The ECLAIRs + GRM system: prospects for GRB spectroscopy between 4 keV and 5 MeV

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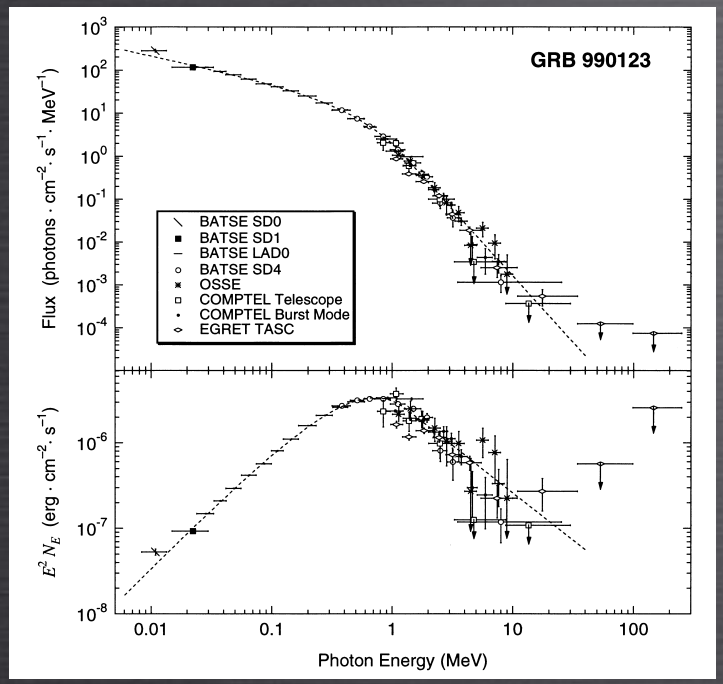
The GRB prompt emission spectrum

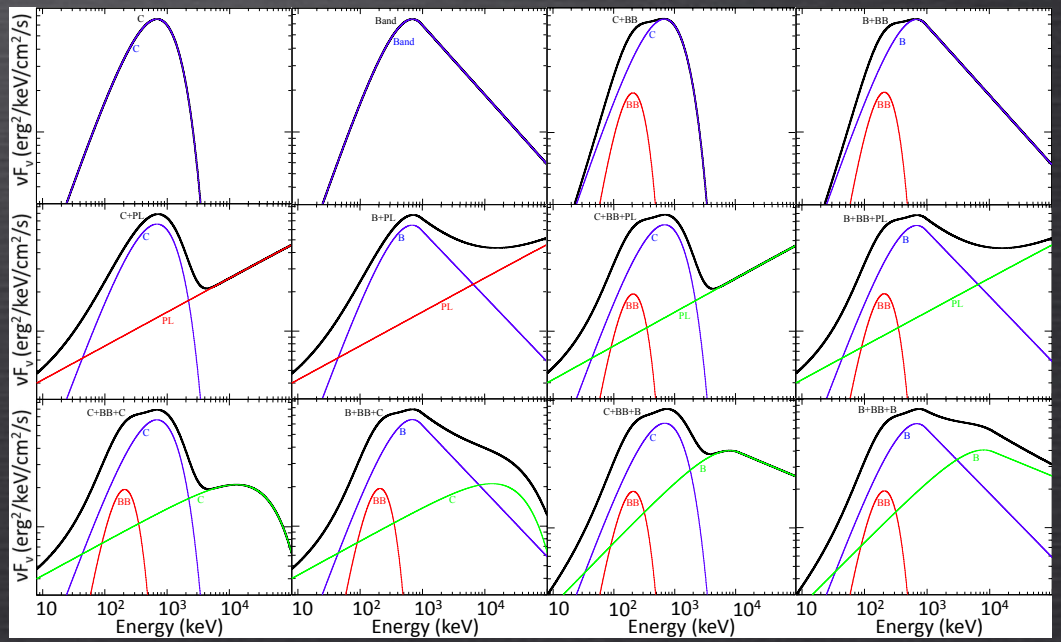


Band function:

$$N_E(E) = A\left(\frac{E}{100\ \text{keV}}\right)^{\alpha} \exp\left(-\frac{E}{E_0}\right), \qquad (\alpha-\beta)E_0 \geq E,$$

$$= A\left[\frac{(\alpha-\beta)E_0}{100\ \text{keV}}\right]^{\alpha-\beta} \exp(\beta-\alpha)\left(\frac{E}{100\ \text{keV}}\right)^{\beta}, \qquad (\alpha-\beta)E_0 \leq E,$$

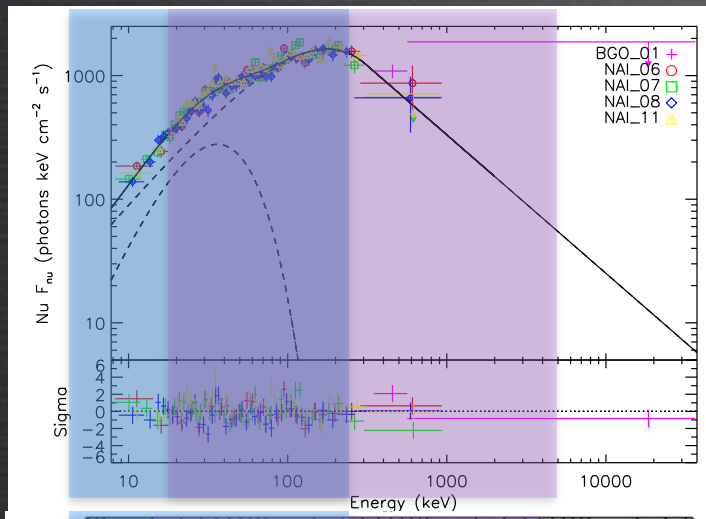
Fermi/GBM showed deviation from the Band spectrum: different combinations of Band, Comptonised, Blackbody and power-law models



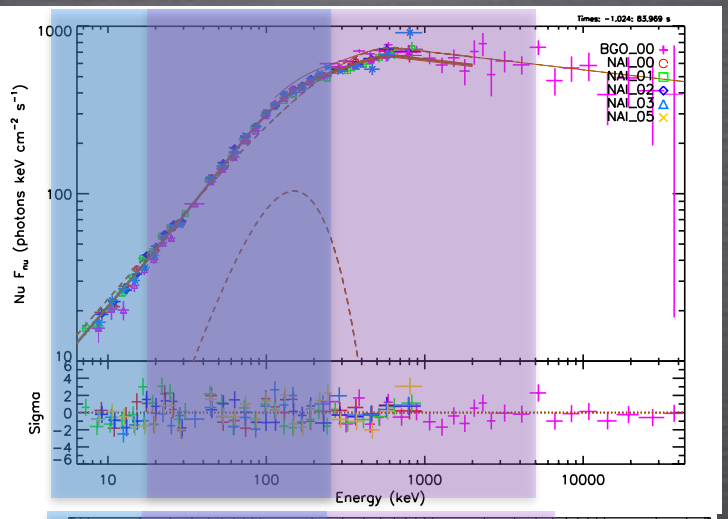
Band+93
Briggs+99
Guiriec+15

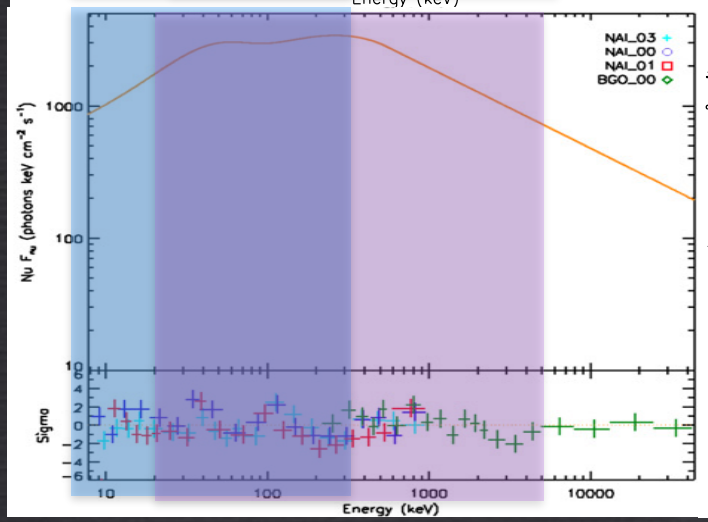
ECLAIRs + GRM view of the prompt emission

