Observations of GRBs with the Large Area Telescope

Elena Moretti
KTH & CIFS
On behalf of the Fermi GBM/LAT Collaborations

High-Energy Emissions from GRB (Past)

EGRET observations of delayed HE gamma-ray emissions

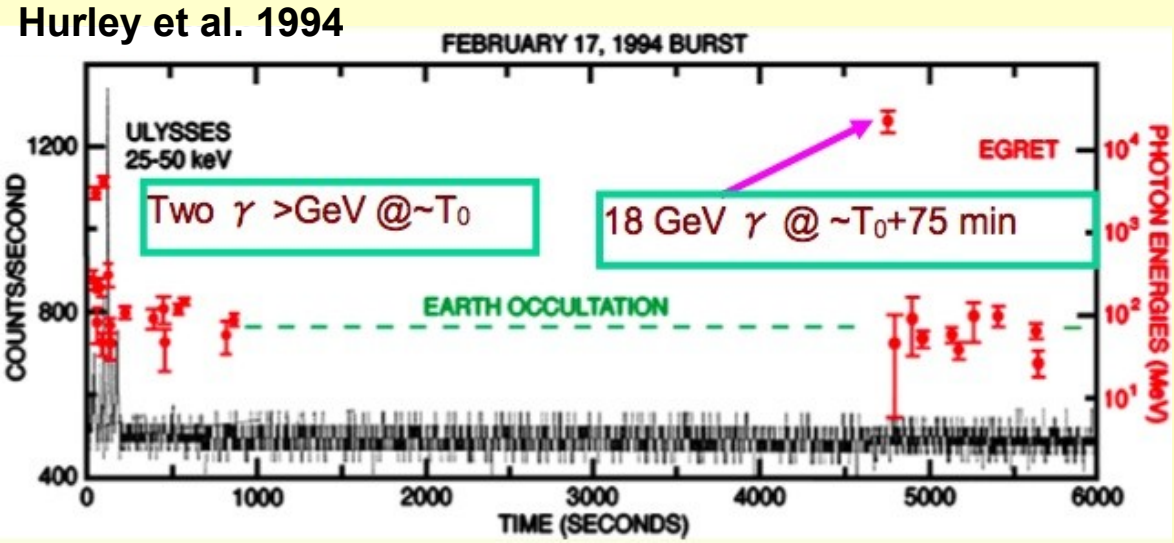
– It is not straightforward to explain by conventional electron synchrotron models

– Proton acceleration?

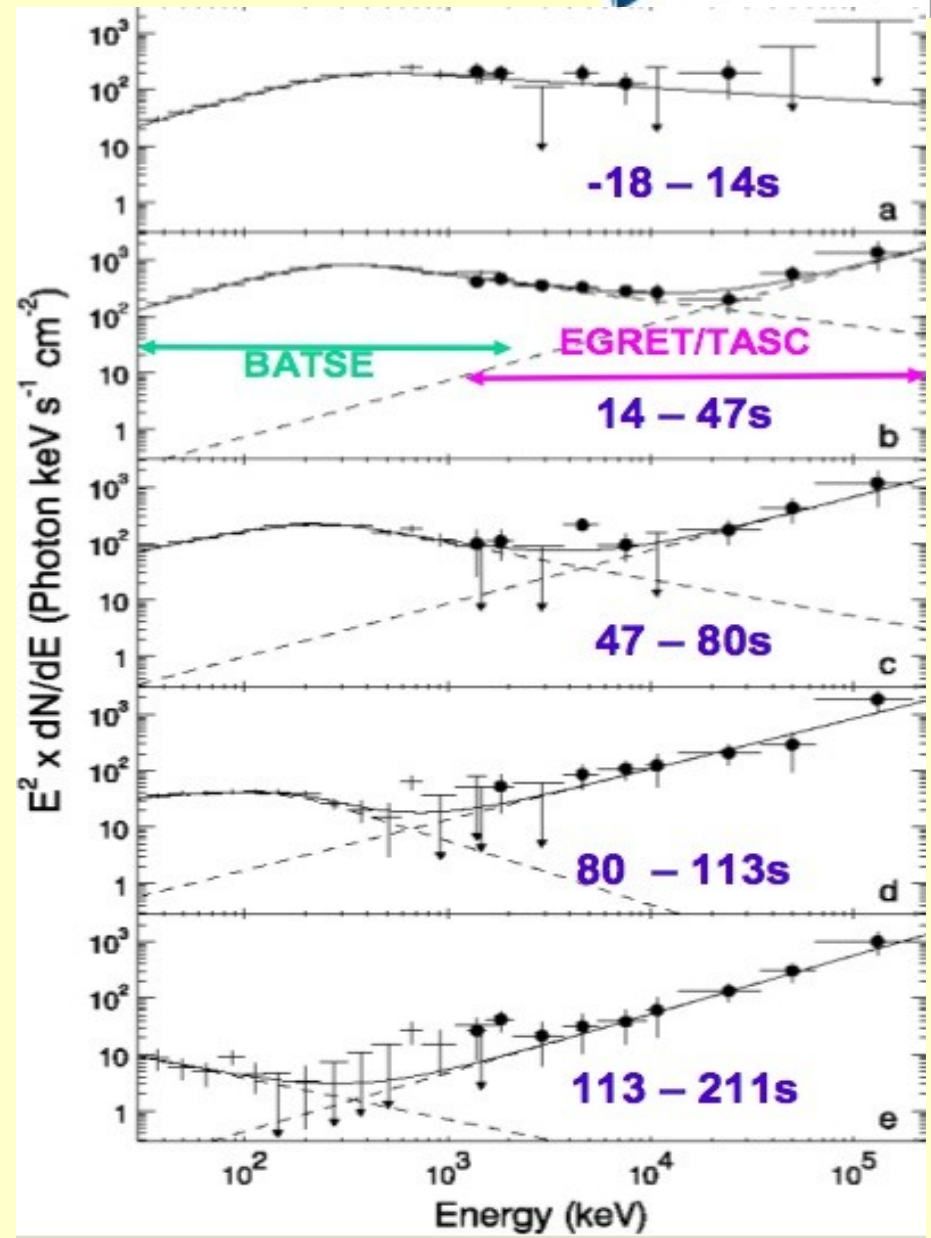
- Extra components?
- 5 EGRET bursts with >50 MeV observations in 7 years

