# *Fermi* Gamma-ray Burst Monitor (GBM)

# The *Fermi* GBM gamma-ray burst time-resolved spectral catalog: brightest bursts in the first four years

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**Abstract** We present the first *Fermi* GBM gamma-ray burst (GRB) time-resolved spectral catalog. Time-resolved spectral analysis with high temporal and spectral resolution is performed to the brightest bursts observed by the *Fermi* GBM in its first 4 years of mission, in a wide gamma-ray energy range with high temporal and spectral resolution of 8 keV up to 40 MeV. This catalog covers the energies of a few hundred keV with high sensitivity where the spectral peaks or breaks usually reside, thus provides unique and crucial information about GRBs. We obtain 1,491 high spectrally and temporally resolved spectra from 81 bursts. The distributions of best-fit parameters, statistics of the parameter populations, parameter correlations, uncertainty correlations, spectral evolutionary trends of the peak energy, and identified blackbodies in the time-resolved spectra are presented in the catalog.

## Data and method

- **Detector selection:** A maximum of 3 thallium activated sodium iodide (NaI) with 1 bismuth germanate (BGO) are used. Detectors with viewing angle larger than 60 degrees or blocked by the LAT or solar panels are removed.
- **Data type selection:** Time-tagged event (TTE) data which stores individual photon events tagged with arrival time (resolution of 2 μs), photon energy channel (128 pseudo-logarithmic energy channels), and detector number is used.
- **Energy channel selection:** 8 keV – 900 keV for NaI and 250 keV – 40 MeV for BGO.
- **Background fitting:** For each burst, a polynomial with order 2 – 4 is fit to every energy channel according to two user-defined background intervals, before and after the emission period and interpolated across the emission period.
- **Burst and spectrum selection:** 10 keV – 1 MeV energy fluence > 4E-5 erg cm$^{-2}$ and/or 10 keV – 1 MeV peak photon flux > 20 ph s$^{-1}$ cm$^{-2}$ (in either 64, 256, or 1,024 ms binning timescales); at least 5 time bins in the light curves when binned with signal-to-noise ratio (S/N) = 30.

## Results

**Fit models:**

1. Band function (BAND, Band et al. 1993)
2. Smoothly broken power law (SBPL, Ryde 1999; Kaneko et al. 2006)
3. Cutoff power law (COMP, aka. Comptonized model)
4. Power law (PL)

**Parameters:**

1. Low-energy power-law index $\alpha$
2. High-energy power-law index $\beta$
3. Peak energy in $\nu F_\nu$ space $E_p$
4. Break energy $E_b$

| | GOOD | | BEST | |
|---|---|---|---|---|
| Model | $N$ | percentage | $N$ | percentage |
| BAND | 939 | 52.1% | 139 | 9.3% |
| SBPL | 1,201 | 66.6% | 170 | 11.4% |
| COMP | 1,276 | 70.8% | 1,030 | 69.1% |
| PL | 1,488 | 82.6% | 152 | 10.2% |
| ALL | 1,802 | - | 1,491 | - |

