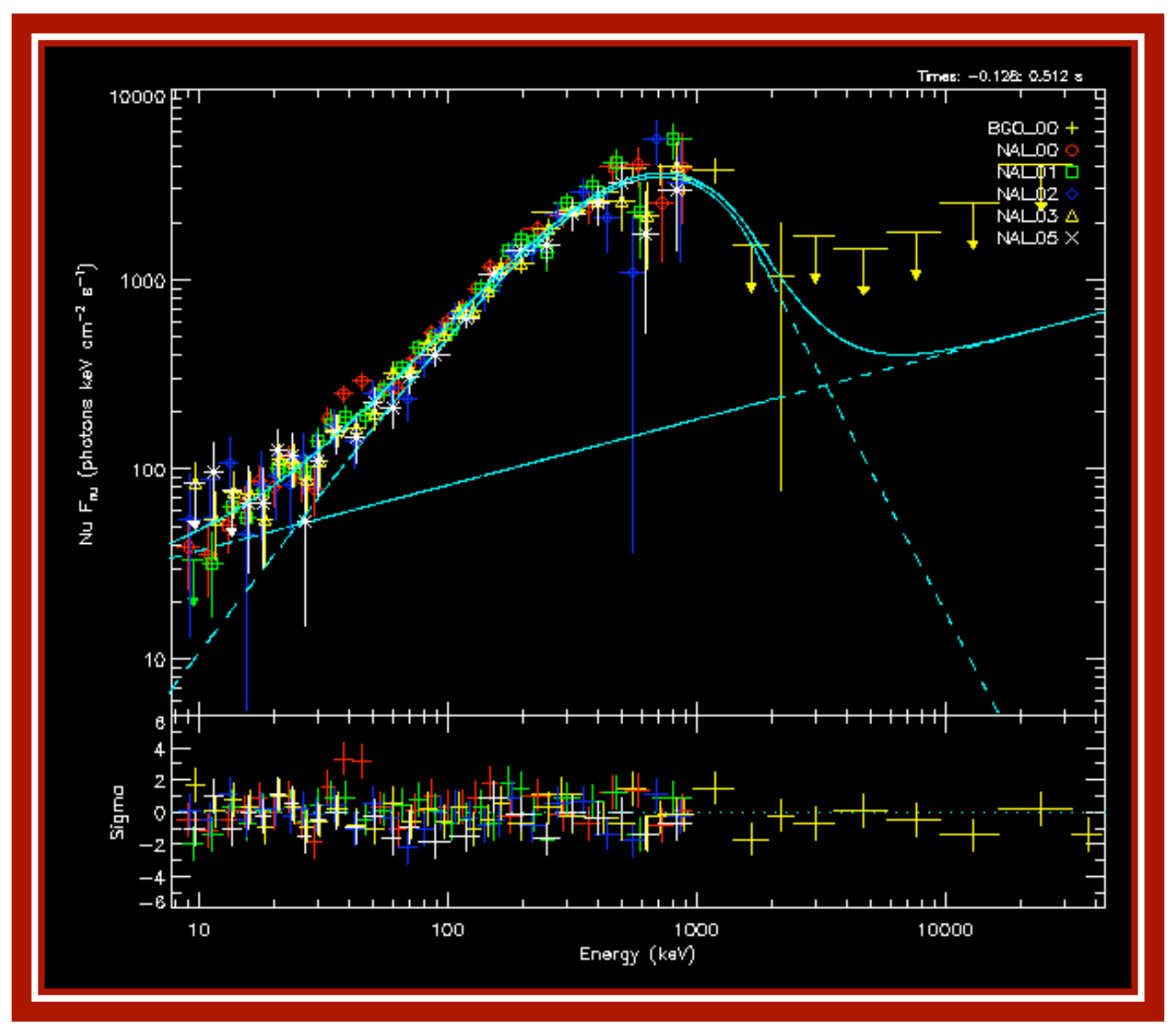

Fig. 2: νF_ν Spectrum (Band + PL) GRB 090228

The integrated spectra are best fit with Band + Power Law (Fig. 1 and Table), suggesting an additional component, which dominates the standard Band Function at both low and high energies (Fig. 2). This extra component could be explained by electron Synchrotron Self-Compton (SSC) or hadronic models. However the low energy contribution up to a few tens of keV remains a challenge for the models.

