



AGILE 10 years of HE gamma astrophysics

G.Barbiellini, F.Longo et al.
INFN Trieste
on behalf of the AGILE team

Sexten, July 24, 2017



A tribute ...

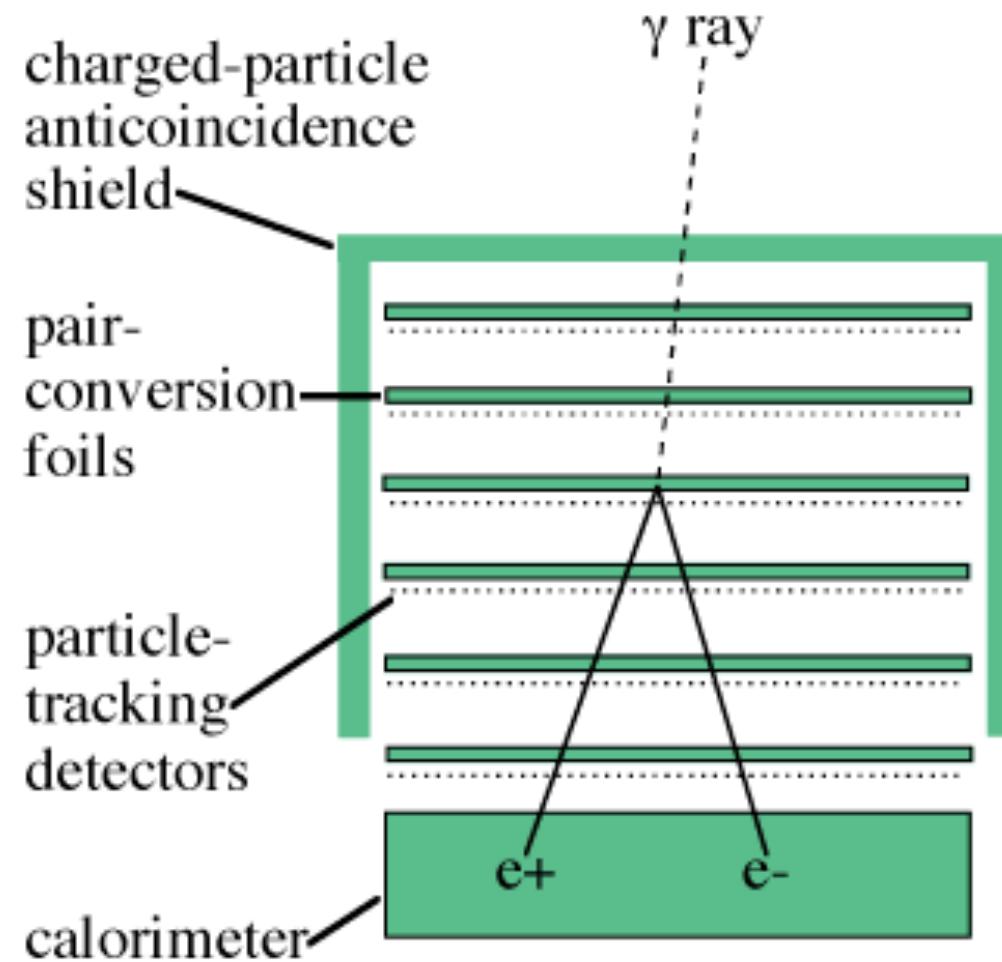


In memory of Nanni

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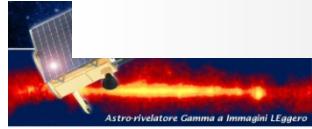


A typical Gamma-ray Detector





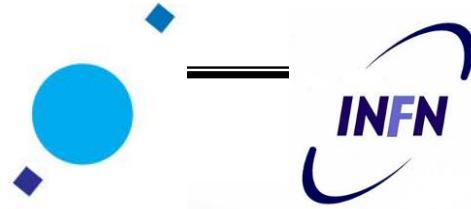
AGILE



AGILE

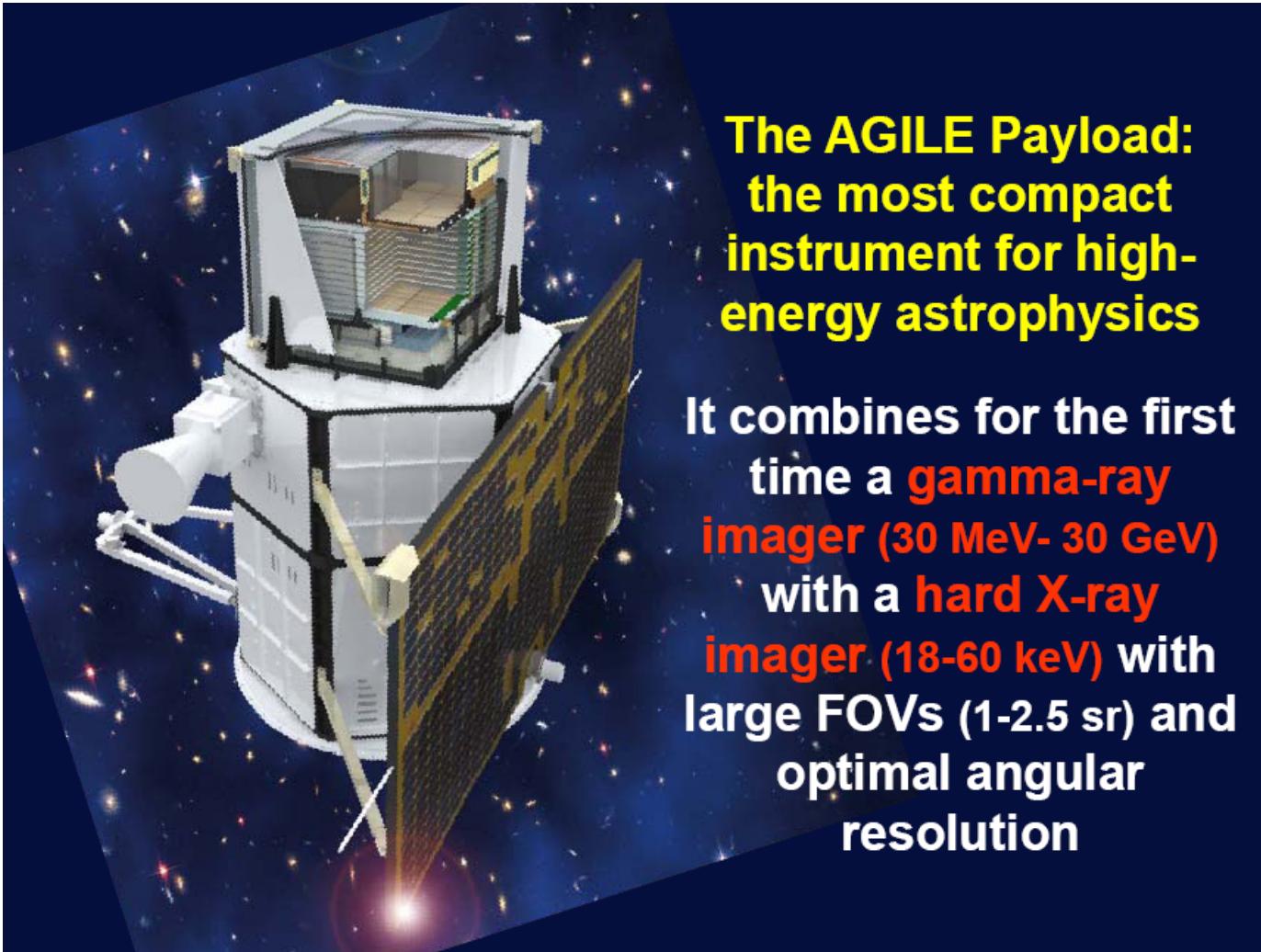


INAF





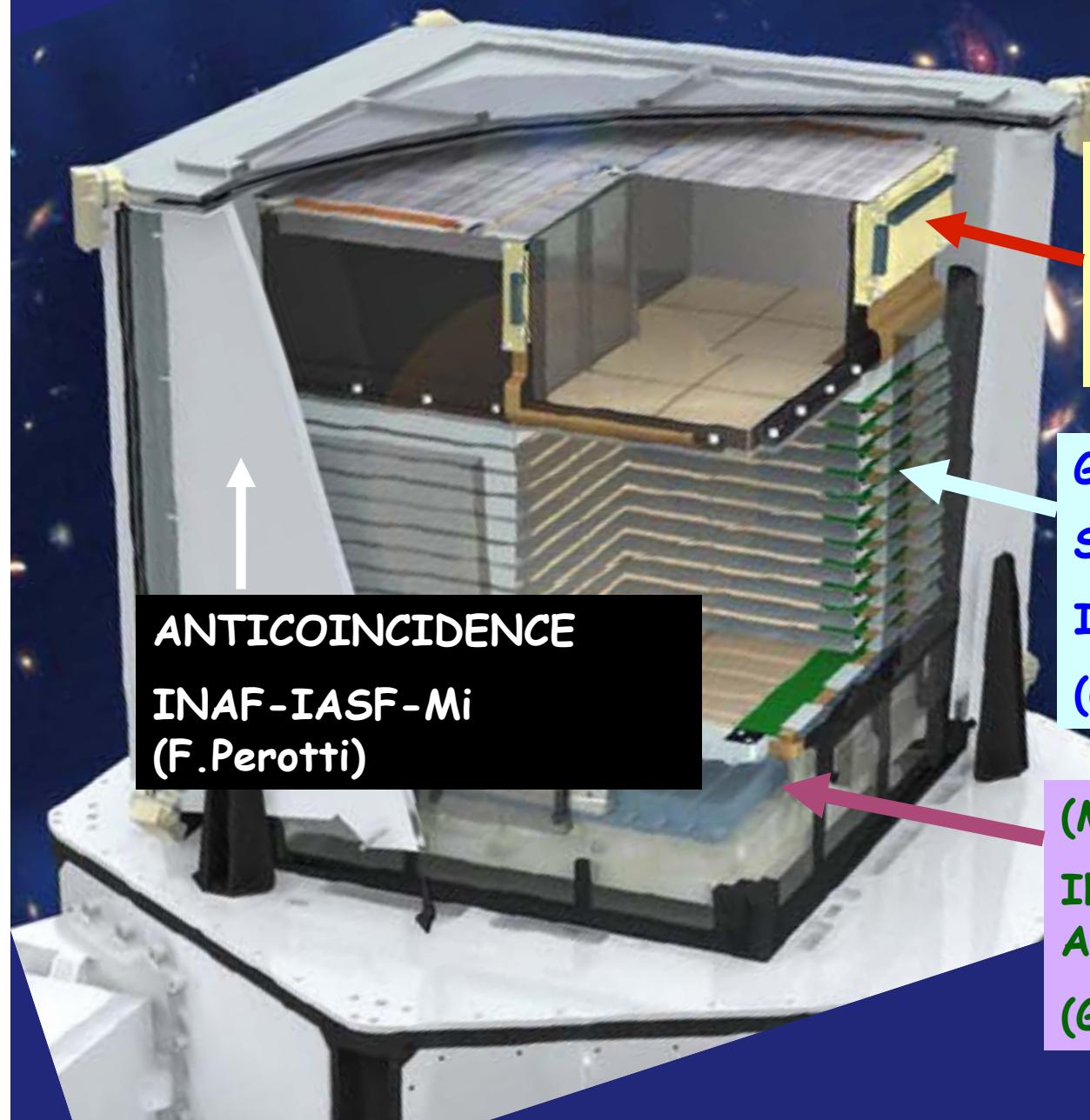
AGILE instrument



The AGILE Payload:
the most compact
instrument for high-
energy astrophysics

It combines for the first
time a **gamma-ray
imager** (30 MeV- 30 GeV)
with a **hard X-ray
imager** (18-60 keV) with
large FOVs (1-2.5 sr) and
optimal angular
resolution

AGILE: inside the cube...



