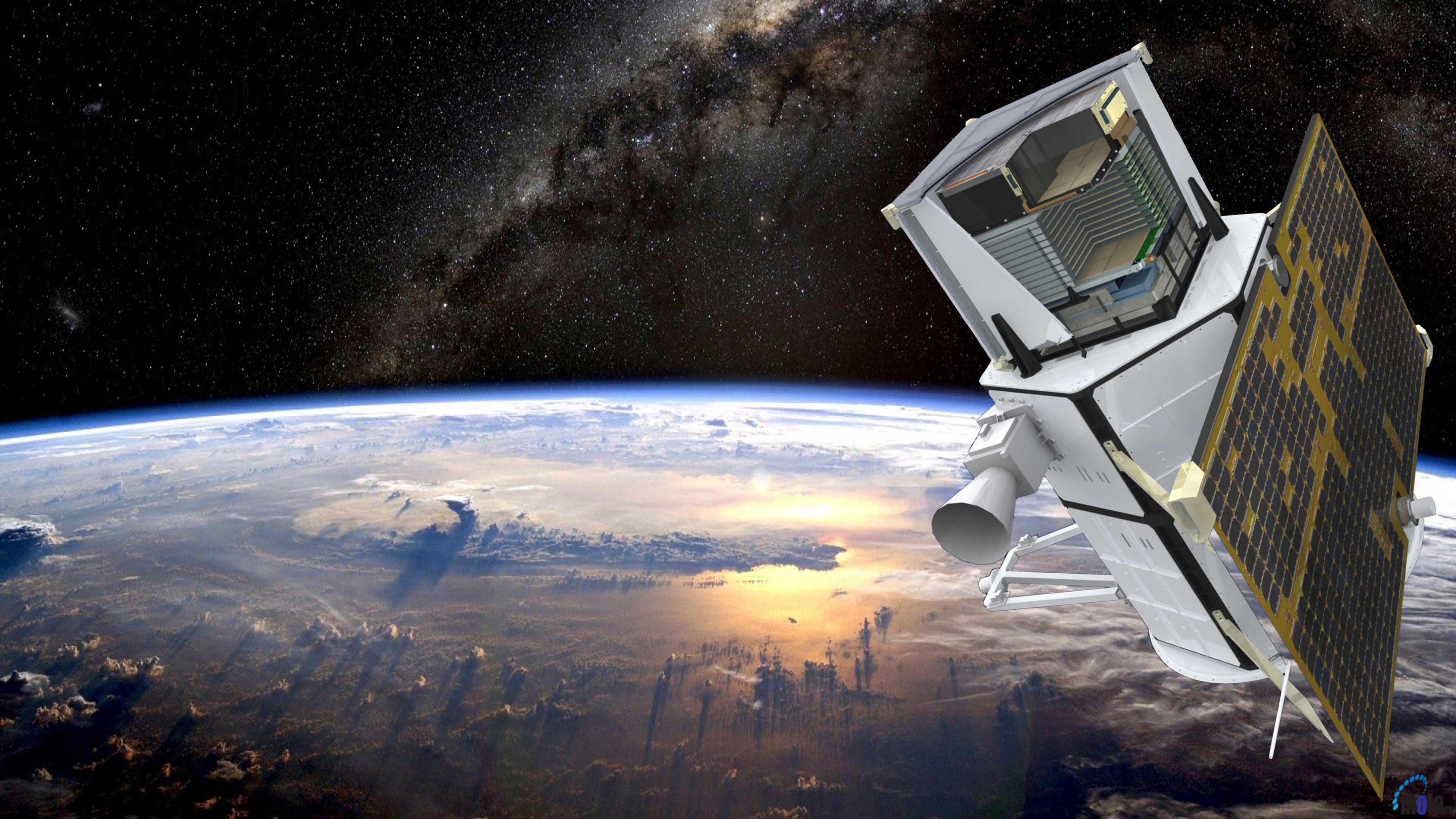
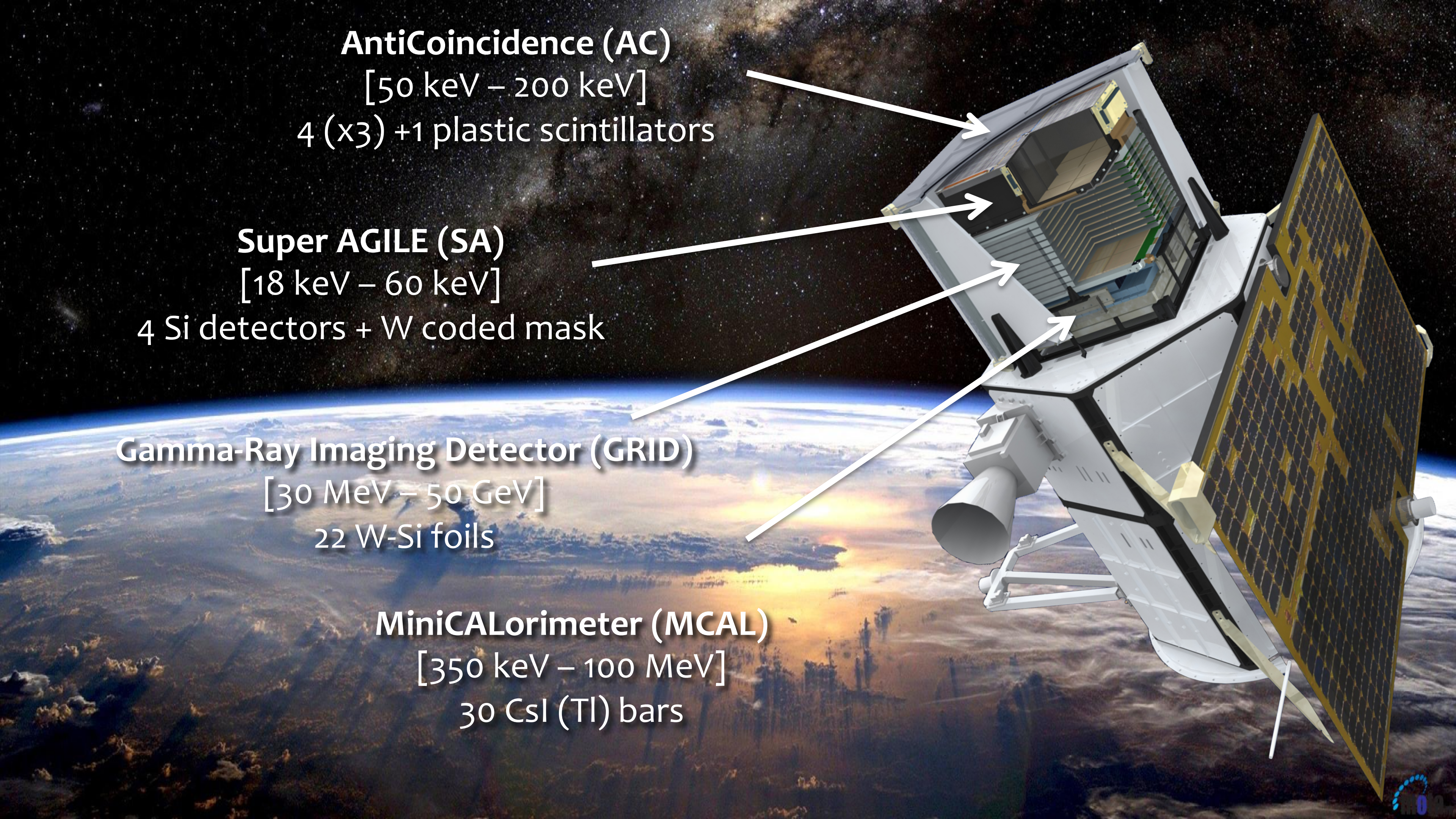
AGILE
GRB observations

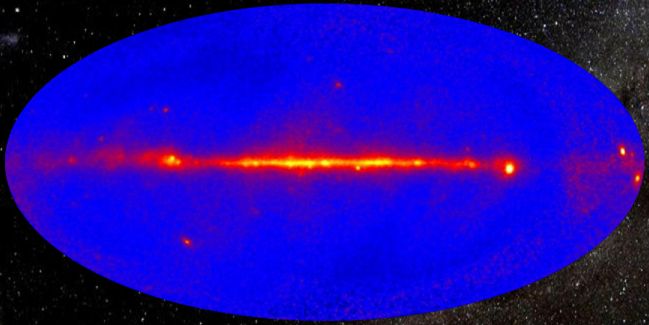
Alessandro Ursi
(INAF-IAPS, Rome)
on behalf of the AGILE Team



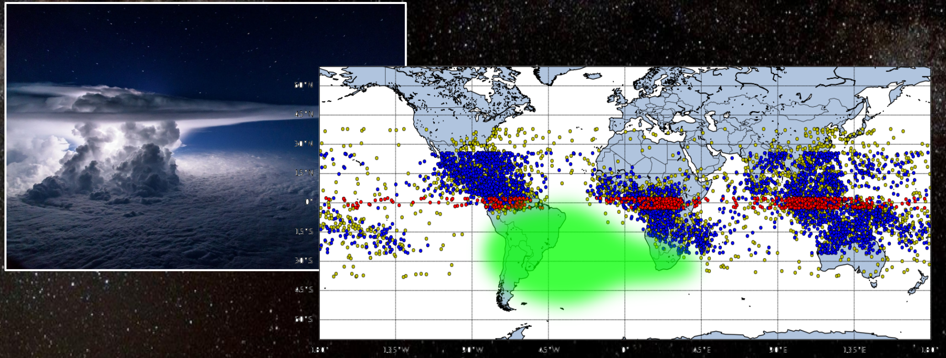


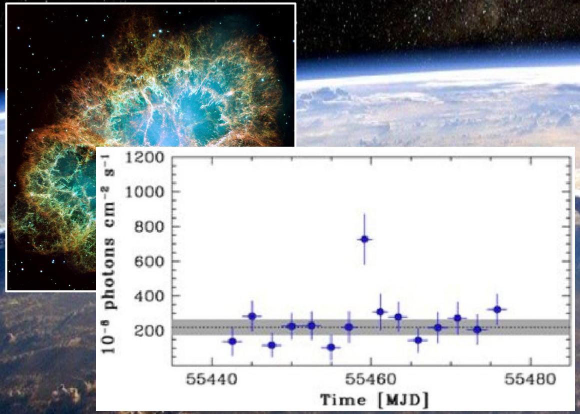
AntiCoincidence (AC)
[50 keV – 200 keV]
4 (x3) +1 plastic scintillators
Super AGILE (SA)
[18 keV – 60 keV]
4 Si detectors + W coded mask
Gamma-Ray Imaging Detector (GRID)
[30 MeV – 50 GeV]
22 W-Si foils
MiniCALorimeter (MCAL)
[350 keV – 100 MeV]
30 CsI (Tl) bars

gamma-ray sky

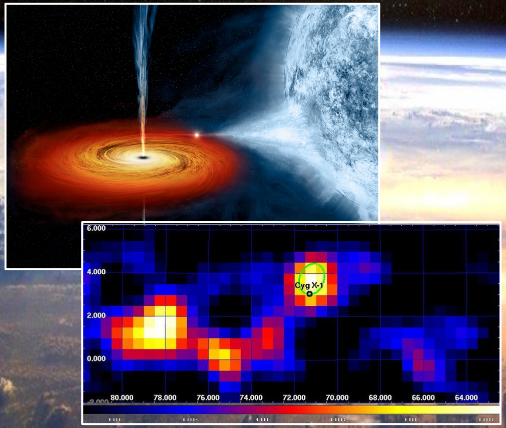


Terrestrial Gamma-ray Flashes (TGFs)

