The present and the future of Gamma-Ray Bursts observation with Fermi LAT

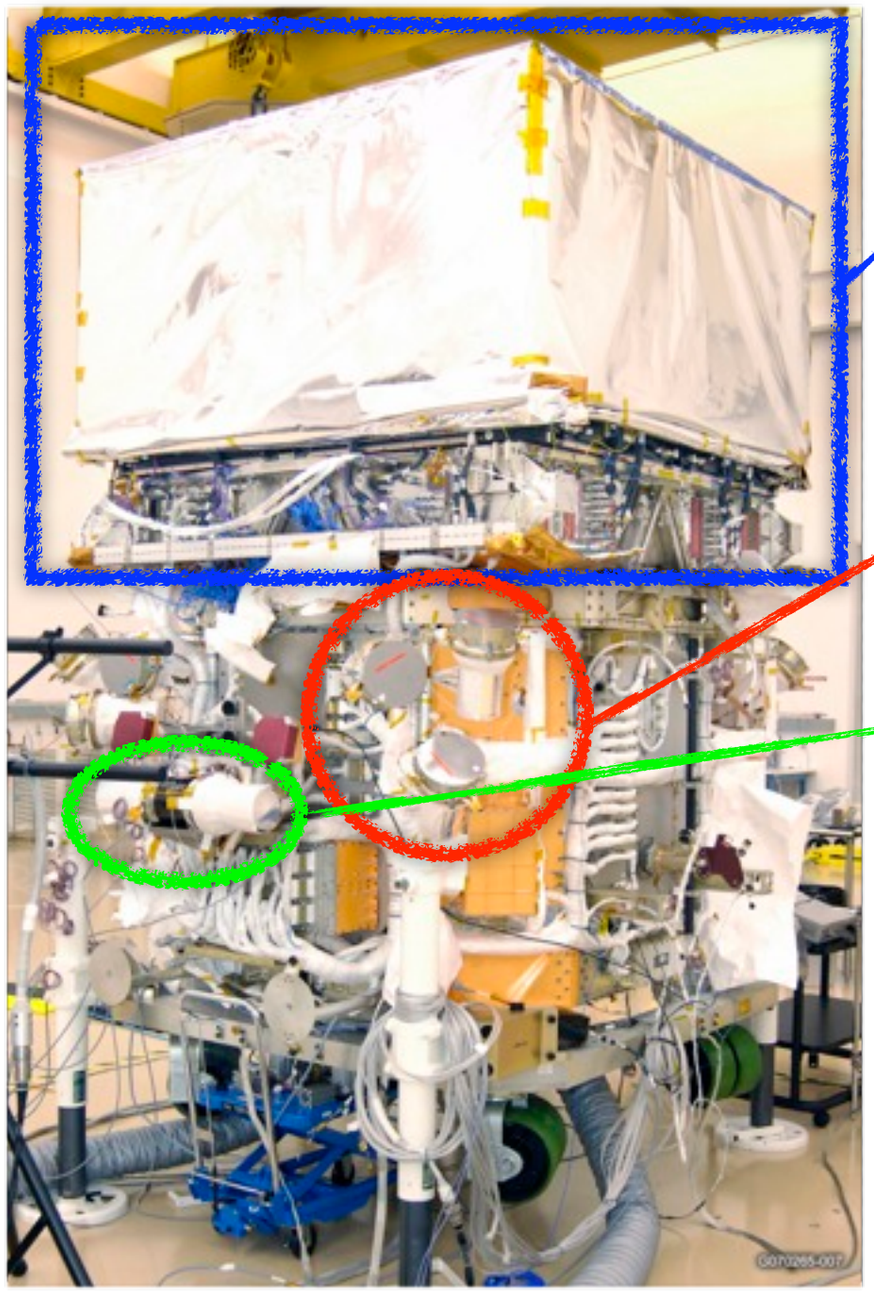
IFC meeting - SLAC

Nicola Omodei

Stanford University

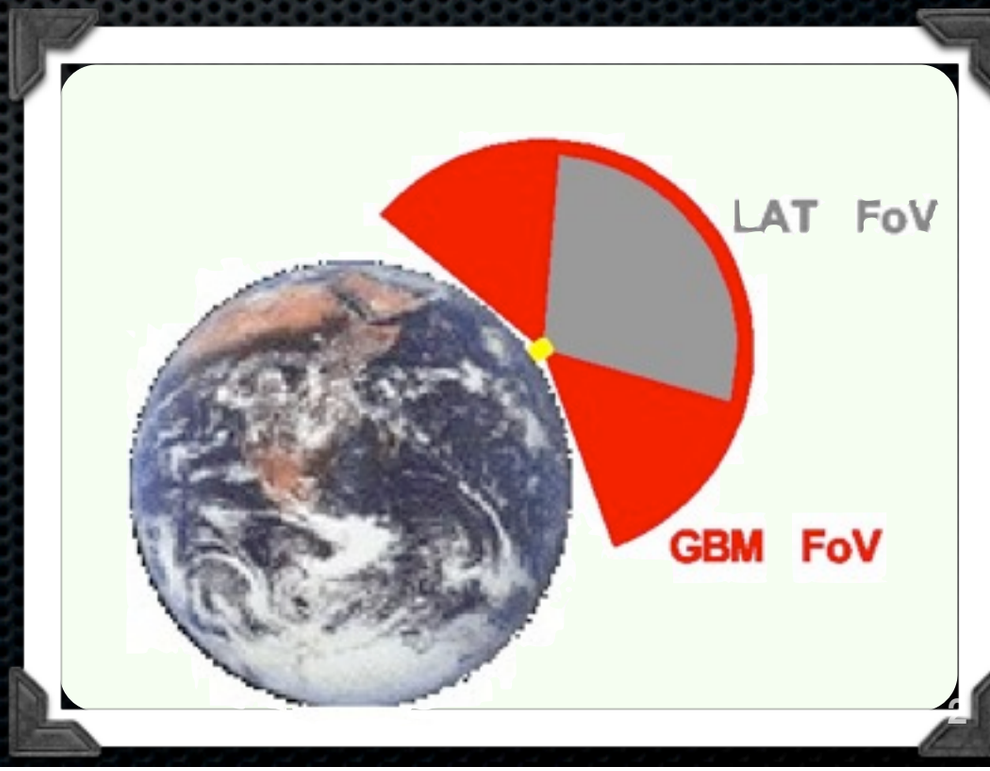
for the Fermi LAT GRB Science Working Group

The Fermi observatory & GRB



LAT : Pair conversion telescope
Trigger, localization, spectroscopy
20 MeV – > 300 GeV

GBM 14 PMT
12 NaI
Trigger, localization, spectroscopy
8 keV – 1 MeV
2 BGO
Spectroscopy
150 keV – 40 MeV



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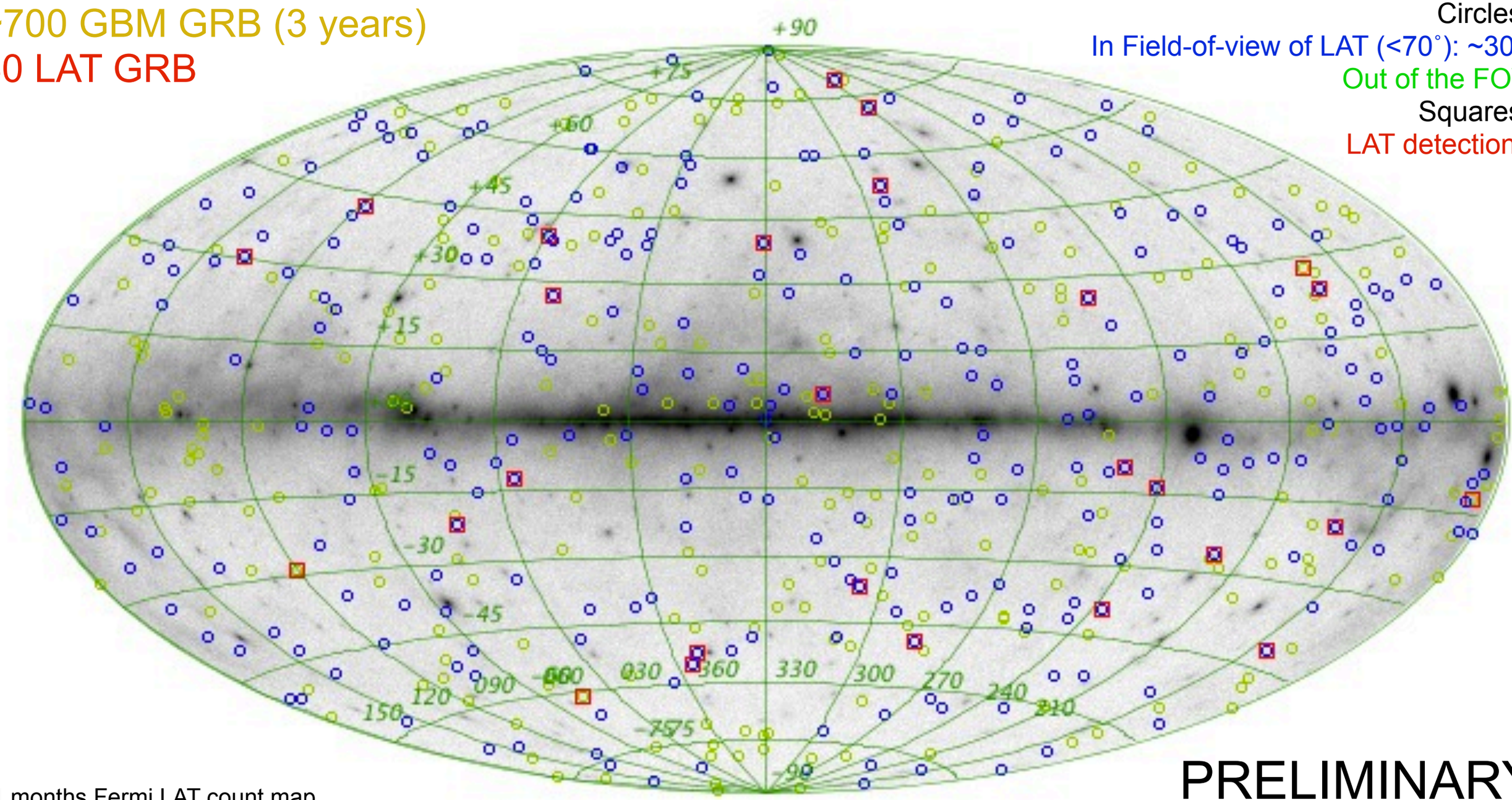
Fermi GRBs

~700 GBM GRB (3 years)
30 LAT GRB

Circles:
In Field-of-view of LAT (<70˚): ~300
Out of the FOV
Squares:
LAT detections



PRELIMINARY

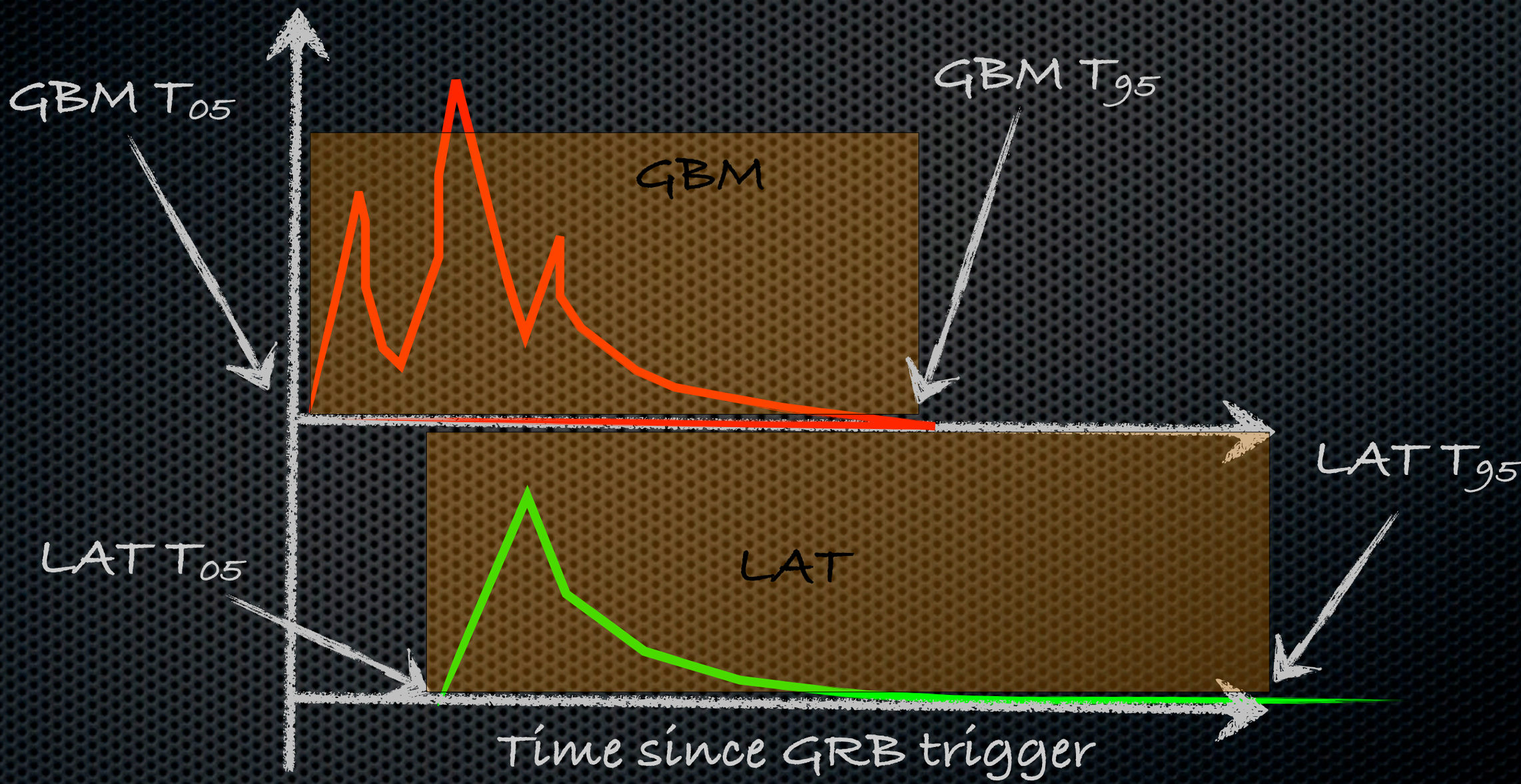
11 months Fermi LAT count map

GRBs are the most distant sources *Fermi* detects
LAT GRB 080916C @ z=4.35 (l.t.t. >12 Gyr!)

