AGILE GRBs: detections and upper limits

Outline

- AGILE quick review;
- The GRB search pipeline;
- The AGILE GRBs;
- The GRB090618: any clue for the detectability in the E>30 MeV band?
- The GRB sample in the GRID FoV;
- UL calculation method;
- Results and conclusions;

The AGILE instrument

Semi-major axis: 6922.5 km (± 0.1 km)

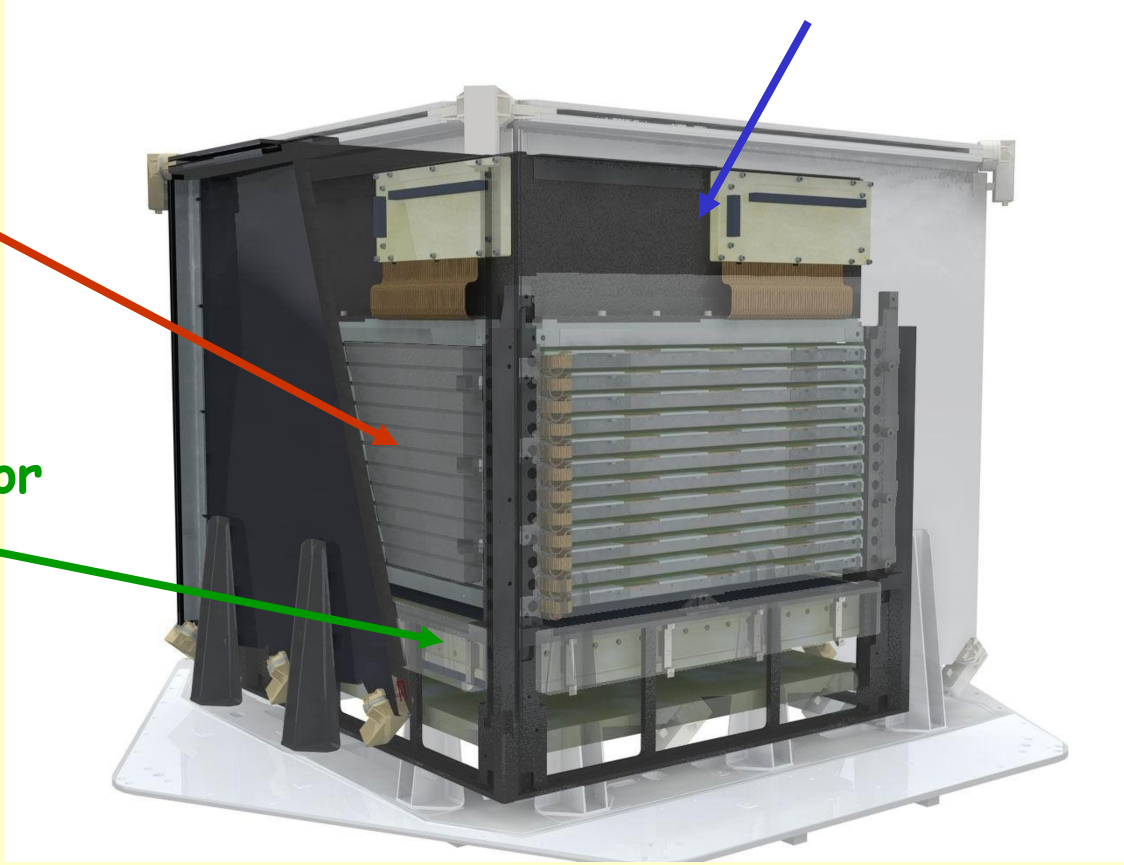
Inclination angle: 2.48° (±0.04°)

Eccentricity: 0.002 (±0.0015)

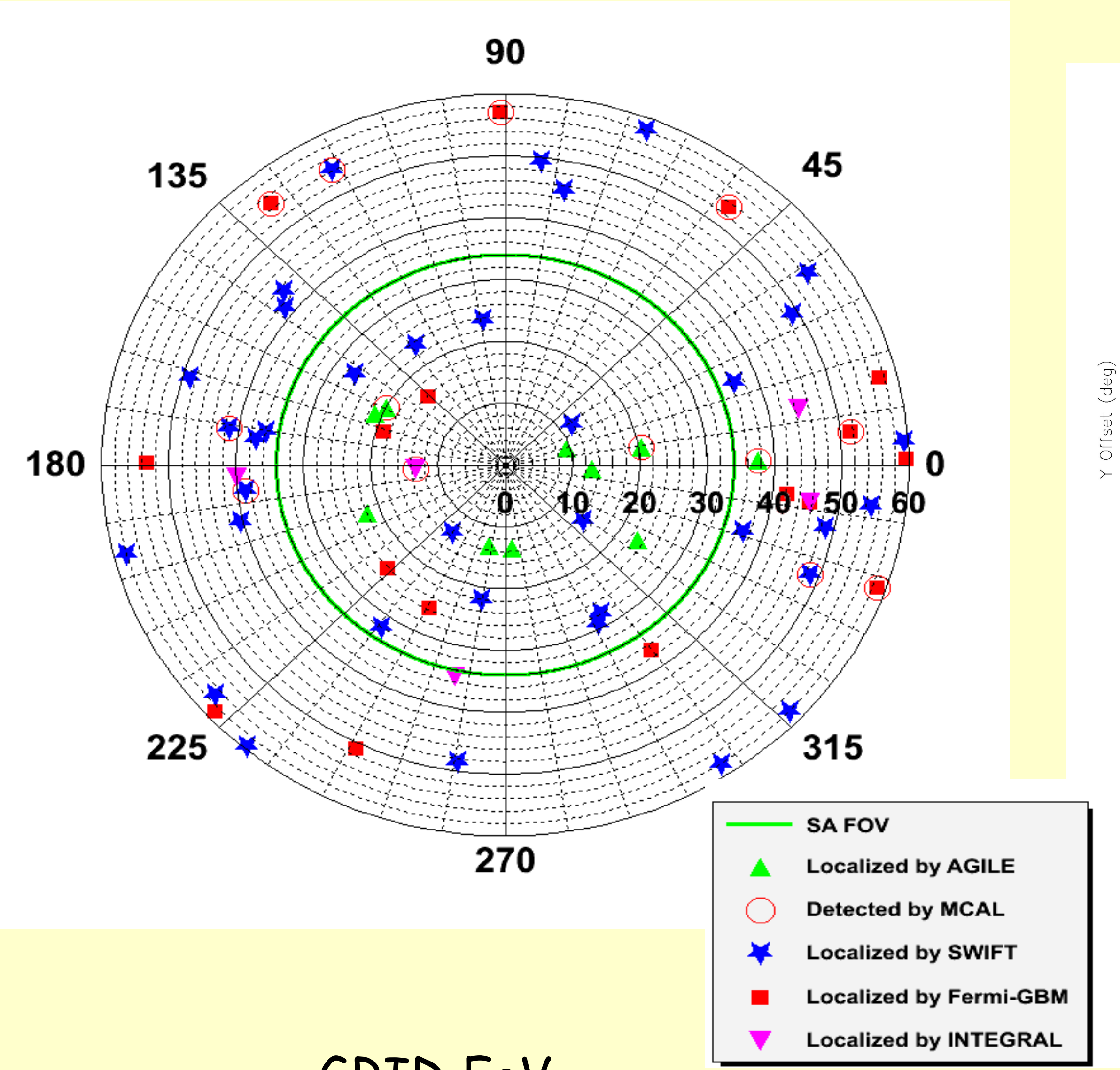
SuperAGILE
Coded aperture
18 – 60 keV
~1 sr FoV