ANTICOINCIDENCE
INAF-IASF-Mi
(F.Perotti)

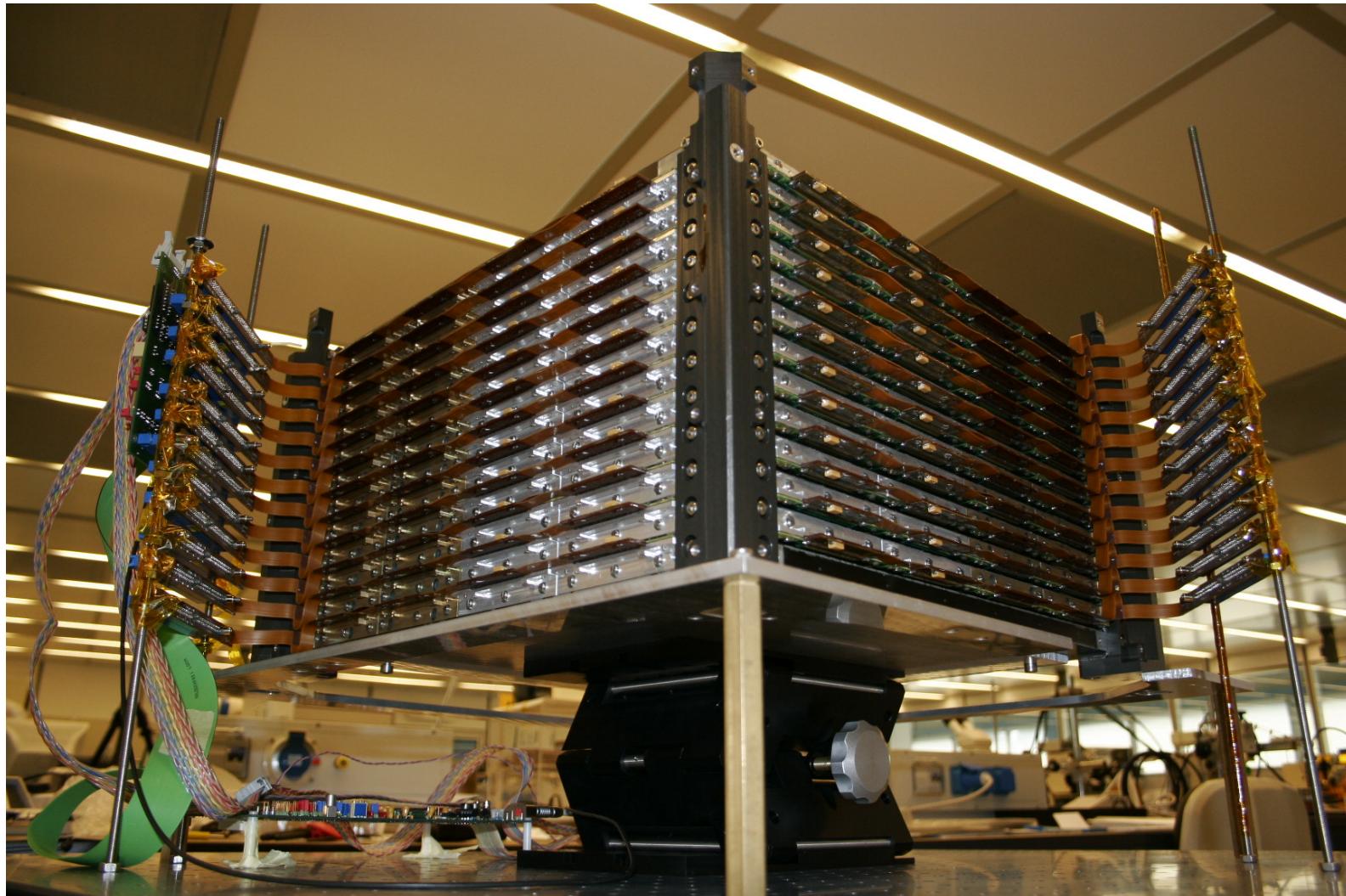
**HARD X-RAY IMAGER
(SUPER-AGILE)**
INAF-IASF-Rm
(E.Costa, M. Feroci)

GAMMA-RAY IMAGER
SILICON TRACKER
INFN-Trieste
(G.Barbiellini, M. Prest)

(MINI) CALORIMETER
INAF-IASF-Bo, Thales-
Alenia Space (LABEN)
(G. Di Cocco, C. Labanti)



The AGILE TRK





The Silicon Tracker

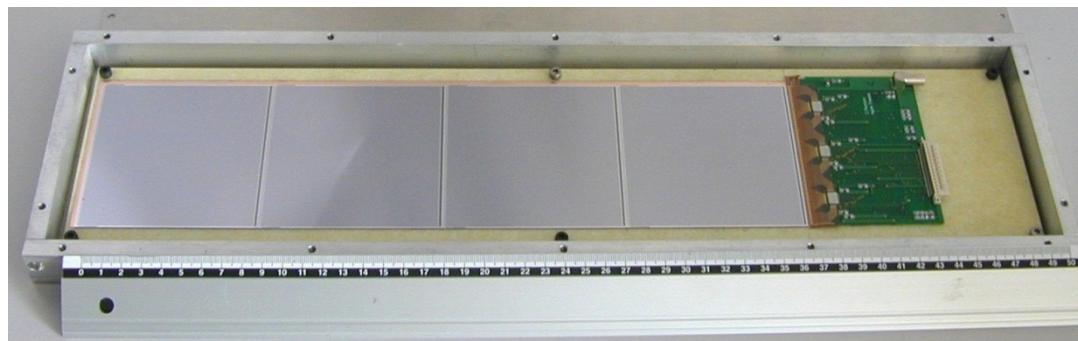
The AGILE silicon detectors

Detector specifications:

- dimension: 9.5x9.5 cm²
- thickness: 410 µm (6 inch technology)
- readout pitch: 242 µm;
physical pitch: 121 µm (one floating strip)
- number of strips/ladder: 384
- Single side and AC-coupled
- leakage current: 2 nA/cm² at V_{bias}=2.5*V_{DD}=200 V
- polarization resistor: 40 MΩ
- coupling capacitor: 55 pF/cm
- Al strip resistance: 4.3 Ω/cm
- max number of bad strips: <1%
- average number of bad strips: <0.5%

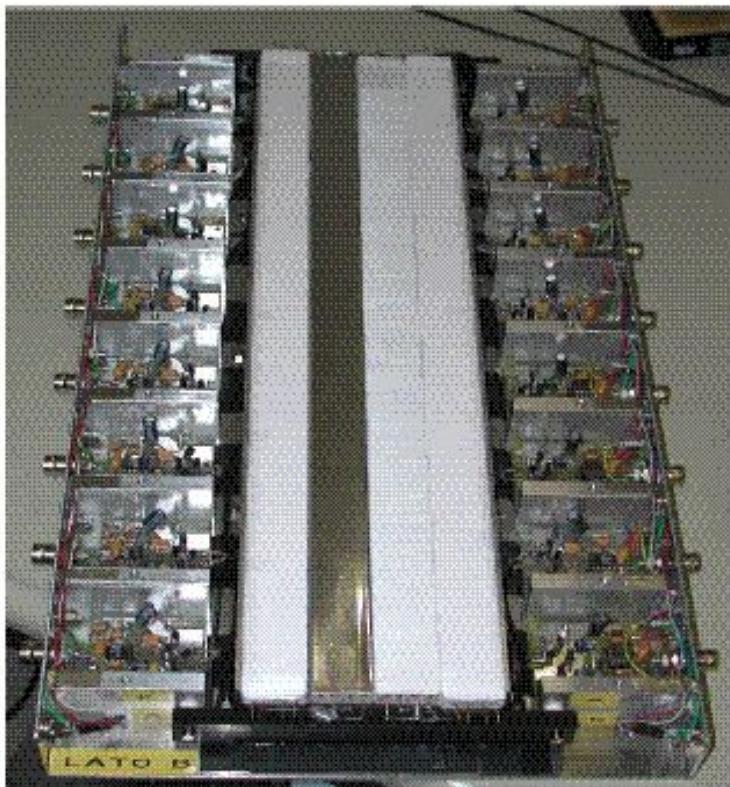
The AGILE frontend chip: TA1 → TAA1

- low noise, low power, SELF-TRIGGERING
- technology: 1.2 µ CMOS, double poly, double metal (final: 0.8 µ BiCMOS on epitaxial layer)
- features:
 - 128 channels
 - gain: 25 mV/fC; range: 18 fC
 - noise (e⁻rms): 165+6.1/pF for T_{peak}=2 µs
 - power: <0.4 mW/channel
 - power rails: ±2 V
 - readout frequency: 5 Mhz
 - gain spread: <1.5%
 - threshold offset spread (TA1): 20% (in TAA1 will be implemented a 3 bit DAC per channel)





The CsI Mini-Calorimeter



MINI-CALORIMETER

DETECTOR

- 30 CsI bars wrapped with tight diffusion material organized in 2 orthogonal trays
- bar dimension: $40 \times 2.3 \times 1.5 \text{ cm}^3$
 - total radiation length: $1.5X_0$ (in axis)

FRONTEND ELECTRONICS

- 1 photodiode on each side of the bar
 - optically coupled

GOAL

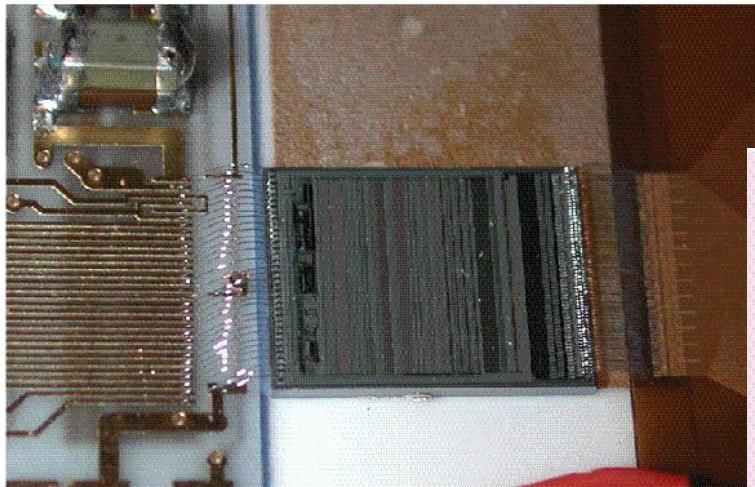
- measure energy deposit of the photon conversion pair (GRID mode)
- detect GRBs and transients in the range 0.25-250MeV (BURST mode)

SCIENTIFIC FEATURES

- energy resolution: 22-24% (FWHM) @ 1MeV
0.7% @ 100MeV
- spatial resolution: 15mm @ 1MeV
2mm @ 100MeV
- timing resolution: 2 μs (BURST mode)