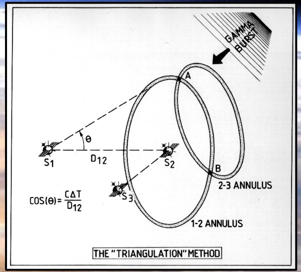




Crab nebula



Cygnus region



IPN partner

LIGO VIRGO

GW follow-up partner

• spinning •

imagers scan 80% sky / 7 min

• low-inclination orbit •

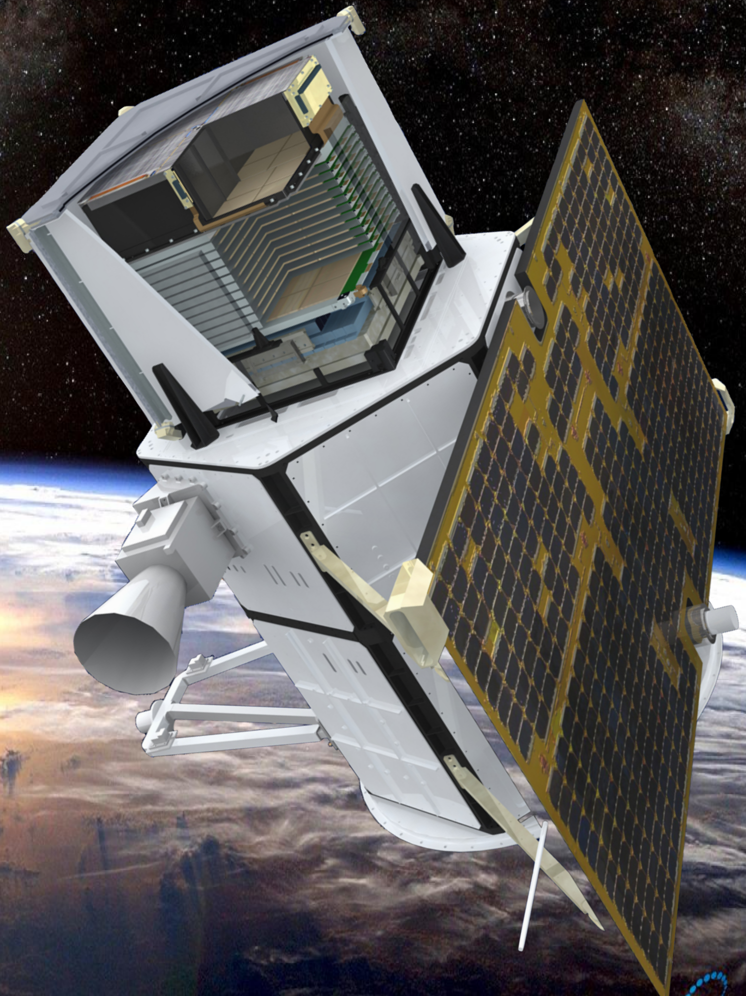
2.5° low background

• sub-ms trigger logic •

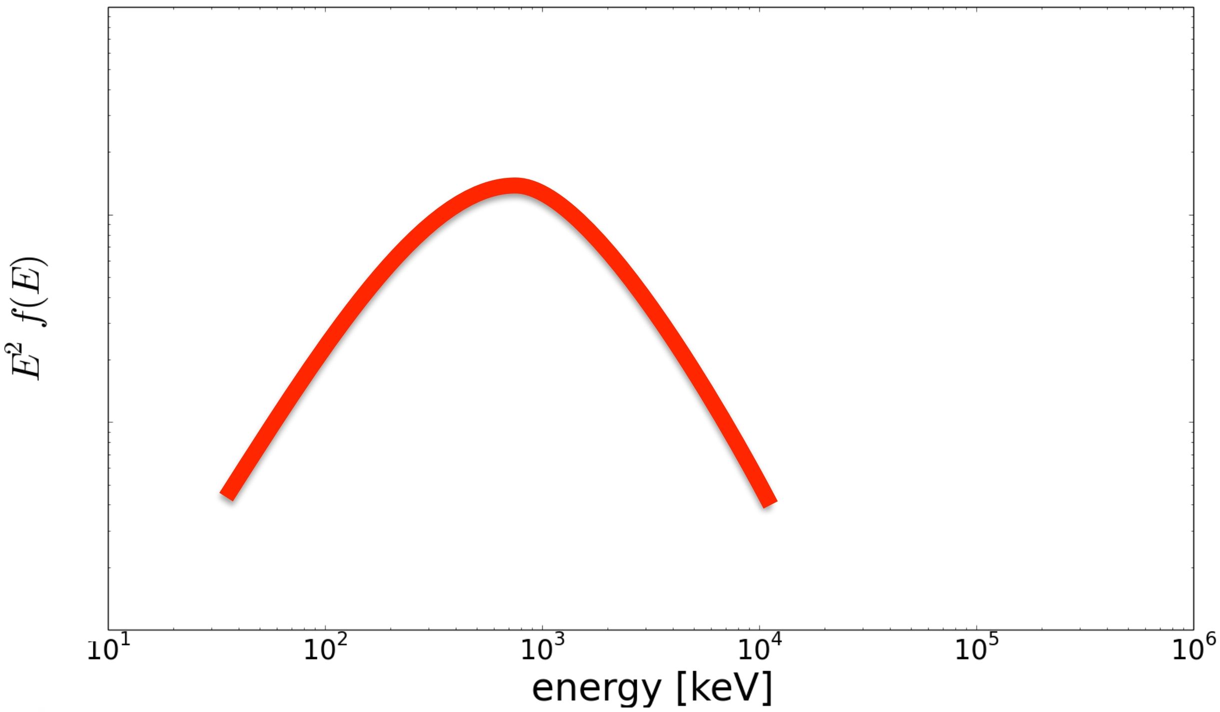
sensitive to fastest transients

• high-energy range •

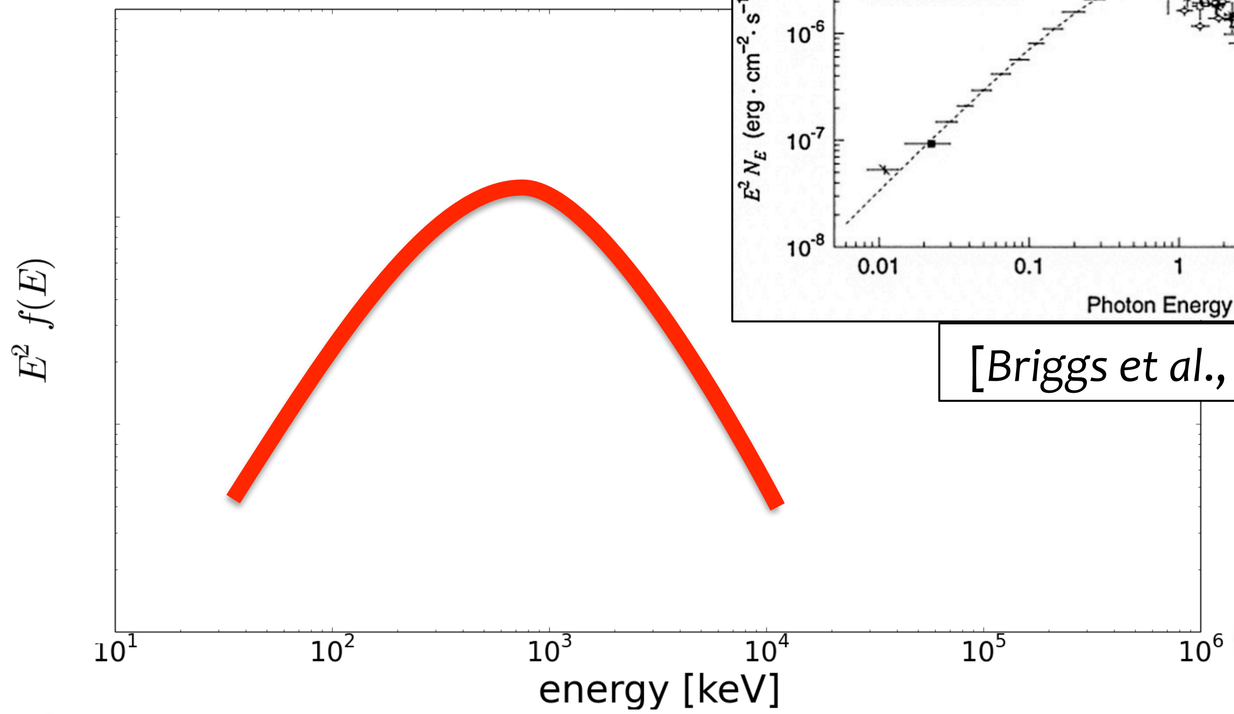
h.e. GRB component

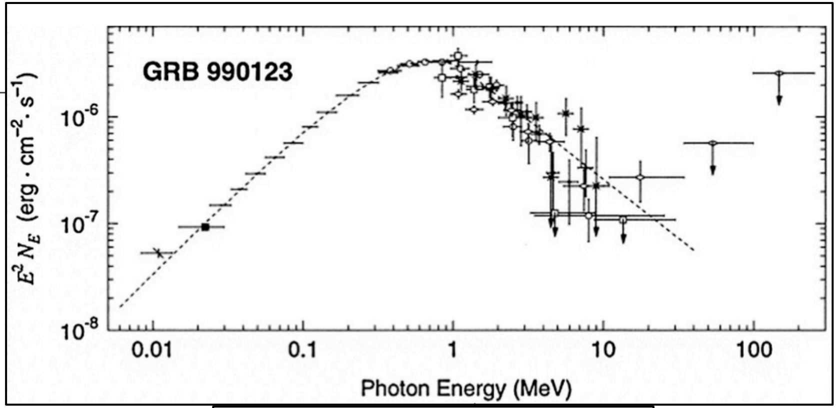


High-Energy GRBs



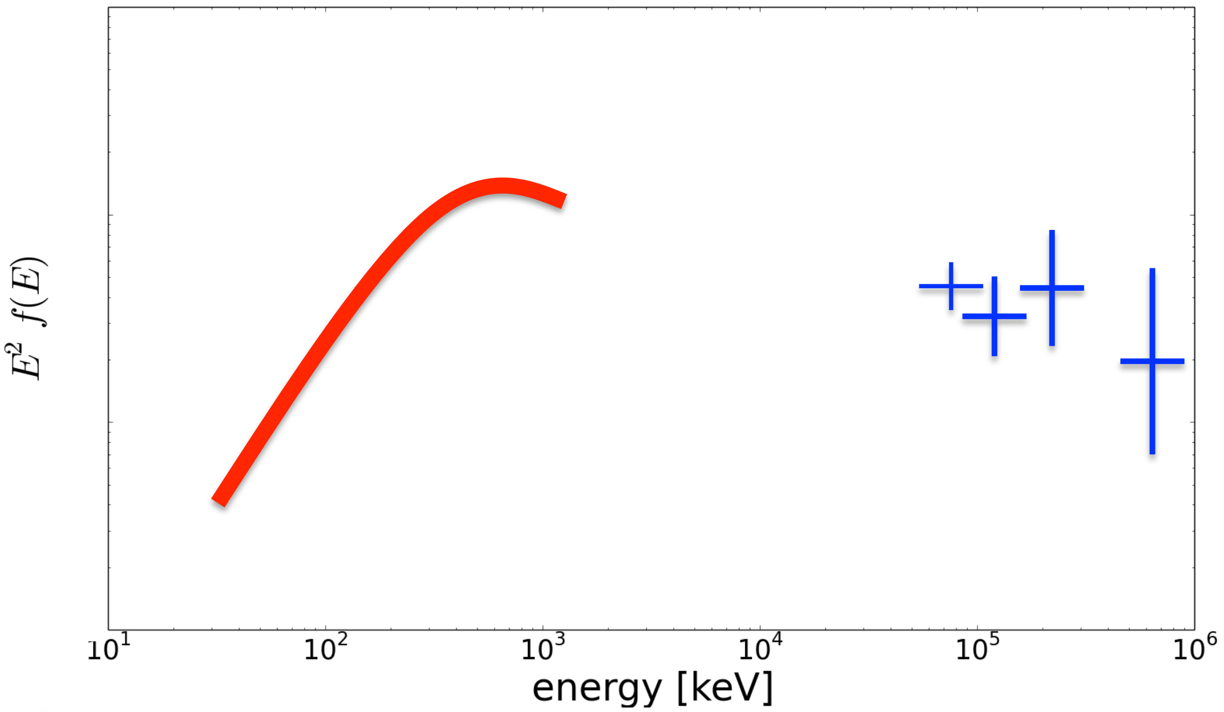
High-Energy GRBs





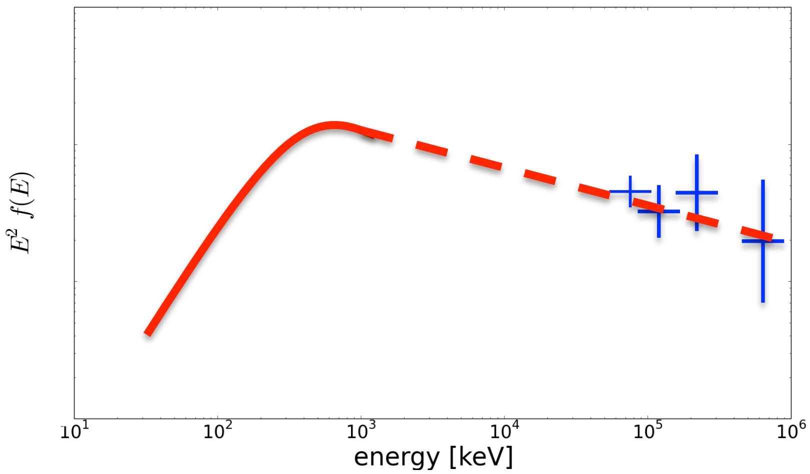
[*Briggs et al.*, 1999]

High-Energy GRBs

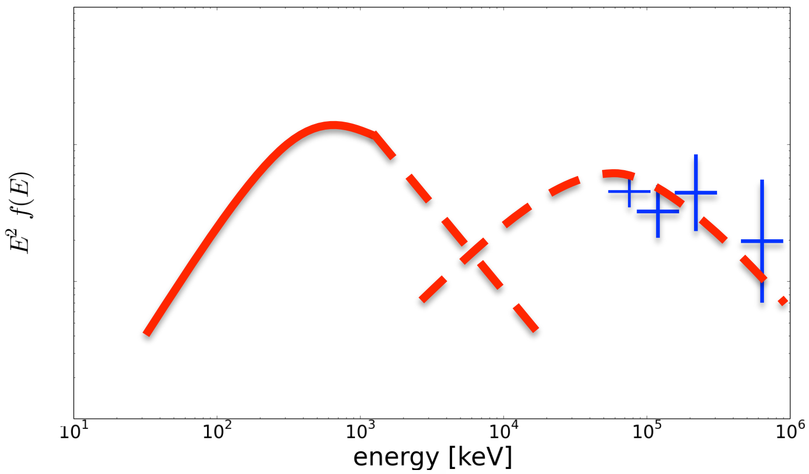


High-Energy GRBs

same model?



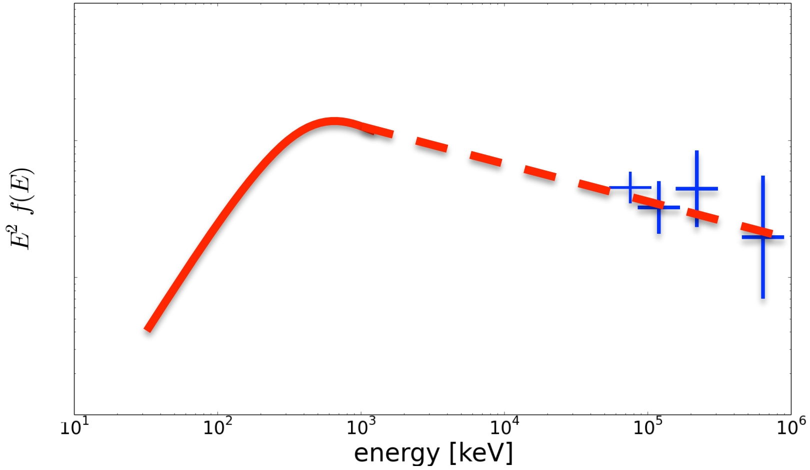
additive component?

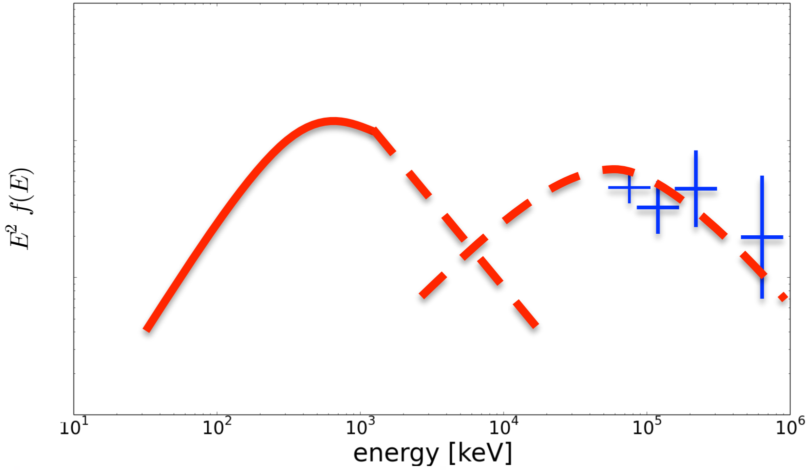


High-Energy GRBs

same model?

additive component?



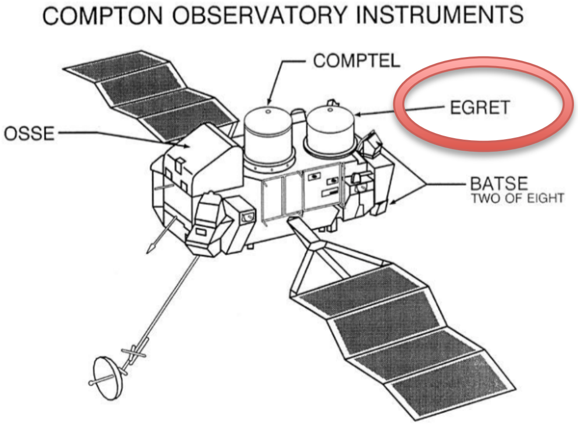


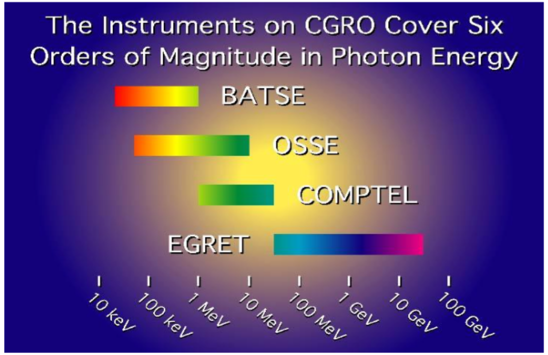
simultaneous?

extended/delayed?

High-Energy GRBs

CGRO (1991-2000)



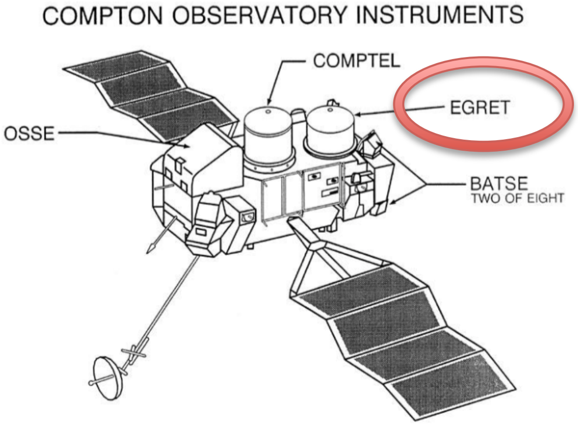


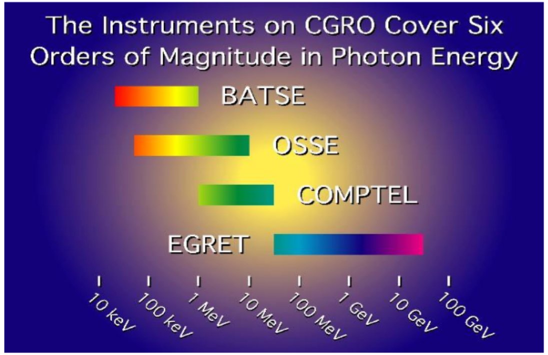
GRBs

E > 100 MeV

High-Energy GRBs

CGRO (1991-2000)

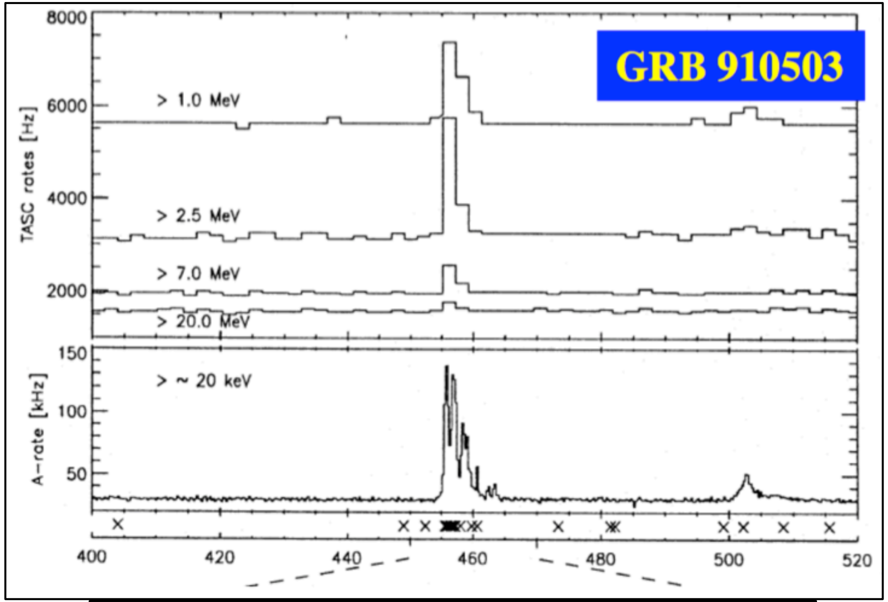




simultaneous

GRBs

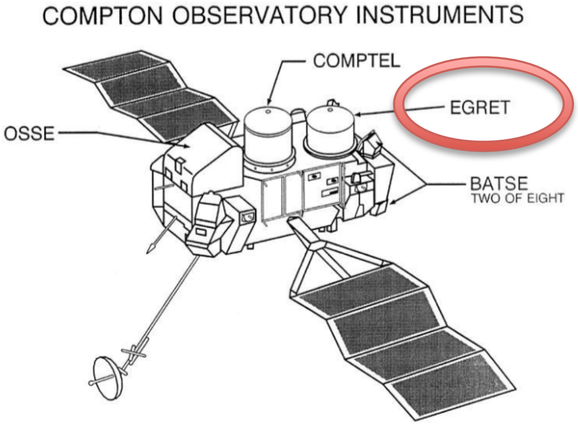
E > 100 MeV

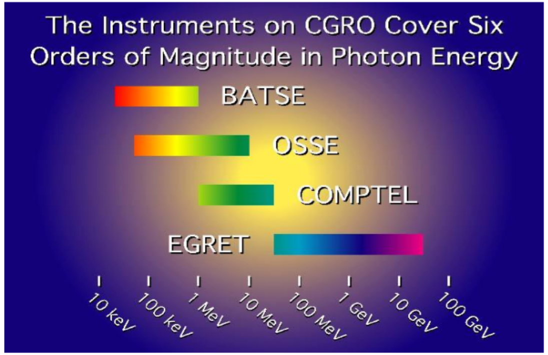


GRB 910503 [*Schneid et al.*, 1992]

High-Energy GRBs

CGRO (1991-2000)





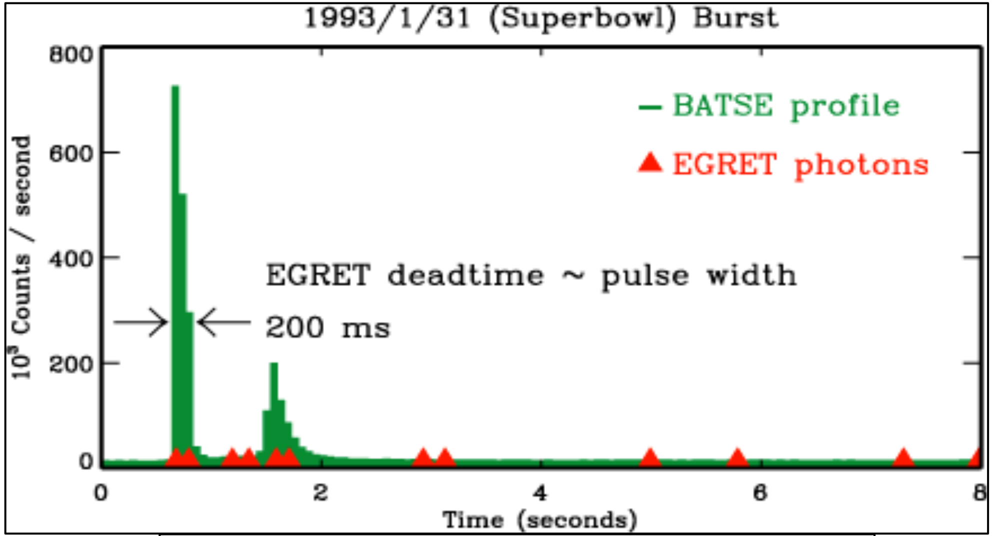
simultaneous

extended/delayed

same model (1 MeV – 1 GeV)

GRBs

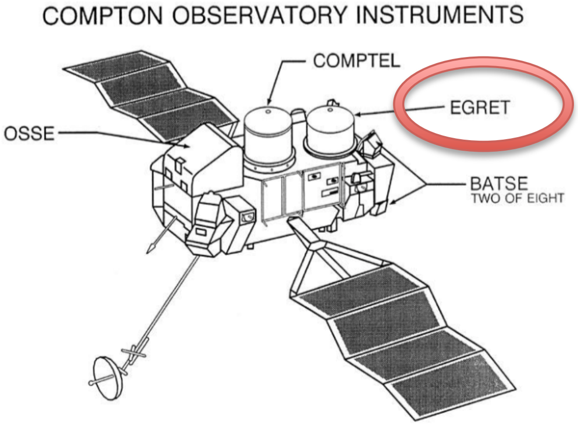
E > 100 MeV

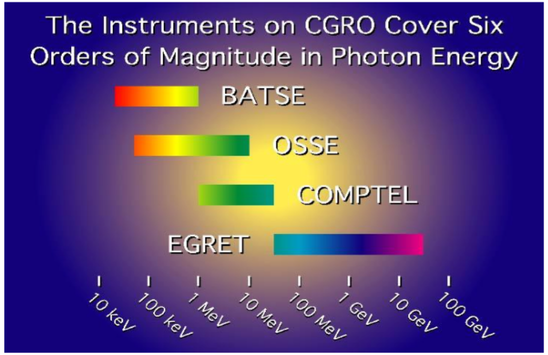


GRB 930131 [*Sommer et al.*, 1994]

High-Energy GRBs

CGRO (1991-2000)





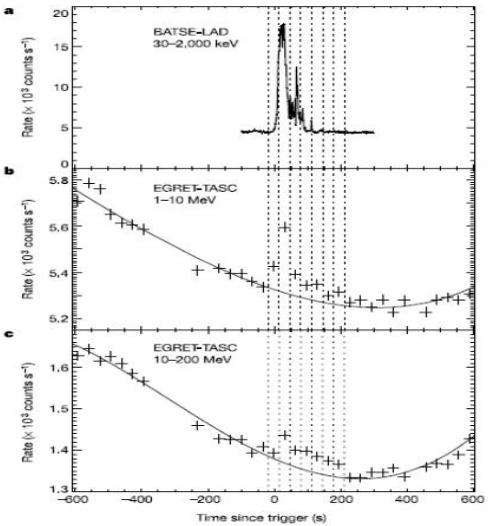
simultaneous

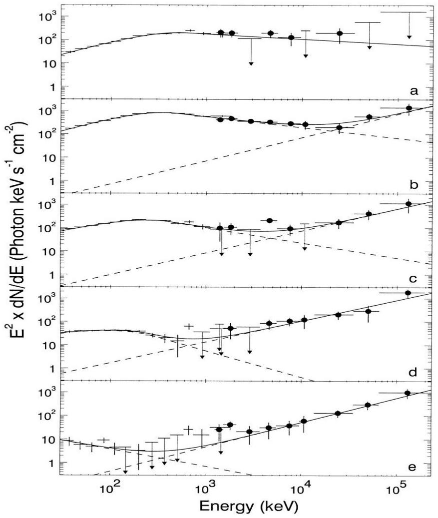
extended/delayed

additive component

GRBs

E > 100 MeV





GRB 941017 [*Gonzales et al.*, 2003]

High-Energy GRBs

prompt emission?

extended/delayed emission?

spectral components?

spectral evolution?

