The observation of Gamma Ray Bursts with AGILE

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on behalf of the AGILE GRB WG

Outline

Introduction;

Description of the AGILE instrumentation;

The AGILE GRBs:

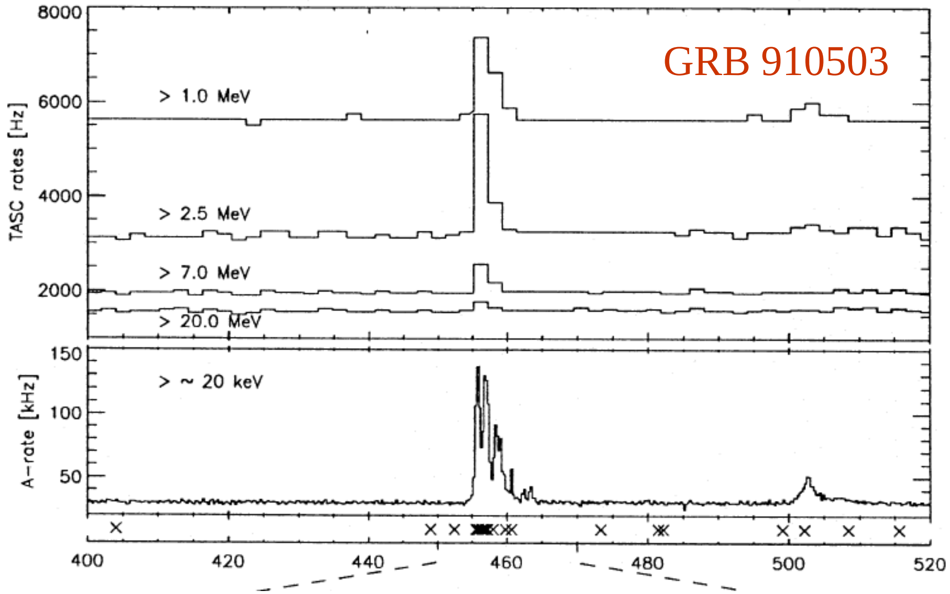
- GRB 080514B (delayed and extended emission, same spectrum at keV and GeV energies);
- GRB 090510 (short with delayed component and spectral evolution);
- GRB 100724B (simultaneous emission at MeV and GeV);
- GRB 090401B (complete covering by Swift);

Upper limits in gamma-rays of the undetected GRBs;

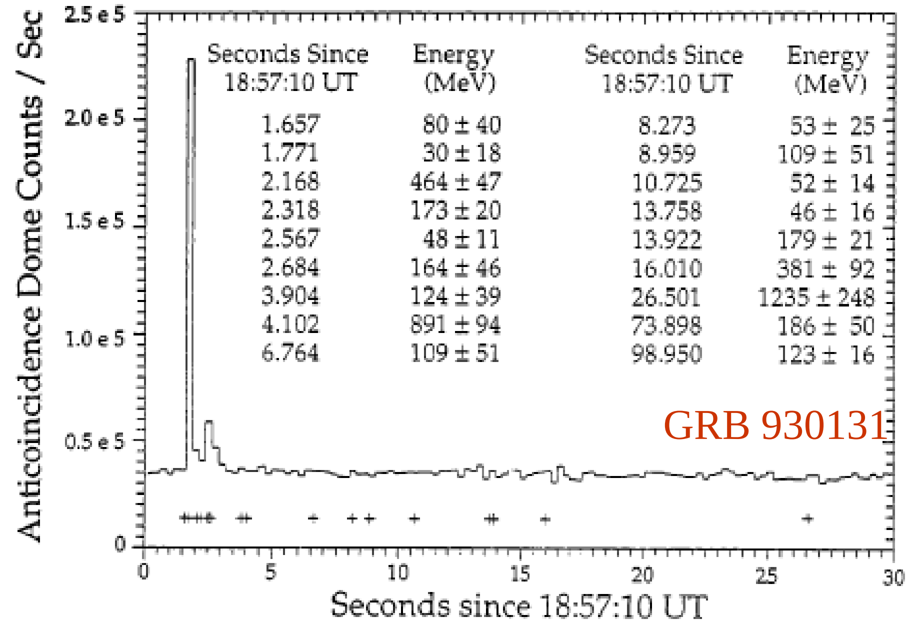
Possible interpetation (prompt vs afterglow emission)

Conclusions

The EGRET heritage



Schneid et al., 1992, A&A



Sommer et al., 1994, ApJ

Five GRBs coincident in time with BATSE triggers were detected by EGRET above 100 MeV;

They showed both simultaneous and extended emission of gamma rays, until a few hundreds of seconds after trigger (with GRB 940217 until more than 5000 s);

In some GRBs (e. g. GRB 930131) the spectrum in 1 MeV – 1 GeV is modeled by the same powerlaw, others (e. g. GRB 941017) show additional components;

The afterglow emission was not yet discovered, thus the redshift was not known.

The context before AGILE

BeppoSAX opened the way to the X-ray and optical follow-up of GRBs and the redshift of several events was discovered;

In the fireball model, the prompt emission is attributed to internal shocks, the afterglow to external shocks;

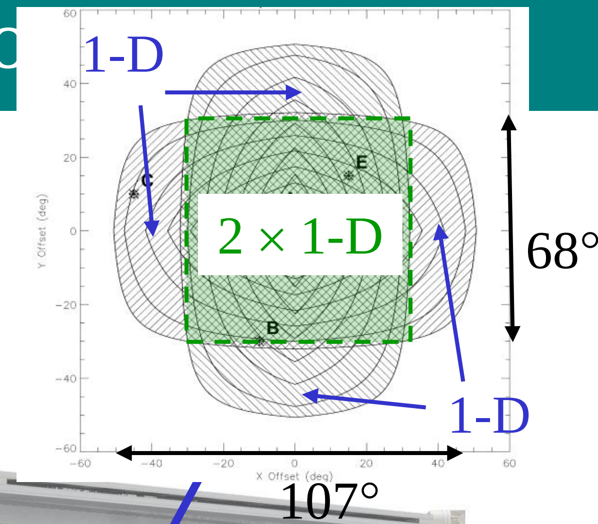
Swift repoints GRBs in ~100 s and observes them in X-rays and optical/UV;

GRBs observed by Swift at redshift of 6.29 (Cusumano et al., 2007), 8.1 (Salvaterra et al., 2009) and even 9.4 (Cucchiara et al., 2011) are among the most distant objects in the Universe;

The complex phenomenology of the afterglow was discovered. The flares in the afterglow likely represent extended activity of the central engine;

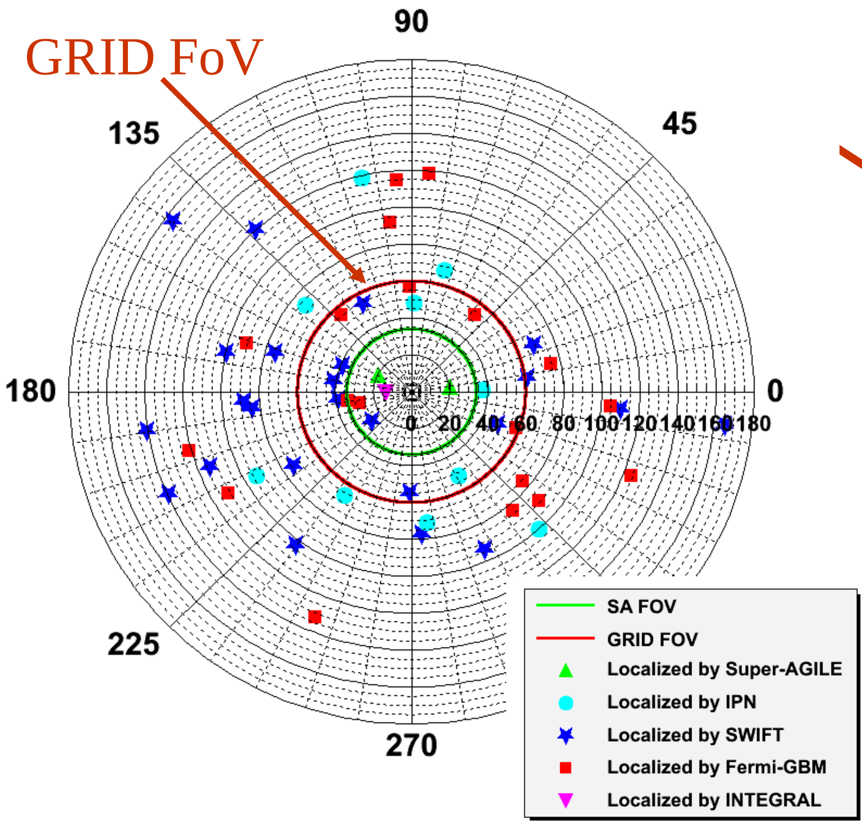
Our knowledge in gamma-rays was confined to the few events observed by EGRET.