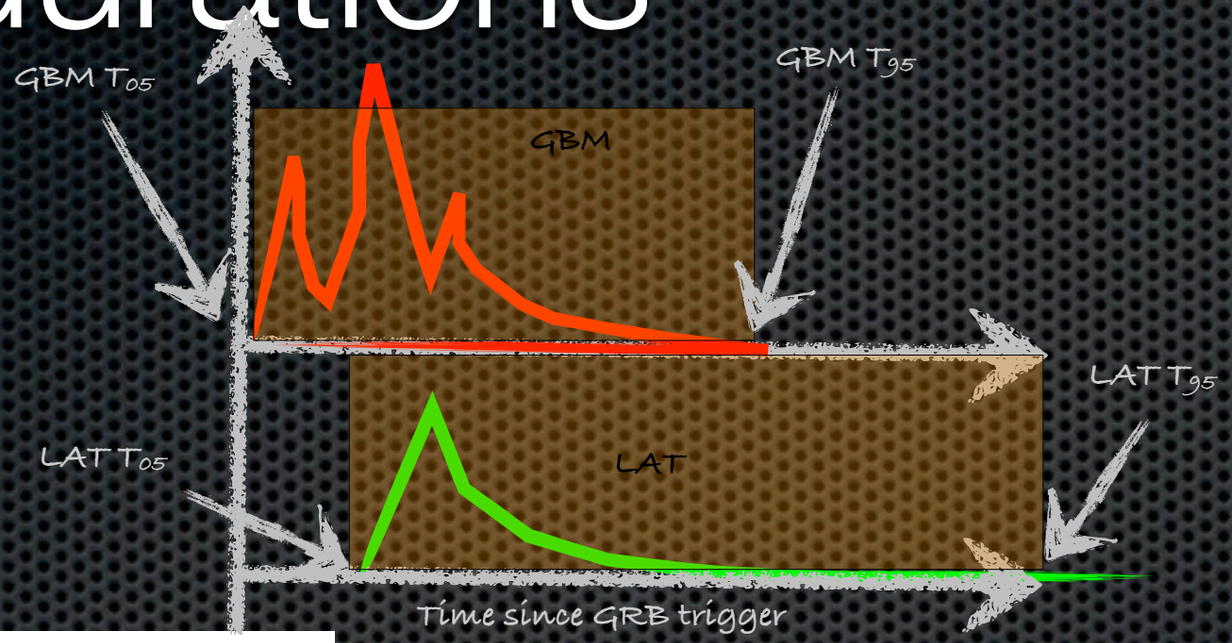
What we have learned

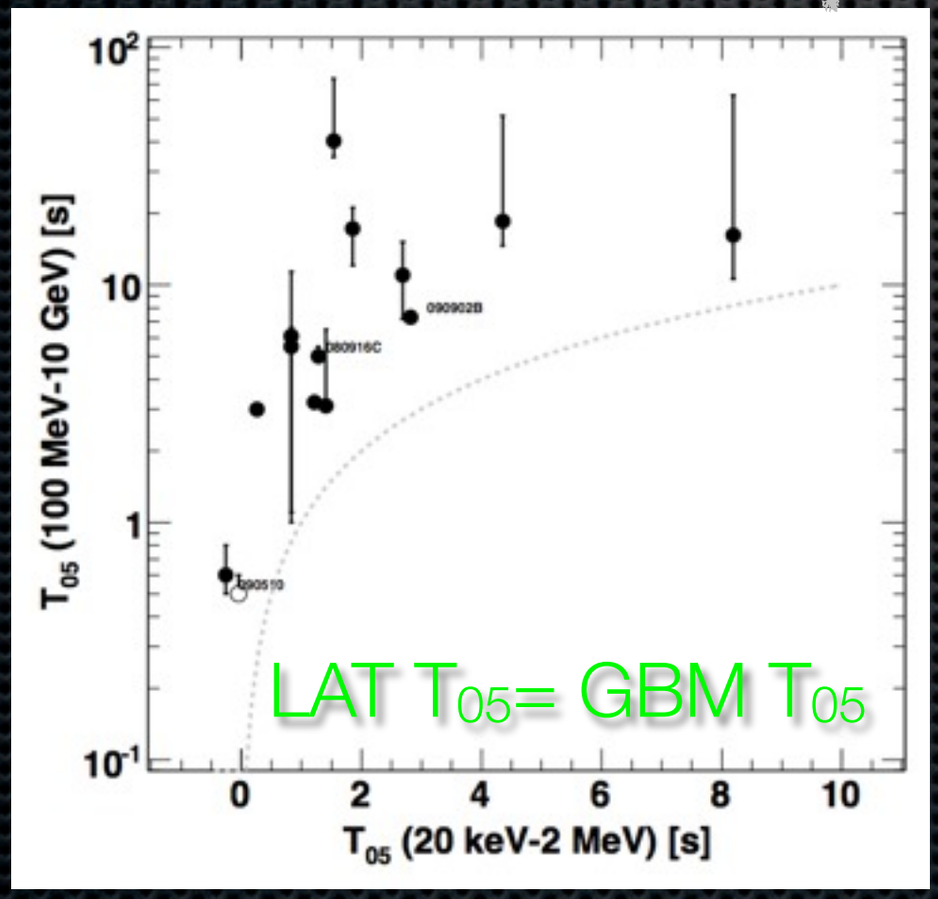
- For LAT detected GRB at high energy:
  - Very energetic events (10^{54} erg) possibly associated with high relativistic shells (Γ~100-1000);
  - Long lasting emission is common;
  - Delayed onset time relative to the low energy GBM emission (new discovery);
  - New Spectral component (in more than one case);
  - Set limit on the Lorentz Invariance Violation & EBL studies

Prompt vs Temporal extended emission



GRB durations





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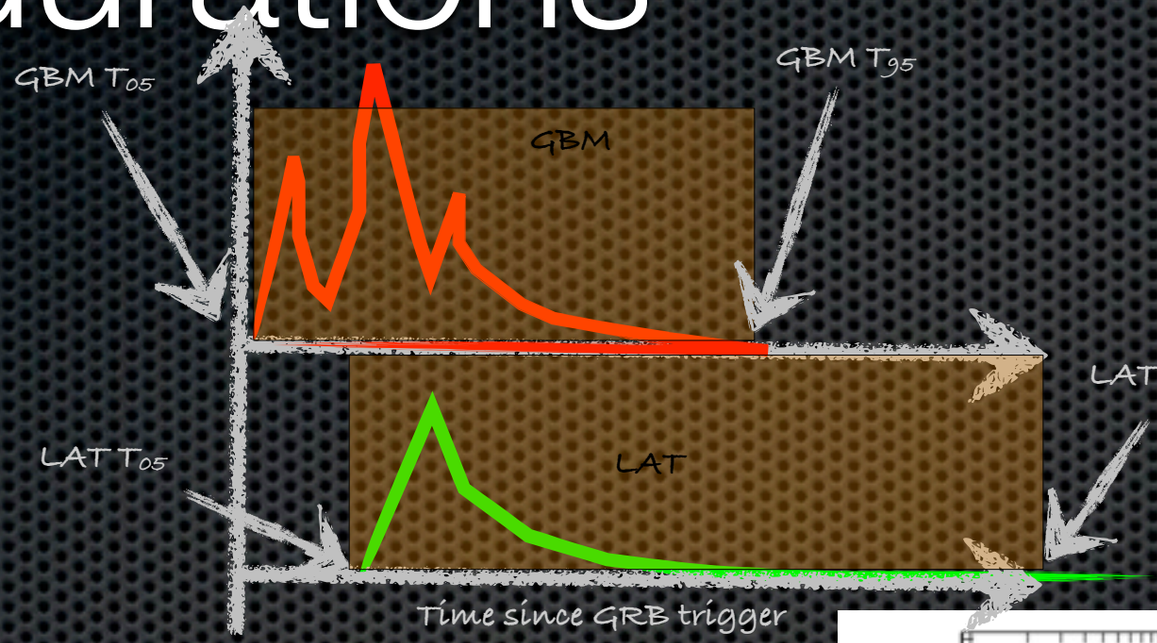
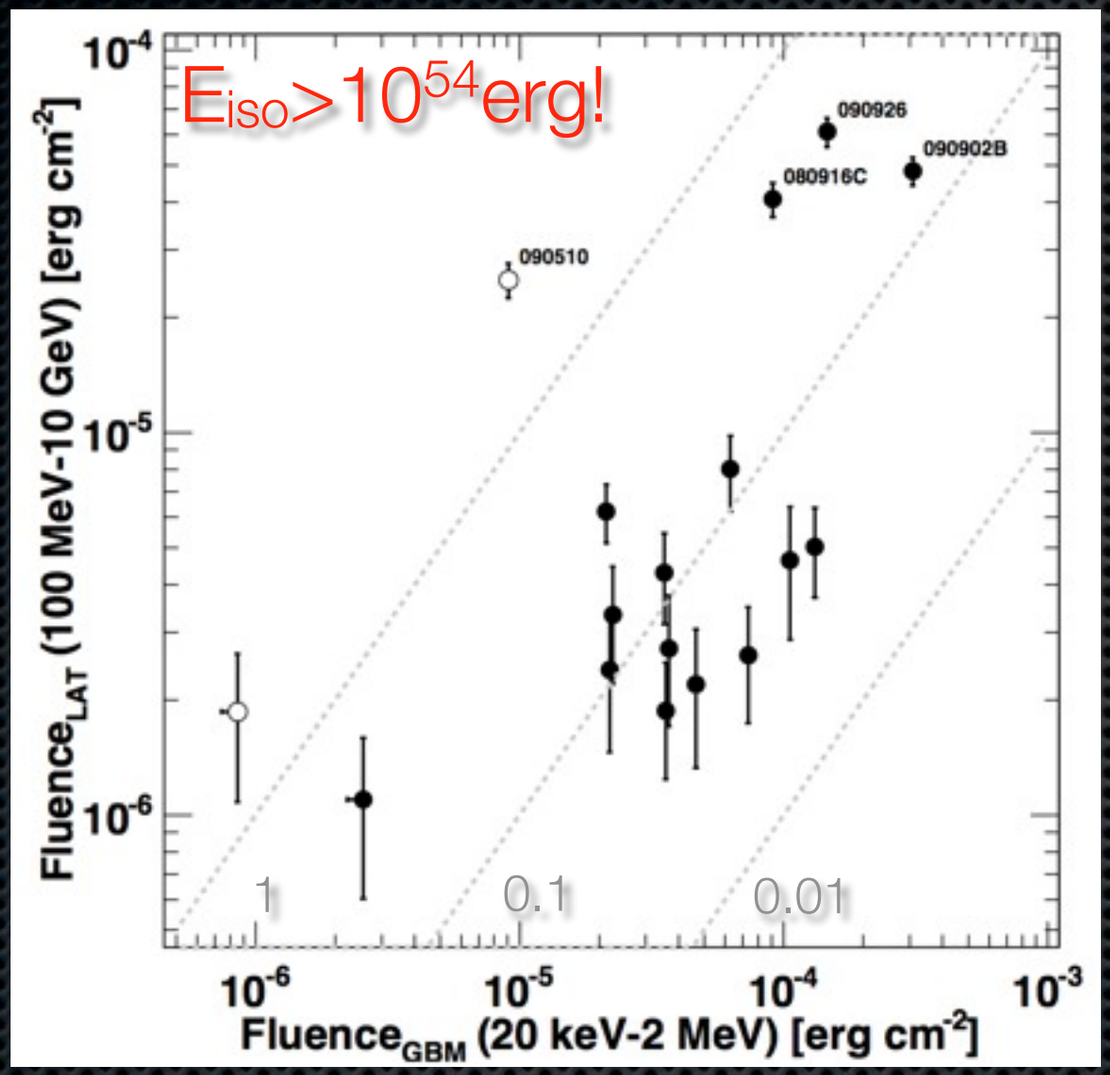
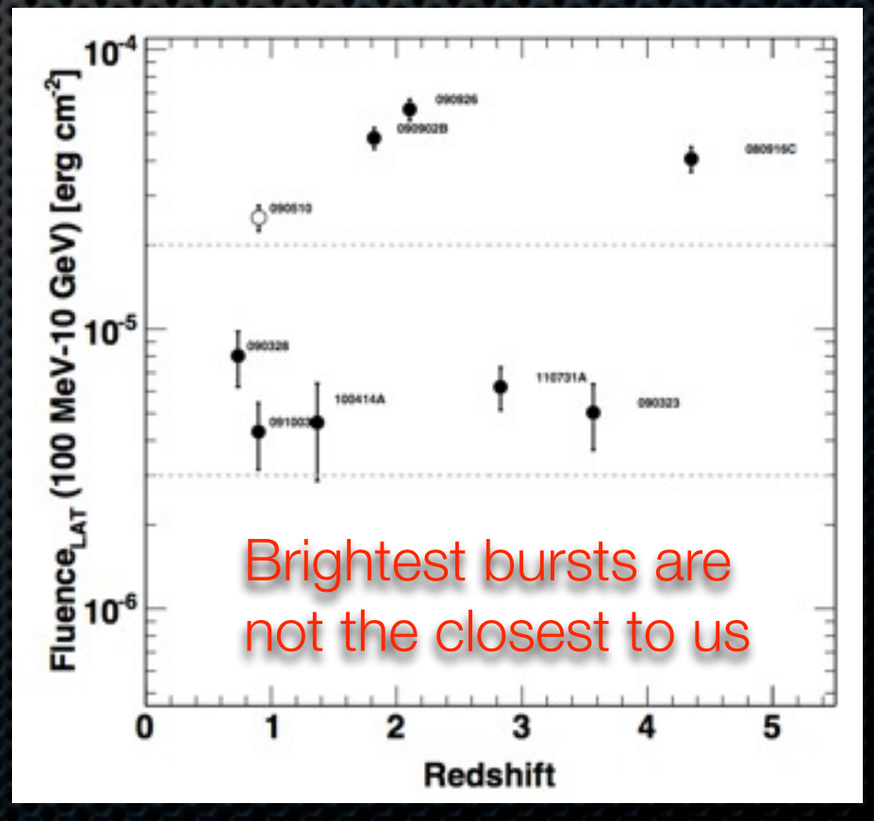


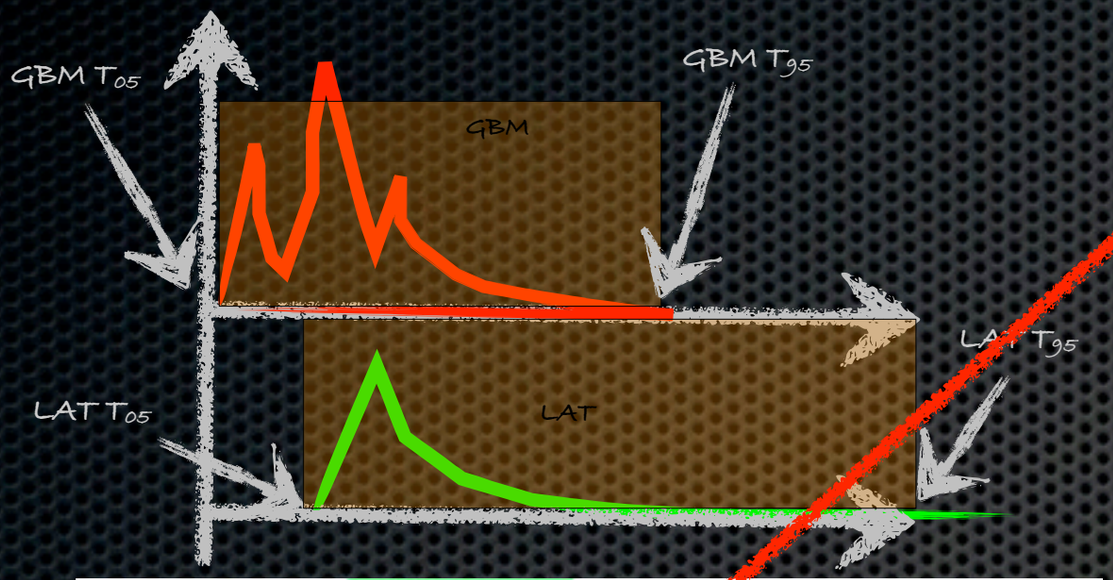
Energetics

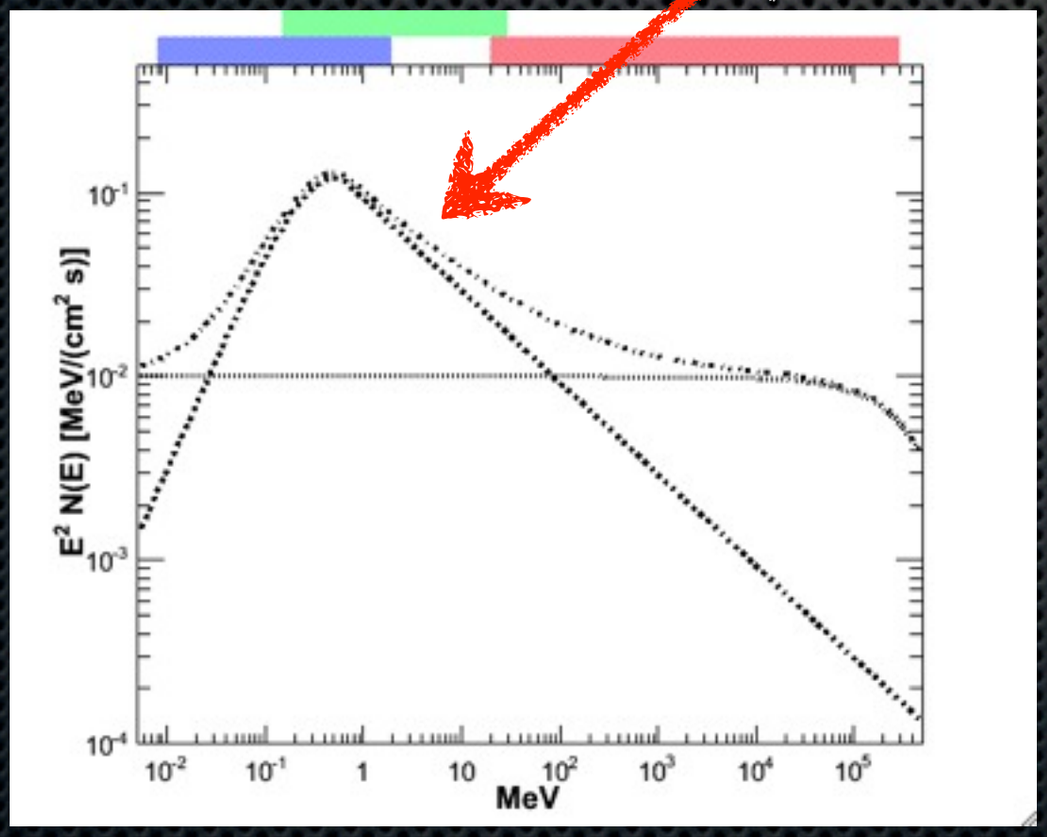


- Four extremely bright bursts.
- Where are the intermediate fluence bursts?
  - Are we seeing a pattern? (historically: "long vs short")
- More statistics is needed!