→

optimal timing

large FoV

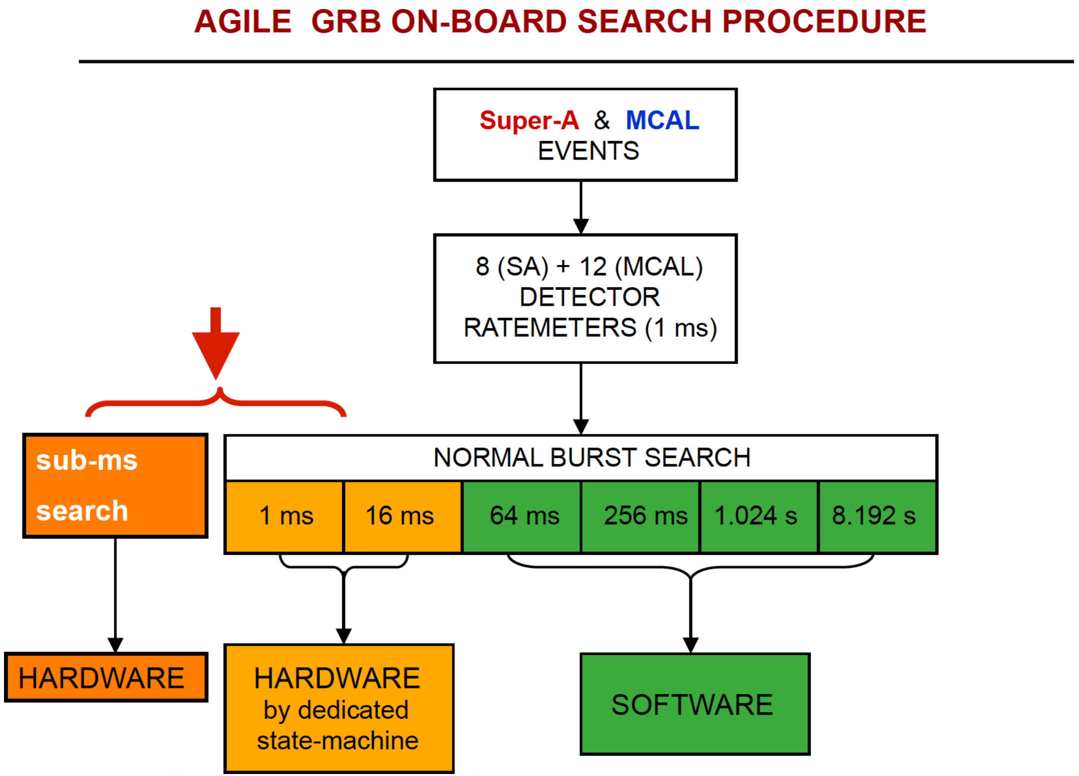
reduced dead time

“new” generation

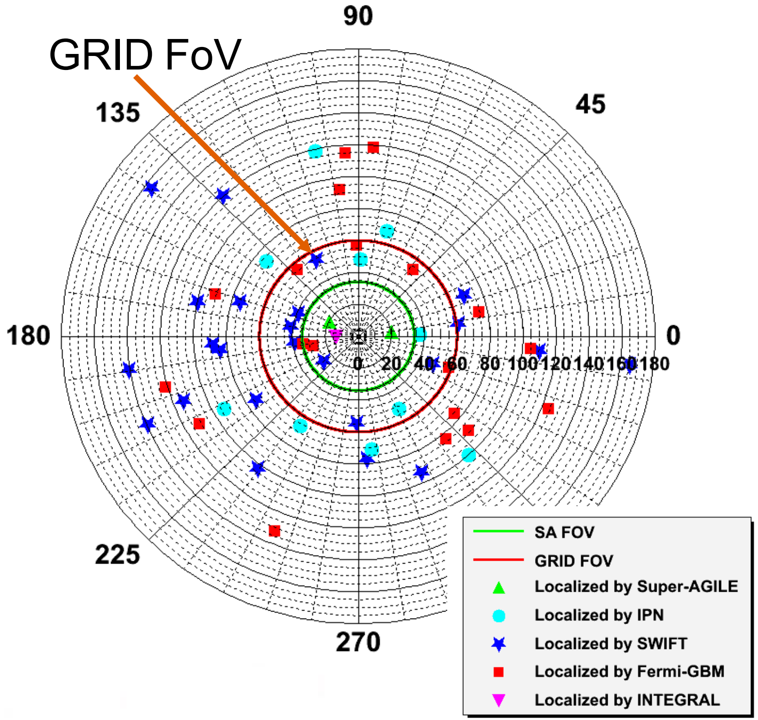
Si detectors…

AGILE & GRBs

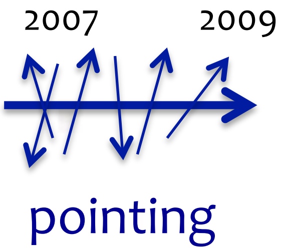
MCAL



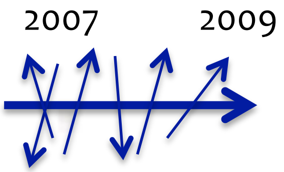
GRID



AGILE & GRBs



AGILE & GRBs

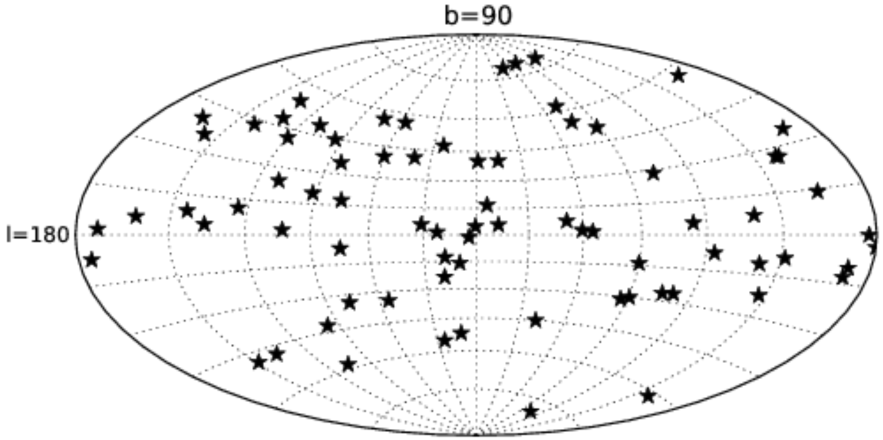


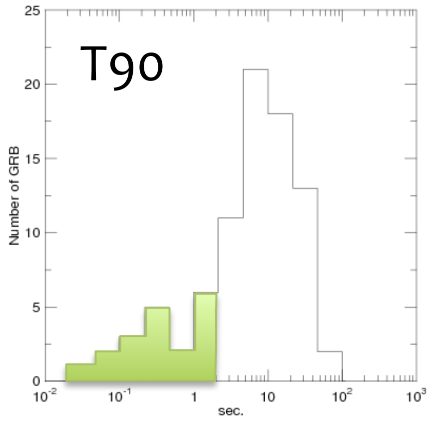
pointing

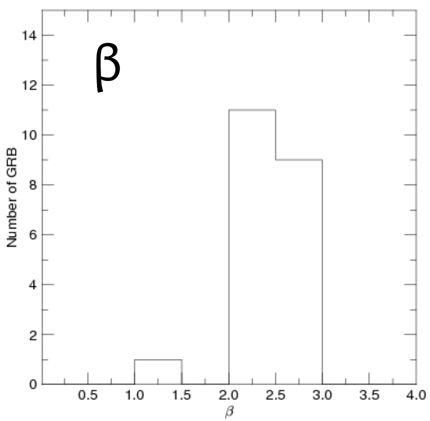
MCAL 1st GRB catalog
[*Galli et al.*, 2013]

84 GRBs

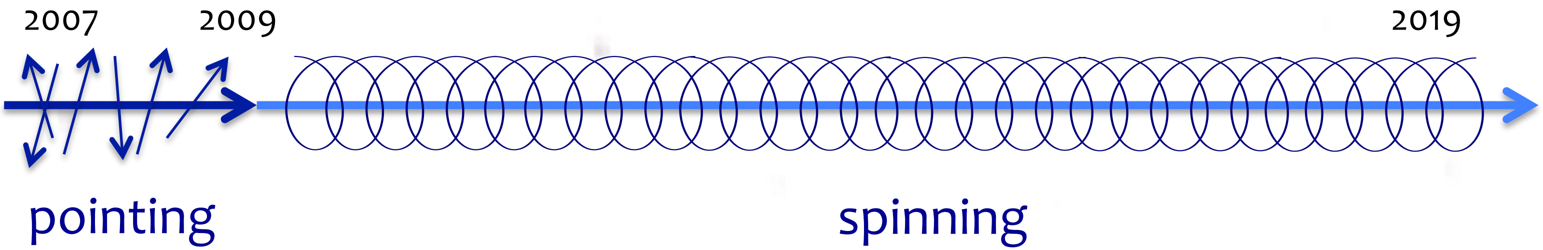
~ ¼ short GRBs







AGILE & GRBs

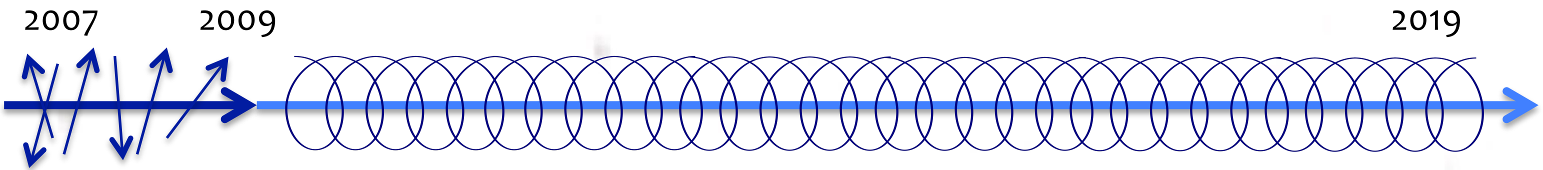


MCAL 1st GRB catalog
[*Galli et al.*, 2013]

84 GRBs

~ ¼ short GRBs

AGILE & GRBs



pointing

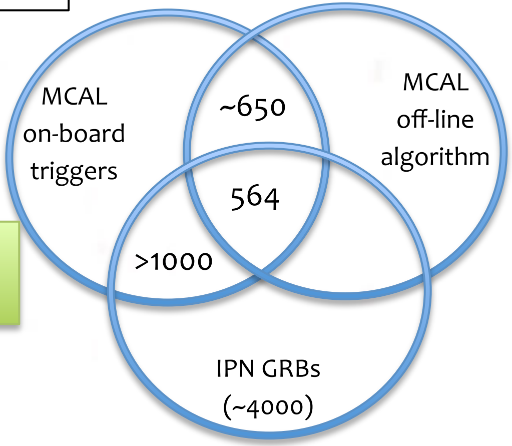
spinning

MCAL 1st GRB catalog
[*Galli et al.*, 2013]

MCAL 2nd GRB catalog
[*Ursi et al.*, in prep.]

84 GRBs

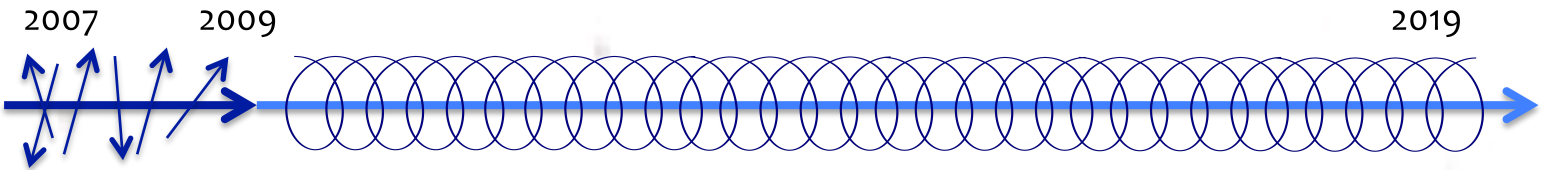
564 GRBs



~ ¼ short GRBs

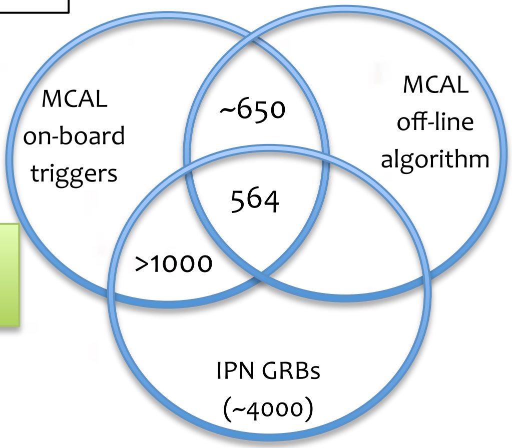
~ ¼ short GRBs

AGILE & GRBs



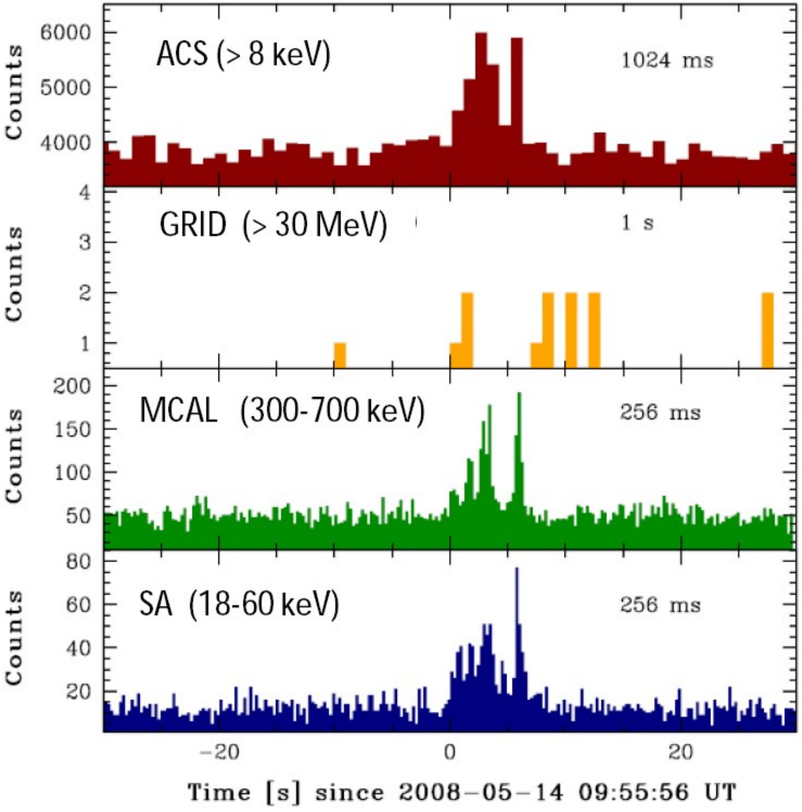
pointing | spinning

MCAL 1st GRB catalog [*Galli et al.*, 2013]	MCAL 2nd GRB catalog [*Ursi et al.*, in prep.]
84 GRBs	**564 GRBs**
~ ¼ short GRBs	~ ¼ short GRBs



for both classes there could be gamma-rays

GRB 080514B

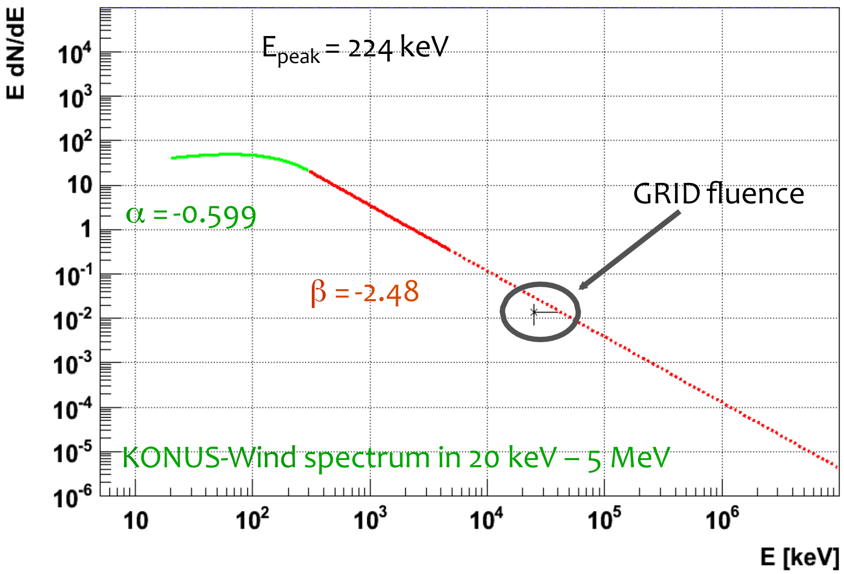


GRB 080514B [*Giuliani et al.*, 2008]