Gamma Ray Imaging Detector
Silicon tracking detector
30 MeV – 50 GeV
~2.5 sr FoV

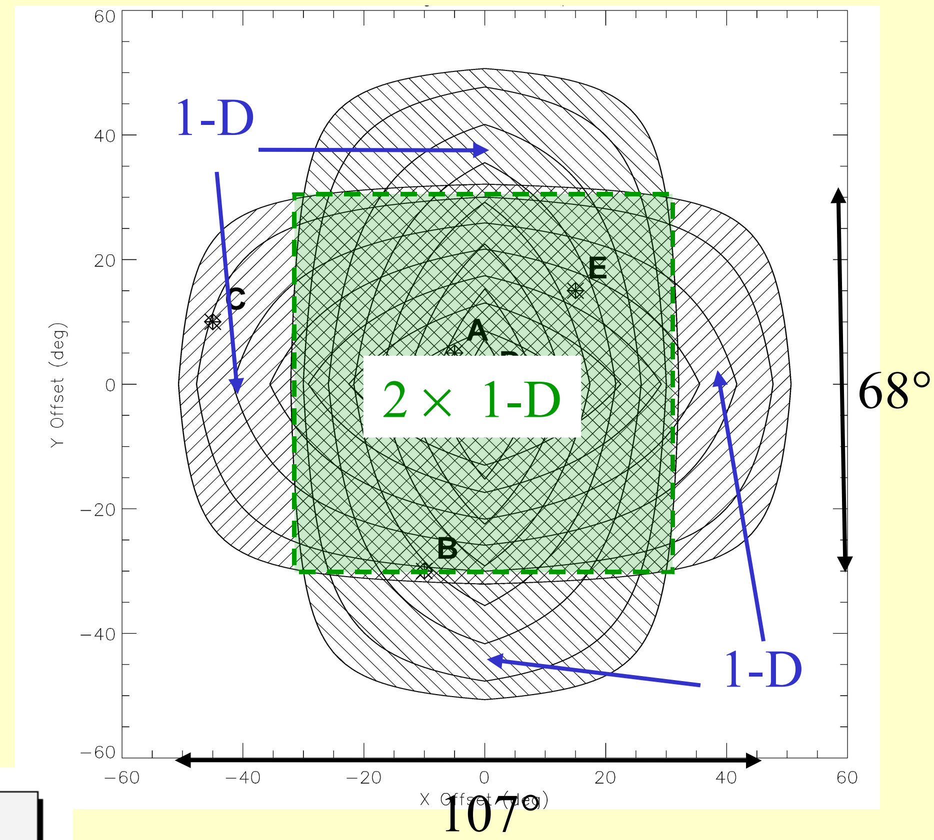
Mini-calorimeter
non imaging scintillator
0.3 – 200 MeV
almost all-Sky FoV



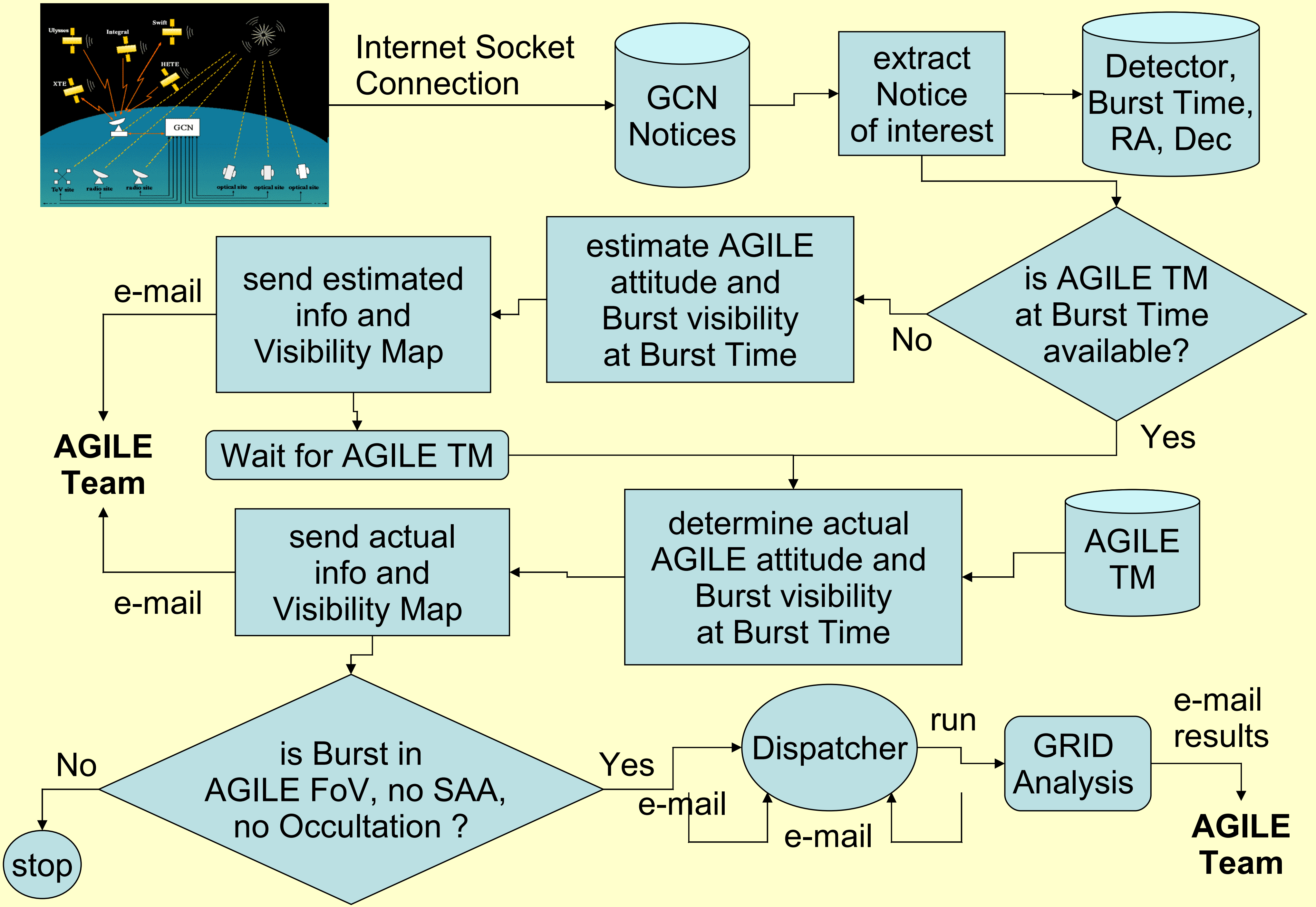
How large is our view?



GRID FoV



SuperAGILE FoV



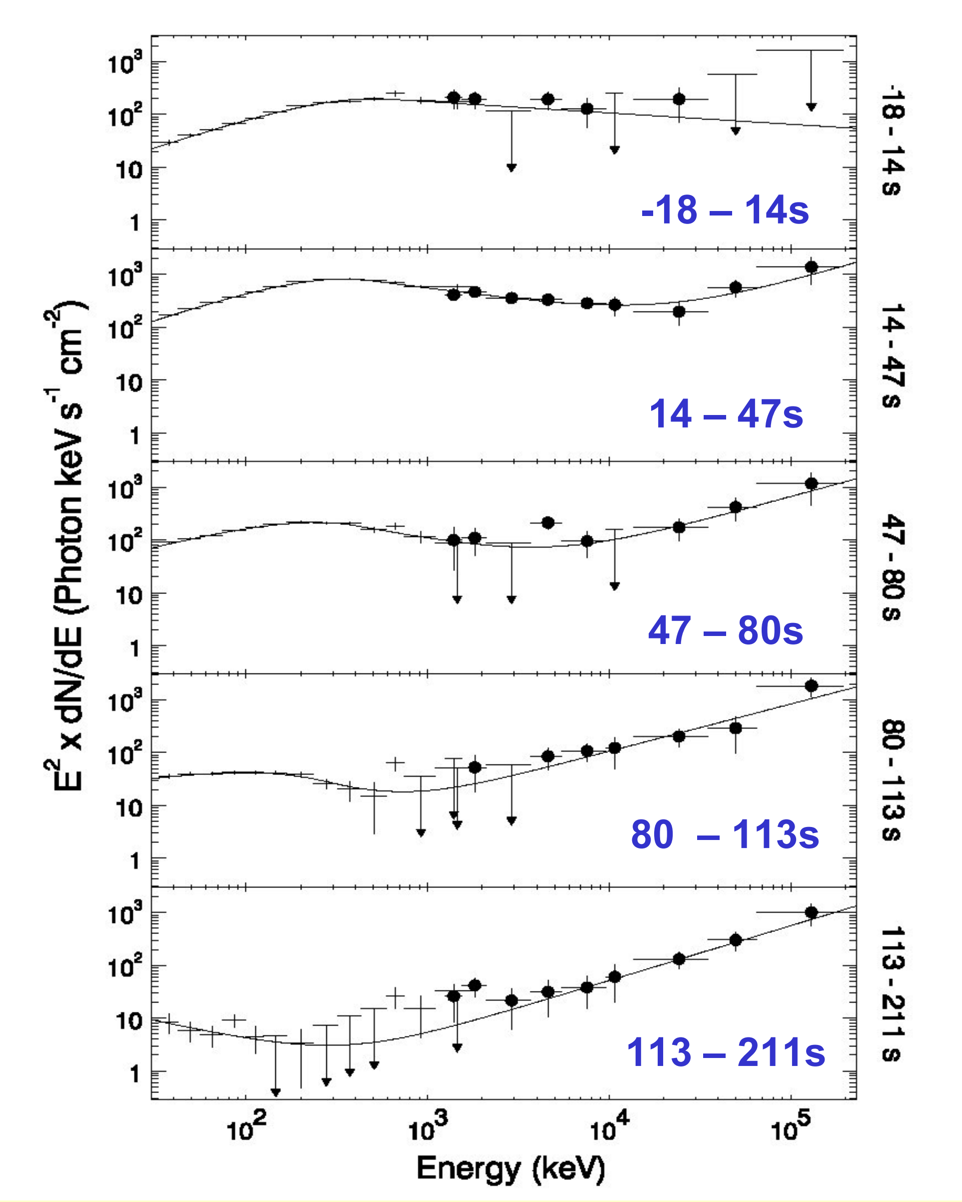
Ulysses
Integral
Swift
HETE
XTE
GCN
TeV site
radio site
radio site
optical site
optical site
optical site
Internet Socket Connection
GCN Notices
extract Notice of interest
Detector, Burst Time, RA, Dec
is AGILE TM at Burst Time available?
No
estimate AGILE attitude and Burst visibility at Burst Time
send estimated info and Visibility Map
e-mail
AGILE Team
Wait for AGILE TM
Yes
determine actual AGILE attitude and Burst visibility at Burst Time
AGILE TM
send actual info and Visibility Map
e-mail
is Burst in AGILE FoV, no SAA, no Occultation ?
No
stop
Yes
Dispatcher
run
GRID Analysis
e-mail
e-mail
e-mail results
AGILE Team

