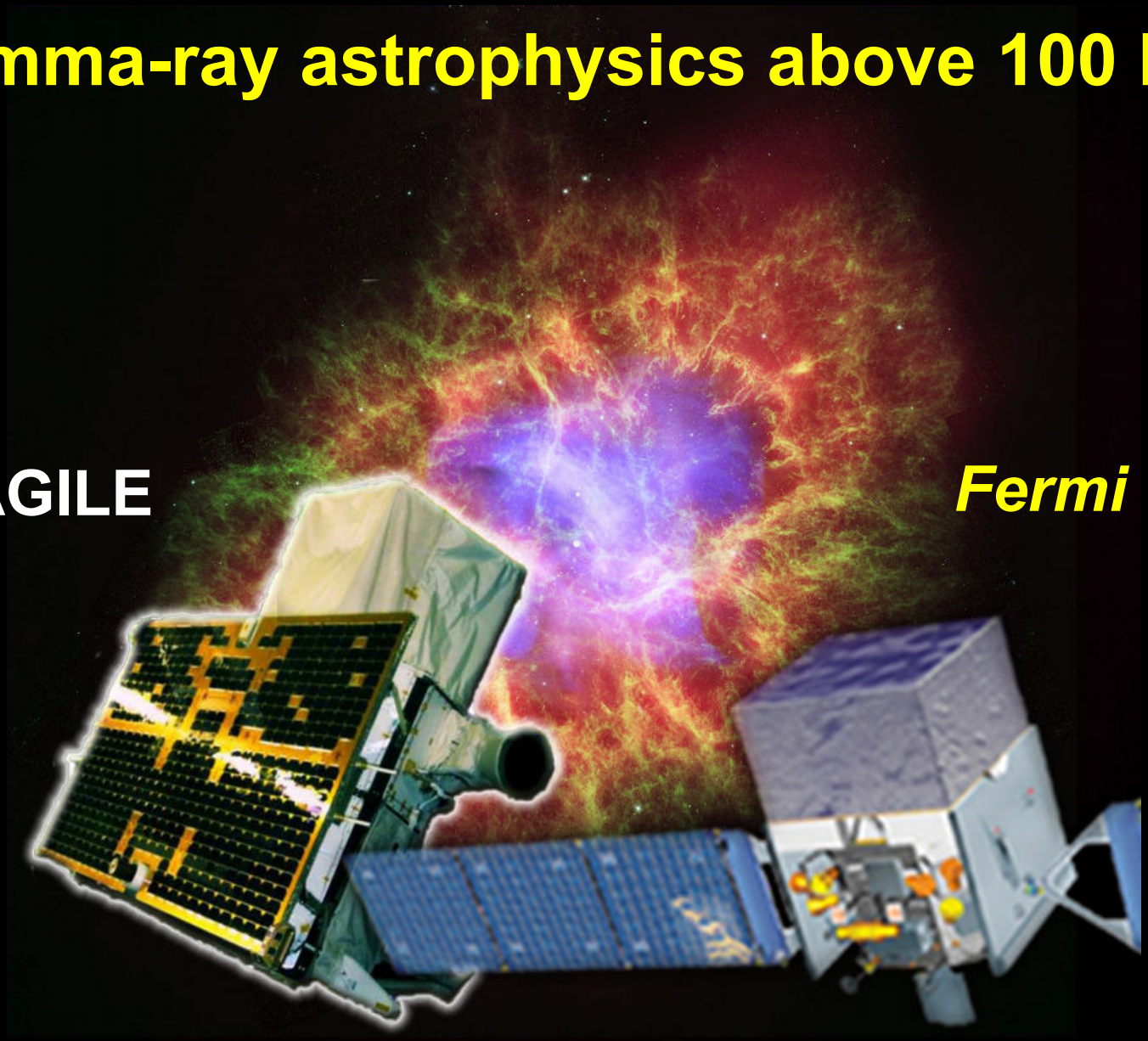
AGILE and Fermi/LAT common projects

F.Longo
University and INFN Trieste
on behalf of the AGILE team

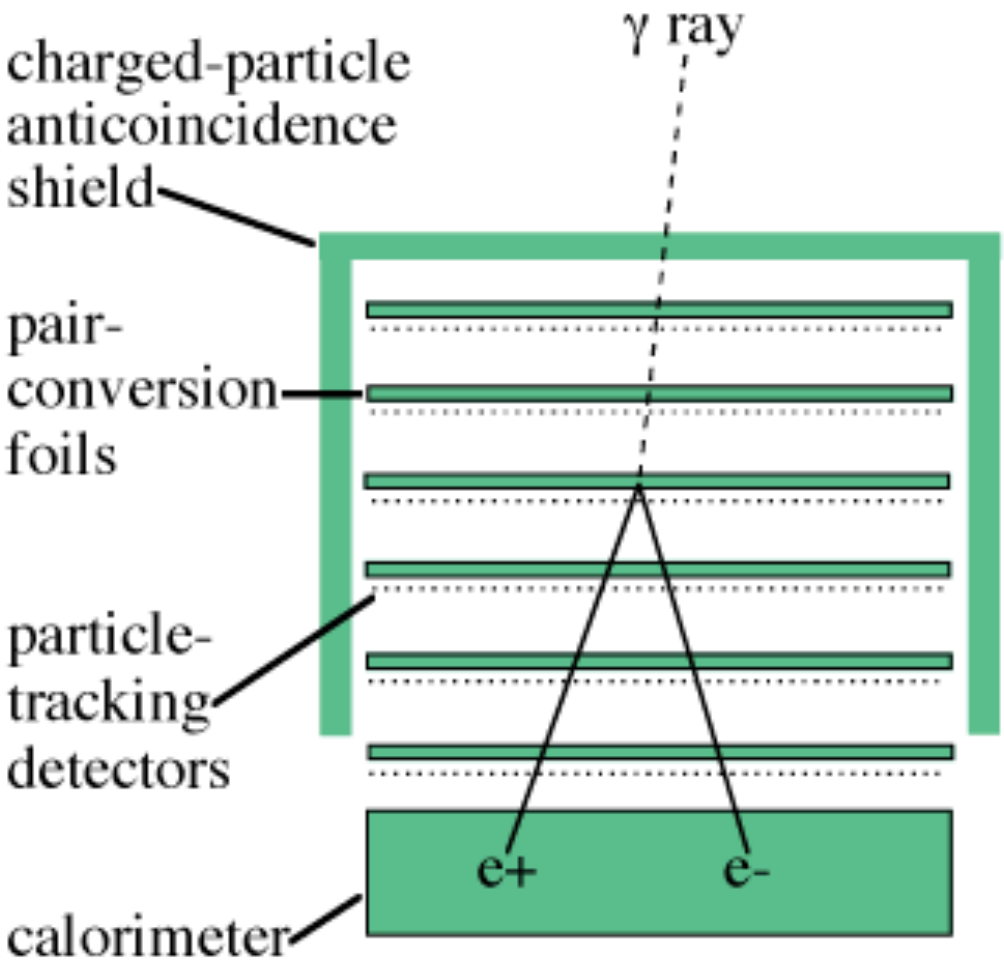
Pisa, March 15, 2018

Gamma-ray astrophysics above 100 MeV



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

Pair production Gamma-ray Detector

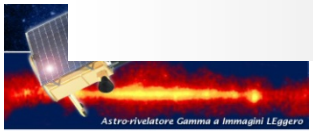


Outline

- The AGILE mission
- Common projects
  - At the “analysis level”
    - A study of the PSF + possible cross calibration
  - On Science topics
    - Galactic Science (SNR, PWN, Crab Nebula)
    - Extragalactic Science (Flaring AGN)
    - Transient Science (GRB, TGF, GW follow-up)
