# Observation of Gamma Ray Bursts with AGILE

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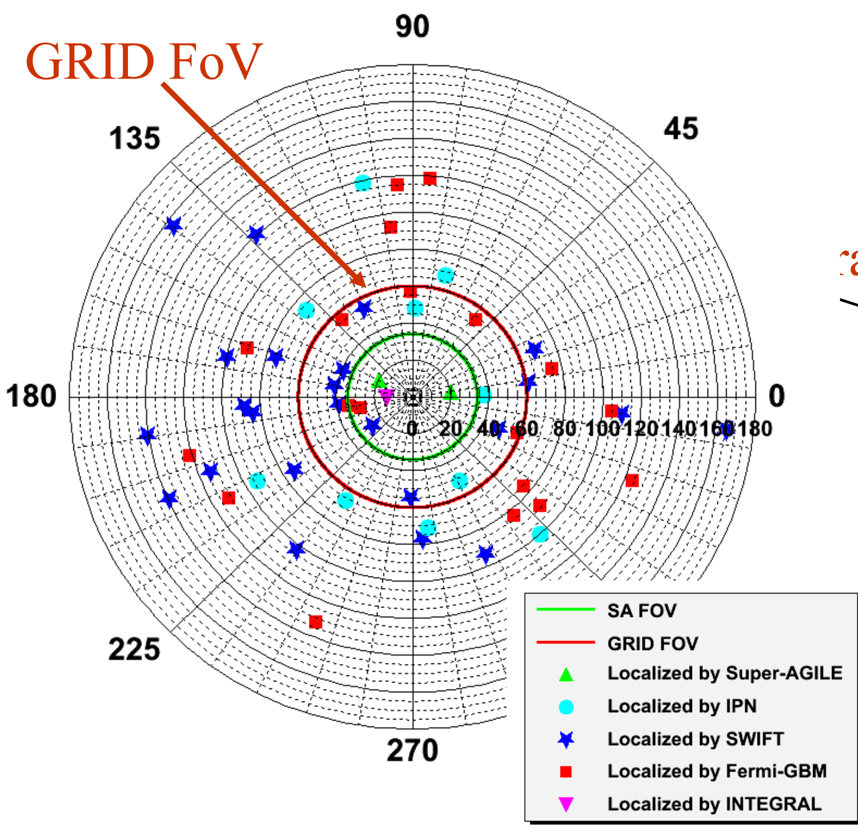
*on behalf of the AGILE team*

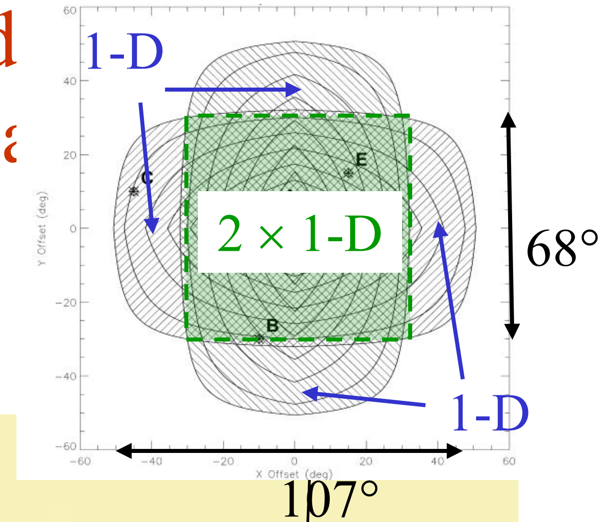
# Two co-aligned imagers and quasi all-sky sensitive scintilla

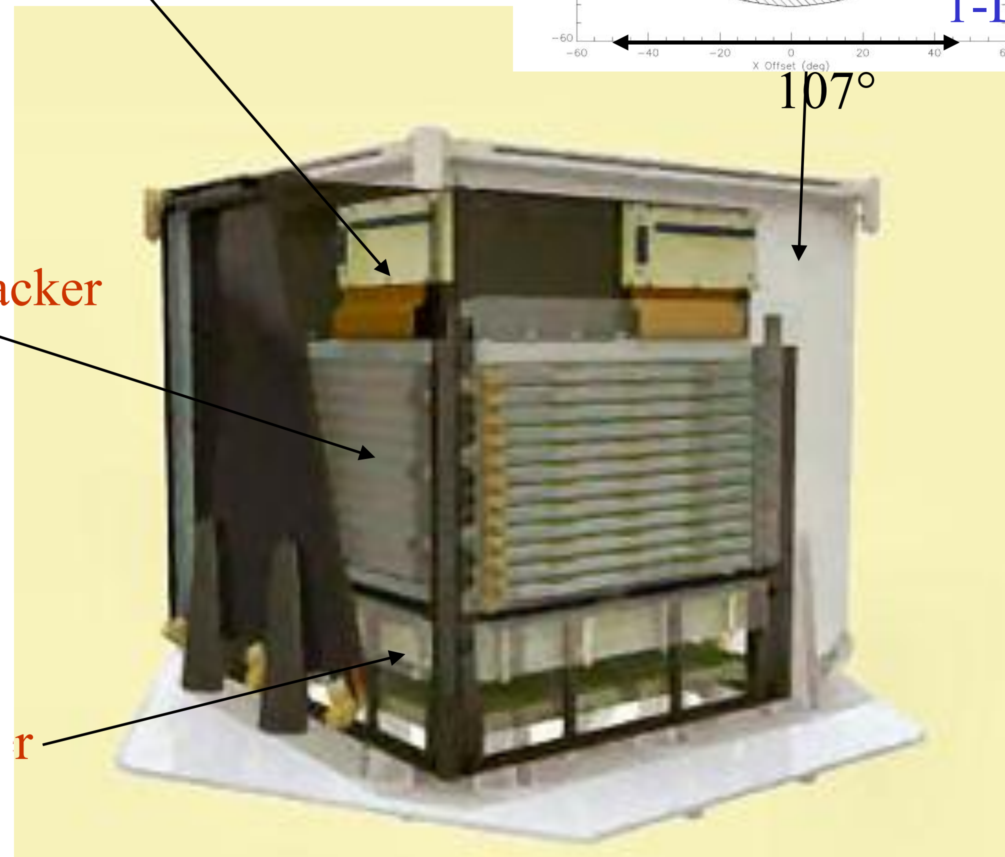
The AGILE payload is composed of two imaging instruments:

GRID FoV




SuperAGILE



racker

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# The census of the GRBs observed by AGILE: pointing mode (July 2007 – October 2009)

## Hard X-rays:

- 29 GRBs localized by SuperAGILE (18 in 2×1-D and 11 in 1-D) => ~1 GRBs/month;
- 3 arcmin radius uncertainty on the localization and minimum detected fluence of $\sim 5\times10^{-7}$ erg cm$^{-2}$
- ~1 GRB/week detected by MCAL and 1 – 2 GRBs/month detected by SuperAGILE outside the FoV;

## Gamma rays:

- Three firm detections: GRB 080514B, GRB 090401B and GRB 090510;
- Two less significant detections: GRB 080721 and GRB 081001;

# What changes in spinning mode (since November 2009)?

## Hard X-rays:

- a strong background modulation is introduced in SuperAGILE by the spinning mode;
- an FFT-based algorithm is introduced in our trigger to reduce the modulation;
- we expect a decrease in the SuperAGILE localization rate down to ~0.3 – 0.5 GRBs/month;
- the MCAL capabilities are marginally affected by the spinning due to the modulation introduced by the Anticoincidence shielding thus no significant variation is expected;

## Gamma rays:

- more Sky is sensed by in gamma rays but the GRBs “transit” in the field of view.

