

Observing GRB with AGILE

GRB130427A

F. Longo

*on behalf of the AGILE GRB group
and the AGILE team*

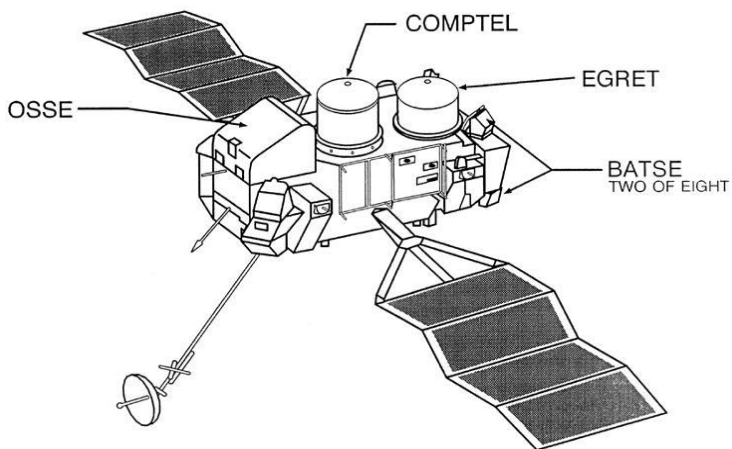


Outline



- **The EGRET heritage;**
- **Description of the AGILE detectors for GRB;**
- **The AGILE HE GRBs sample:**
 - **GRB 080514B (extended emission, same spectrum at keV – GeV);**
 - **GRB 090401B (complete coverage by Swift)**
 - **GRB 090510 (short with delayed component and spectral evolution);**
 - **GRB 100724B (simultaneous emission at MeV and GeV);**
 - **GRB 130327B (confirmation by LAT, no Swift Detection)**
 - **GRB 130427A (First with detection in Likelihood analysis by AGILE/GRID)**
- **Upper limits in gamma-rays of the undetected GRBs;**
- **The AGILE MCAL GRB sample and the AGILE contribution to IPN**
- **Conclusions**

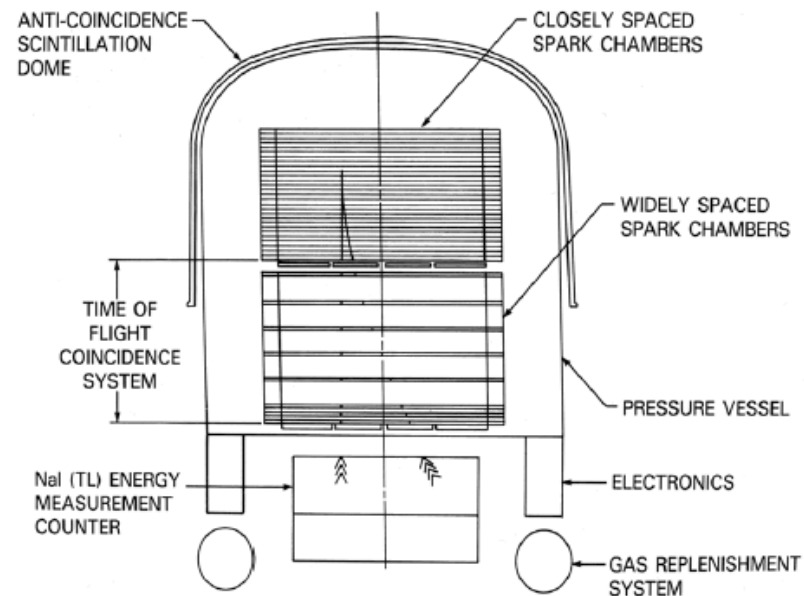
COMPTON OBSERVATORY INSTRUMENTS



The Instruments on CGRO Cover Six Orders of Magnitude in Photon Energy



10 keV 100 keV 1 MeV 10 MeV 100 MeV 1 GeV 10 GeV 100 GeV

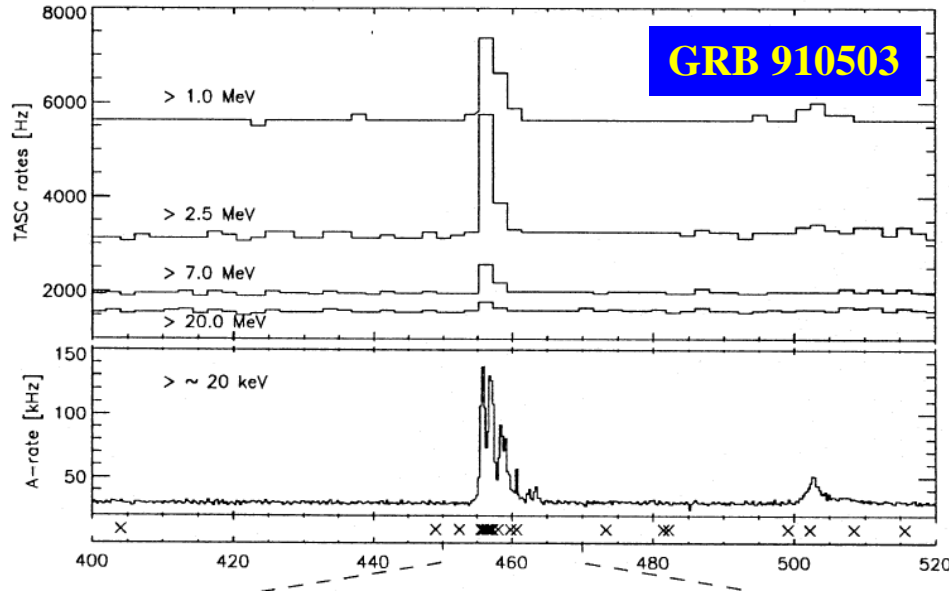


EGRET

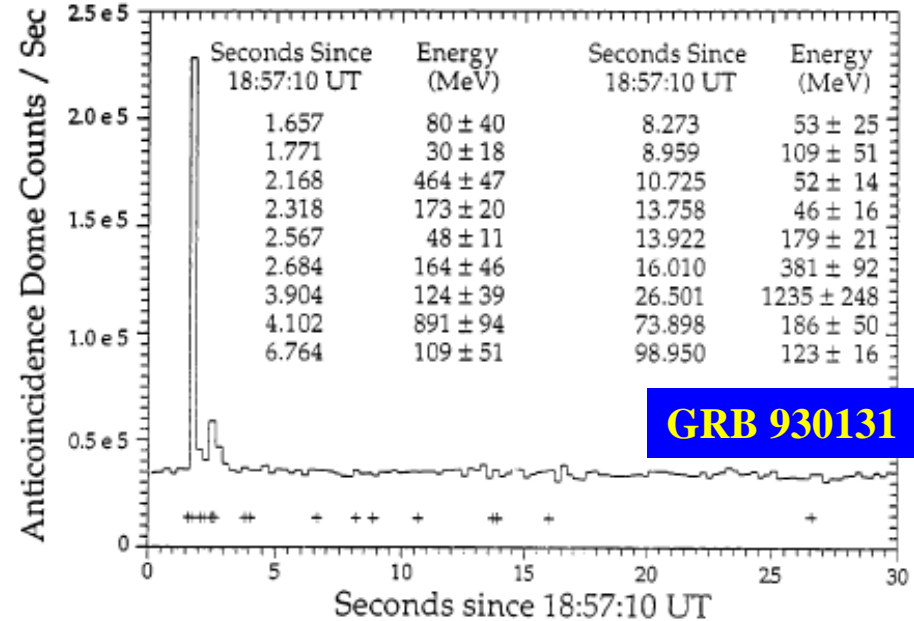
- 1991-2000
- 30 MeV - 30 GeV
- AGN, GRB, Unidentified Sources, Diffuse Bkg



The EGRET heritage on GRBs



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 described by the same model, others (e. g. GRB 941017) show additional components;

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

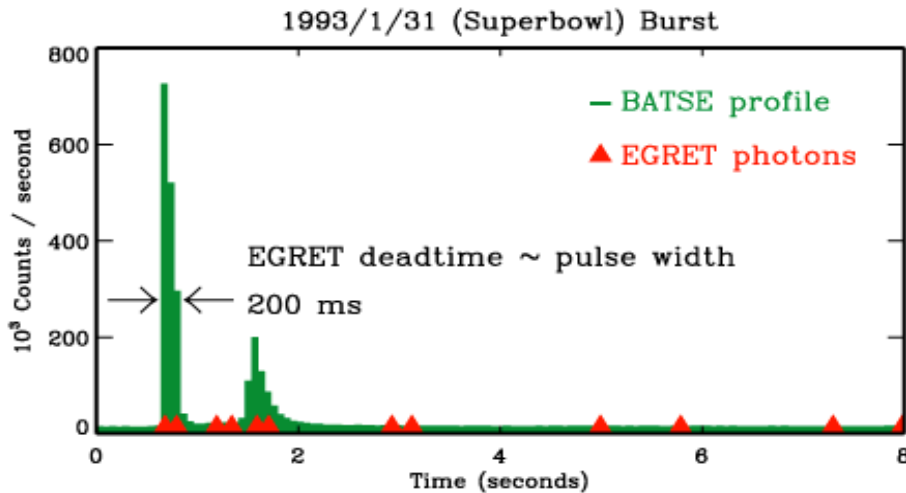


The EGRET heritage on GRBs

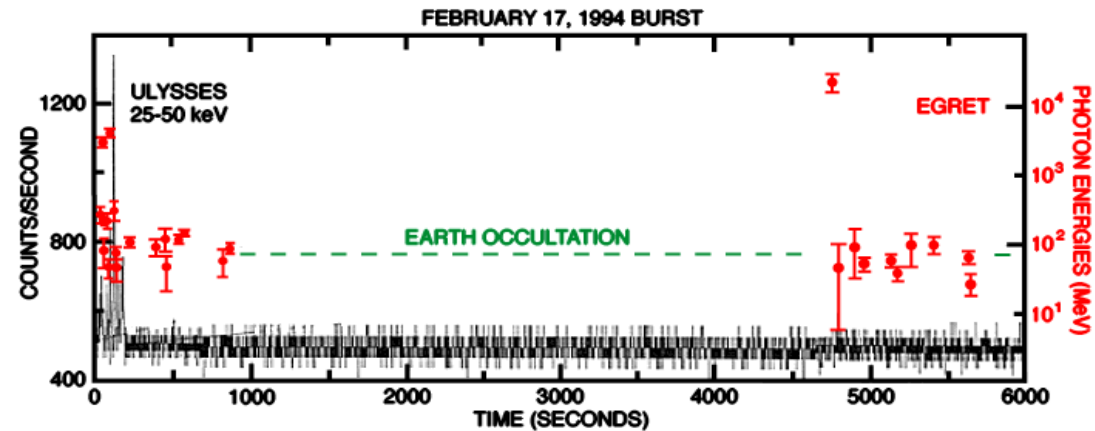


- Need fast timing for gamma-ray detection (improving EGRET deadtime, 100 msec \rightarrow 100 microsec or less).

Prompt Emission (GRB 930131)