- first GeV-bright GRB after EGRET
- afterglow with photometric redshift of 1.8

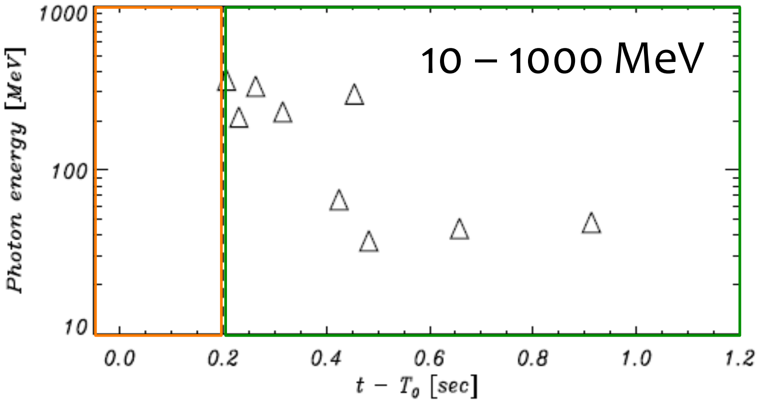
extended emission

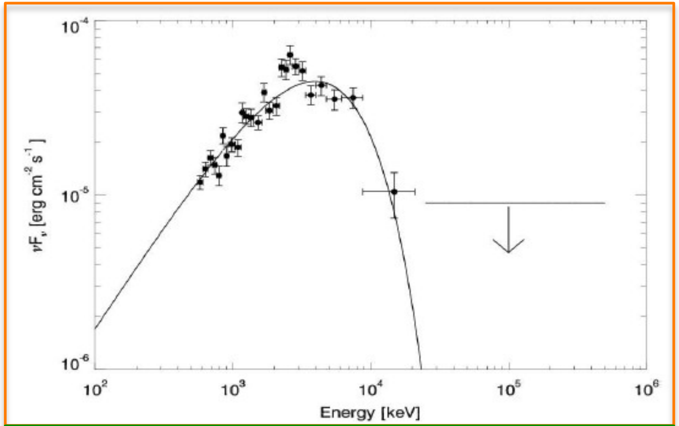
same model



GRB 090510

GRID

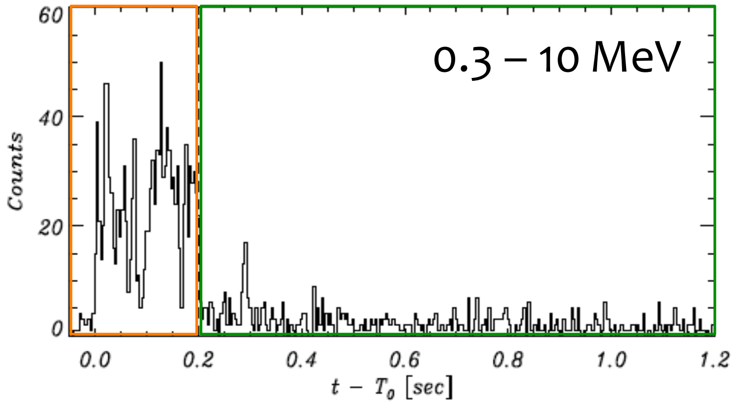


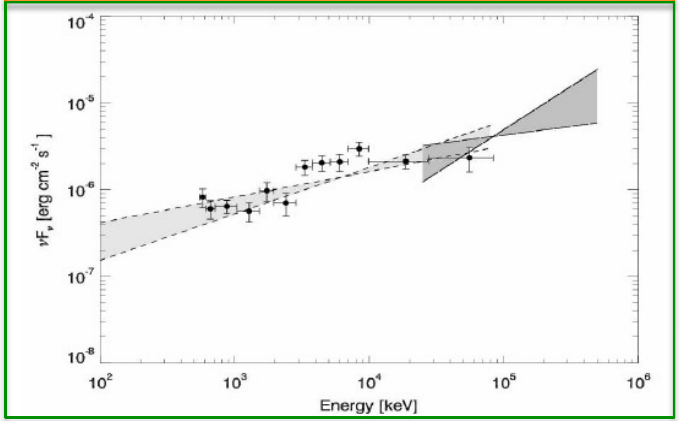


Powerlaw + cutoff

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

MCAL





Powerlaw

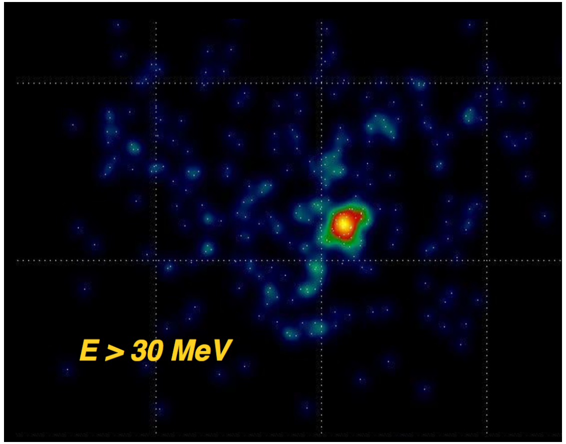
$F = 3.1 \times 10^{-6}$ erg/cm^2
(0.5 – 10 MeV)

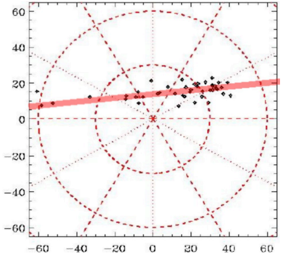
$F = 2.9 \times 10^{-5}$ erg/cm^2
(25 – 500 MeV)

GRB 090510 [*Giuliani et al.*, 2010]

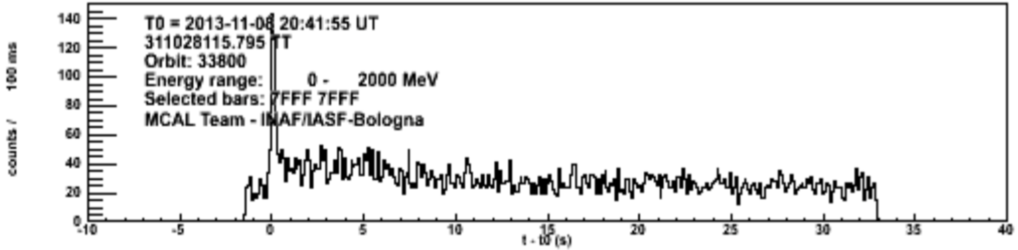
extended/delayed emission

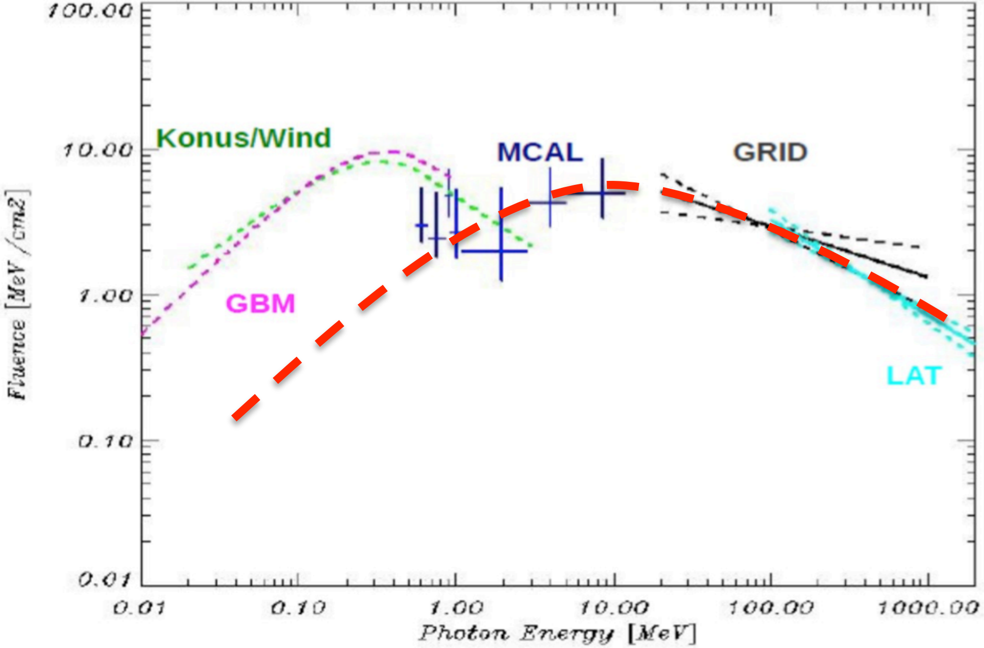
GRB 131108A





GRB 131108A [*Giuliani et al.*, 2014]

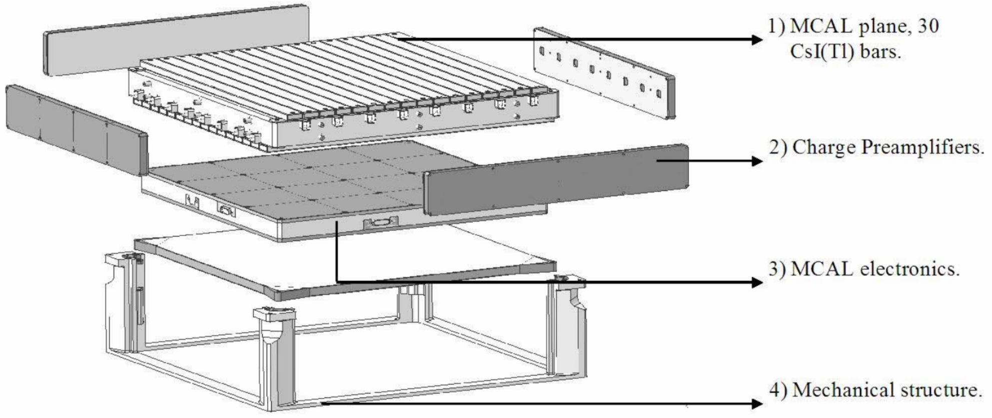


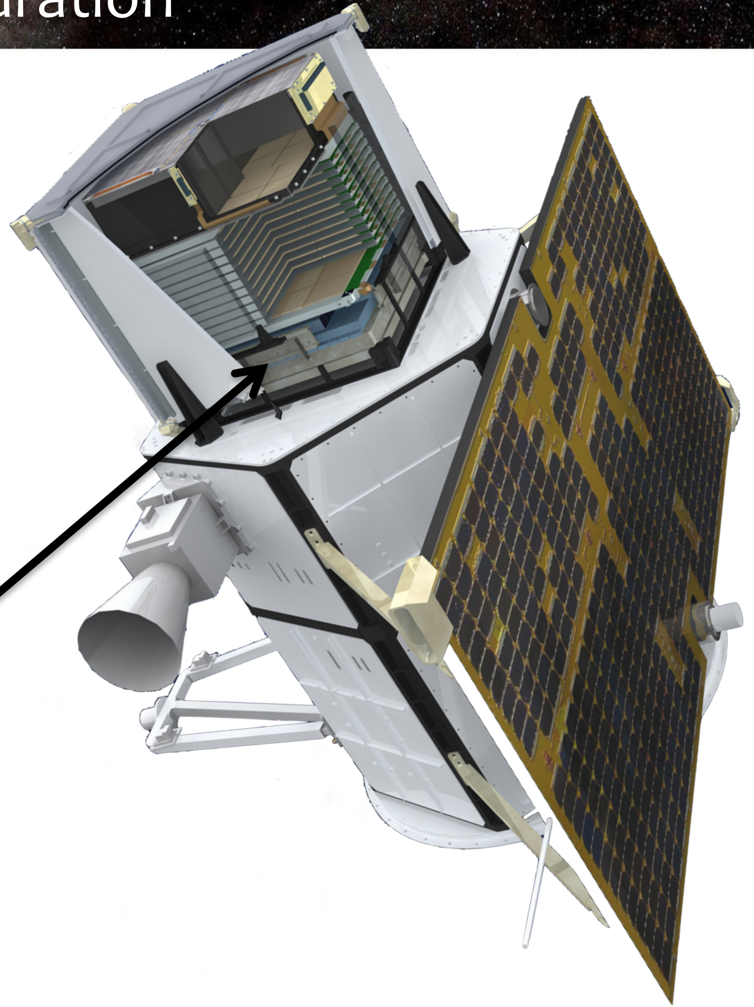


- 66 photons in first 80 s
- F (30 MeV - 1 GeV) = $2.56 \cdot 10^{-5}$ erg cm^{-2}
- z = 2.4

additive component

A new MCAL configuration





MiniCALorimeter (MCAL)
[350 keV – 100 MeV]
30 CsI (Tl) bars

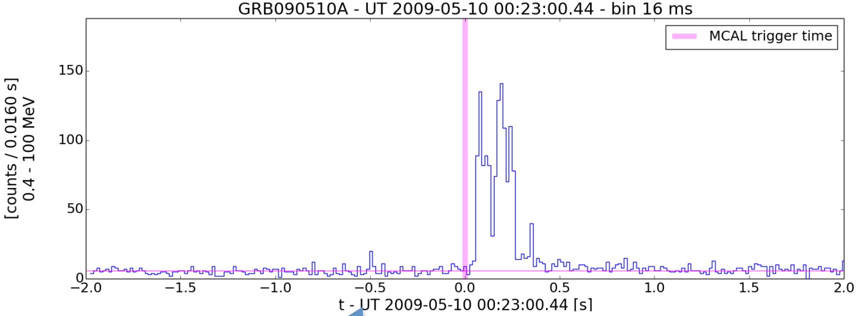
A new MCAL configuration

	HARDWARE LOGIC (static threshold)			SOFTWARE LOGIC (dynamic threshold)			
	293 µs	1 ms	16 ms	64 ms	256 ms	1 s	8 s
old	8 counts	10 counts	41 counts	7 σ	5 σ	5 σ	5 σ
new	7 counts	7 counts	8 counts	5 σ	4 σ	4 σ	4 σ

Telespazio S.p.A. (TPZ)

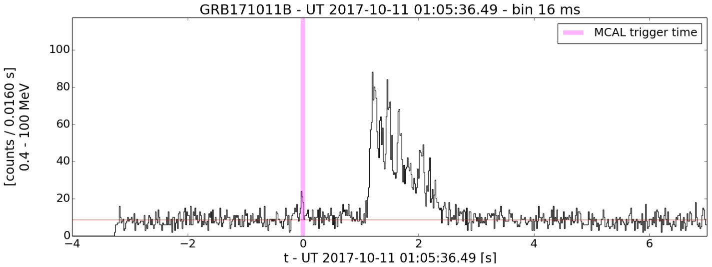
A new MCAL configuration

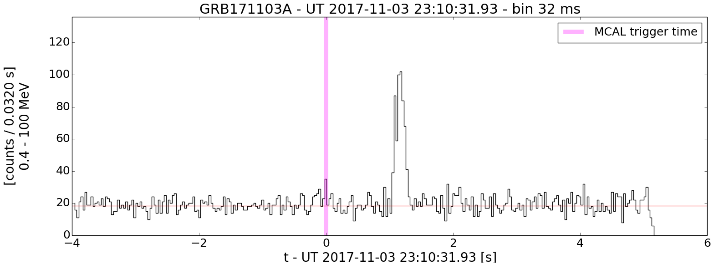
previous MCAL configuration

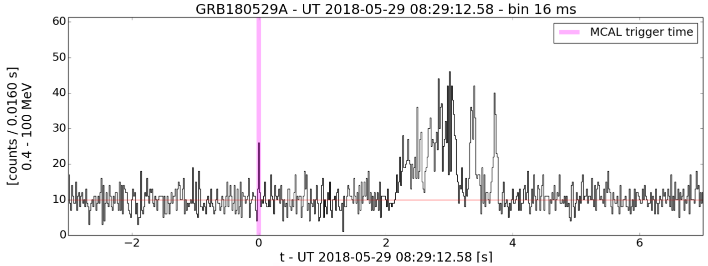


precursor not triggered!

enhanced "MCAL-GW" configuration



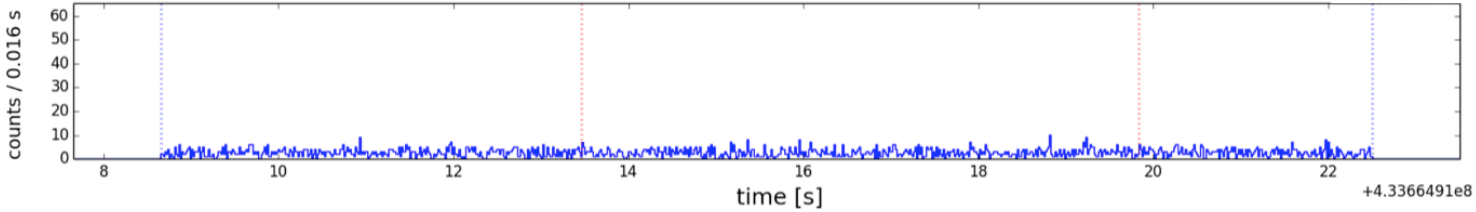




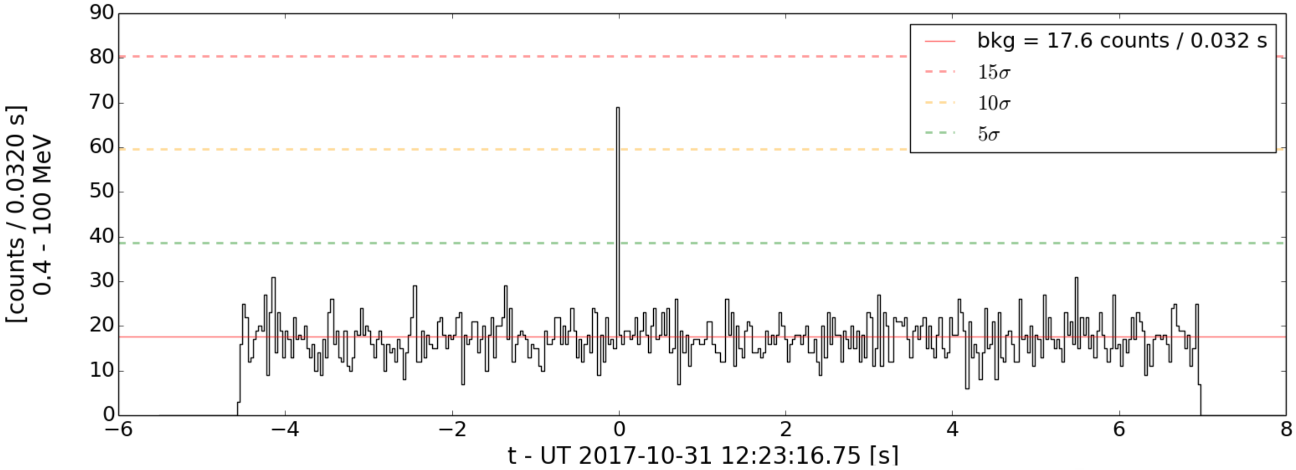
[*Ursi et al.*, 2019]