GRB 090924

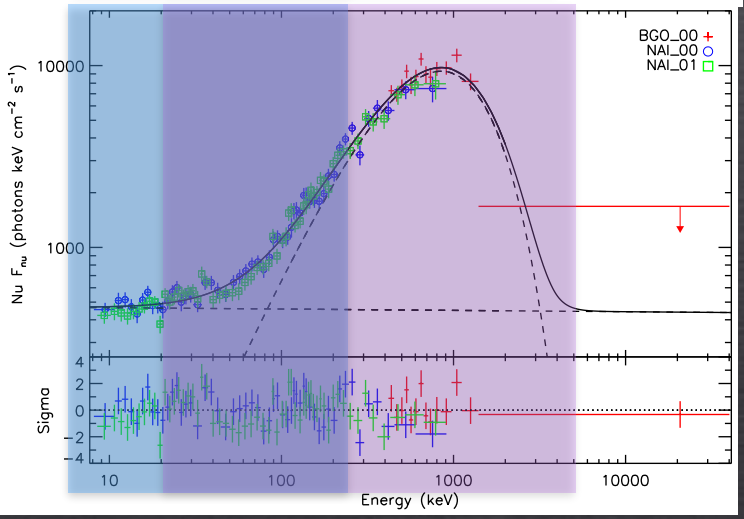


GRB 100724B





GRB 120323A



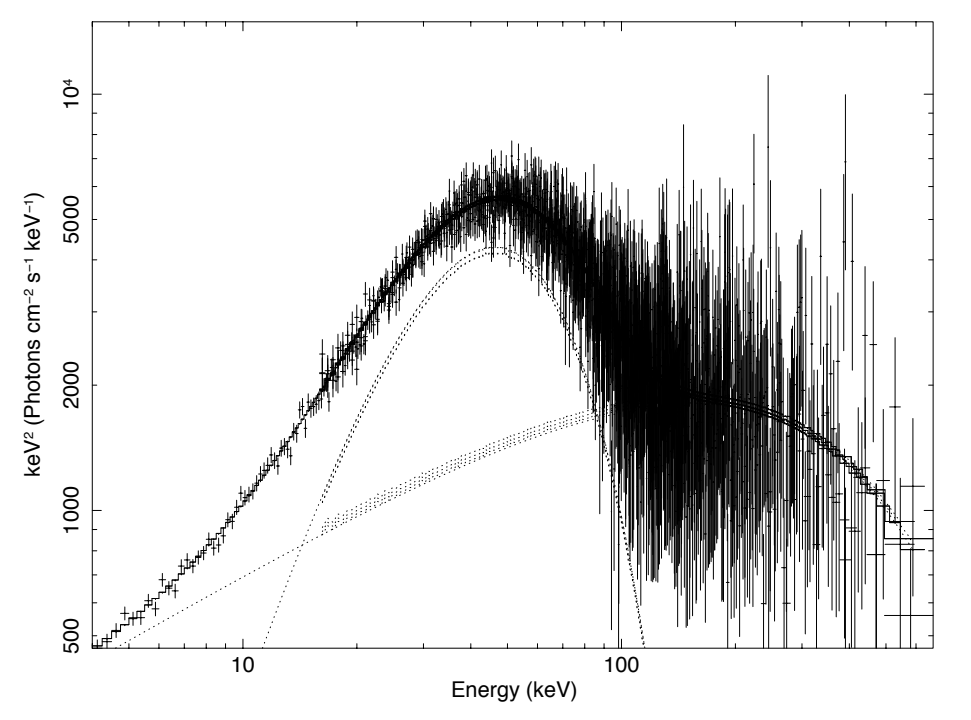
GRB 090902B

ECLAIRs + GRM (4-5000 keV) will allow us to detect the most interesting features of GRB prompt emission

Guiriec+11 Tierney+13
Guiriec+13

GRB 120323A: a short GRB with BB component

Guiriec+13

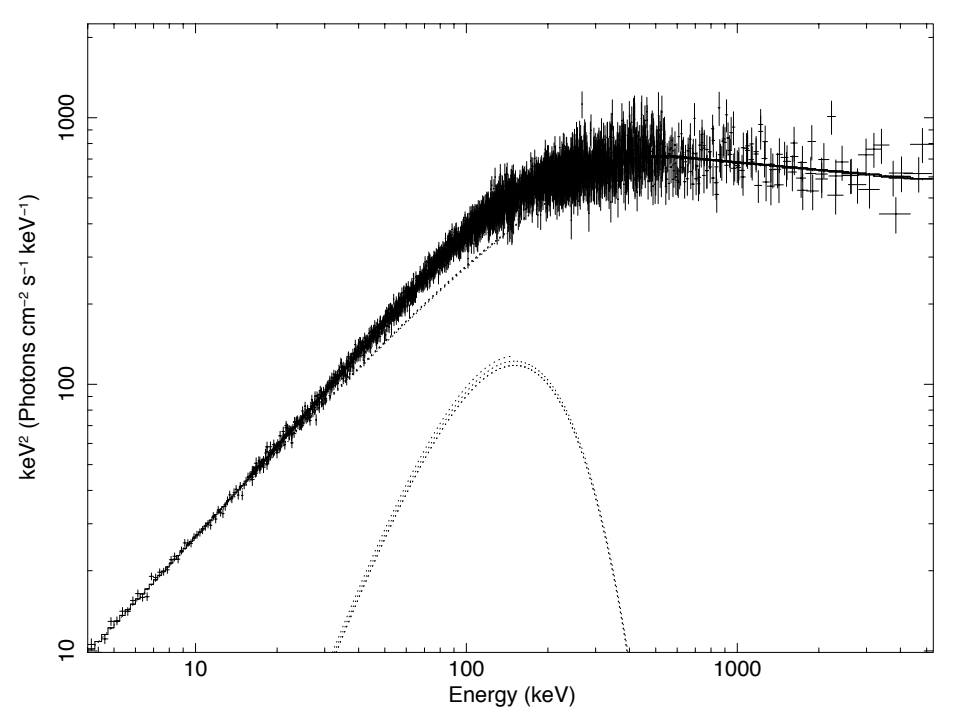


model	gamma	Ecut (keV)	KT (keV)	Cstat/dof
cutPL	0.45±0.01	37.8±0.6		5027/1493
cutPL+BB	1.47±0.03	288±36	11.8±0.1	1501/1492

- Short GRB detected by Fermi/GBM
- prompt emission time-integrated spectrum: comptonised model + blackbody (~ 50% of total fluence)
- best-fitting model: comptonised + b-body
- all spectral parameters well constrained and consistent with injected parameters

GRB 100724B: a long GRB with BB component

Guiriec+11



model	alpha	beta	Ep (keV)	KT (keV)	Cstat/dof
Band	0.70±0.01	2.06±0.02	276±5		3179/2518
Band+BB	0.90±0.01	2.09±0.03	490±25	38.5±0.7	2520/2513

- Long GRB detected by Fermi/GBM
- prompt emission time-integrated spectrum: Band function + blackbody (~ 10% of total fluence)
- best-fitting model: band + b-body
- all spectral parameters well constrained and consistent with injected parameters

The GRB prompt emission spectrum

Band function is empirical and not a physical model: what is the emission mechanism??