- Conclusions

AGILE

AGILE



agenzia spaziale italiana

INAF

INFN

CARLO GAVAZZI
Carlo Gavazzi Space SpA

OERLIKON CONTRAVES

ALCATEL ALENIA SPACE
An Alcatel/Finmeccanica company

telespazio
A Finmeccanica/Alcatel company

Galileo Avionica

MIPOT

ENEA


AGILE: inside the cube…
HARD X-RAY IMAGER
(SUPER-AGILE)
INAF-IASF-Rm
(E.Costa, M. Feroci)
GAMMA-RAY IMAGER
SILICON TRACKER
INFN-Trieste
(G.Barbiellini, M. Prest)
ANTICOINCIDENCE
INAF-IASF-Mi
(F.Perotti)
(MINI) CALORIMETER
INAF-IASF-Bo, Thales-Alenia Space (LABEN)
(G. Di Cocco, C. Labanti)

The Silicon Tracker

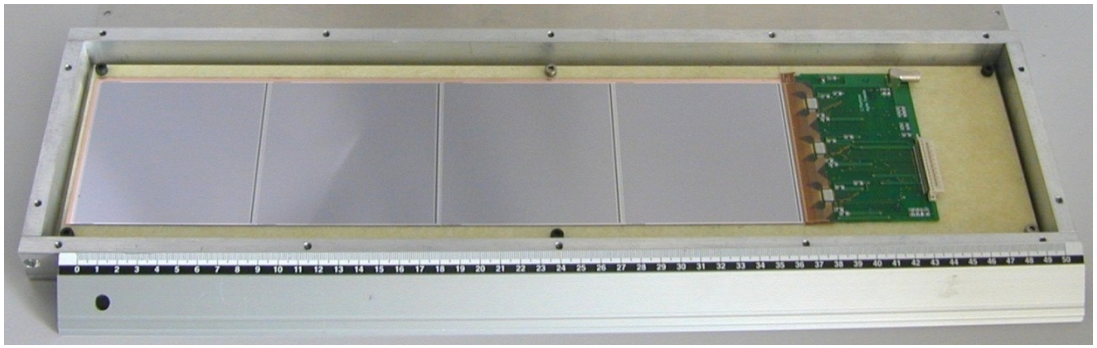
The AGILE silicon detectors

Detector specifications:

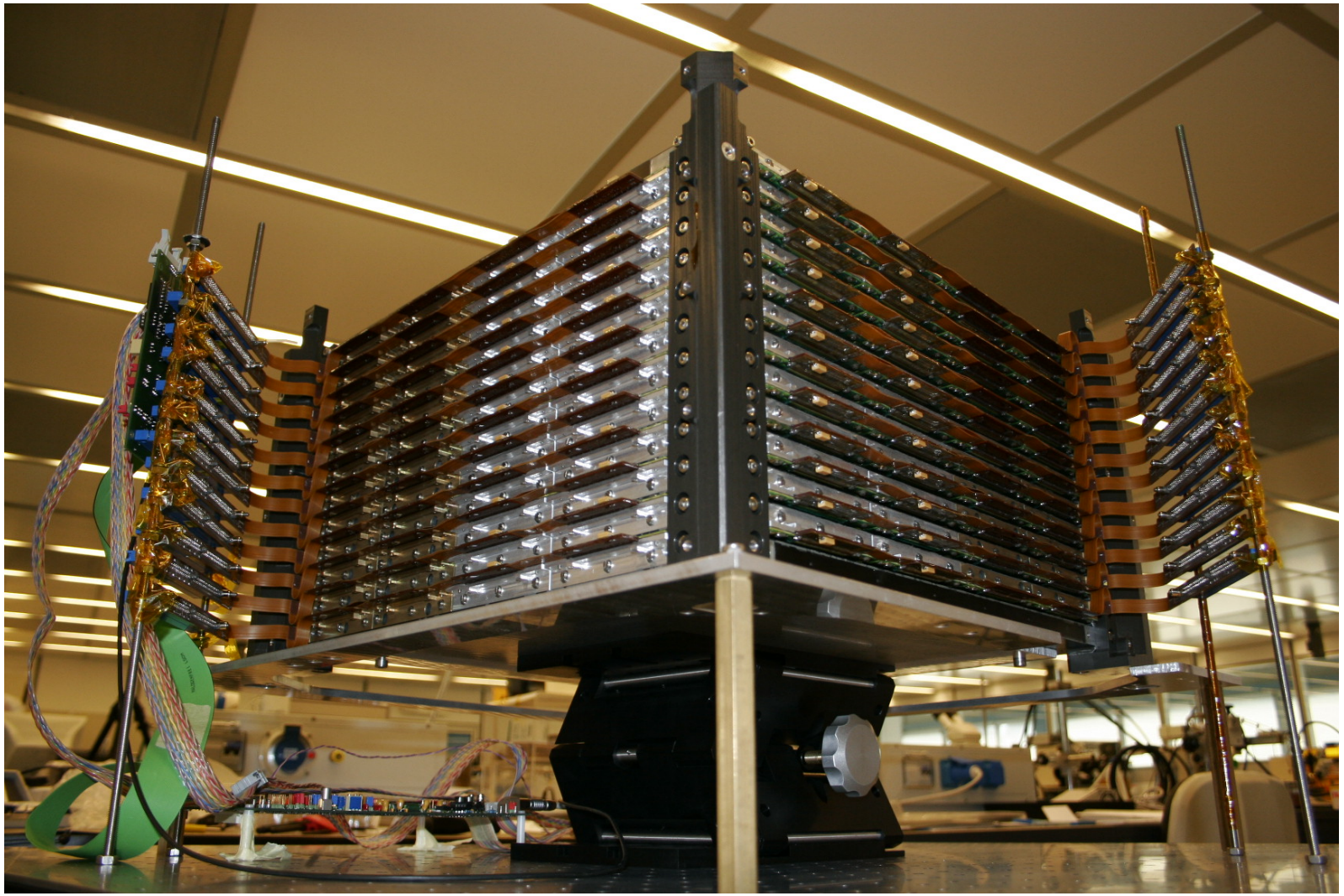
- dimension: 9.5x9.5 cm^2
- thickness: 410 μm (6 inch technology)
- readout pitch: 242 μm;
  physical pitch: 121 μm (one floating strip)
- number of strips/ladder: 384
- Single side and AC-coupled
- leakage current: 2 nA/cm^2 at Vbias=2.5*V_{FD} =200 V
- polarization resistor: 40 MΩ
- coupling capacitor: 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