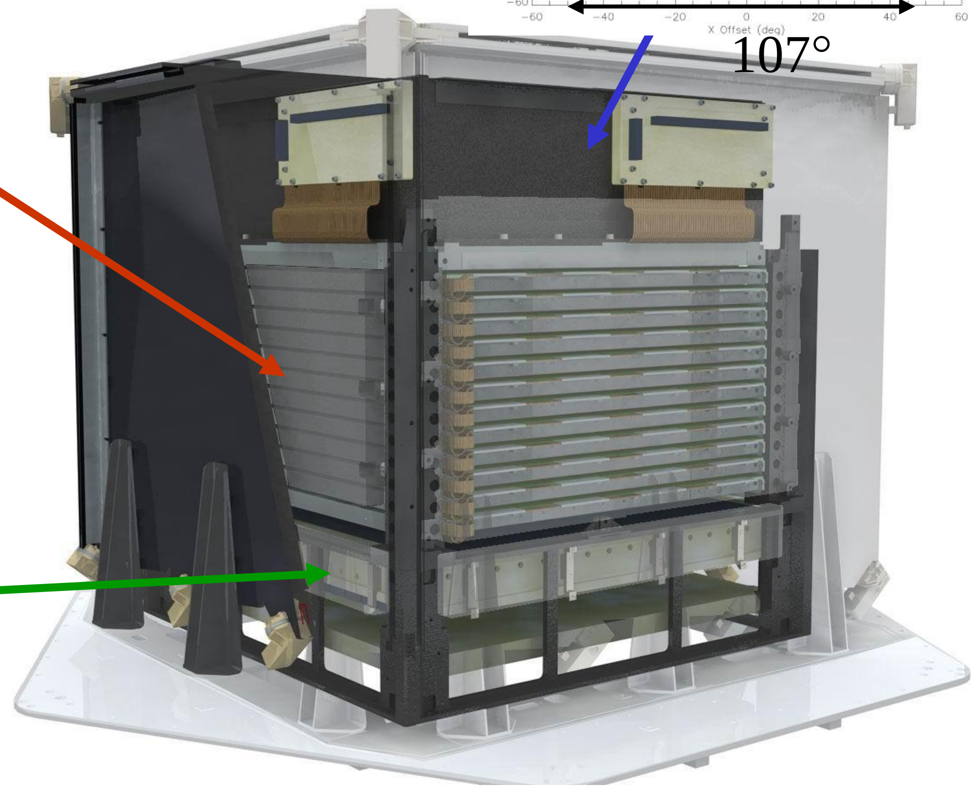
The AGILE instrumentatio



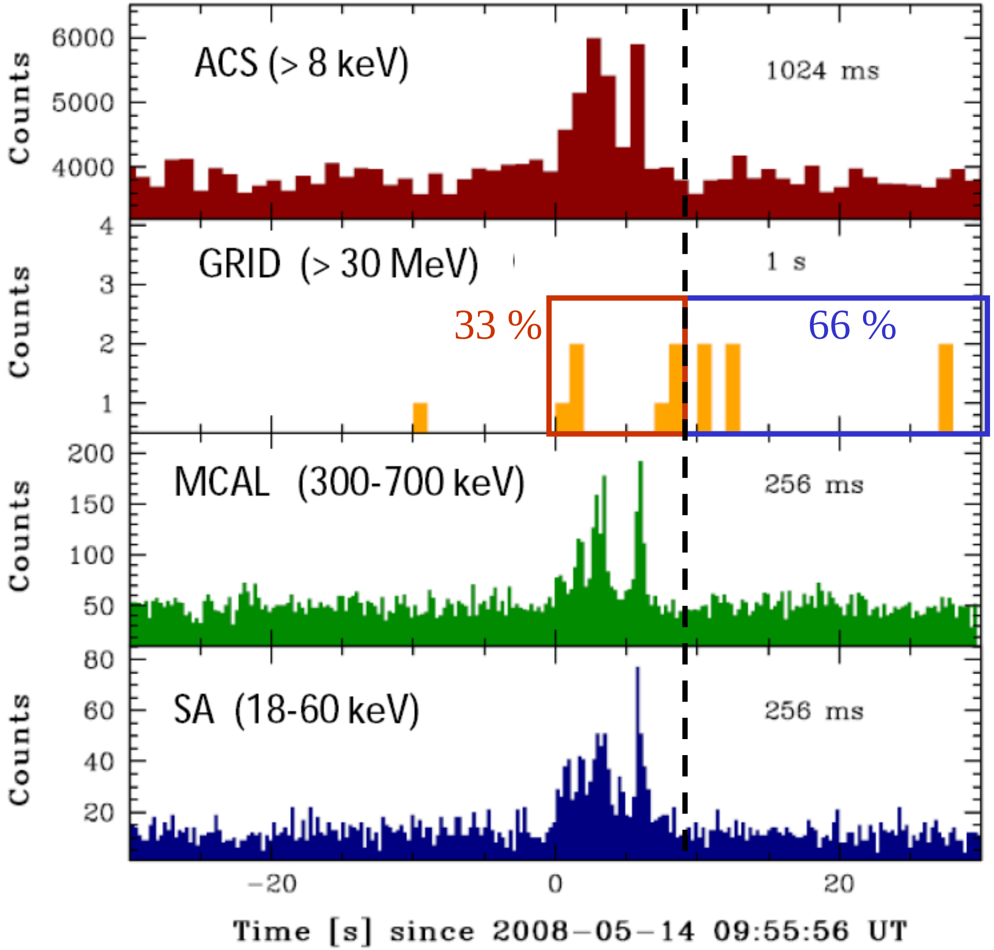
Gamma Ray Imaging Detector
Silicon tracking detector