- synchrotron? line of death problem
- low energy spectral index useful to constrain models

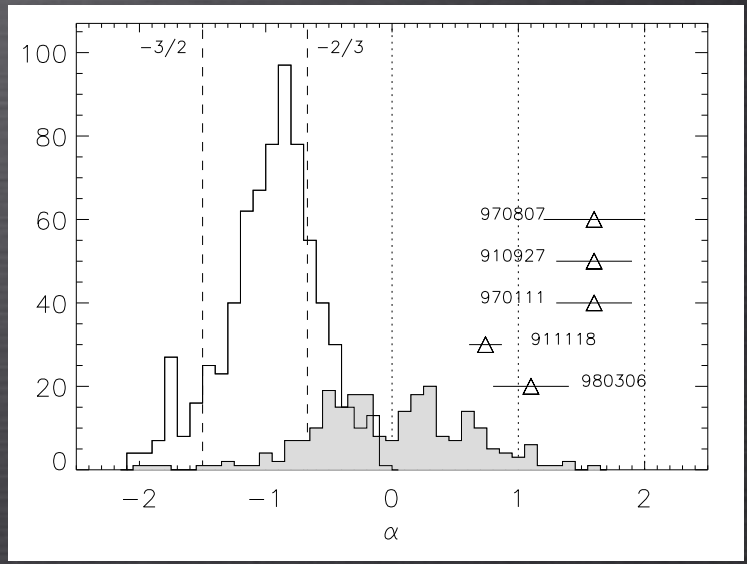
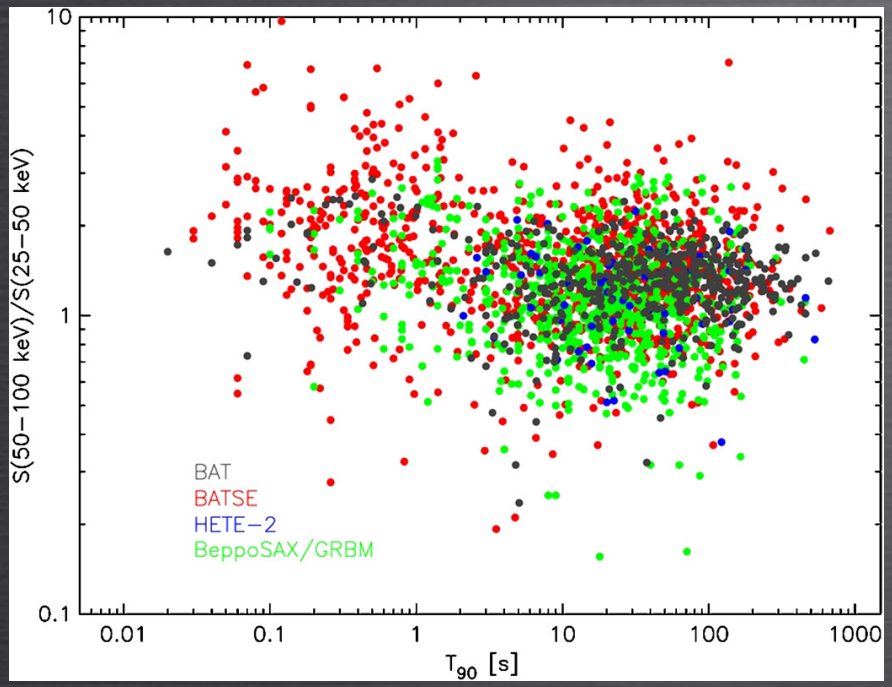


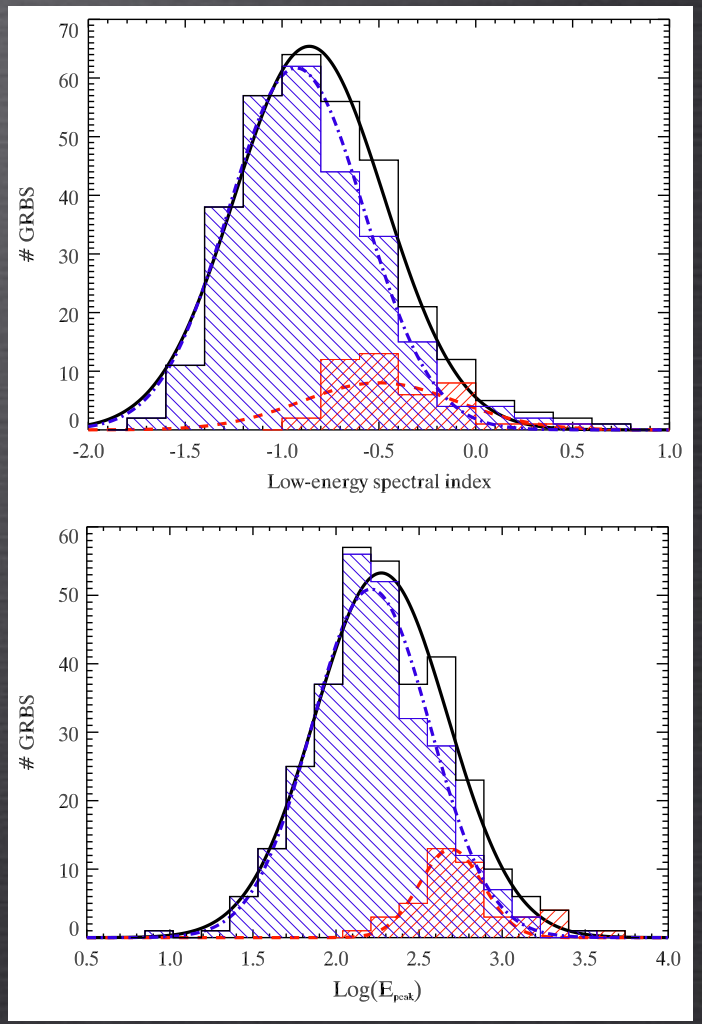
Table 1. Low energy limiting photon spectral index α [i.e. $N(E) \propto E^{\alpha}$] for various emission models. For clarity the indices for the energy spectrum $F(E)$ and for its EF_E representation are also reported.

α $N(E)$	$\alpha+1$ $F(E)$	$\alpha+2$ EF_E	model/spectrum
-3/2	-1/2	1/2	Synchrotron emission with cooling
-1	0	1	Quasi–saturated Comptonization
-2/3	1/3	4/3	Instantaneous synchrotron
0	1	2	Small pitch angle/jitter inverse Compton by single e^-
1	2	3	Black Body
2	3	4	Wien

Katz+94
Preece+98,+02
Ghirlanda+03

The GRB prompt emission spectrum





Are spectral parameters different between short and long GRBs??

- short GRBs are harder because they have larger E_{pk} or harder low energy index?

Kouveliotou+93
Ghirlanda+04,+09,+15
Nava+11

The GRB prompt emission spectrum

Band function is an empirical model: what is the emission mechanism??

- synchrotron? line of death problem
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Are spectral parameters different between short and long GRBs??