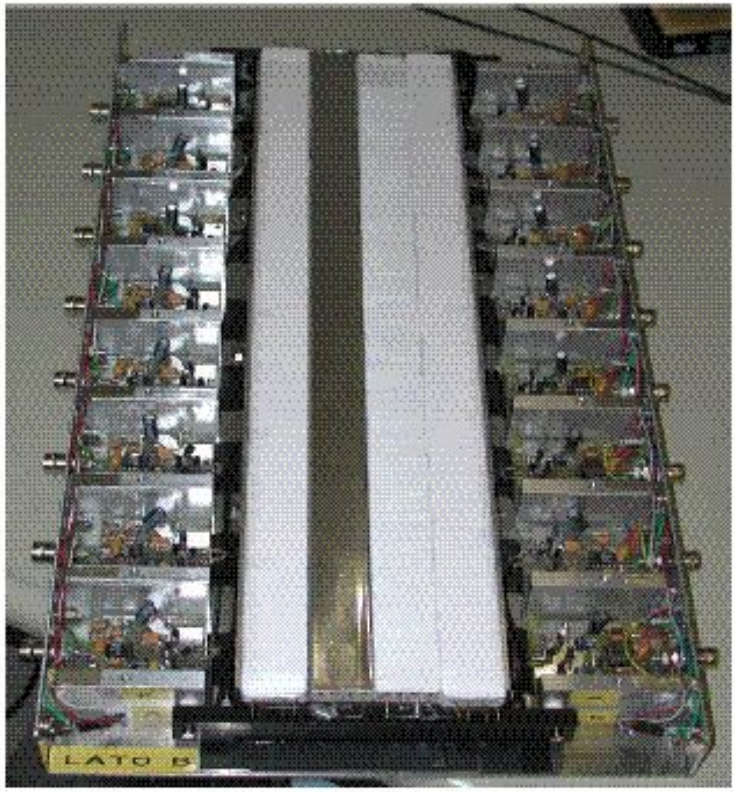
- low noise, low power, SELF-TRIGGERING
- technology: 1.2 μ CMOS, double poly, double metal (final: 0.8 μ BiCMOS on epitaxial layer)
- features:
  - 128 channels
  - gain: 25 mV/fC; range: 18 fC
  - noise (e^- rms): 165+6.1/pF for T_{peak}=2 μs
  - power: <0.4 mW/channel
  - power rails: ±2 V
  - readout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



The AGILE TRK



The CsI Mini-Calorimeter



MINI-CALORIMETER

DETECTOR

30 CsI bars wrapped with tight diffusion material organized in 2 orthogonal trays

- bar dimension: 40x2.3x1.5 cm^3
- total radiation length: $1.5X_0$ (in axis)

FRONTEND ELECTRONICS

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

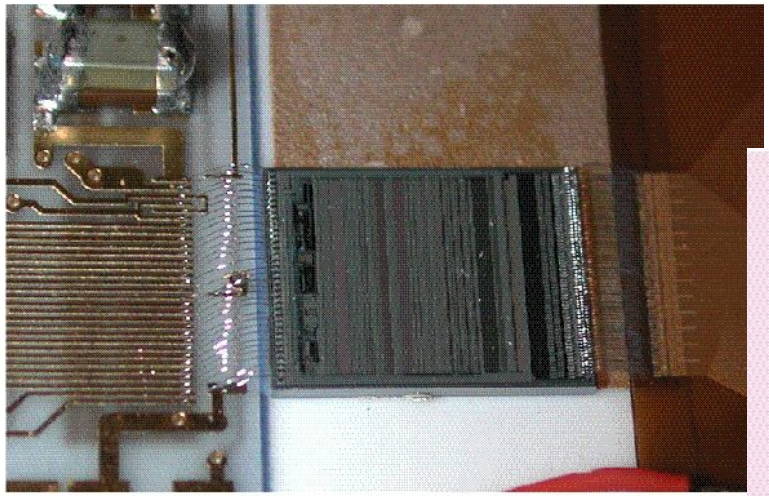
GOAL

- 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: 2μs (BURST mode)