The EGRET inheritance on GRB

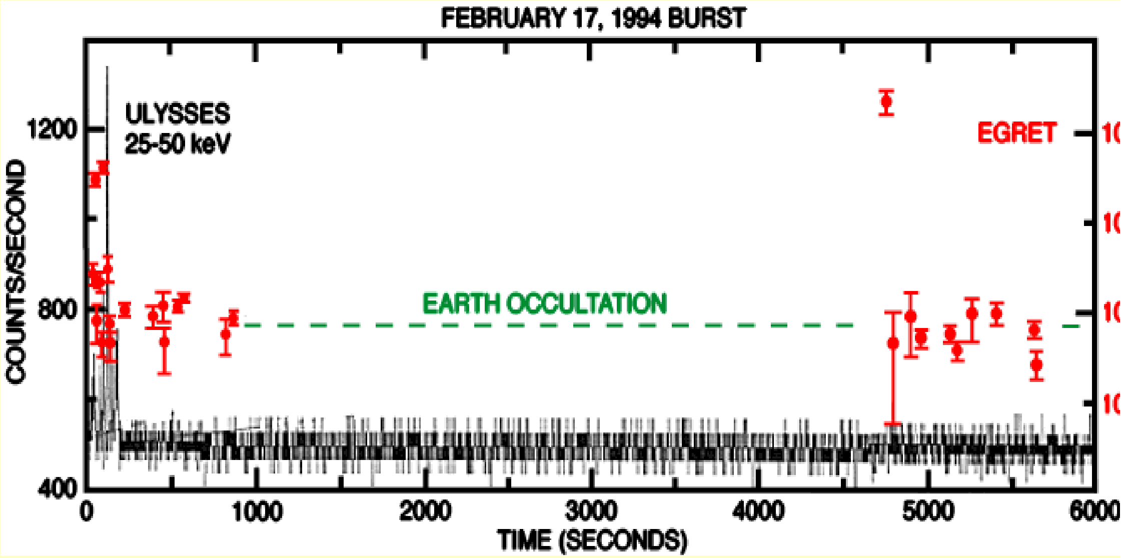
Gonzalez, Nature 2003 424, 749

2 main not solved issues:

- The high energy component (as in 941017); → seen again in 090510
- The very late high energy emission (as in 940217) → not seen again!



Hurley et al. 1994



Detected

Hard X-rays:

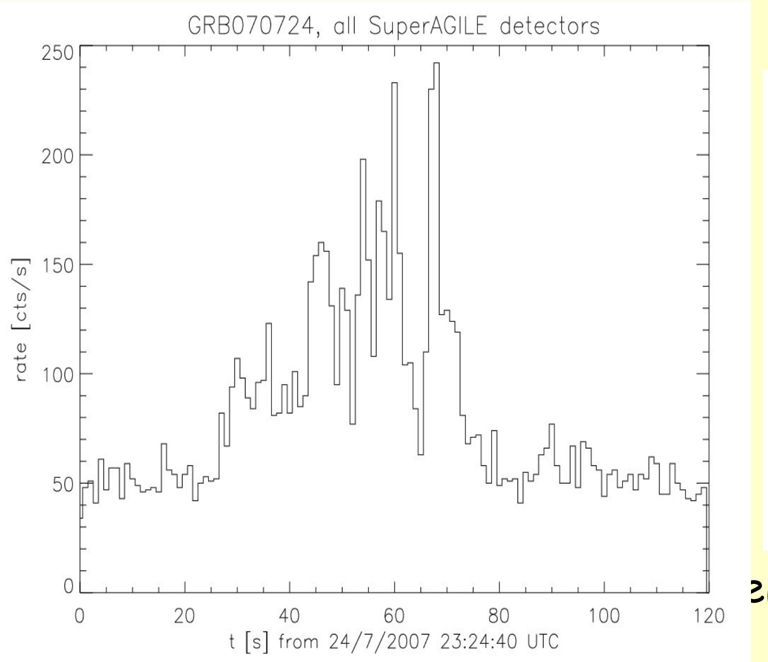
- 29 GRBs localized by SuperAGILE since July 2007 => ~1 GRB/month;
- 3 arcmin radius uncertainty on the localization and minimum detected fluence of ~5×10^{-7} erg cm^{-2}

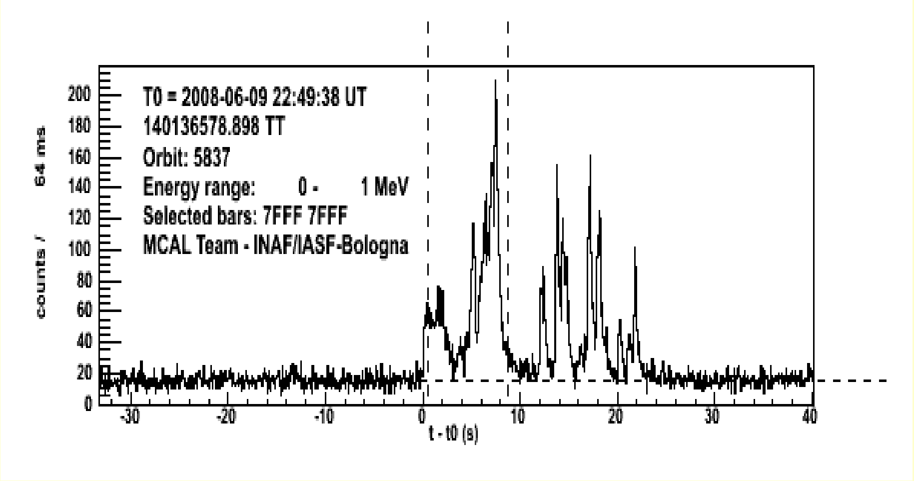
Soft Gamma rays

- ~1 GRB/week detected by MCAL and 1 – 2 GRBs/month detected by SuperAGILE outside the FoV (303 from July 2007 to April 2009);