A new MCAL configuration

focusing on each MCAL time bin



high-significance spikes

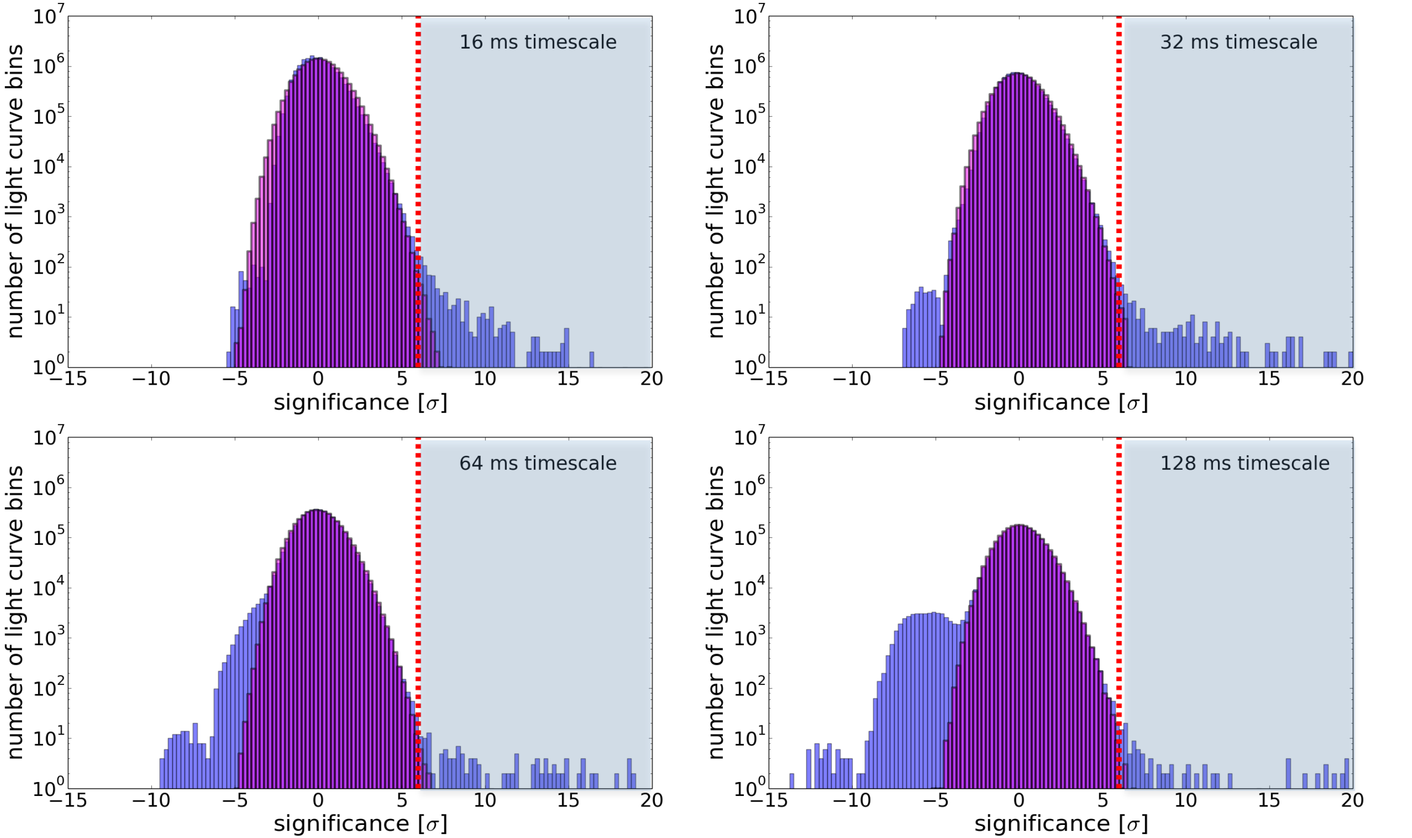


A new MCAL configuration

MCAL bins

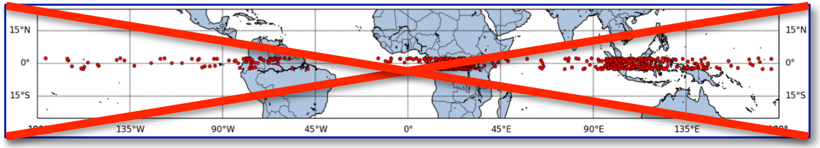
vs

Poisson



[*Ursi et al.*, 2019]

A new MCAL configuration

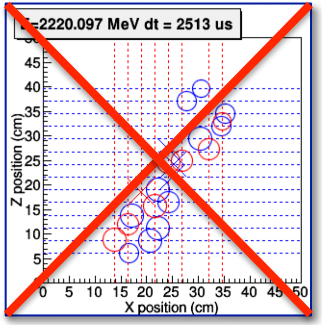


TGFs?

· no geographic pattern

· no TGF selection criteria

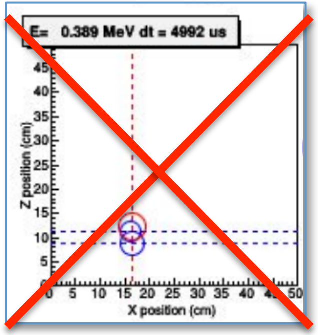
· not enough “short” duration



charged particles?

· no tracks

· no suspect counts



electronic noise?

· no “low-energy”

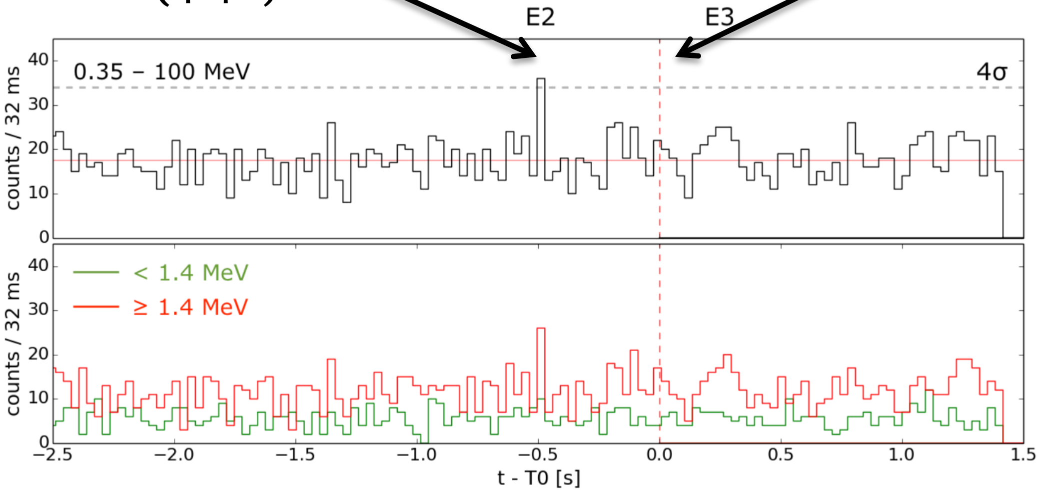
· no clustering

GW 170104

MCAL
(4.4σ)

Δt = 0.46 s

GW



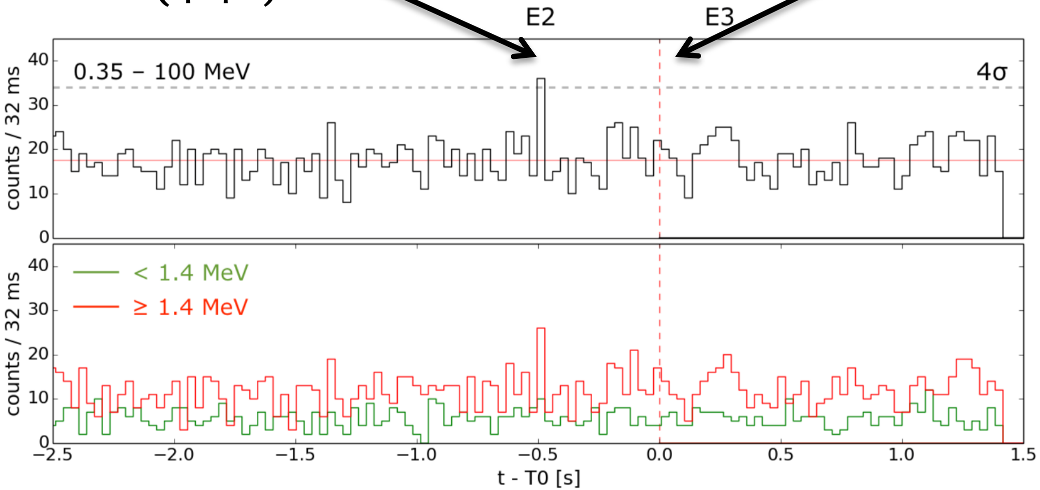
[*Verrecchia et al.*, 2017a]

GW 170104

MCAL
(4.4σ)

Δt = 0.46 s

GW

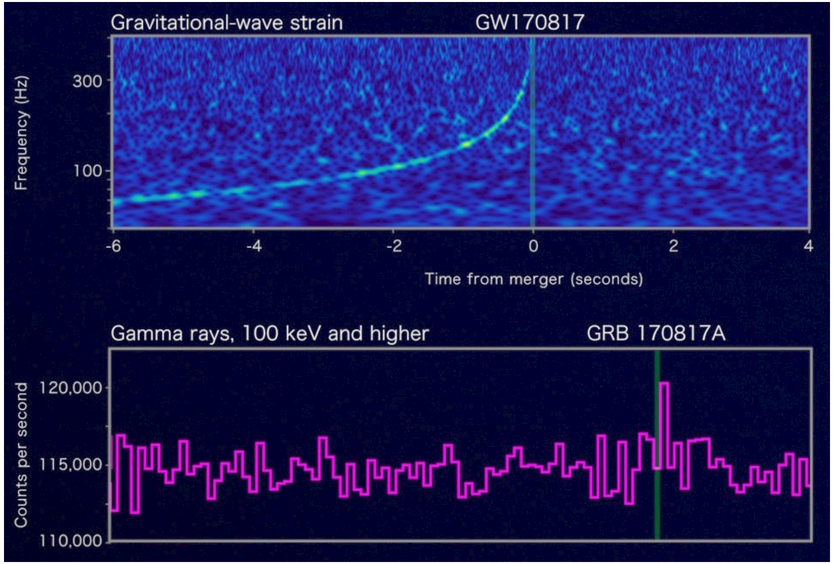


[*Verrecchia et al.*, 2017a]

GW

Δt = 1.74 s

INTEGRAL
(4.6σ)



A new MCAL configuration

adopted during LIGO/Virgo O2 run

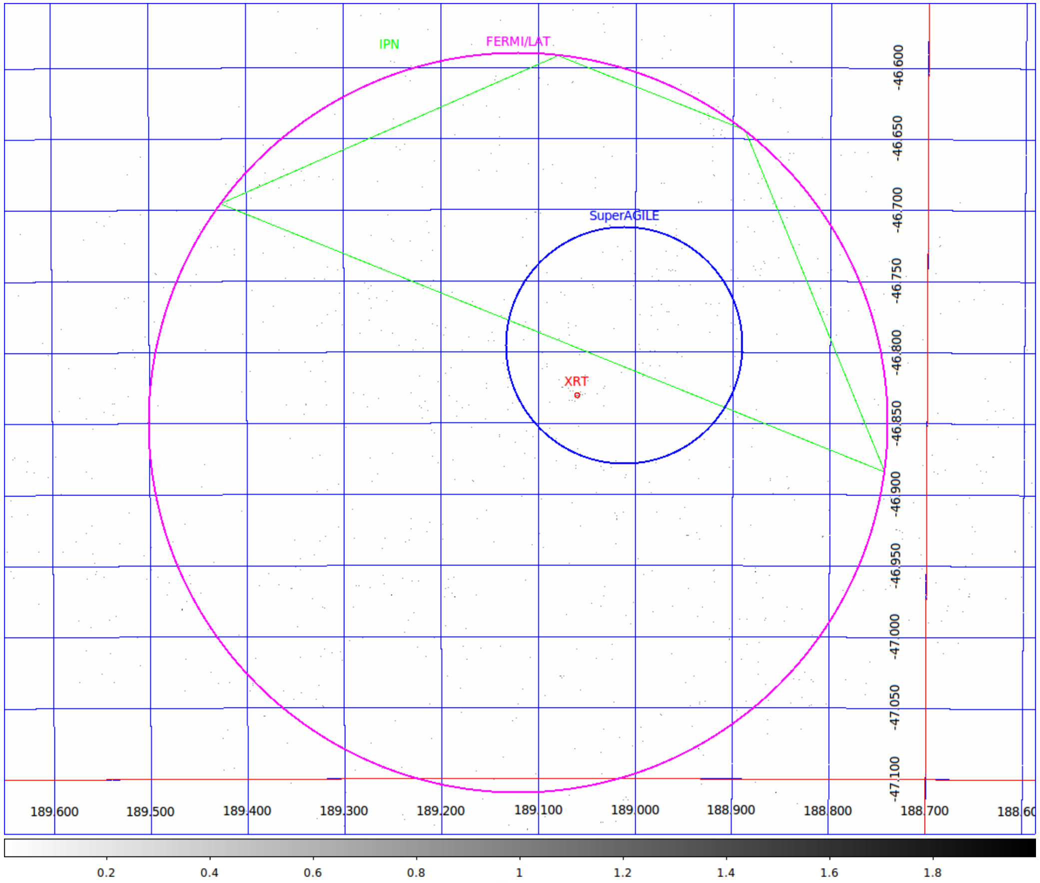
GW170104	Tavani et al., GCN #20375
TR170120	Lucarelli et al., GCN #20489
TR170218	Verrecchia et al., GCN #20690
TR170225	Ursi et al., GCN #20741
TR170227	Ursi et al., GCN #20769
TR170314	Cardillo et al., GCN #20863
TR170503	Ursi et al., GCN #21062
GW170808	Verrecchia et al., GCN #21224
GW170809	Ursi et al., GCN #21434
GW170814	Longo et al., GCN #21477
GW170817	Pilia et al., GCN #21525
TR170819	Pittori et al., GCN #21605
GW170823	Cardillo et al., GCN #21660
TR170825	Cardillo et al., GCN #21700

... and O3!

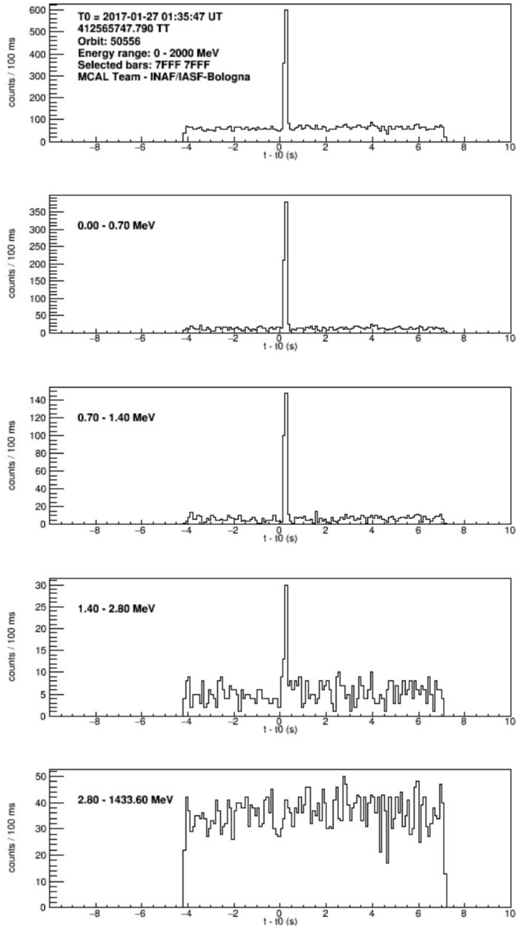
S190408an	Lucarelli et al., GCN #24063
S190421ar	Ursi et al., GCN #24140
S190426c	Cardillo et al., GCN #24245
S190503bf	Ursi et al., GCN #24379
S190510g	Ursi et al., GCN #24437
S190512at	Ursi et al., GCN #24507
S190513bm	Casentini et al., GCN #24526
S190519bj	Lucarelli et al., GCN #24603
S190517h	Ursi et al., GCN #24572
S190521g	Casentini et al., GCN #24623
S190521r	Casentini et al., GCN #24636
S190602aq	Casentini et al., GCN #24722
S190630ag	Pittori et al., GCN #24933
S190701h	Lucarelli et al., GCN #24953
S190706ai	Lucarelli et al., GCN #25001
S190707q	Longo et al., GCN #25018
S190720a	Casentini et al., GCN #25116
S190727h	Ursi et al., GCN #25167
S190728q	Longo et al., GCN #25193
S190814bv	Pilia et al., GCN #25327
S190828j	Longo et al., GCN #25498
S190828l	Longo et al., GCN #25510
S190901ap	Cardillo et al., GCN #25613
... ...	... ...