SuperAGILE X-ray detector



SUPER-AGILE

DETECTOR

- plane with 16 silicon tiles organized in 4 1D detectors
- each detector: 1536 readout strips (0.121mm pitch)
- a coded mask system

FRONTEND ELECTRONICS

- 12 self-triggering readout ASICs (128 channels each) per each detector, positioned on a kapton-FR4 hybrid

GOAL

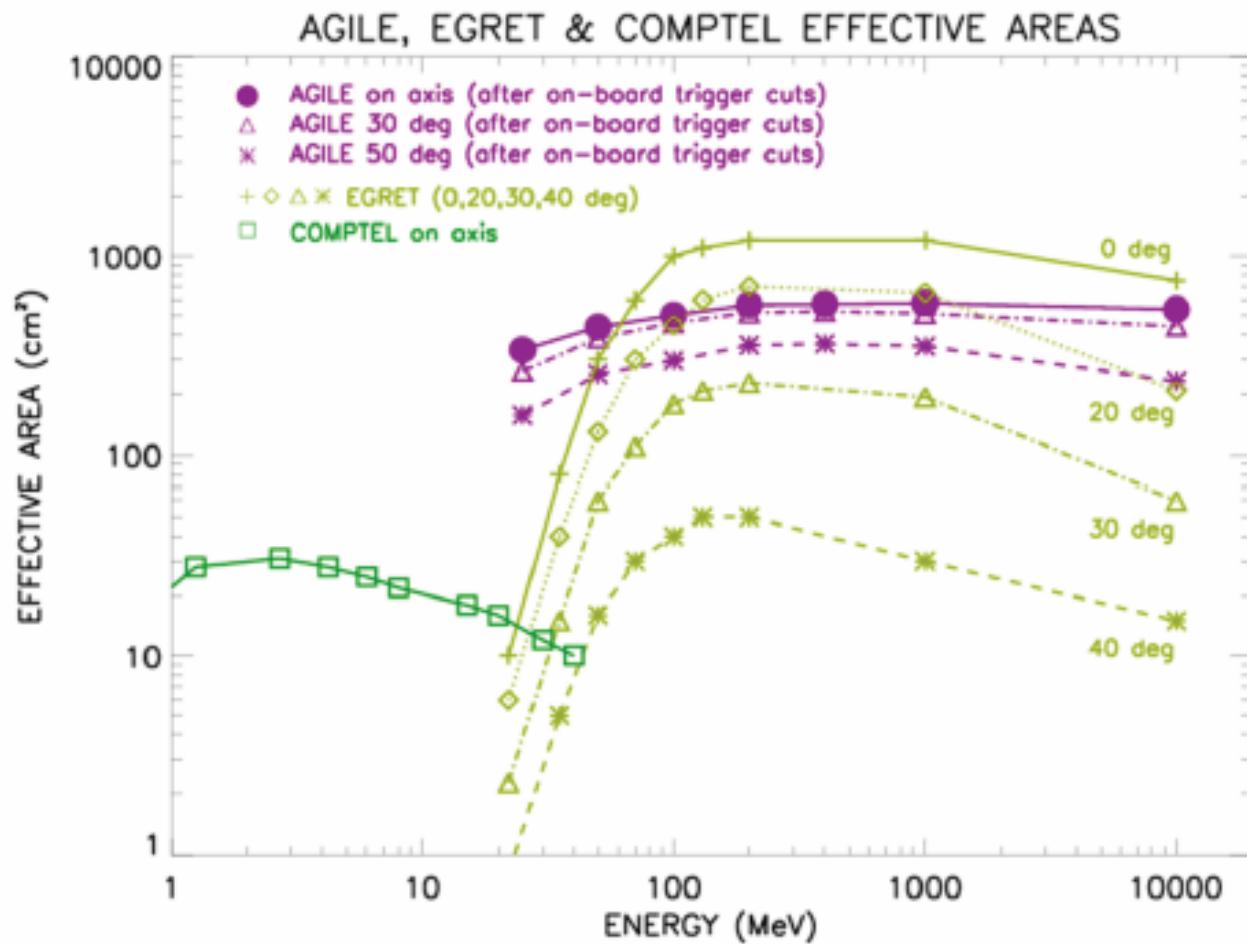
measure X-rays in the energy range 10-40keV to detect GRBs, transients, galactic and extra-galactic sources

SCIENTIFIC FEATURES

- imaging: 1'-3' at ~20mCrab
- timing resolution: 5 μ s
- energy resolution: 4keV (FWHM)
- flux sensitivity: ~5mCrab (15keV)

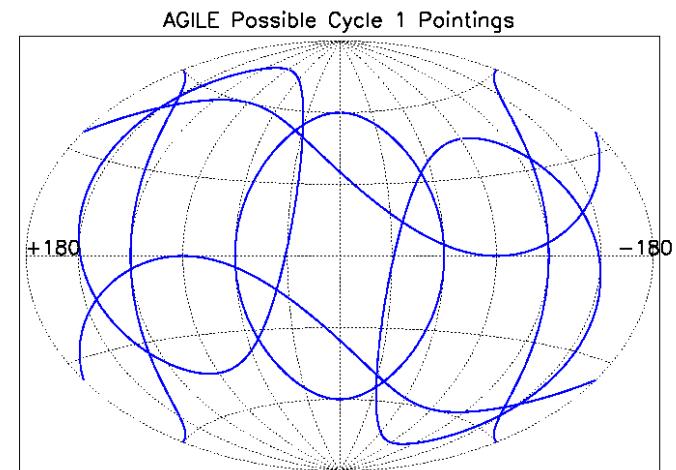
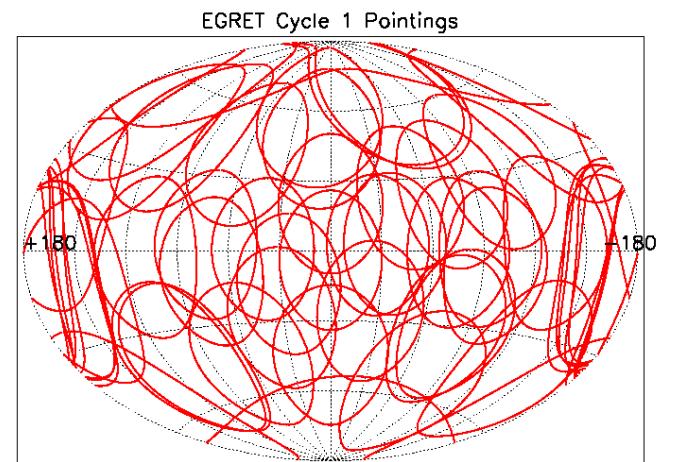
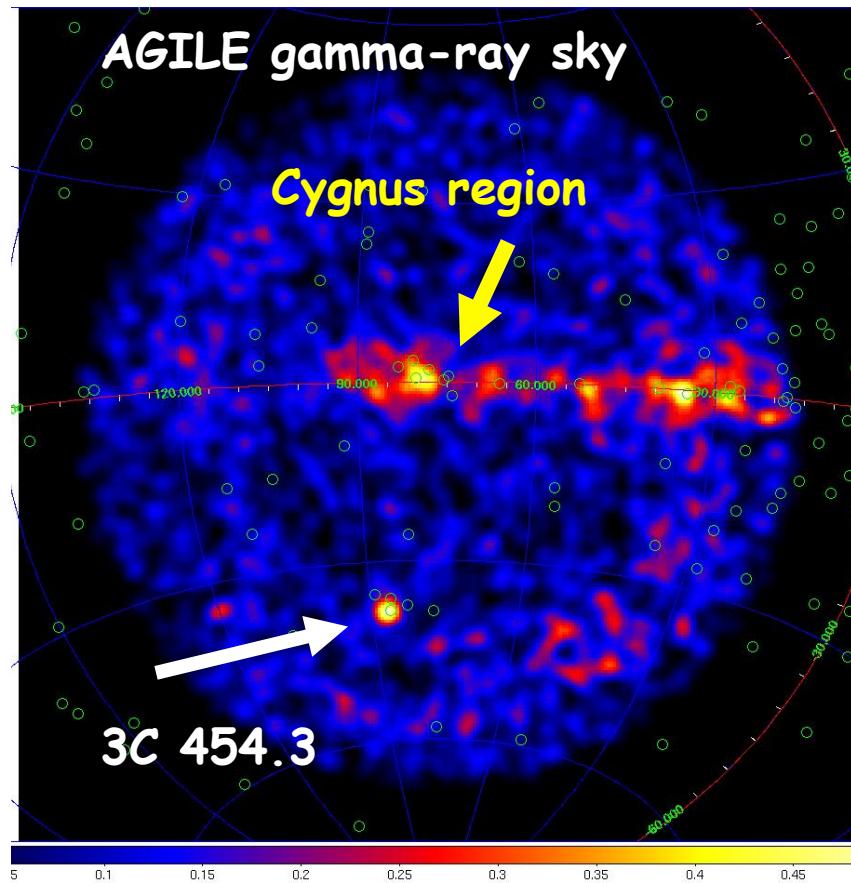


Performance



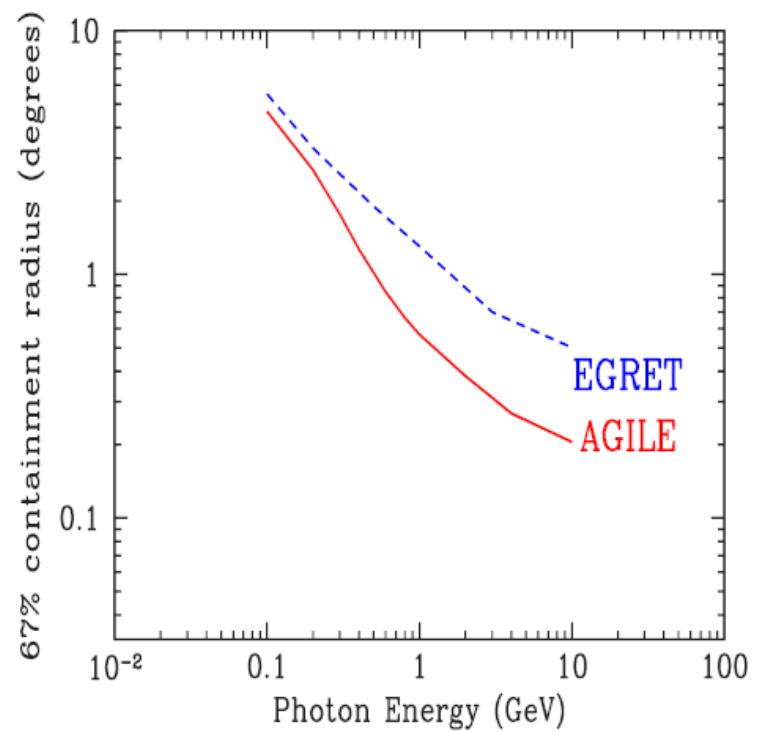
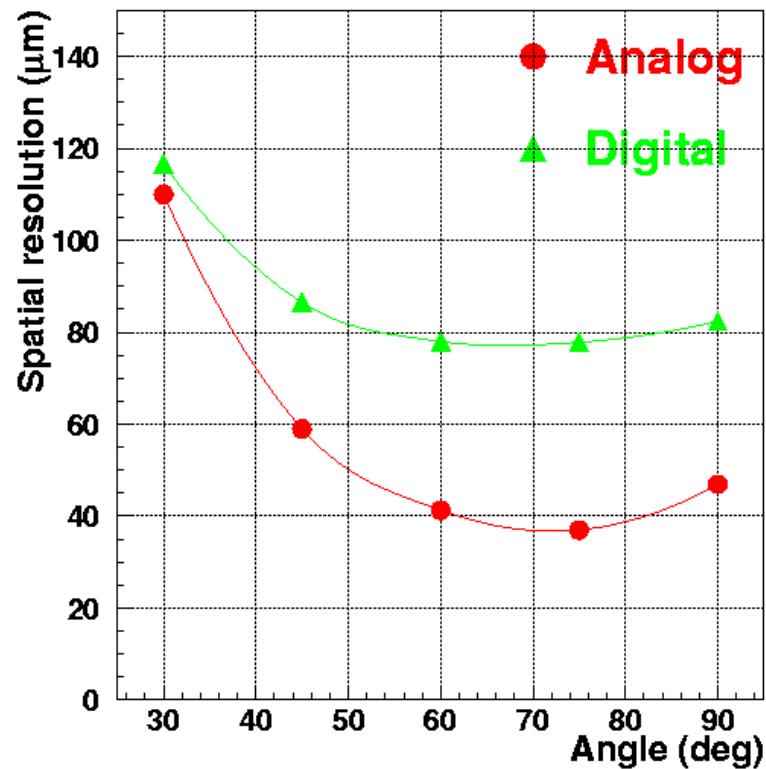