- The E_{peak} values of the time-integrated are well above the maximal values observed in long GRBs.
- These data are equally well fit with a cutoff Power Law function plus an additional PL. The advantage of using the Band + PL fits (even if it is not statistically preferred) is that we are able to constrain β.
- LAT data above 100 MeV are consistent with GBM data (see poster P3-171 of Valerie Connaughton).

Name	time interval (MET - trigger (s))	E_{peak} (keV)	α	β	PL index
GRB 090227B	-0.128 to 0.384	1947+105-98	-0.36+0.05-0.013	-3.44+0.58-0.80	-1.51+0.04-0.03
GRB 090228	-0.128 to 0.512	723+45-41	-0.24+0.10-0.10	-4.74+1.14-inf	-1.64+0.03-0.02
GRB 090510	-0.500 to 1.000	3695+284-265	-0.51+0.08-0.08	-3.65+0.75-inf	-1.38+0.04-0.03
GRB 090510 (GBM +LAT)[3]	-0.500 to 1.000	3936+280-260	-0.58+0.06-0.05	-2.83+0.14-0.20	-1.62+0.03-0.03

References [1]Ford et al., ApJ, 439, 307 (1995), [2]Asano, Guiriec & Mészáros, arXiv:0909.0306 (2009), [3]Abdo et al., arXiv:0908.1832 (2009), [4]R. D. Preece, et al., ApJL, 506, 23-26 (1998), Ghirlanda et al., A&A 496, 585-595 (2009), Mazets et al., in ASP Conf. 312, 102 (2004), Paciesas et al., in AIP Conf. Proc. 662, 248 (2001)

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Time-Resolved Spectroscopy

Technique

With GBM's improved capabilities beyond previous GRB instruments, fine time-resolved spectroscopy can be performed on shorter timescales (up to 2 milliseconds) and over a larger energy range [8 keV to 40 MeV]. The binning of the light curves has been chosen to minimize the error bars on the instantaneous E_{peak} value, which is a compromise between the statistical content and the spectral evolution in the same time bin. The Band Function has been chosen to fit each time interval. When β was undefined, we fixed it to the 1-σ upper limit, and used this value to compute the other parameters (E_{peak} and α).

Results

The evolution of E_{peak} is very similar to what we observe in long bursts, except contracted in time and shifted to higher energies. For example, for these three bursts, we see E_{peak} tracking the lightcurve, especially above 1 MeV (Fig. 3 to 5). However, some features differ from the common trends in long bursts. Also, the hardest part of the burst is not always the first peak of the light curve, neither does it occur at the most intense part of the burst (as was observed in GRB 090227B).

We notice that E_{peak} evolves over a large energy range (Fig. 6), and that α frequently violates the -2/3 limit for electron synchrotron emission with slow cooling, and also violates the -3/2 limit for electron synchrotron emission with fast cooling (Fig. 7)[4].