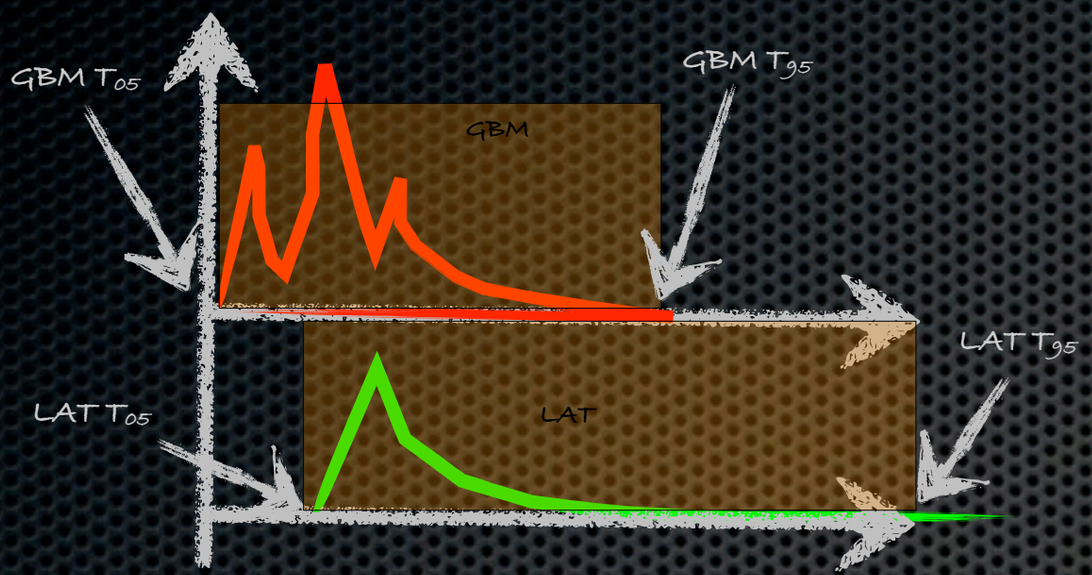
Spectral information

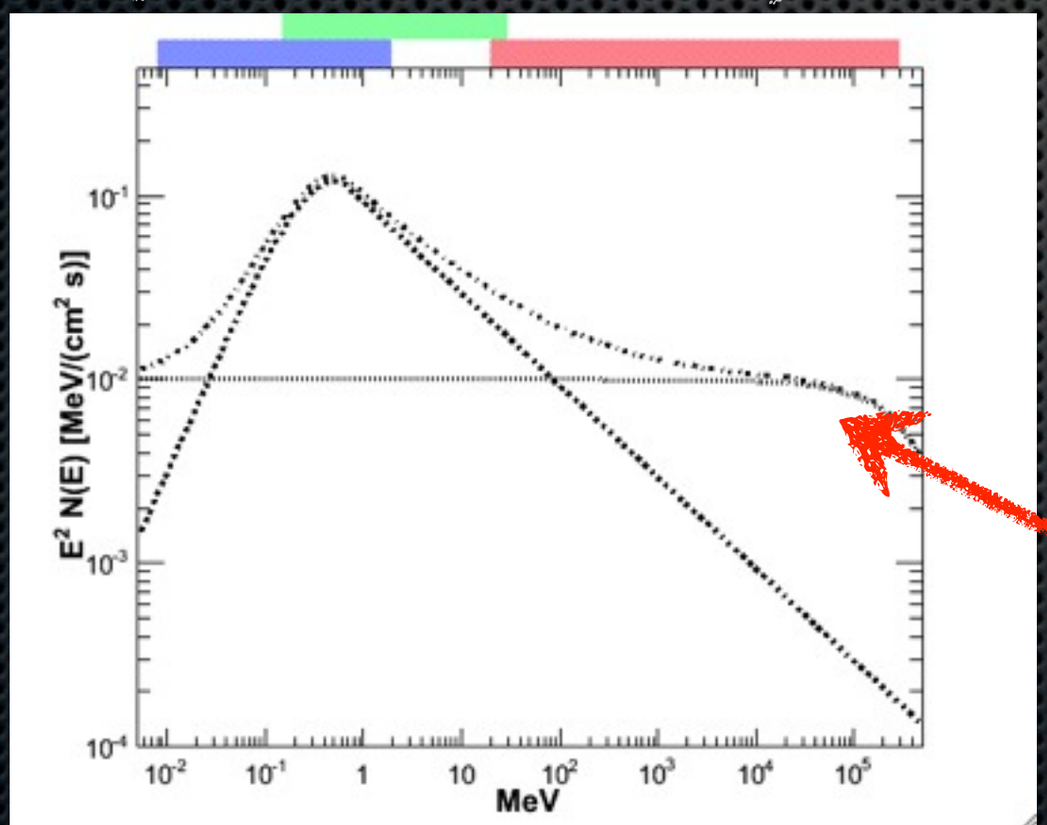




- Prompt emission:
  - Double broken power-law
  - Spectral Variation
  - Thermal component also seen in few cases
- Temporal Extended
  - Power-law
  - Cutoff

Spectral information

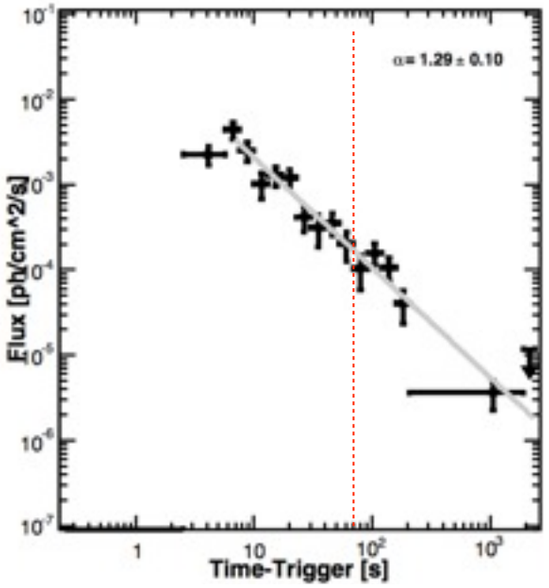


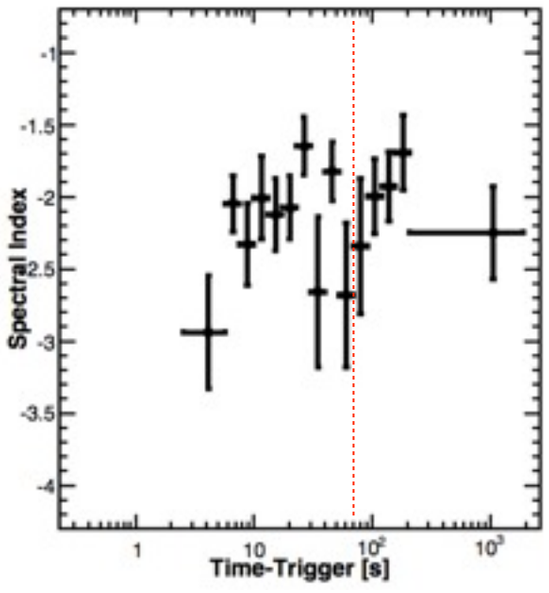


- Prompt emission:
  - Double broken power-law
  - Spectral Variation
  - Thermal component also seen in few cases
- Temporal Extended emission
  - Powerlaw ~-2
  - Smooth time decay

Extended Emission as seen by the LAT

GRB080916C





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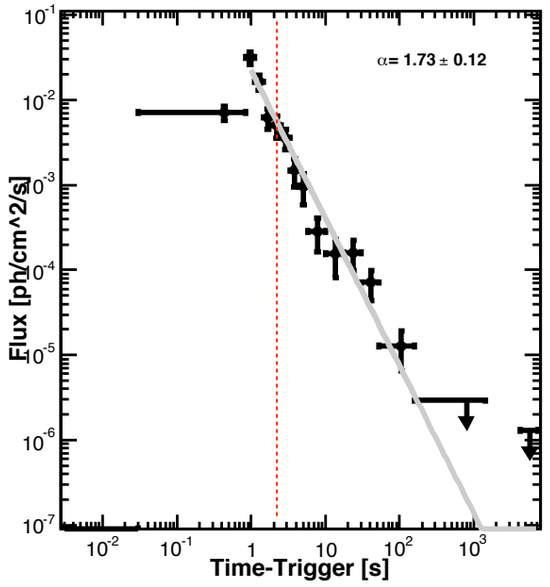

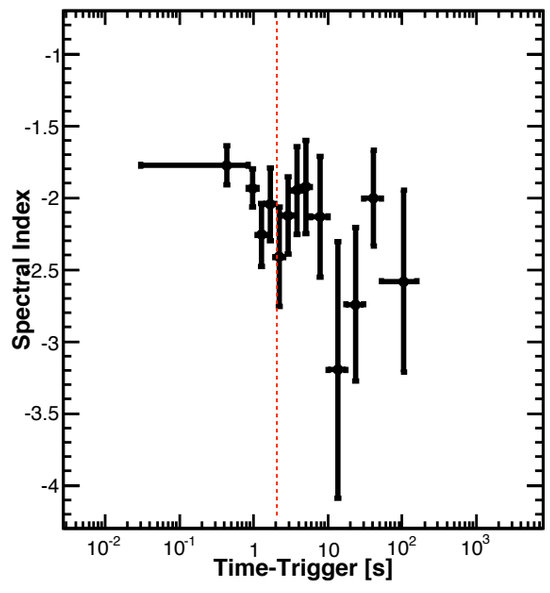

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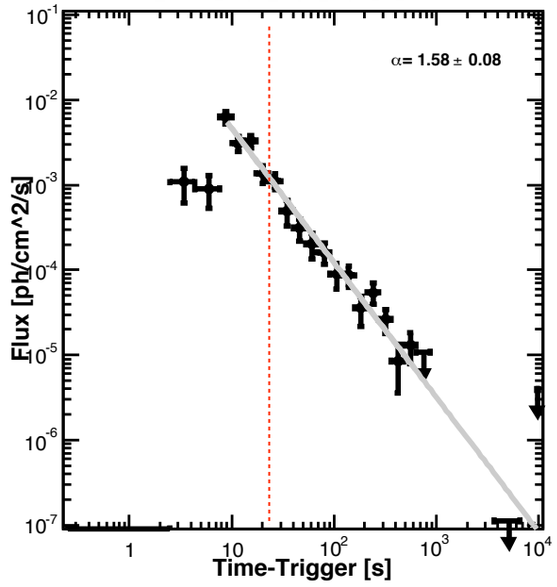

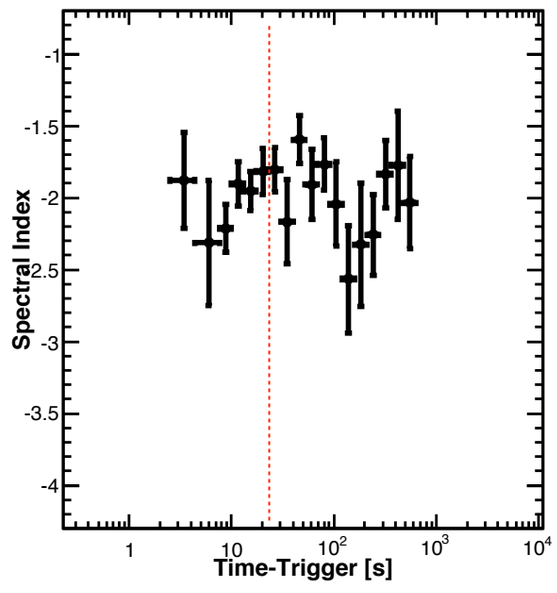

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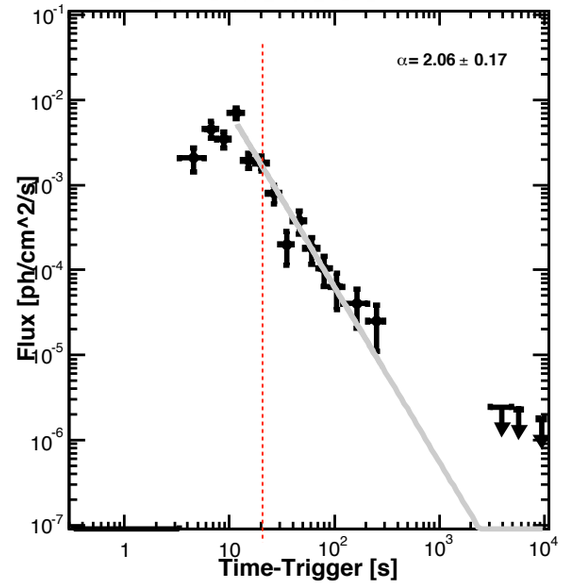

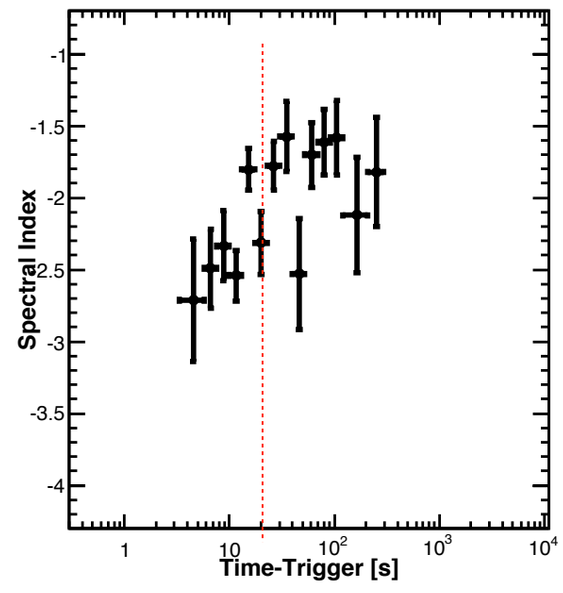

- Red lines: GBM T95 durations
- Flux decays as a power law in time ($t^{-\alpha}$), $\alpha \sim 1 - 2$
- No clear breaks. Different type of spectral evolutions.

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Radiative or Adiabatic expansion?

Radiative

$$L_{\rm iso,r} = \frac{3\epsilon_{\rm e} E_{\rm k,f}}{2a^{10/7}} t_{\rm dec}^{3/7}\, t^{-10/7} \qquad t \gg t_{\rm peak}$$

Adiabatic

$$L_{\rm iso,a} = \frac{3}{2a}\,\frac{\epsilon_{\rm e} E_{\rm k,f}}{t}; \qquad t \gg t_{\rm peak}$$

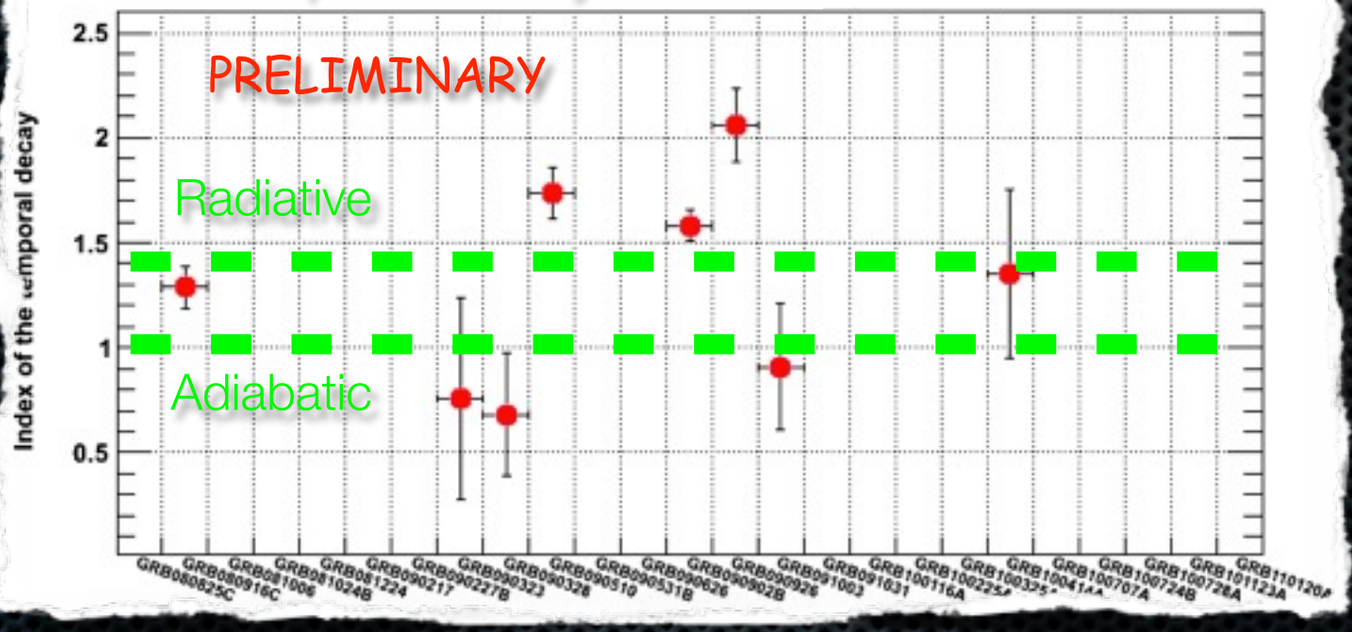
Ghisellini et al. 2009

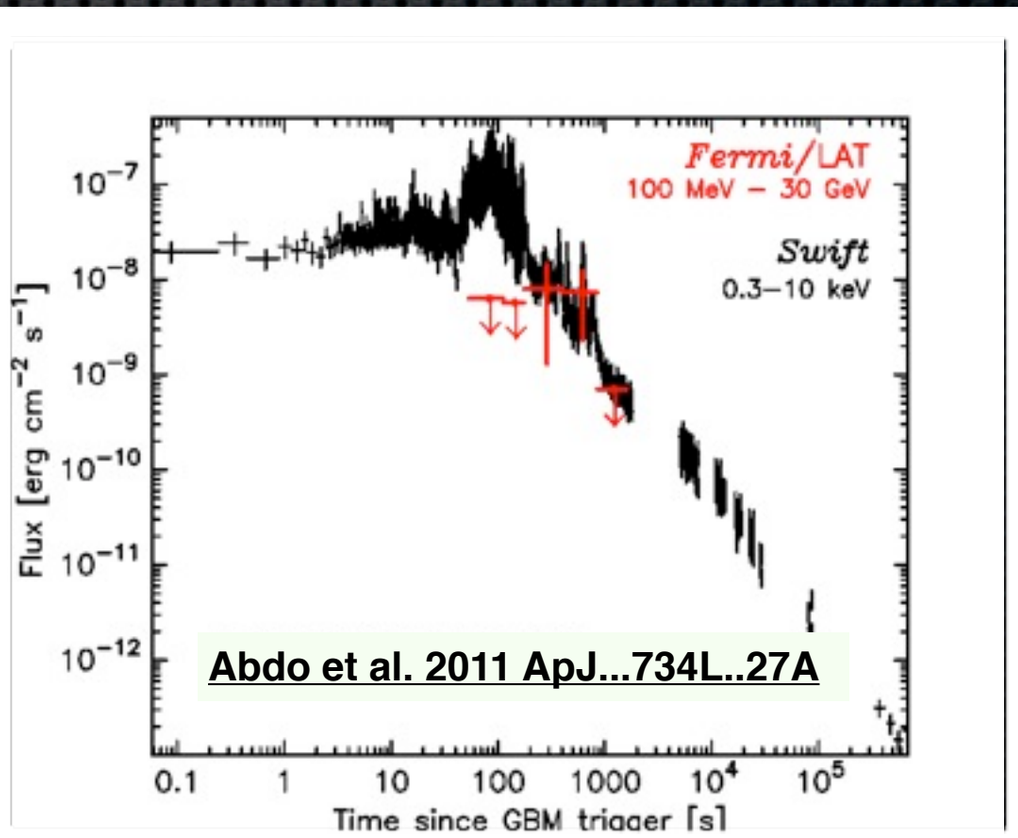
Are we looking the radiative/adiabatic expansion of a fireball?