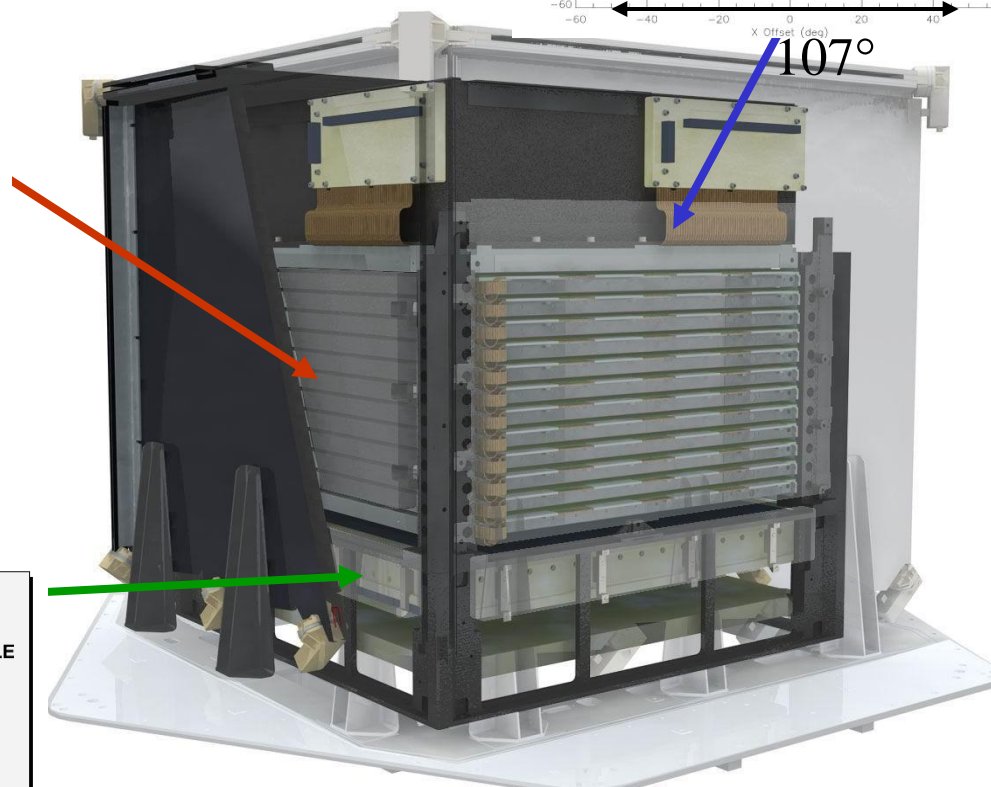
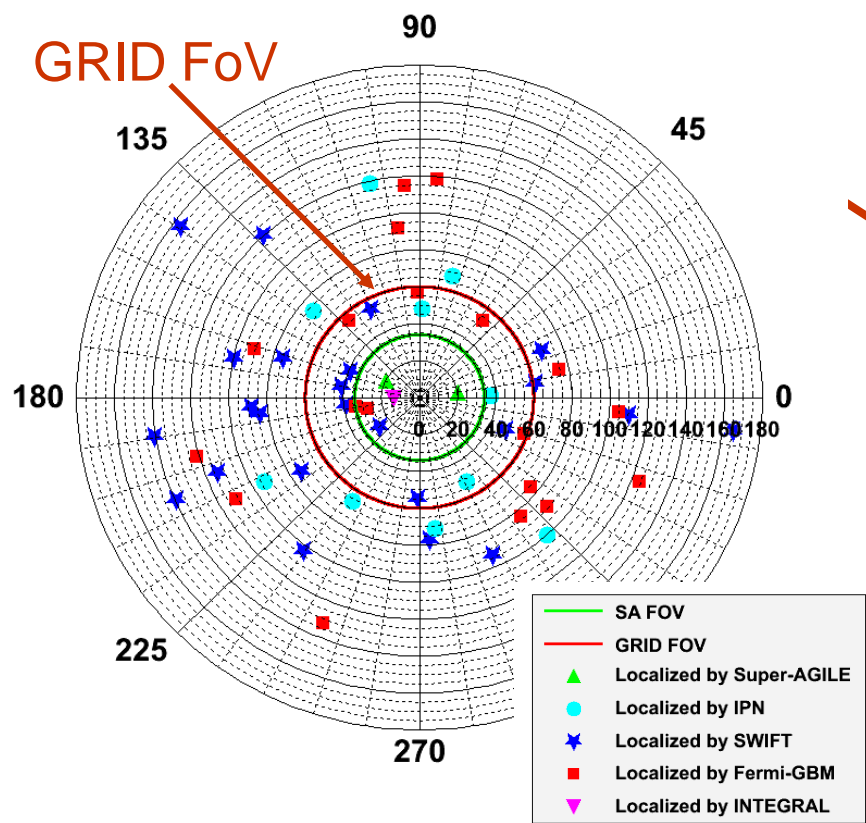
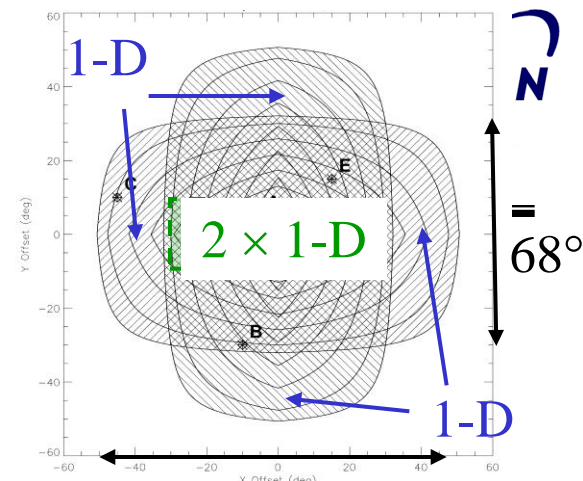
Delayed Emission (GRB 940217)





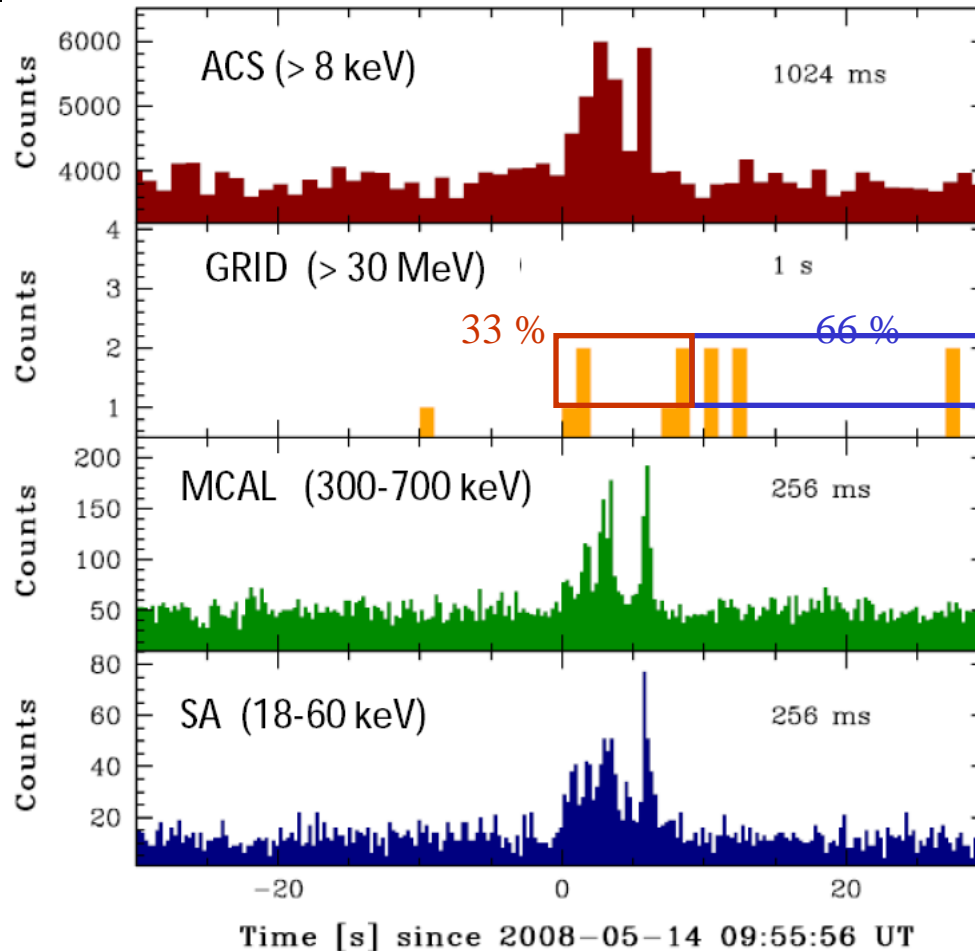
AGILE and GRB

Gamma Ray Imaging Detector
Silicon tracking detector
30 MeV – 50 GeV





Gamma-ray extended emission in GRB 080514B

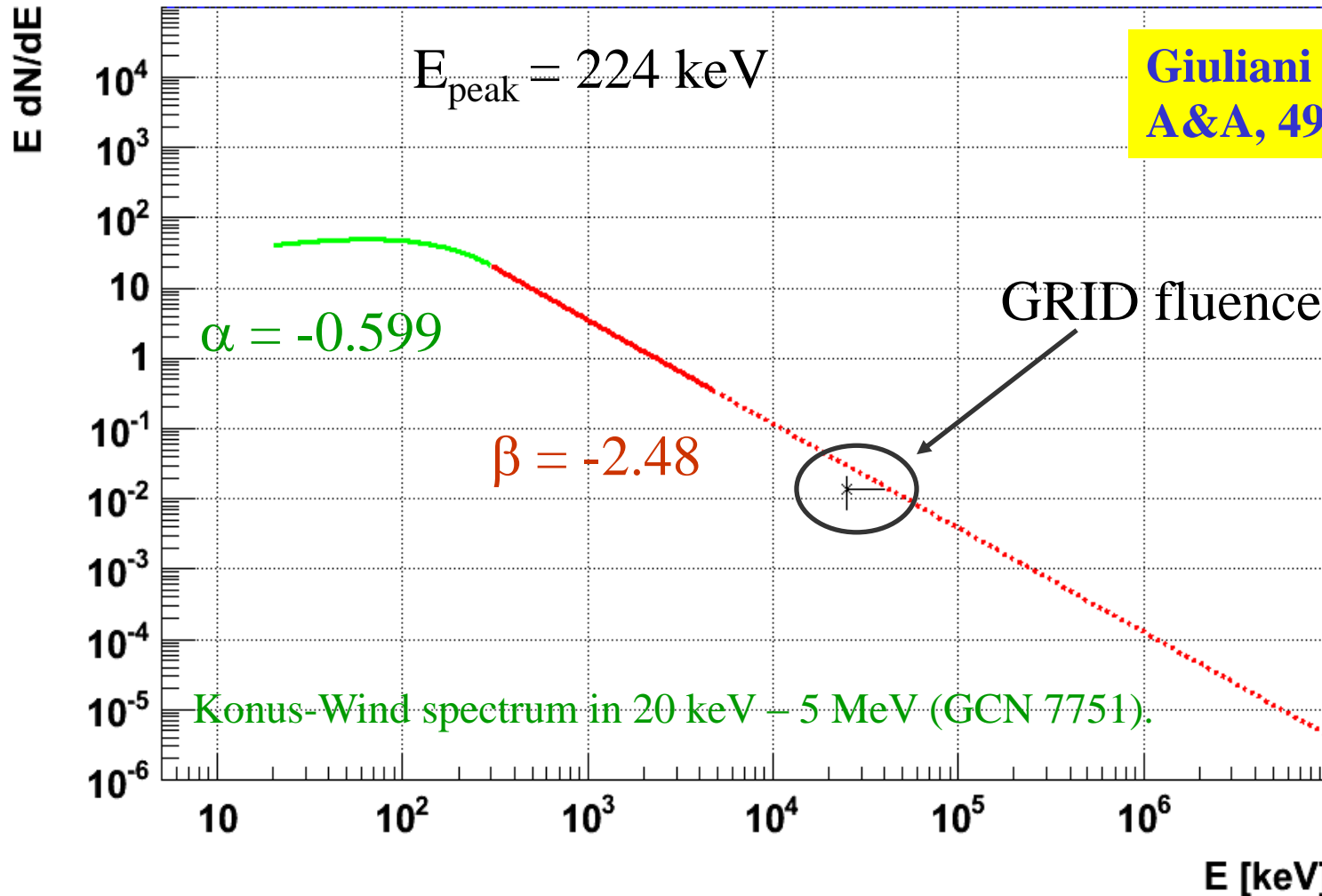


Giuliani et al., 2009,
A&A, 491, L25 – L28

GRB 080514B is the first GeV-bright GRB after EGRET and it is also associated to an afterglow and a photometric redshift measure of 1.8 (A. Rossi et al., 2009, A&A).



A single spectral model for the whole spectrum of GRB 080514B



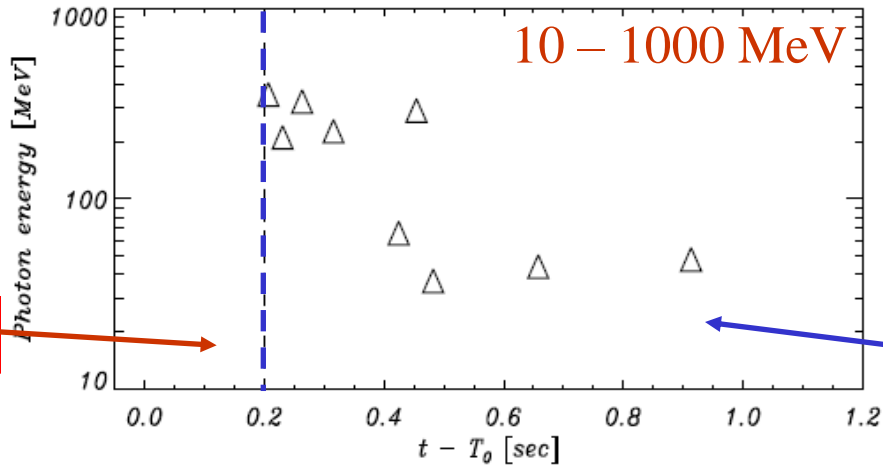
The same Band model fits the spectrum from 20 keV up to 50 MeV.



GRB 090510: the delayed emission

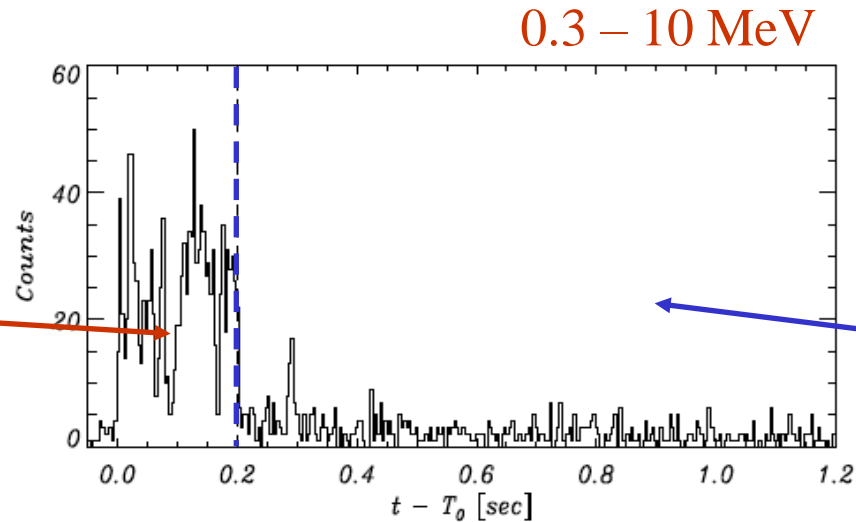
Giuliani et al. 2010,
ApJ, 708, L84 – L88

prompt emission interval



delayed emission interval

prompt emission interval



delayed emission interval

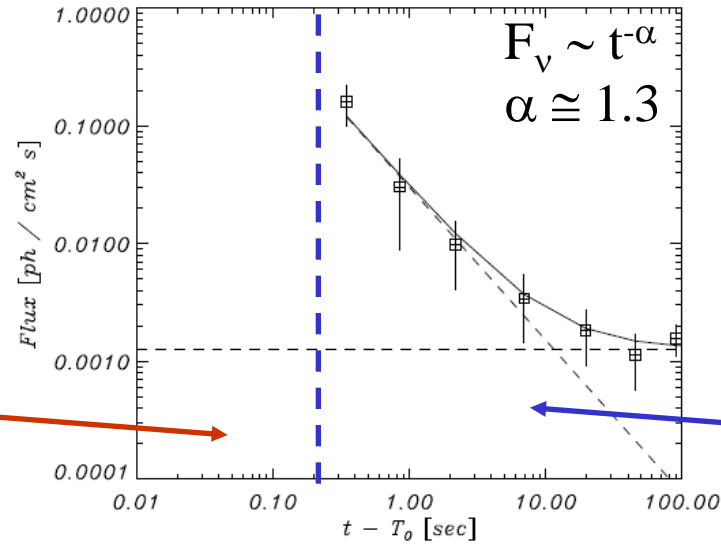
GRB 090510 has been localized by Swift and detected also by Fermi/LAT (Ackermann et al. 2010) and AGILE (Giuliani et al. 2010). The redshift is 0.903 (De Pasquale et al. 2010).