SuperAGILE X-ray detector



SUPER-AGILE

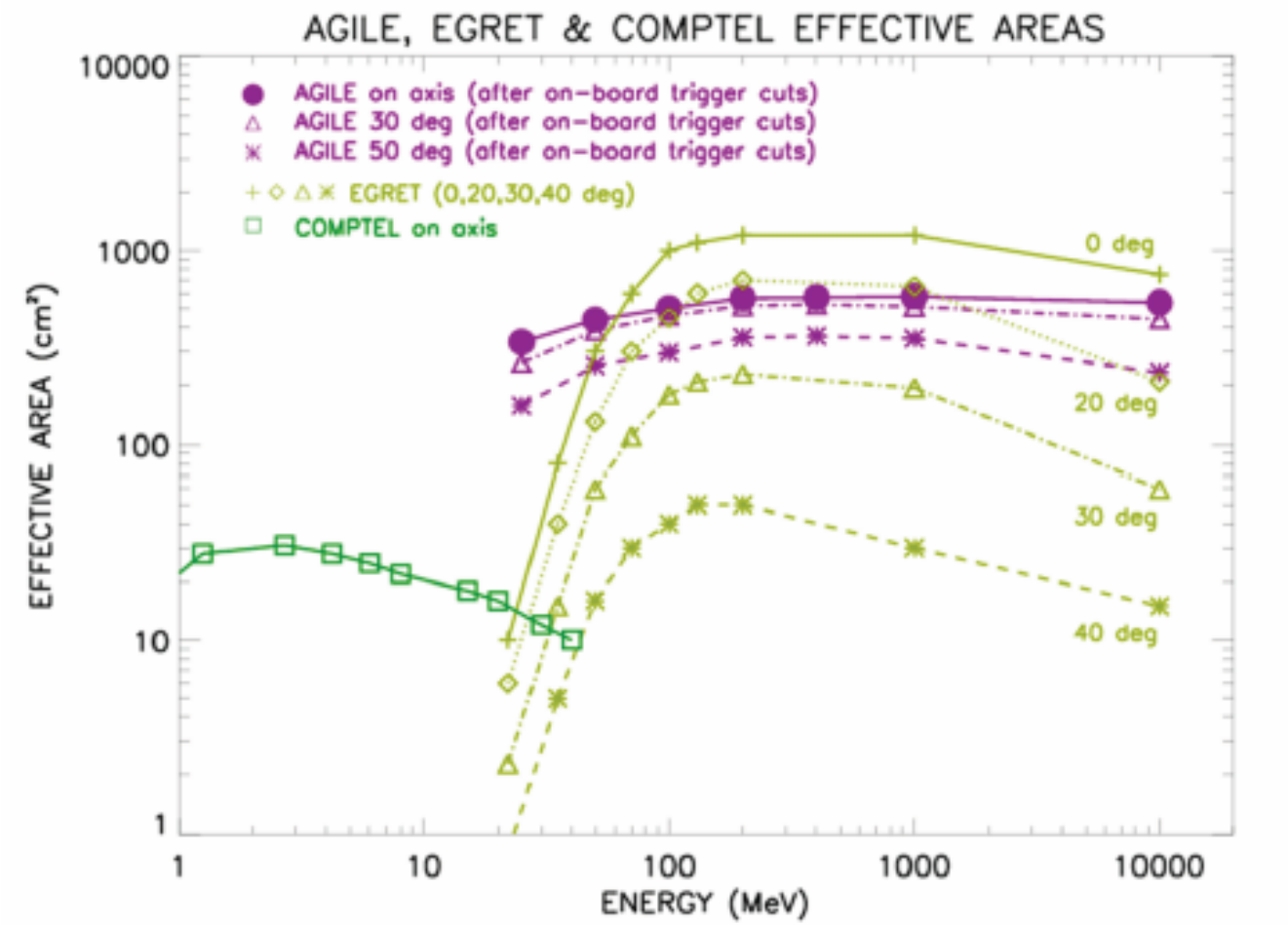
DETECTOR
- plane with 16 silicon tiles organized in 4 1D detectors
- each detector: 1536 readout strips (0.121mm pitch)
- a coded mask system

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

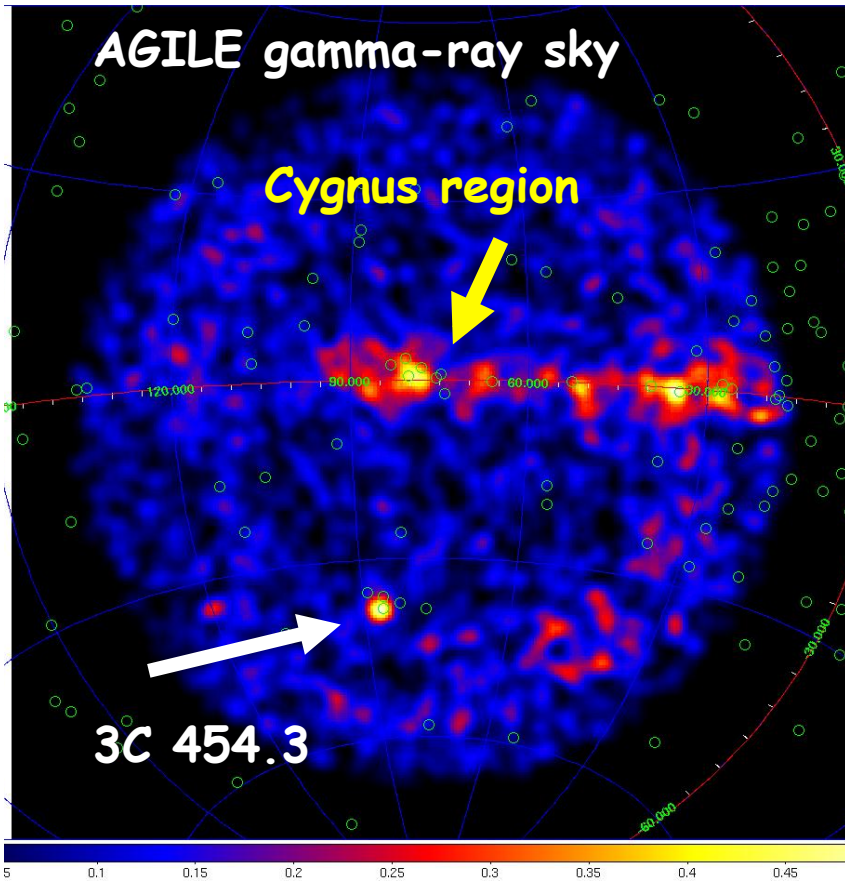
GOAL
measure X-rays in the energy range 10-40keV to detect GRBs, transients, galactic and extra-galactic sources