Gamma rays

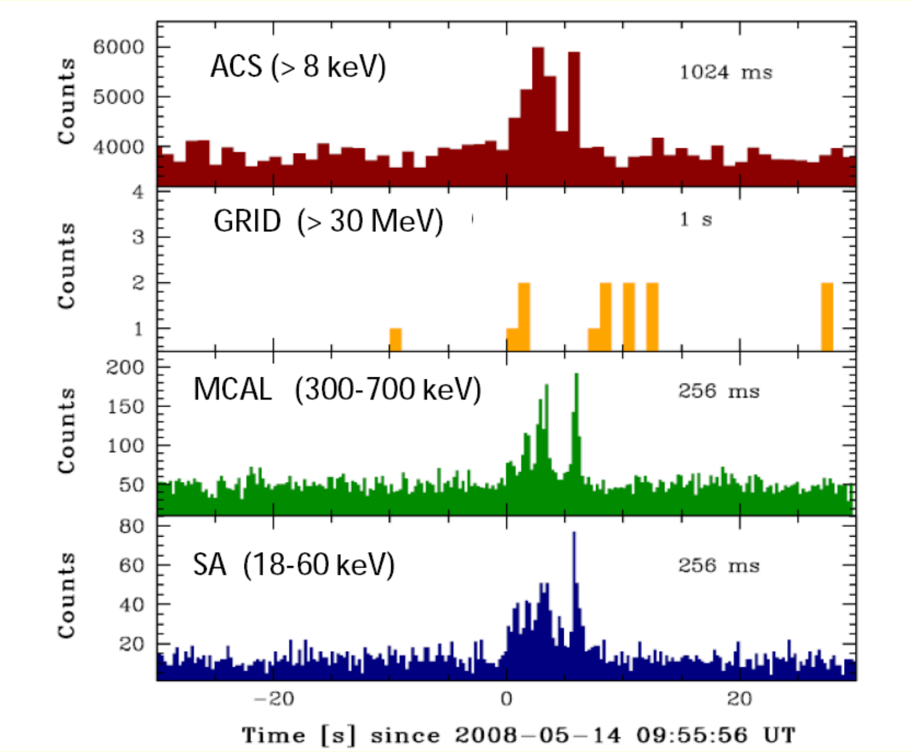
- Three firm detections: GRB 080514B, GRB 090401B and GRB 090510;
- Two less significant detections: GRB 080721 and GRB 081001;





Detected in GRID

Giuliani et al. 2008

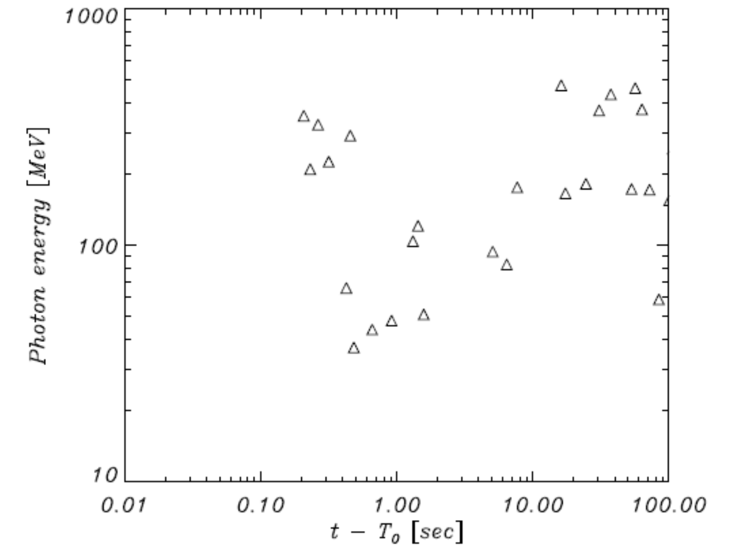


- GRB 080514B: long GRB, with extended emission of gamma rays and single Band spectrum (20 keV – 50 MeV);

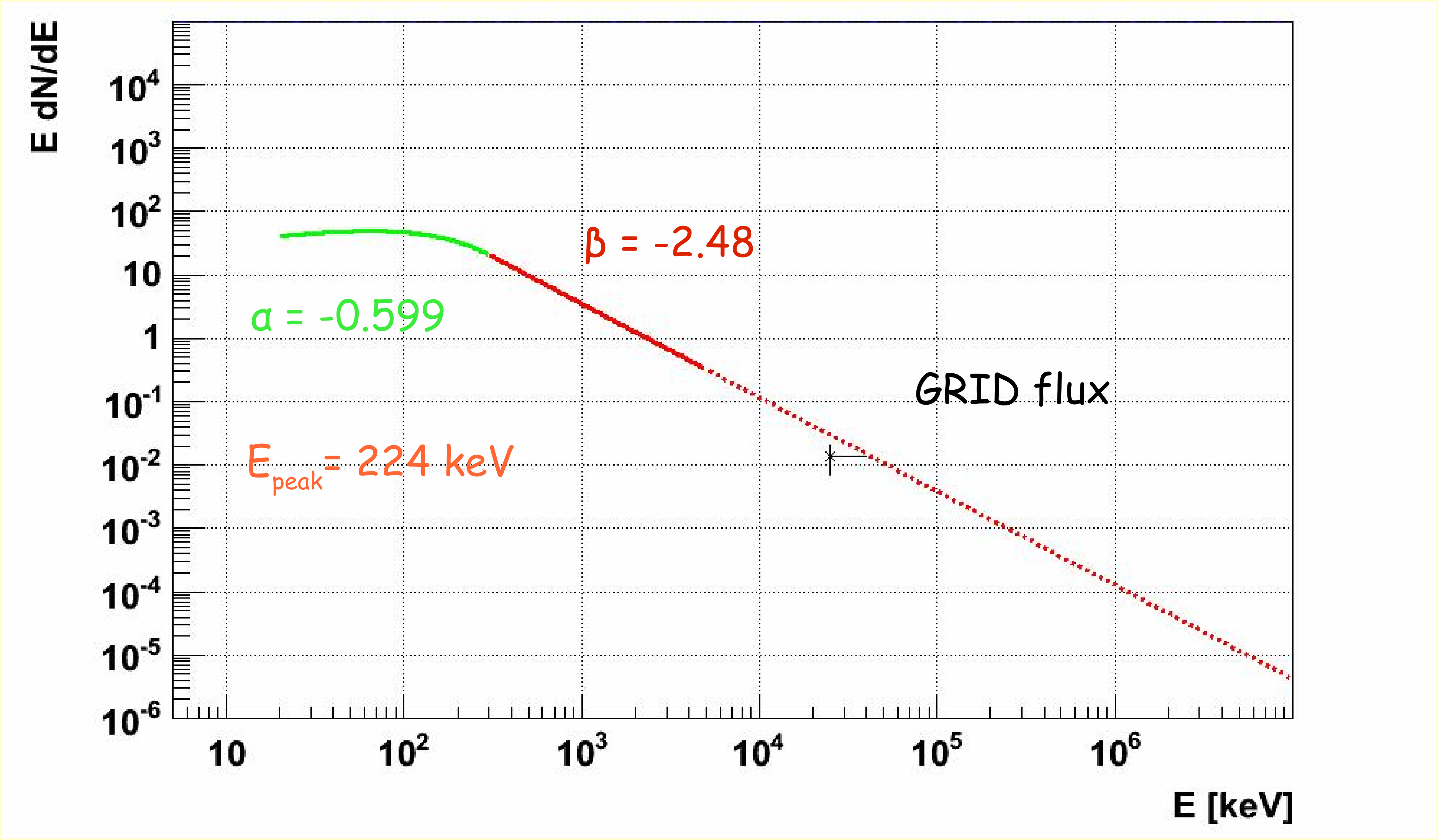
- GRB 090401B: long GRB with multiple peak structure, simultaneous and extended emission of gamma rays