- short GRBs are harder because they have larger E_{pk} or harder low energy index?

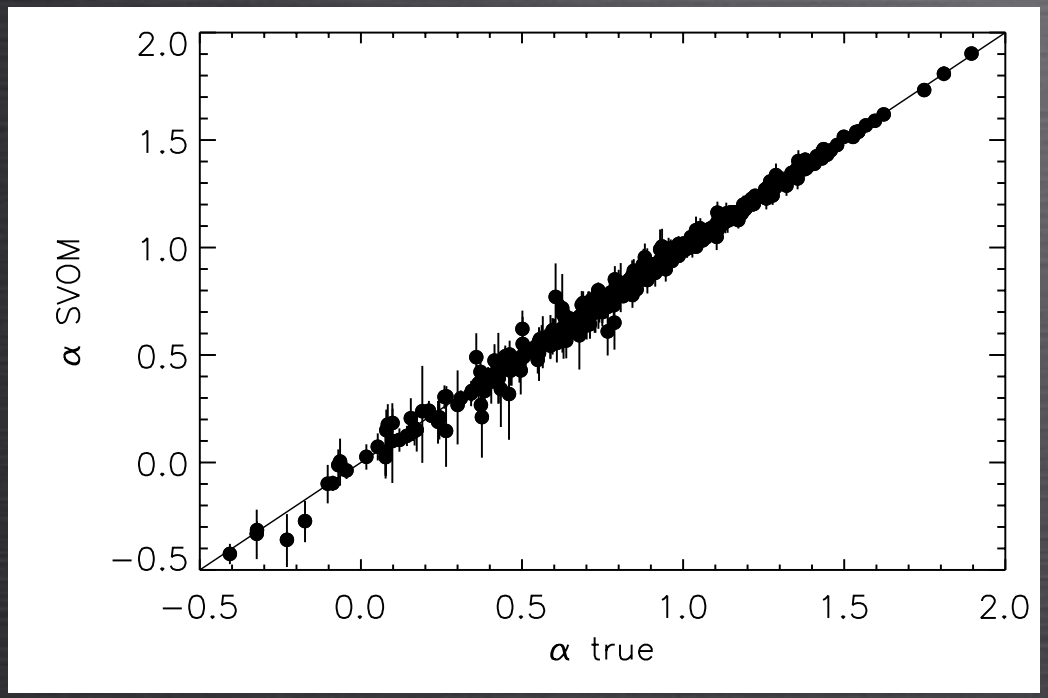
ECLAIRs + GRM

will help to determine with great precision these parameters!

Spectral parameters with ECLAIRs + GRM

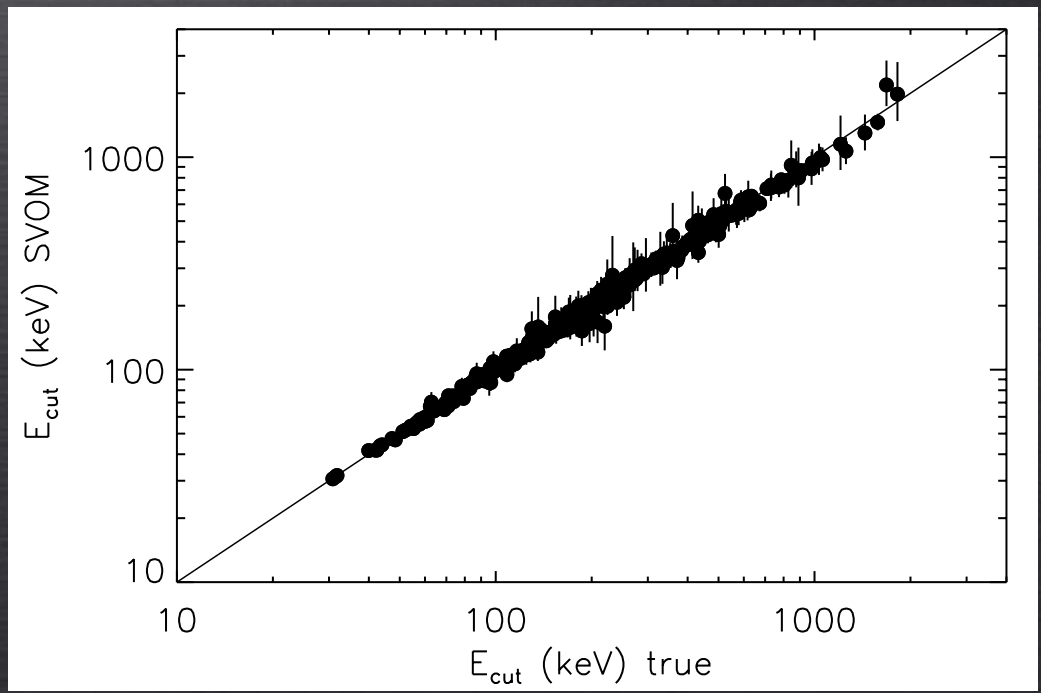
- 446 GRBs with comptonised model from the Fermi/GBM spectral catalogue