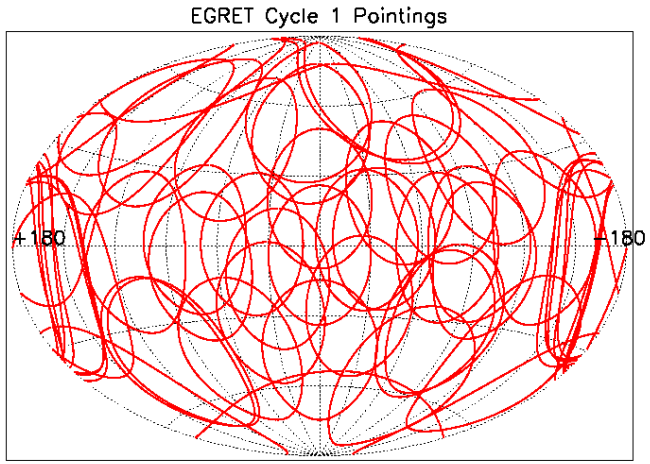
SCIENTIFIC FEATURES
- imaging: 1'-3' at ~20mCrab
- timing resolution: 5μs
- energy resolution: 4keV (FWHM)
- flux sensitivity: ~5mCrab (15keV)

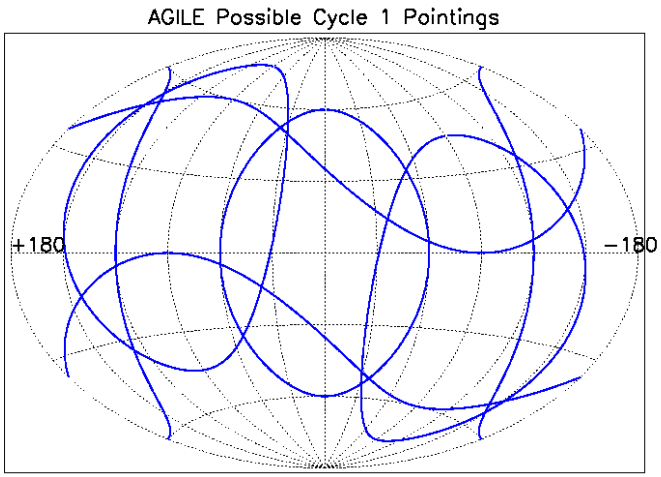
Performance



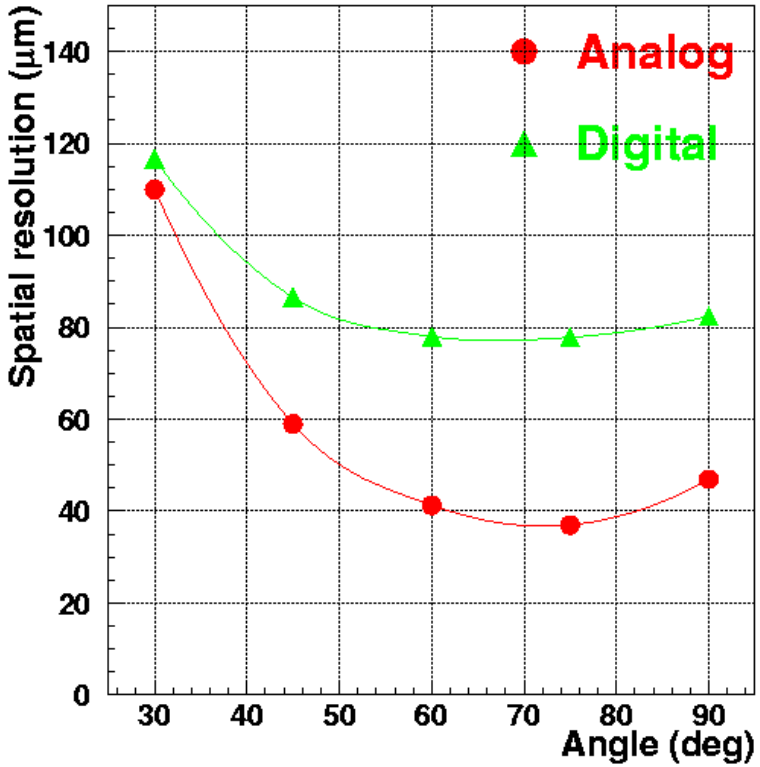
Si Self Trigger and FoV