– No evidence of cutoff or extra HE component in the summed spectrum

Hurley et al. 1994



Gonzalez, Nature 2003 424, 749



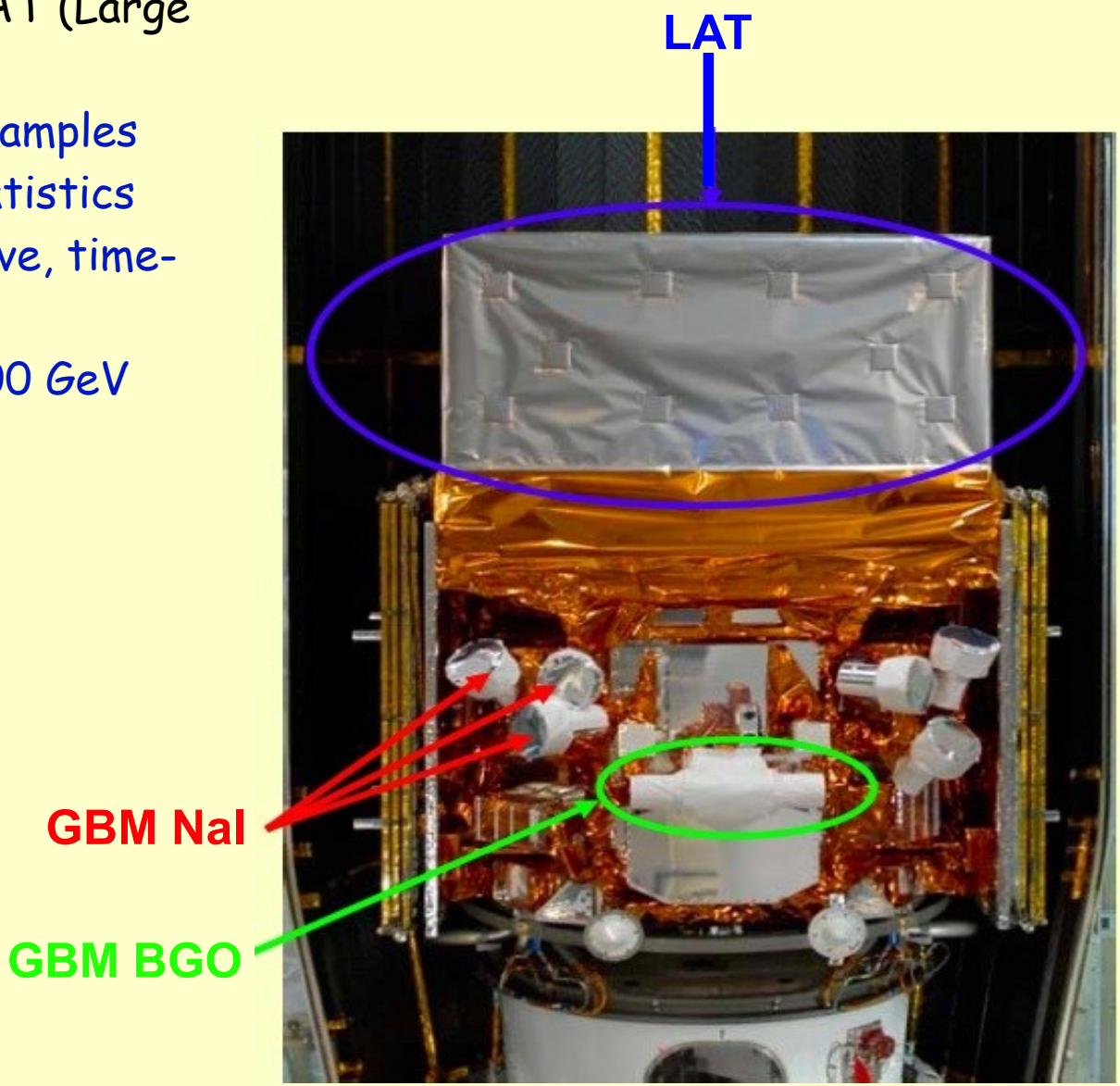
The Fermi observatory instruments

Improved performance of Fermi LAT (Large Area Telescope)

- Larger FOV (>2.4 sr): more GRB samples
- Larger effective area: better statistics
- Less dead time: detailed lightcurve, time-resolved analysis
- Wider energy coverage: up to >300 GeV

Fermi Gamma-ray Burst Monitor

- Views entire unocculted sky
- NaI:8keV-1MeV
- BGO: 200 keV - 40 MeV



GBM-LAT synergy for GRB studies

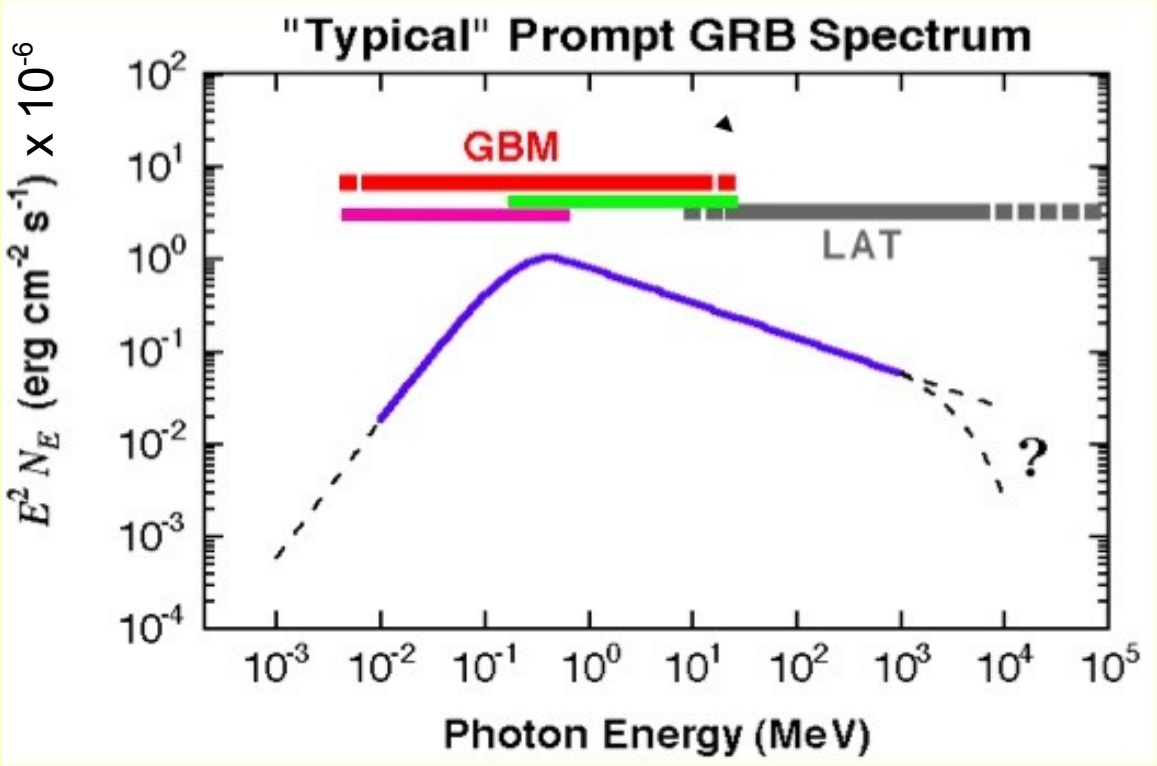
Both LAT and GBM can independently trigger

✔ Spectral coverage of more than 7 decades (8keV->300GeV)