GRB 090510: the delayed emission

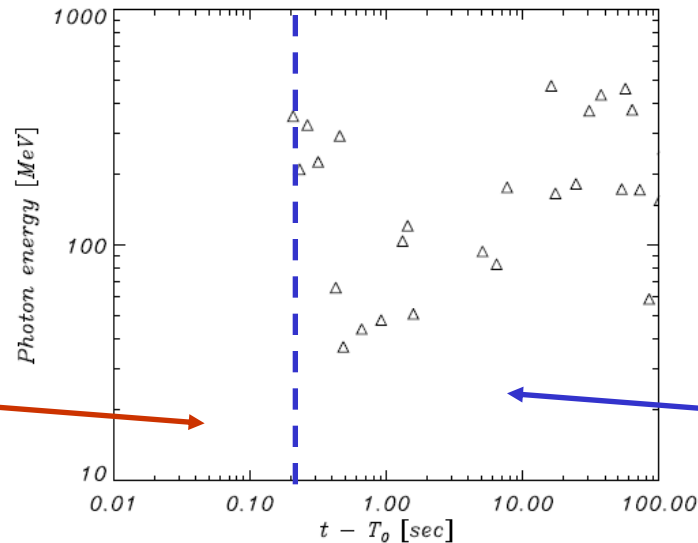


Giuliani et al. 2010,
ApJ, 708, L84 – L88



prompt emission interval

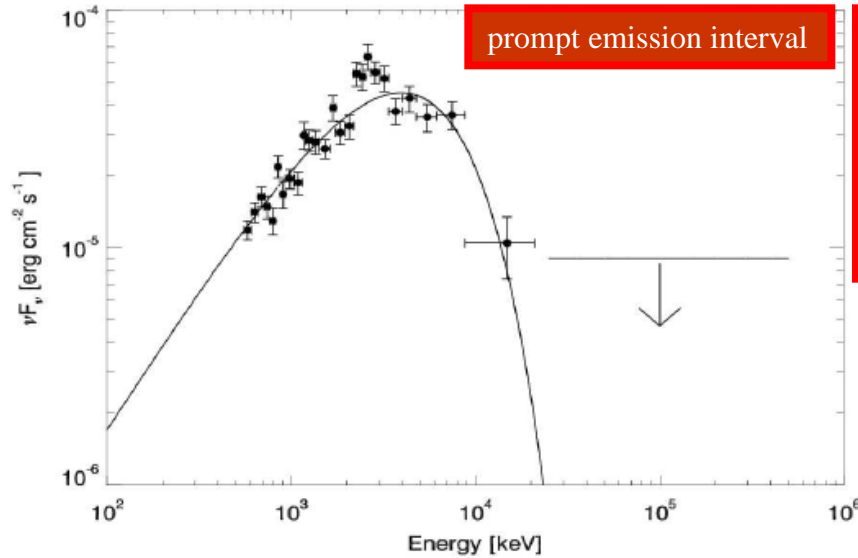
delayed emission interval



prompt emission interval

delayed emission interval

GRB 090510: spectral evolution in a short GRB



prompt emission interval

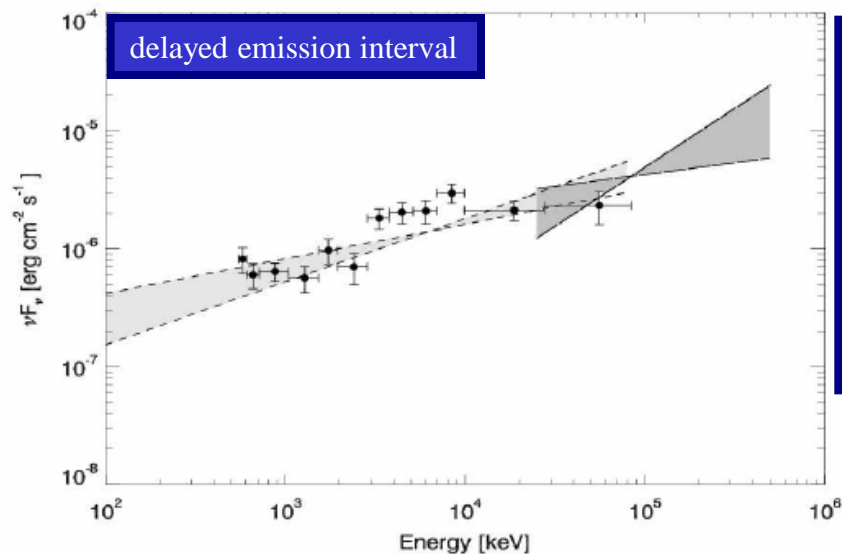
Powerlaw with cutoff

$$\alpha_1 = 0.6 \pm 0.3$$

$$E_c = 2.8 \pm 0.9 \text{ MeV}$$

$$1.8 \times 10^{-5} \text{ erg/cm}^2 \text{ (0.5 - 10 MeV)}$$

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



delayed emission interval

Powerlaw without cutoff

$$\alpha_2 = 1.6 \pm 0.1$$

$$3.1 \times 10^{-6} \text{ erg/cm}^2 \text{ (0.5 - 10 MeV)}$$

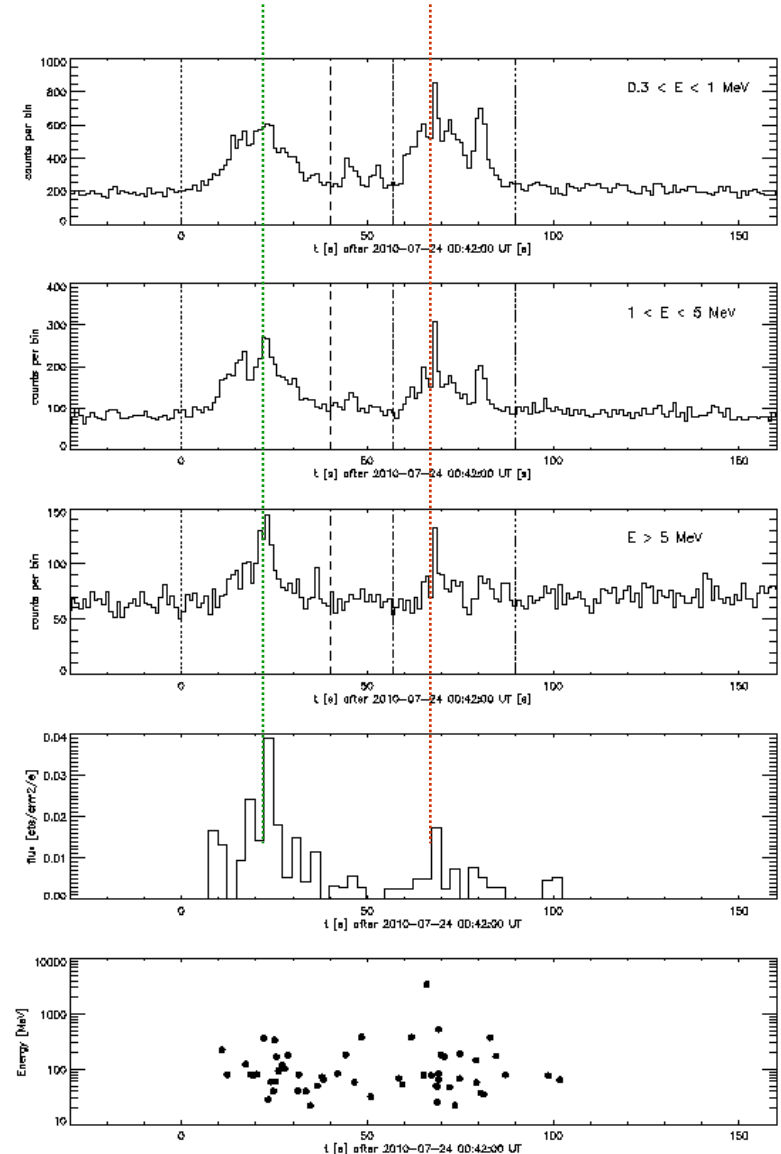
$$\alpha_3 = 1.4 \pm 0.4$$

$$2.9 \times 10^{-5} \text{ erg/cm}^2 \text{ (25 - 500 MeV)}$$

GRB 100724B: simultaneous onset of GeV and MeV



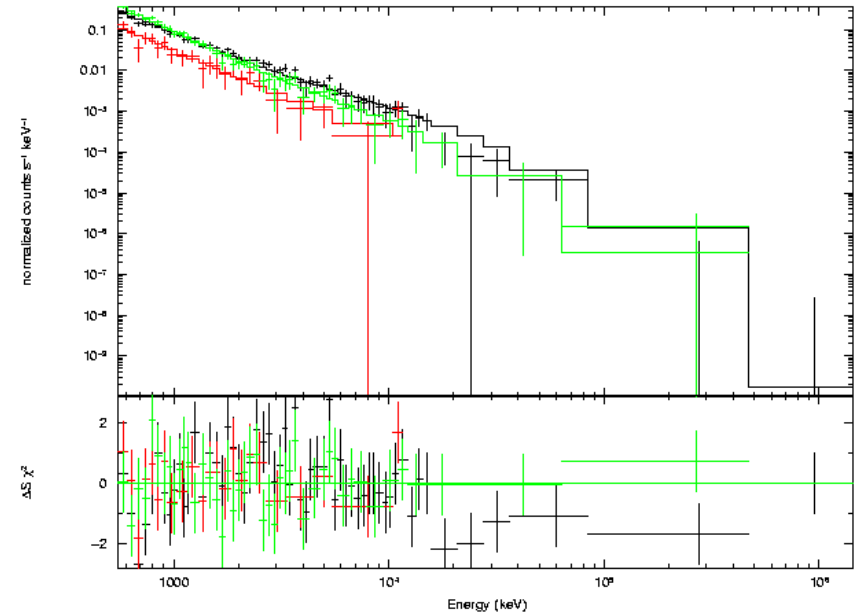
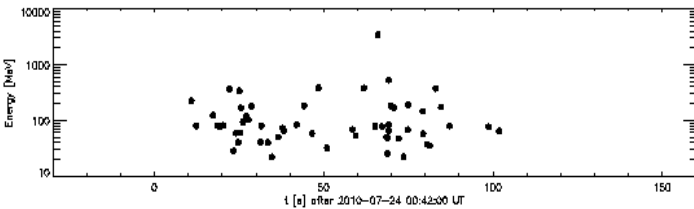
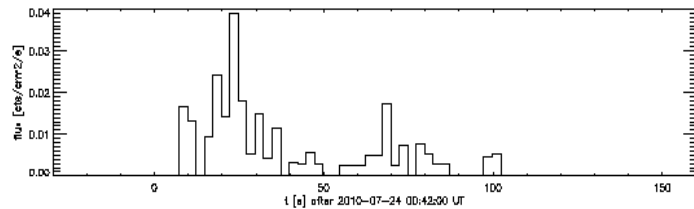
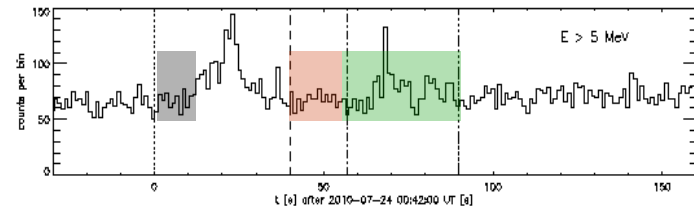
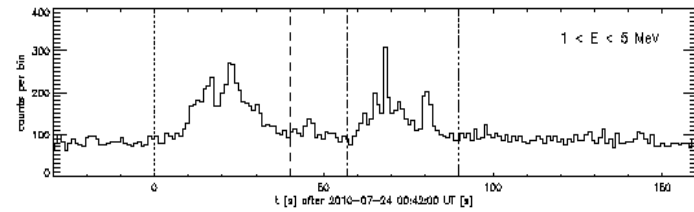
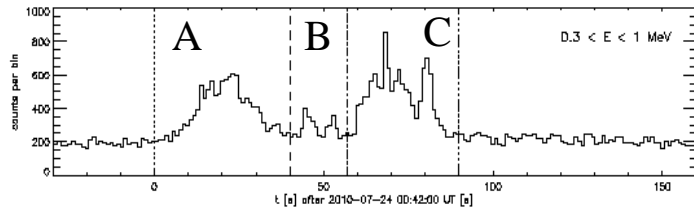
- No time lag is found between the MeV and GeV emission. The two main bumps in the lightcurve show a remarkably similar shape at MeV and GeV.
- Due to the spinning operative mode, GRB 100724B remained within the AGILE/GRID FoV between t_0+6s and t_0+125s .
- The GRB is not detected during the next “transit” in the FoV ($t_0 + 410s$, $t_0 + 529s$).
- SuperAGILE was not collecting data for telemetry sharing reasons.