GRID FoV



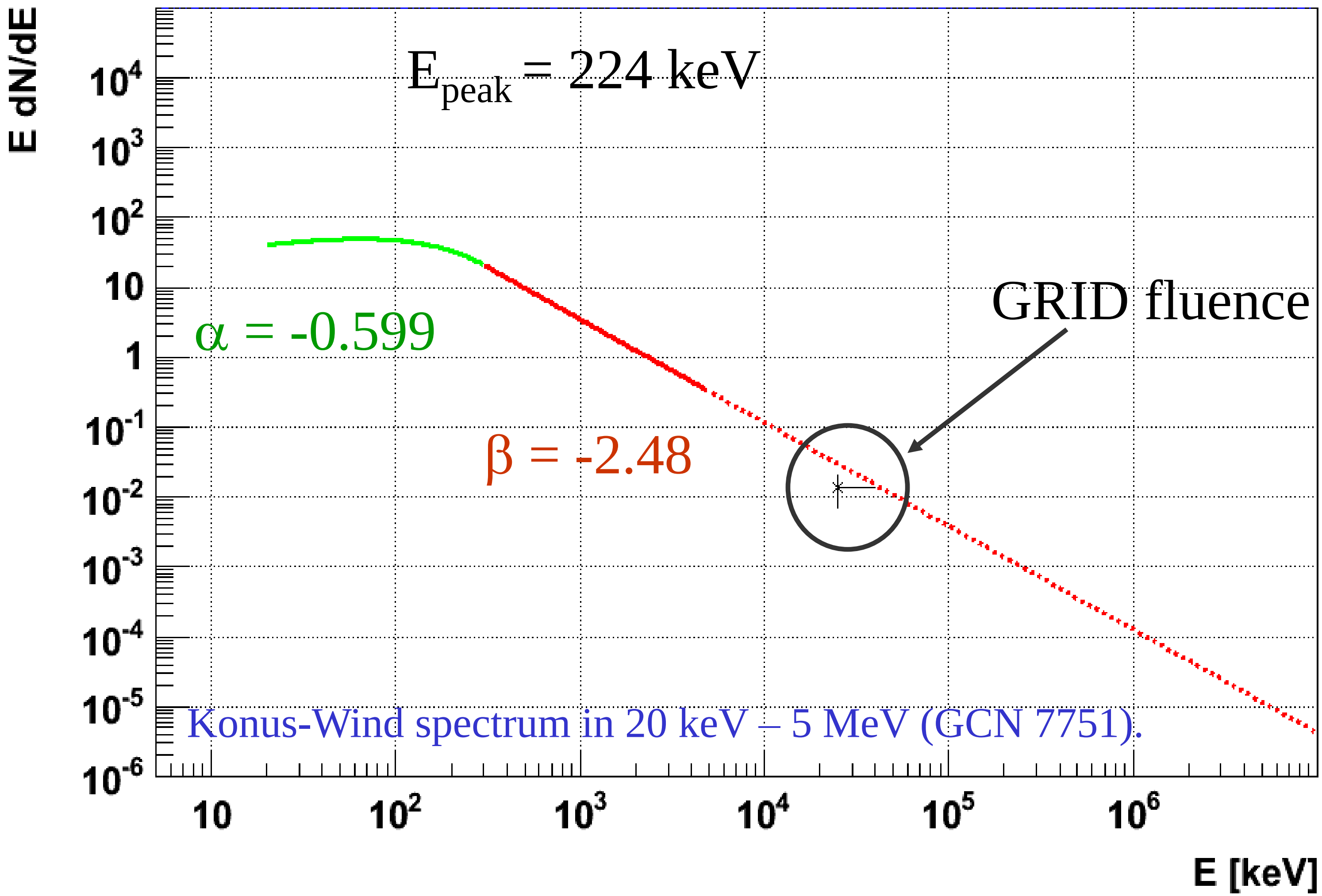


Gamma-ray extended emission in GRB 080514B



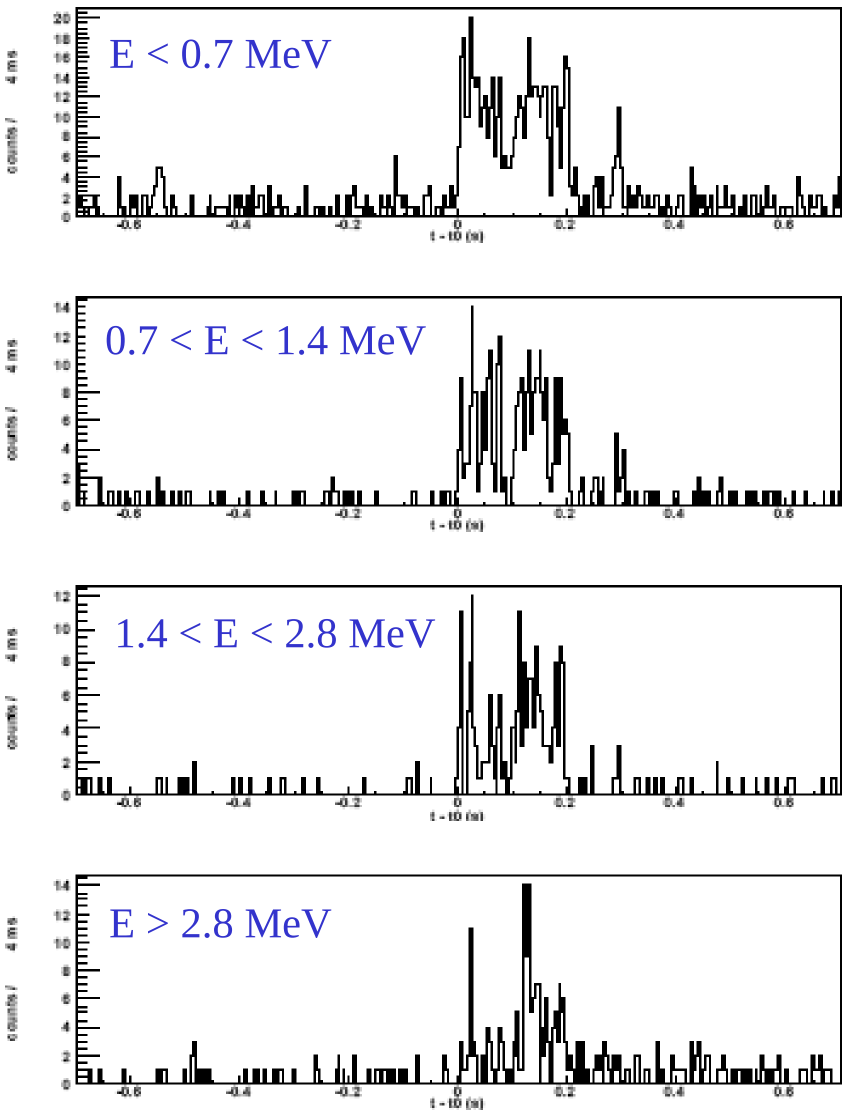
GRB 080514B (Giuliani et al., 2008, A&A) is the first gamma ray bright GRB after EGRET and it is also associated to an afterglow and a photometric redshift measure of 1.8 (A. Rossi et al., 2008, A&A).

A single model for the whole spectrum of GRB 080514B



The same Band model fits the spectrum from 20 keV up to 50 MeV.

Short GRB 090510: the prompt emission in the MeV band



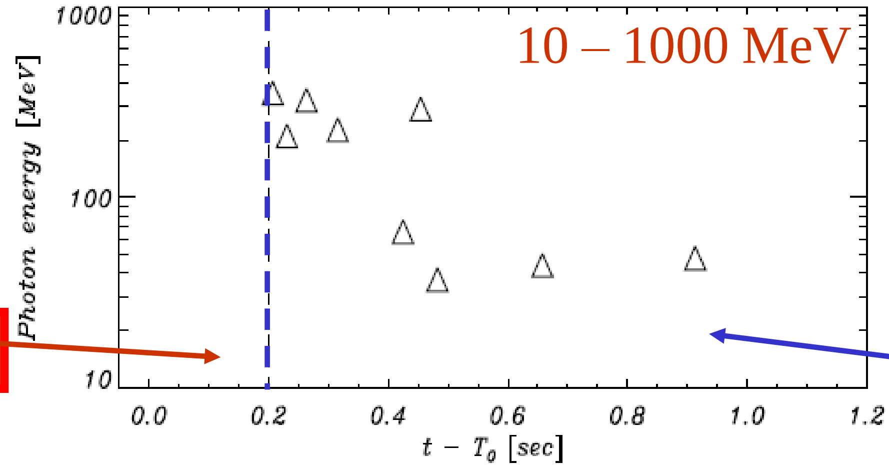
Lightcurves of the AGILE/MCAL with 4 ms bin size.

A clear spectral evolution is detected, with the second peak harder than the first one.