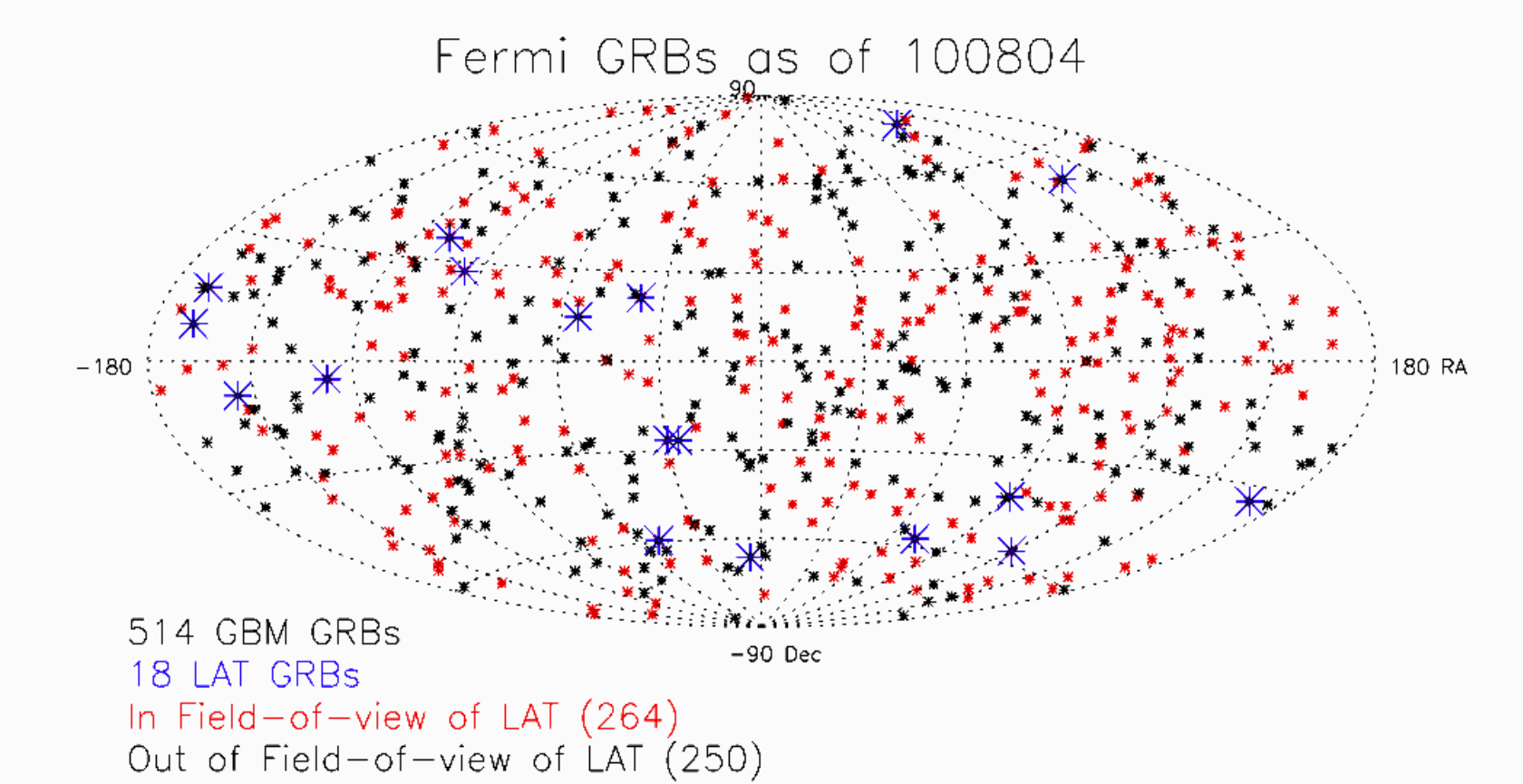
- Bright burst: study of the cut-off,if any.

✔ Detailed temporal/spectral resolution:

- Is there any "extra component"?
- How common is the extended/delayed GeV emission?
- Intrinsic lag because cosmological effects?



Fermi GRBs



The GBM detects ~250 GRBs/year (~540 total)

~18% short

~50% in the LAT FoV

The LAT detects ~10 GRBs/year: 20 total as of today

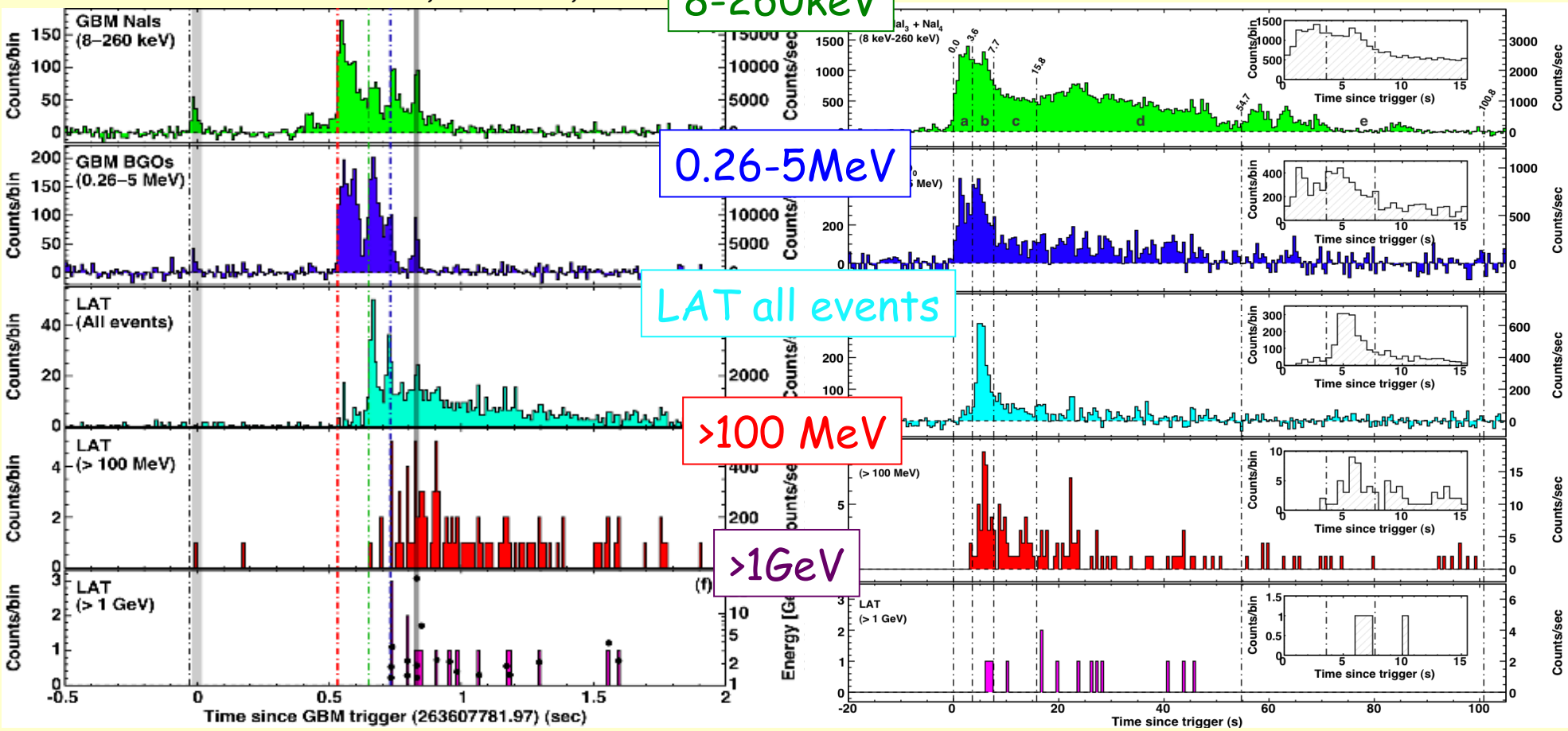
Properties: Delayed Onset

GRB 090510 (short)