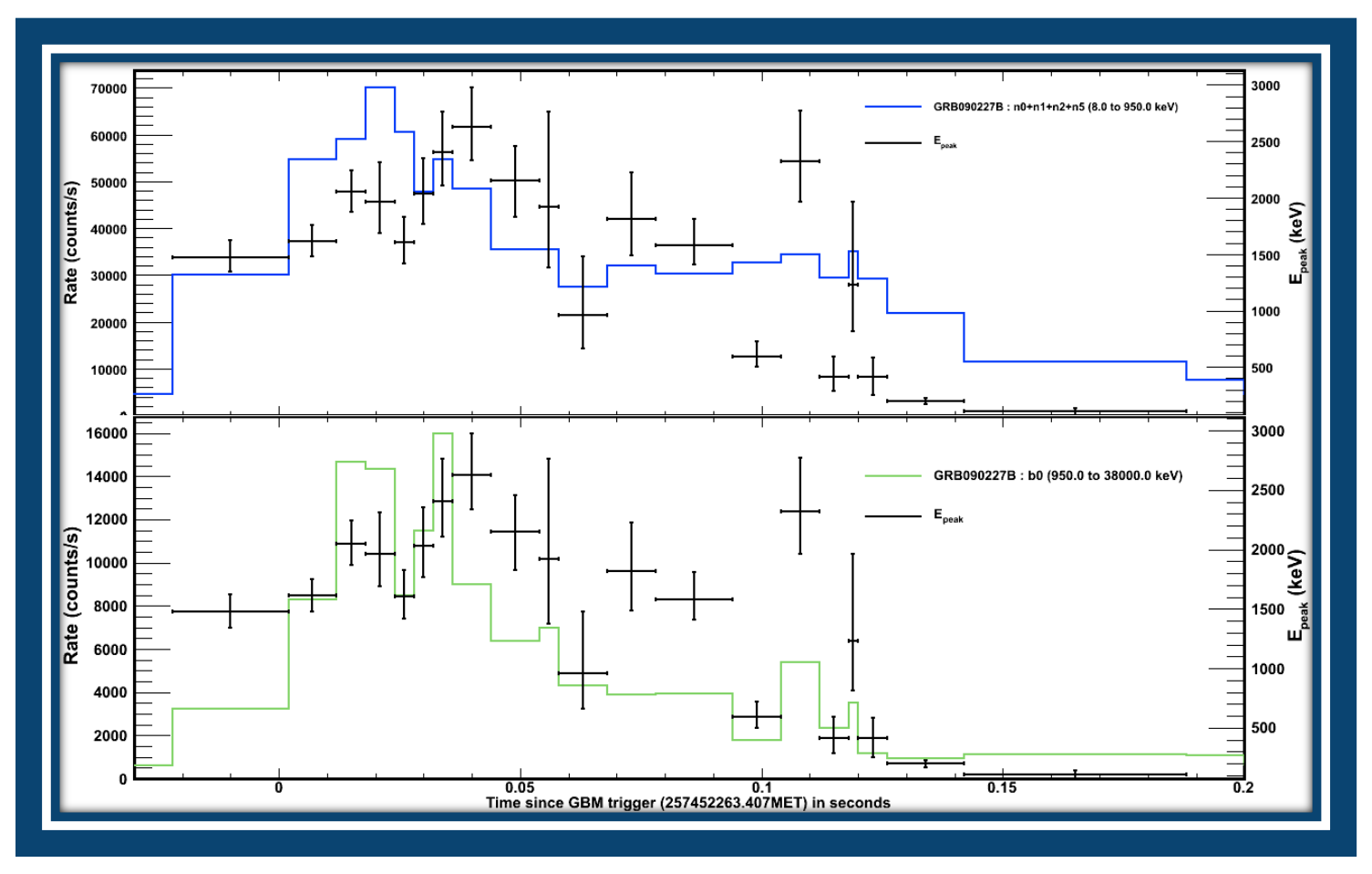

Fig. 3: E_{peak} Evolution for GRB 090227B

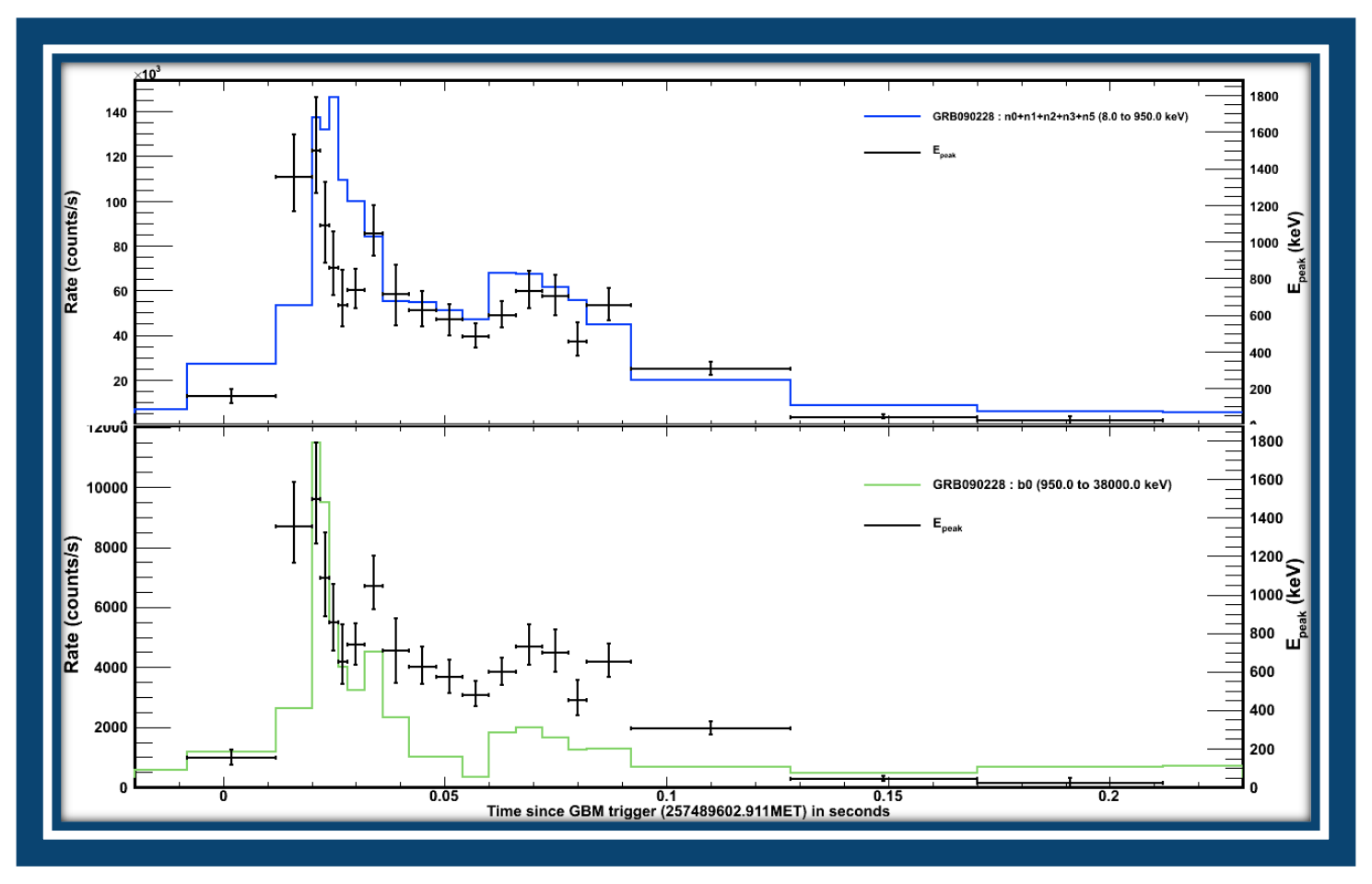

Fig. 4: E_{peak} Evolution for GRB 090228

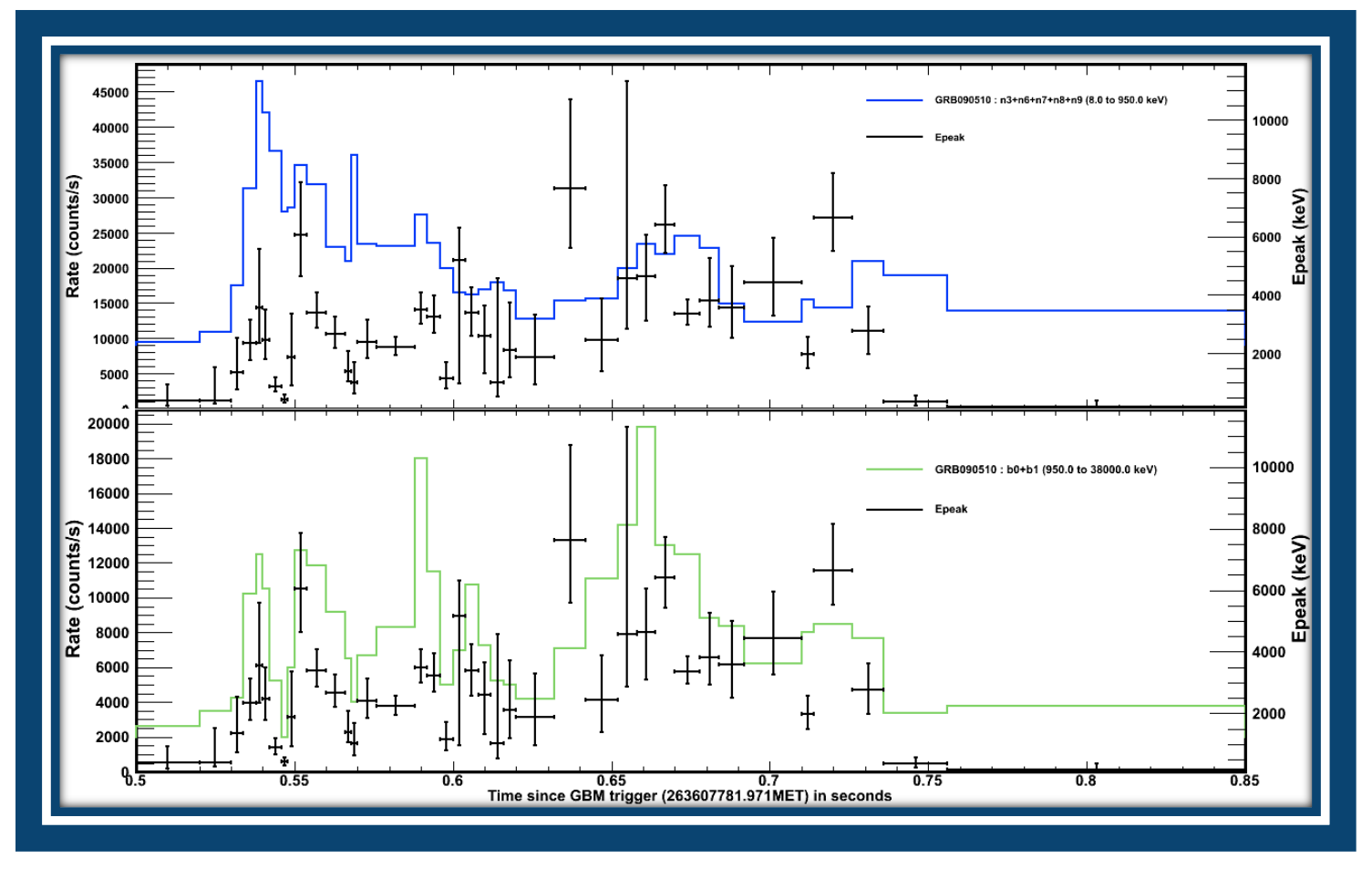

Fig. 5: E_{peak} Evolution for GRB 090510

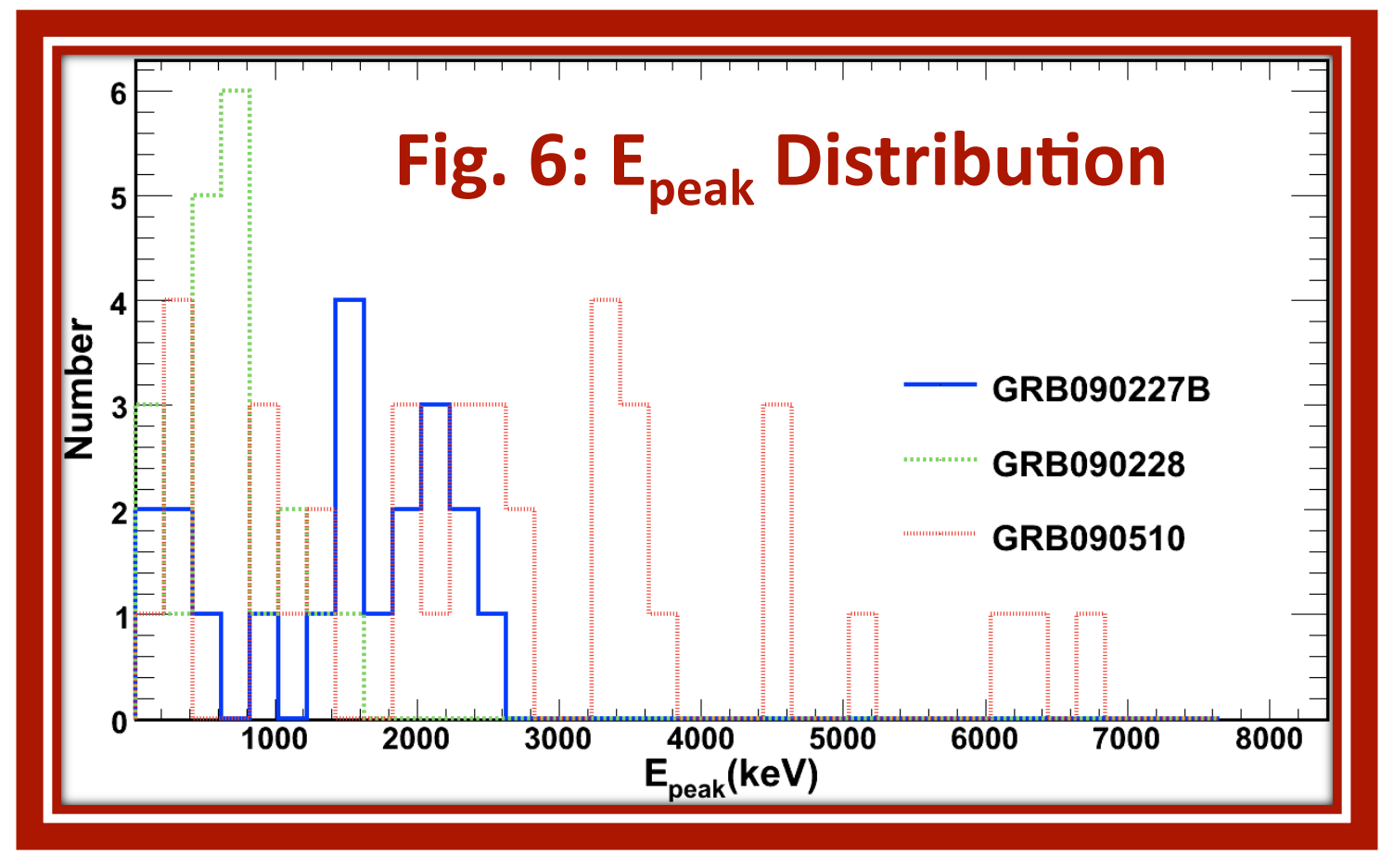

Fig. 6: E_{peak} Distribution

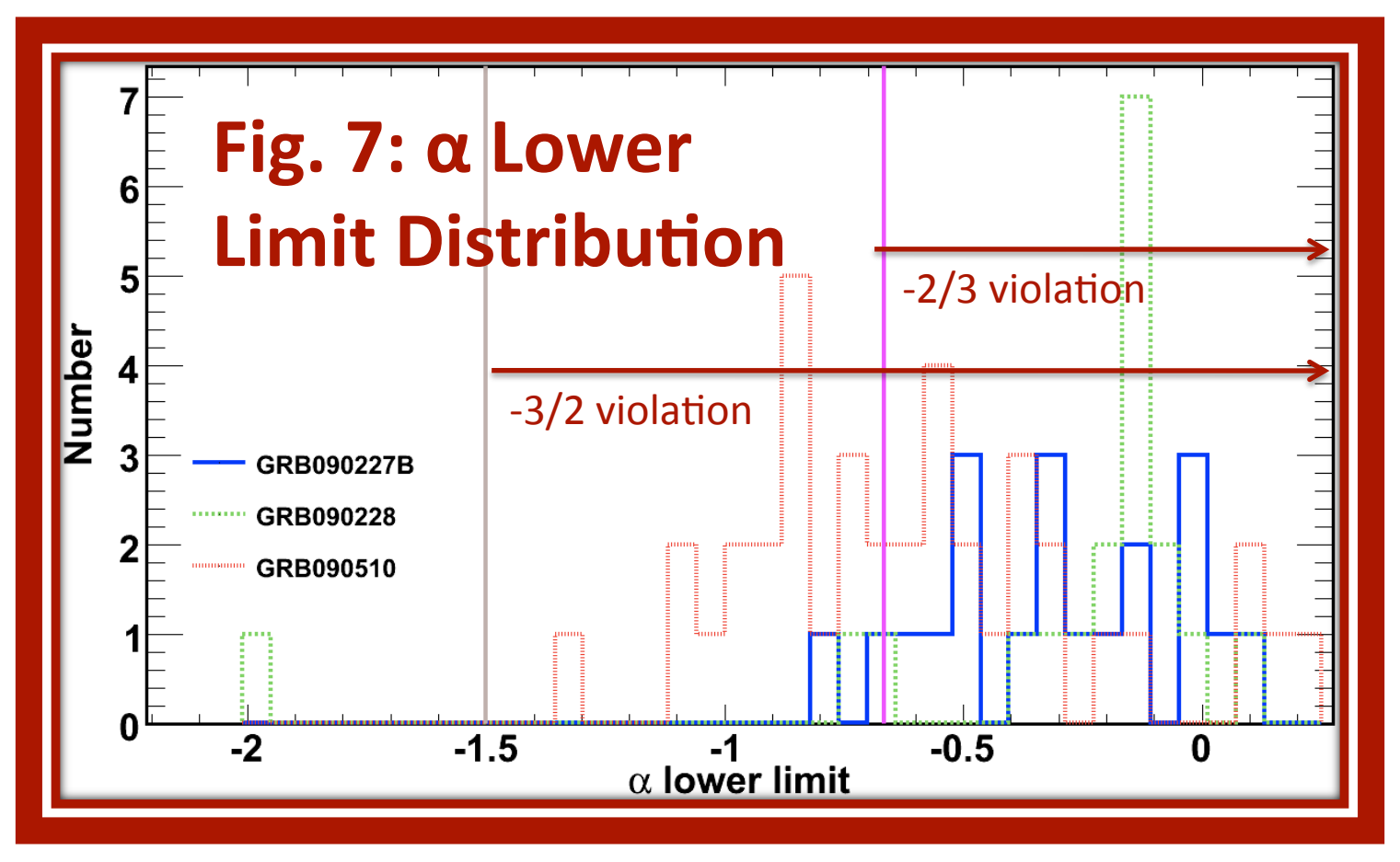

Fig. 7: α Lower Limit Distribution

Interpretation

E_{peak} increases drastically with the rise of the peaks of the lightcurves and decreases after that. This observation supports what we can expect from electron synchrotron emission in the internal shocks model (acceleration and cooling of the electrons). However, the violation of α is still an issue, which could require additional processes.

Conclusions

With GBM, we can study GRB from 8 keV to 40 MeV, which is crucial for the understanding of the prompt emission. While GBM's effective area is not as large as its famous predecessor BATSE (which had an energy limit of 10 MeV), we showed that we can perform fine time-resolved spectroscopy of short GRBs down to timescales of 2 ms. The time-integrated spectra of these three short GRBs are best fit with Band+PL, suggesting an additional component, which dominates the standard Band spectrum at low and high energy, and could be explained by electron SSC or hadronic emission. The E_{peak} values of the time-integrated spectra are well above the values seen in the hardest long GRBs.

The time-resolved spectroscopy of short bursts is similar to what we observed in long bursts with E_{peak} tracking the lightcurve, except contracted in time and shifted to higher energy.

The time-resolved spectroscopy analysis of these GRBs seems to support electron synchrotron emission in the framework of the internal shocks even if the hard values of α remain a major issue.

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