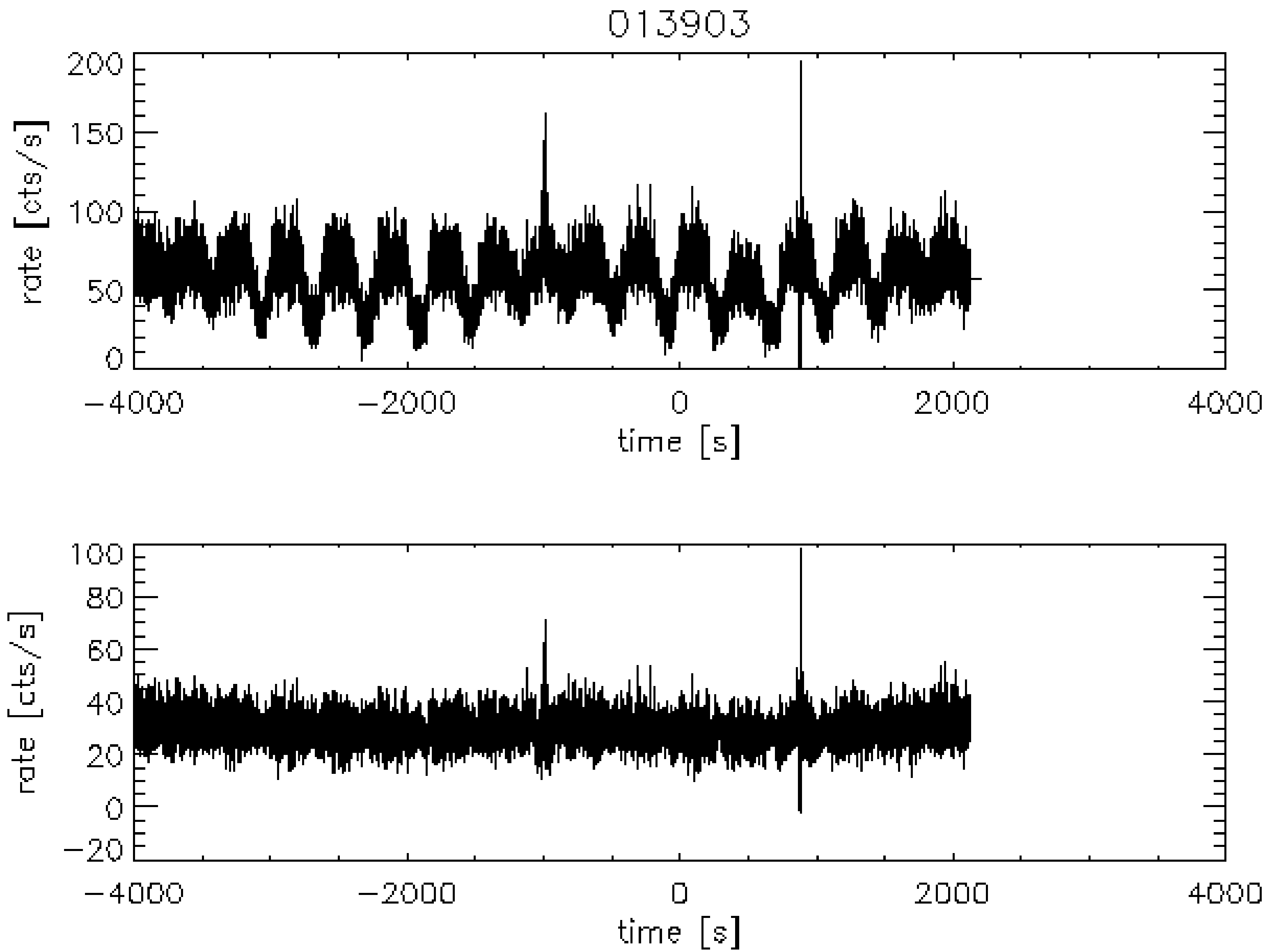
# A correction algorithm for SuperAGILE based on the FFT

- the background modulation due to the spinning is subtracted from the lightcurve:

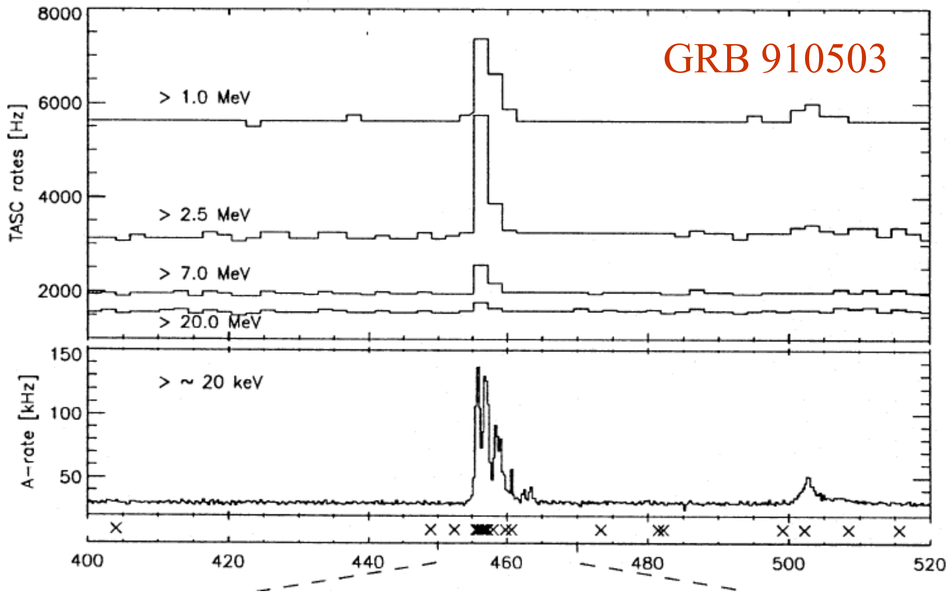
1. the FFT of the lightcurve is calculated;
2. the low frequencies (0.001 – 0.01 Hz) are reduced with a dedicated filter;
3. the reverse-FFT is calculated to obtain back the lightcurve (now frequency filtered);

- the filter is tuned to previous detections in order to avoid the suppression of the GRB signal in the lightcurve.

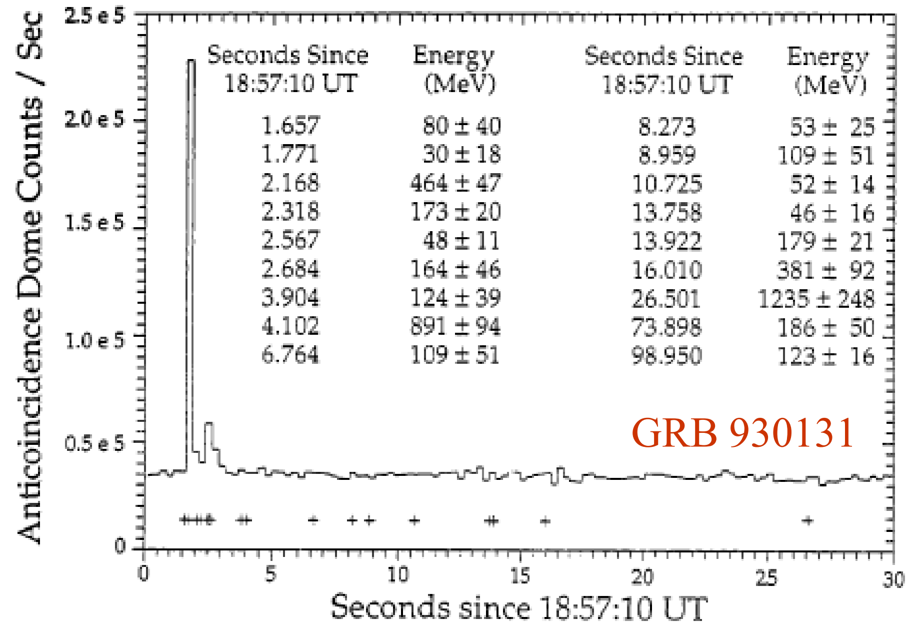
# GRB 100102A triggered outside the field of view