Abdo et al. 2009, Nature 462, 331

GRB 080916C (long)

Abdo et al. 2009, Science 323, 1688



Delay: ~0.5s

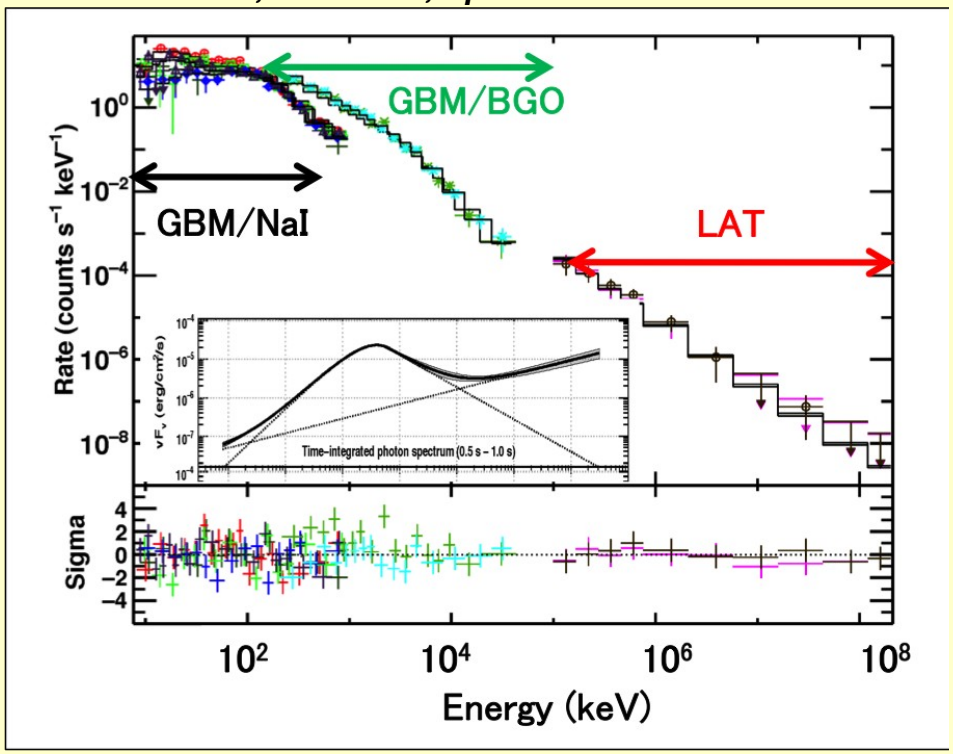
Delay: ~5s

Almost all GRBs show a delayed onset!!!

Properties: Extra HE spectral component

GRB 090510 (short)

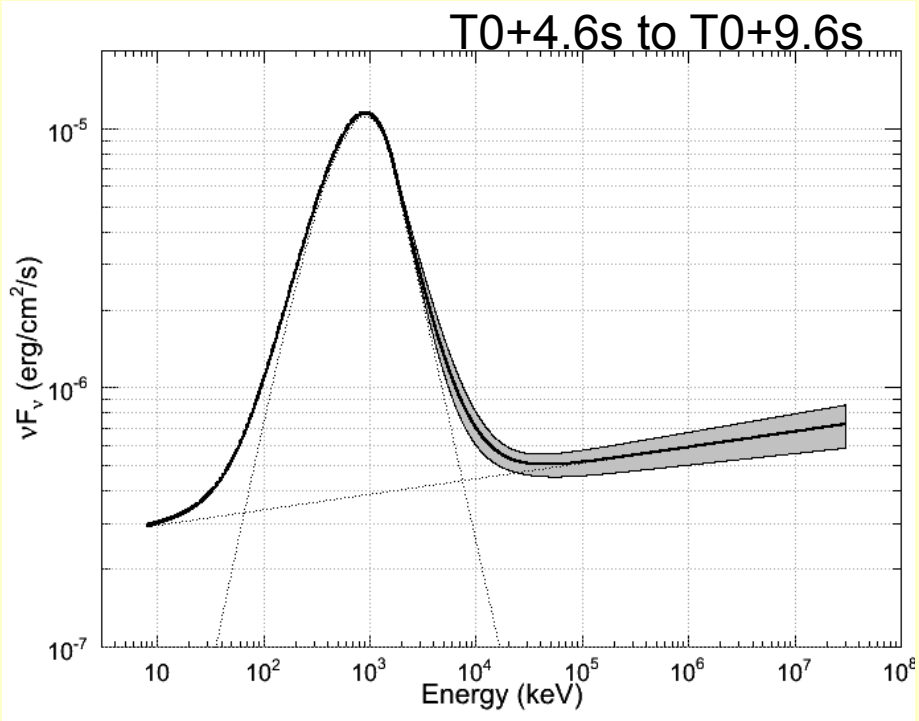
Abdo, A. A. et al., ApJ submitted



First extra component by Fermi
At > 5 sigma level

GRB 090902B (long)

Abdo, A. A. et al., ApJL 706, 138 (2009)