Si Self Trigger and FoV





Analog readout and PSF





The AGILE launch



Sriharikota launch base (India)
PSLV-C8 launch, April 23, 2007





AGILE two lifes

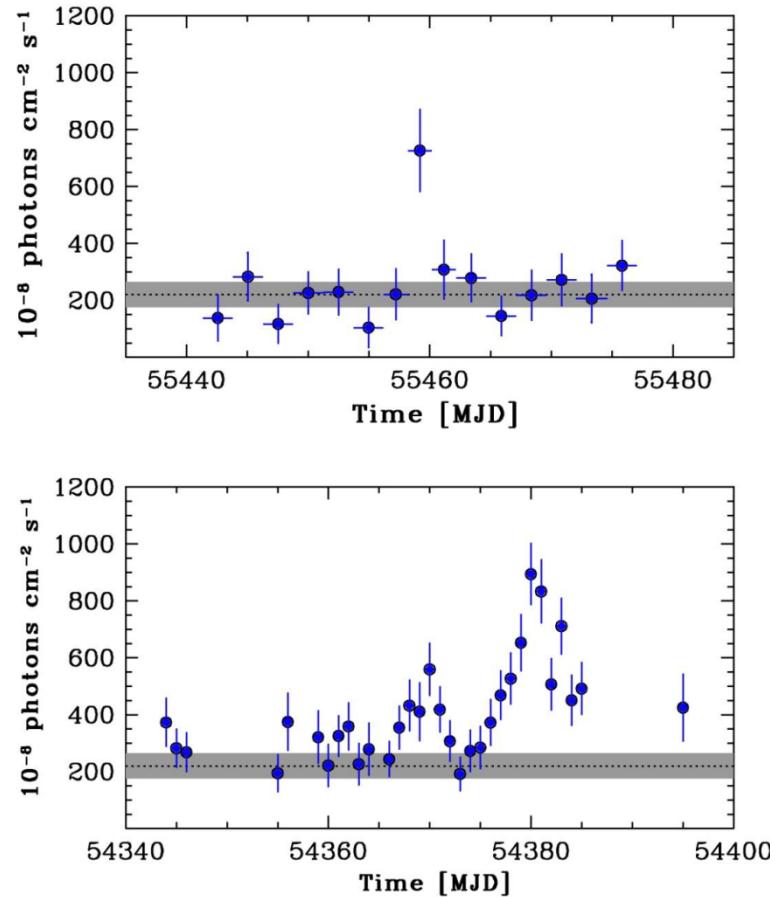
	pointing- AGILE	spinning- AGILE
time period	Jul.07 – Oct.09	Nov. 2010 -
attitude	fixed	variable (spinning, 1°/sec)
sky coverage	1/5	~ 70%
source livetime fraction	~ 0.5	~ 0.2
1-day exposure (30 degree off-axis, 100 MeV)	~ 2 10⁷ (cm² sec)	(0.5-1) 10⁷ (cm² sec)



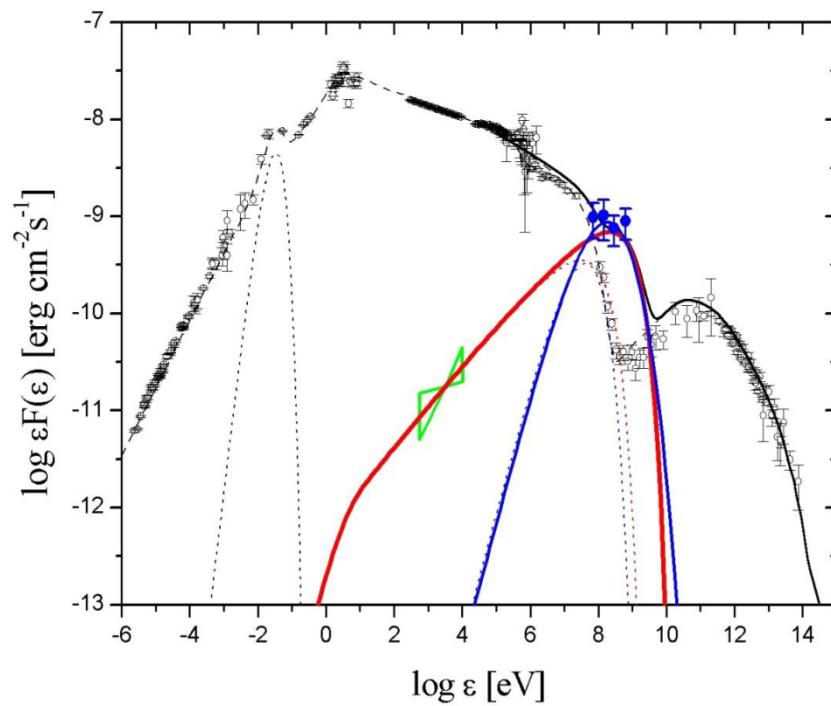
The flaring Crab

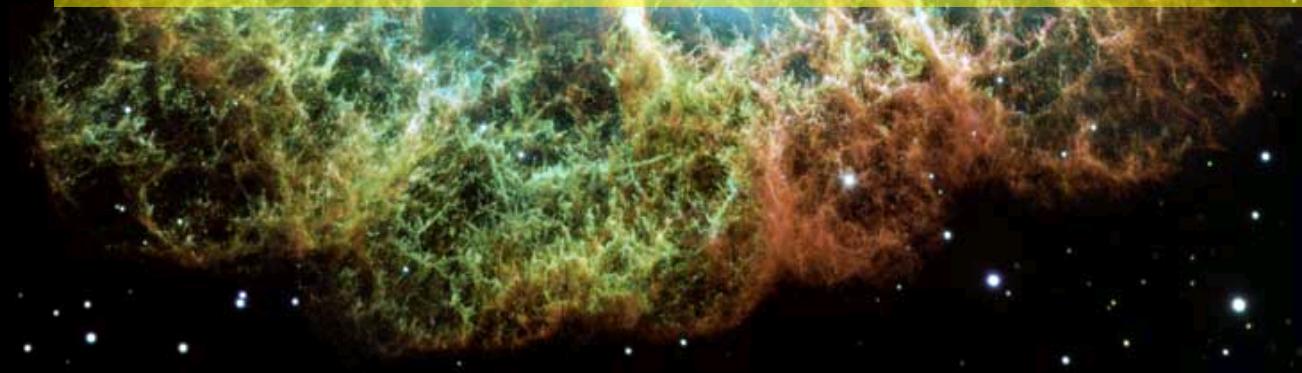


Galactic Transients: The Flaring Crab

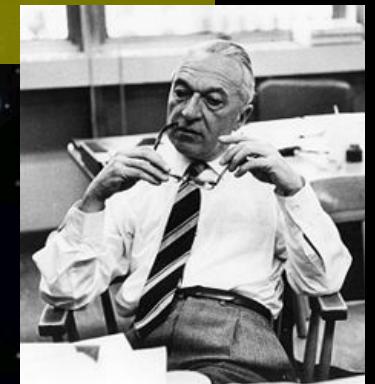


Tavani et al. 2011





The Bruno Rossi Prize in High Energy Astrophysics awarded by AAS to astrophysicist Marco Tavani and the AGILE Team for the discovery of gamma-ray flares from the Crab Nebula (January 10, 2012).