# The EGRET heritage




Schneid et al., 1992, A&A




| Seconds Since 18:57:10 UT | Energy (MeV) | Seconds Since 18:57:10 UT | Energy (MeV) |
|---|---|---|---|
| 1.657 | 80 ± 40 | 8.273 | 53 ± 25 |
| 1.771 | 30 ± 18 | 8.959 | 109 ± 51 |
| 2.168 | 464 ± 47 | 10.725 | 52 ± 14 |
| 2.318 | 173 ± 20 | 13.758 | 46 ± 16 |
| 2.567 | 48 ± 11 | 13.922 | 179 ± 21 |
| 2.684 | 164 ± 46 | 16.010 | 381 ± 92 |
| 3.904 | 124 ± 39 | 26.501 | 1235 ± 248 |
| 4.102 | 891 ± 94 | 73.898 | 186 ± 50 |
| 6.764 | 109 ± 51 | 98.950 | 123 ± 16 |

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.

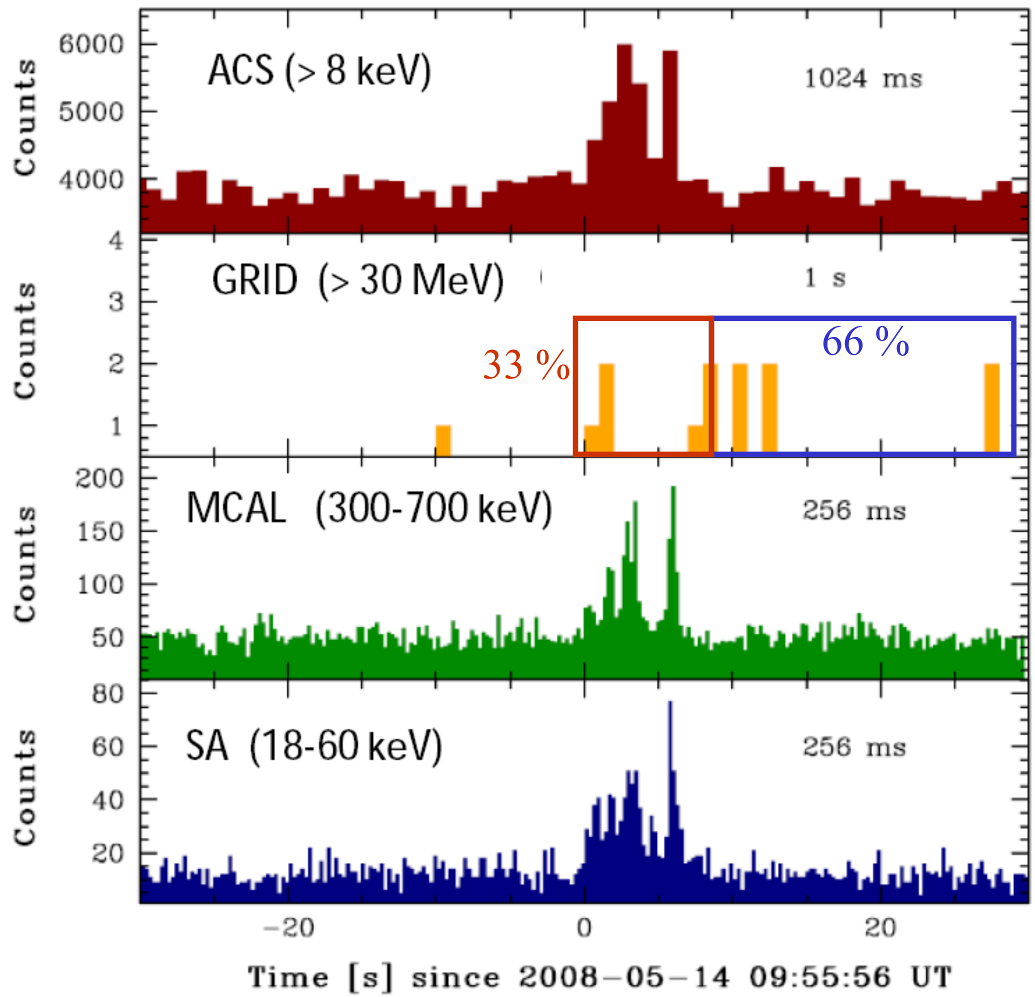
# Distinctive features of the AGILE GRBs

- GRB 080514B: long GRB, with extended emission of gamma rays and single Band spectrum (20 keV – 50 MeV);

- GRB 090510: short GRB with delayed emission and spectral evolution;

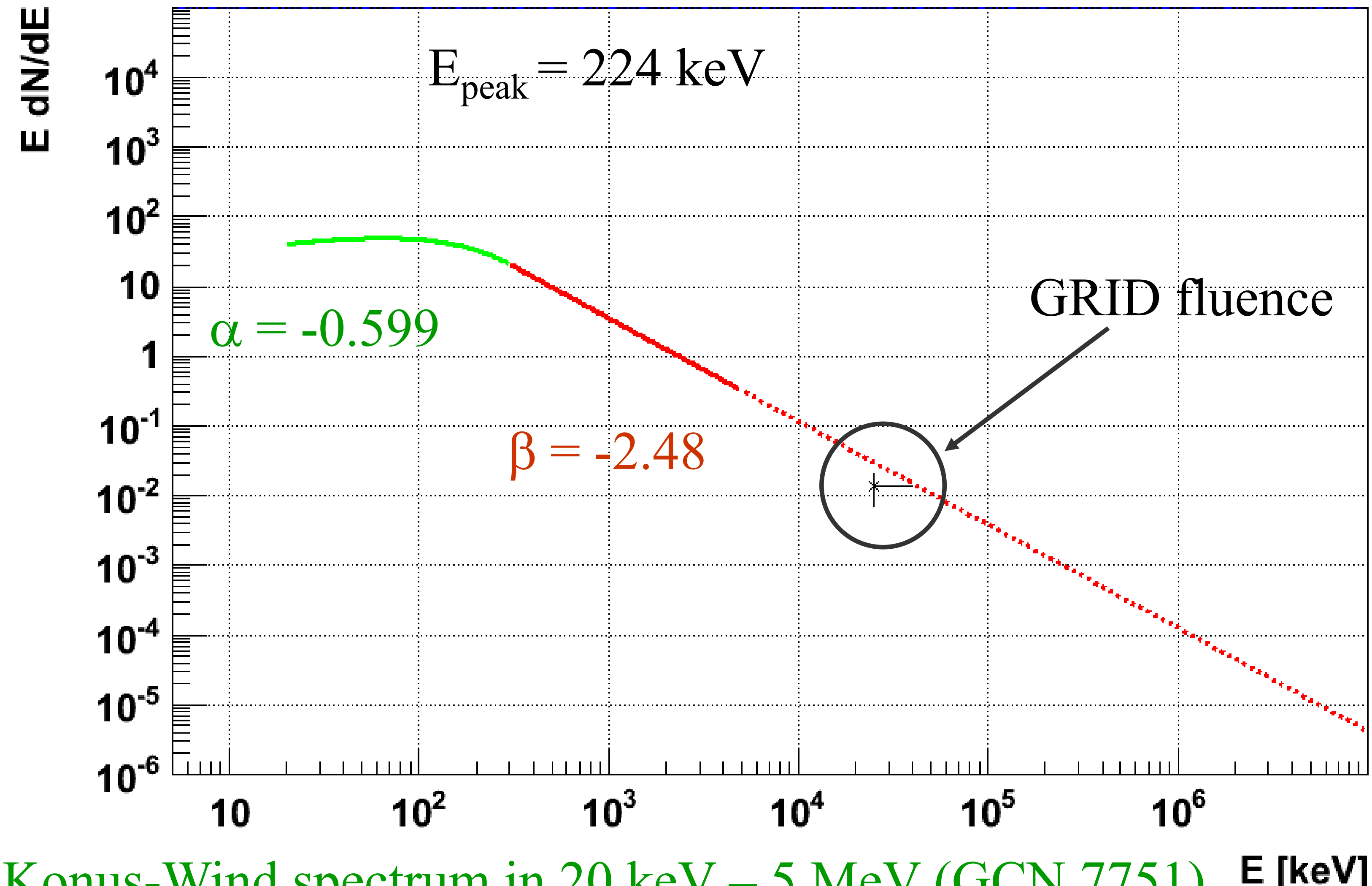
- GRB 090401B: long GRB with multiple peak structure, simultaneous and extended emission of gamma rays;