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

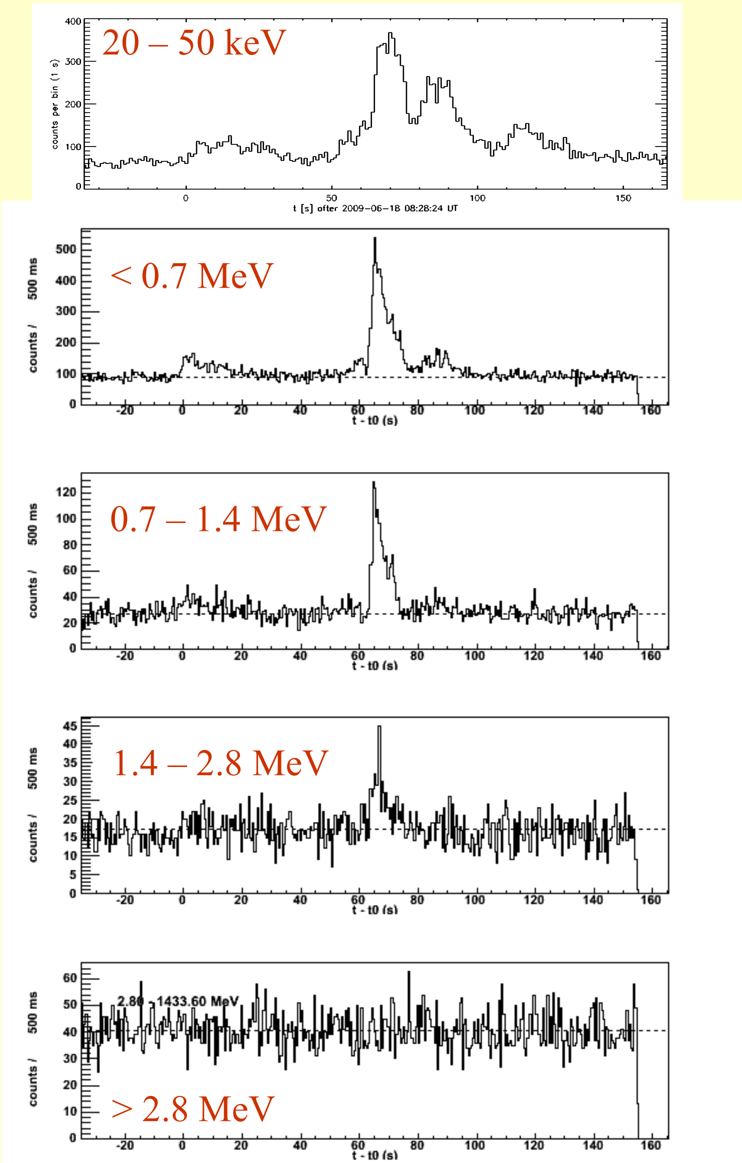
Giuliani et al. 2009

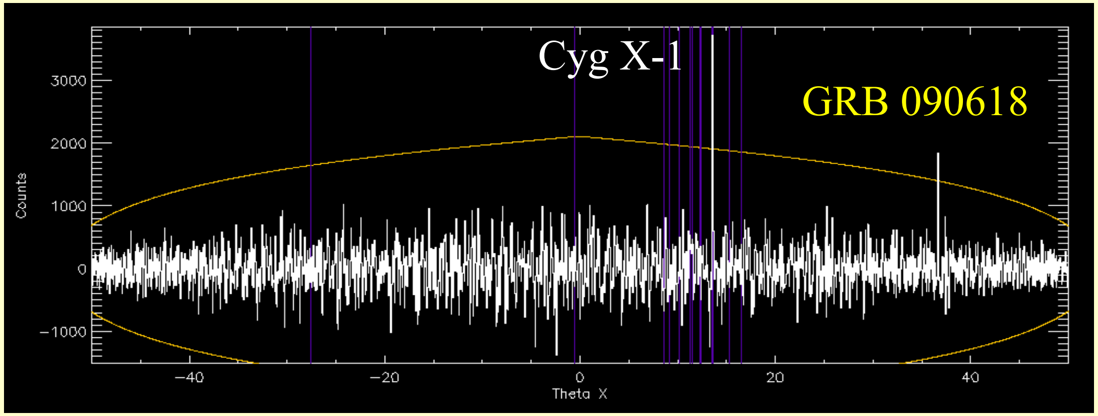


The spectrum of 080514B



Not detected: the case of 090618

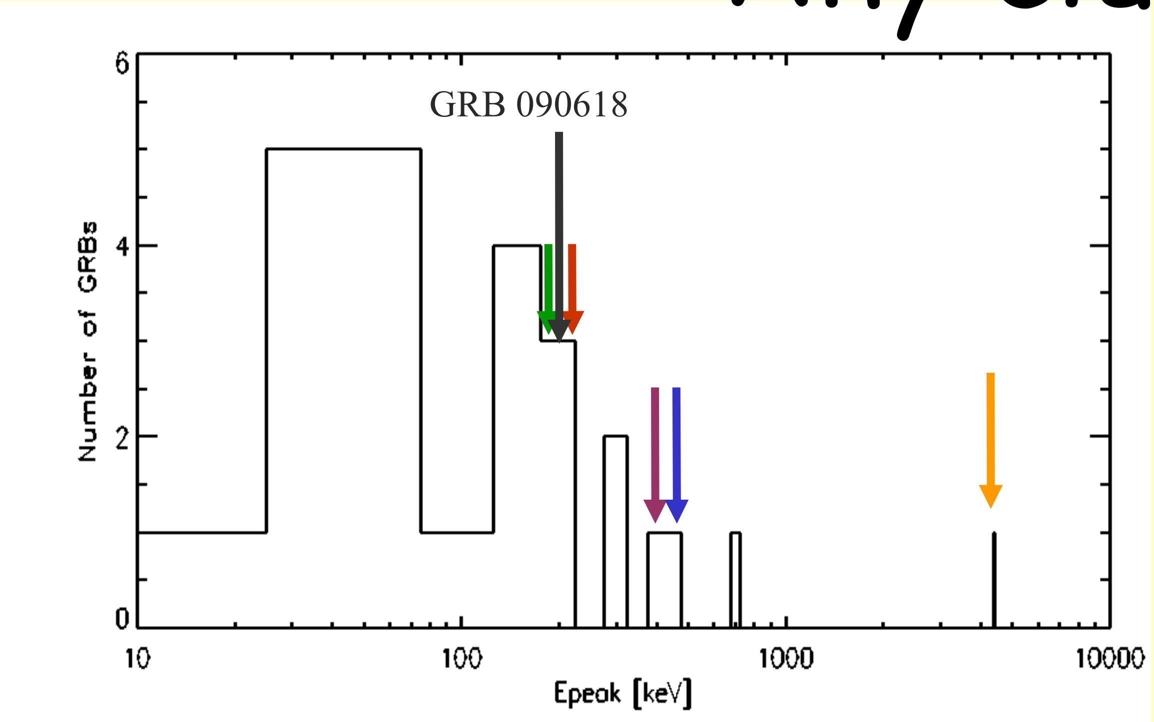


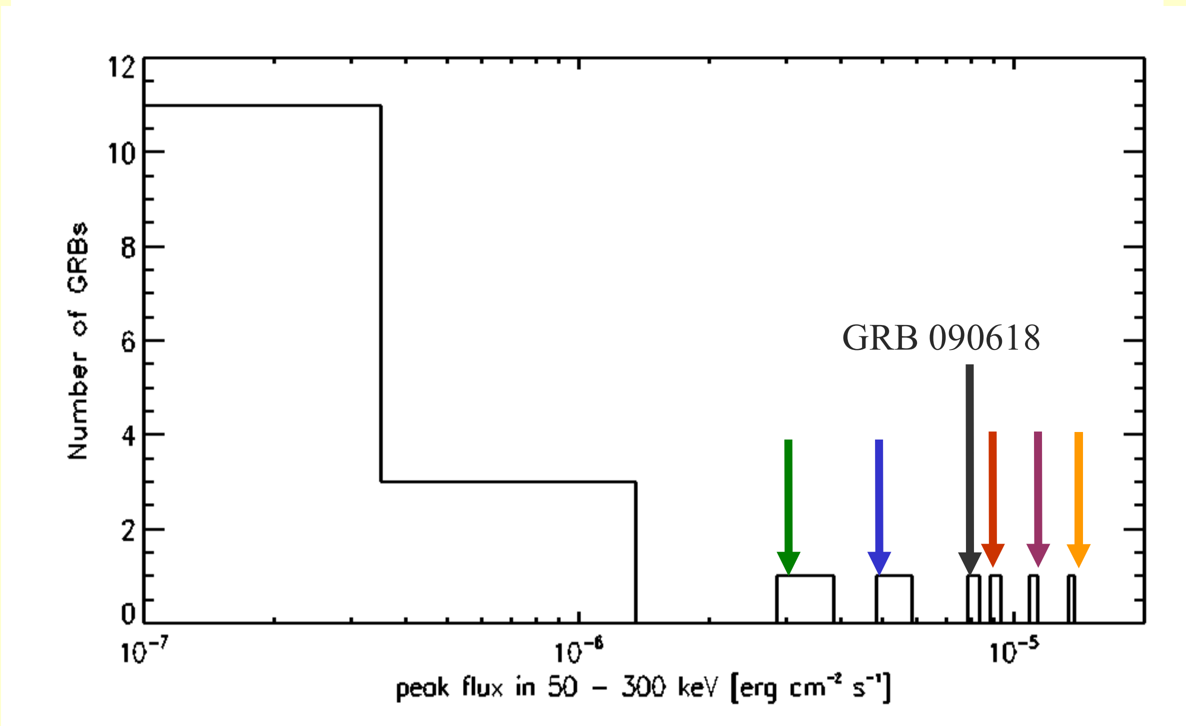


GRB 090618 compared with Cyg X-1 in the orbital image of SuperAGILE (20 – 50 keV, 3 ks exposure).

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

Any clue?