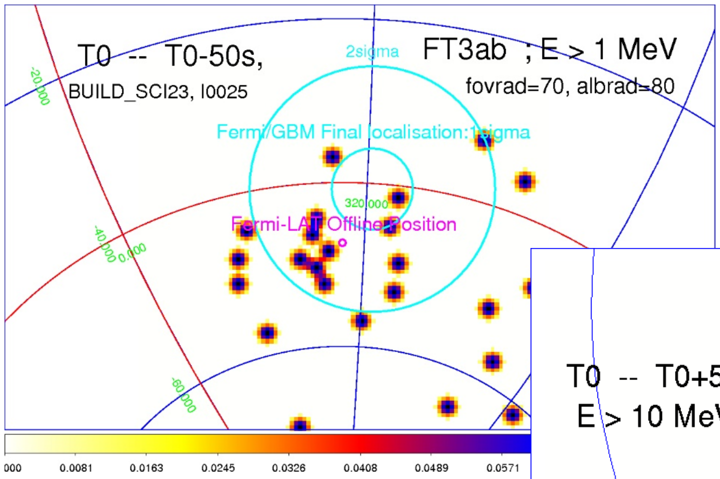
GRB 170114B

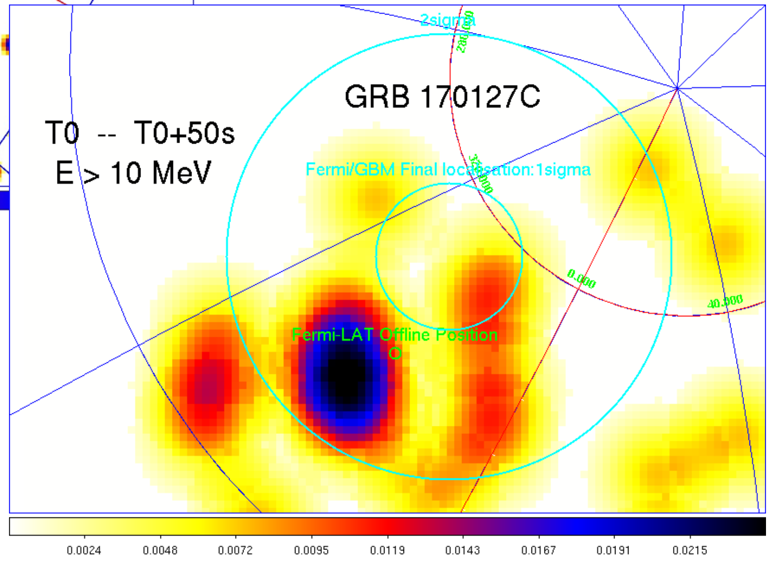
- Super AGILE localization
- important example for GW counterpart searches



GRB 170127C







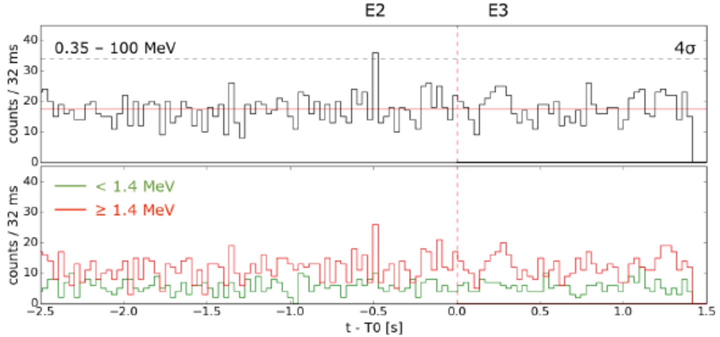
- GRID localization

extended/delayed emission

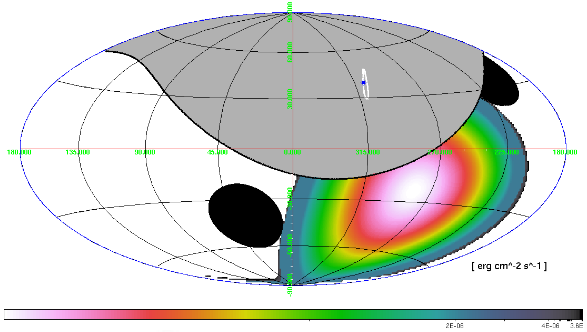
GW 170104

GW 170817

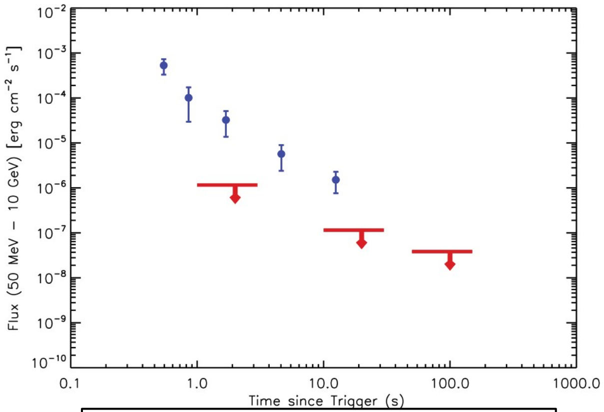
T0 covered by MCAL



Earth occultation at T0

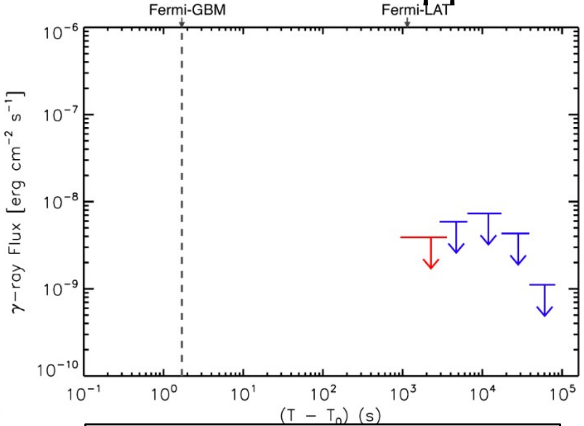


GRID upper limits



[*Verrecchia et al.*, 2017a]

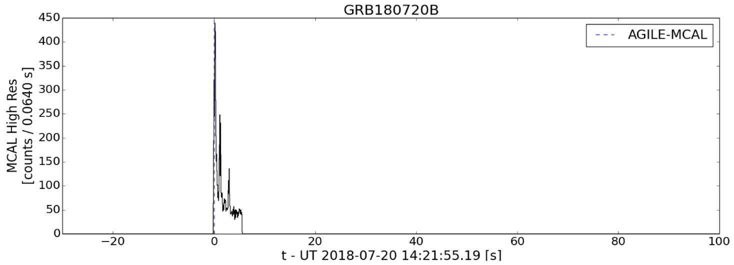
GRID closest available upper limits



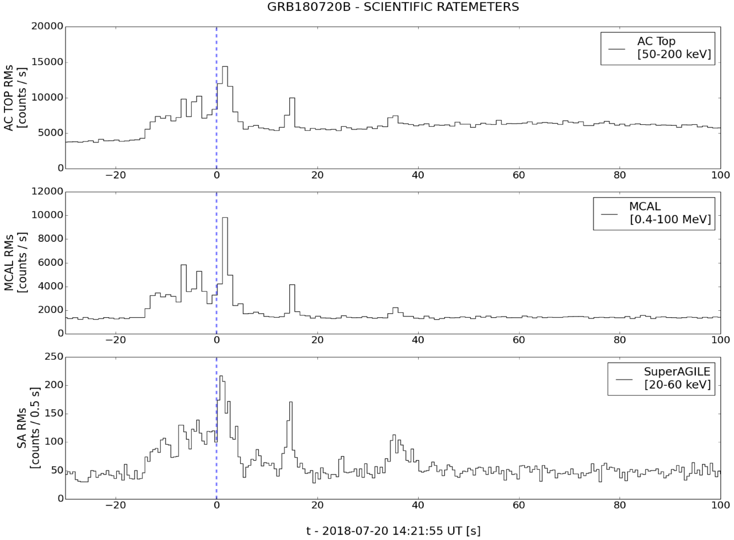
[*Verrecchia et al.*, 2017b]

GRB 180720B

MCAL triggered

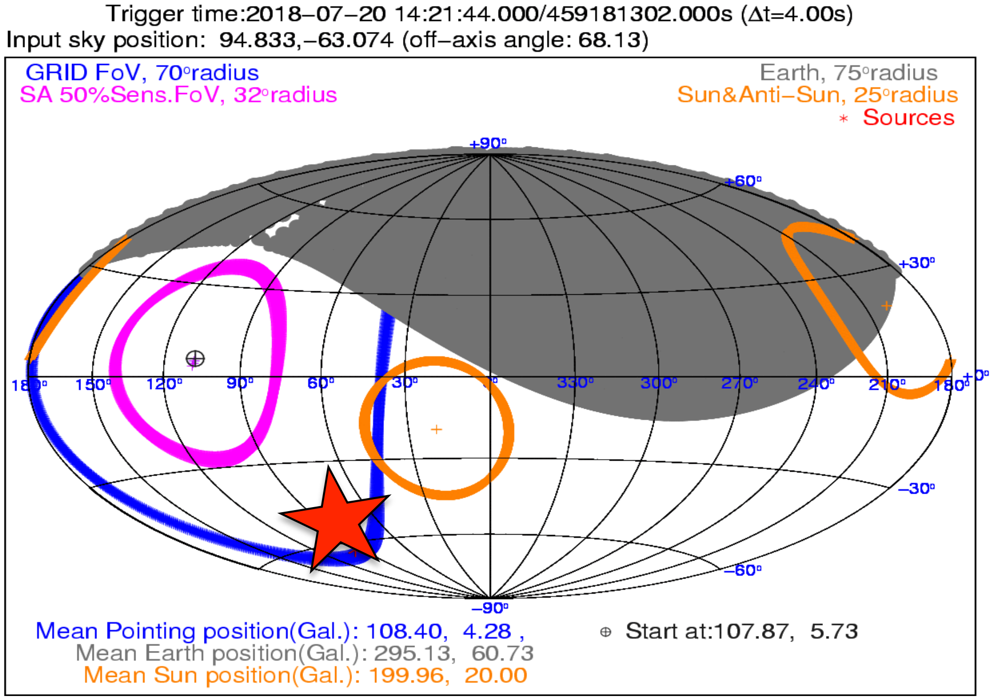


RATEMETERS



extended/delayed emission

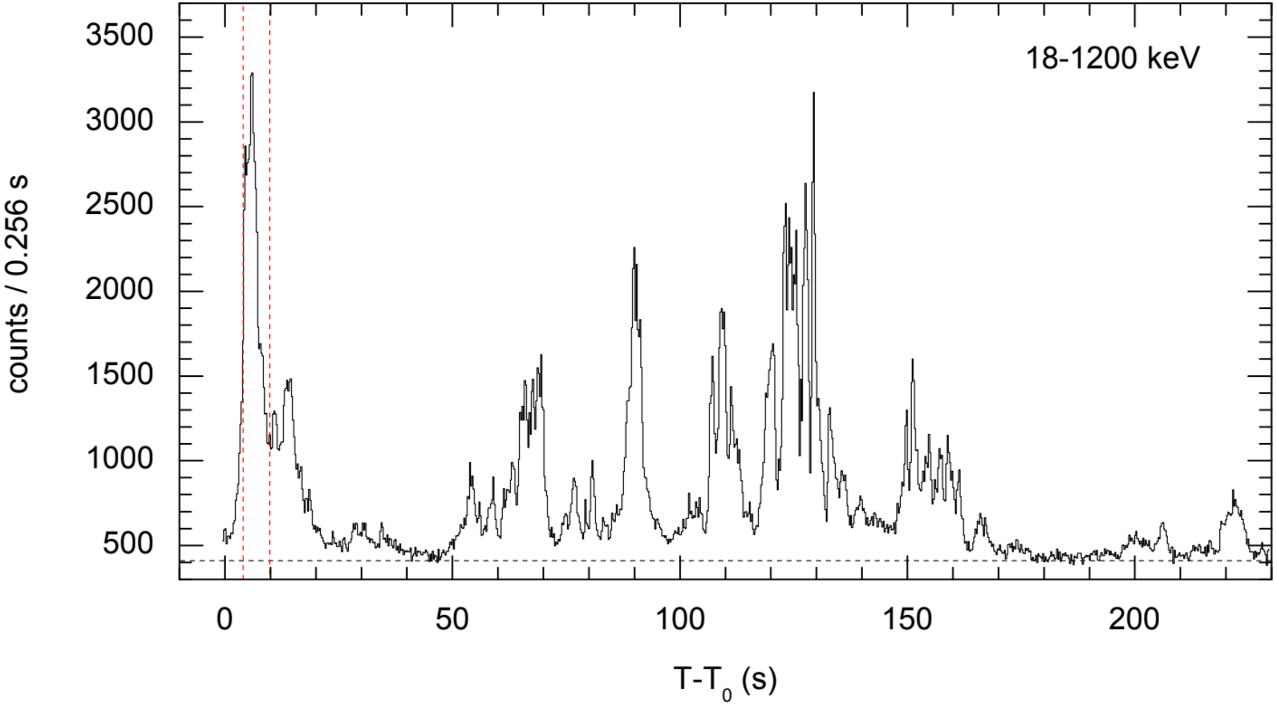
detected by HESS at TeV energies!



GRID? no spoiler...

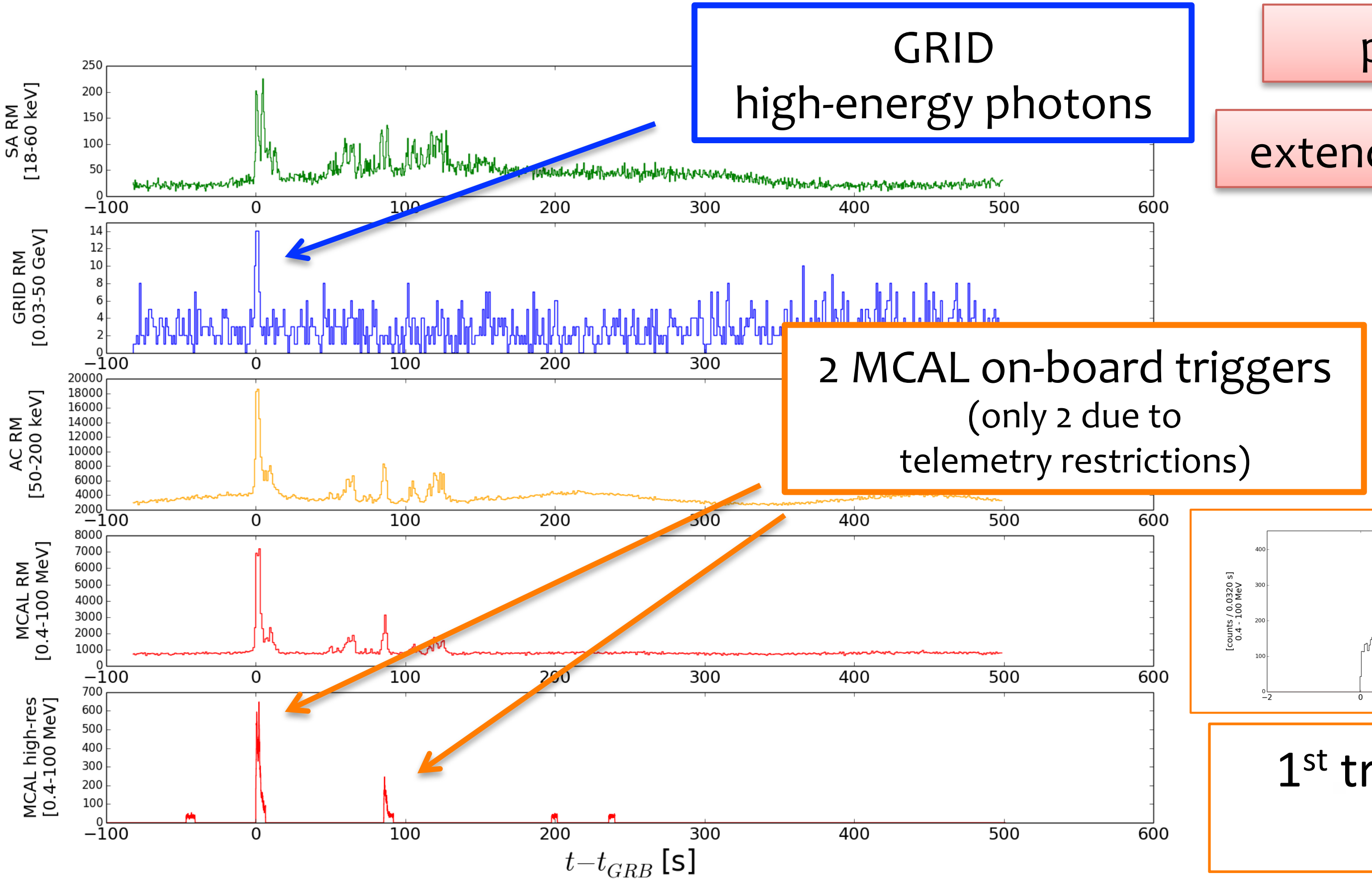
GRB 180914B

KONUS-Wind light curve



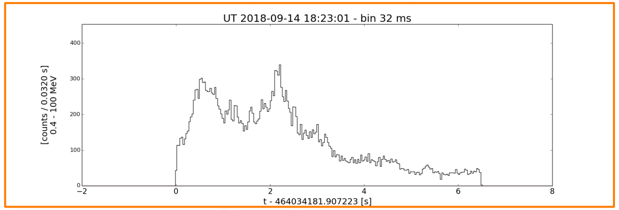
[*courtesy of D. Frederiks*]

GRB 180914B



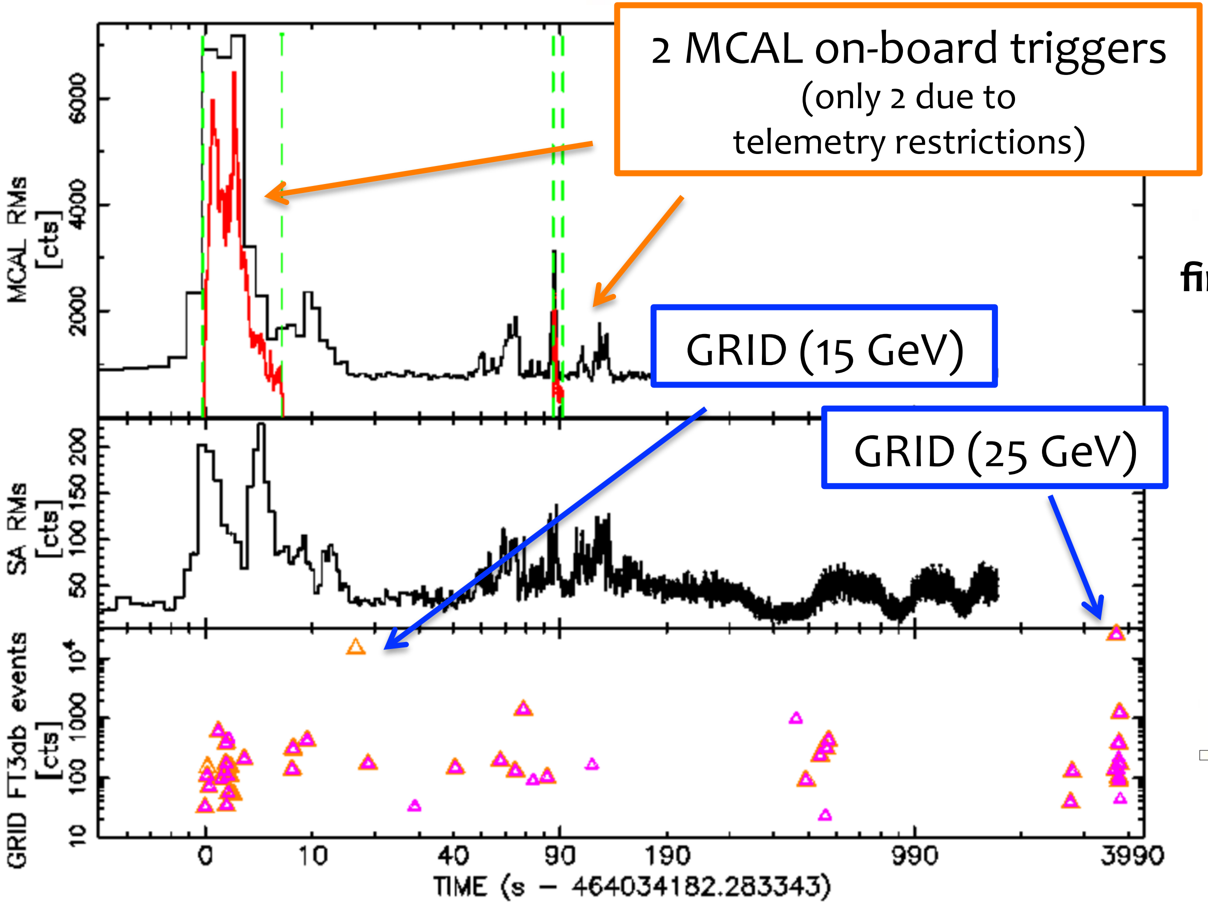
prompt emission

extended/delayed emission



1st trigger on sub-ms timescale!

GRB 180914B

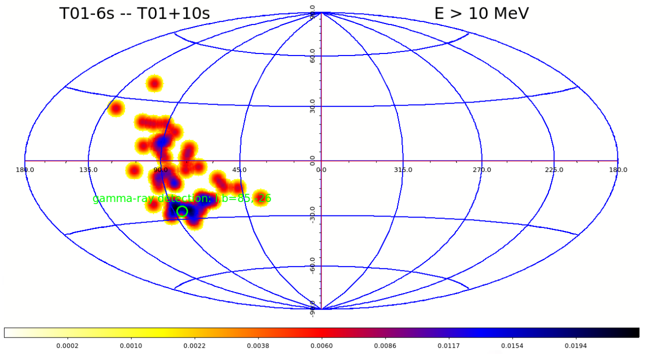


prompt emission

extended/delayed emission

first AGILE/GRID localization as first!