Giuliani et al. 2010, ApJ, 708, L84 – L88

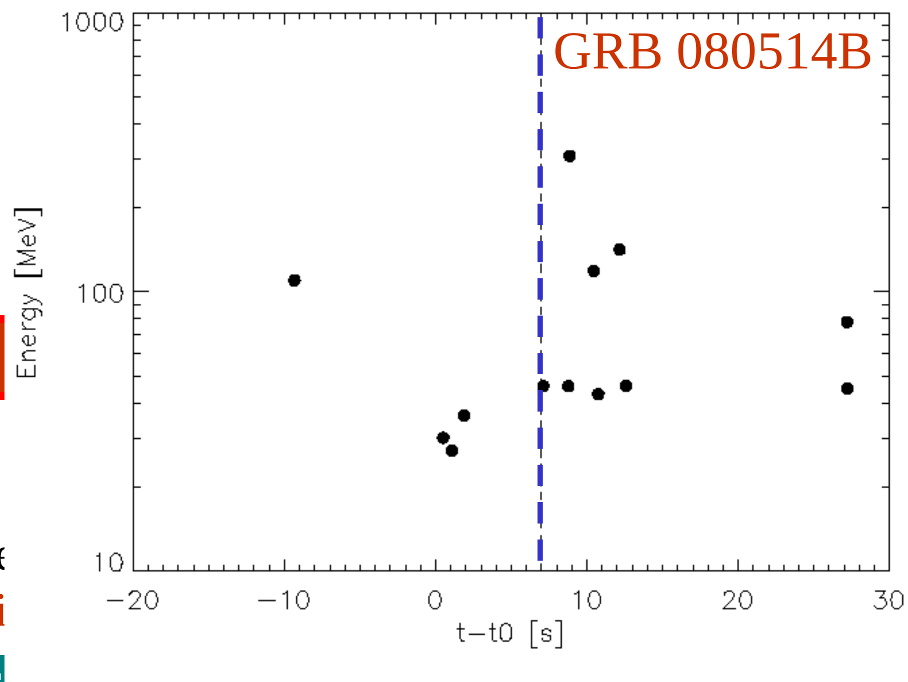
GRB 090510: the delayed emission

Giuliani et al. 2010, ApJ, 708, L84 – L88



prompt emission interval

delayed emission interval



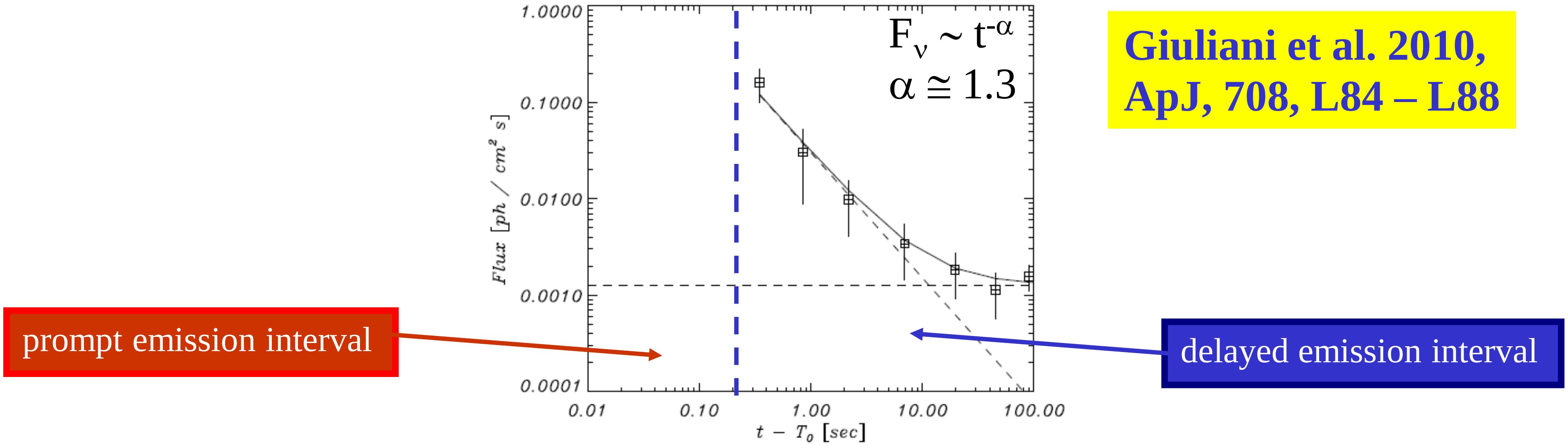
prompt emission interval

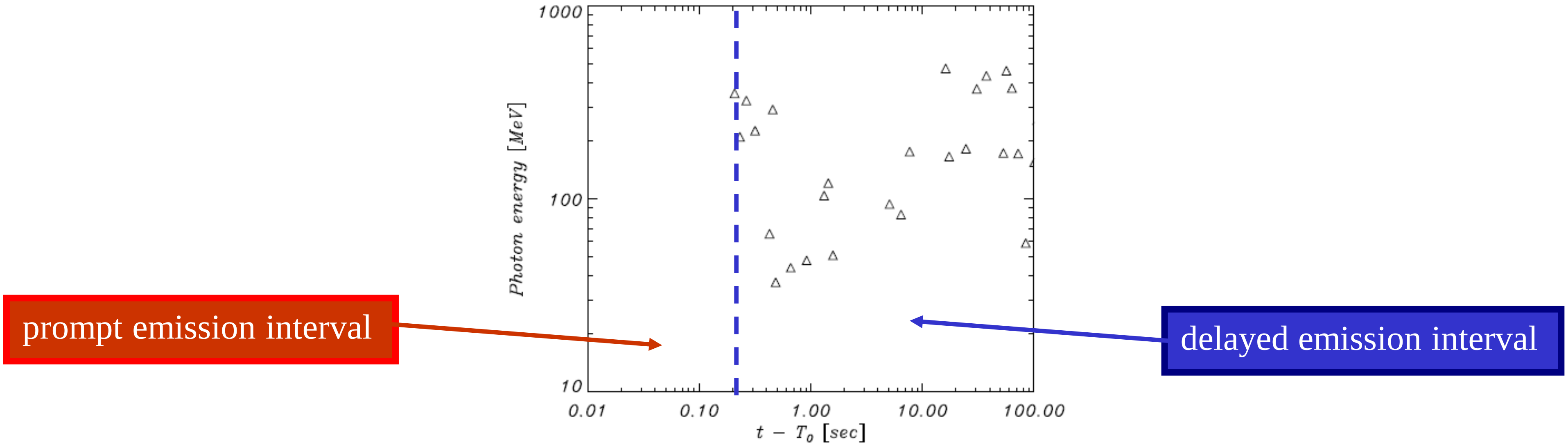
delayed emission interval

GRB 090510 has bee ermi/LAT (Ackermann et al. 2010) and AGILE (Gi squale et al. 2010).

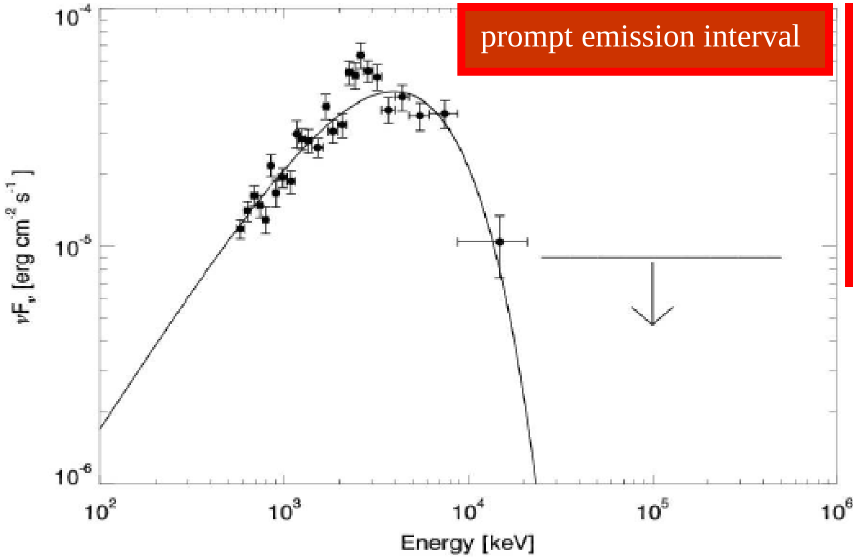
GRB 090510: the delayed emission

Giuliani et al. 2010, ApJ, 708, L84 – L88





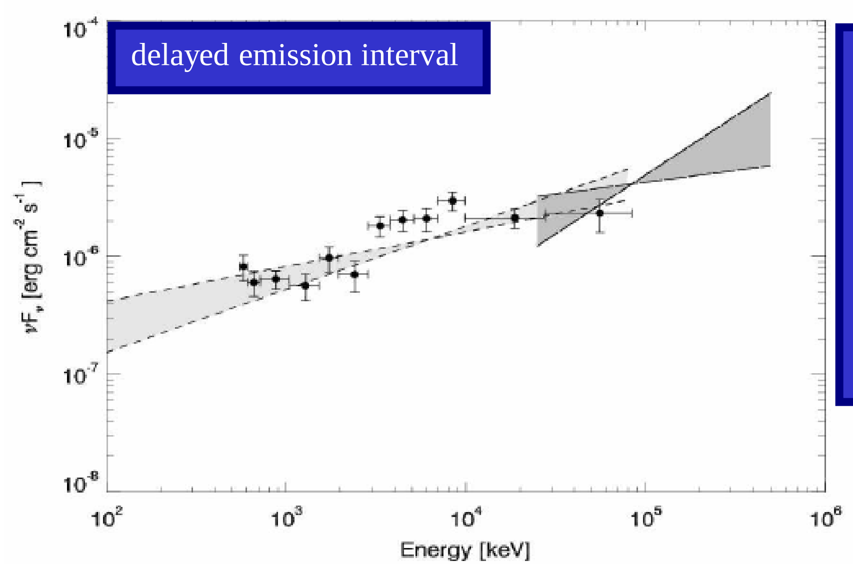
GRB 090510: spectral evolution in a short GRB