Grueber+14



Low energy spectral index

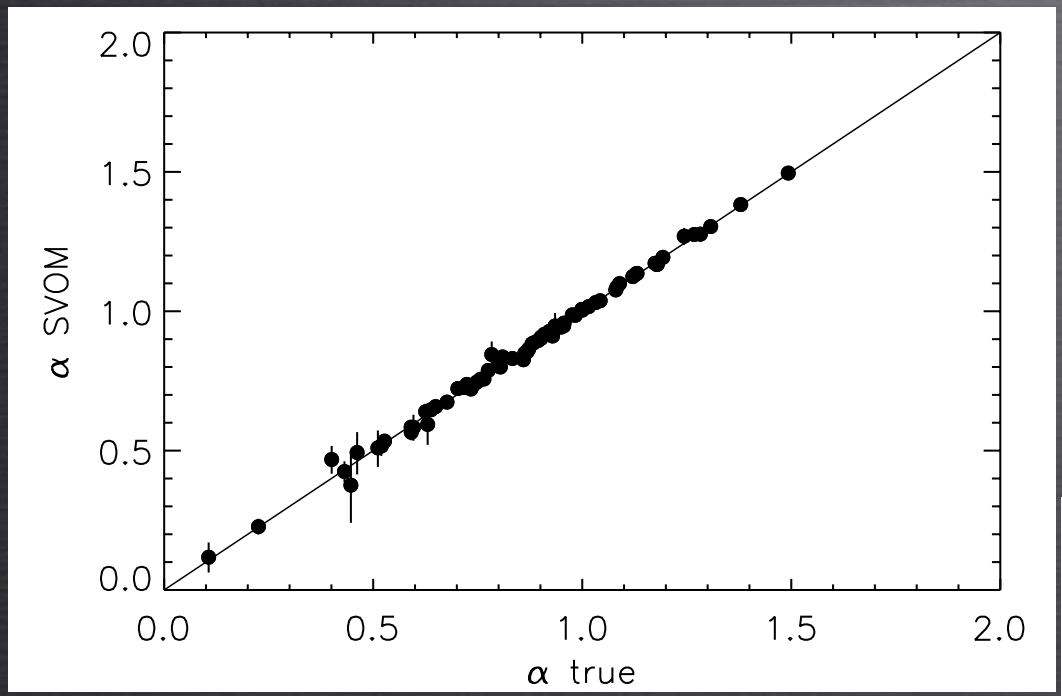
Cutoff energy



Spectral parameters with ECLAIRs + GRM

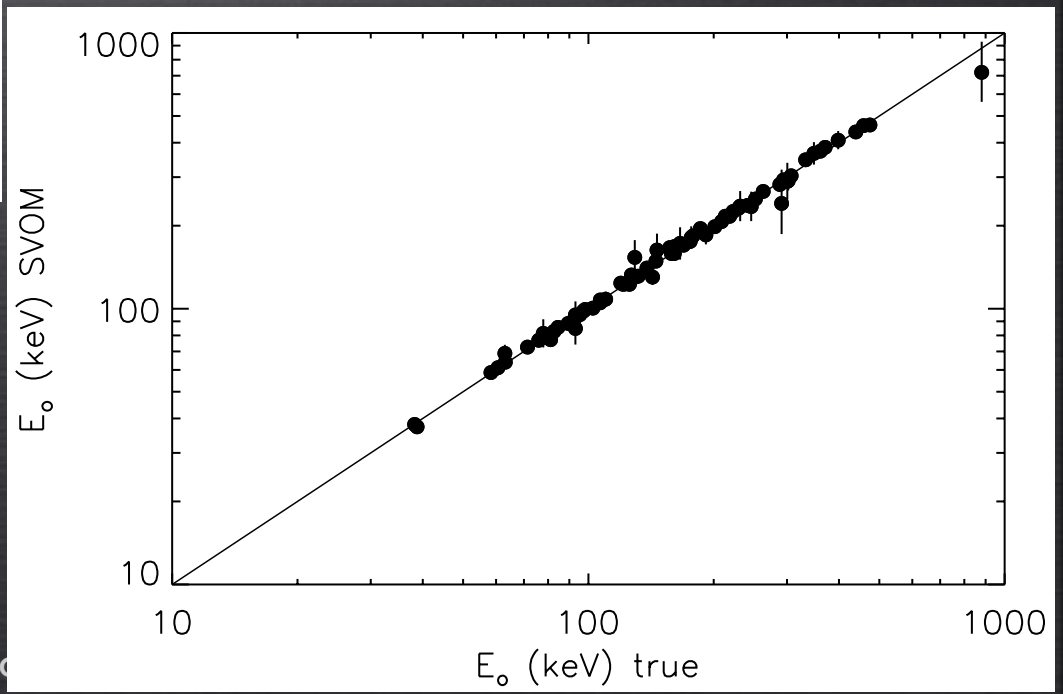
- 76 GRBs with band model from the Fermi/GBM spectral catalogue