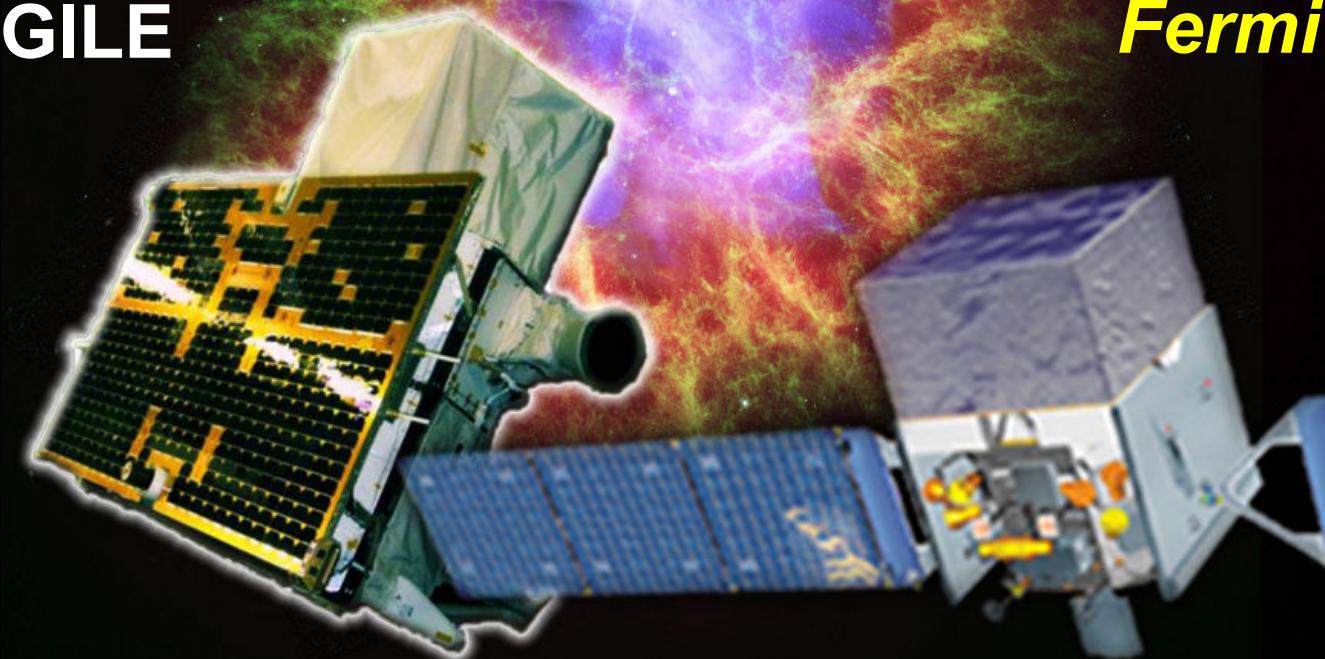


Bruno B. Rossi

Gamma-ray astrophysics above 100 MeV

AGILE

Fermi



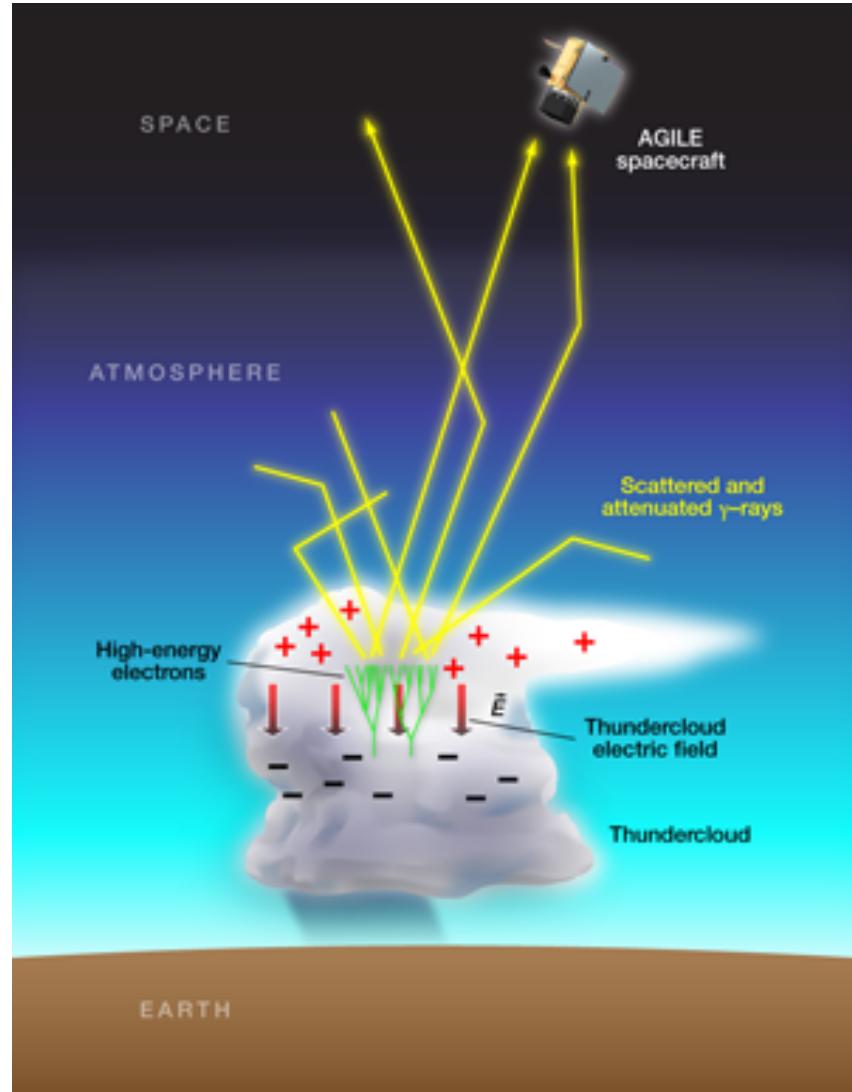
Picture of the day, Feb. 28, 2011, NASA-HEASARC