Del Monte et al., A&A, 535, 120, (2011)



GRB 100724B: spectral evolution

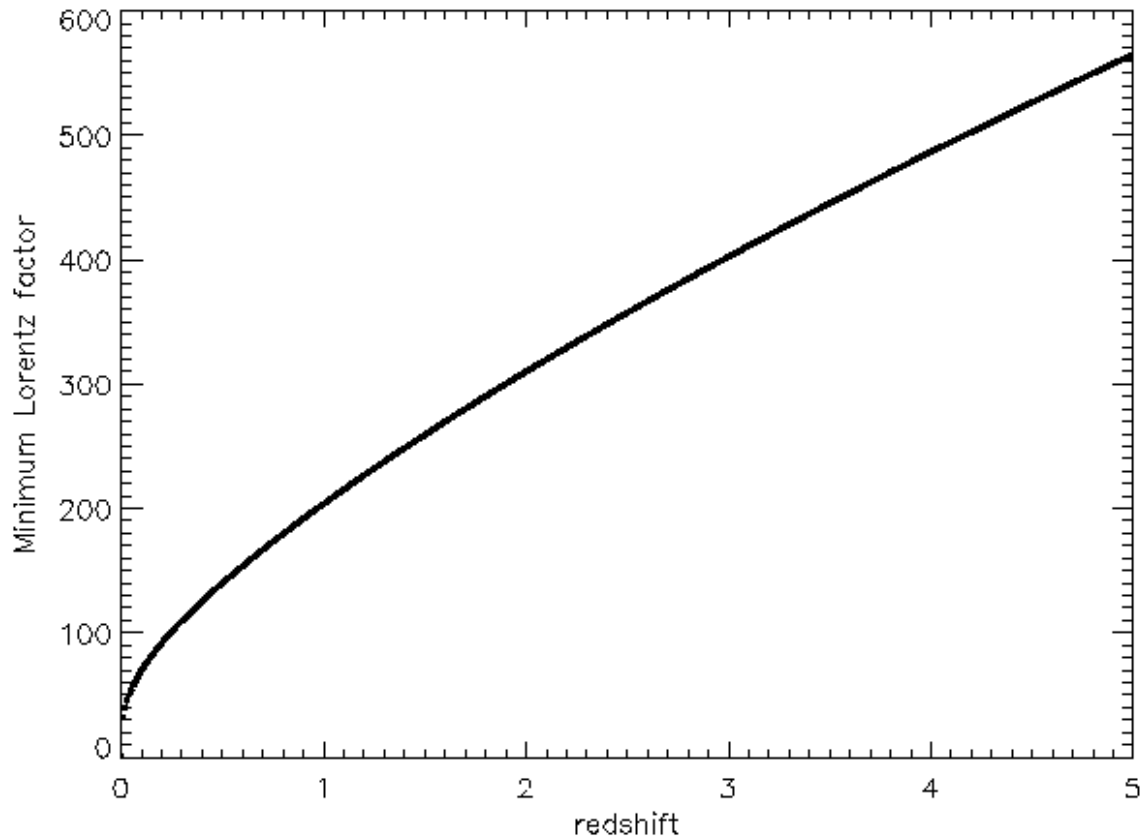


Del Monte et al., A&A, 535, A120 (2011)

- 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



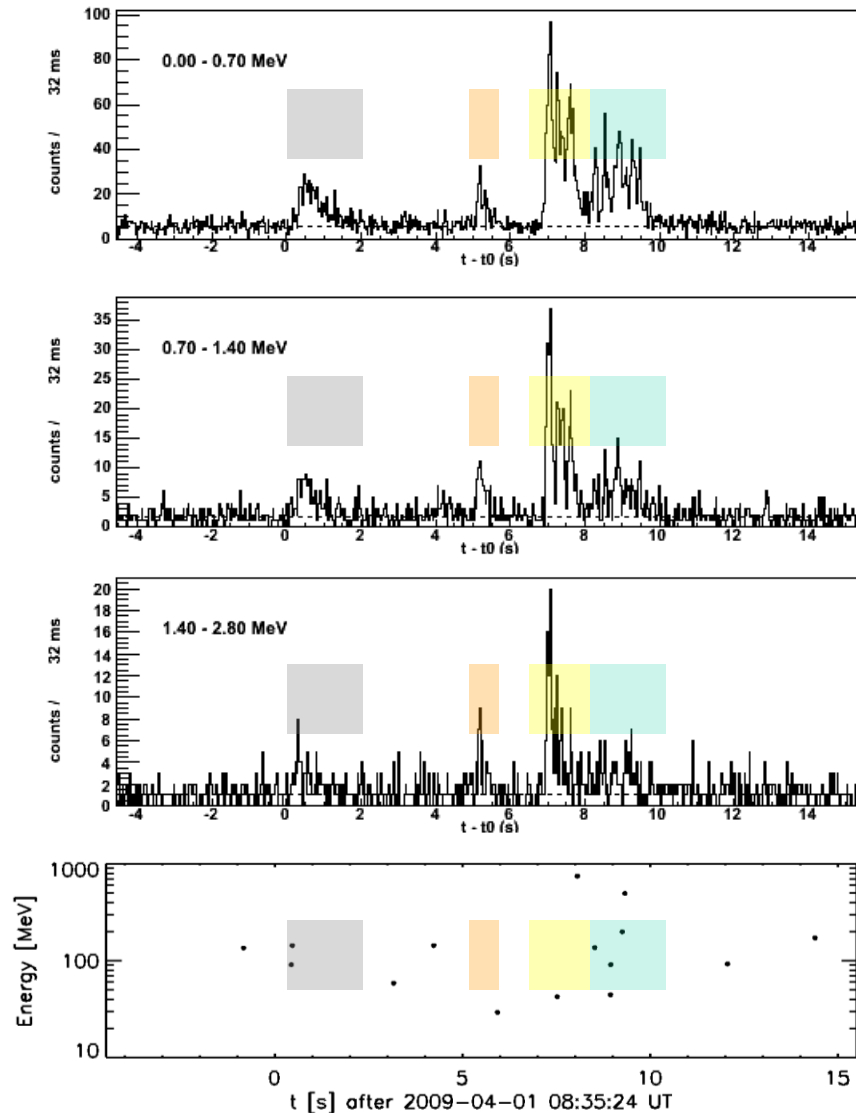
Following the method reported in the Supporting Online Material of the paper about GRB 080916C (Abdo et al 2009, Science, 323, 1688), $\Gamma_{\min} = \Gamma_{\min}(z, \Delta t, E_{\max}, \beta)$.

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

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



GRB 090401B: prompt emission

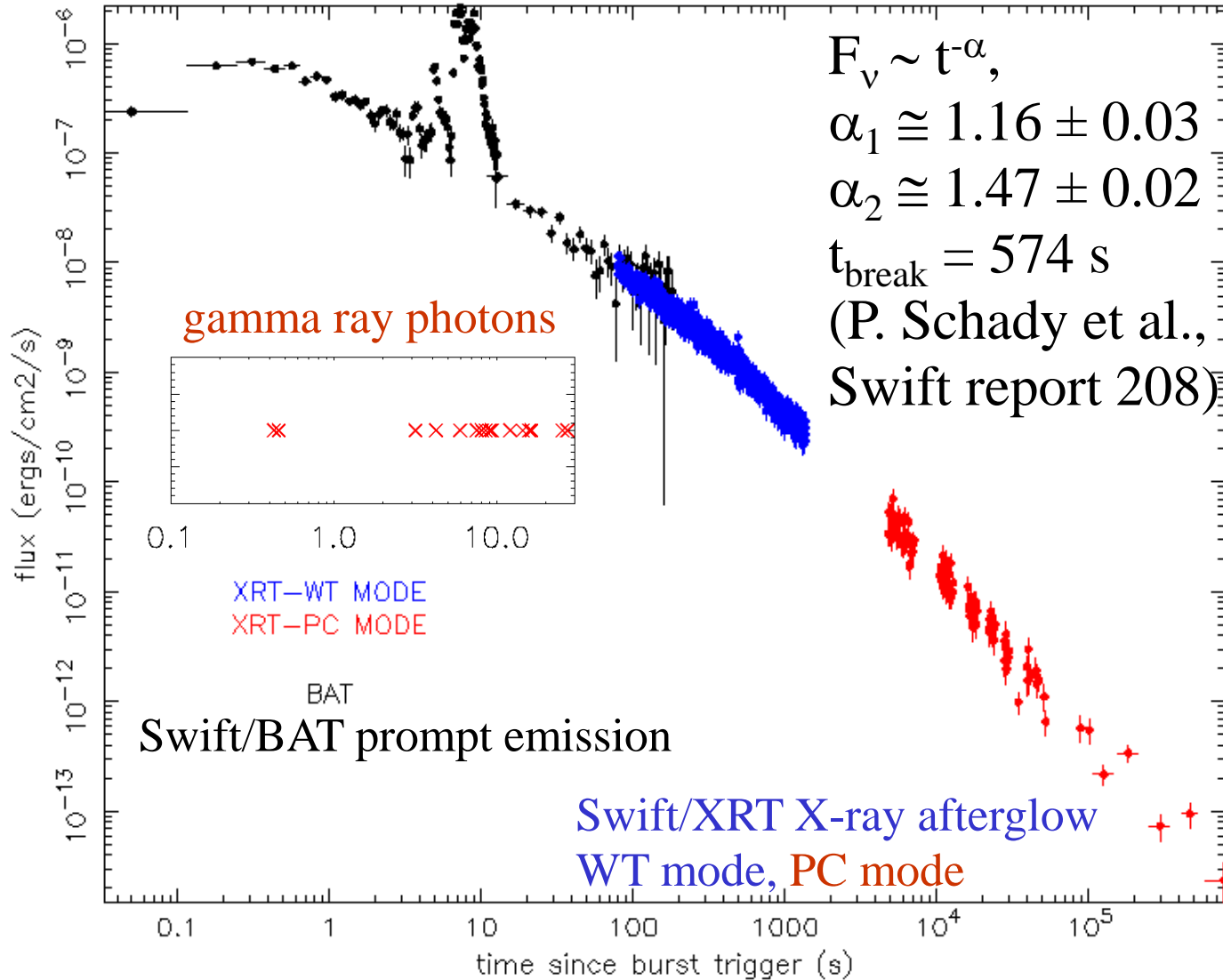


68 % of the gamma ray photons are emitted during prompt;

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



GRB 090401B: a complete coverage of the afterglow

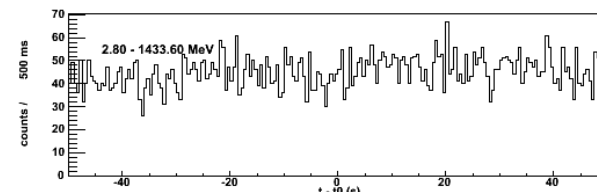
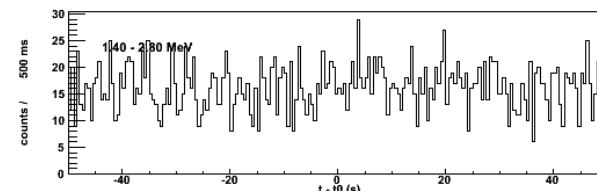
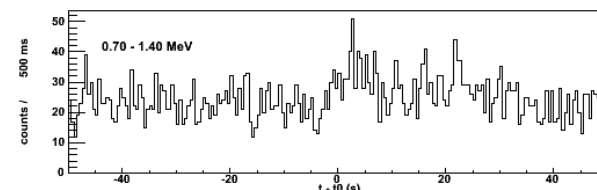
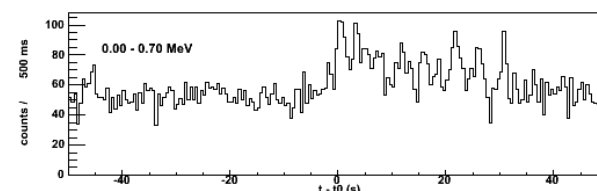
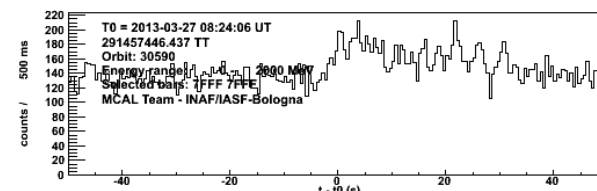
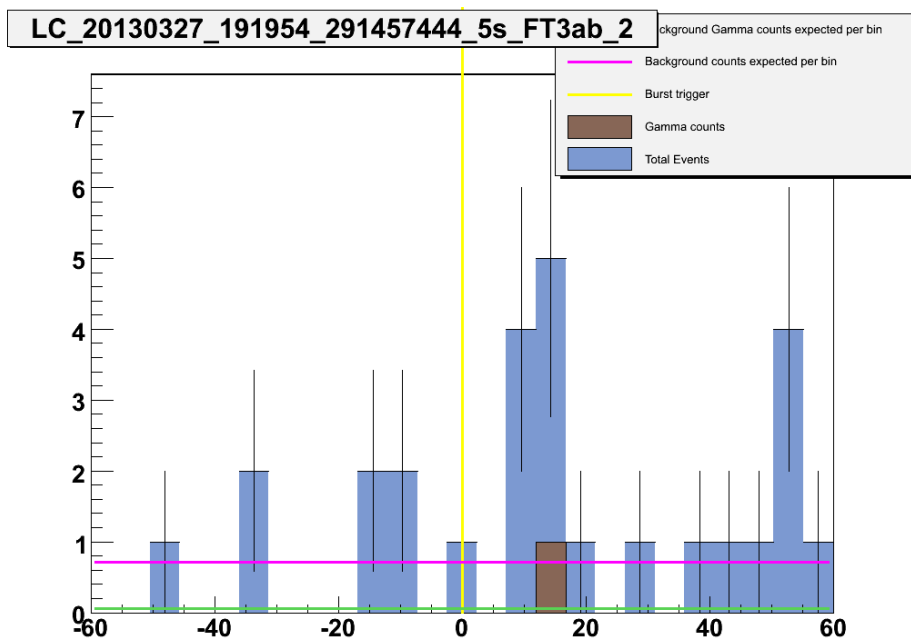