Grueber+14



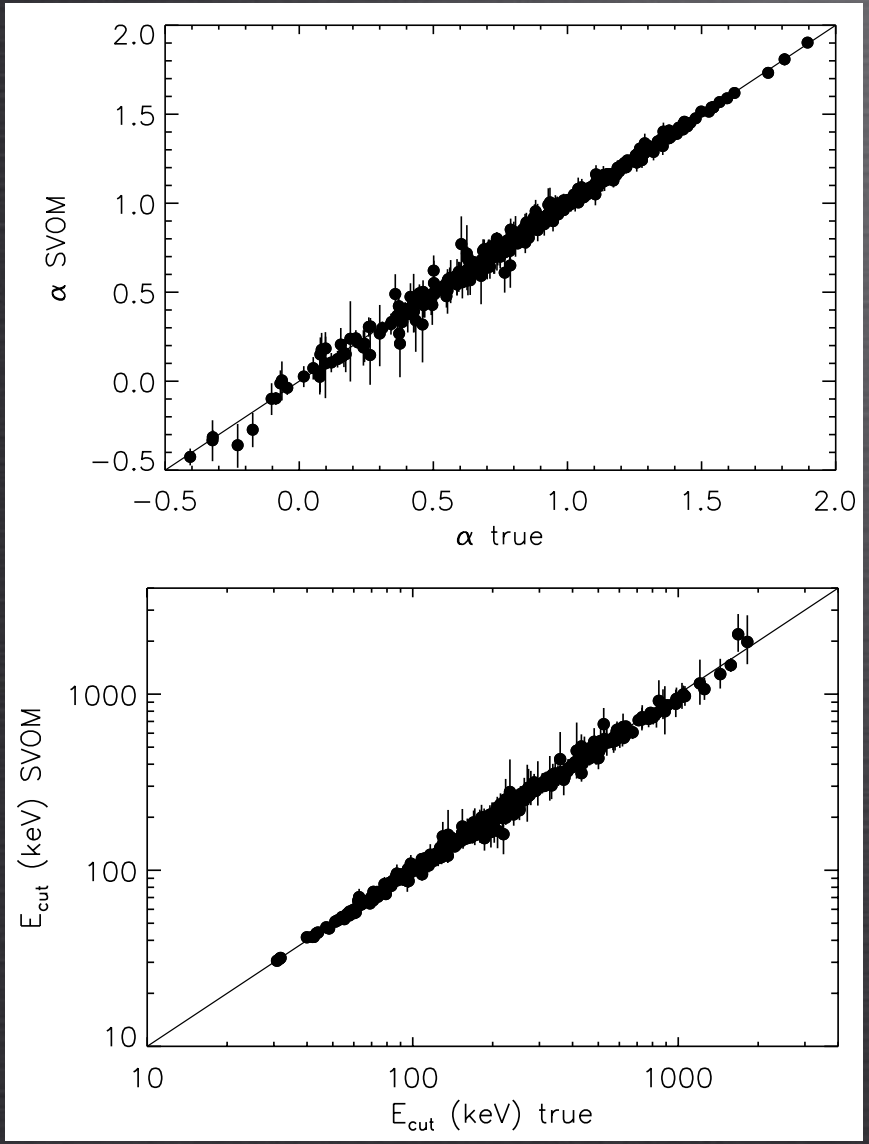
Low energy spectral index

Peak energy

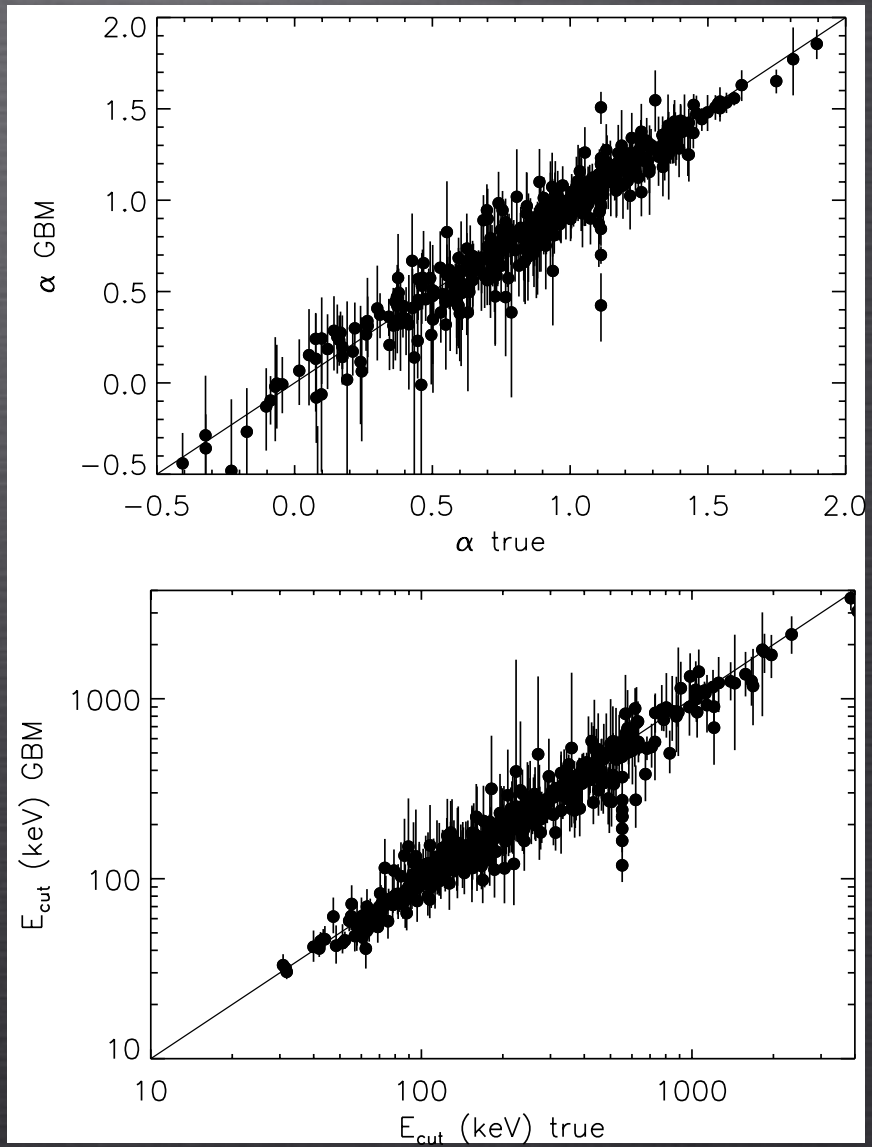


Spectral parameters with ECLAIRs + GRM

Comptonised model



ECLAIRs + GRM



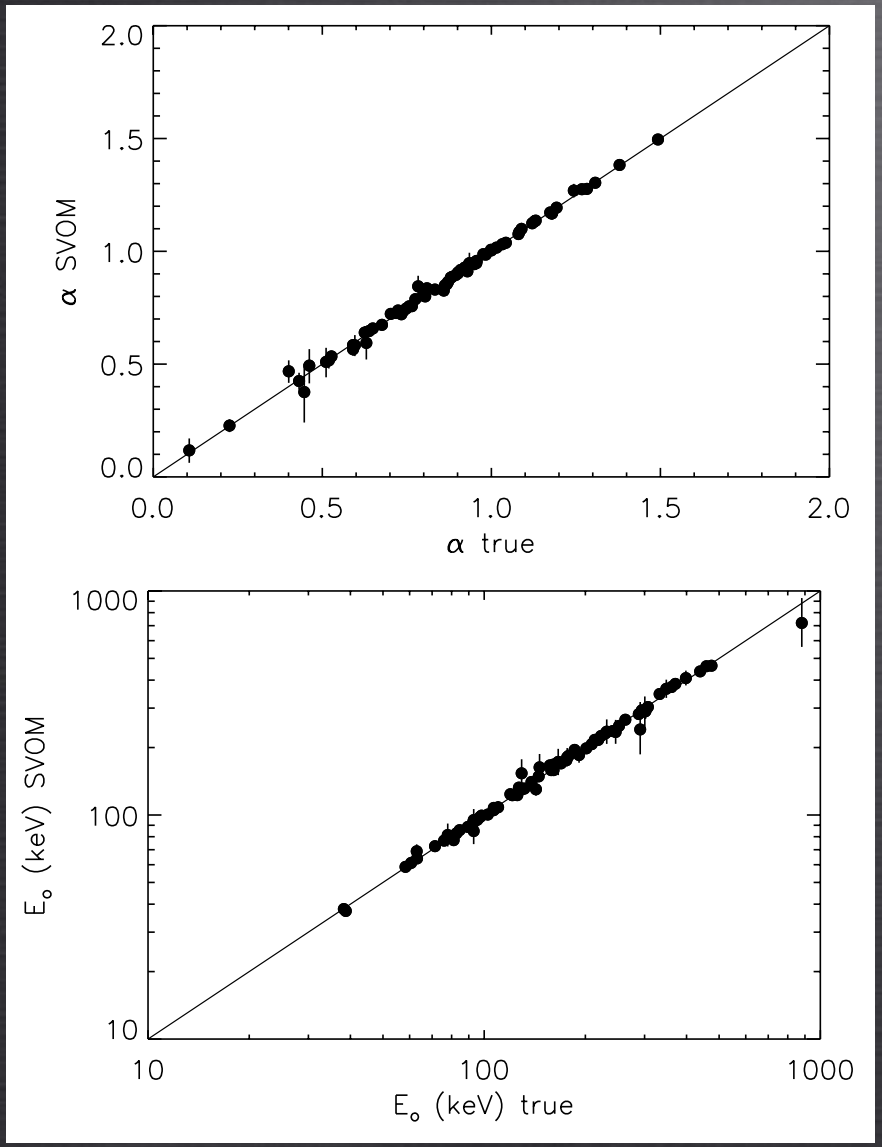
GBM

Low energy spectral index

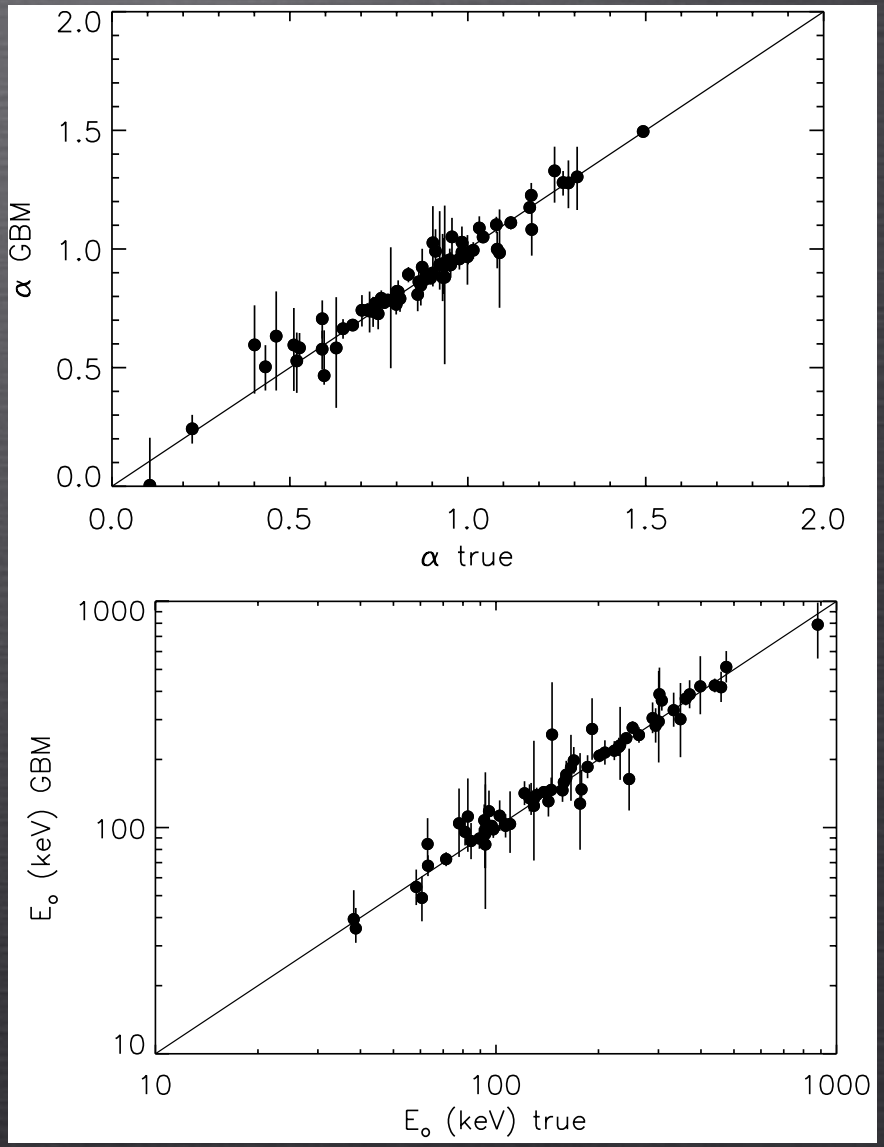
Cutoff energy

Spectral parameters with ECLAIRs + GRM

Band model



ECLAIRs + GRM



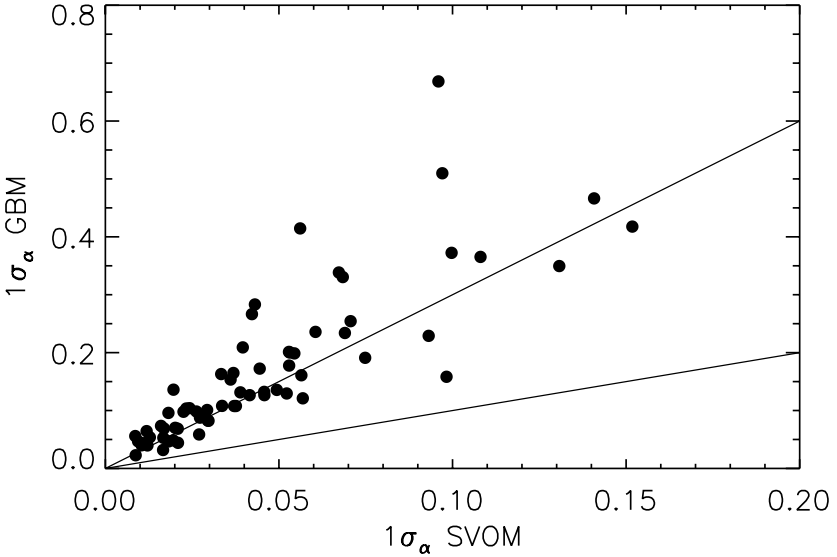
GBM

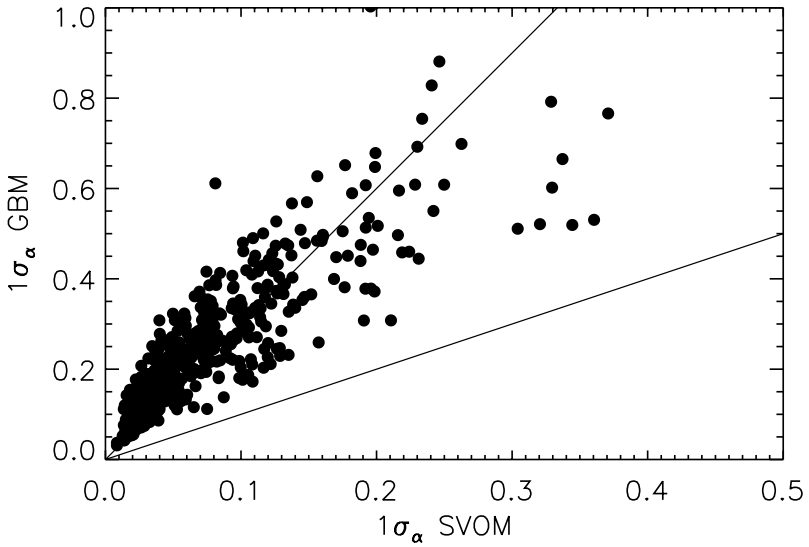
Low energy spectral index

Peak energy

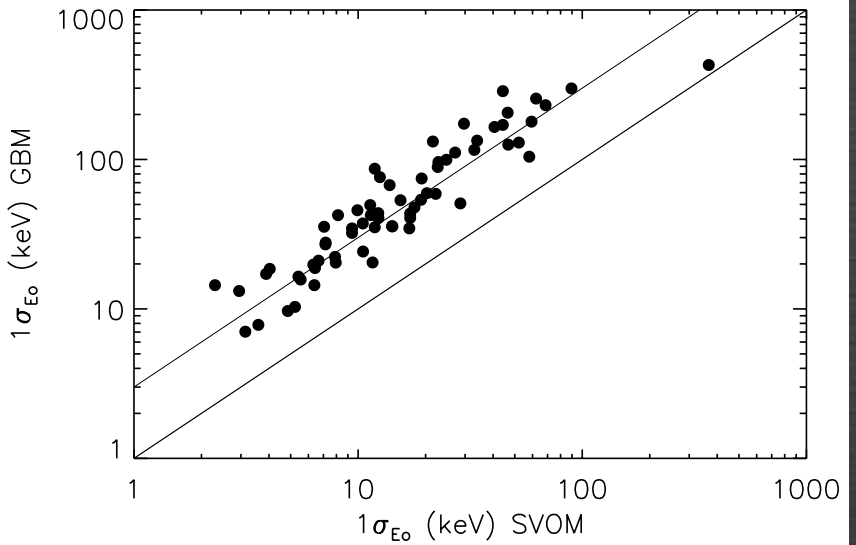
Spectral parameters with ECLAIRs + GRM

Low energy spectral index