(confirmed by Fermi/LAT)

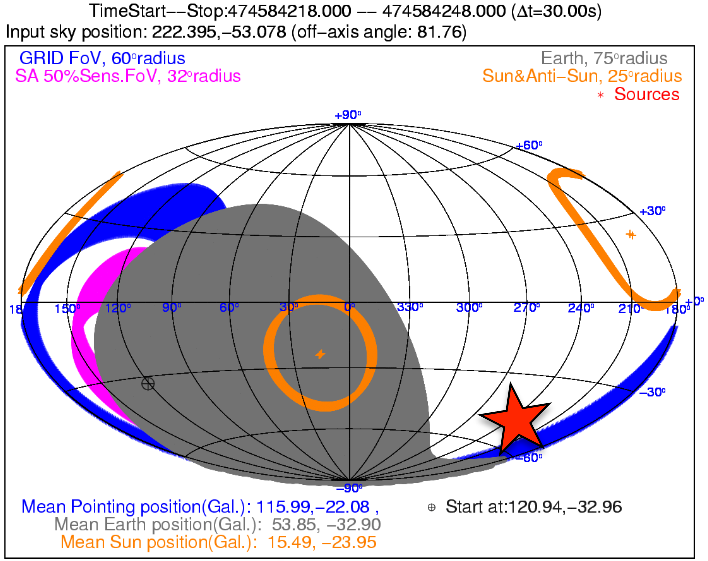


z ~ 1.1

GRB 190114C

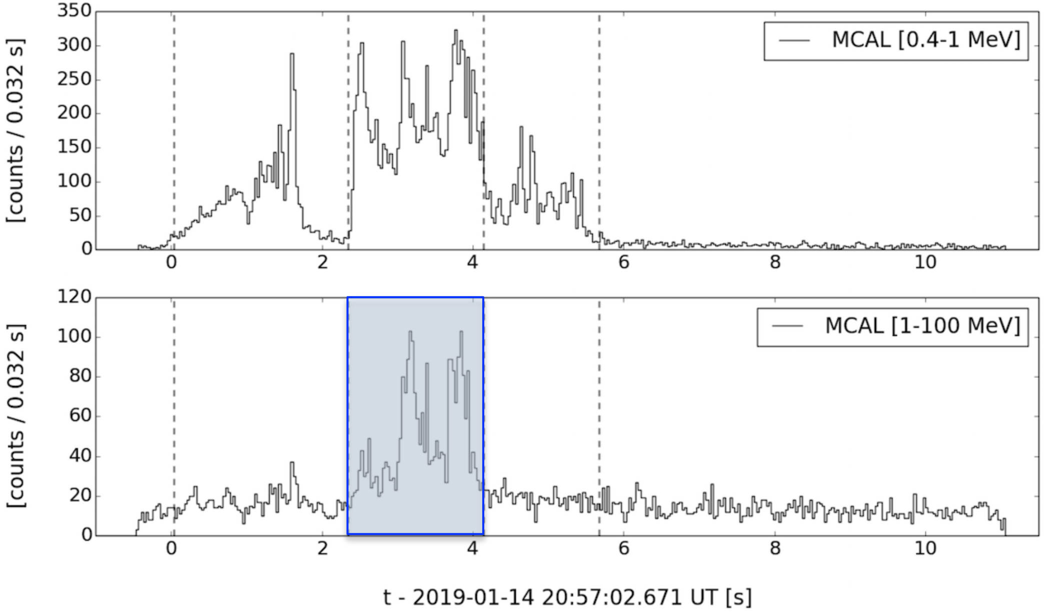
extended/delayed emission

detected by MAGIC at TeV energies!



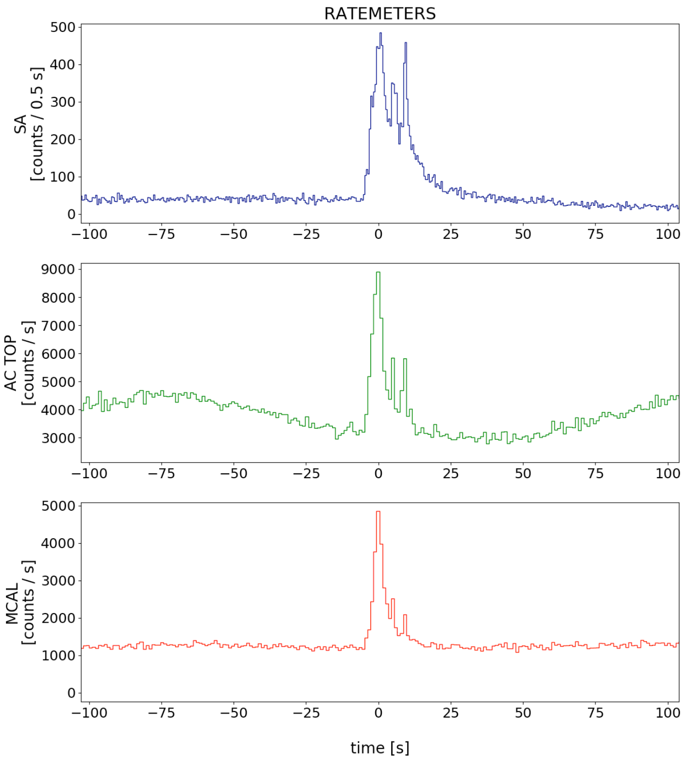
at T0 just outside GRID FoV!

but interesting MCAL...



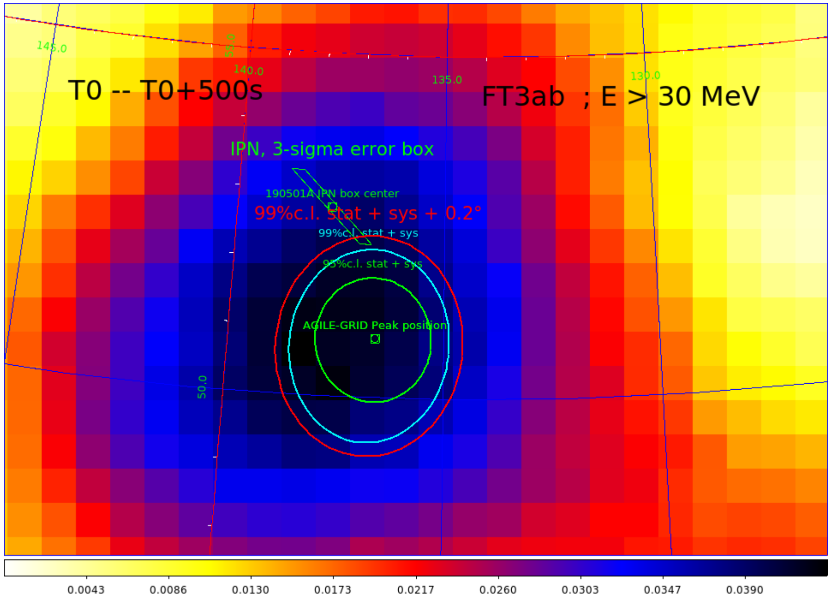
[*Ursi et al.*, in prep.]

GRB 190501A



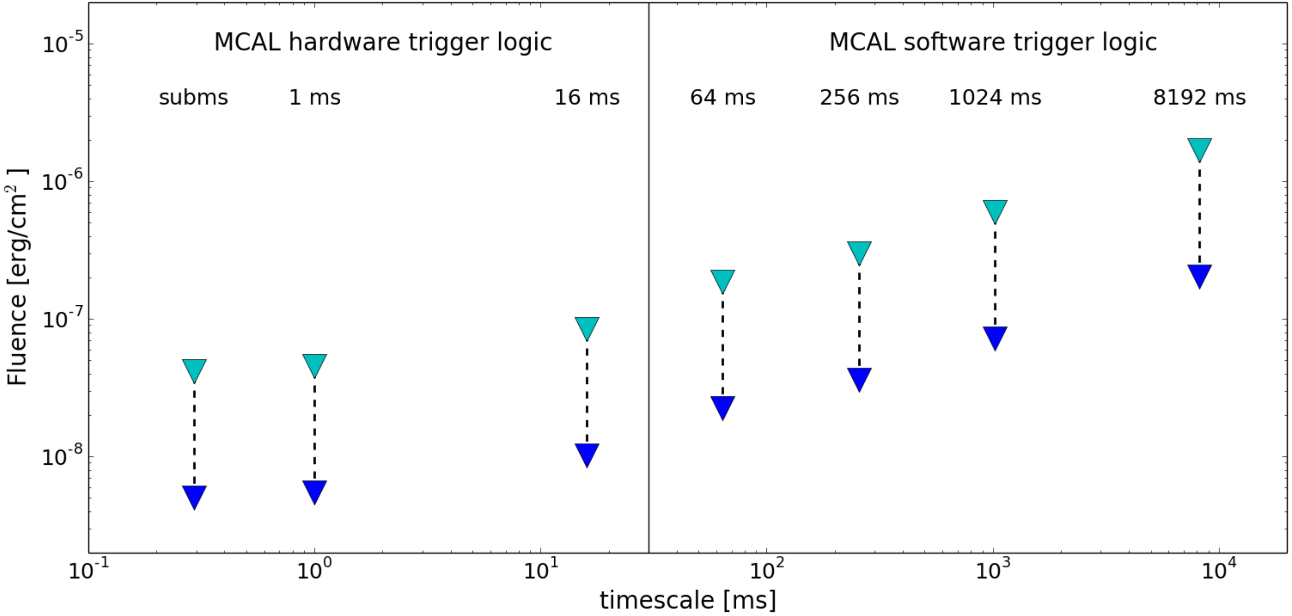
prompt emission

another GRID localization



upper limits

HARDWARE LOGIC (static threshold)			SOFTWARE LOGIC (dynamic threshold)			
293 µs	1 ms	16 ms	64 ms	256 ms	1 s	8 s
7 counts	7 counts	8 counts	5 σ	4 σ	4 σ	4 σ

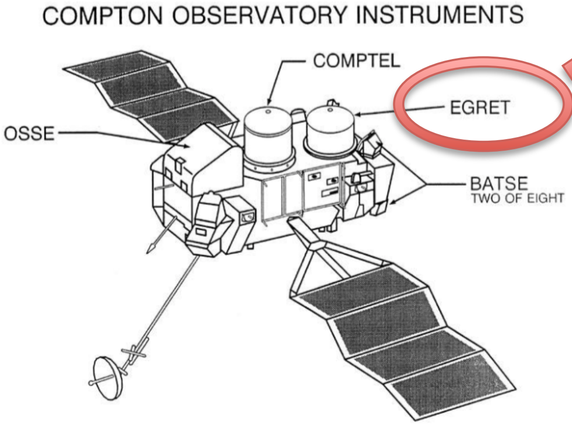


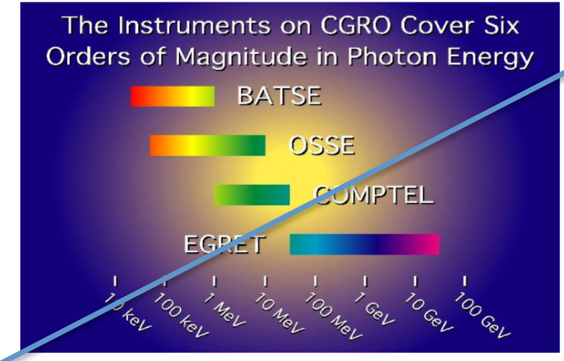
Conclusions

- investigations on the GRB high-energy component
  - simultaneous prompt emission, extended/delayed emission
  - unique spectral model, additive extra component
- sensitive to sub-ms timescales for fastest transients
- continuously observing large fraction (SA, GRID) or all accessible sky (MCAL, RMs)
- enhanced trigger capabilities
- prompt electromagnetic follow-up of GWs
- high-energy upper limits (MCAL and GRID)

Thank you!

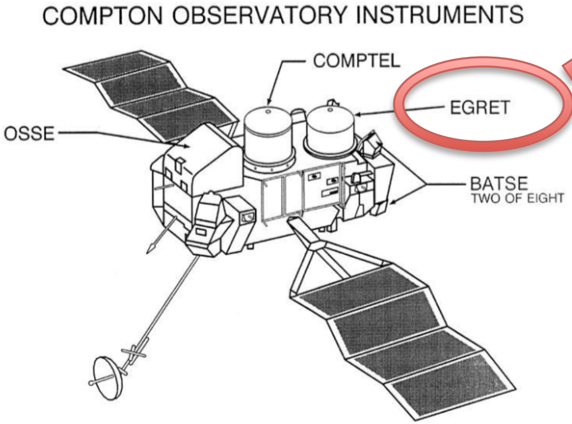
CGRO (1991-2000)

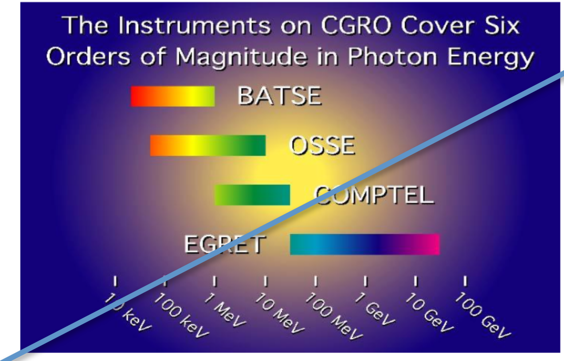




- 30 MeV - 30 GeV
- spark chamber FoV 0.5 sr

CGRO (1991-2000)





- 30 MeV - 30 GeV
- spark chamber FoV 0.5 sr

GRBs

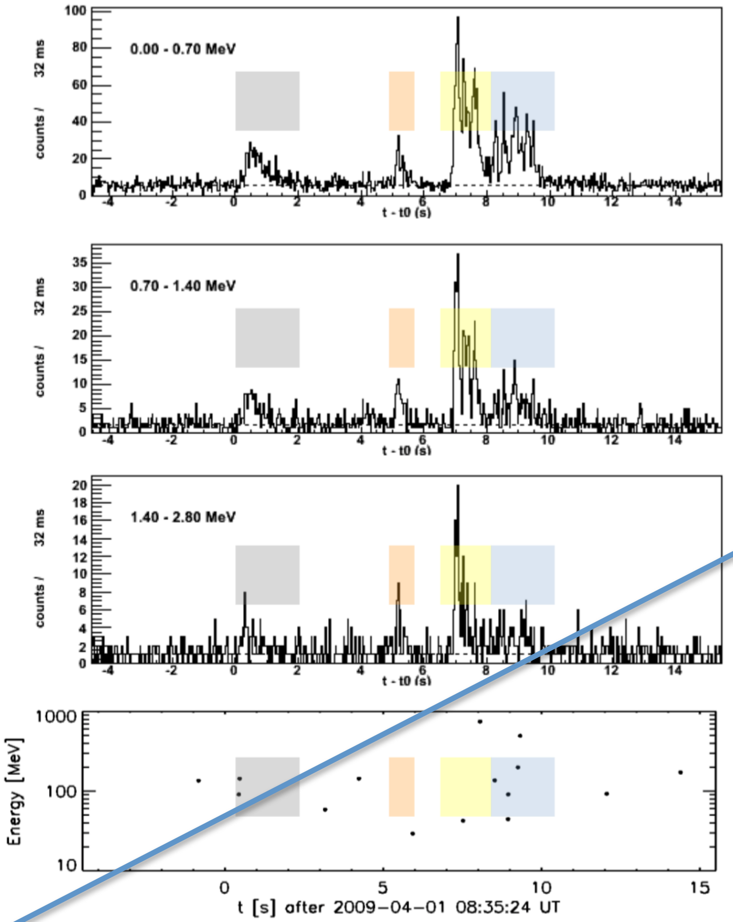
E > 100 MeV

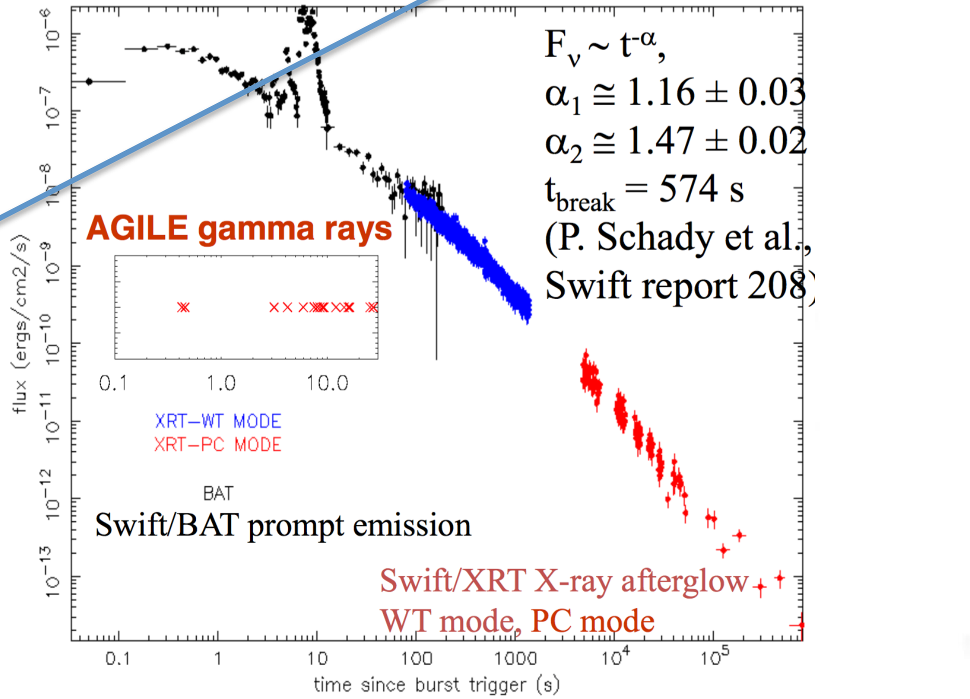
	080514B	090401B	090510	100724B	130327B	130427A	131108A
In the Light Curve :							
- Extended emission ,.....................	X	X	X			X	X
- Delayed onset			X				
- L ~ t^-a			X				X
- Prompt emission				X	X		
- Superlong Bursts						X	
In the spectrum :							
- Extra component			X				X

GRB 090401B

prompt emission (68%)