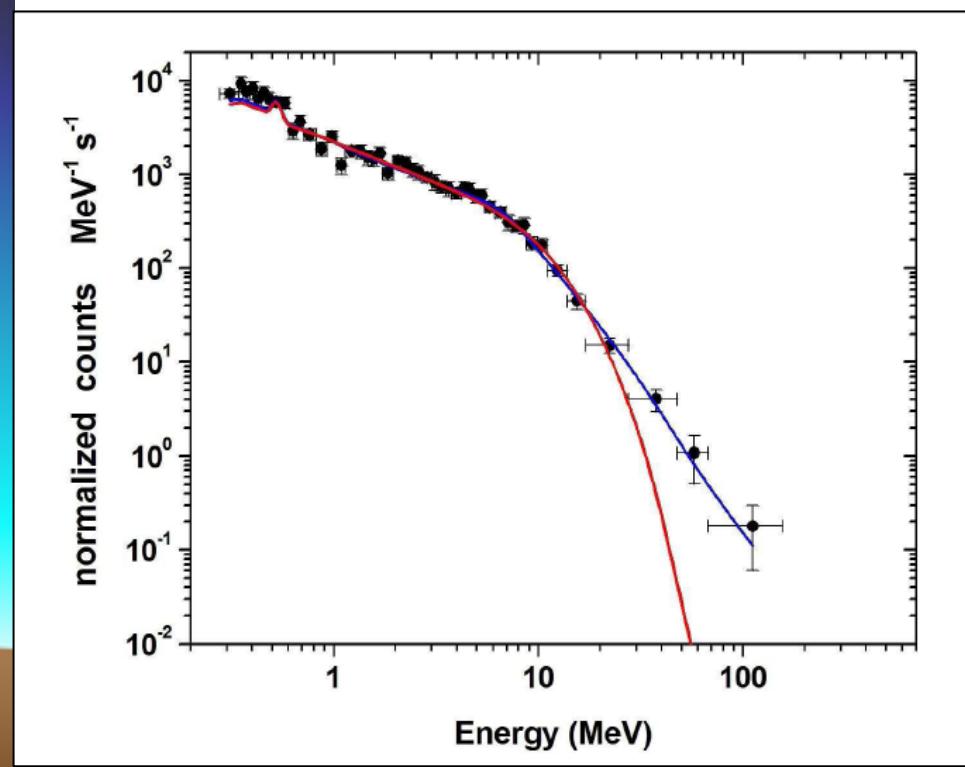
Key AGILE results



Terrestrial Gamma Ray Flashes

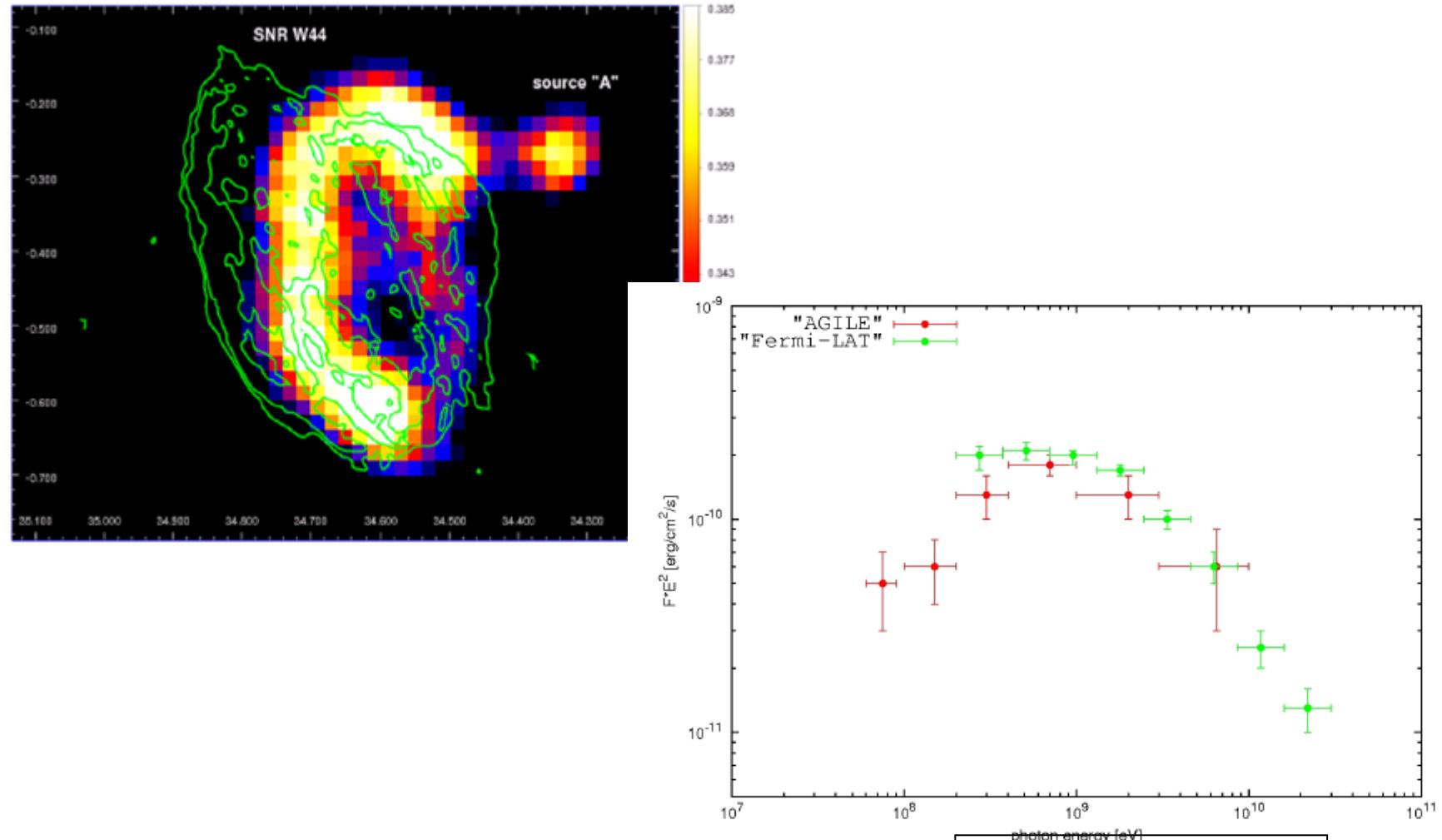


Marisaldi et al. 2010





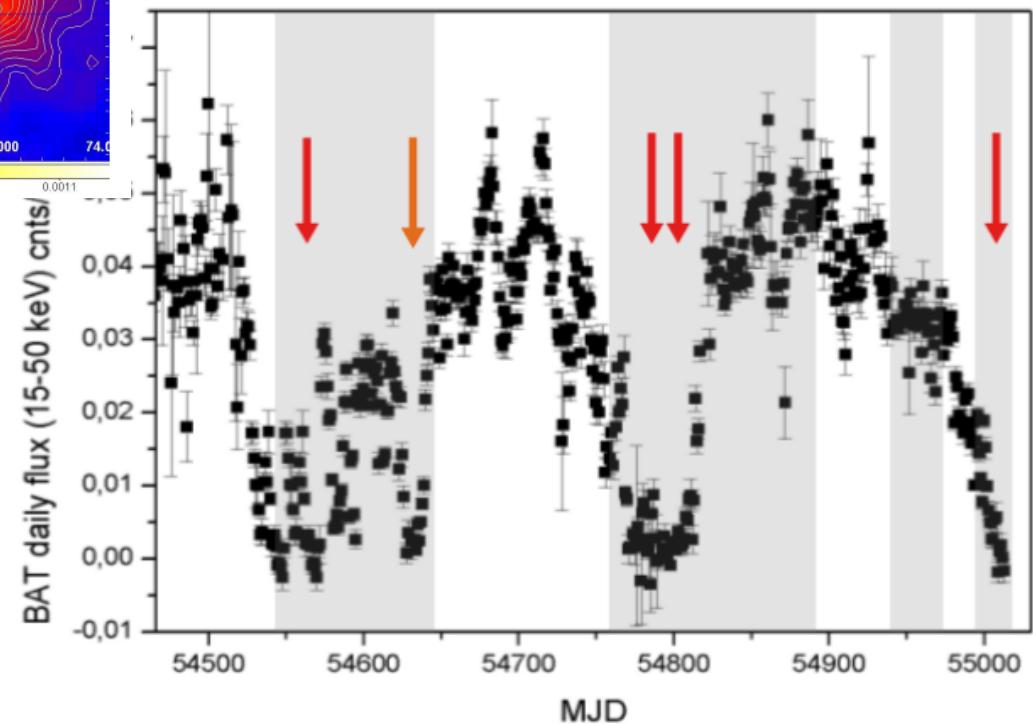
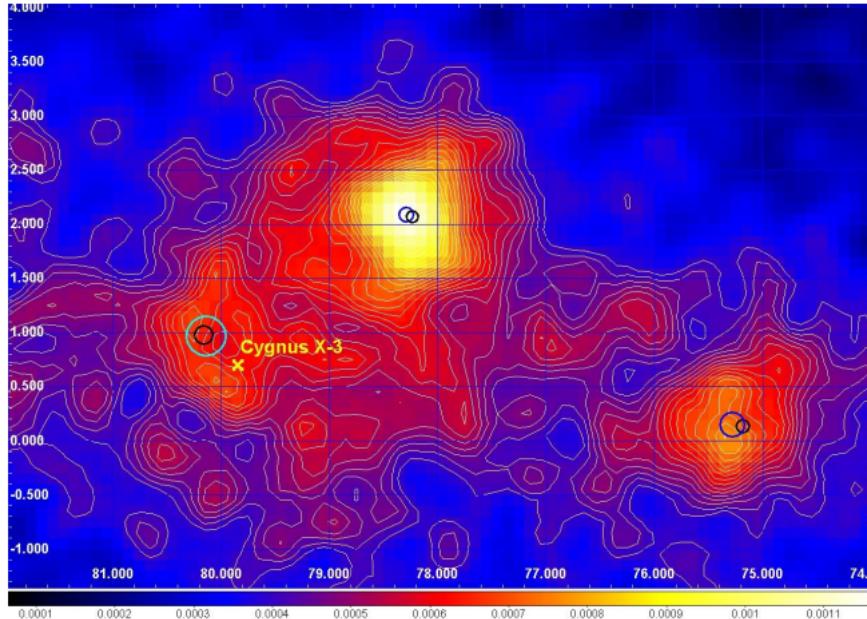
Supernova Remnants