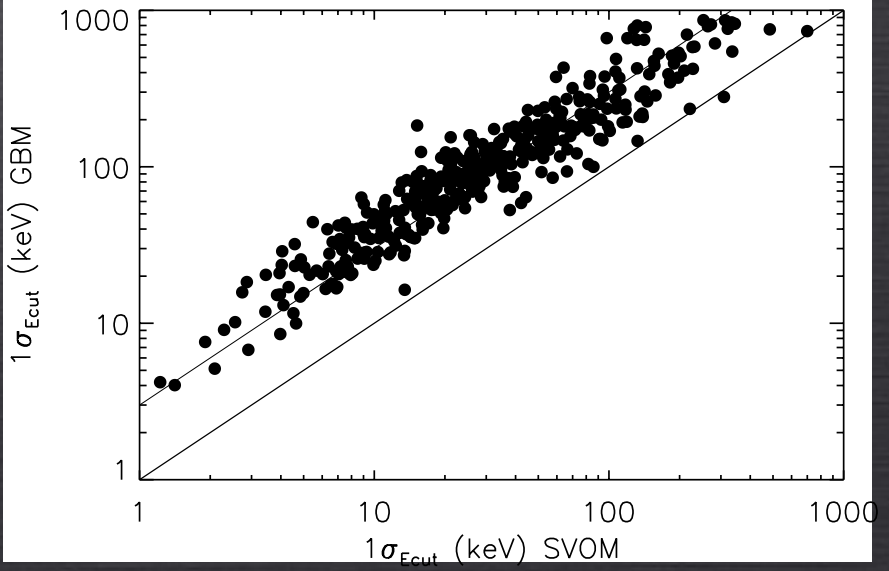




Cutoff/peak energy



Band model



Cpl model

Conclusions

The complete study of GRB prompt high-energy emission will require combining the data from the ECLAIRs and GRM instruments, from 4 keV to a few MeV. The excellent performance of the ECLAIRs and GRM instruments (the low energy threshold of 4 keV and its good sensitivity at MeV energies) will permit:

- to identify and characterize these multiple components in more detail
- to measure with precision the low energy spectral parameters of GRB prompt emission spectra, providing direct insights on the emission mechanisms responsible for the prompt emission