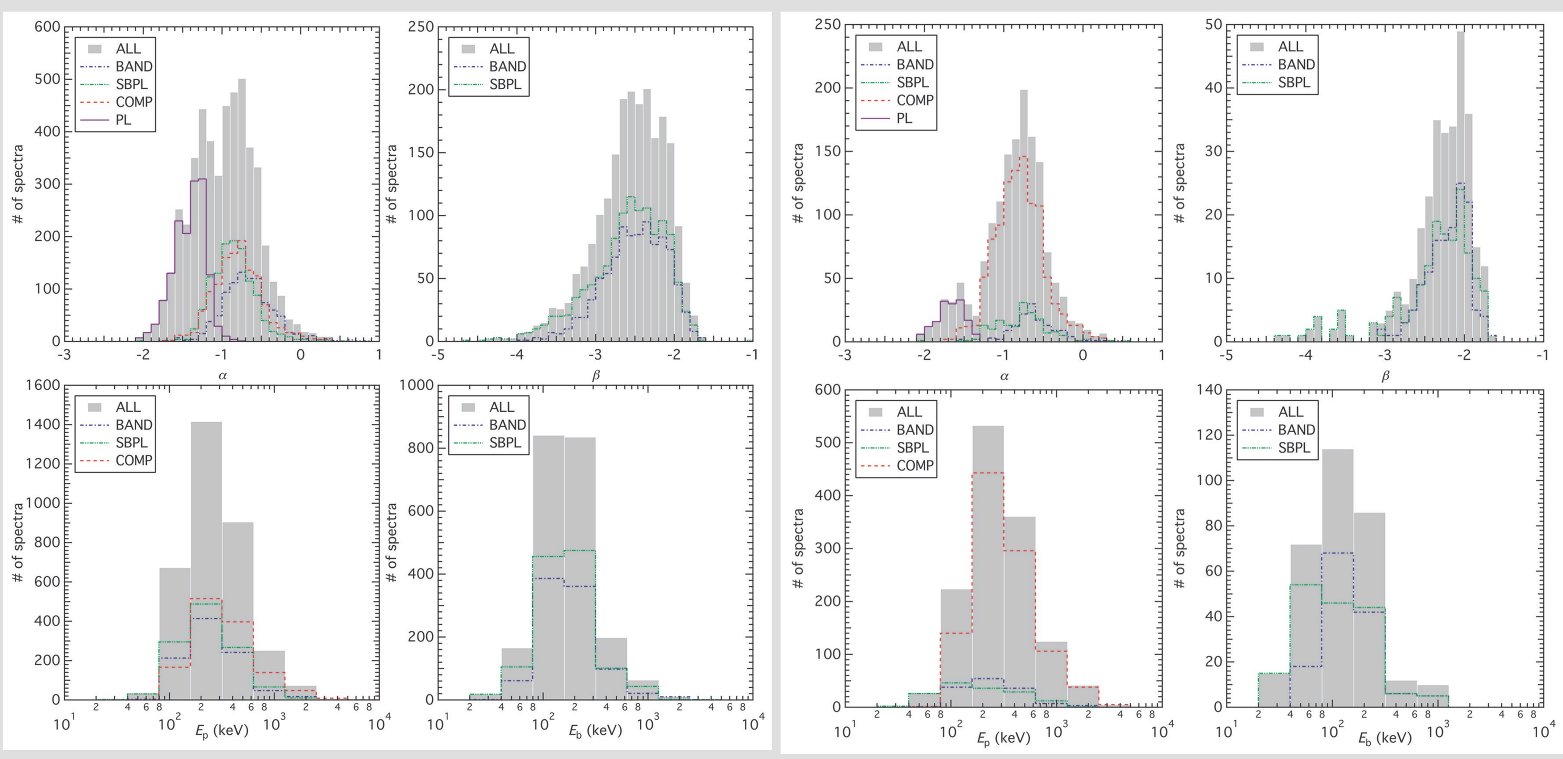
**GOOD sample:**

- Non-power-law indices parameters Q: $\sigma_Q/Q < 0.4$
- Low-energy power-law index $\alpha$: $\sigma_\alpha < 0.4$
- High-energy power-law index $\beta$: $\sigma_\beta < 1.0$ (Goldstein et al. 2012; Gruber et al. 2014)