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

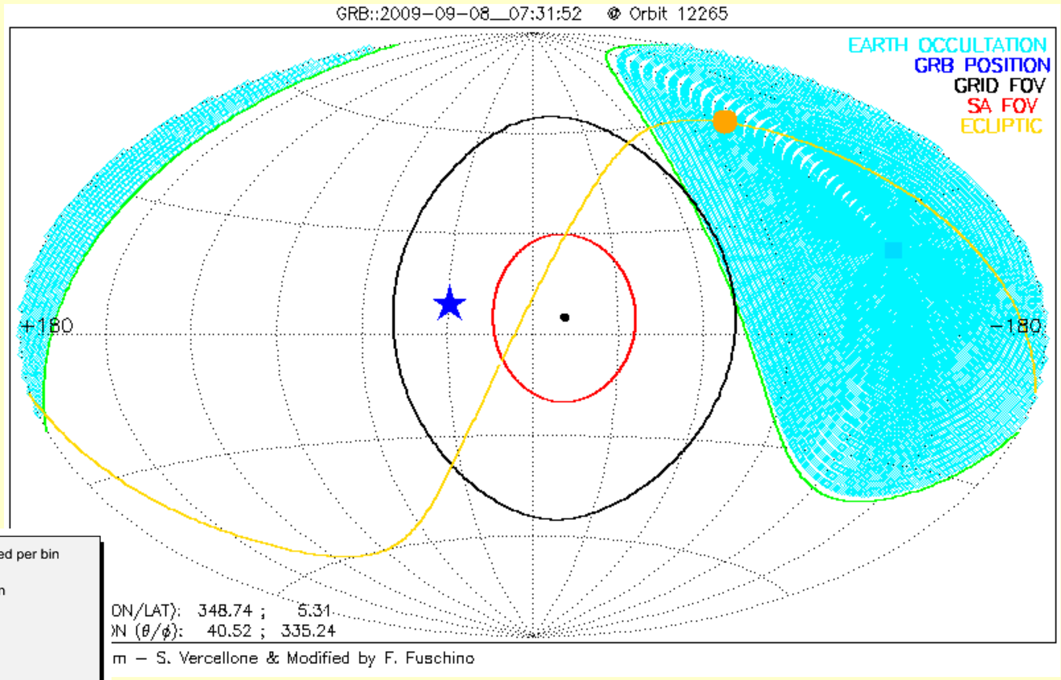
GRB 080514B, GRB 090401B and GRB 090510 are firmly detected by GRID;

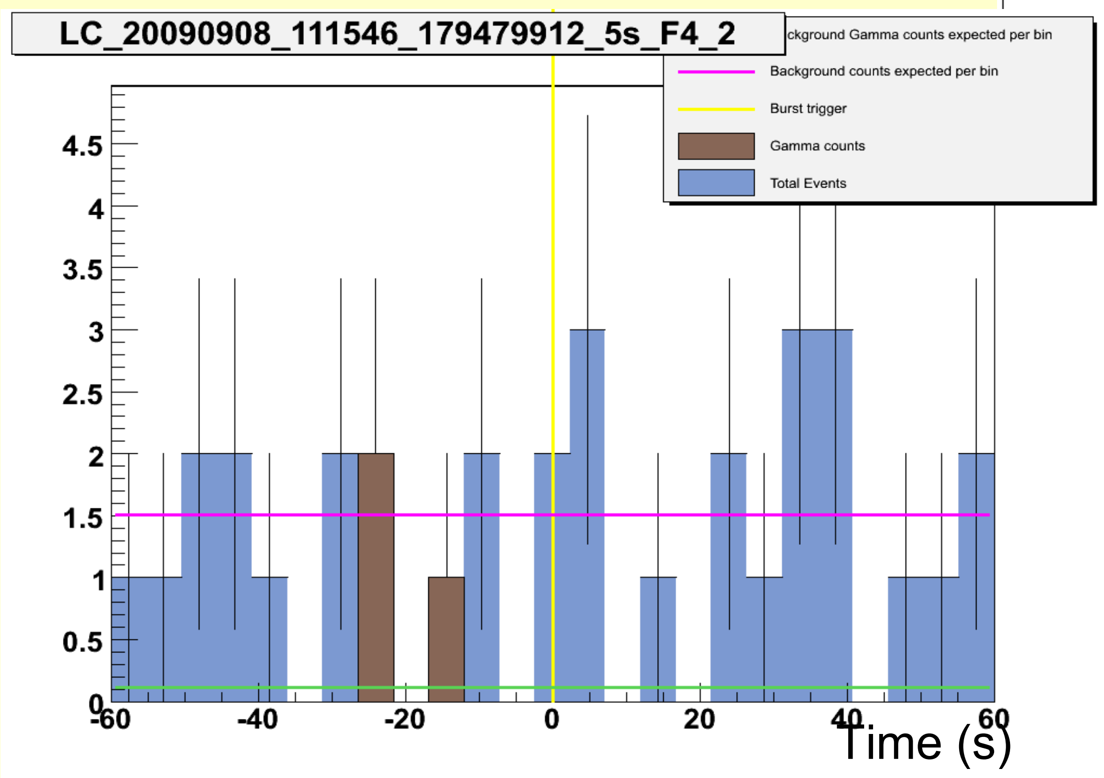
GRB 080721 and GRB 081001 have smaller significance in GRID;

The sample

36 localized by SWIFT
17 localized by Fermi-GBM
10 localized by SuperAGILE
5 localized by INTEGRAL
10 detected by MCAL

30 GRBs with spectral informations

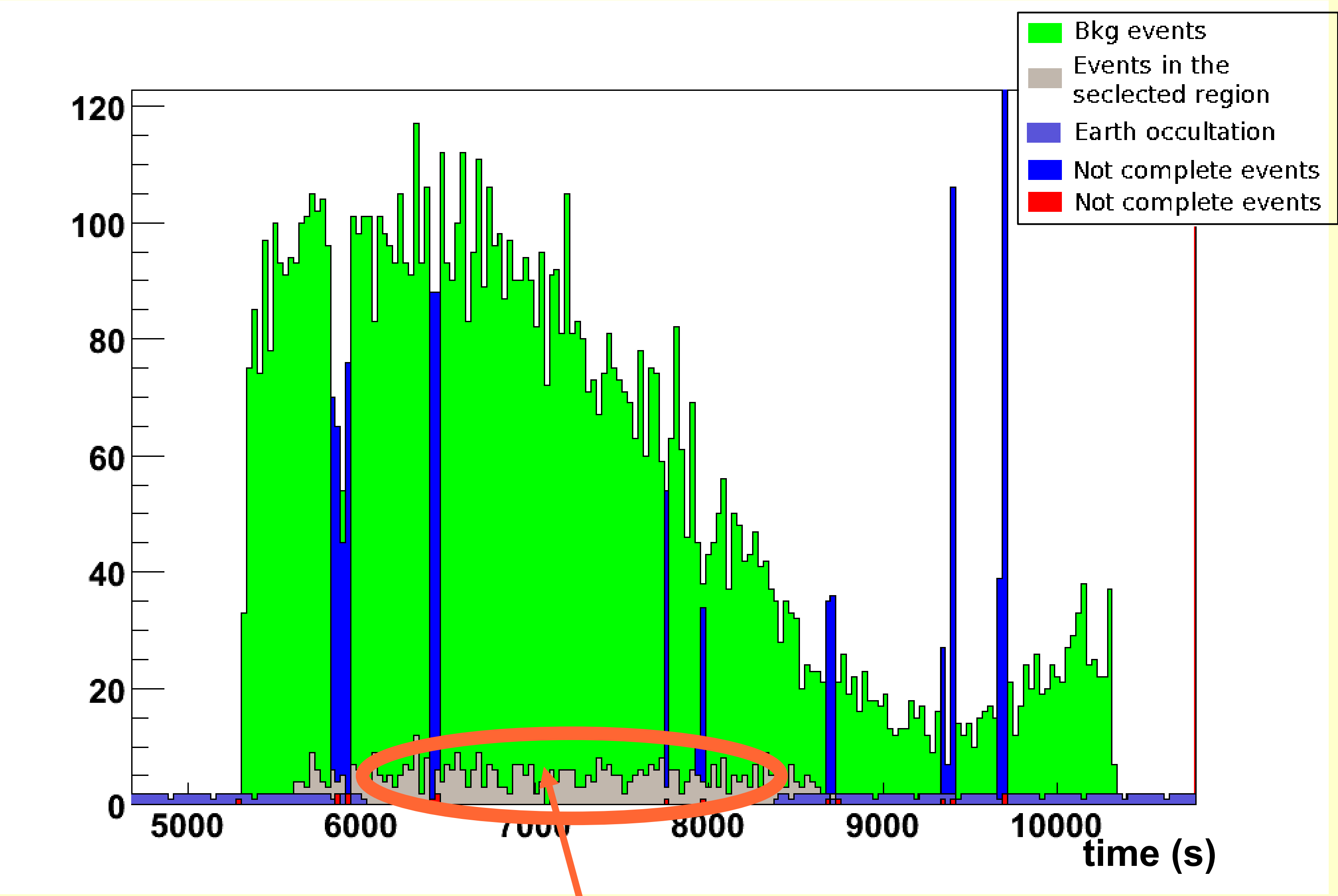




Background extraction

To extract the background we want to look:

- into a region where there is no signal (before the trigger);
- into the same spatial region as the one where we extract the signal: 15 deg;
- when this region is not occulted by earth;
- when the data taken by AGILE are complete with all information.