On the other hand...

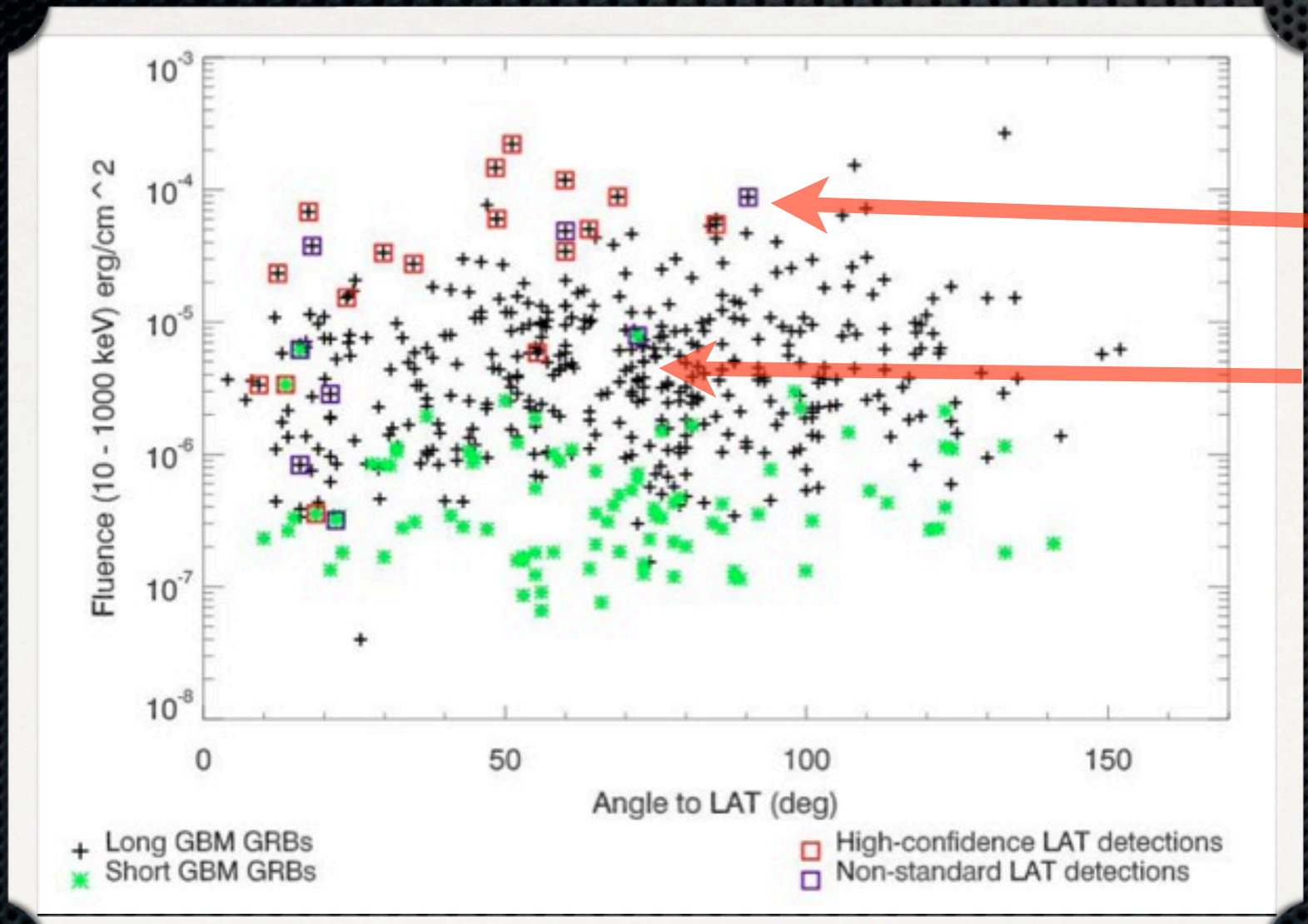
Simultaneous detection of gamma rays with X-ray flares points to the connection with the central engine

Temporal decay index





The “tip of the iceberg”



- We detect the Brightest GBM GRB
- Few cases of sub-luminous GBM bursts with High LAT flux

Prospects for the future

- We are scratching the surface! Number of detected GRB increases as linear with time:
  - Fermi during 10 years extended mission: 100 GRB detected by the LAT, >2000 detected by the GBM

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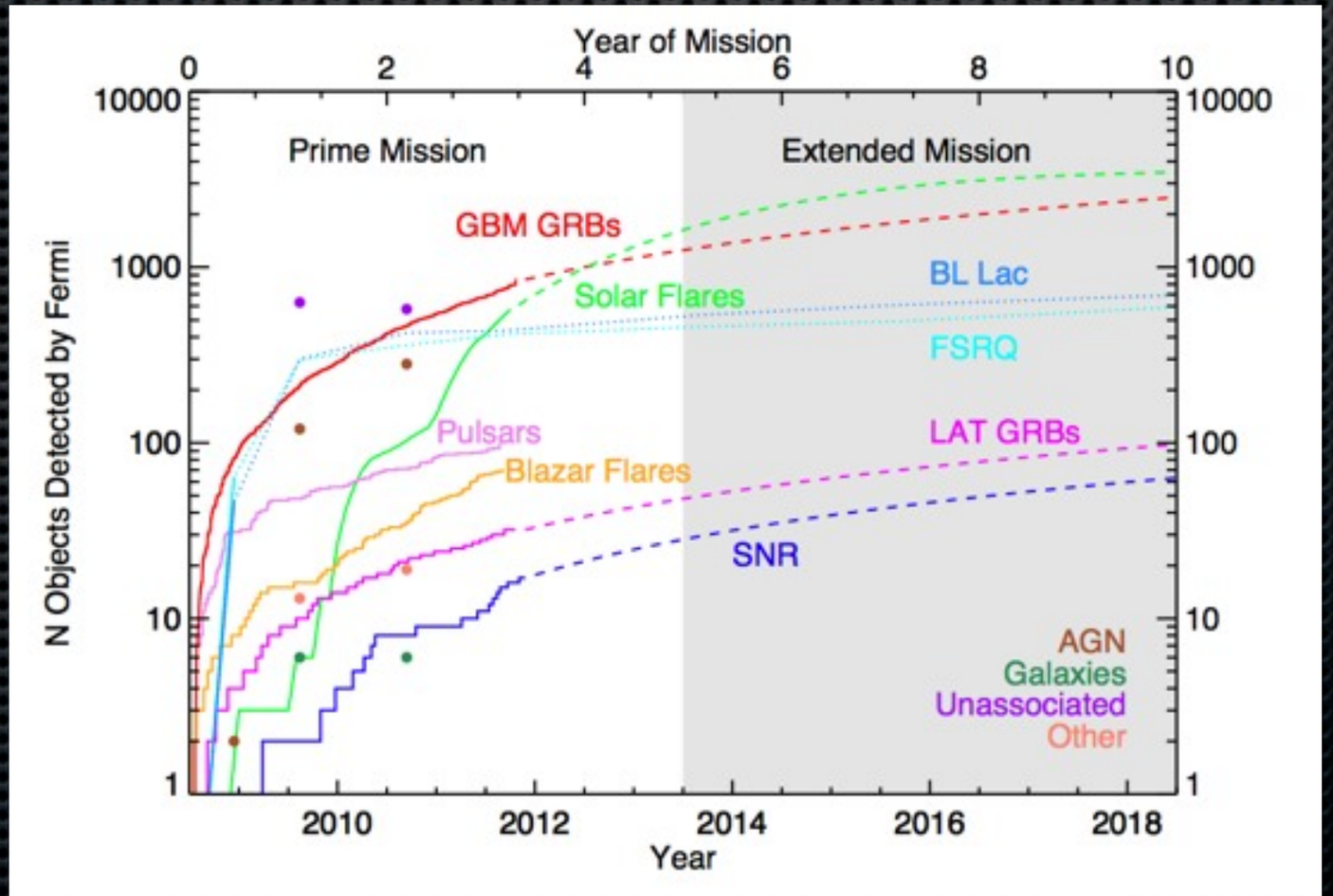

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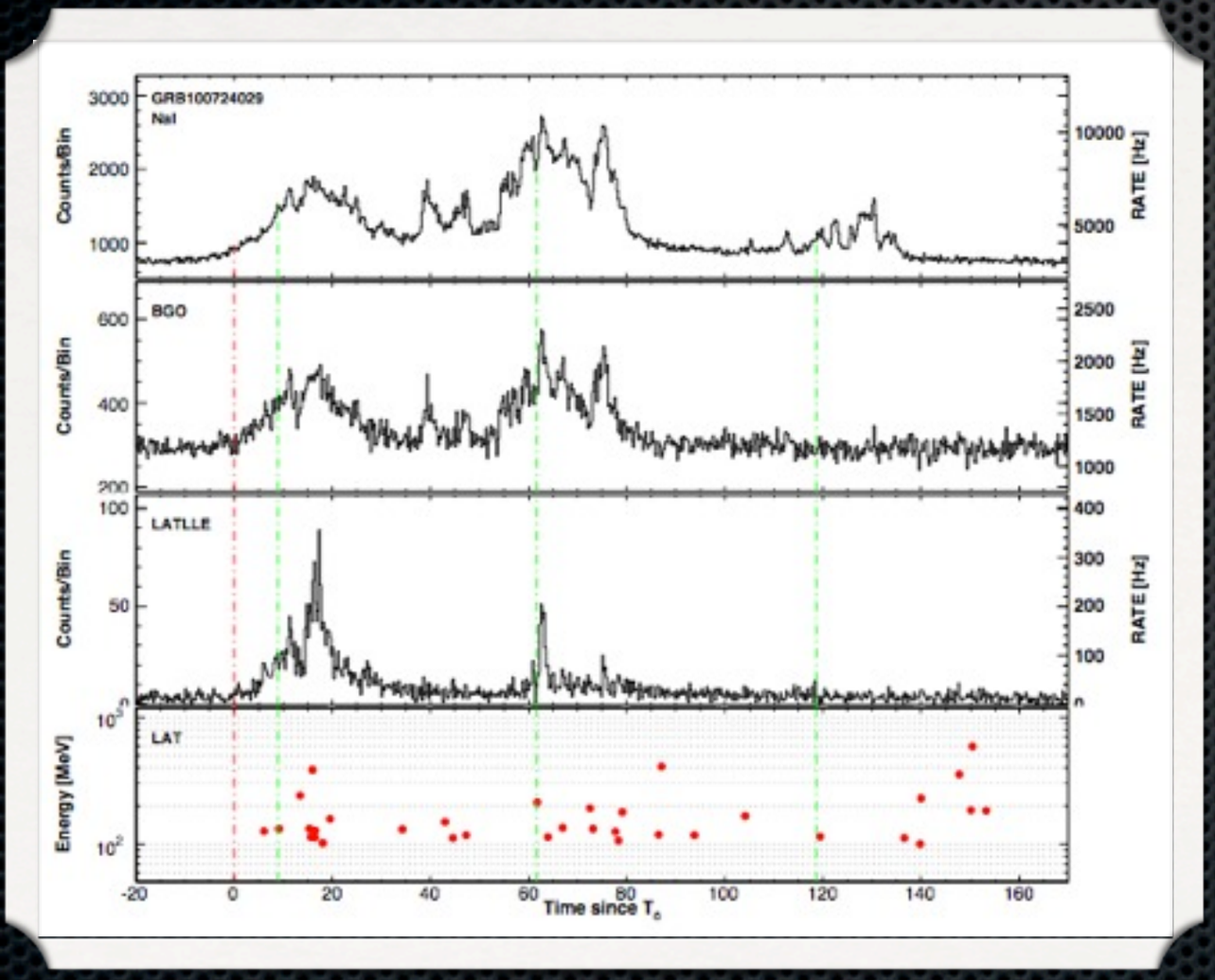
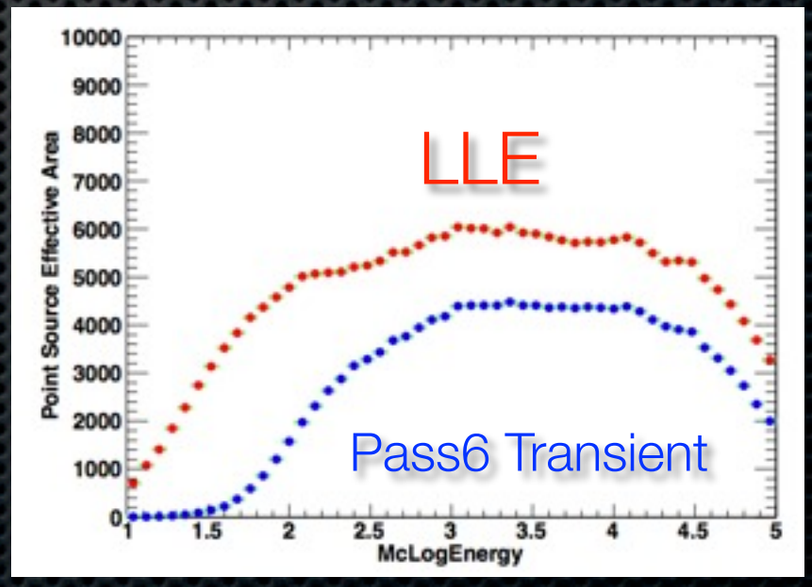
Prospects for the future

- We are scratching the surface! Number of detected GRB increases as linear with time:
  - Fermi during 10 years extended mission: 100 GRB detected by the LAT, >2000 detected by the GBM
- But,... there are many new things coming up...
  - LAT Low Energy Extension (LLE);
  - New flight software GRB trigger optimized for LAT onboard detection;
  - Pass8:
    - Improved reconstruction and event classification
    - Improved the effective area both at low and high energies
    - Covariance ellipse accessible event by event basis