# Temporal properties of 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




Konus-Wind spectrum in 20 keV – 5 MeV (GCN 7751).

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

# Distinctive features of the AGILE GRBs

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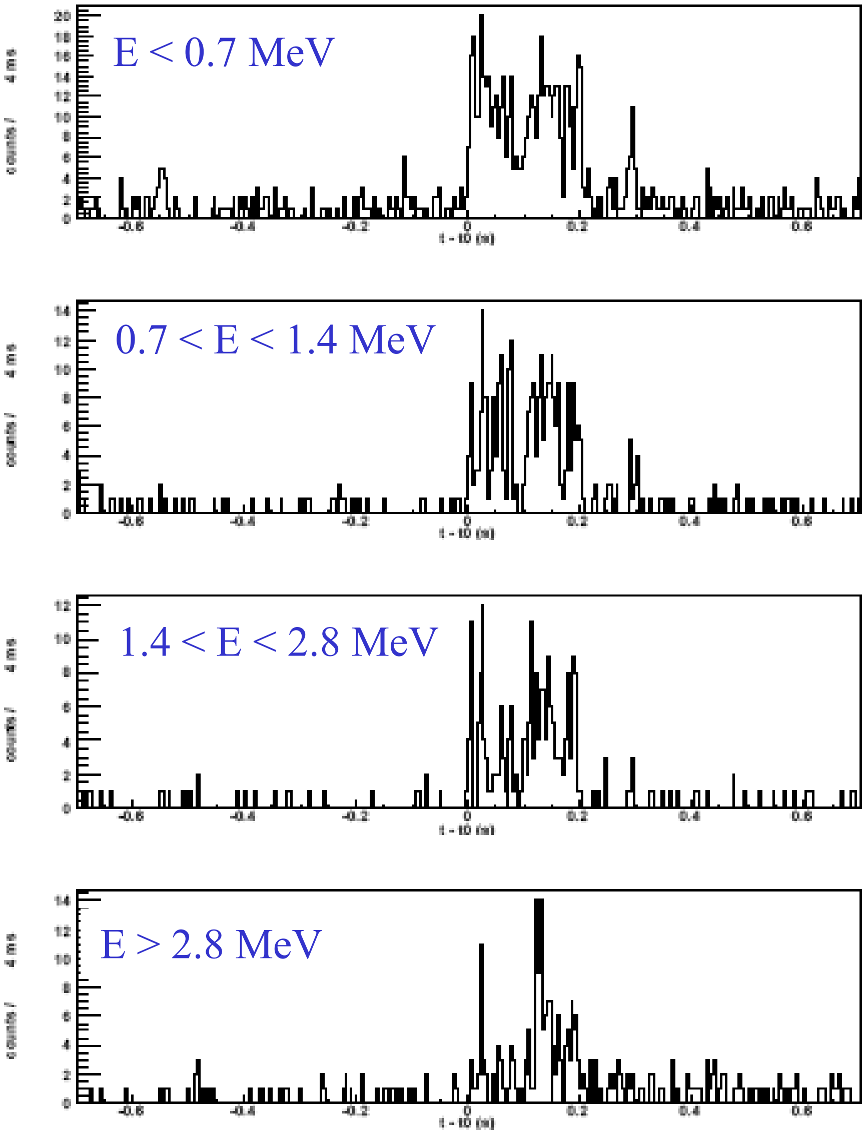
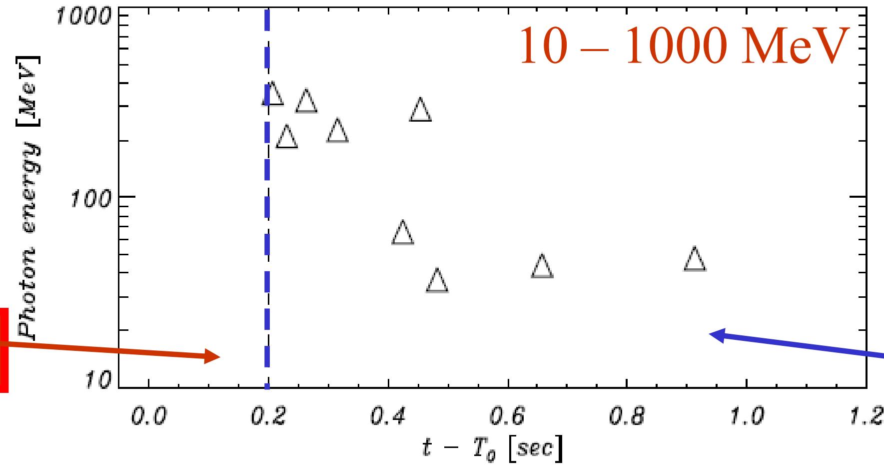
# Short GRB 090510: the prompt emission in the MeV band




Lightcurves of the MCAL with 4 ms bin size.

The second peak is harder than the first one.