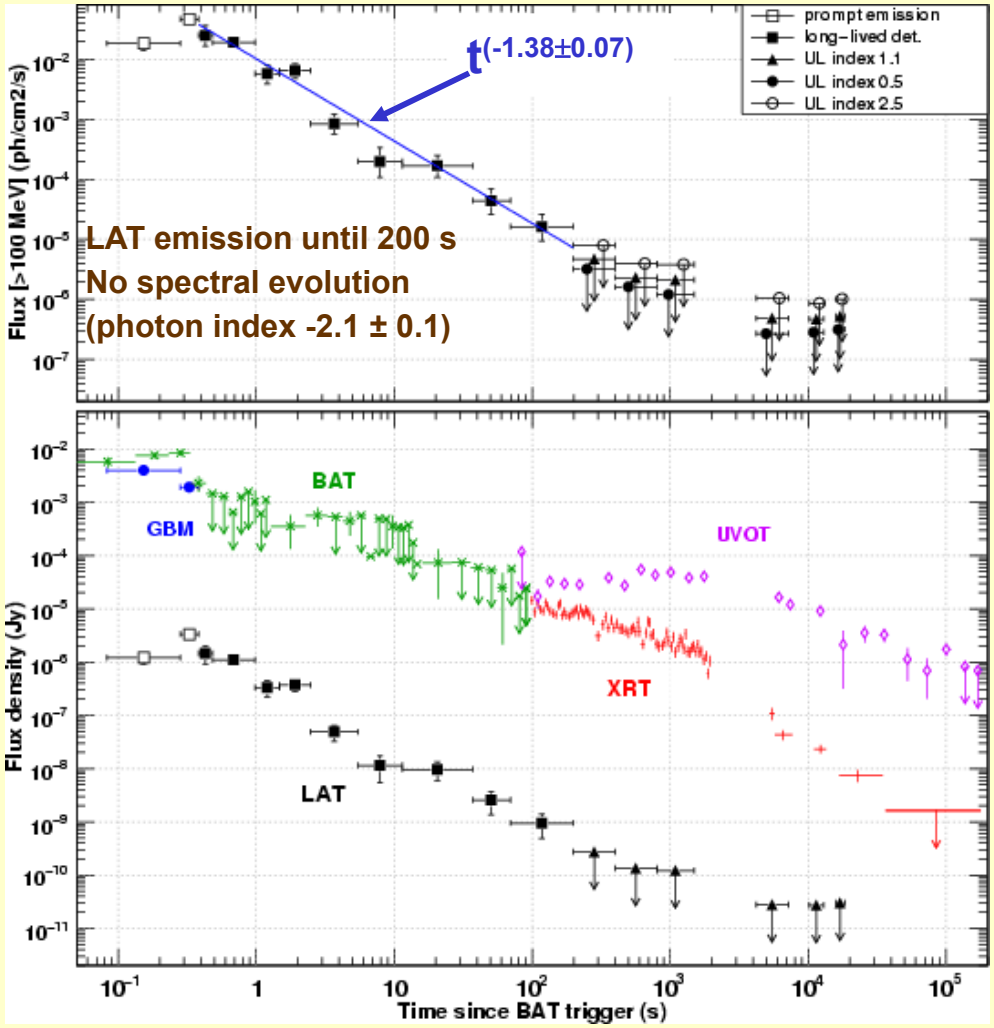
First time a low-energy extension of the PL component has been seen

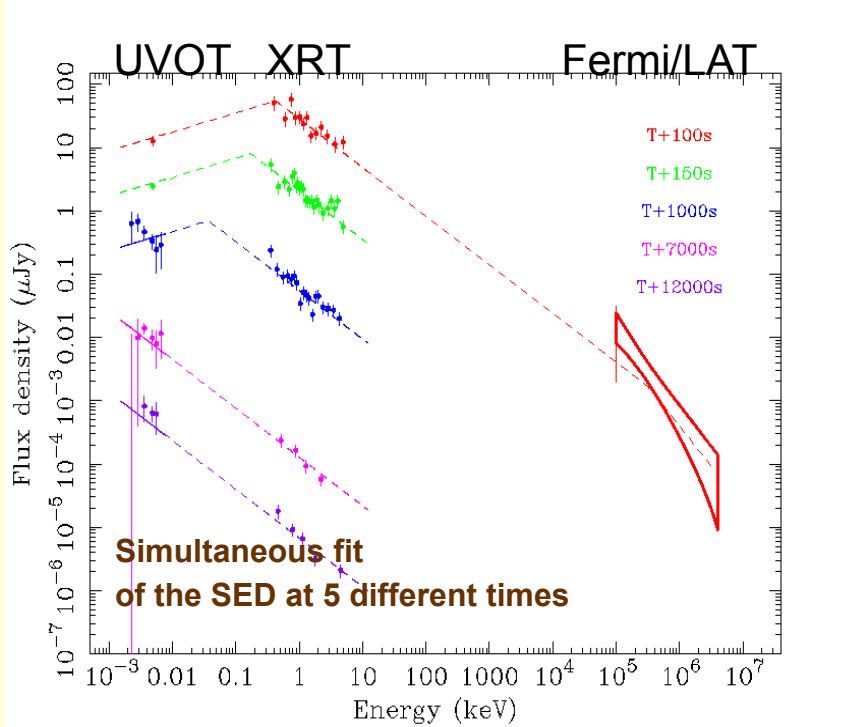
3 LAT GRBs shows extra PL component (090510, 090902B, 090926A)

Properties: Long lived HE component

GRB 090510 (short GRB)

De Pasquale et al., ApJL 709, 146 (2010)





- **Forward shock model** can reproduce the spectrum **from the optical up to GeV energies**
- Extensions needed to arrange the temporal properties

Several GRBs show this long lived component as 090816C, 090902B, and 090926A

Properties: Γ_{min} calculation

compactness problem: large luminosity + small emitting region = large optical depth (γ-γ -> e+e- large)

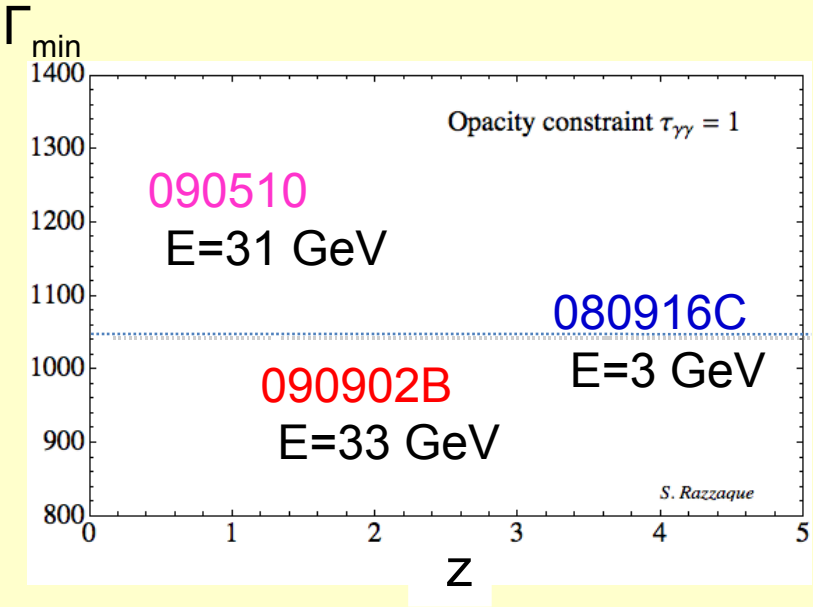
Possible solution: relativistic motion (**Γ>>1**)

$$\tau_{\gamma\gamma}(E) = \frac{3}{4}\frac{\sigma_T d_L^2}{t_v \Gamma}\frac{m_e^4 c^6}{E^2(1+z)^3}\int_{\frac{m_e^2 c^4 \Gamma}{E(1+z)}}^{\infty}\frac{d\epsilon'}{\epsilon'^2}\, n\left(\frac{\epsilon'\Gamma}{1+z}\right)\varphi\left[\frac{\epsilon' E(1+z)}{\Gamma}\right]$$