LAT Low Energy events

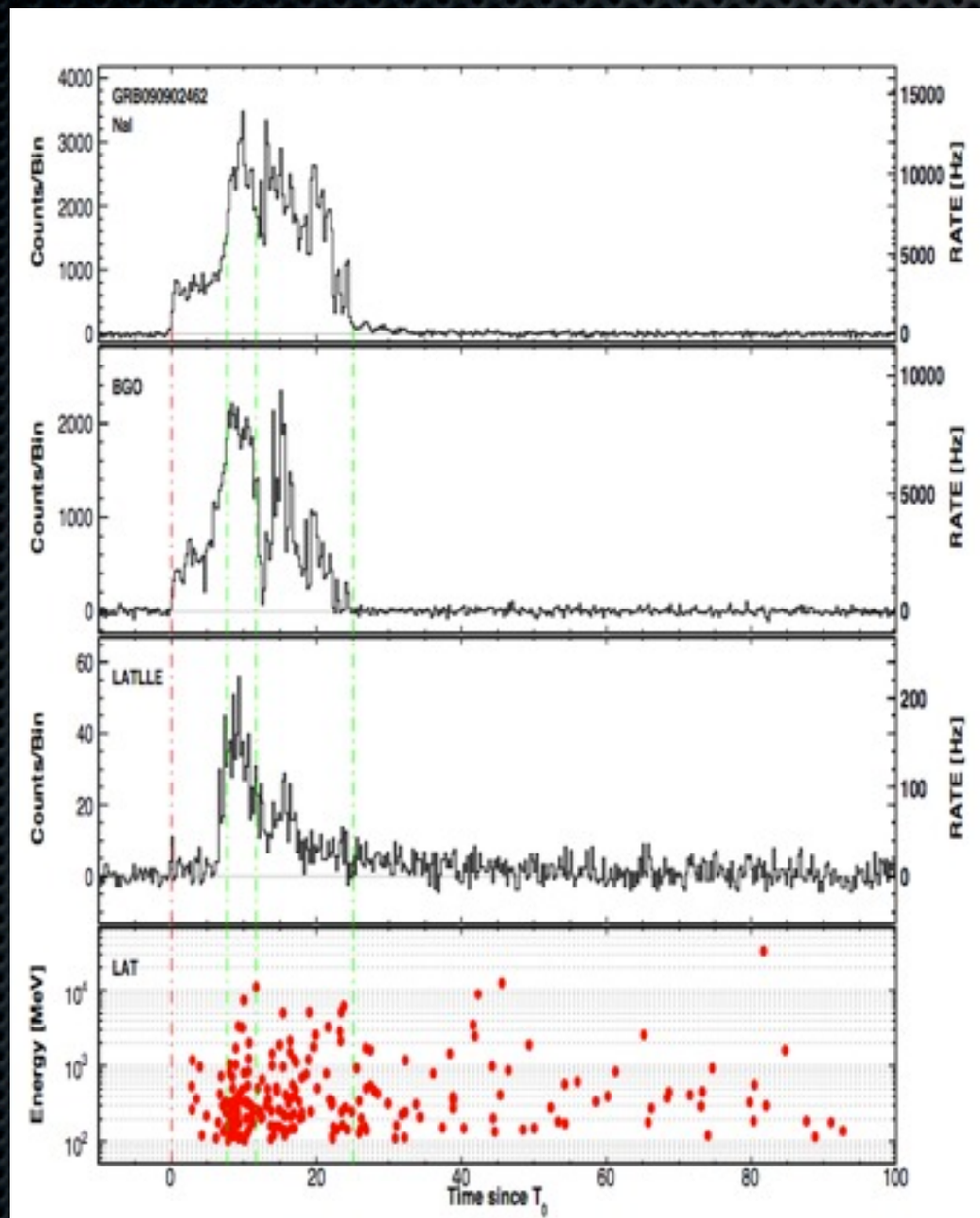


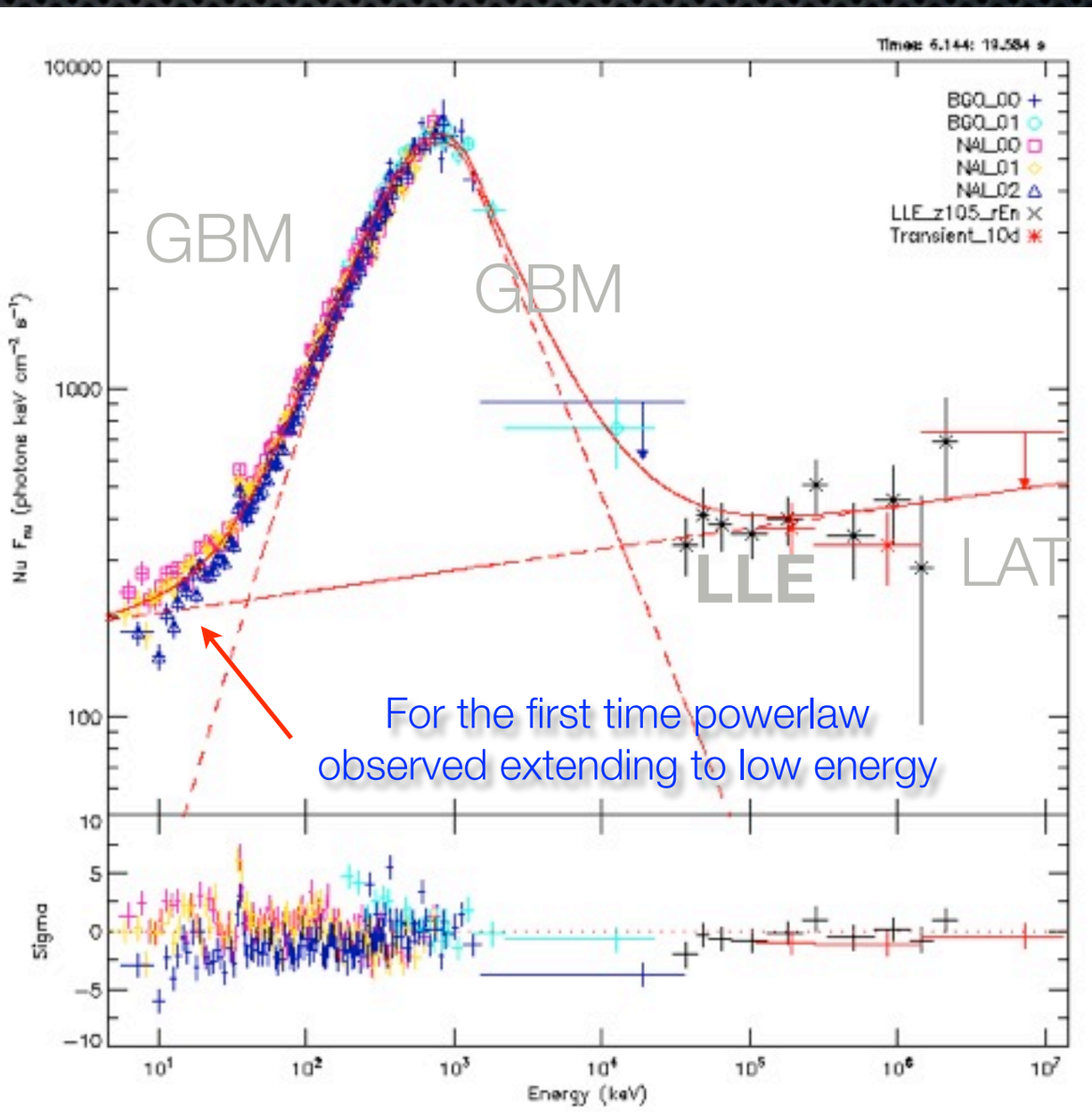
- Loose selection of events
- Big improvement at low energy for short duration transients, such as GRB and Solar Flares



Background contamination also increases

LLE, some examples...





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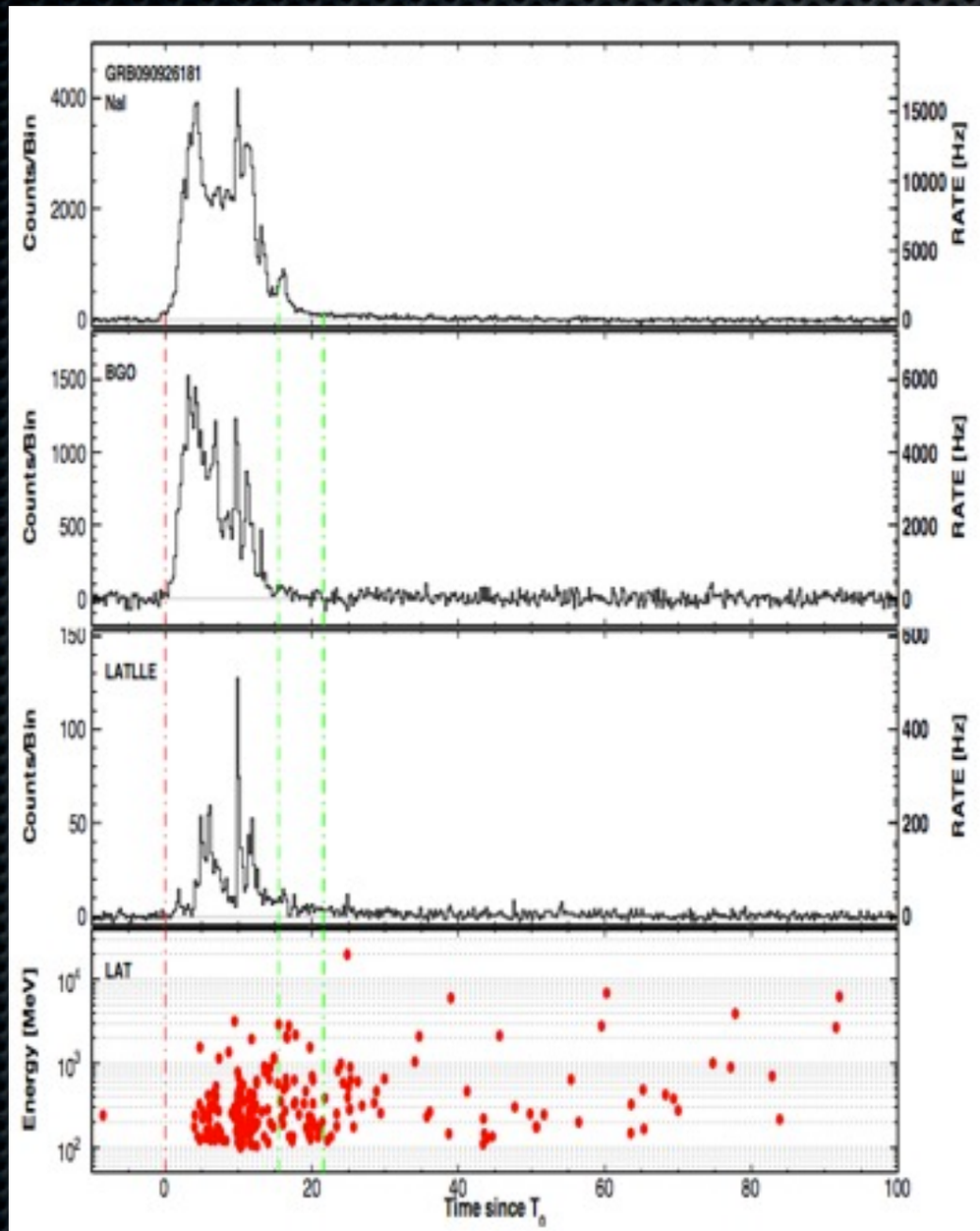

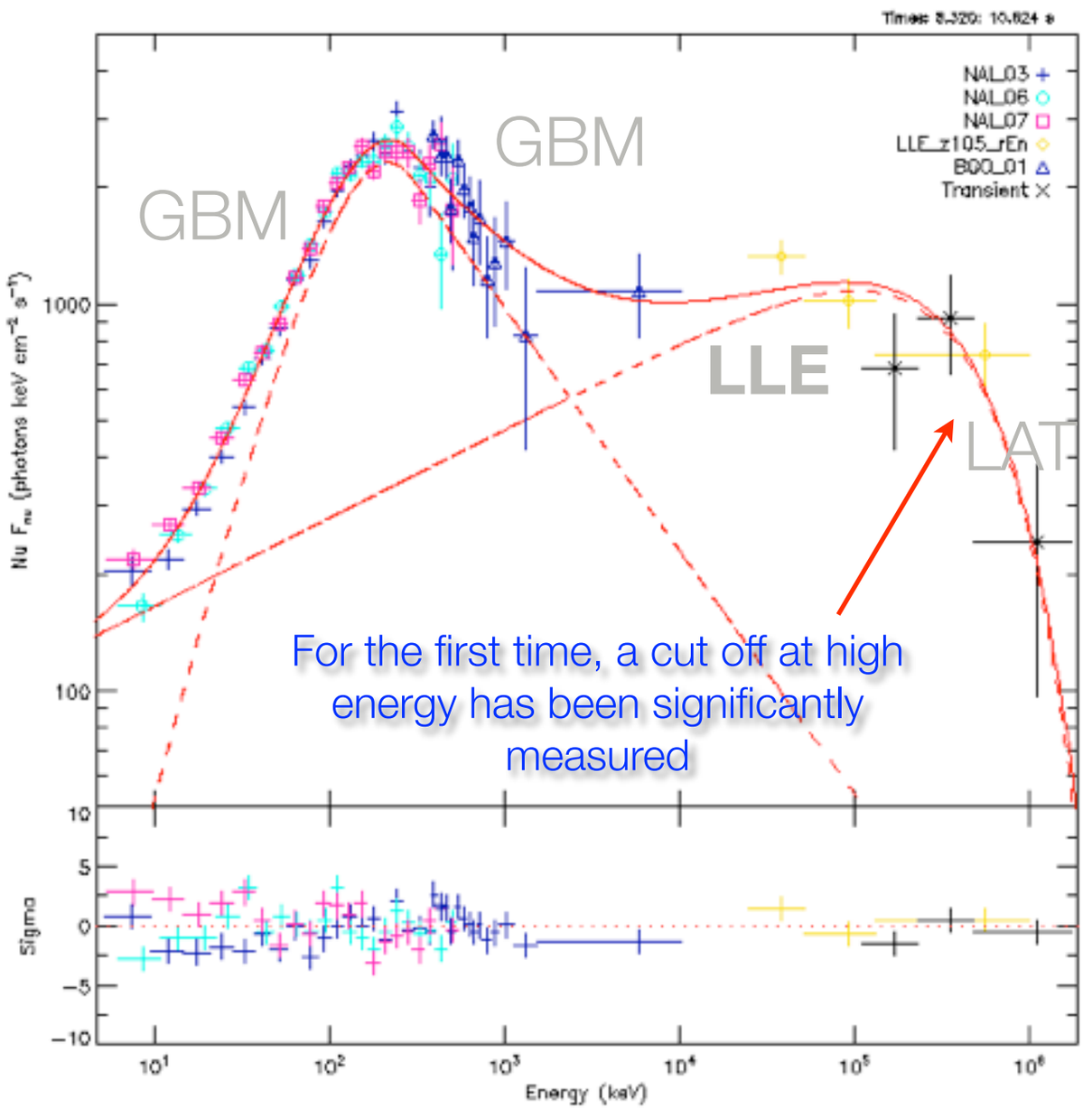

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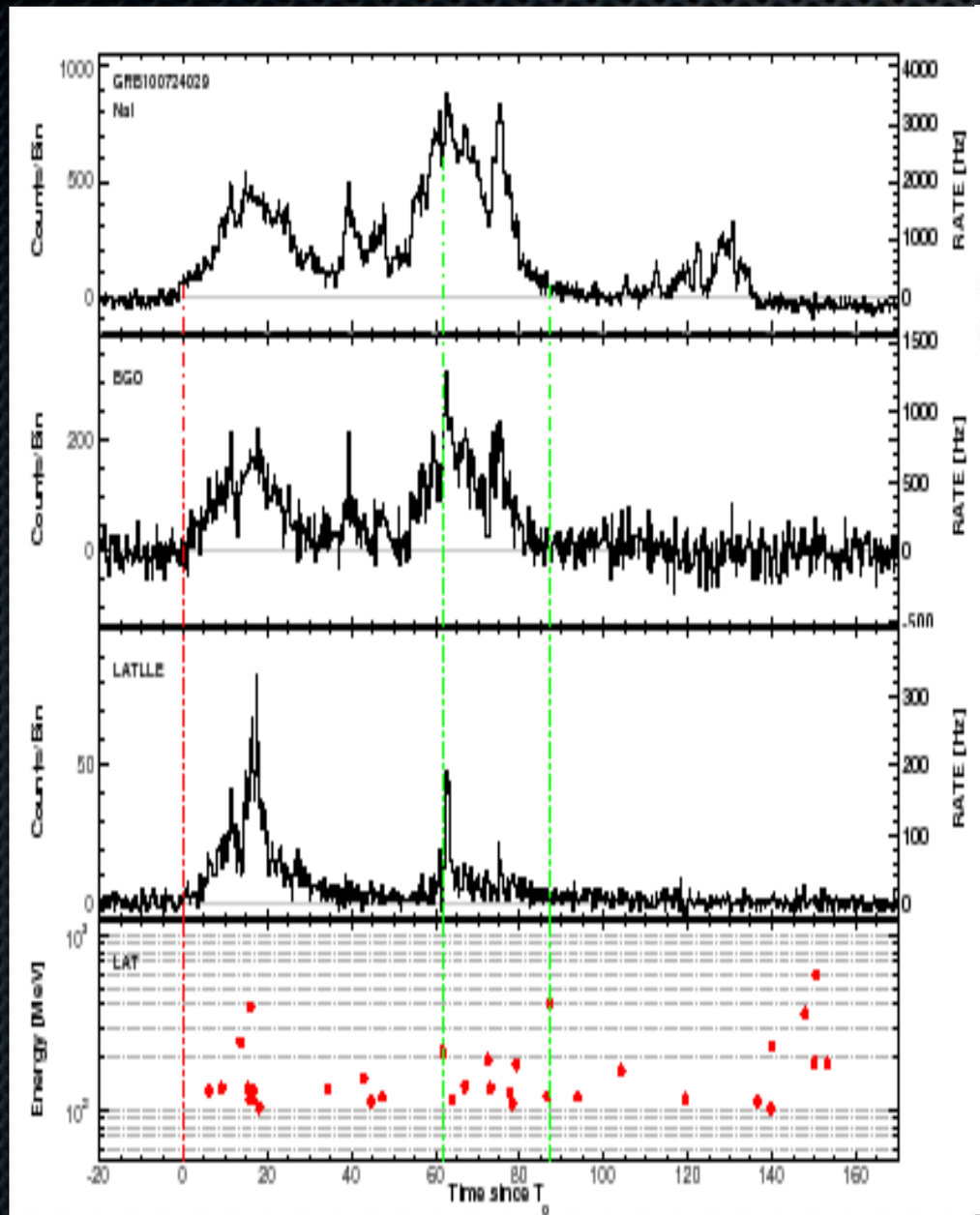