Powerlaw with cutoff

$\alpha_1 = 0.6 \pm 0.3$
Ec = 2.8 ± 0.9 MeV
1.8×10^{-5} erg/cm^2 (0.5 – 10 MeV)

Giuliani et al. 2010, ApJ, 708, L84 – L88



Powerlaw without cutoff

$\alpha_2 = 1.6 \pm 0.1$
3.1×10^{-6} erg/cm^2 (0.5 – 10 MeV)

$\alpha_3 = 1.4 \pm 0.4$
2.9×10^{-5} erg/cm^2 (25 – 500 MeV)

GRB 100724B: simultaneous onset of GeV and MeV

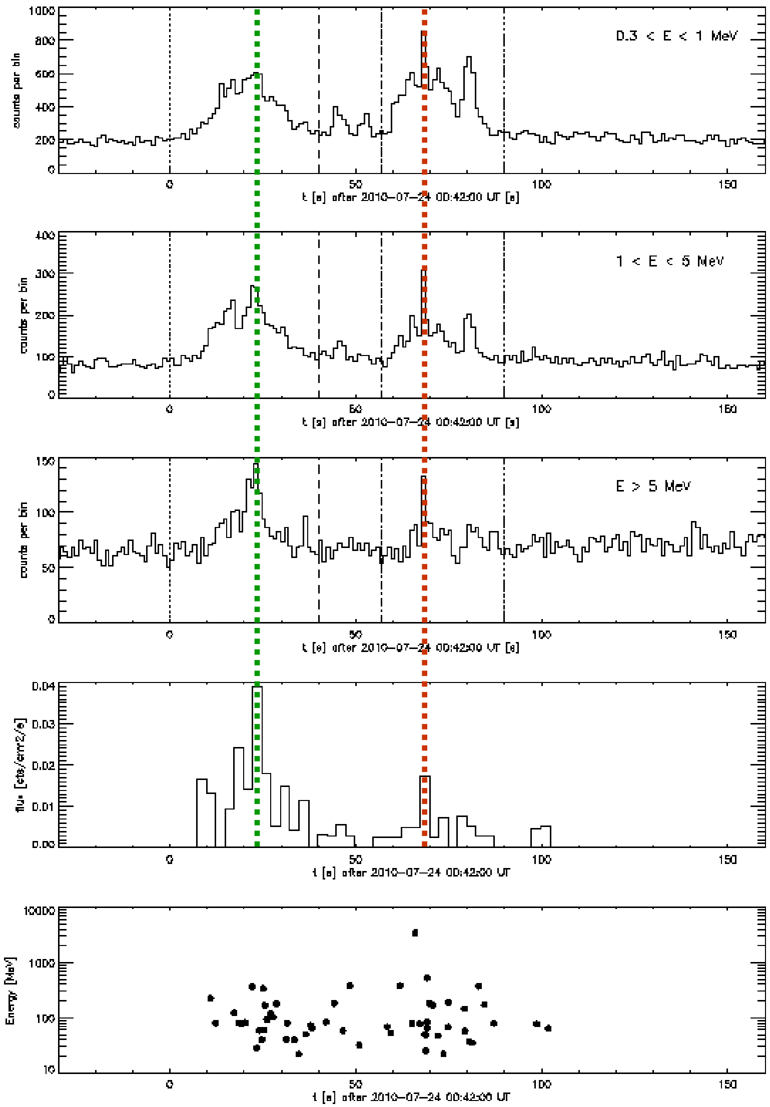
No time lag is found between the MeV and GeV emission. The two main bumps in the lightcurve show a remarkably similar shape at MeV and GeV.

Due to the spinning operative mode, GRB 100724B remained within the GRID FoV between t_0 + 6 s and t_0 + 125 s.

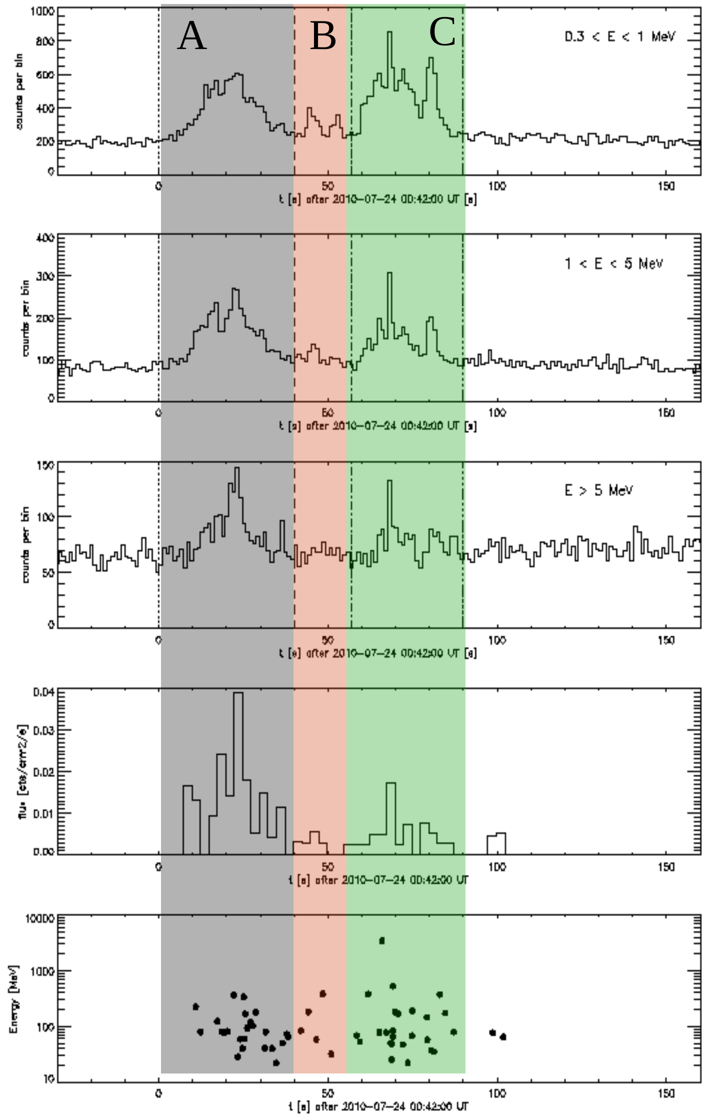
The GRB is not detected during the next “transit” in the FoV (from t_0 + 410 s until t_0 + 529 s).

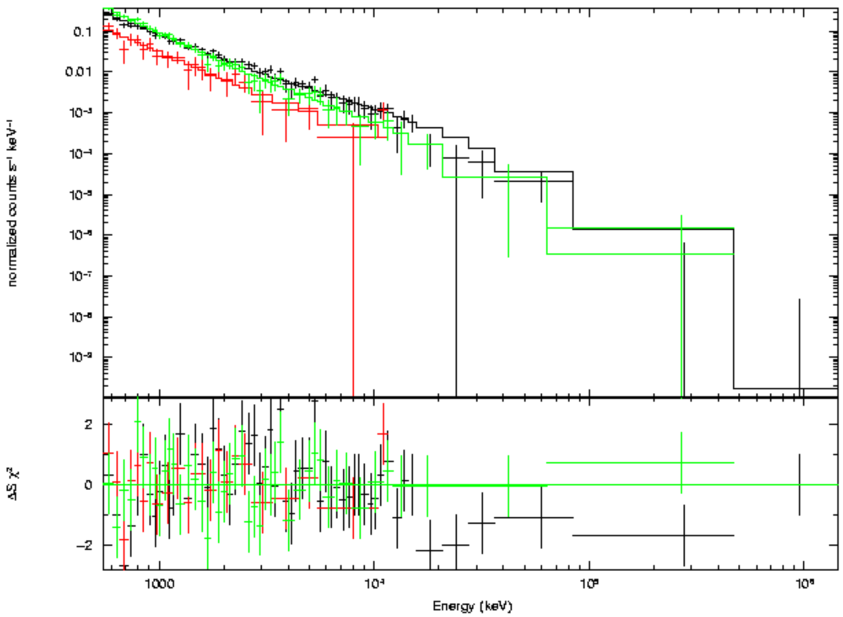
SuperAGILE was not collecting data for telemetry sharing reasons.