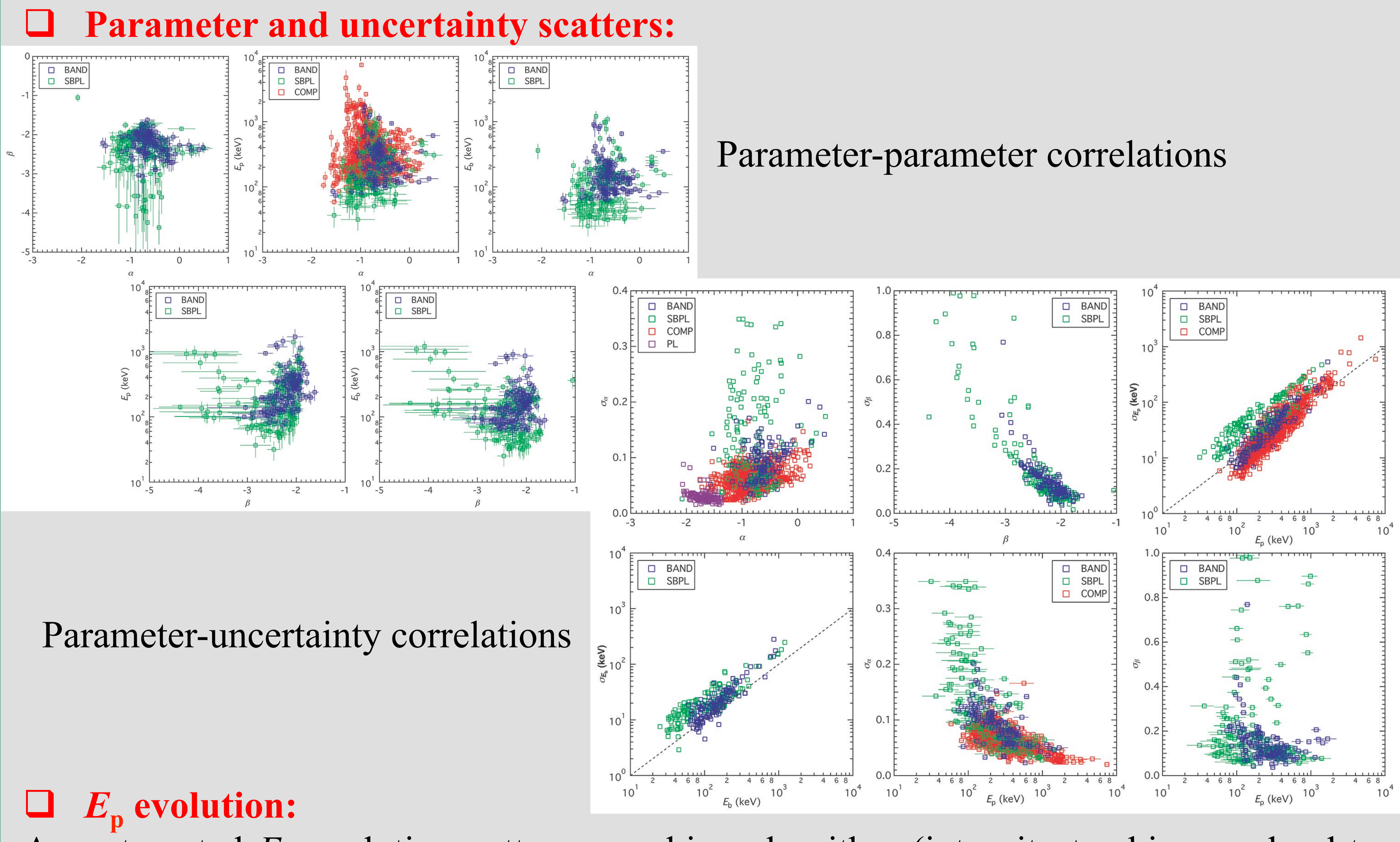
**BEST sample:**

The GOOD model with lowest CSTAT (Cash 1979) instead of Chi$^2$, due to Poisson background of GBM.