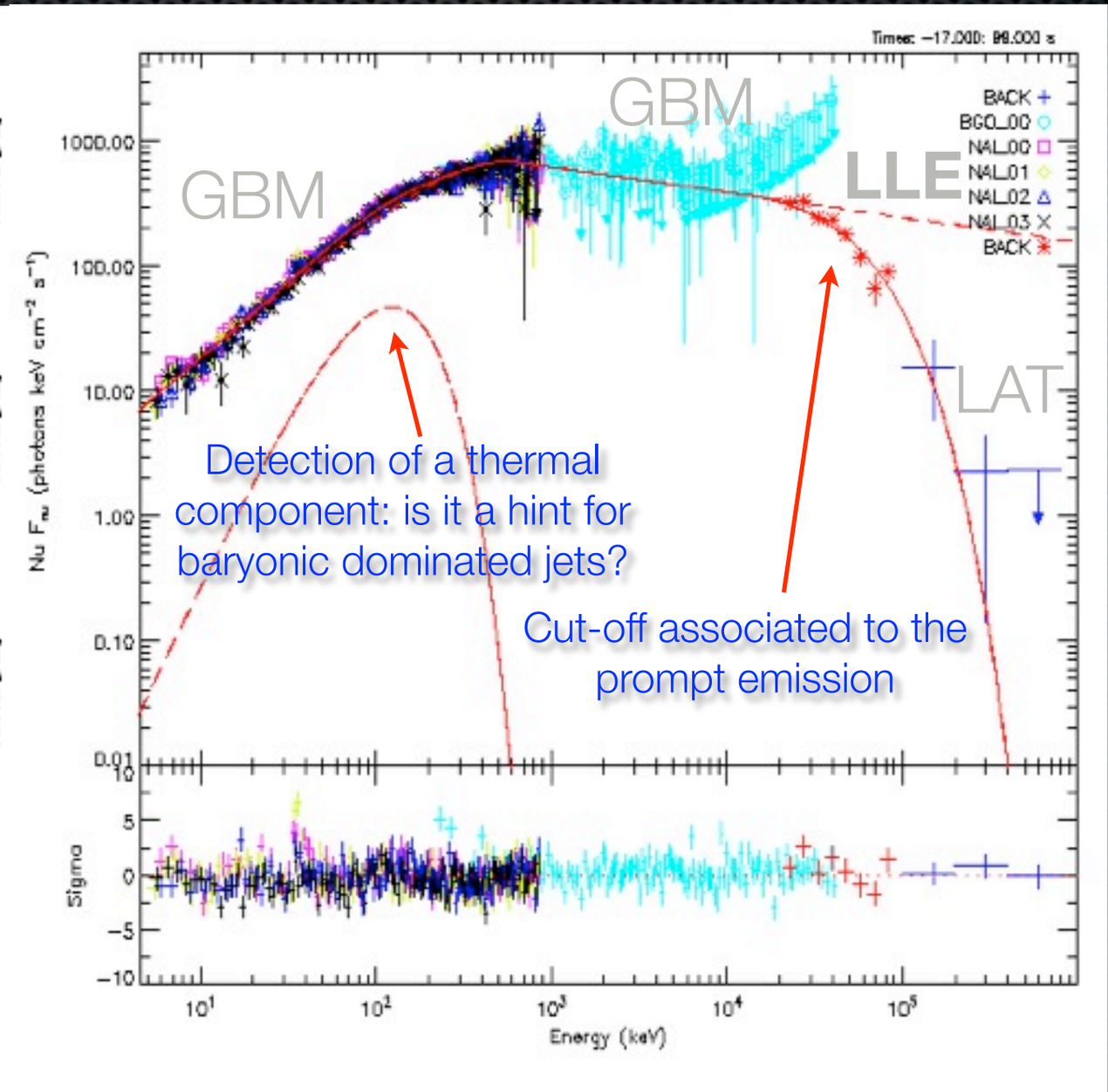

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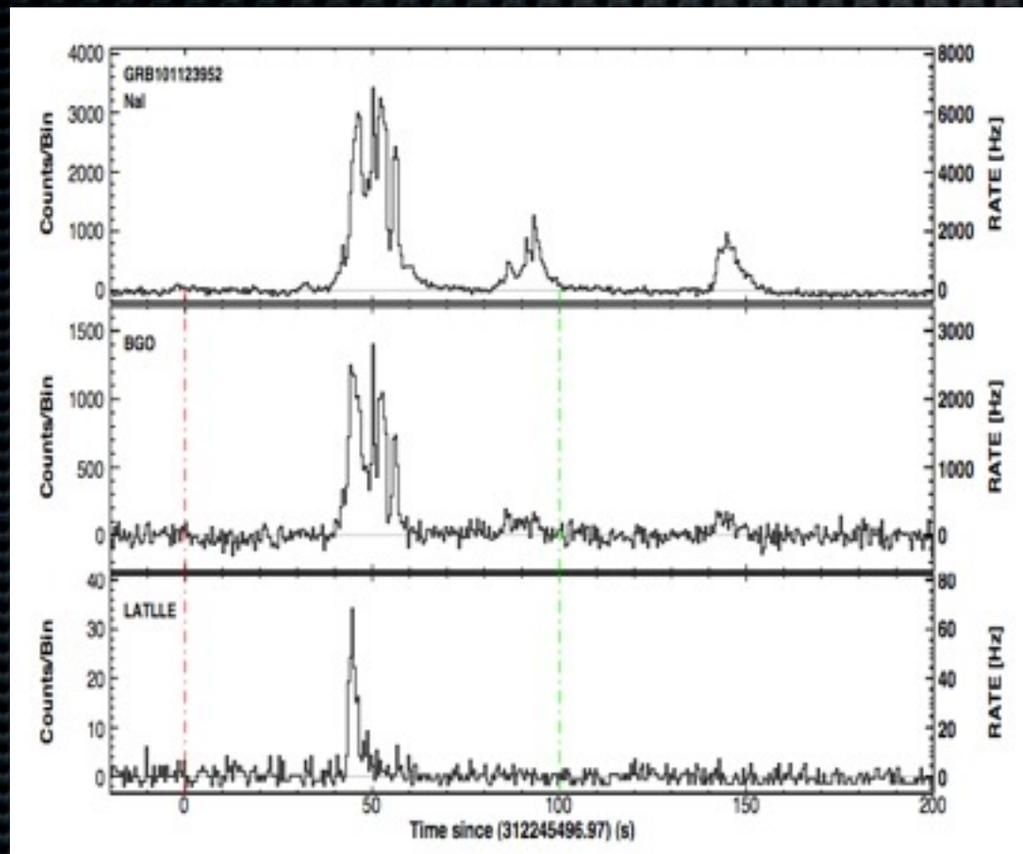
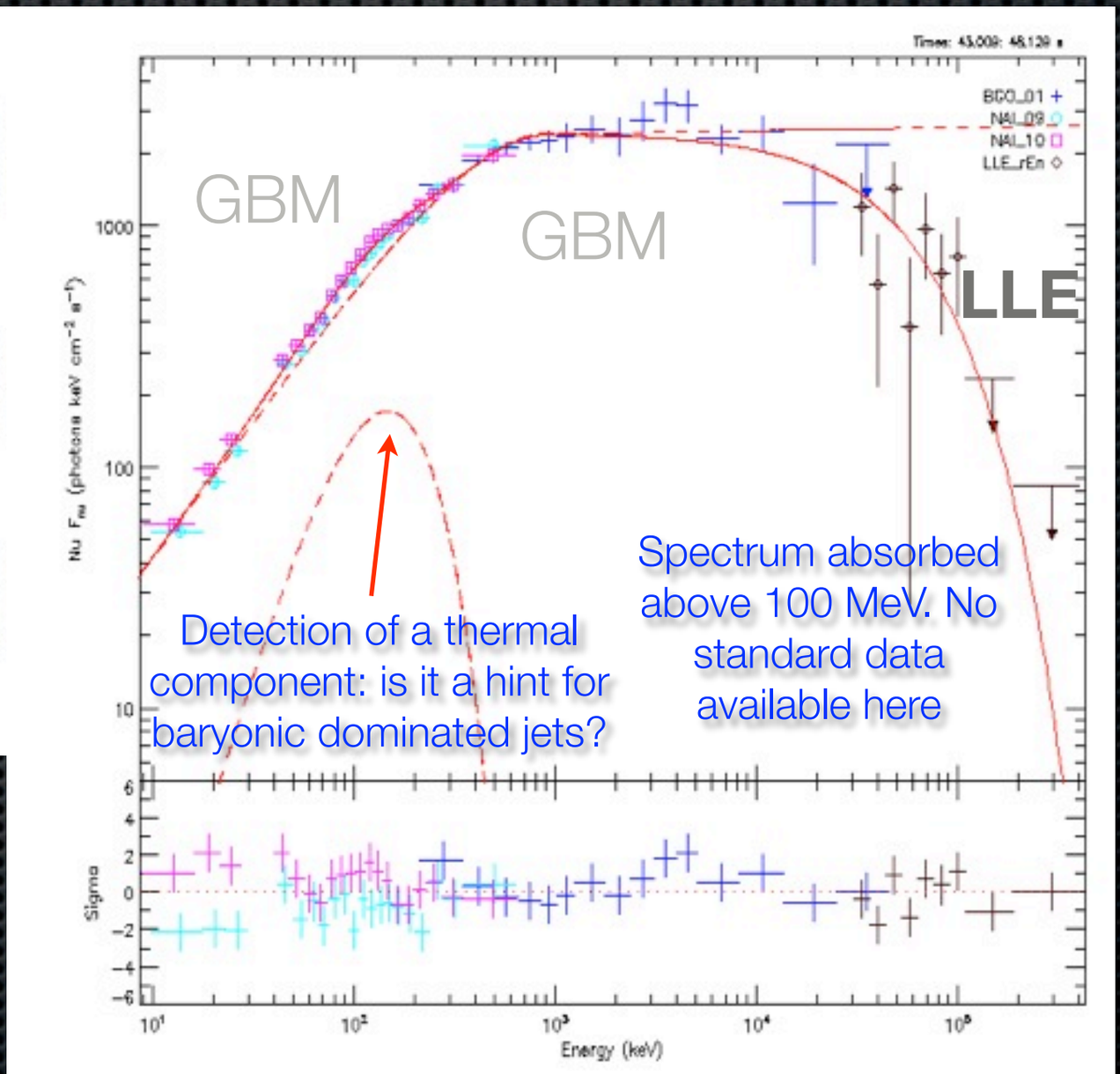
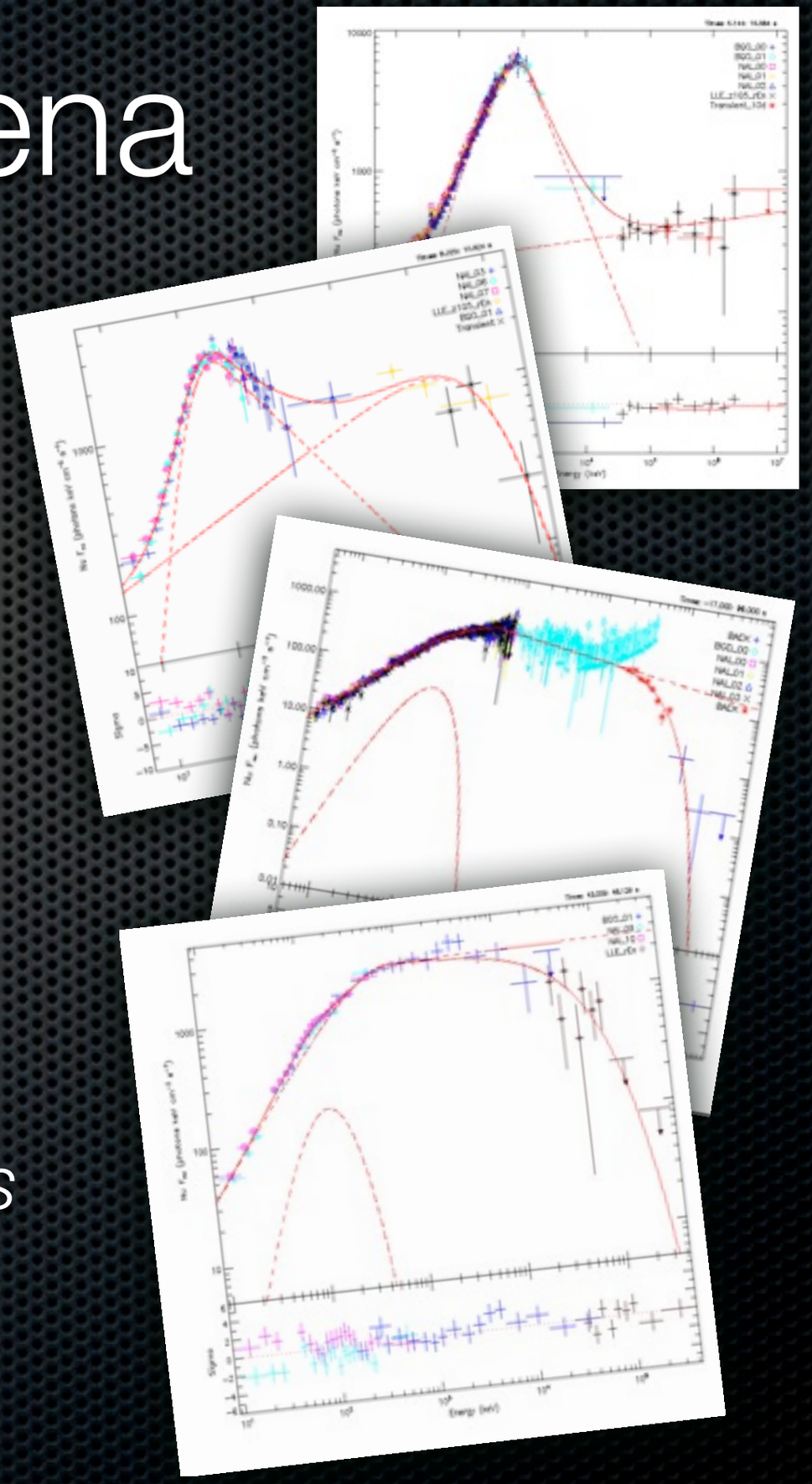




Very rich phenomena

- We are seeing many more details and we are collecting new informations...
- Still open questions, could be answered with more statistics and an improved analysis;
- *How common are these properties in GRB?*

Very rich phenomena



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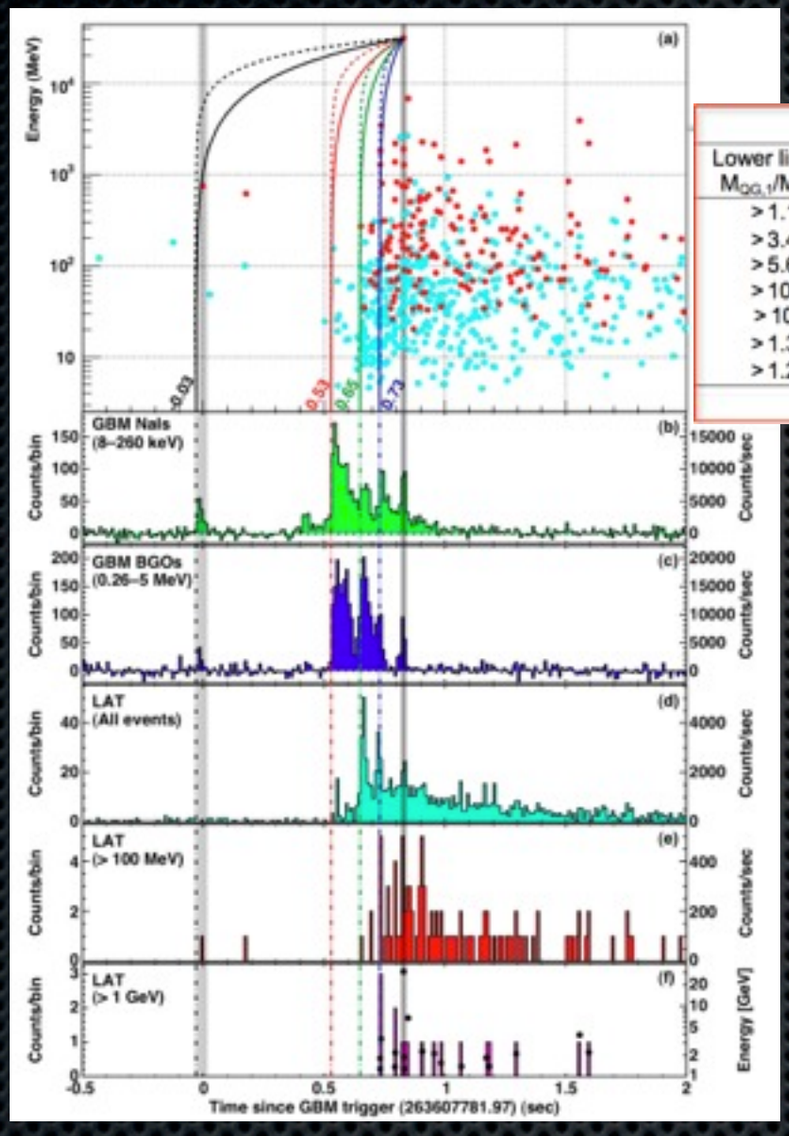
GRB as cosmological probes