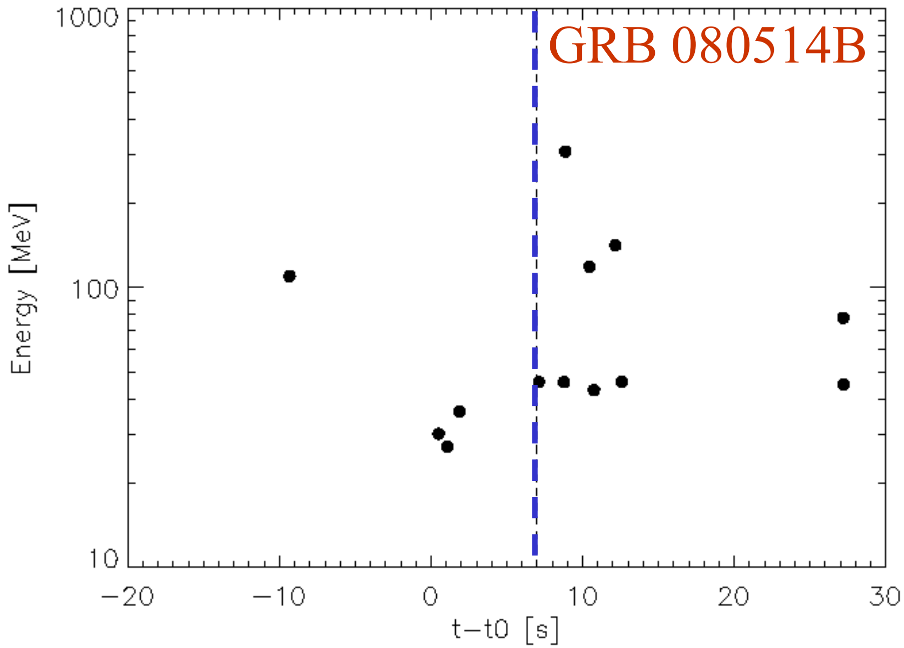
# GRB 090510: the delayed emission




Giuliani et al. 2009, ApJ, L84 – L88

prompt emission interval

delayed emission interval




prompt emission interval

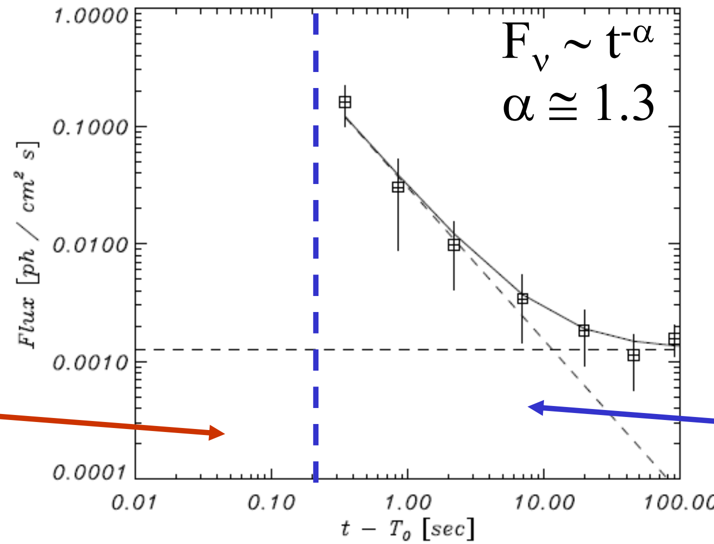
delayed emission interval

GRB 090510 has b… …tected also by Fermi/LAT (GCN 9334) and A… …GCN 9353).