The modulation in the all bkg event distribution is no longer present in the selected region events.

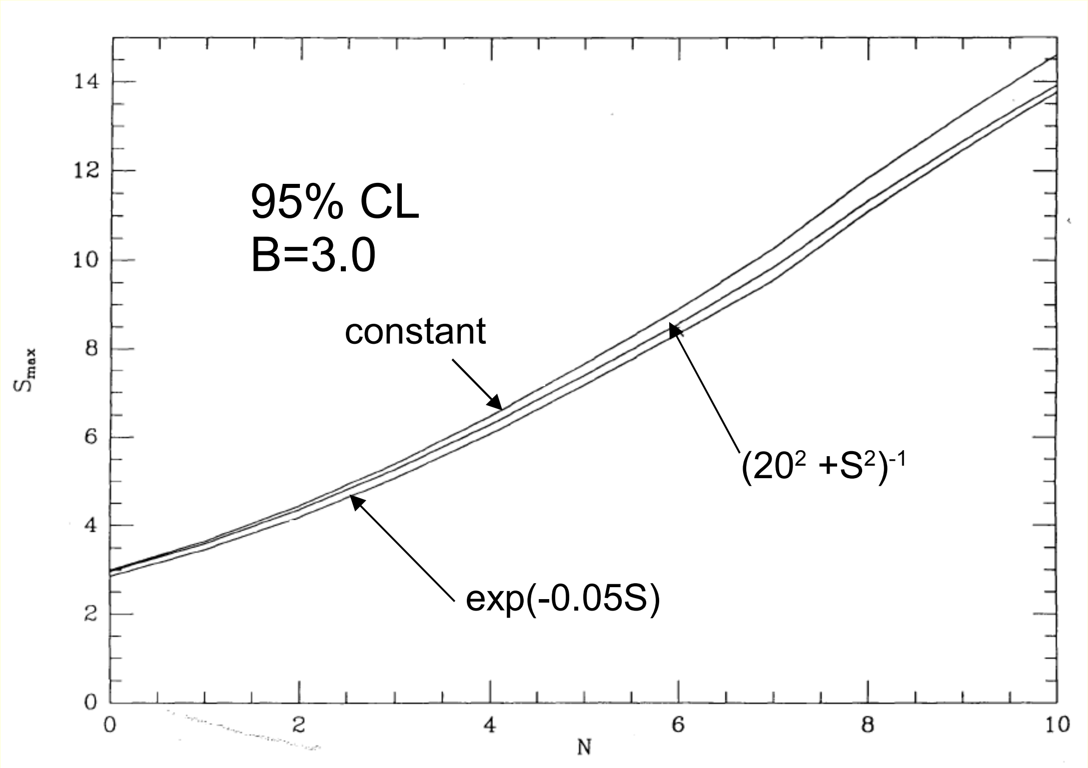
The Helene Method

We know the mean value of background counts, but not the background counts expected in the signal region (B), nor the number of signal counts (S). We suppose that the probability distribution of S is constant from 0 to ∞.

From Bayes's theorem: $f_{N,B}(S) \propto p(S)P_S(N)$

The posterior probability distribution ($f_{N,B}(S)$) for a conditional distribution function ($P_S(N)$) that is a Poisson distribution with a constant a prior ($p(S)$) is:

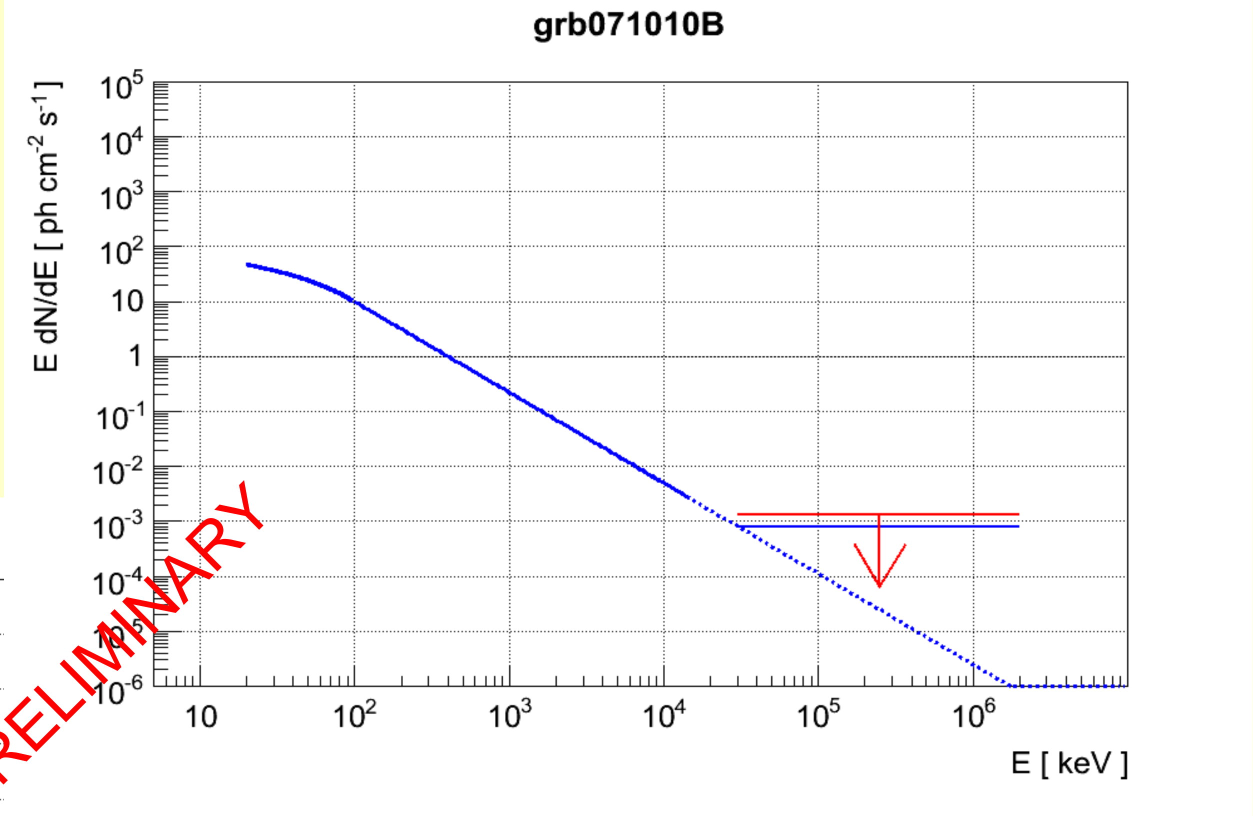
$$f_{N,B}(S) = C\,\frac{e^{-(S+B)}(S+B)^N}{N!}$$