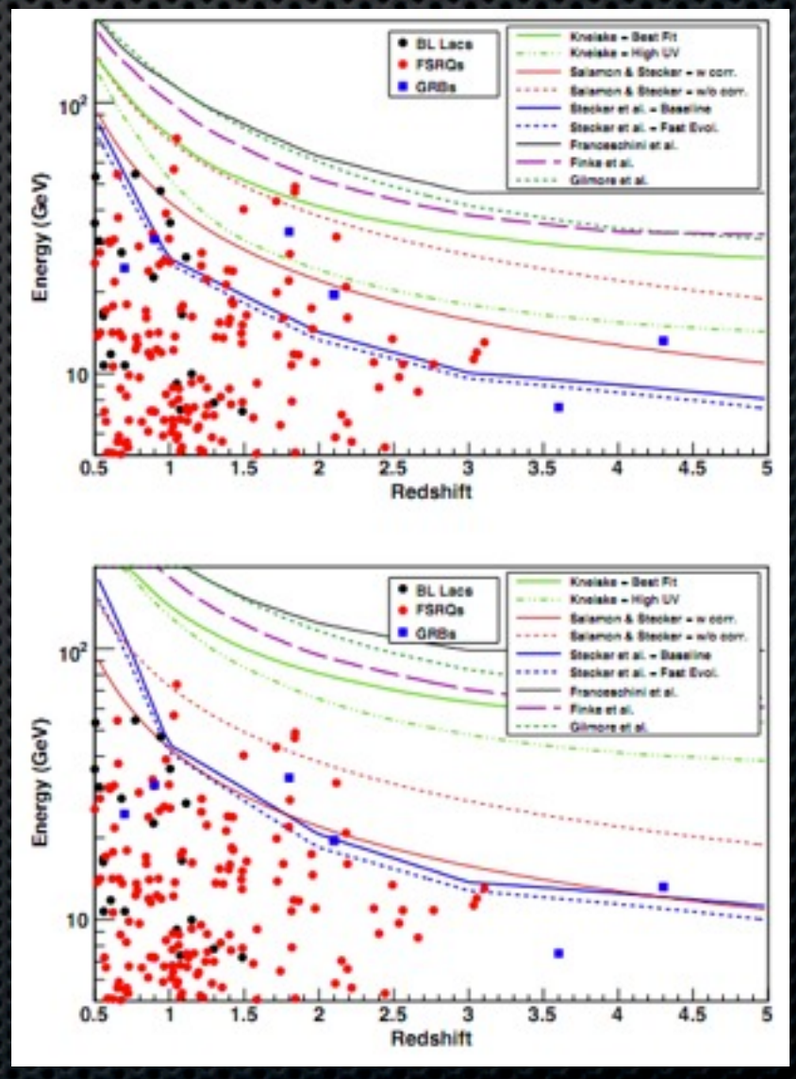
- Measuring the dispersion of the speed of light:
- For linear models (1st order): $M_{qg} > M_{pl}$



Lower limit on $M_{QG,1}/M_{Planck}$
> 1.19
> 3.42
> 5.63
> 10.0
> 102
> 1.33
> 1.22

Published in Nature, vol 462, p331 (plus comment on p291)
also see, e.g., Ellis, Mavromatos, and Nanopoulos arXiv:0901.4052 / Phys.Lett. B674 (2009) 83-86 and Amelino-Camelia, Ellis, Mavromatos, Nanopoulos and Sarkar, Nature 393, 763 (1998)

- Probe EBL models (Some are already excluded)



Abdo et al. 2010ApJ...723.1082A

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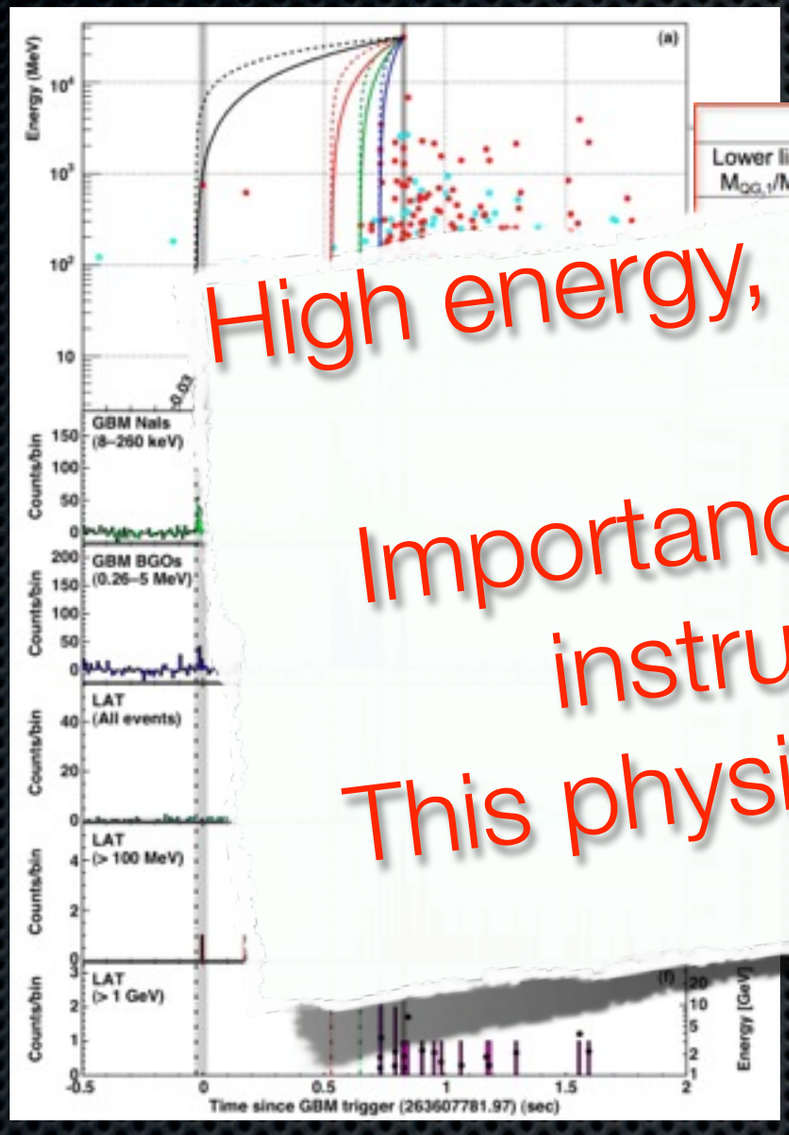

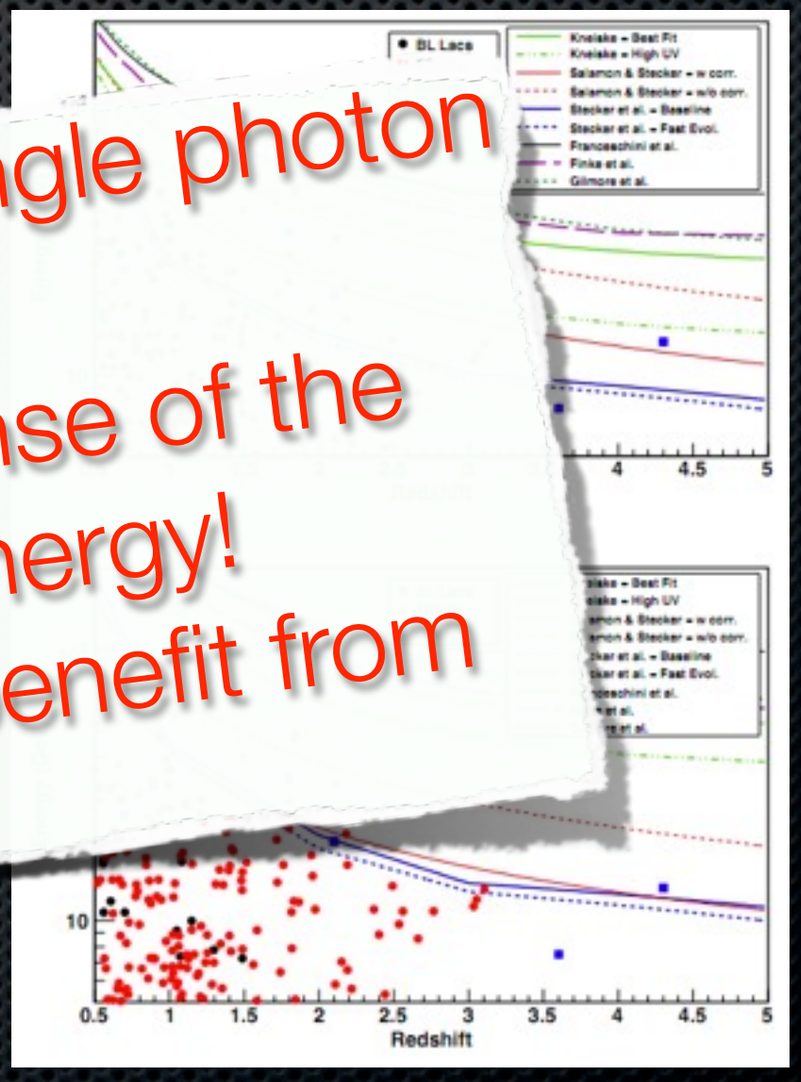

High energy, where every single photon matters!

Importance of the response of the instrument at high energy!

This physics will greatly benefit from Pass8!

Abdo et al. 2010ApJ...723.1082A

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Discovery Space: intermediate duration transients (~10^3-10^4 sec.)

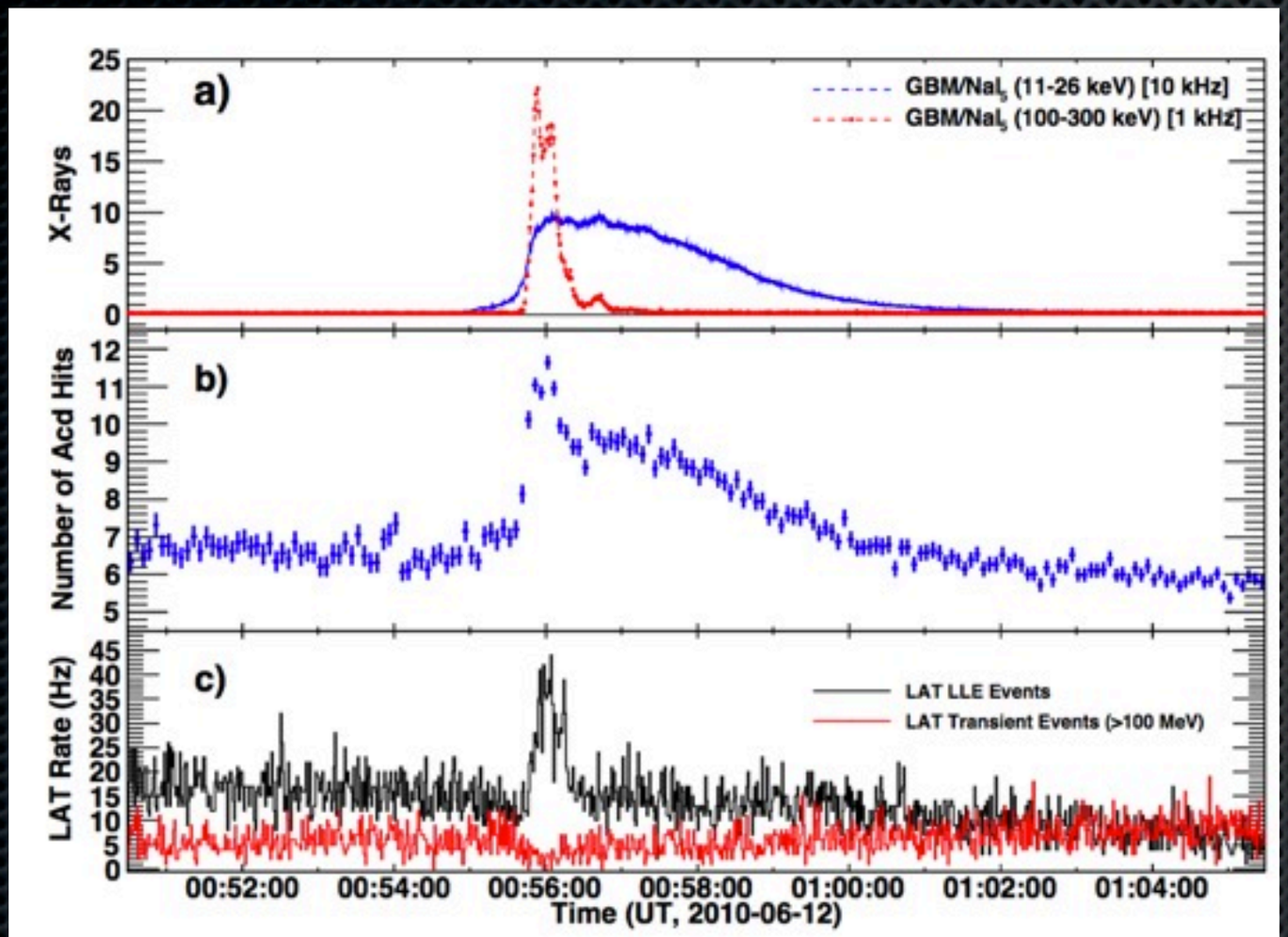
- Orphan Gamma-ray afterglows (only temporal extended emission)
- Unveiling the high redshift GRBs (Meszaros and Rees, 2010)
  - Constrain the Pop III star progenitor population
- More generally, the search for luminous transients at GeV energies in this poorly explored time domain could also reveal other interesting phenomena that have not yet been anticipated.

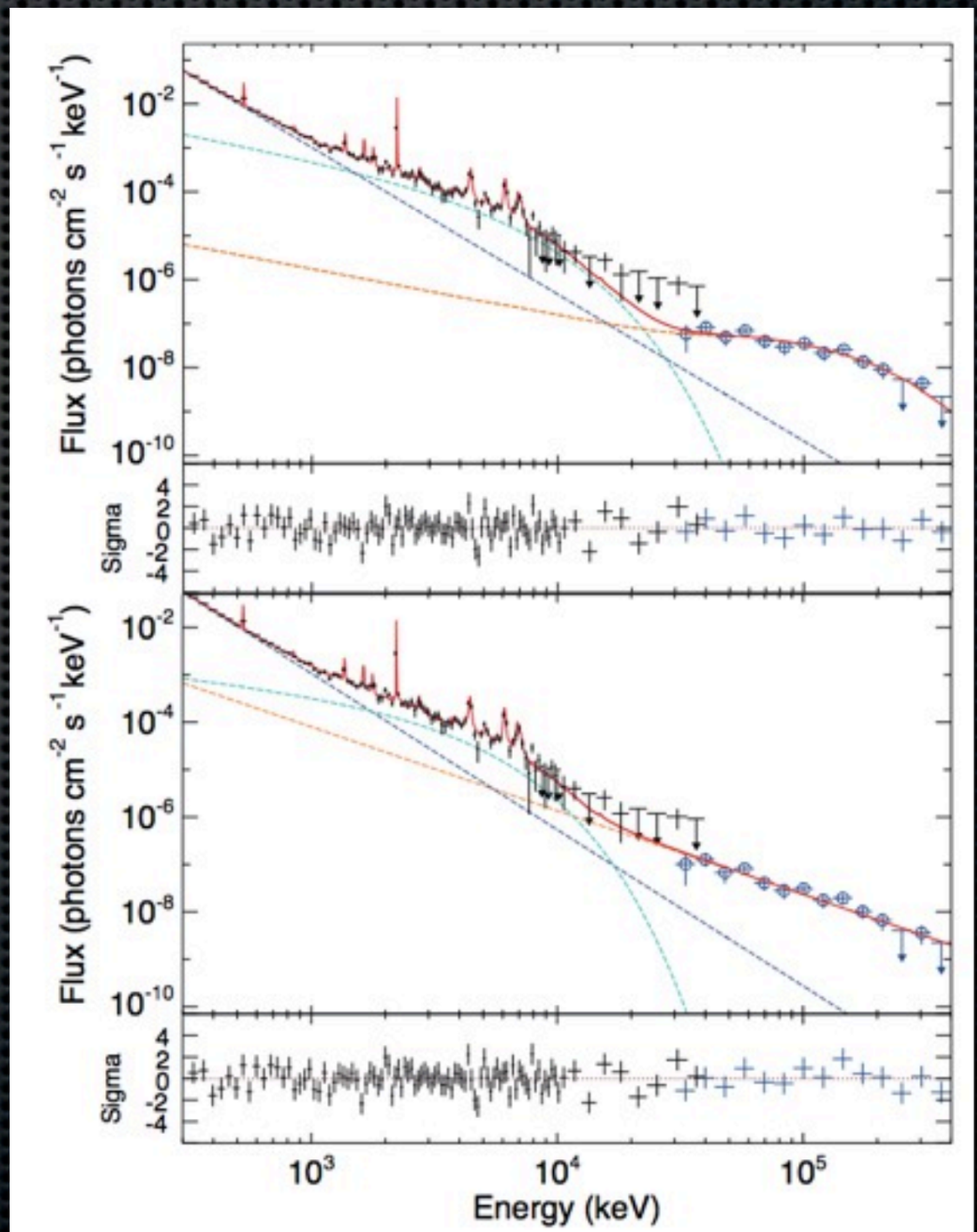
Summary of goals for GRB studies with extended operation

- Increase the population of GRB by a factor of 3
  - Step forward in the understanding of GRBs at high energy, i.e. temporal extended emission;
  - Fermi is the most prolific detector of GRBs, likely to be the instrument detecting the electromagnetic counterpart to a GW source;
  - alert sent to ground within minutes, facilitating broadband observations
- Extension to low energy: filling the gap between the LAT and the GBM energy bands
  - Understand the details of the GRB prompt emission, how particle are accelerated in internal shocks;
  - Participating in the debate over *baryonic* vs *magnetically dominated* jets.
  - High energy emission in *internal* or *external* shocks?
- Improve the analysis at high energy
  - Improve limits on Lorentz Invariance Violation (2^{nd} order effect)
  - Study the opacity of the Universe (every single photon matters!)