# GRB 090510: the delayed emission

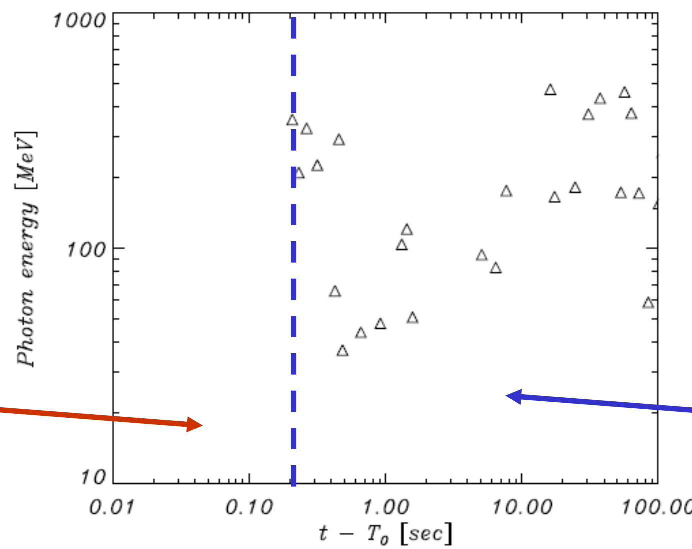
Giuliani et al. 2009, ApJ L84 – L88

prompt emission interval



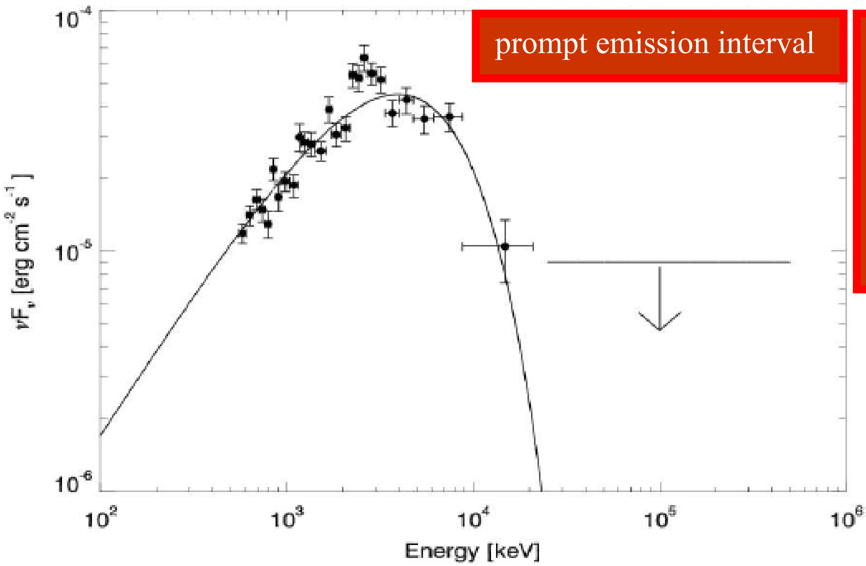

delayed emission interval

prompt emission interval



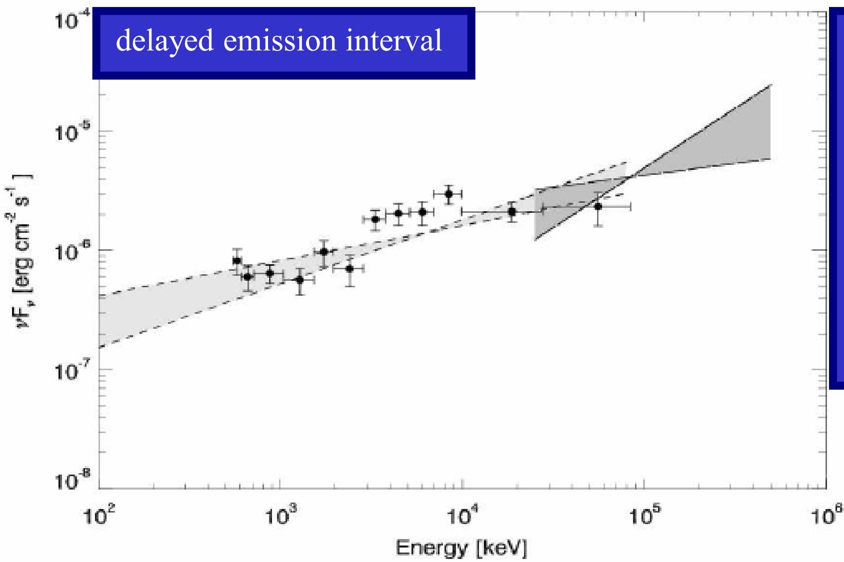

delayed emission interval

# GRB 090510: spectral evolution in a short GRB




**Powerlaw with cutoff**

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




**Powerlaw without cutoff**

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

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

# Distinctive features of the AGILE GRBs

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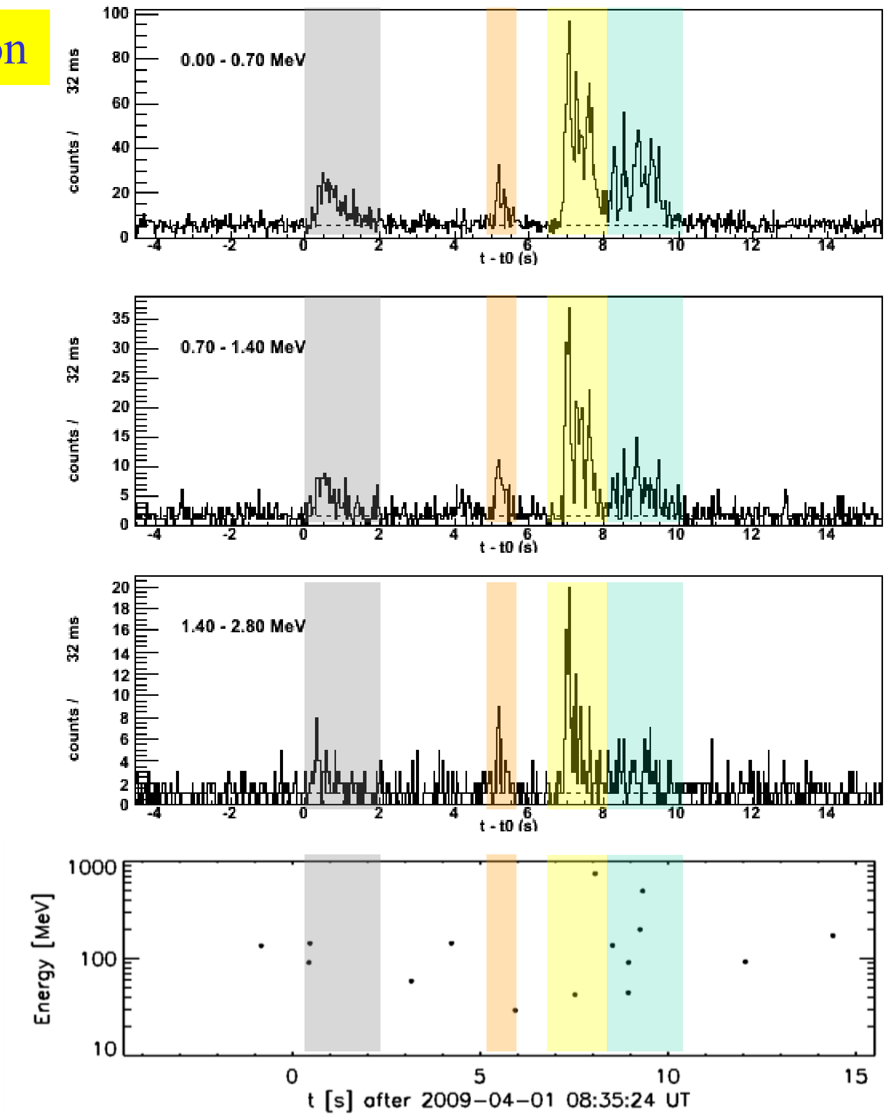
- GRB 090510: short GRB with delayed emission and spectral evolution;

- GRB 090401B: long GRB with multiple peak structure, simultaneous and extended emission of gamma rays;