Preliminary info on GRB 130327B



- GRB detected by AGILE GRID (GCN 14344) and Fermi/LAT (GCN 14347)
- Correlated emission at High energy and Low Energy (GCN 14347)
- No XRT detection (GCN 14398) → no redshift known





GRB 130327B



TITLE: GCN CIRCULAR
NUMBER: 14344
SUBJECT: GRB 130327B: gamma-ray detection by AGILE
DATE: 13/03/27 23:24:56 GMT
FROM: Ettore Del Monte at IASF/INAF <sa.grb@iaps.inaf.it>

F. Longo (University of Trieste and INFN Trieste), A. Giuliani (INAF/IASF Milan), M. Marisaldi (INAF/IASF Bologna), E. Del Monte (INAF/IAPS Rome), F. Lazzarotto, I. Donnarumma, Y. Evangelista, M. Feroci, L. Pacciani, P. Soffitta, E. Costa, I. Lapshov, M. Rapisarda (INAF/IAPS Rome), G. Barbiellini, (INFN Trieste), A. Bulgarelli, F. Gianotti, M. Trifoglio, G. Di Cocco, C. Labanti, F. Fuschino, M. Galli (INAF/IASF Bologna), A. Chen, S. Mereghetti, F. Perotti, P. Caraveo (INAF/IASF Milan), M. Tavani, V. Vittorini, A. Argan, G. Piano, S. Sabatini, M. Cardillo (INAF/IASF Rome), G. Pucella (ENEA Frascati), A. Pellizzoni, A. Trois (INAF/OA Cagliari), M. Pilia (ASTRON), S. Vercellone (INAF/IASF Palermo), P. W. Cattaneo, A. Rappoldi (INFN Pavia), P. Picozza, A. Morselli, E. Striani, (INFN Roma-2), M. Prest, E. Vallazza (Universita' dell'Insubria), P. Lipari, D. Zanello (INFN Roma-1), P. Giommi, C. Pittori, F. Lucarelli, P. Santolamazza, F. Verrecchia (ASDC) and G. Valentini (ASI), on behalf of the AGILE Team, report:

The AGILE Gamma Ray Imaging Detector (GRID) detected emission from GRB 130327B, localised by Fermi/GBM (<http://gcn.gsfc.nasa.gov/other/386065447.fermi>). The GRB occurred at approximately 28 deg off-axis in the field of view of the AGILE/GRID.

A preliminary analysis of the AGILE/GRID data in temporal coincidence with the GRB shows a significant excess of gamma-ray events above 80 MeV at the location of the event. Most of the events detected by the AGILE/GRID have times between $\sim t_0 + 9$ sec and $t_0 + 14$ sec where t_0 is 27 March 2013 at 08:24:04.05 UT.

The GRB was also detected also by the AGILE/MCAL, operating in the energy range 0.5 - 100 MeV.

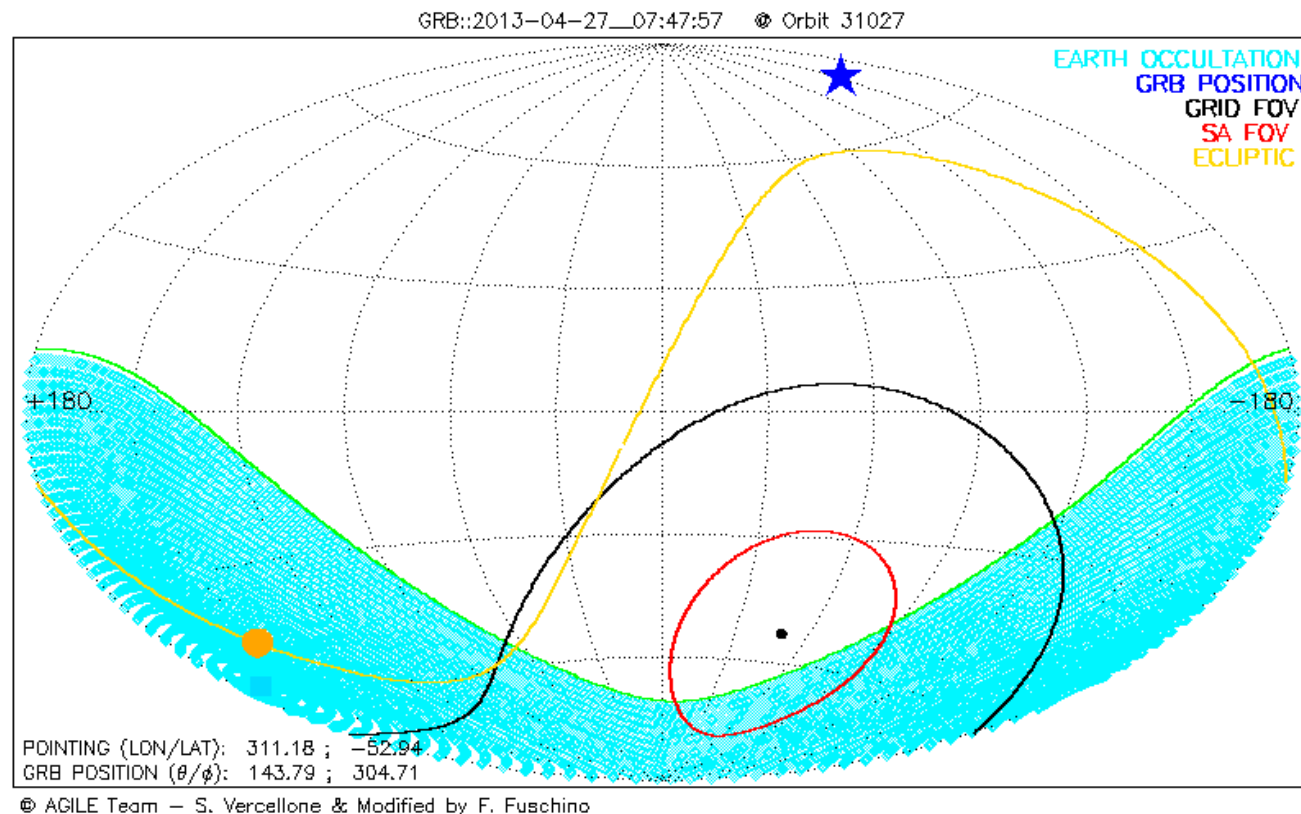
A more detailed analysis of the AGILE data is in progress. More observations of this interesting burst are strongly encouraged.



Preliminary info on GRB 130427A



- Outside of the FoV for the first 500 s
- Detected by the automated flaring source pipeline
- First detection by Likelihood of the extended emission

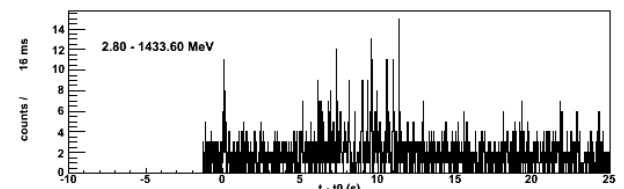
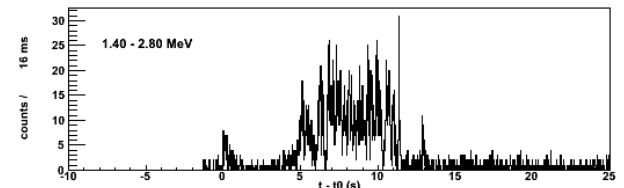
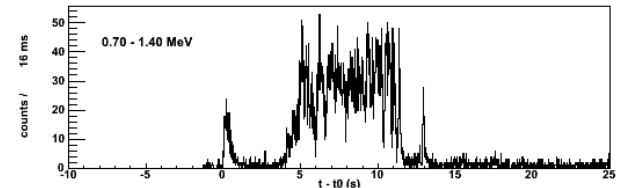
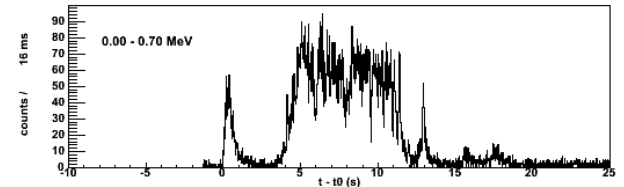
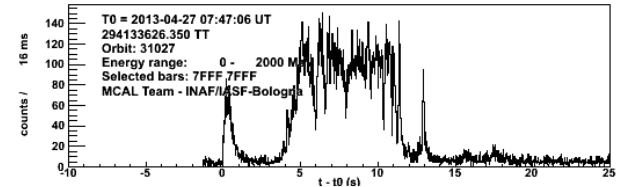
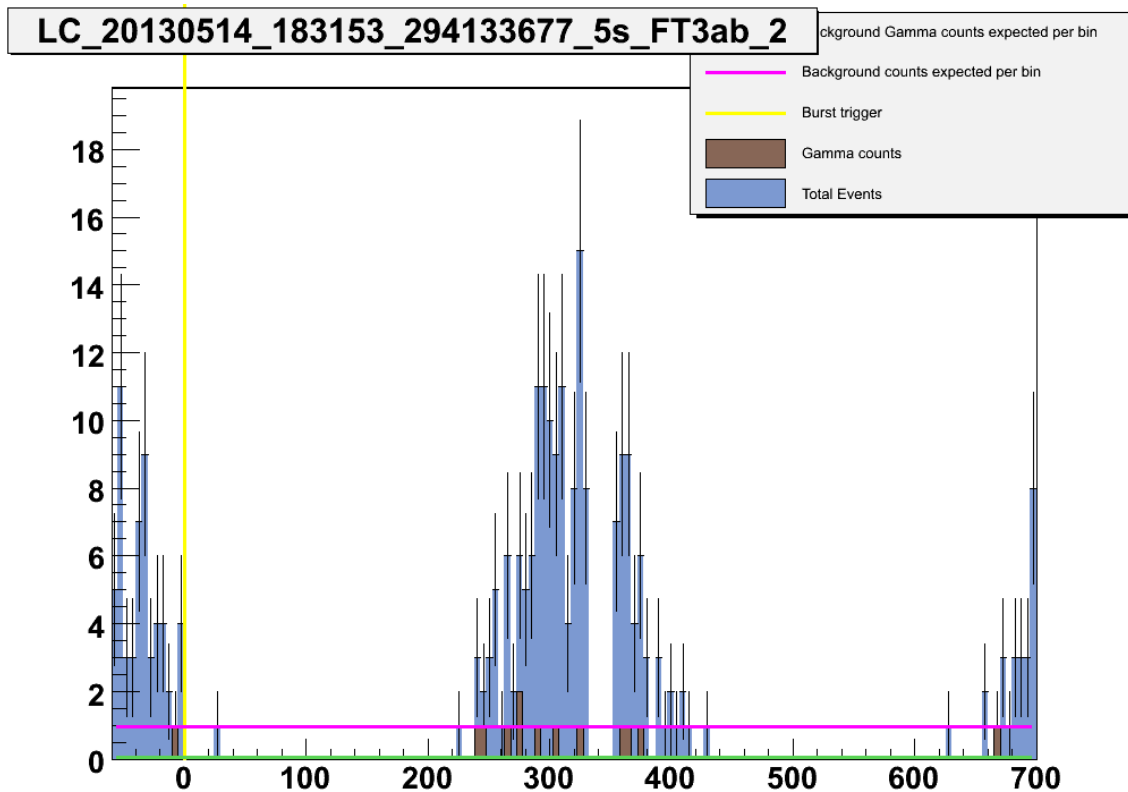