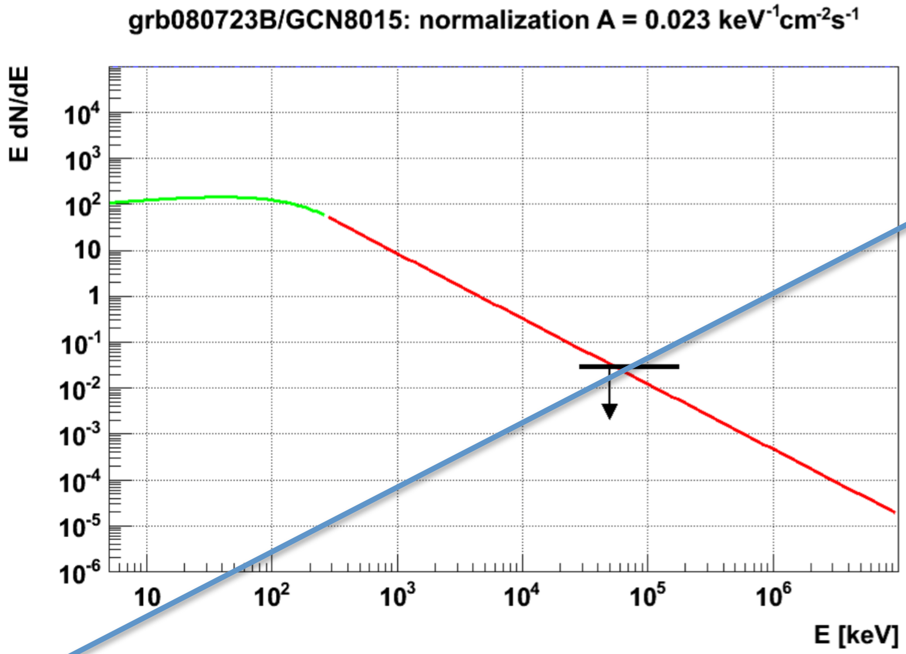
extended/delayed emission (32%)

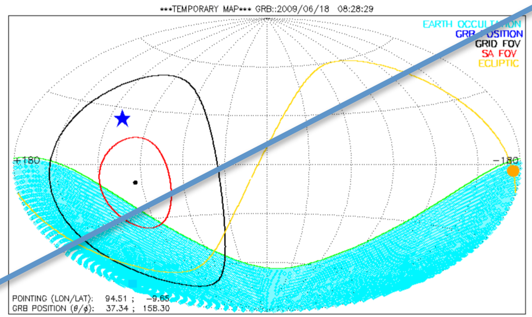


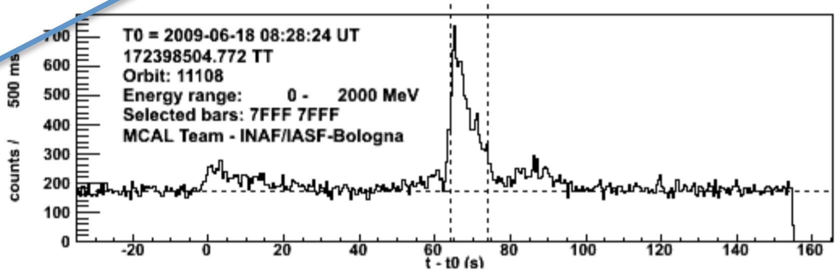


no high-energy emission

GRID upper limits

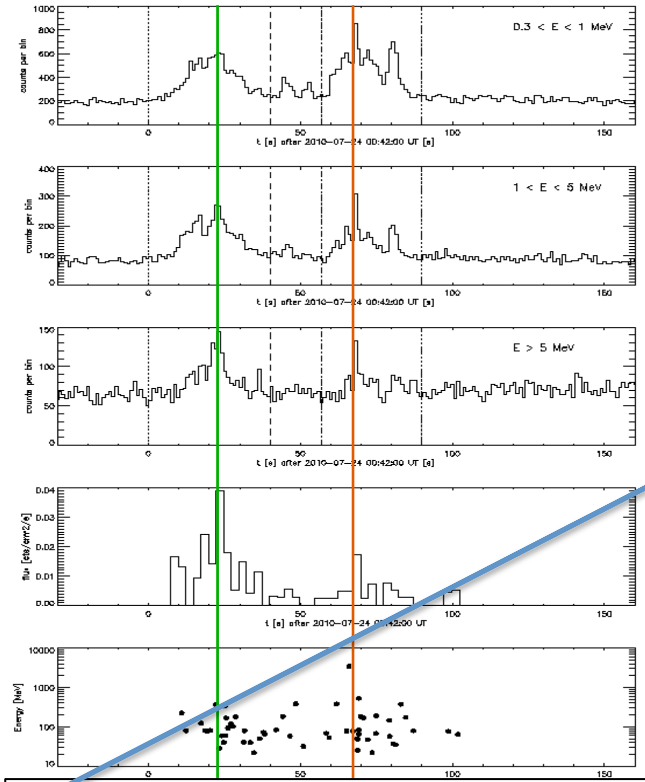






- among the brightest MCAL events
- 37° off-axis
- no gamma-ray emission above 100 MeV
- β ~ -3.2

β=2.0 β=2.2 β=2.4



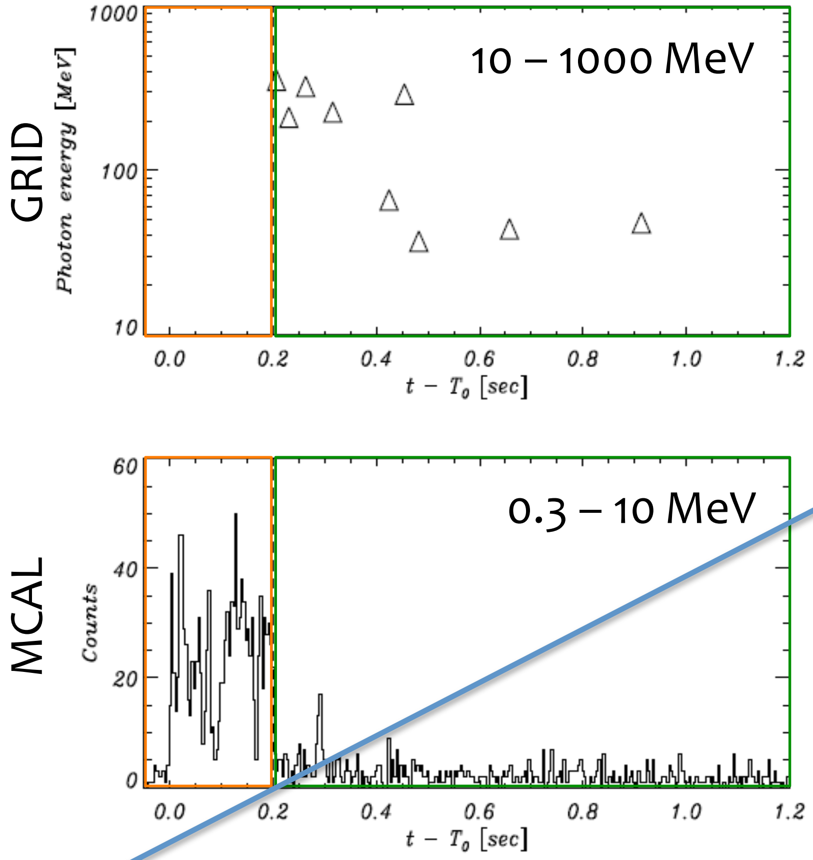
GRB 100724B [*Del Monte et al.*, 2011]

simultaneous emission

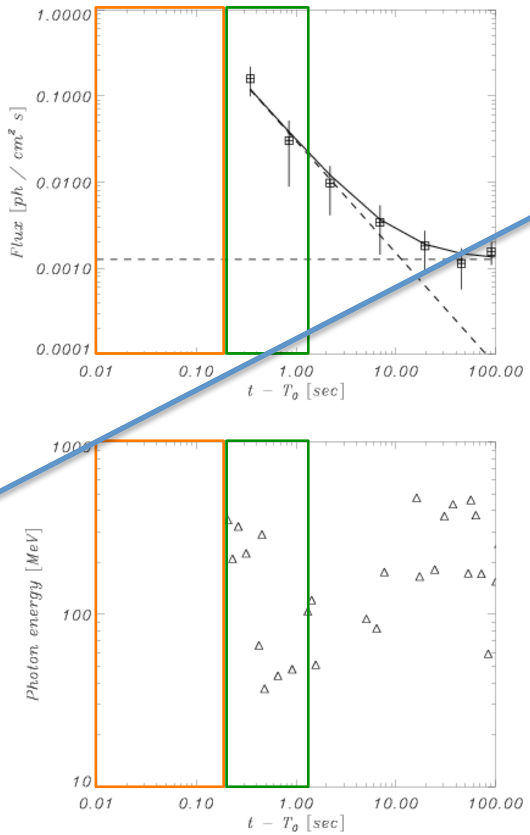
- main bumps simultaneous at MeV and GeV
- gamma-rays in [t_0+6 s, t_0+125 s] (first transit)

  no gamma-rays in [t_0+410 s, t_0+529 s] (second transit)
- no spectral cutoff until 3.5 GeV

GRB 090510



GRB 090510 [*Giuliani et al.*, 2010]



$z \sim 0.9$

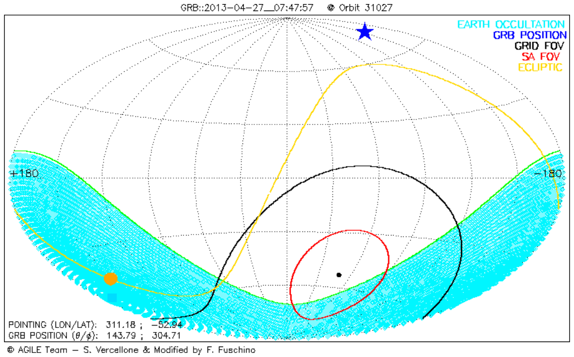
E_{iso} = 1052 erg

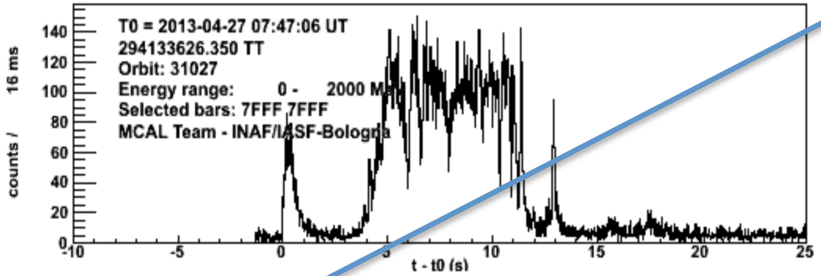
$E_{p1} \sim 3$ MeV

$E_{p2} > 50$ MeV

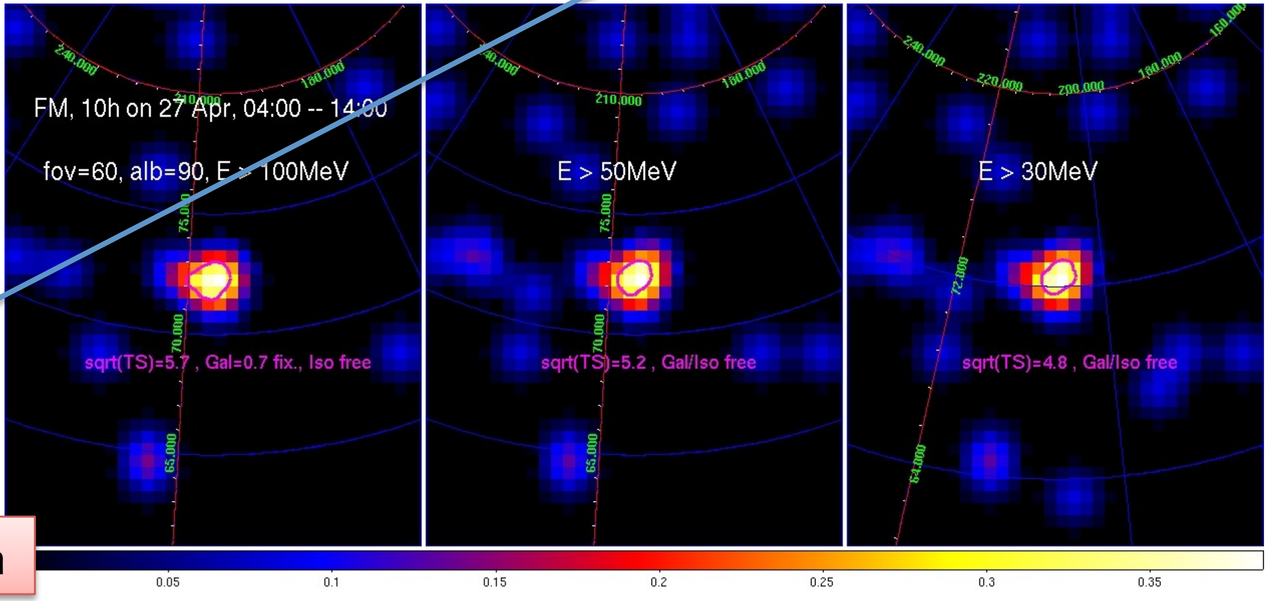
$F = t^{-1.3}$

extended/delayed emission





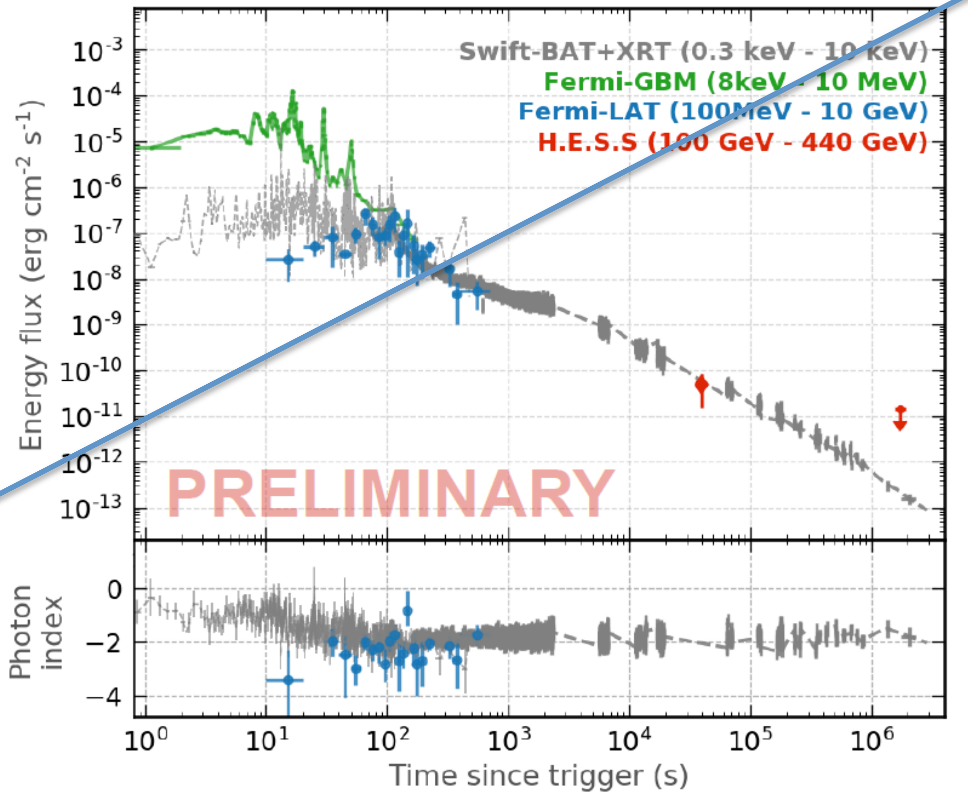
- in the FoV after 500 s
- first GRB automatically detected by GRID flaring source pipeline
- first detection by Likelihood of the extended emission

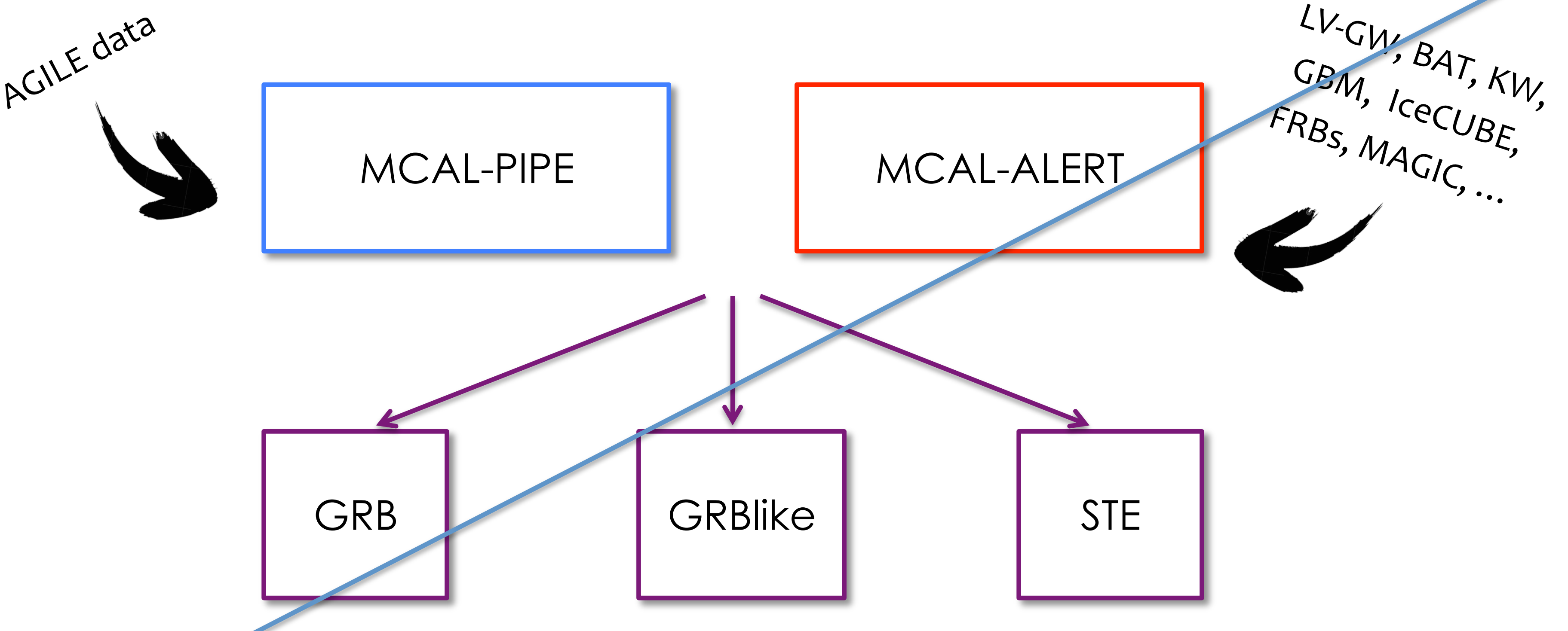


extended/delayed emission

GRB 180720B Lightcurve

- Multi-peaked and very bright prompt emission.
- Fermi-LAT detection up to 700 s after trigger. Photon index ~ -2.0.
- H.E.S.S. flux (100 to 440 GeV). Photon index consistent with -2.0.
- Gamma-ray energy flux at same level as X-Ray.
- Afterglow falling at same rate in al wavelenghts.





- automatic notices
- alert to AGILE Team
- online database

MCAL GRB pipeline

- 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 ~0.03 ph cm^{-2} s^{-1} => ~10^{-7} erg cm^{-2} 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;

Conclusions

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

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

    - Both classes of long and short are detected in the gamma energy band.

    - Some events have a single spectrum other have additional spectral compone

- Gamma-ray emitting GRBs seem to be characterised by high fluence and high Lor factor. It is still debated if gamma-rays are produced in internal (prompt) or exte (afterglow) shocks.

AGILE & GW:

- AGILE good fast coverage of all sky
- participated to LIGO-Virgo O2 run, improved sensitivity to weak MCAL events