Γ_{min} calculation from highest energy photon

$$\Gamma_{\min}(E_{\max}) = \left[\frac{4 d_L^2 A}{c^2 t_v}\frac{m_e^2 c^4}{(1+z)^2 E_{\max}} g\sigma_T\right]^{\frac{1}{2-2\beta}}\left[\frac{(\alpha-\beta)E_{\rm pk}}{(2+\alpha)100\ {\rm keV}}\right]^{\frac{\alpha-\beta}{2-2\beta}} \times \exp\left(\frac{\beta-\alpha}{2-2\beta}\right)\left[\frac{2 m_e^2 c^4}{E_{\max}(1+z)^2 100\ {\rm keV}}\right]^{\frac{\beta}{2-2\beta}} ;$$

$$\text{for } \Gamma_{\min} > \sqrt{\frac{(1+z)^2 E_{\max} E_{\rm pk}(\alpha-\beta)}{2 m_e^2 c^4 (2+\alpha)}} ,$$



Γ_{min}~1000 for short and long GRBs

Quantum gravity mass constrain

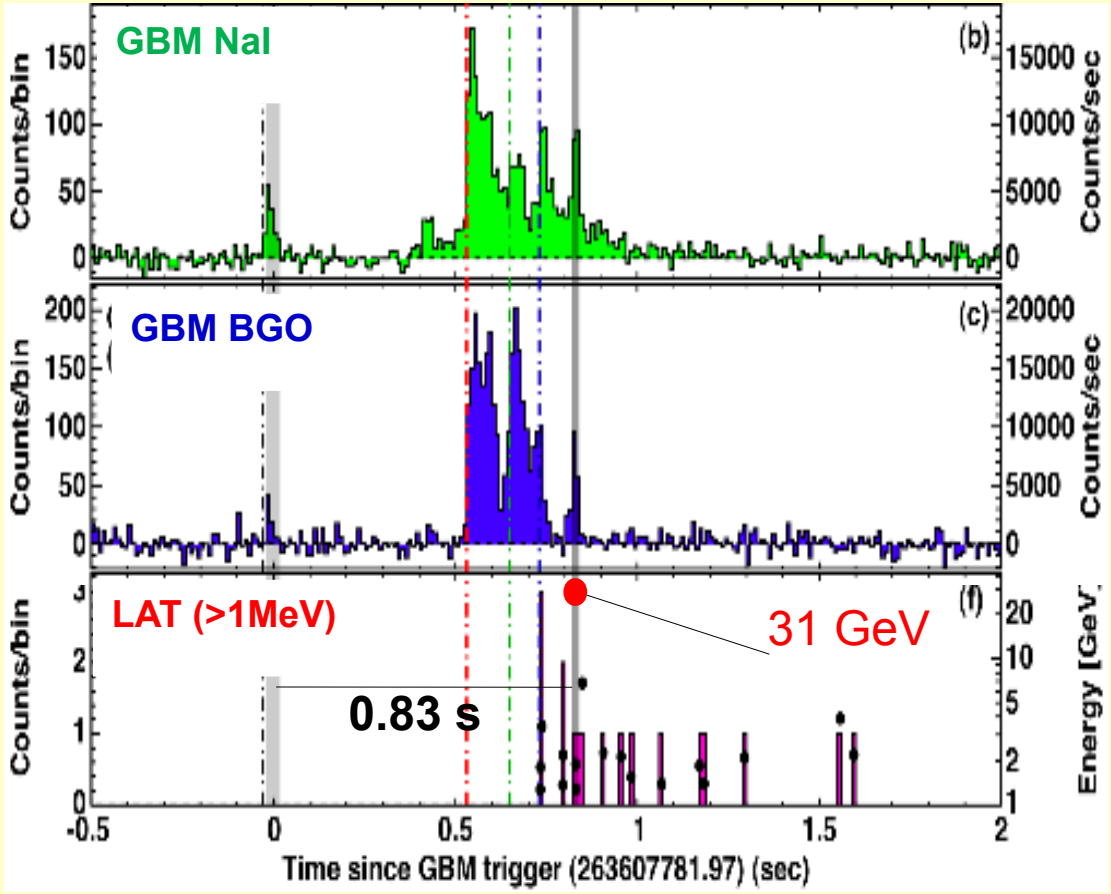
A Constraint on the quantum gravity mass (M_{QG}) can be derived by direct measurement of photon arrival time (assuming the emitted time is the same for all photons):

$$M_{QG,1}/M_{plank} > 1.19$$

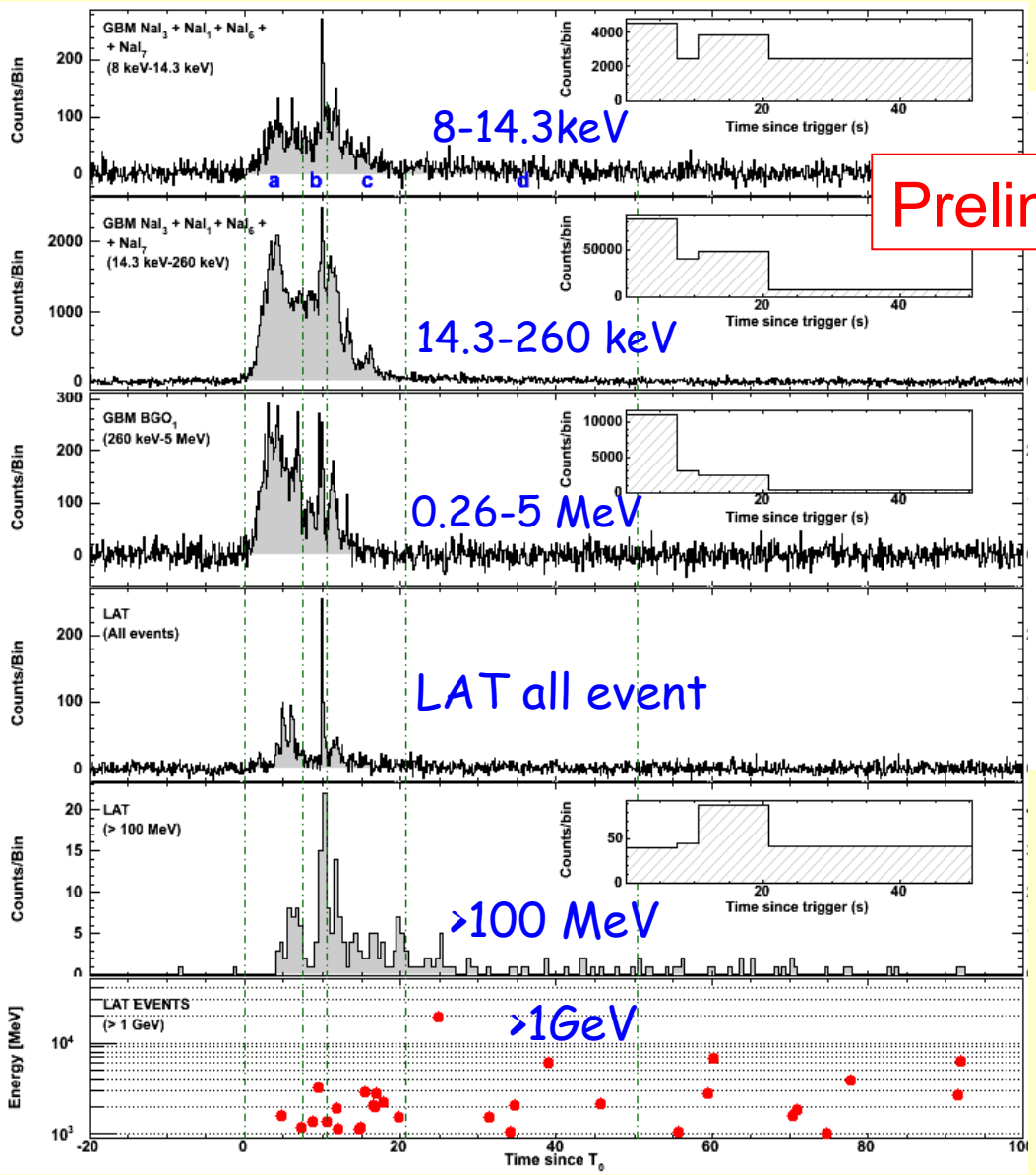
This value disfavors quantum gravity models which linearly alters the speed of light (n=1)