Giuliani et al. 2011



Galactic Transients: Cygnus X3

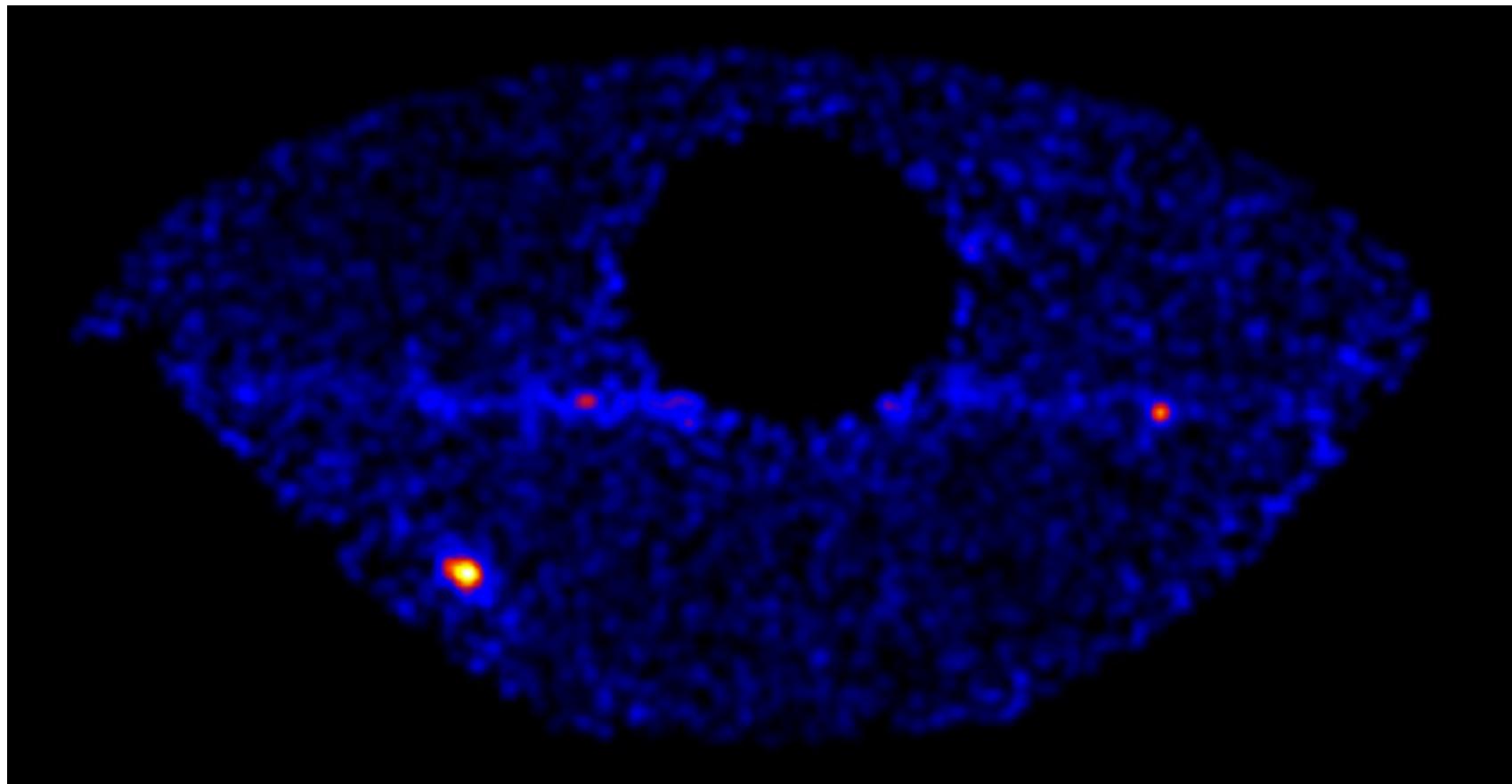


Tavani et al. 2009



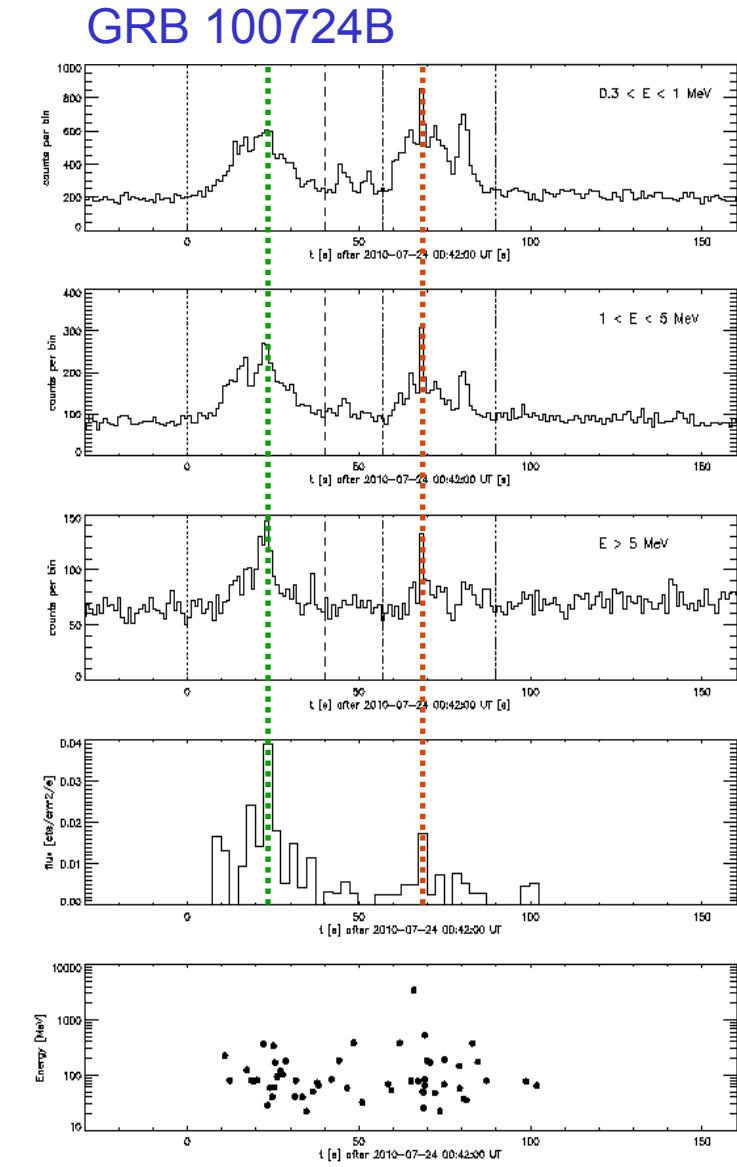
The Flaring 3C454.3

Vercellone et al. 2010

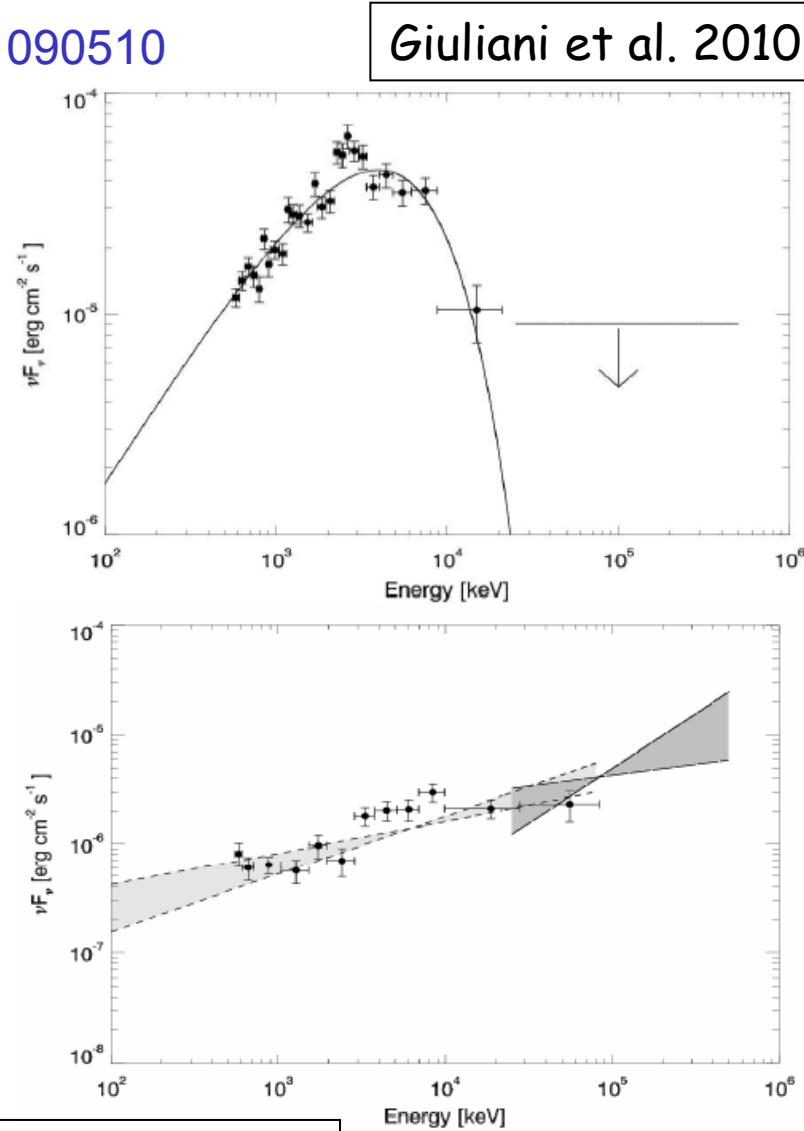




Gamma Ray Bursts

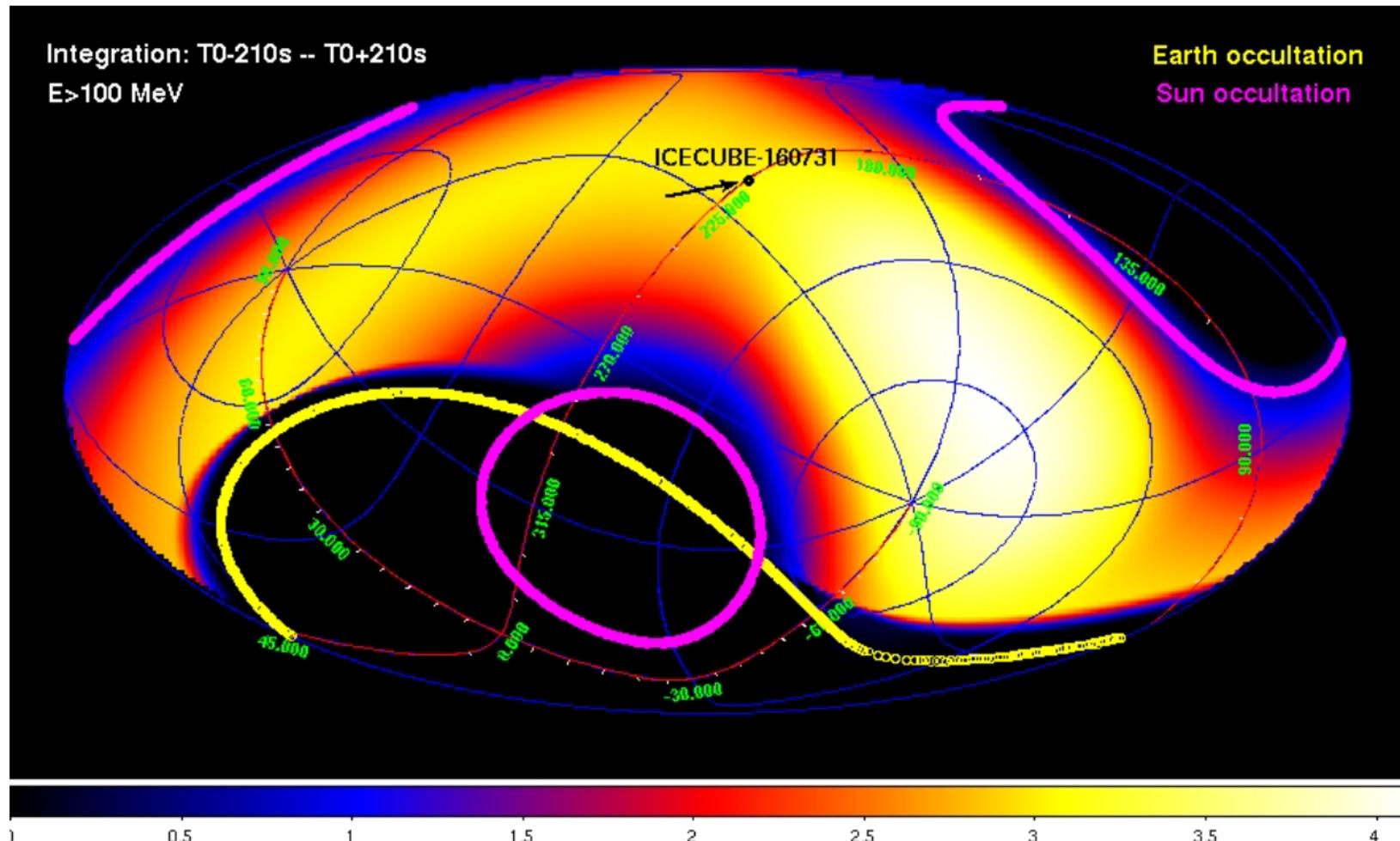


GRB 090510



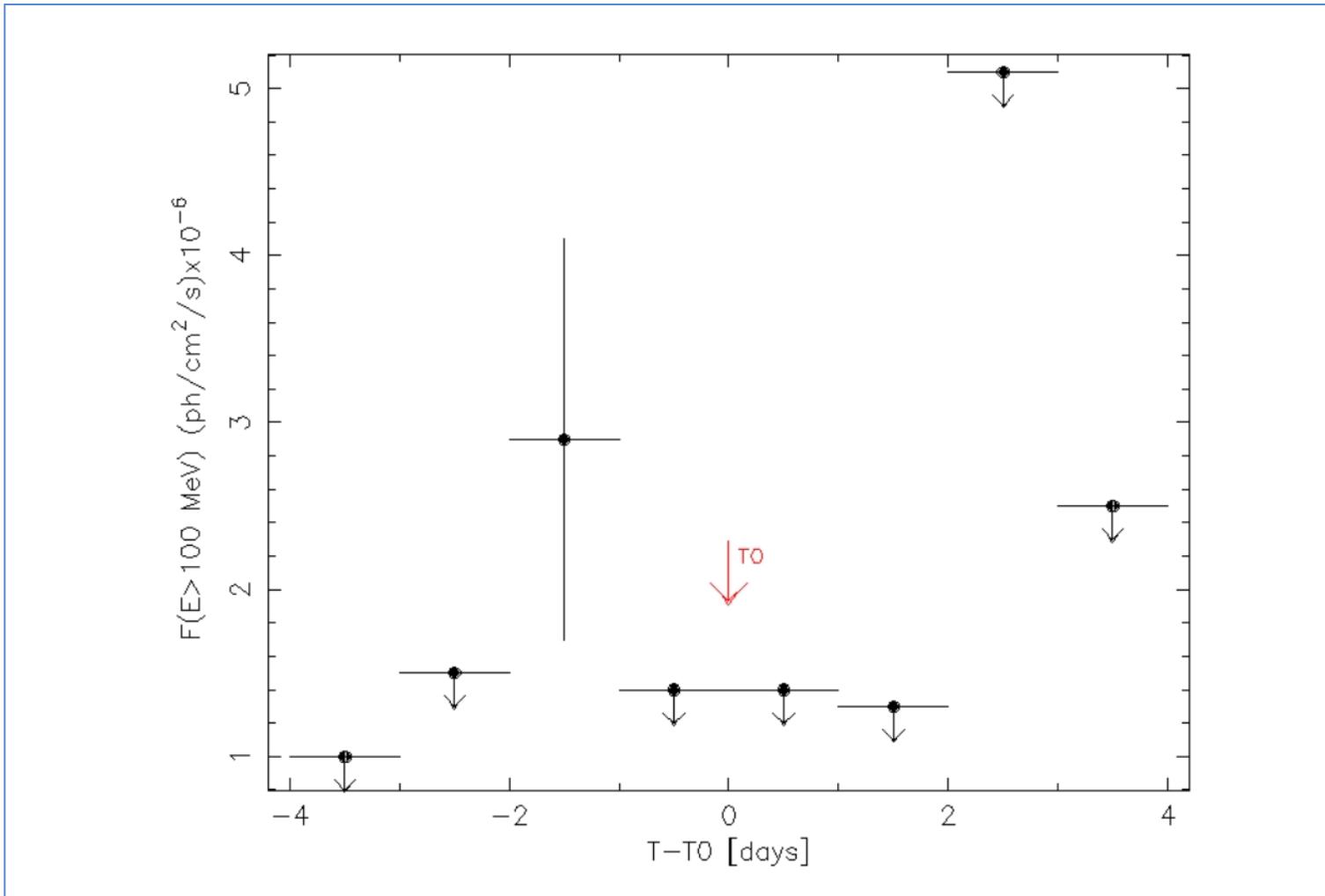


New!! Follow up of Neutrino events



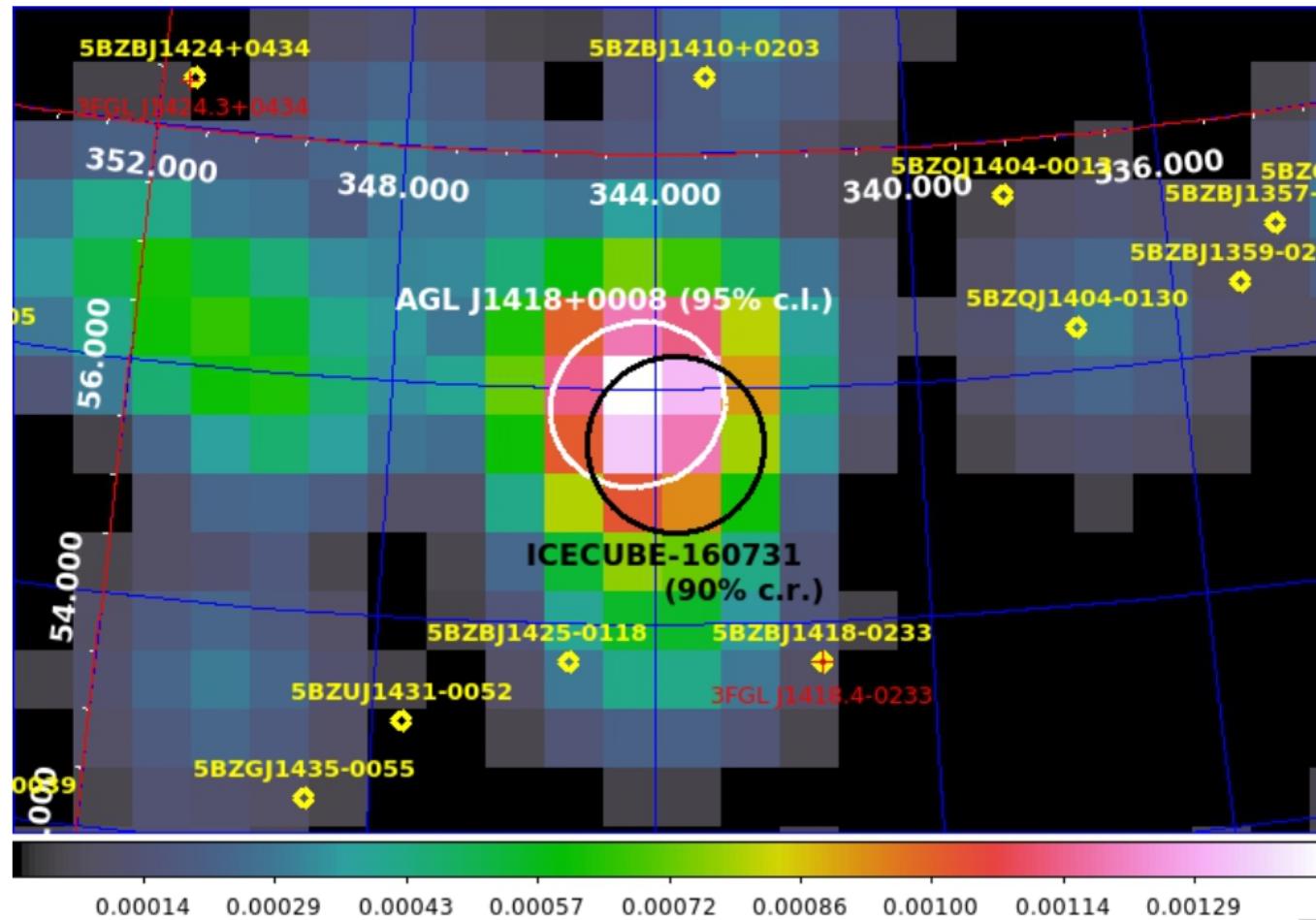


New!! Follow up of Neutrino events





New!! Follow up of Neutrino events

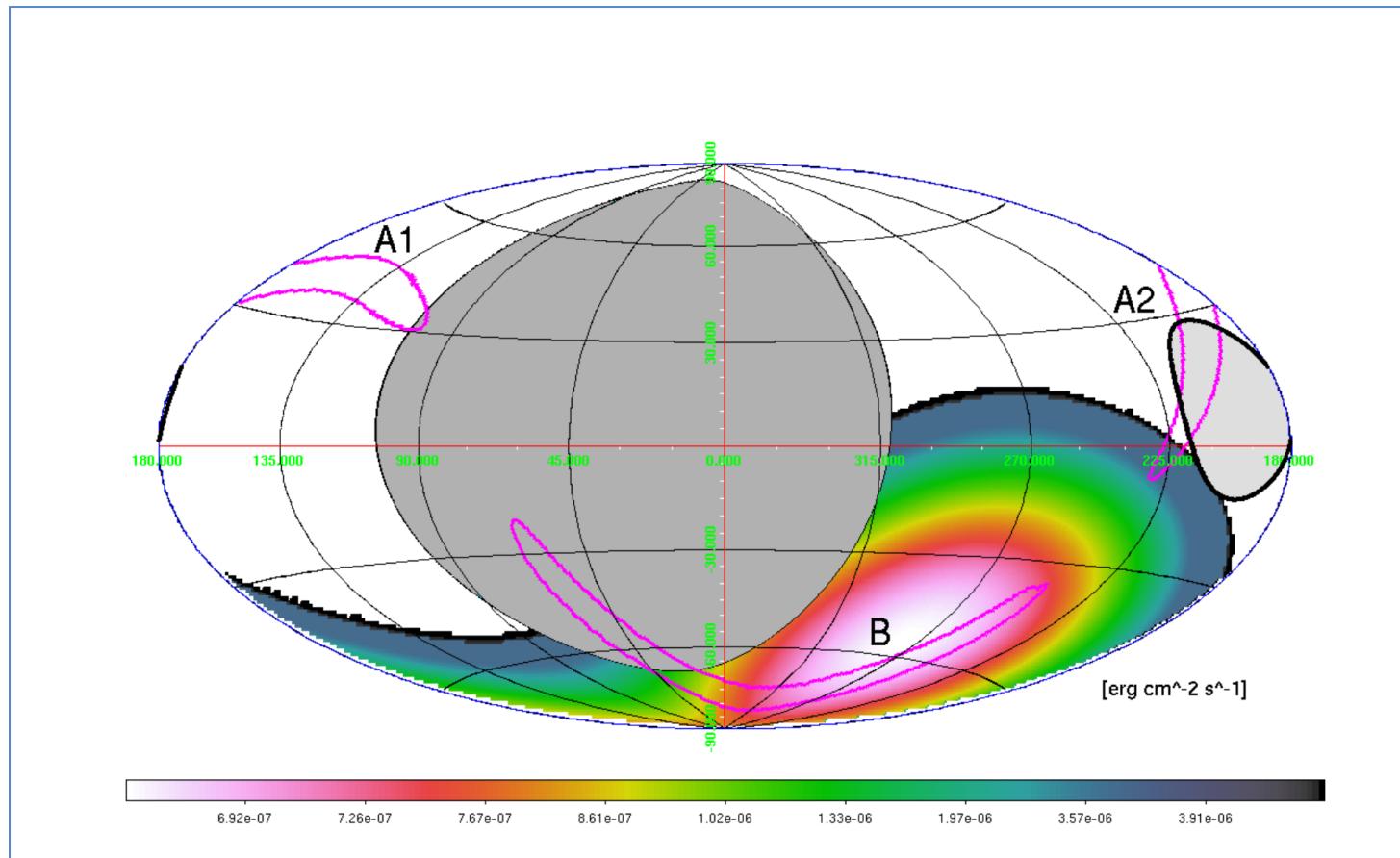


Lucarelli et al 2017

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New!! Follow up of GW events

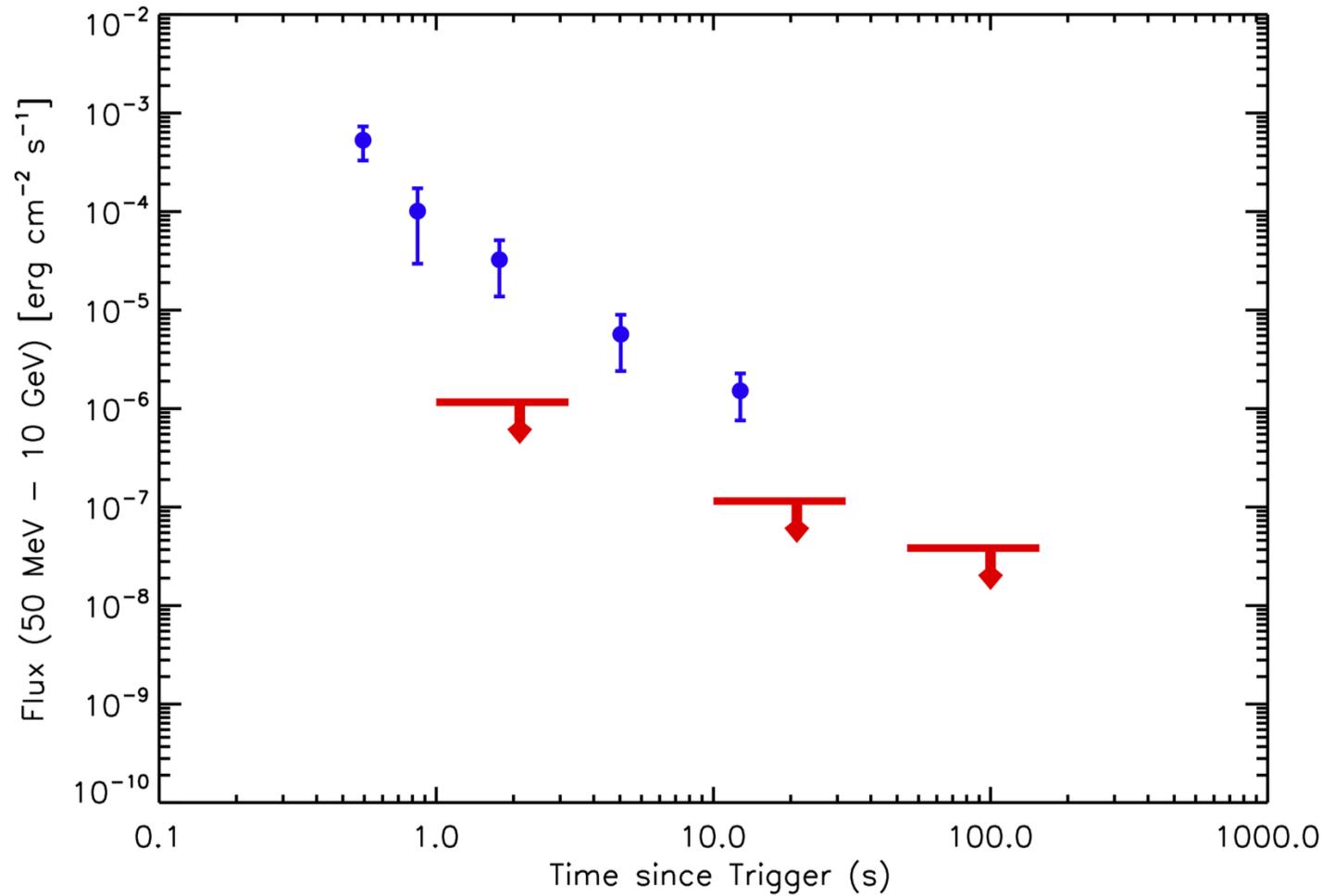


Verrecchia et al 2017