Del Monte et al., A&A, 535, A120 (2011)



GRB 100724B: spectral evolution





Del Monte et al., A&A, 535, A120 (2011)

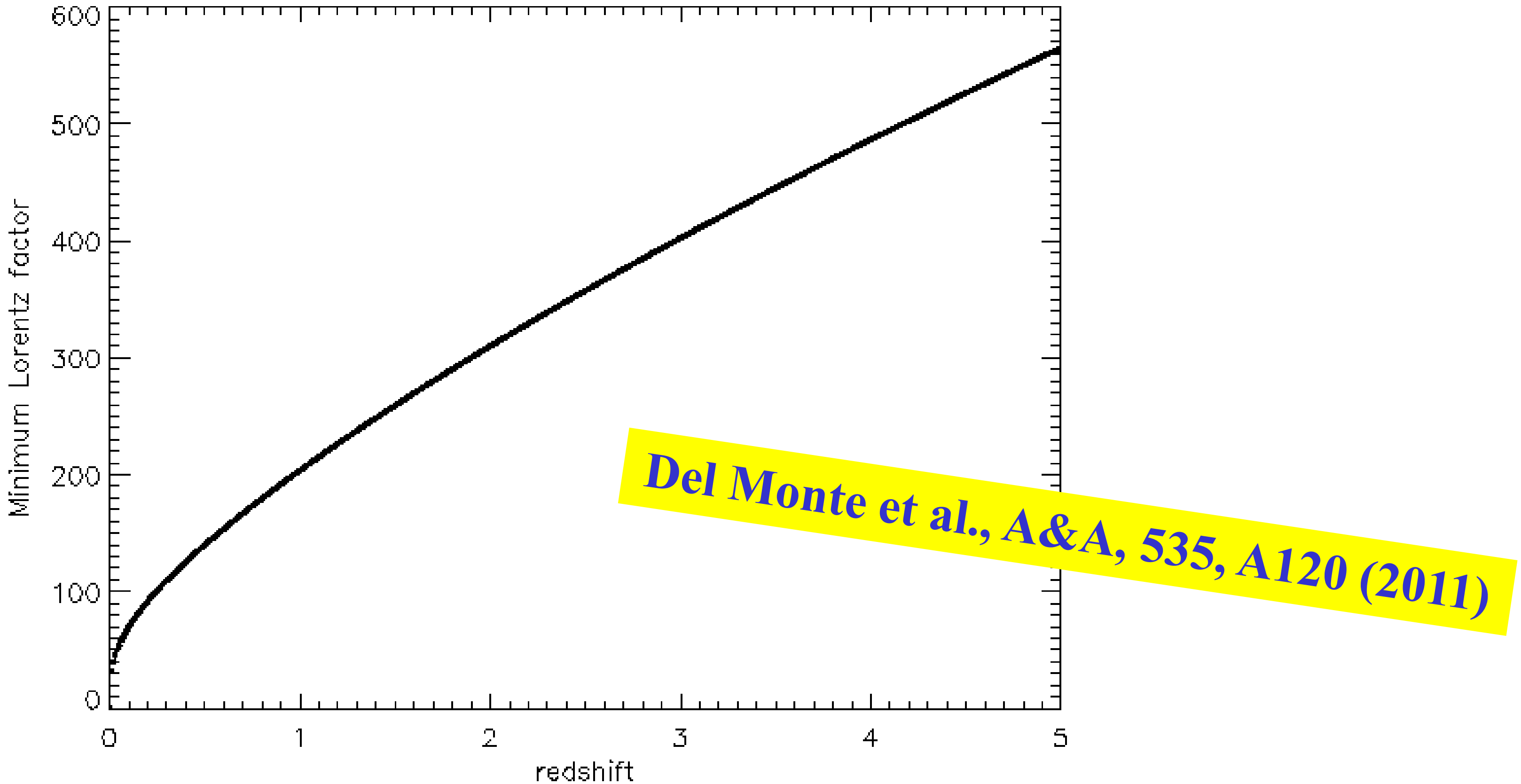
A: t_0 , t_0 + 40 s; photon index=2.01 ± 0.04

B: t_0 + 40 s , t_0 + 57 s; photon index=2.19 (+0.26,-0.19)

C: t_0 + 57 s , t_0 + 90 s; photon index=2.35 (+0.08,-0.07)

A variation at 4.2σ is found in the spectral indices.

GRB 100724B: minimum bulk Lorentz factor

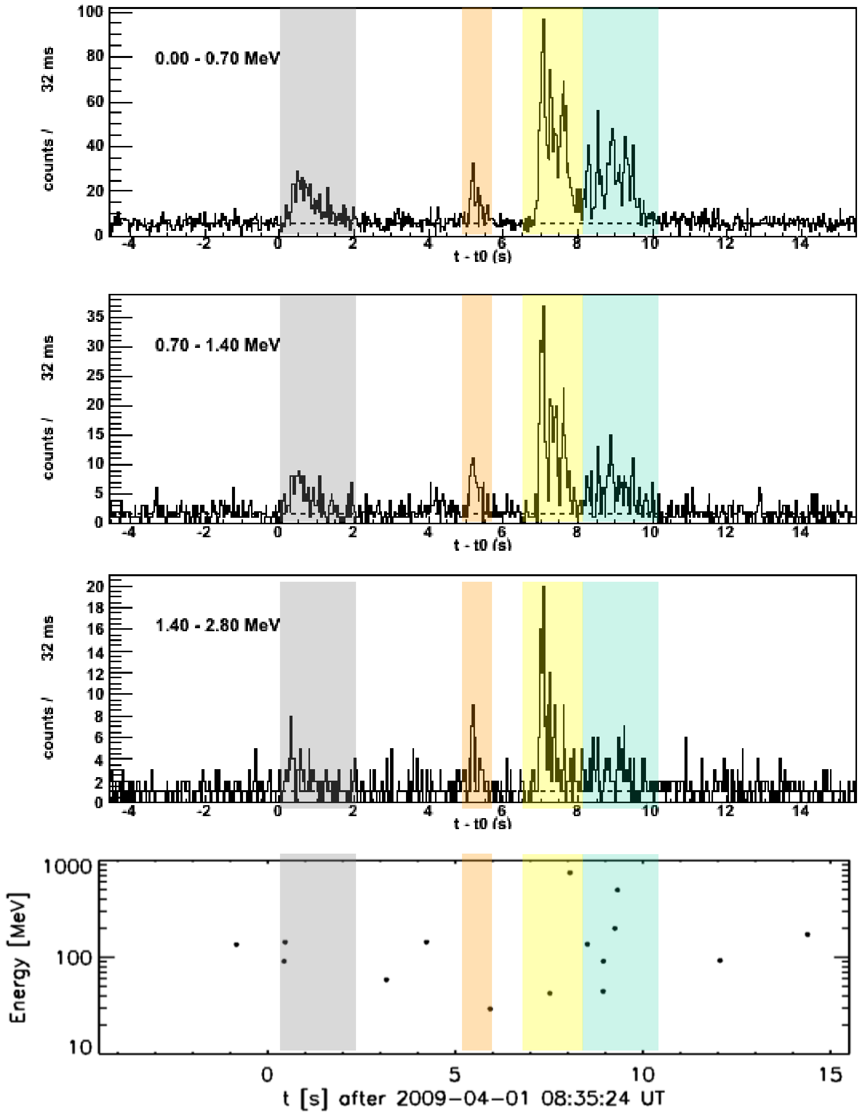


Following the method reported in the Supporting Online Material of the paper about GRB 080916C (Abdo et al 2009, Science, 323, 1688), $\Gamma_{min} = \Gamma_{min}(z, \Delta t, E_{max}, \beta)$.

The estimated Lorentz factor is similar to other GeV-bright GRBs (e. g. GRB 080916C, GRB 090902B and GRB 090510).