GRB 090510

Abdo et al. 2009, Nature 462, 331

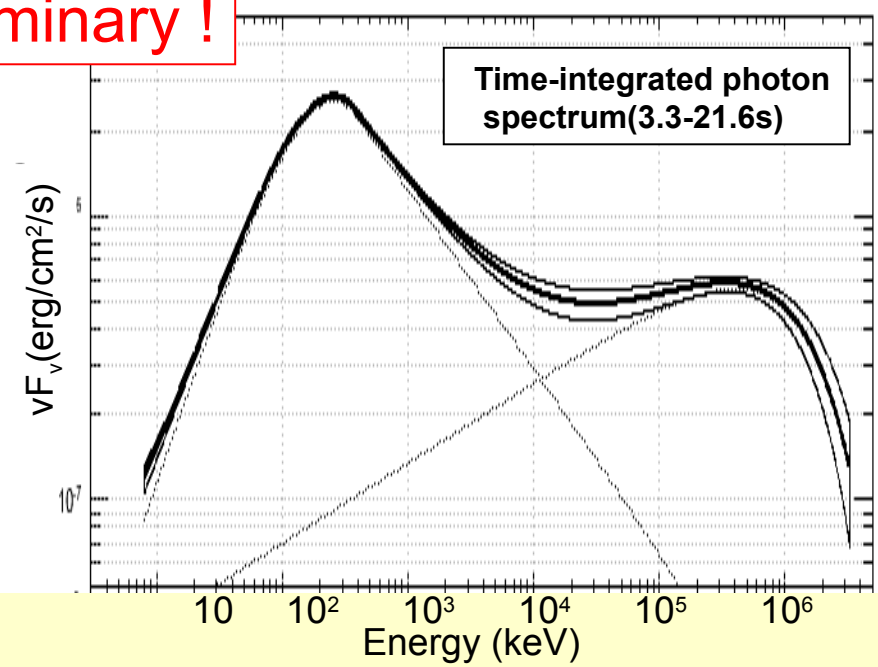


Properties: cut-off on HE spectral component



Preliminary !

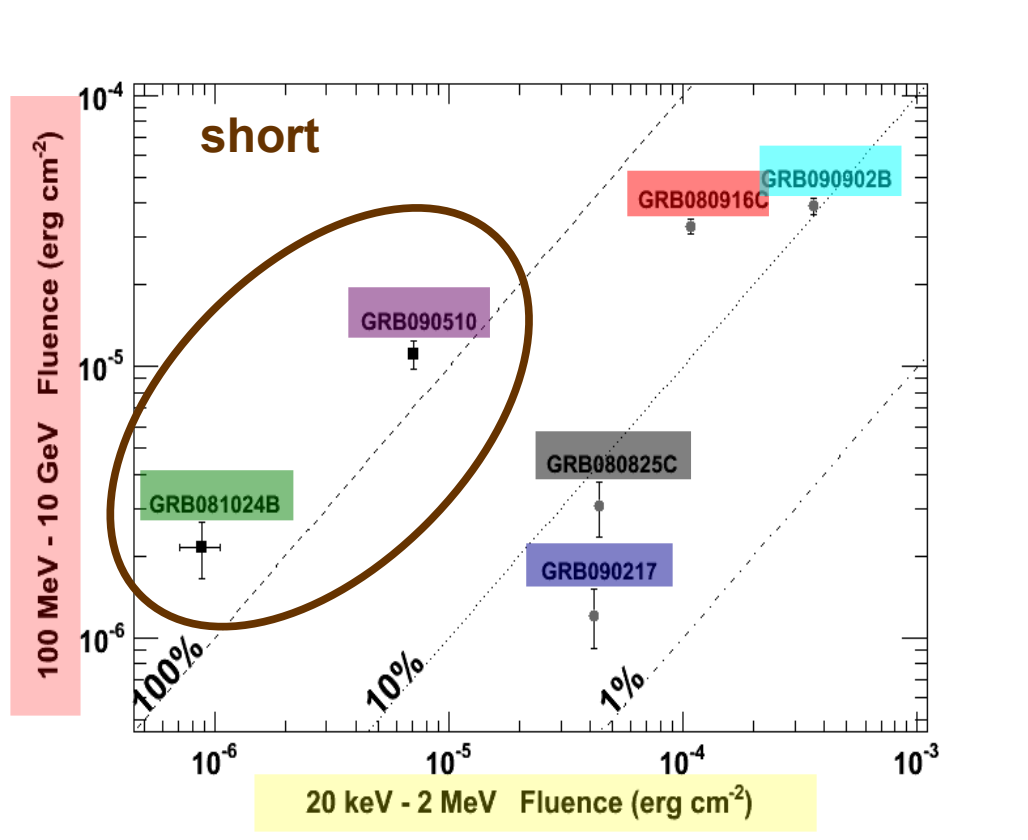
GRB 090926A (long)



- Extra component shows at >5 σ
- spectral break at ~1.4 GeV
- First direct measurement of Γ ~ 630 (if cutoff due to γ-γ absorption)

Properties: HE fluence

Abdo, A. A. et al., ApJ 712, 558 (2010)