Preliminary info on GRB 130427A

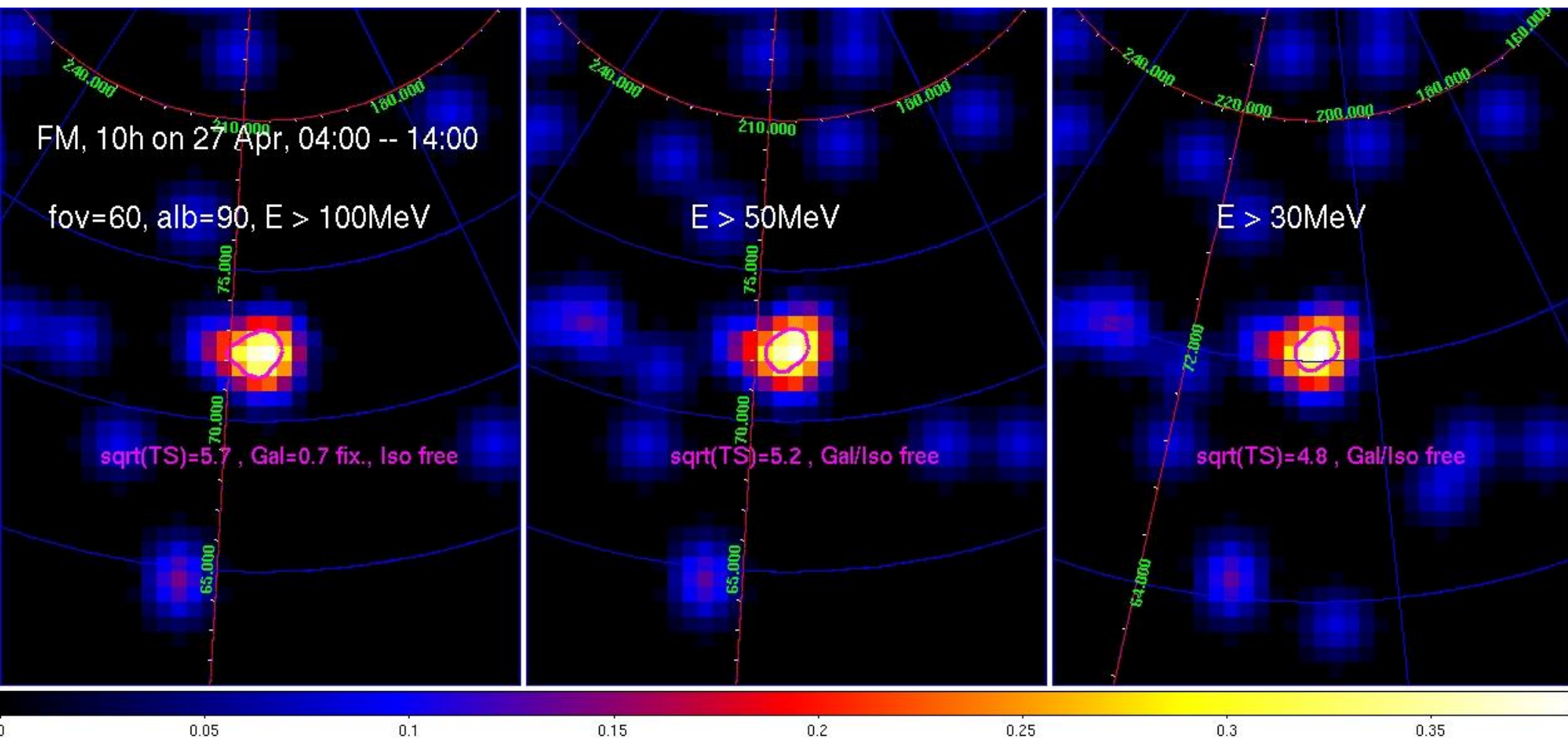


- Outside of the GRID FoV for the first ~ 200 s
- Strong prompt detection by MCAL



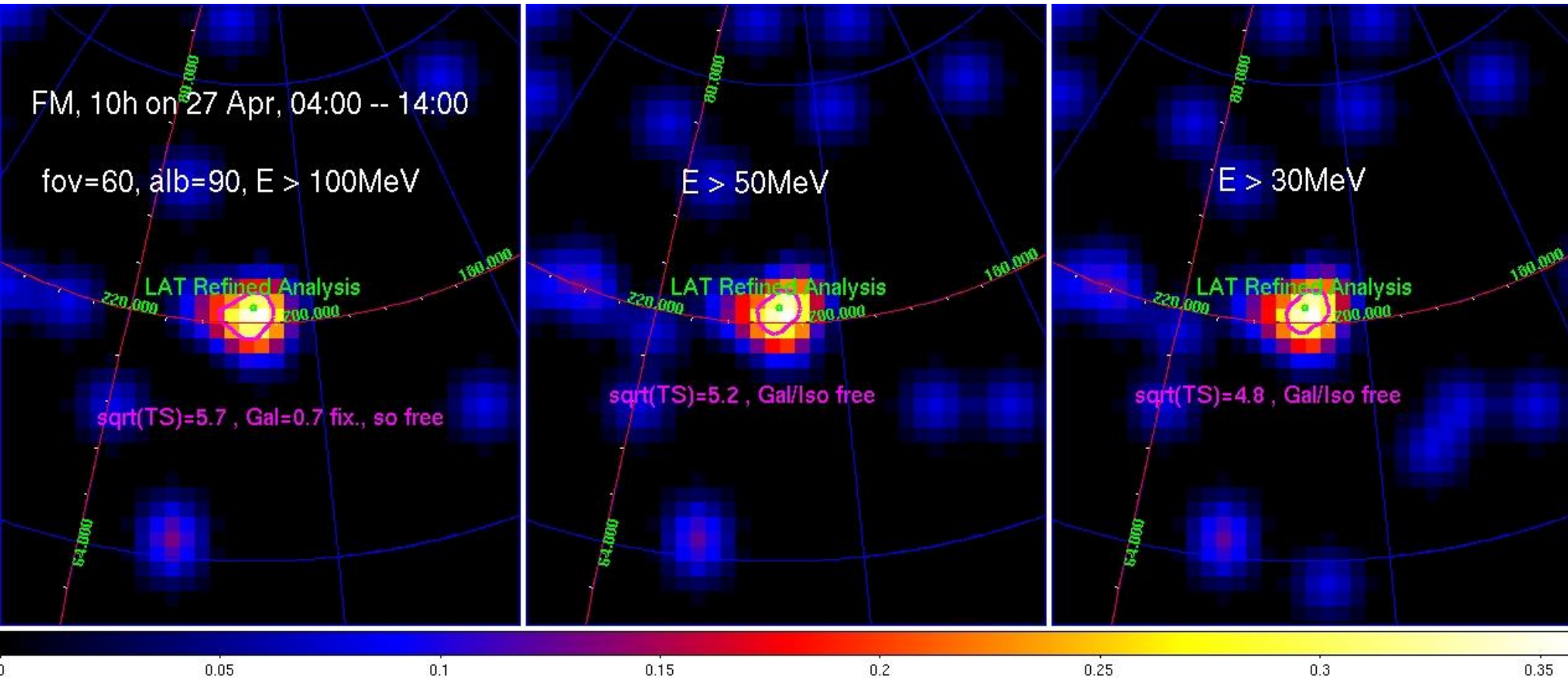


Preliminary info on GRB 130427A



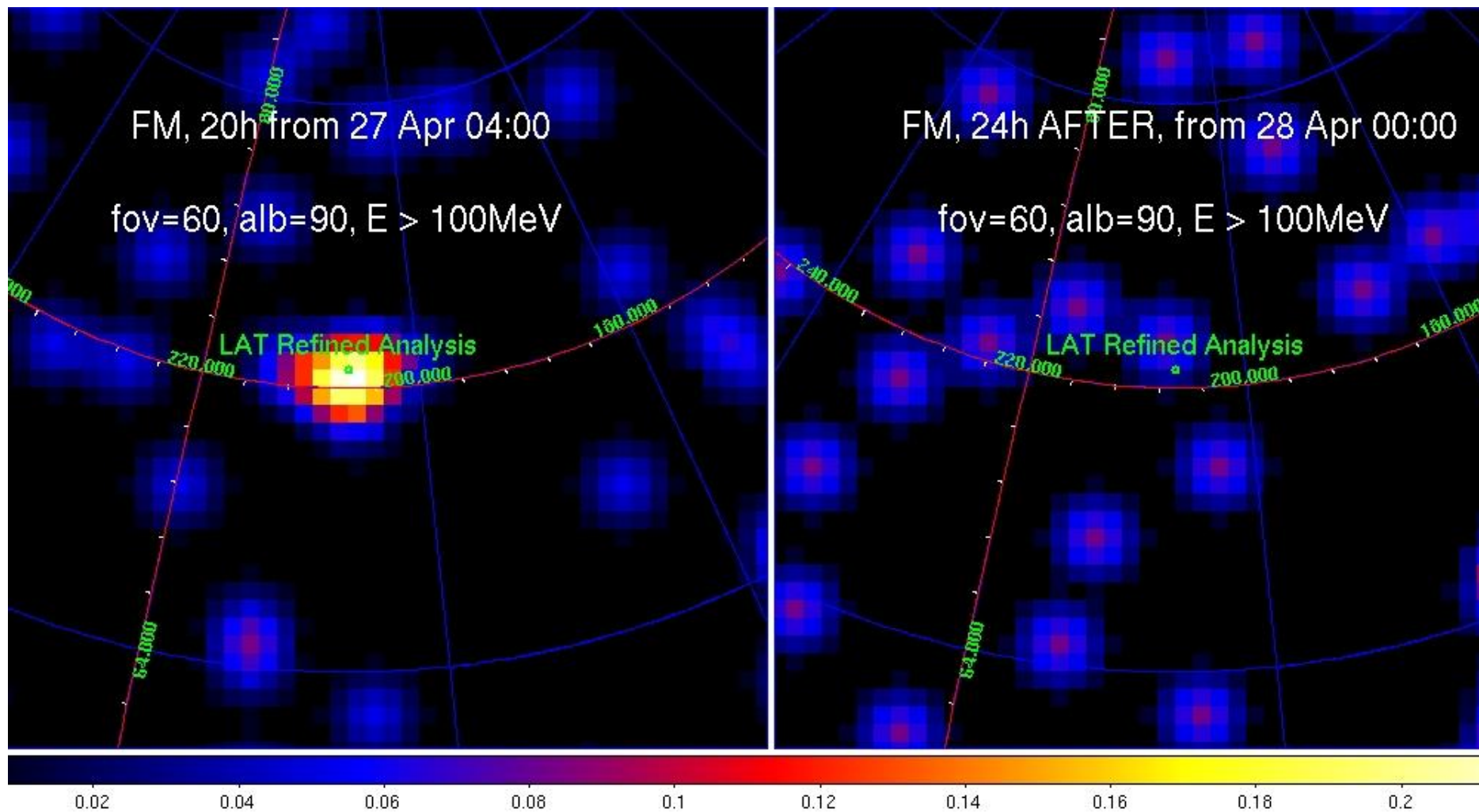


Preliminary info on GRB 130427A





Preliminary info on GRB 130427A





Preliminary info on GRB 130427A



TITLE: GCN CIRCULAR
NUMBER: 14515
SUBJECT: GRB 130427A: high energy gamma-ray detection by AGILE
DATE: 13/04/30 15:57:24 GMT
FROM: Francesco Verrecchia at ASDC <francesco.verrecchia@asdc.asi.it>

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F. Verrecchia, C. Pittori (ASDC and INAF/OAR), A. Giuliani (INAF/IASF-Mi), M. Marisaldi (INAF/IASF-Bo), F. Longo (University of Trieste and INFN Trieste), F. Lucarelli (ASDC and INAF/OAR), E. Del Monte, F. Lazzarotto, I. Donnarumma, Y. Evangelista, M. Feroci, L. Pacciani, P. Soffitta, E. Costa, I. Lapshov, M. Rapisarda (INAF/IAPS Rome), G. Barbiellini, (INFN Trieste), A. Bulgarelli, F. Gianotti, M. Trifoglio, G. Di Cocco, C. Labanti, V. Fioretti, F. Fuschino, M. Galli (INAF/IASF-Bo), A. Chen, S. Mereghetti, F. Perotti, P. Caraveo (INAF/IASF-Mi), M. Cardillo, E. Striani, M. Tavani (INAF/IAPS Rome, and Univ. Roma Tor Vergata), A. Argan, G. Piano, S. Sabatini, V. Vittorini (INAF/IAPS Rome), G. Pucella (ENEA Frascati), A. Pellizzoni, A. Trois (INAF/OA Cagliari), M. Pilia (ASTRON), S. Vercellone (INAF/IASF-Pa), P. W. Cattaneo, A. Rappoldi (INFN Pavia), A. Morselli, P. Picozza (INFN Roma-2), M. Prest, E. Vallazza (Universita' dell'Insubria), P. Lipari, D. Zanella (INFN Roma-1), P. Giommi (ASI), and G. Valentini (ASI), on behalf of the AGILE Team, report:

The AGILE Gamma Ray Imaging Detector (GRID) detected high energy emission from GRB 130427A (A. Maselli et al., GCN 14448), also reported by Fermi-LAT (S. Zhu et al., GCN 14471).

A preliminary analysis of the AGILE-GRID data in temporal coincidence with the GRB shows a significant excess of gamma-ray photons above 50 MeV at the location of the event. The emission detected by the AGILE-GRID mostly occurred between $\sim t_0 + 180$ sec and $t_0 + 700$ sec where t_0 is 27 April 2013 at 07:47:15 UT. During this interval, the burst position was inside the instrument FOV.

A maximum likelihood analysis of the AGILE-GRID data integrating over 12 hours, from 2013-04-27 05:00 UT to 2013-04-27 17:00 UT, using the standard parameters used by AGILE quick look to detect persistent gamma-ray sources, yields a detection at a significance level larger than 6 sigma, and a mean flux $F = (8.0 \pm 2.7) 10^{-6}$ ph/cm²/s ($E > 100$ MeV).