Backups

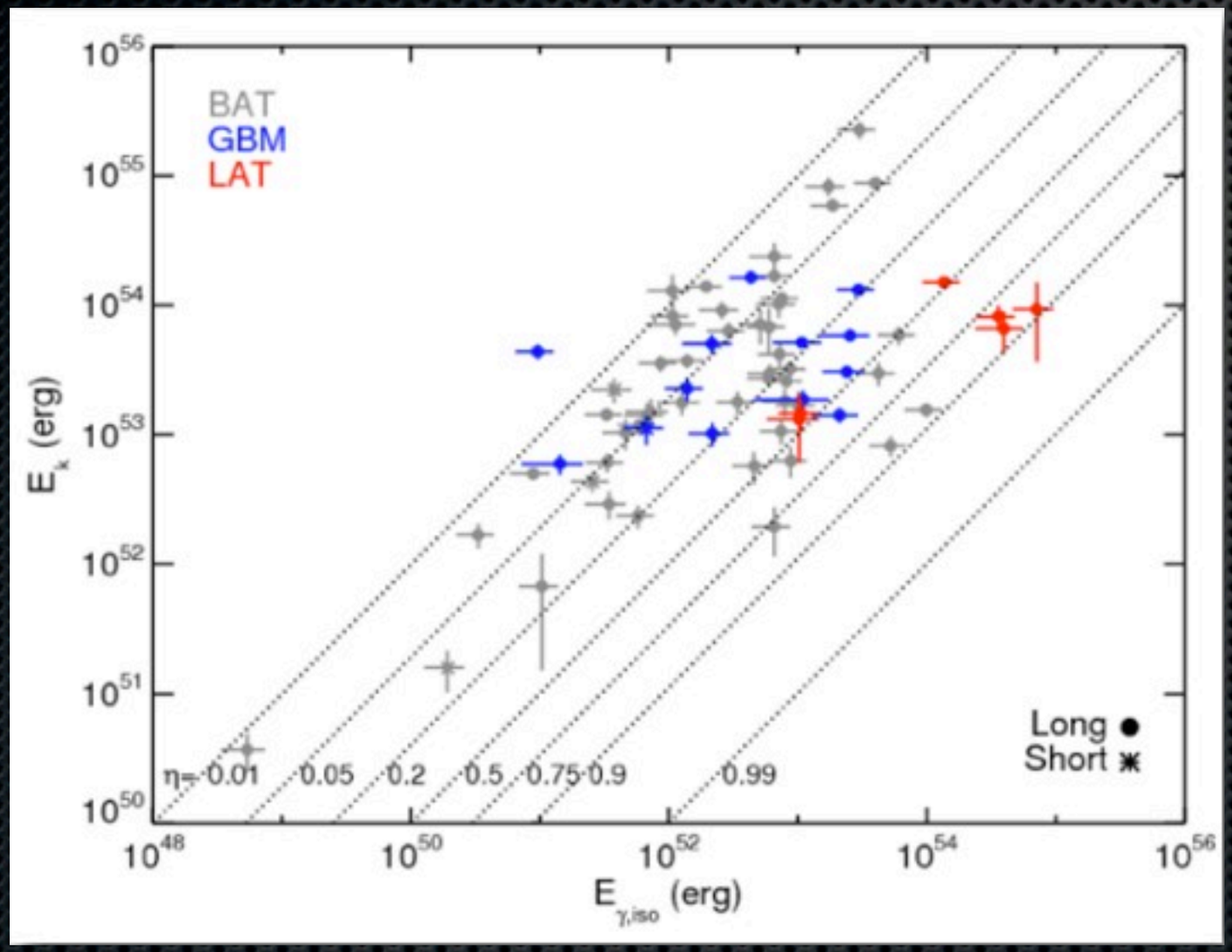
How about Solar Flares?





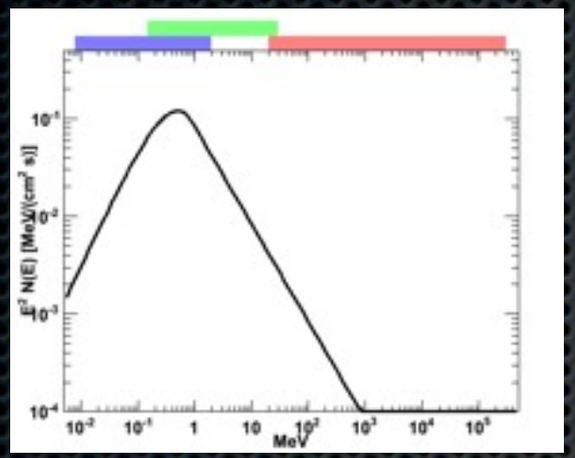
- First Solar flare paper submitted;
- LLE analysis key for unveiling the gamma-ray emission;
- Emission > 100 MeV can be described as pion decays as well as electron bremsstrahlung;
  Nicola Omodei

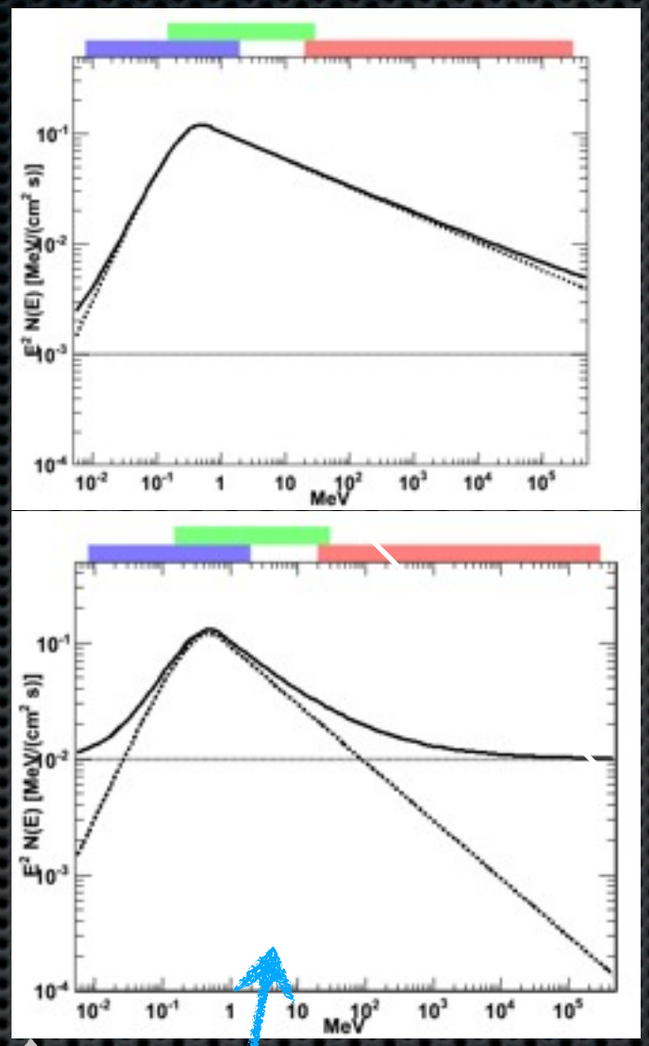
Multi messenger

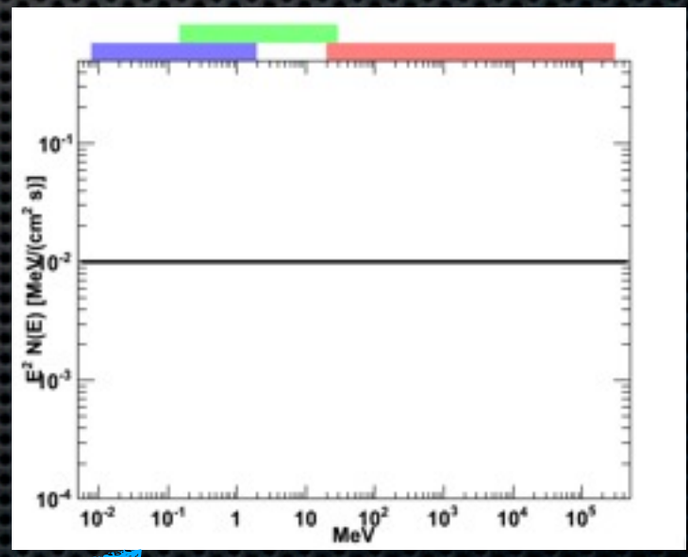


- Kinetic energy (from Swift) vs High energy emission
- LAT detected GRBs are among the most efficient GRB in converting kinetic energy into gamma rays
- GBM deliver a prolific series of GRB triggers: narrowing GW searches

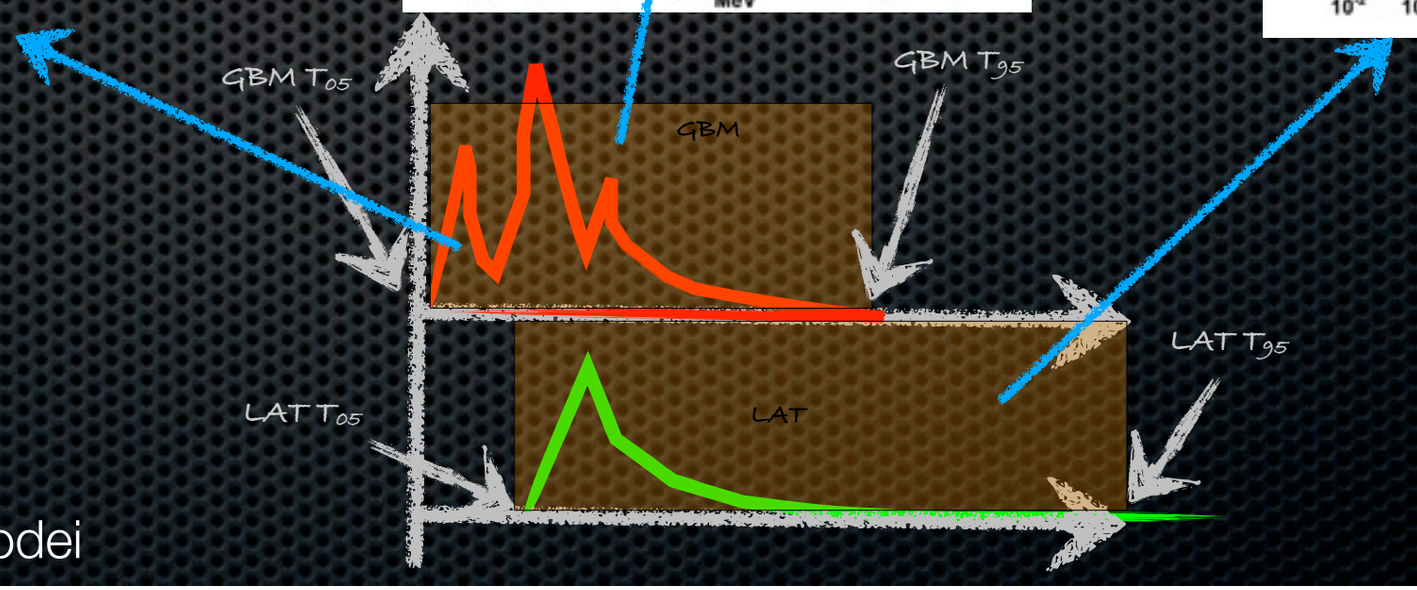
GRB Spectral Dynamic



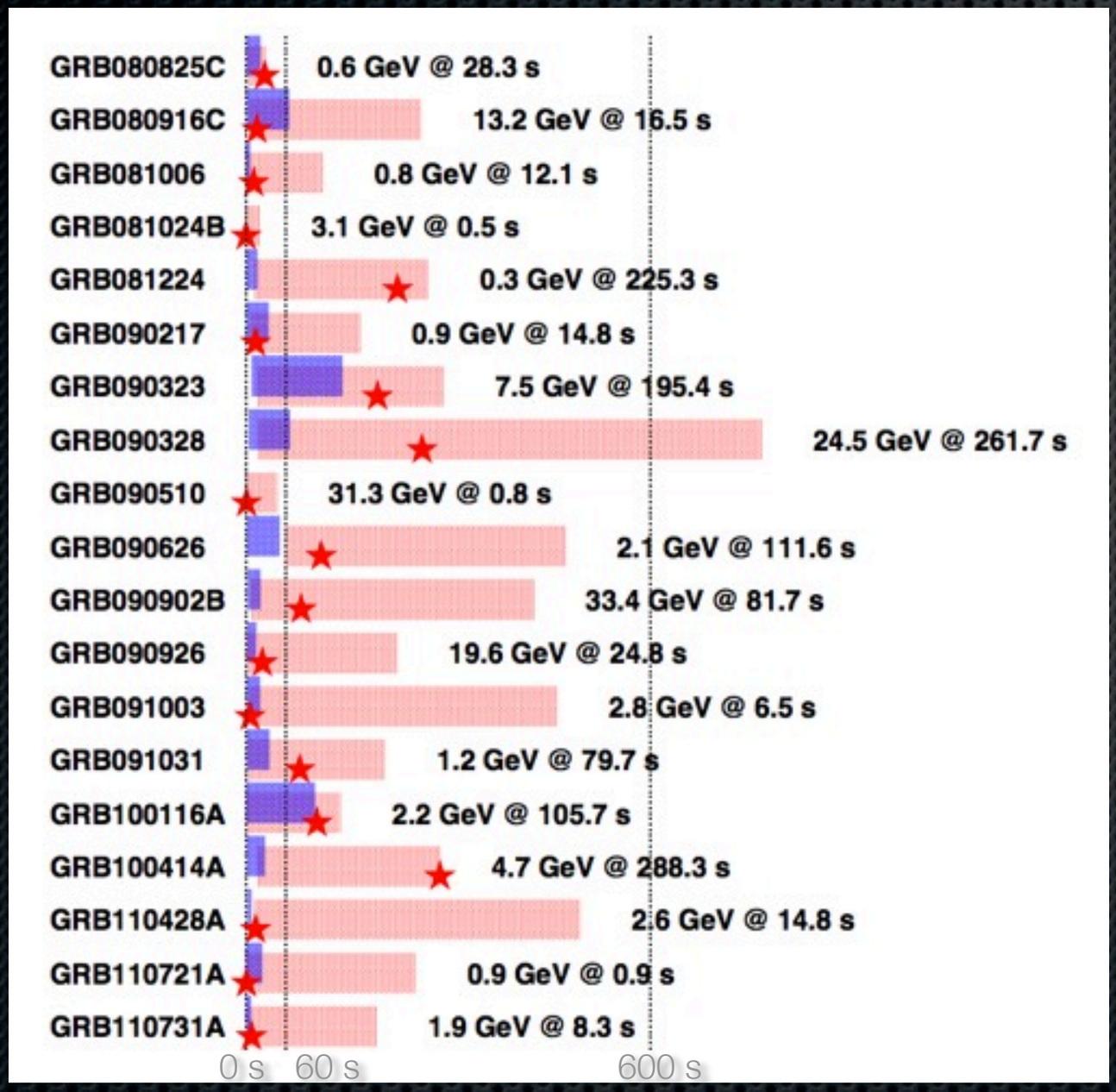




- How common are these characteristics in GRBs?



GRB durations



- Highest energy event not related with the GBM duration
- Associated with the extra component