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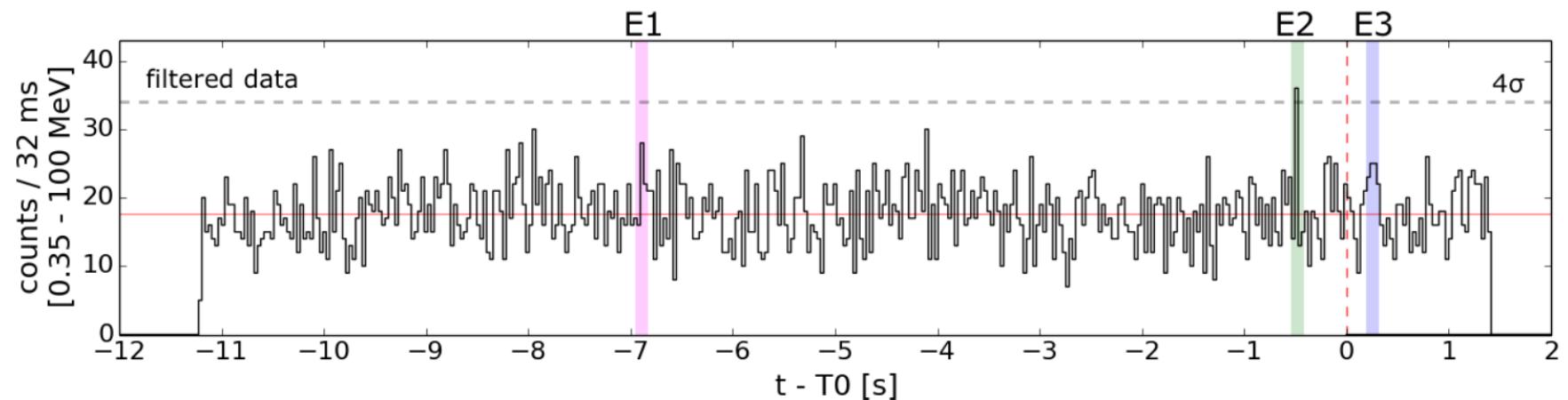
New!! Follow up of GW events



Verrecchia et al 2017



New!! Follow-up of GW events



Verrecchia et al 2017



Conclusions

- **AGILE crucial contributions to testing particle acceleration theories, plasma instabilities in the Universe and on the Earth !**
 - **Big surprise: discovery of gamma-ray flares from the Crab Nebula: 2012 Bruno Rossi Prize**
 - **Origin of cosmic rays, SNR W44, first direct evidence of neutral pion emission**
 - **Relativistic jets in microquasars and blazars**
 - **Gamma-ray emission up to 100 MeV from Terrestrial Gamma-Ray Flashes**
 - **Rapid follow up of Neutrino and GW events**
- **Rapid reaction, multiwavelenght connection, wide band instruments, online analysis**