The preliminary photon spectral index obtained with this integration is 1.55 ± 0.30 .

Due to the exceptionally high fluence above 100 MeV of this burst, it is possible for the first time to derive its properties using the maximum likelihood techniques routinely used in the standard data analysis of AGILE-GRID point sources.

The GRB also triggered the AGILE Minicalorimeter (MCAL), sensitive to gamma-rays above 350 keV, at the time 07:47:06 UT. According to the MCAL light curve, the emission lasts for about 20 s divided into three main episodes. Although the large initial off-axis angle (more than 120 degrees) prevents an accurate spectral analysis of MCAL data, significant emission above 15 MeV is detected.

This measurement was obtained with AGILE observing a large portion of the sky in spinning mode.

This message may be cited.



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 FoV;
- 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 $\sim 0.03 \text{ ph cm}^{-2} \text{ s}^{-1} \Rightarrow \sim 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1}$;
- A likelihood search of gamma-ray delayed components (up to 3600 s after trigger) for the same events does not give positive results;
- The detection rate of GRBs by AGILE/GRID is discussed and it is found that AGILE observes on average the same population as EGRET.

**Longo et al. 2012,
A&A, 547. id.A95**

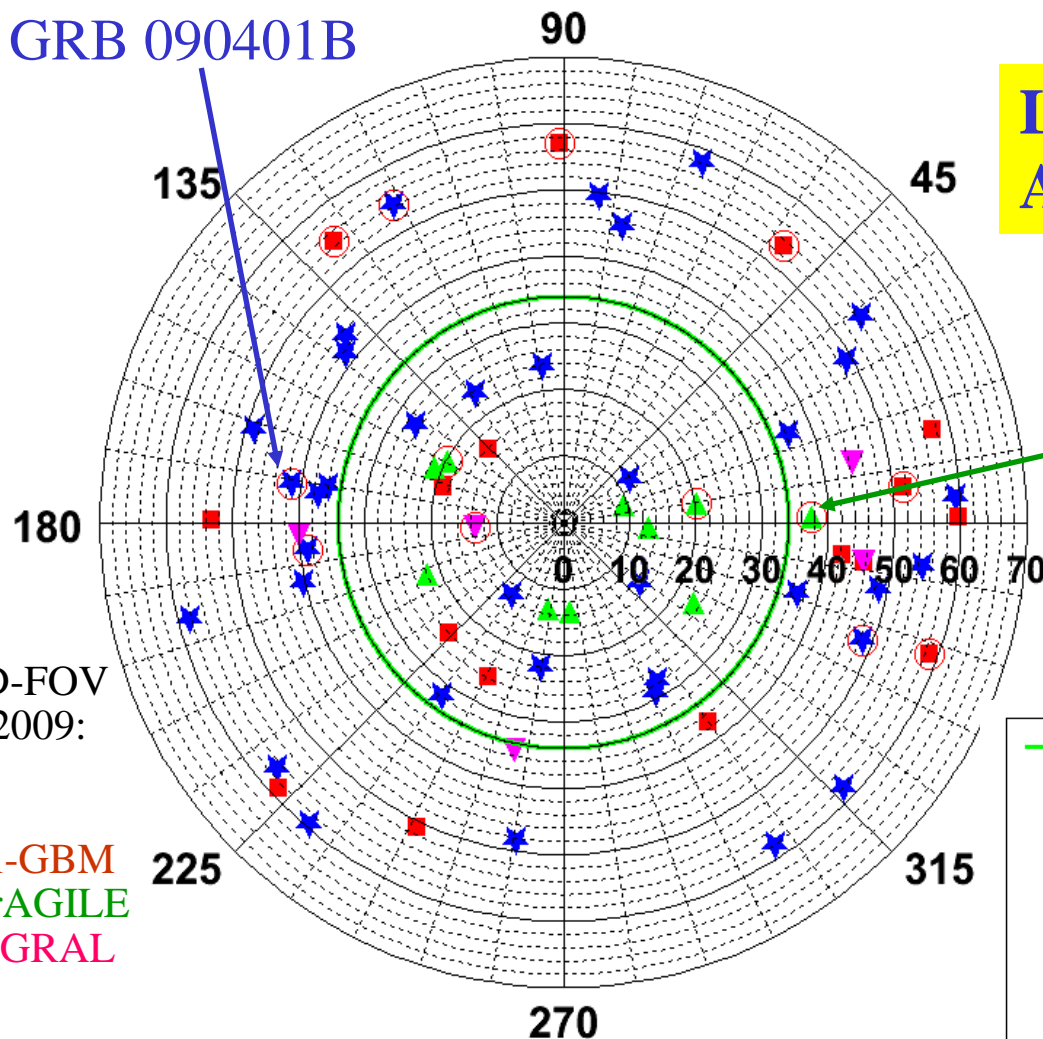


Upper limits in gamma rays: the sample



GRB 090401B

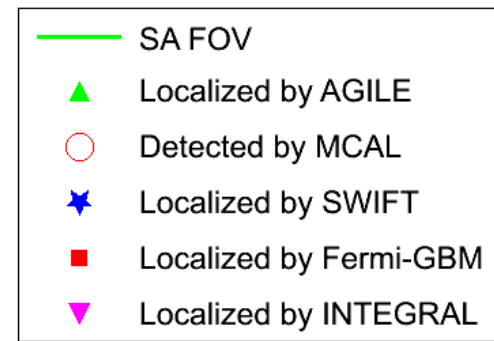
Longo et al. 2012,
A&A, 547. id.A95



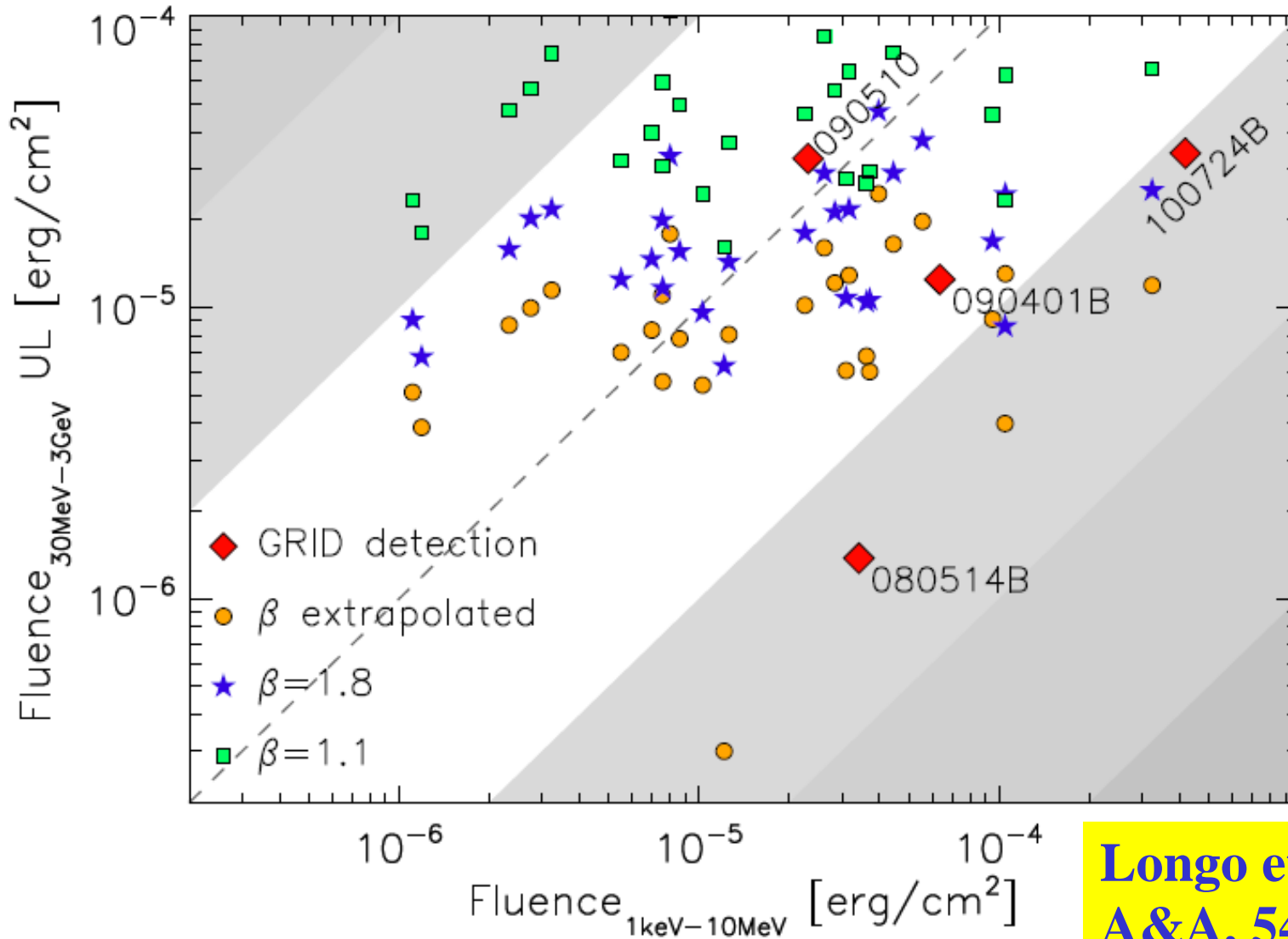
GRB 080514B

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



GeV emitting GRBs as high fluence events



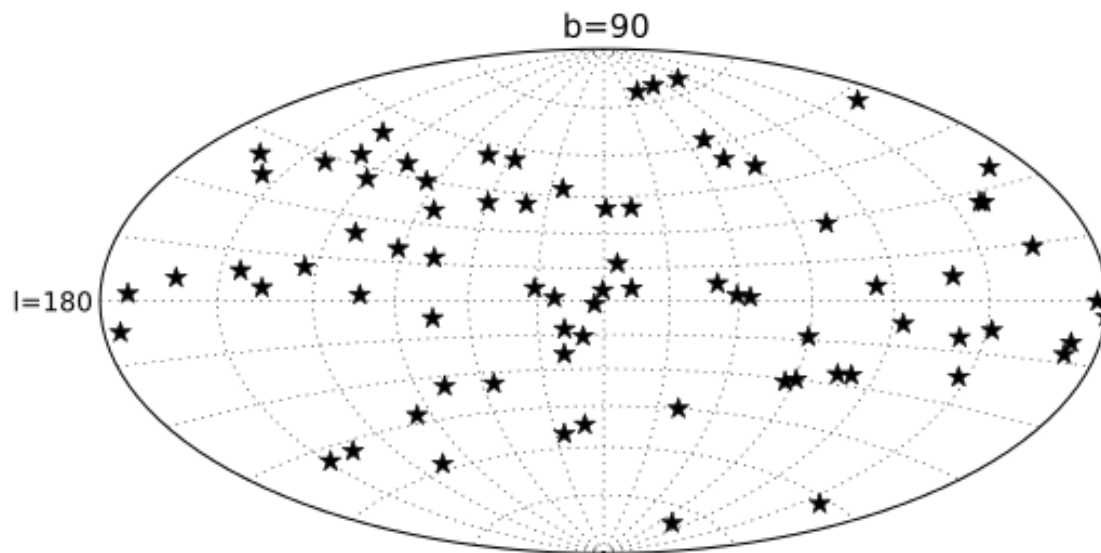
**Longo et al. 2012,
A&A, 547. id.A95**



MCAL GRB catalog



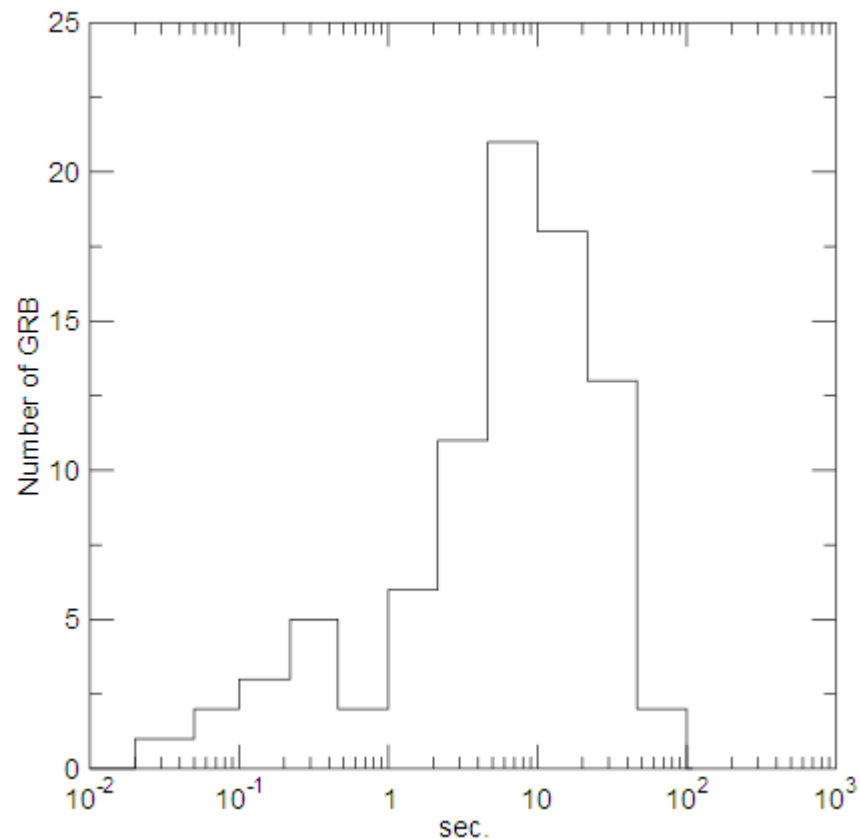
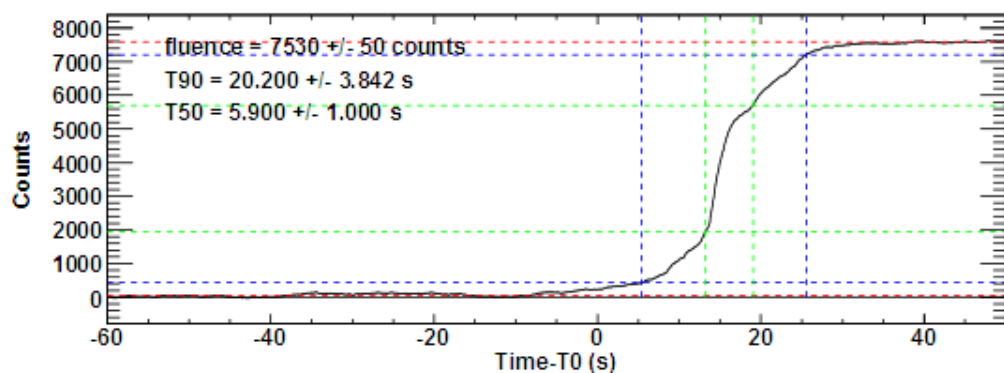
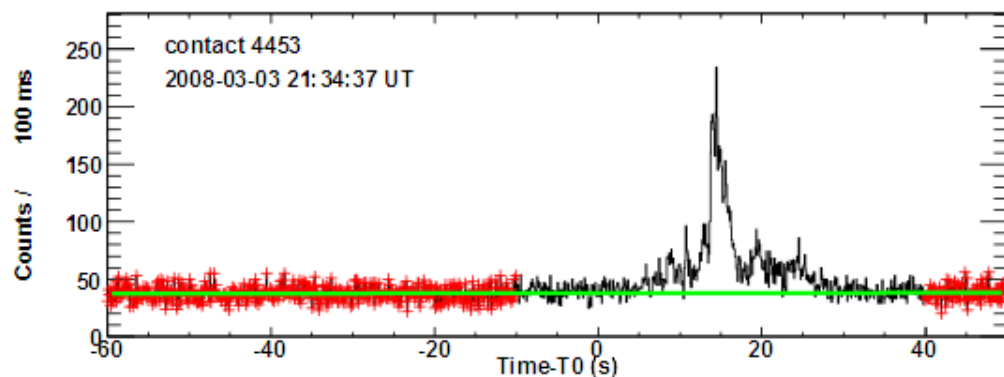