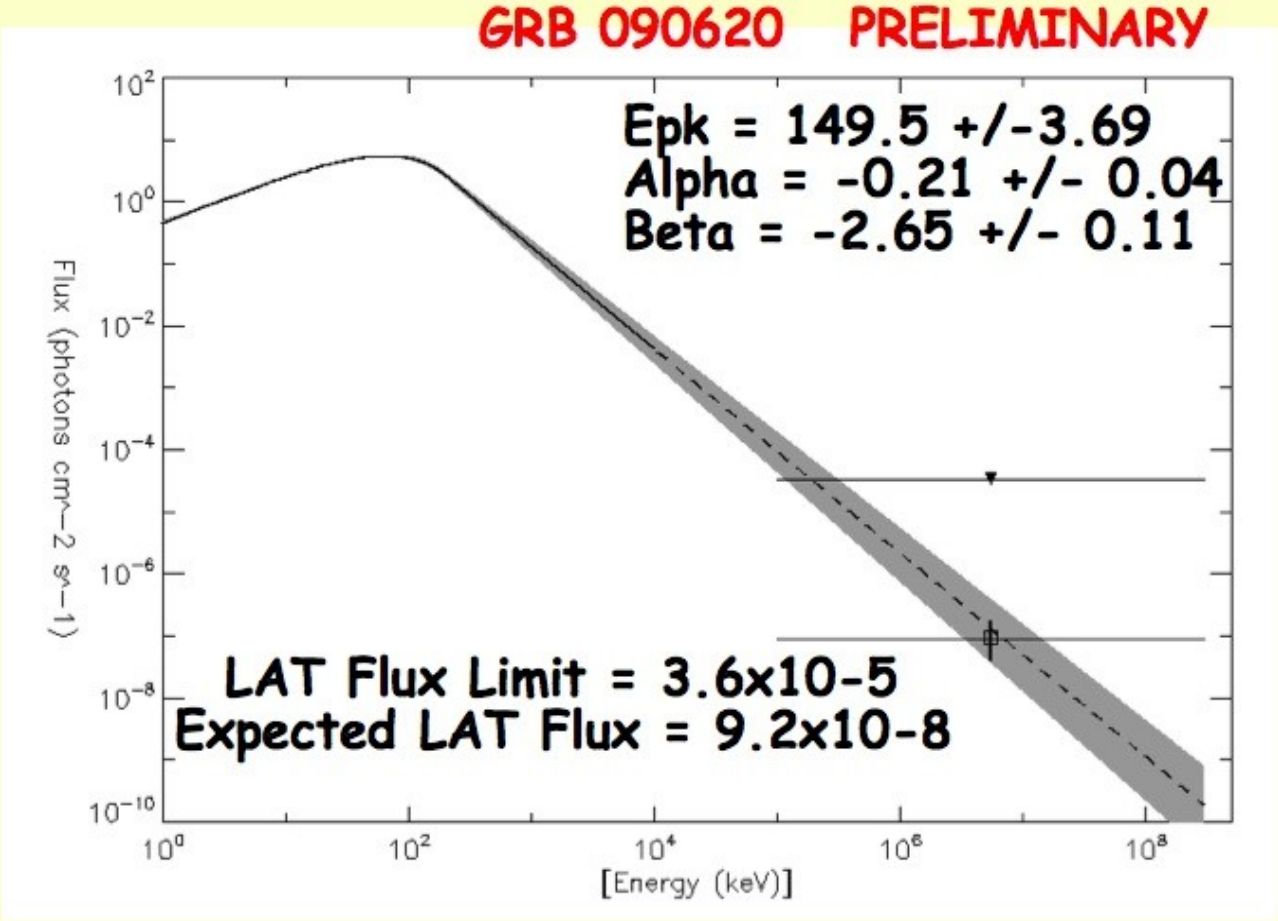
The GRBs emits less in the 100 MeV-10 GeV band respect to the 20 keV-2MeV band! (HE emission not common)

Long GRBs seem to emit ~5-20 times less at HE than at LE respect to short GRBs

Computing UL on HE emission

Only ~52% of Fermi GRBs are in LAT field of view

- ~80% of "Gold" sample do not predict LAT counts;
- ~20% do show discrepancies and hint at spectral curvature;



GRB1	Angle from LAT	Duration (or class)	# of events > 100 MeV	# of events > 1 GeV	Delayed HE onset	Long-lived HE emission	Extra spectral comp.	Highest photon Energy	Redshift
080825C	~ 60°	long	~ 10	0	?		X	~ 600 MeV	
080916C	49°	long	145	14			?	~ 13.2 GeV	~ 4.35
081024B	21°	short	~ 10	2			?	3 GeV	
081215A	~ 86°	long	—	—	—	—	--	—	
090217	~ 34°	long	~ 10	0	X	X	X	~ 1 GeV	
090323	~ 55°	long	~ 20	> 0	?		?		3.57
090328	~ 64°	long	~ 20	> 0	?		?		0.736
090510	~ 14°	short	> 150	> 20				~ 31 GeV	0.903
090626	~ 15°	long	~ 20	> 0	?		?		
090902B	51°	long	> 200	> 30				~ 33 GeV	1.822
090926	~ 52°	long	> 150	> 50				~ 20 GeV	2.1062
091003A	~ 13°	long	~ 20	> 0	?	?	?		0.8969
091031	~ 22°	long	~ 20	> 0	?	?	?	~ 1.2 GeV	
100116A	~ 29°	long	~ 10	3	?	?	?	~ 2.2 GeV	
100225A	~60	long	~10	1	?	?		~9.5 GeV	
100325A	~10	long	~5	0	?	?	?	800 MeV	
100414A	~70	long	~20	> 0	?	?	?	4 GeV	

What's up? Low Energy Events

TITLE: GCN CIRCULAR
NUMBER: 11155
SUBJECT: GRB100826A: Fermi-LAT Observations
DATE: 10/08/30 20:52:22 GMT
FROM: Julie McEnery at NASA/GSFC <julie.e.mcenery@nasa.gov>
Julie McEnery (NASA/GSFC) and Nicola Omodei (Stanford) report on behalf of the Fermi-LAT collaboration.
The Fermi Large Area Telescope (LAT) detected emission from GRB 100826A also detected by GBM (trigger 304556304) at 22:58:22.89 on August 26, 2010.
The GBM location was at a very large angle of (~70 degrees) to the LAT boresight, and **no significant excess is seen using standard analysis procedures.**
Using a non-standard data selection, over 350 counts above background were detected within a 50 s interval coinciding with the first GBM broad peak. The LAT light curve has a very similar structure to this GBM peak, with the maximum count rate occurring at ~22 s post-trigger. **A preliminary study of the instrument performance at such a large inclination suggests that these events are likely to be low energy gamma-rays, with energies less than 200 MeV.** This data selection has insufficient spatial resolution to provide a reliable LAT localization.

Summary

- Some observed properties
  - High energy emission (>100 MeV) observed in both long and short bursts
  - Delayed onset between LAT and GBM ("the missing peak")
    - Characteristic Spectral evolution
    - Separate region from initial GBM emission (Internal Shocks?)
    - Not seen in 090217
    - Both in long and short bursts
- Single Band-function dominates 6 decades of energy band
  - Extra component dominates in few cases (both in long and shorts)
- Long lived high-energy emission detected both in Long and Short bursts
- Cut-off observed in the HE spectral component
- Fundamental physics tested (LIV, Gamma min)
- HE emission not a common propriety of GRBs

Thanks