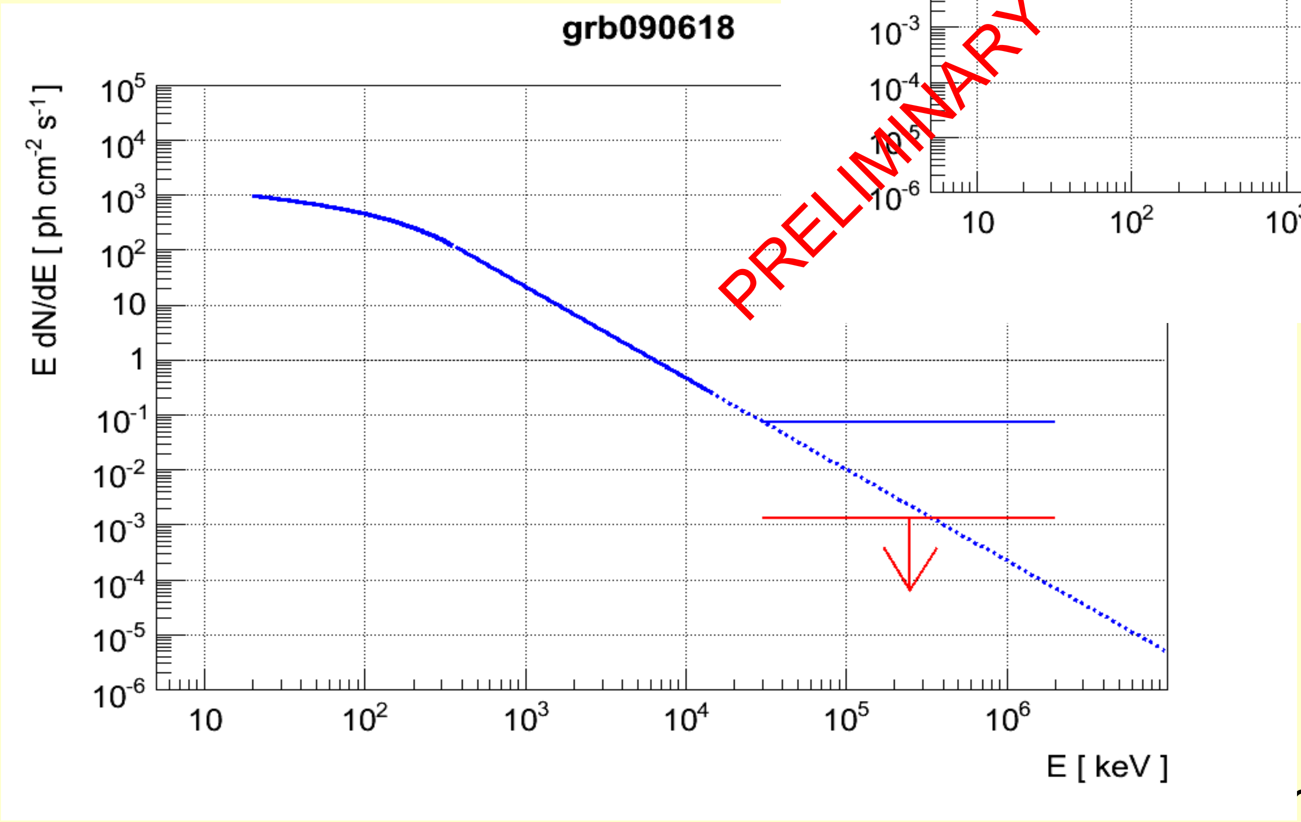


The UL on S does not change if priors with a decreasing probability for high S counts are used.

Results

Temporal integrated spectra with spectral parameters from Konus-Wind or WAM or BAT or GBM.





Conclusions

- ✓ AGILE detected 3 GRBs so far: 080514B, 090401, 090510
- ✓ Al the GRBs in the GRID-Fov were analysed and their flux upper limit calculated tipically it is $0.015 - 0.04$ ph/cm^2.
- ✓ High energy emission in prompt phase both from long and short GRBs
- ✓ High energy emission not a common property for all GRBs 1/8months (disagreement with pre-launch expectations: 0.5-1/month obtained from EGRET/GRID FoV ratio) but EGRET detected 1/10 GRBs in its FoV per year while GRID 1/20!
- ✓ High energy emission not always from an extra-component
- ✓ Is the peak flux parameter that determines the detectability?

Thank you!

References for the method

- Helene O. 1983 Nucl. Instr. Meth. 212, 319;
- Helene O. 1984 Nucl. Instr. Meth 228, 120;
- Kraft, Burrows, Nousek 1991 ApJ 374, 344;

UL calculation with the Helene method

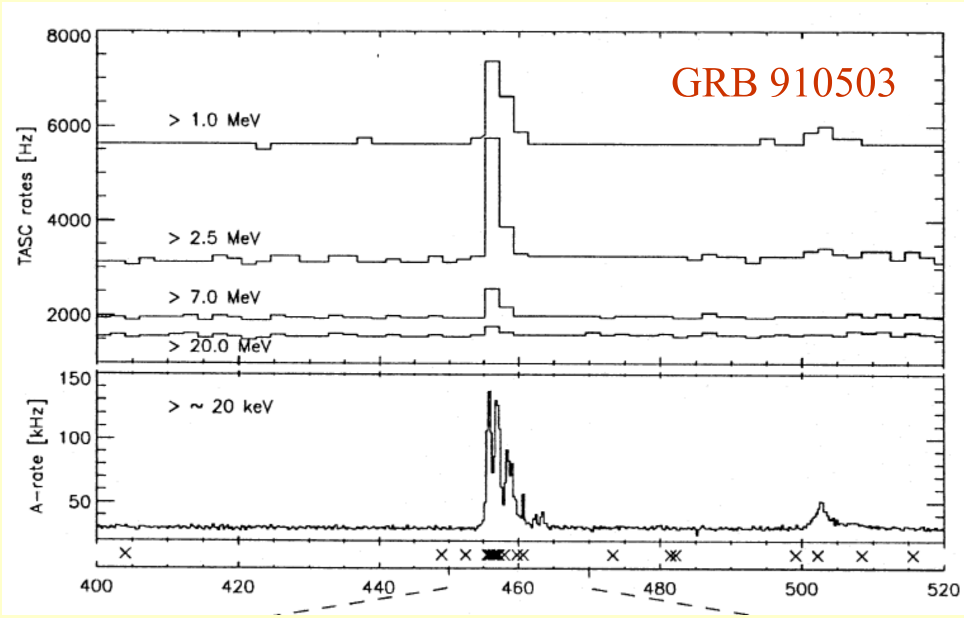
There are several errors in quoting UL on a source flux:
- Using the UL on the source flux only from the Poisson distribution of the mean of the background counts (forgetting to use the information from the signal or at least the hypothesis on the signal);
- Using N' = N – B as the upper limit on signal (forgetting the Poisson fluctuations on signal and on background).

With the Helene method we can quote the UL on source flux considering the Poisson fluctuations on signal and background.

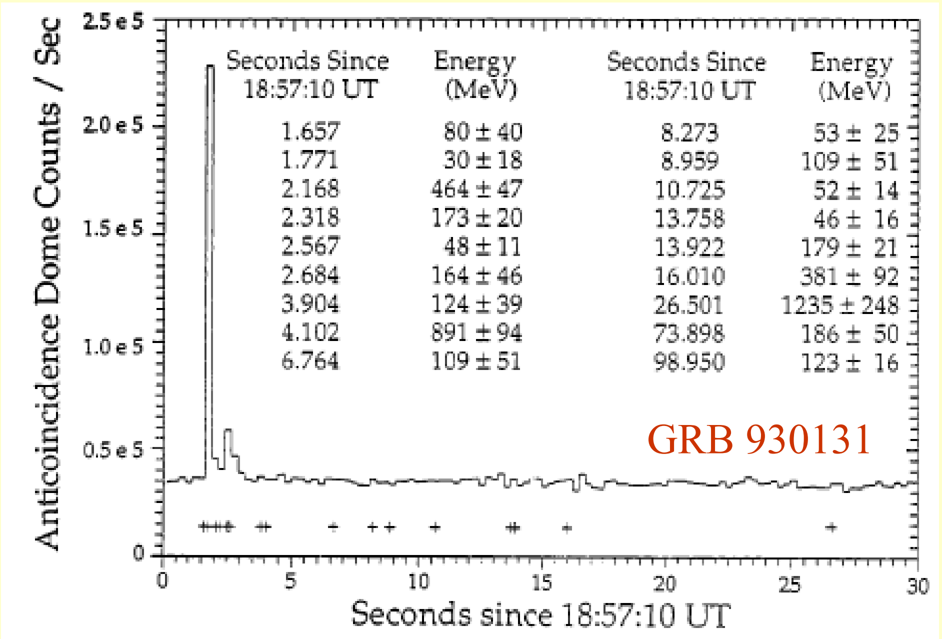
With this method we calculate an upper and a lower limit on signal counts.
If the lower limit is not 0.0 we have a detection.

To be compared with other methods (eg. Li and Ma)

Es: 95% CL with B = 4 we have a detection with N = 9.
95% CL with B = 6 we do not have a detection at N = 10.



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.

- Prompt high energy emission can be explained by the synchrotron and inverse Compton emission both in internal and external shocks.
- GeV cut off will constraint the bulk Lorentz factor of GRBs and the radius of the internal energy dissipation (Fan &Piran 2009).
- A lack of strong SSC GeV emission will disfavour the barionic model and favour the internal magnetic energy dissipation (Fan &Piran 2009).
- For some GRBs 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;
- Following Fan 2009, the gamma rays are delayed because the early outflow have Lorentz factor smaller (baryon pollution) than the late emission;