GRB 090401B: prompt emission

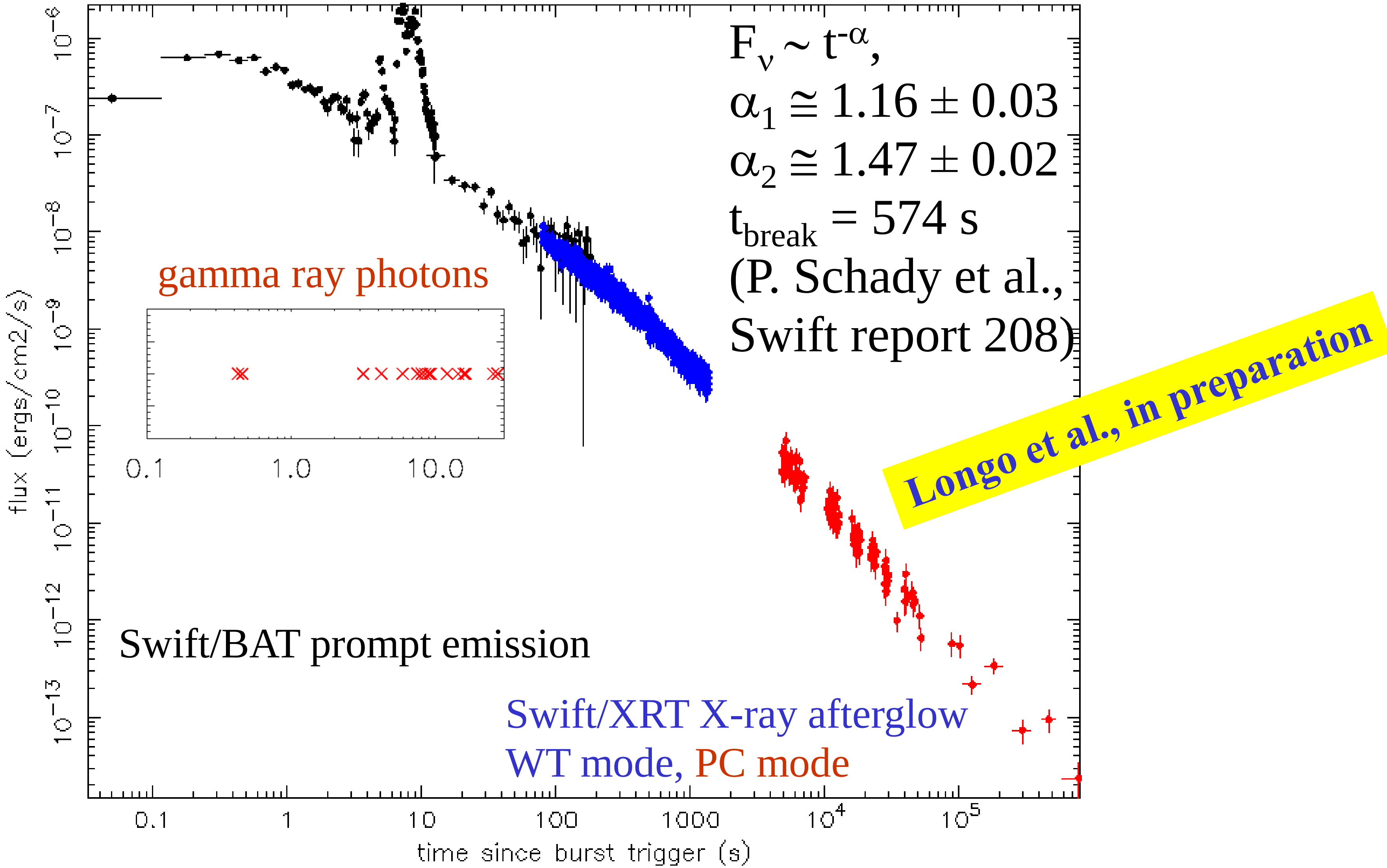
Longo et al., in preparation



68 % of the gamma ray photons are emitted during prompt;

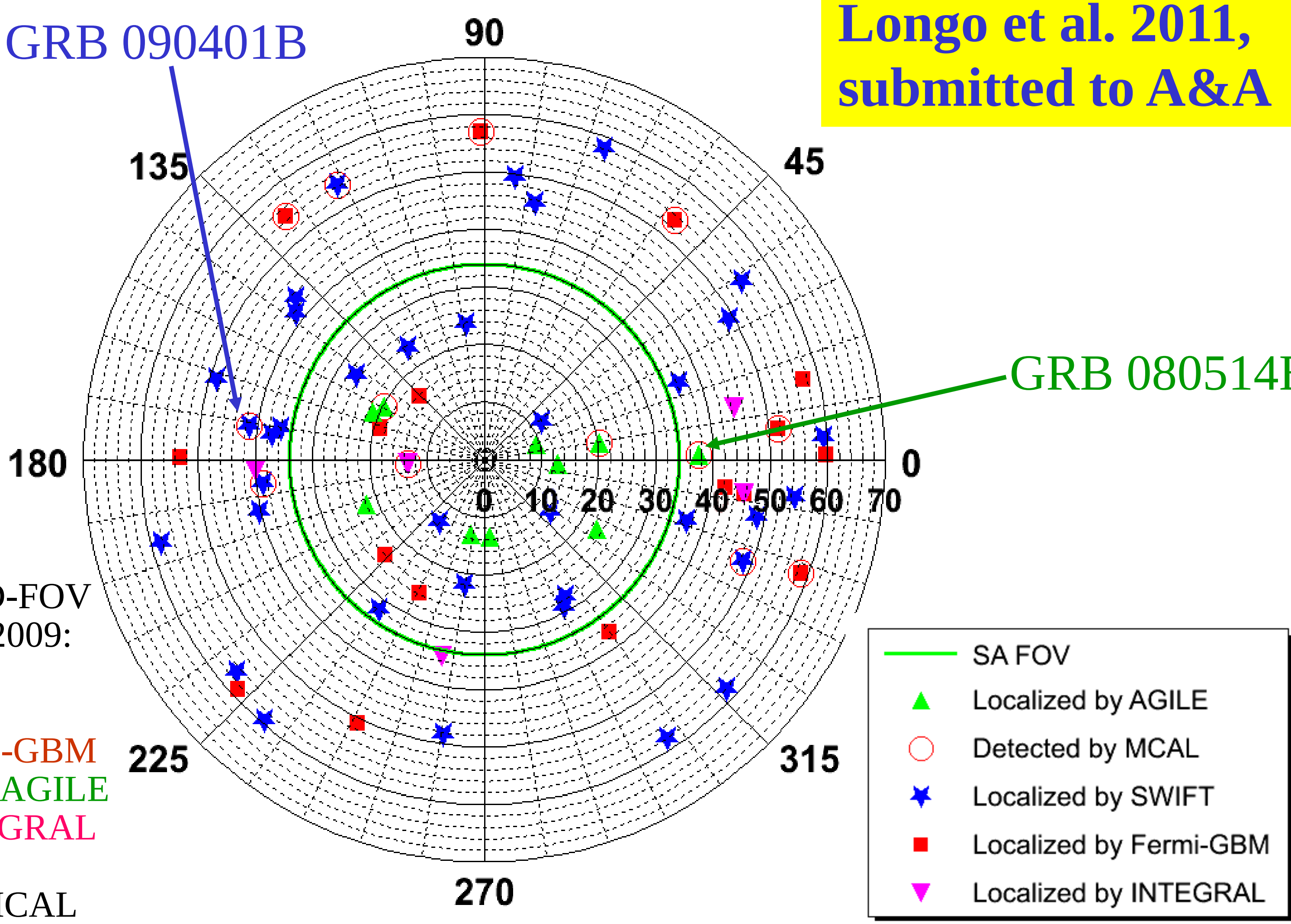
32 % of the gamma ray photons are in the extended emission

GRB 090401B: the importance of the afterglow



Upper limits in gamma rays: the sample

Longo et al. 2011, submitted to A&A



68 GRBs in the GRID-FOV
July 2007 – October 2009:

36 localized by Swift
17 localized by Fermi-GBM
10 localized by SuperAGILE
5 localized by INTEGRAL

13 also detected by MCAL

Upper limits in gamma-rays: results and expected flux

~10^{-7} erg/cm^2/s

Band function model

GRB	UL ($\times10^{-3}$) cts/(s cm^2)	Expected ($\times10^{-3}$) cts/(s cm^2)
071010B	1.06	$0.03^{+0.06}_{-0.03}$
080721	7.86	$2.81^{+3.33}_{-2.25}$
080723B	0.95	$0.66^{+0.97}_{-0.58}$
090222	5.65	$0.04^{+1.38}_{-0.04}$
090618	1.12	$0.32^{+0.33}_{-0.16}$
090620	2.00	$0.24^{+0.11}_{-0.13}$
090709	0.75	$0.18^{+0.87}_{-0.10}$
090904B	0.53	$0.62^{+0.46}_{-0.51}$
091010	2.51	$0.04^{+0.2}_{-0.01}$
070724B	0.78	$0.11^{+0.8}_{-0.06}$
070824	21.84	$1.28^{+5.4}_{-0.46}$
080413A	1.08	$0.08^{+0.18}_{-0.06}$
080413B	2.11	$0.04^{+0.32}_{-0.02}$
080613B	0.75	$0.64^{+0.21}_{-0.55}$
080714	3.37	$0.07^{+0.27}_{-0.03}$
080916A	2.92	$0.01^{+0.23}_{-0.01}$
081001	5.38	$0.45^{+2.11}_{-0.19}$
081130B	3.33	$0.09^{+0.32}_{-0.05}$
081203A	1.40	$0.10^{+3.75}_{-0.002}$
081224	2.92	$1.44^{+3.48}_{-0.49}$
090319	0.52	$0.02^{+0.25}_{-0.006}$
090326	3.75	$0.02^{+0.16}_{-0.01}$
090410	0.80	$0.06^{+0.33}_{-0.03}$
090418B	0.75	$0.12^{+0.11}_{-0.06}$
090516	1.61	$0.04^{+0.19}_{-0.03}$
090516B	0.87	$0.13^{+0.58}_{-0.05}$
090715B	0.10	$0.04^{+0.04}_{-0.04}$

Longo et al., submitted

Exponential cutoff + BATSE average Band function model ($-2.58 < \beta < -2.19$).