Backup slides

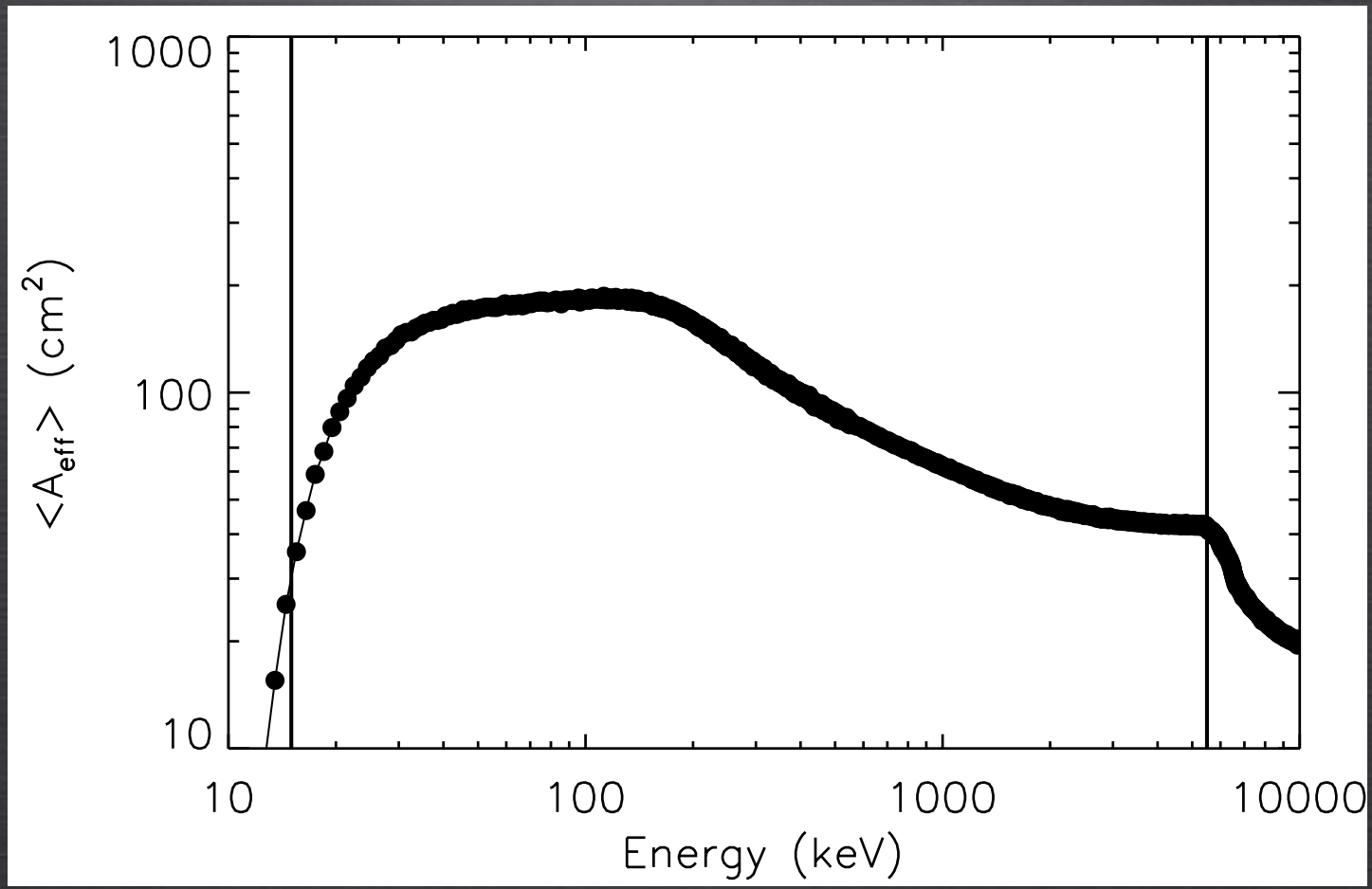
Methodology

- XSPEC Fakeit to simulate GRB spectrum
- **ECLAIRs**: ancillary response file, redistribution matrix and background files from Geant4 simulations with the updated mask for on-axis sources without the Earth in the field-of-view
- **GRM**: 3 GRD detectors, response file and background for 30 degree off-axis sources without the Earth in the field-of-view
- fit of the simulated spectrum with comptonised and Band models in XSPEC to check if we can retrieve the simulated spectrum with the injected parameters

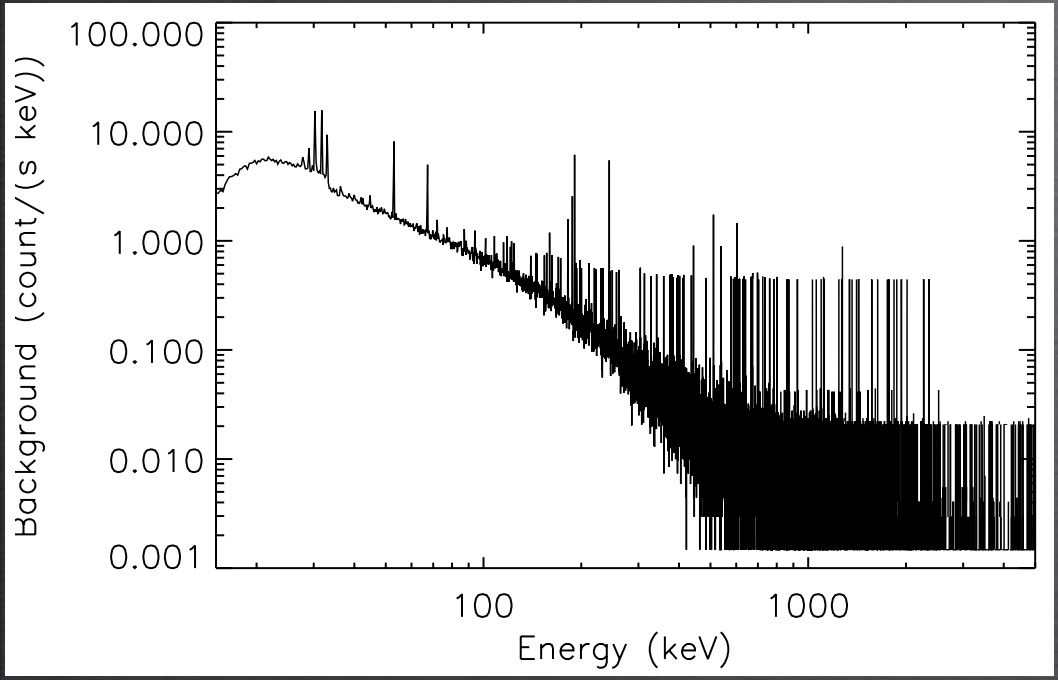
Methodology

- **Aim**: test performances of ECLAIRs + GRM compared to GBM (NaI+BGO detectors)
- initial spectra: best fit models (446 comptonised and 76 band) from Fermi/GBM spectral catalogue (Grueber et al. 2014)
- simulated as they would be observed by ECLAIRs + GRM (4-5500 keV) and by GBM (4 NaI + 1 BGO detectors, 8-40000 keV)
- fitted in XSPEC with comptonised (CUTOFFPL) and Band (GRBM) models

GRD effective area (on-axis sources)



GRD background



Background for 1 GRD with the Earth outside the f.o.v.:

- CXB
- Earth's albedo
- CR induced radiation from Earth's atmosphere
- activation after passage through SAA

Moretti+09
Churazov+06
Sazonov+07