# GRB 090401B: prompt emission at MeV energy

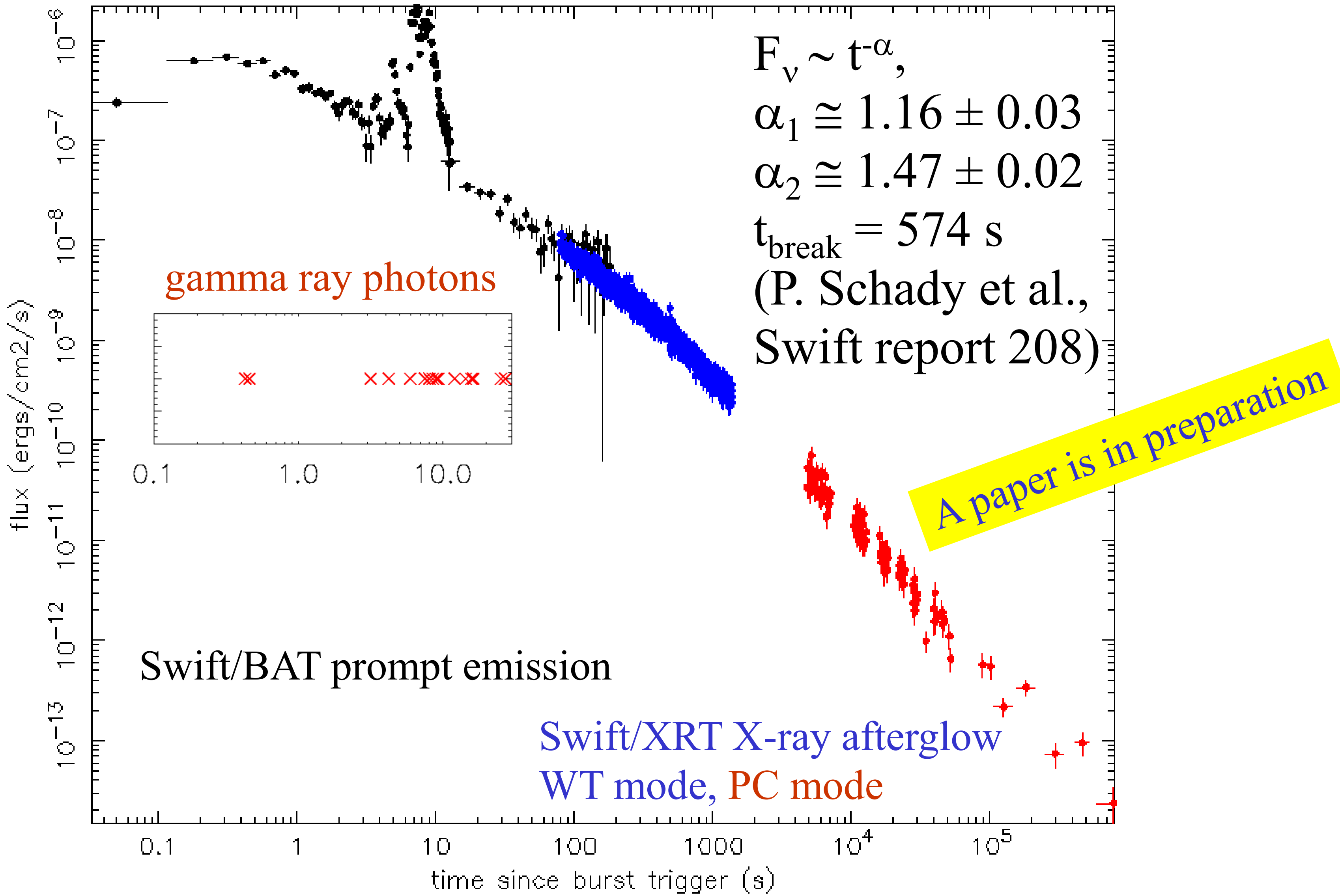
A paper is in preparation



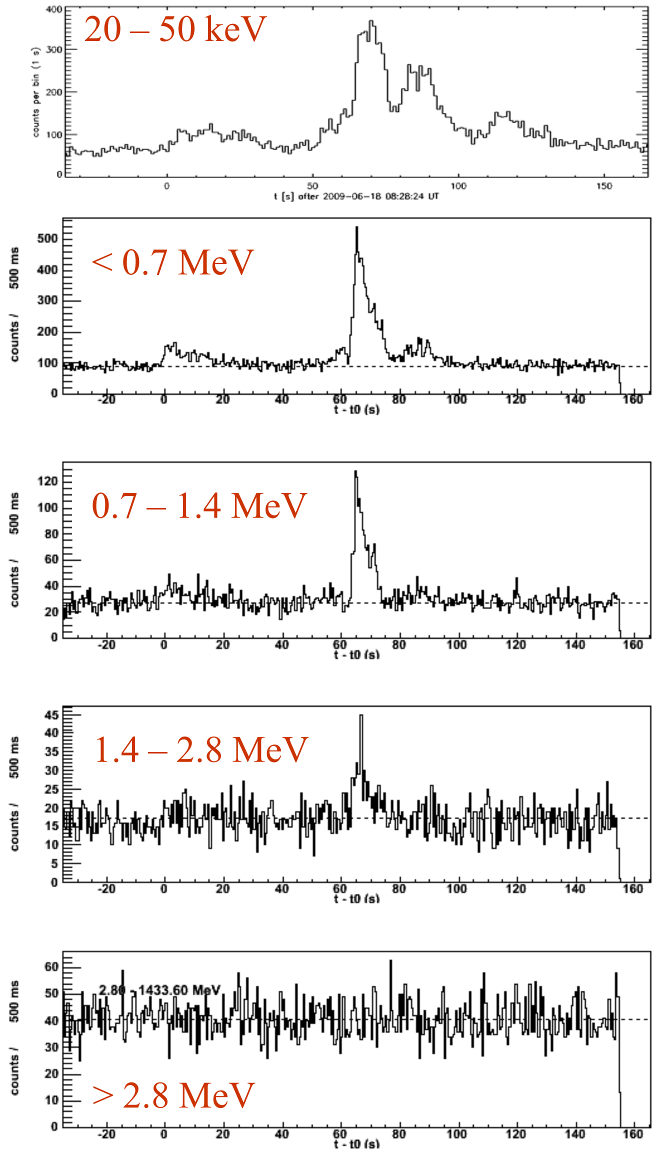

68 % of the gamma ray photons are emitted during prompt;

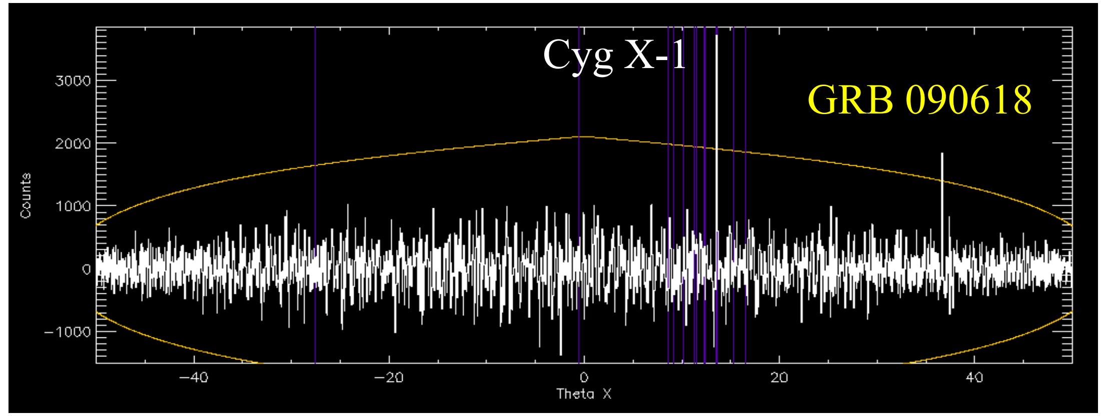
32 % of the gamma ray photons are in the extended emission

# GRB 090401B: afterglow emission



# The interesting case of GRB 090618



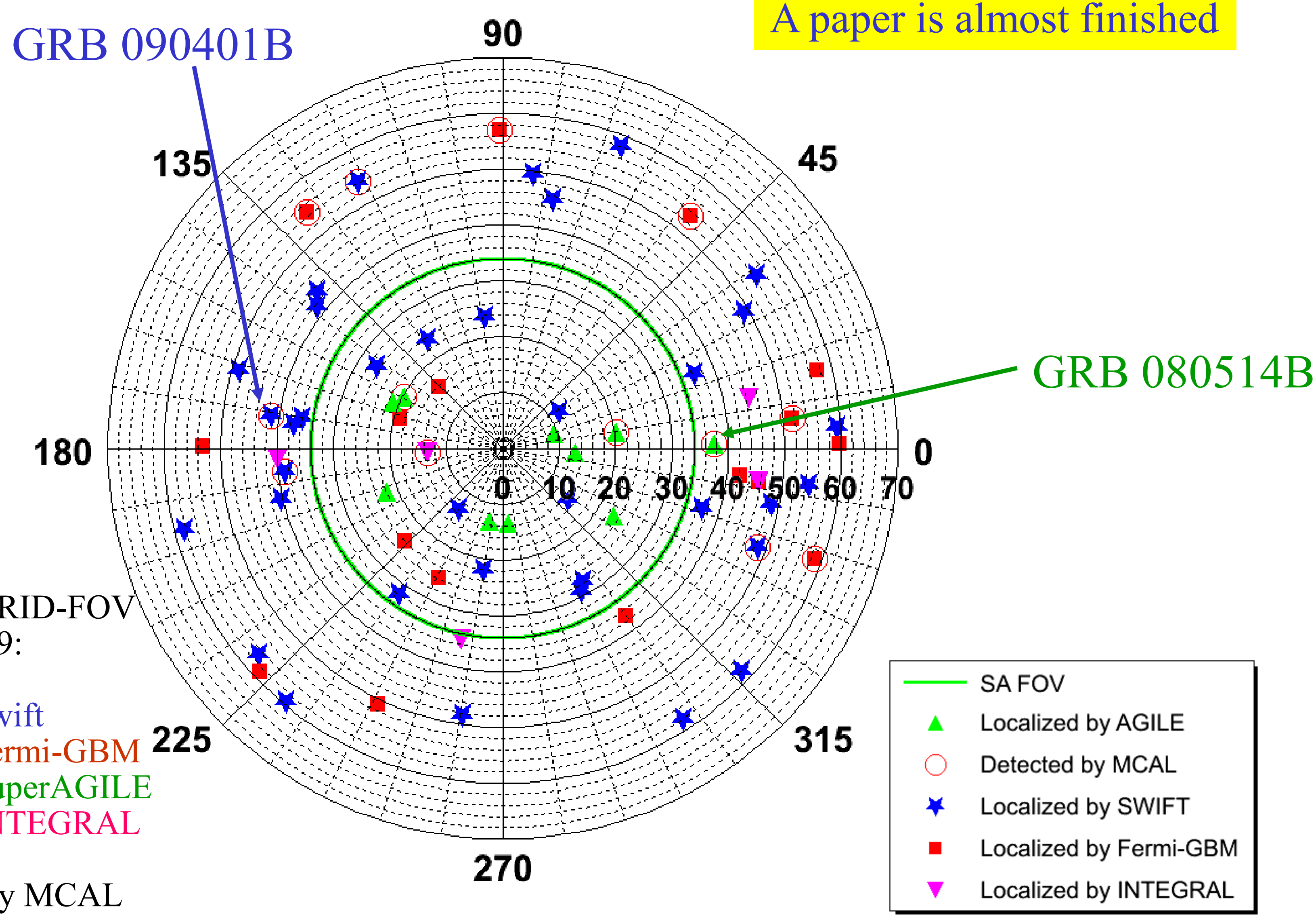




GRB 090618 compared with Cyg X-1 in the orbital image of SuperAGILE (20 – 50 keV, 3 ks exposure).