Expected flux derived from the available spectral info and compared with upper limits.

Sample of 68 GRBs in the AGILE/GRID field of view (between 2007 and 2009) localized by Swift, Fermi/GBM, SuperAGILE and INTEGRAL.

No gamma ray afterglow is detected 3600 s after trigger.

Upper limits in gamma-rays: the results

The upper limits are estimated with a Bayesian approach for a sample of 68 undetected GRBs from July 2007 until October 2009 with position inside the GRID Field of View;

40 GRBs have spectral information (from Konus-Wind, Suzaku/WAM and Fermi/GBM), that is used to convert counts into flux;

In six cases the upper limit is stringent with respect to the extrapolation of the GRB spectrum at lower energy;

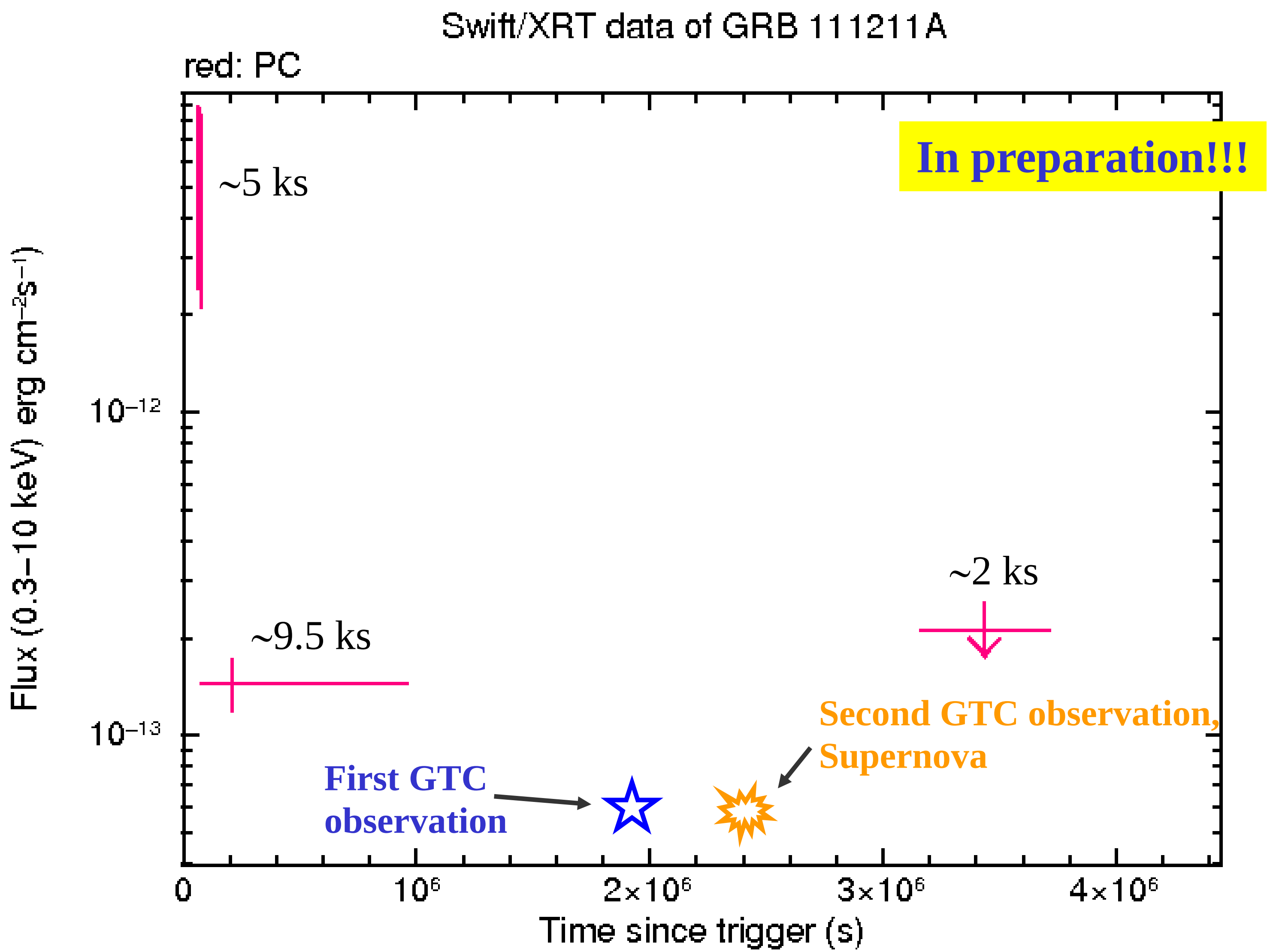
The corresponding 3 sigma upper limit is ~0.03 ph cm^{-2} s^{-1} => ~10^{-7} erg cm^{-2} s^{-1};

A likelyhood search of gamma-ray delayed components (up to 3600 s after trigger) for the same events does not give positive results;

The AGILE/GRID upper limits are consistent with the MAGIC upper limits at TeV;

The detection rate of GRBs by AGILE/GRID is discussed and it is found that AGILE observes on average the same population as EGRET;

The X-ray afterglow of GRB 111211A



Prompt or afterglow emission?

In favour of the prompt (internal shock) interpretation:

- the same Band spectrum, and simultaneity (e. g. GRB 100724B) suggest that a single mechanism is at work (Maxham et al. 2011);
- the correlated variability at MeV and GeV (e. g. GRB 080916C, Abdo et al., Science, 2009) is an indication of simultaneous emission in the same region.

In favour of the afterglow (external shock) interpretation:

- delayed onset, longer duration and powerlaw time decay are typical of the external shock (Ghisellini et al. 2010);
- Kumar & Barniol-Duran 2010 find that the external forward shock parameters from the gamma-ray spectrum and lightcurve are compatible with them from late-time optical and X-ray data;
- additional powerlaw components (e. g. GRB 090902B), may be explained with synchrotron emission from external shock (Zhang et al. 2011).

Preliminary summary from the AGILE GRBs

Only a small subsample of GRBs emits in gamma rays: the overall detection rate (AGILE + Fermi) is ~10 events per year (consistent with the expectations of Band et al. 2009);

GeV emitting are the brightest GRBs (> 10^{-5} erg/cm^2 at keV – MeV, Ghisellini et al. 2010) and have a high minimum Lorentz factor (600 – 1000);

Both long (e. g. GRB 080514B, GRB 0904041B, GRB 100724B) and short events (e. g. GRB 090510) are detected in the gamma energy band;

Some events have a single spectrum (e. g. GRB 080514B, Giuliani et al. 2009; GRB 100724B) other have additional spectral components (e. g. GRB 090510, Giuliani et al. 2010, Ackermann et al. 2010; GRB 090902B <50 keV and >100 MeV, Abdo et al. 2009);

Up to now no signature seems to be found in the X-ray and optical afterglow of the GeV emitting GRBs but see also Swenson et al. 2010. In particular, no gamma rays are detected by AGILE simultaneously with flares in the afterglow, while a flare from GRB 100728A has been detected by Fermi/LAT (Abdo et al., arXiv:1104.5496);

Gamma-ray emitting GRBs seems to be in the "high tail" of the population and characterised by high luminosity and high Lorentz factor. It is still debated if gamma-rays are produced in internal (prompt) or external (afterglow) shocks.