<u>GOOD</u> <u>BEST</u>

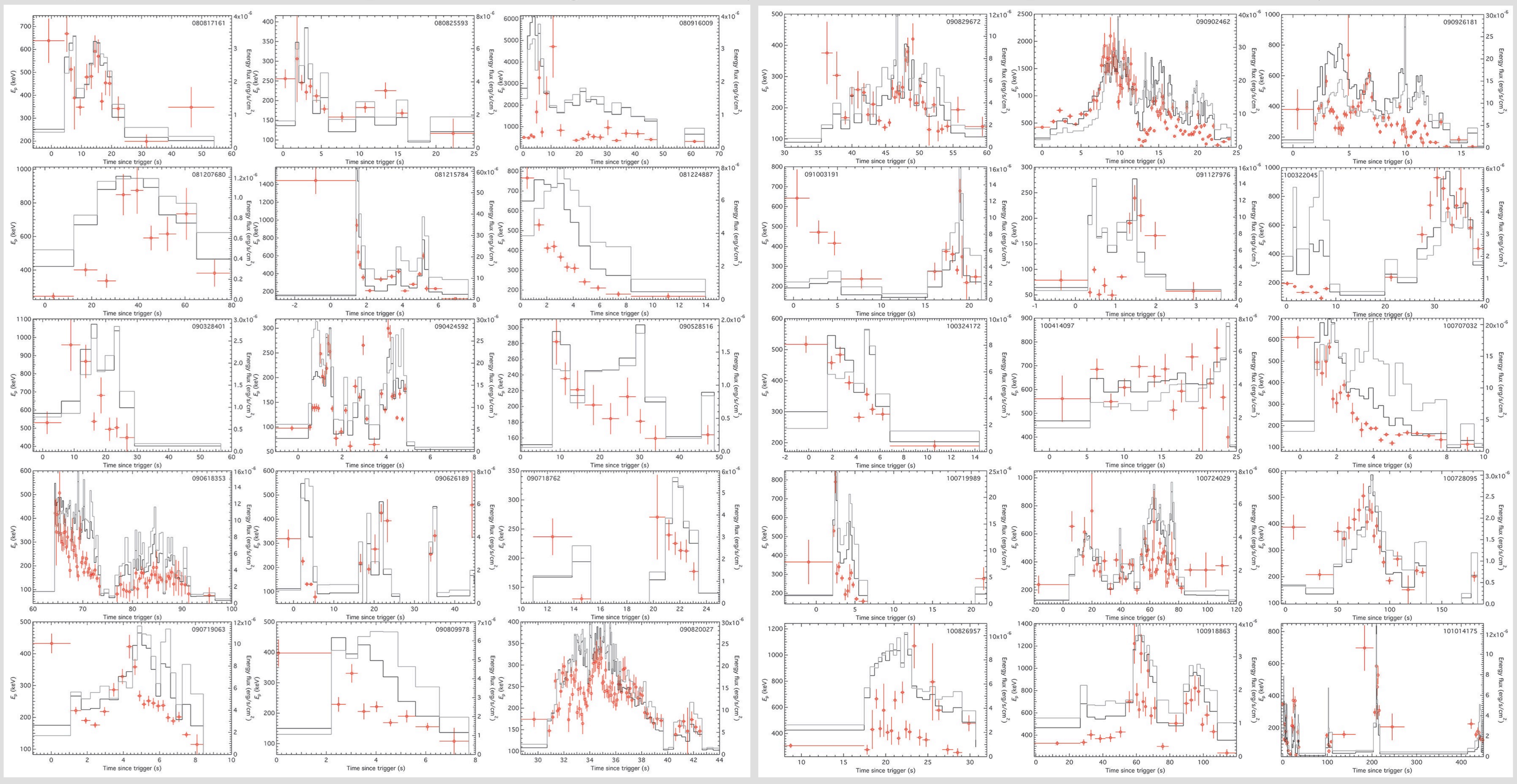



**Parameter and uncertainty scatters:**




**$E_p$ evolution:**

An automated $E_p$ evolution pattern searching algorithm (intensity tracking vs. hard-to-soft) has been developed, with high accuracy (96.5% as compared to human eyes).



**Blackbody search:**

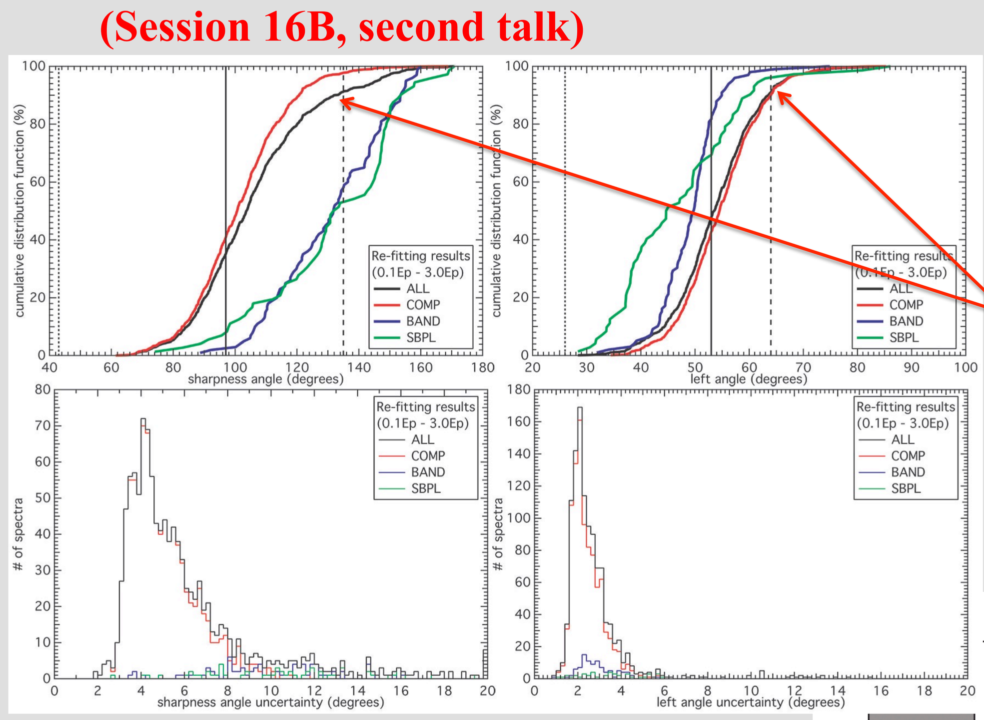
Simulation performed to identify true blackbodies by CSTAT difference:

$$f_{\mathrm{PLBB}}(E) = A_{\mathrm{PL}} \left(\frac{E}{100\ \mathrm{keV}}\right)^{\alpha} + A_{\mathrm{BB}} \left[\frac{(E/1\ \mathrm{keV})^2}{\exp(E/kT) - 1}\right]$$

| GRB name | $N$ | $\Delta$CSTAT$_{\mathrm{crit}}$ |
|---|---|---|
| 090618353 | 2 | 19.55 |
| 090902462 | 32 | 32.75 |
| 110622158 | 2 | 12.32 |
| ~~110920546~~ | ~~6~~ | ~~148.37~~ |

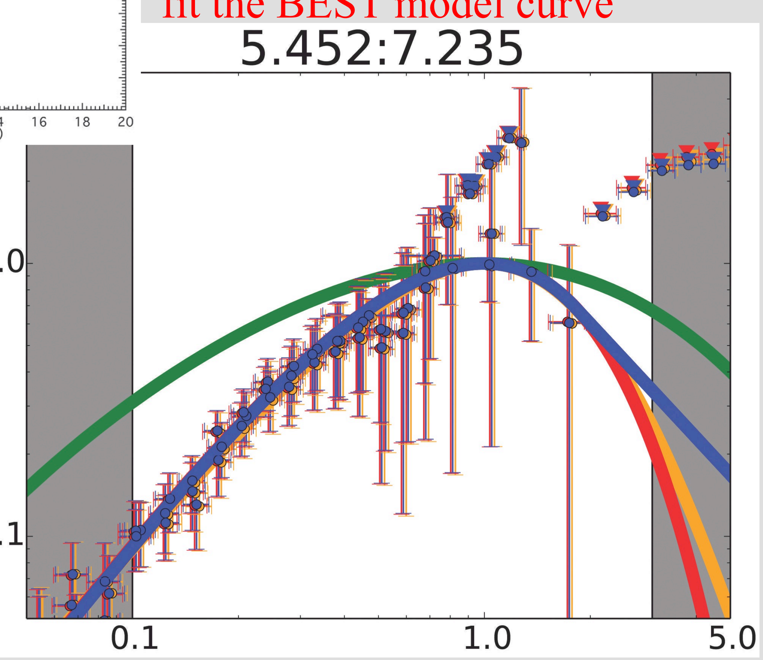
## Follow-up paper based on the fit results from this catalog

**>>> See the talk of Hoi-Fung Yu on the spectral sharpness of gamma-ray bursts! (Session 16B, second talk)**

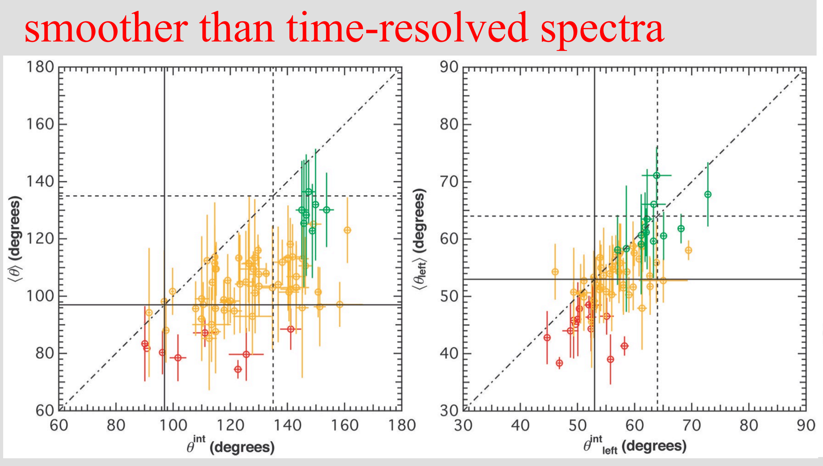



- Novel quantity to measure the spectral sharpness
- Optically thin synchrotron is not compatible with the data

- Maxwellian synchrotron doesn't fit the BEST model curve




- Time-integrated spectra are much smoother than time-resolved spectra



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