Despite the remarkable value of $E_{peak}$ = 186 keV (GCN 9553) and a rescaled peak flux of $8.3 \times 10^{-6}$ erg/cm$^2$/s (in 50 – 300 keV), this GRB is not detected in the gamma ray band. Notice that z=0.54

# Upper limits in gamma rays: the sample

A paper is almost finished




68 GRBs in the GRID-FOV until 17 April 2009:

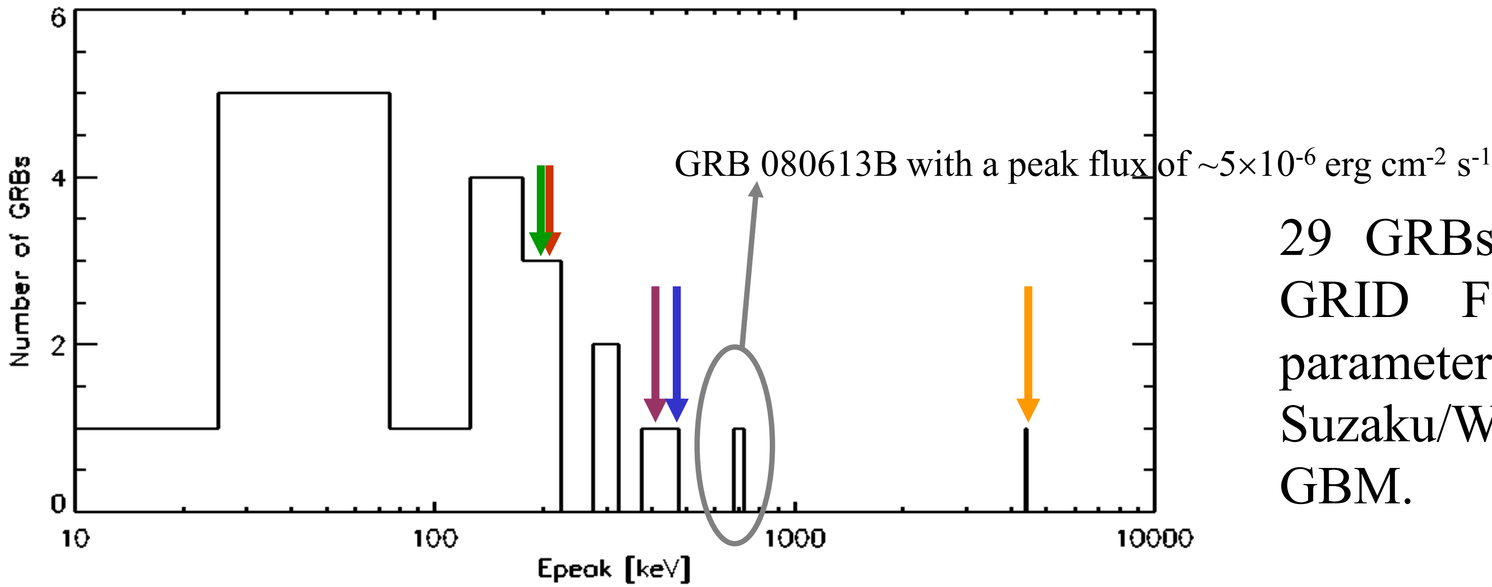
36 localized by Swift
17 localized by Fermi-GBM
10 localized by SuperAGILE
5 localized by INTEGRAL

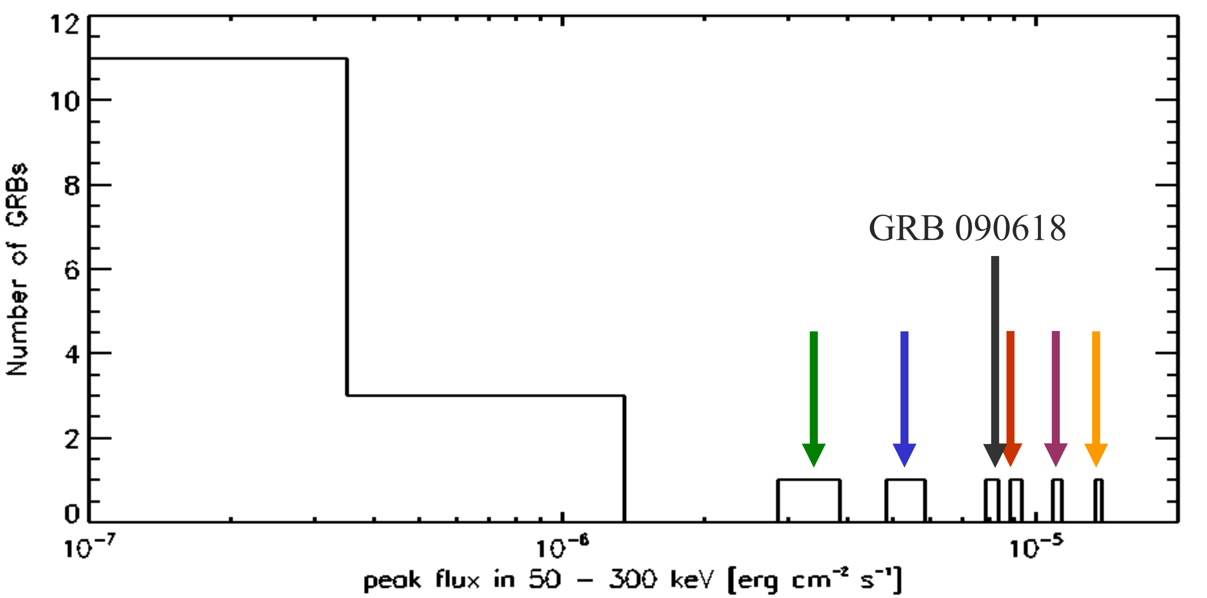
13 also detected by MCAL

# Upper limits in gamma rays: the results

- We estimated the upper limit of the 69 GRBs localized in the GRID FoV in July 2007 – April 2009;
- the background is estimated inside the GRID PSF before trigger and for 10 times the burst duration;
- 40 GRBs have spectral information (from Konus-Wind, Suzaku/WAM and Fermi/GBM), that is used to convert counts into flux;
- the corresponding 3 sigma upper limit ranges in 0.015 - 0.04 ph $cm^{-2}$ $s^{-1}$

# Population studies and the gamma ray emission




29 GRBs are found in the GRID FoV with spectral parameters by Konus-Wind, Suzaku/WAM or Fermi/GBM.

GRB 080514B, GRB 090401B and GRB 090510 are firmly detected by GRID;

GRB 080721 and GRB 081001 have smaller significance in GRID;

# The not ubiquitous GeV emission

- Only a small subsample of GRBs emits in gamma rays:

  AGILE/GRID detected 5 GRBs in 2.8 years;
  Fermi/LAT detected 17 GRBs in 1.9 years;
  the rate is ~9 events per year (consistent with Band et al. 2009);

- The impact of the lack of GeV emission on the currently accepted models of the GRB prompt emission is being investigated;

- Up to now no signature is found in the X-ray afterglow of the gamma ray emitting GRBs but the sample is still small;

- In particular, no gamma rays are detected by AGILE simultaneously with flares in the afterglow.

# The extended emission

- The extended emission of gamma rays is a common feature of the GRBs (both long and short) detected in this energy band;

- For some events the fluence emitted in gamma rays follows the same Band model of the keV – MeV emission, while up to now only GRB 090510 shows a spectral evolution;

- The gamma ray emission of GRB 090510 is debated: prompt or afterglow? (see e.g. Ghirlanda, Ghisellini and Nava 2009);

- Following Fan 2009, the gamma rays may be delayed because the early outflow has Lorentz factor smaller (baryon pollution) than the late emission;

# Conclusions and future perspectives

- the gamma ray emission is not a common feature of GRBs;
- it is concentrated in the prompt phase…
- … but it is often extended well after the end of the prompt emission;
- some GRBs have a single spectrum (keV – GeV), while others (e. g. GRB 090510) show spectral evolution;
- the afterglow of gamma ray emitting GRBs is not peculiar and no gamma rays are detected simultaneously with flares in the afterglow;
- the presence of gamma rays in the prompt emission correlates pretty well with the flux in the 50 – 300 keV energy band;
- typical AGILE upper limits for GRBs are 0.015 – 0.04 ph/cm$^2$.