- Contains the data of the 85 hard gamma-ray bursts observed by the MCAL (April 2007 - October 2009)
- Timing data for 84 and spectral data for 21 bursts



Galli et al. 2013,
A&A, accepted



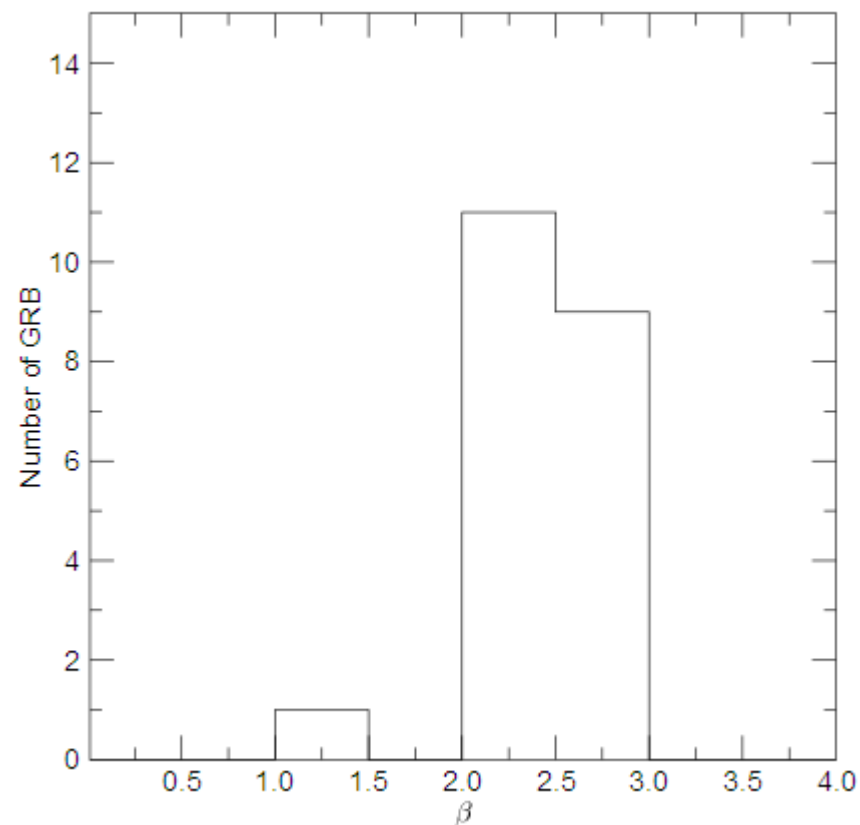
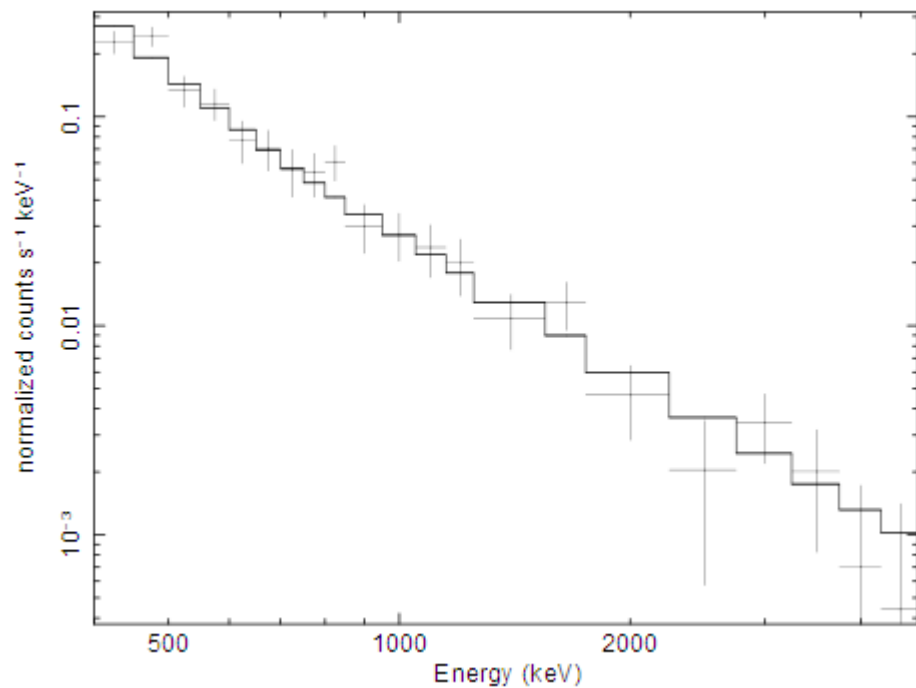
MCAL GRB catalog – timing analysis



Galli et al. 2013,
A&A, accepted



MCAL GRB catalog – spectral analysis



**Galli et al. 2013,
A&A, accepted**

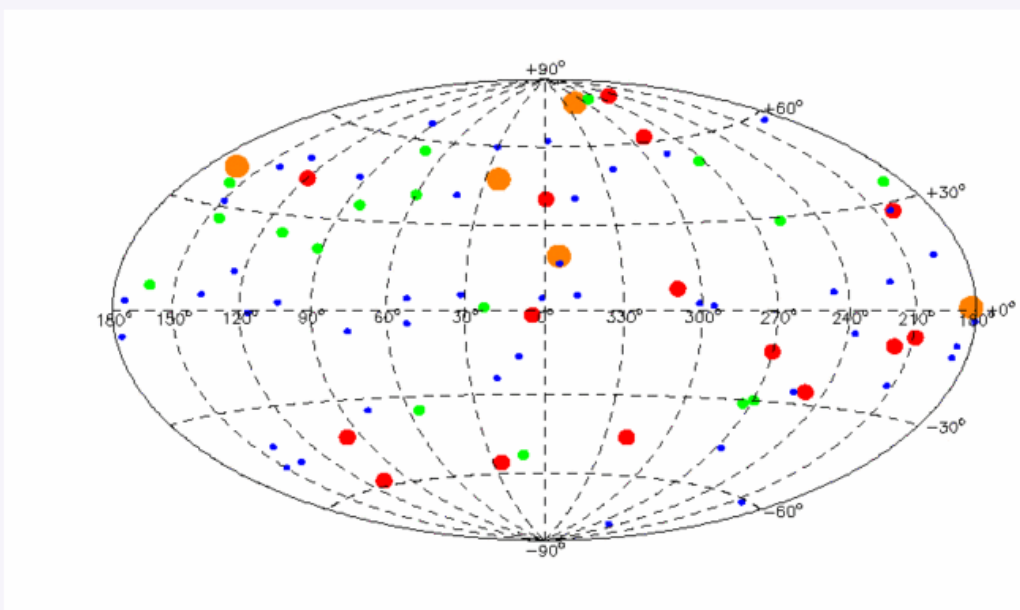


MCAL GRB catalog



The AGILE MCAL Gamma-ray Burst Catalog

GRB observed from April 2007 to October 2009
(AGILE Pointing Mode)



ALL **Published** **Others**

<http://www.asdc.asi.it/mcalgrbcatalog/>

asdc
ASI Science Data Center
VO
Tools

VO mode: off (turn on)
Help

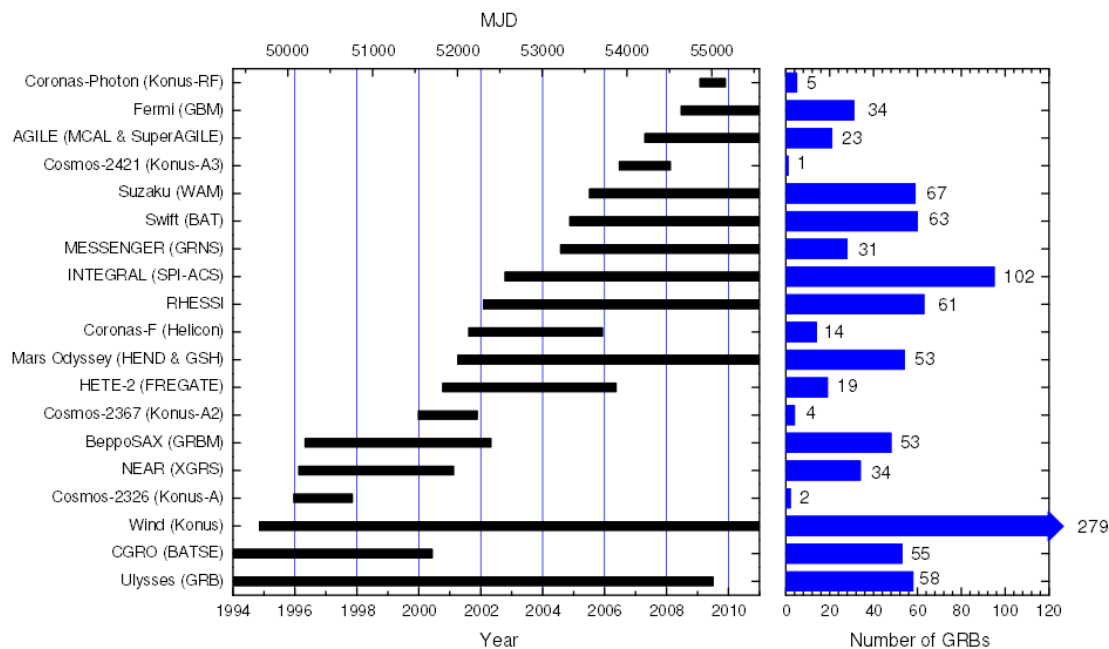
Cone Search
Source Name
Resolve name
 RA, Dec L, B Clean
(e.g. 00 02 34.6 -53 01 10.2 or 0 64417. -53 0198)
radius 60 arcmin Search
Reset filter



AGILE contribution to IPN



- Participation to catalog of Short Burst di Konus (arXiv:1301.3740)
 - 23 detections by AGILE
- Participation to the IPN supplement to GBM catalog – (arXiv:1301.3522)
 - 67 detections by AGILE
- 33 GCN by IPN with AGILE authors
- GRB data sent to IPN ~ 240





Conclusions



- 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/cm² at keV – MeV) and have high minimum Lorentz factor (600 – 1000);
- Both classes of long (e. g. GRB 080514B, GRB 090401B, GRB 100724B, GRB 130327B, 130427A) and short (e. g. GRB 090510) are detected in the gamma energy band.
- Some events have a single spectrum (e. g. GRB 080514B; GRB 100724B) other have additional spectral components (e. g. GRB 090510);
- Gamma-ray emitting GRBs seem to be characterised by high fluence and high Lorentz factor. It is still debated if gamma-rays are produced in internal (prompt) or external (afterglow) shocks.
- AGILE detected all the major characteristics of HE GRB (delayed emission, extended emission, power-law extracomponent)
- A cross calibration work with Fermi has started.