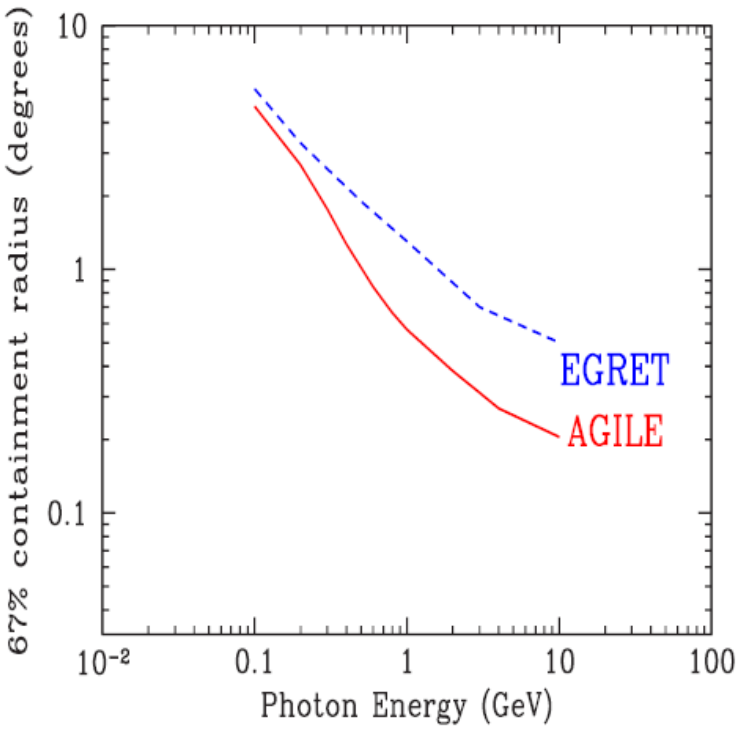




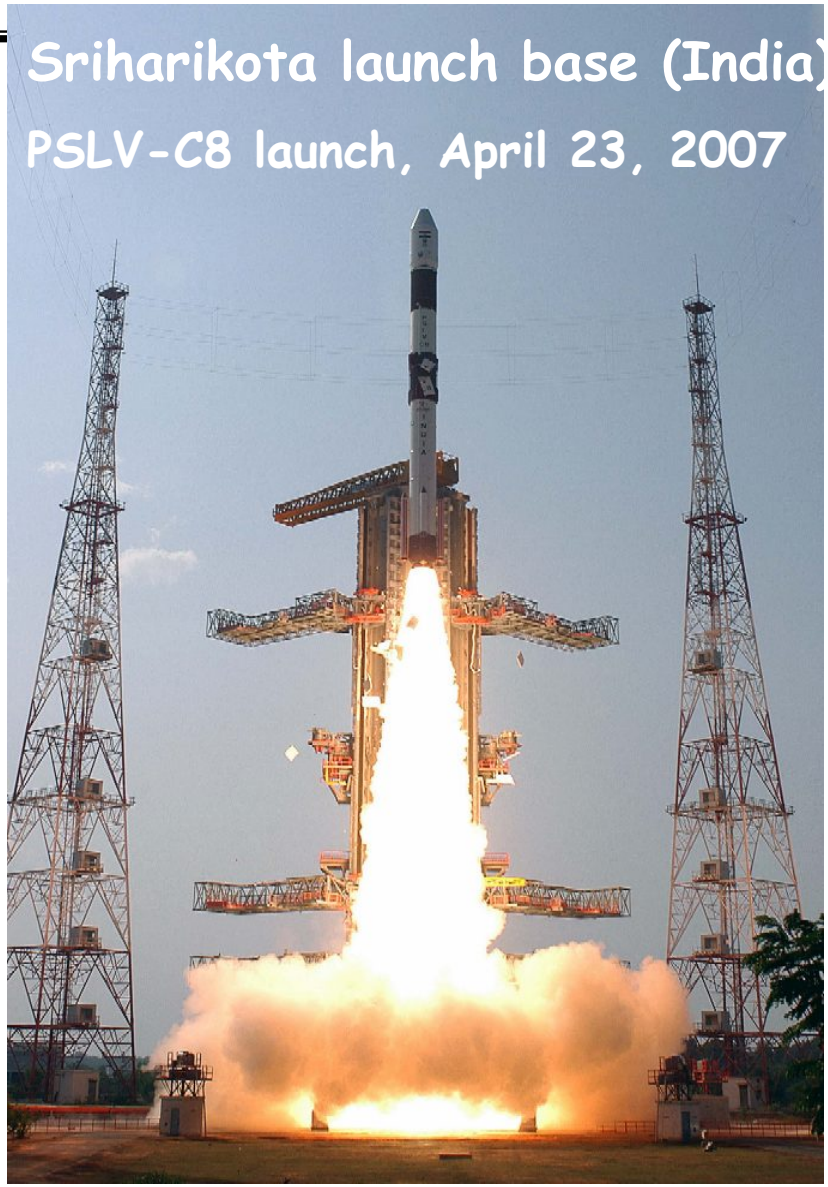


Analog readout and PSF

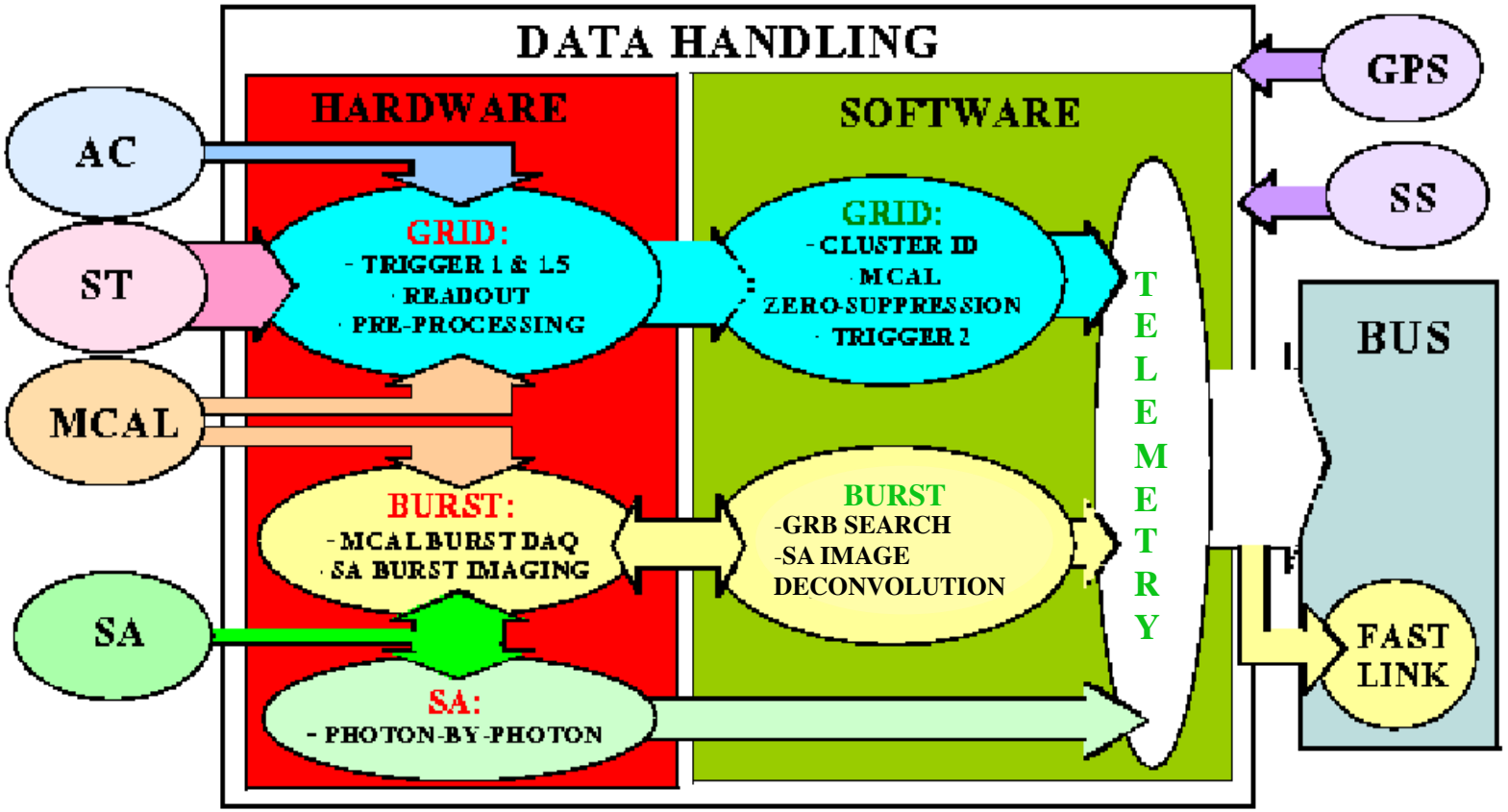




The AGILE launch



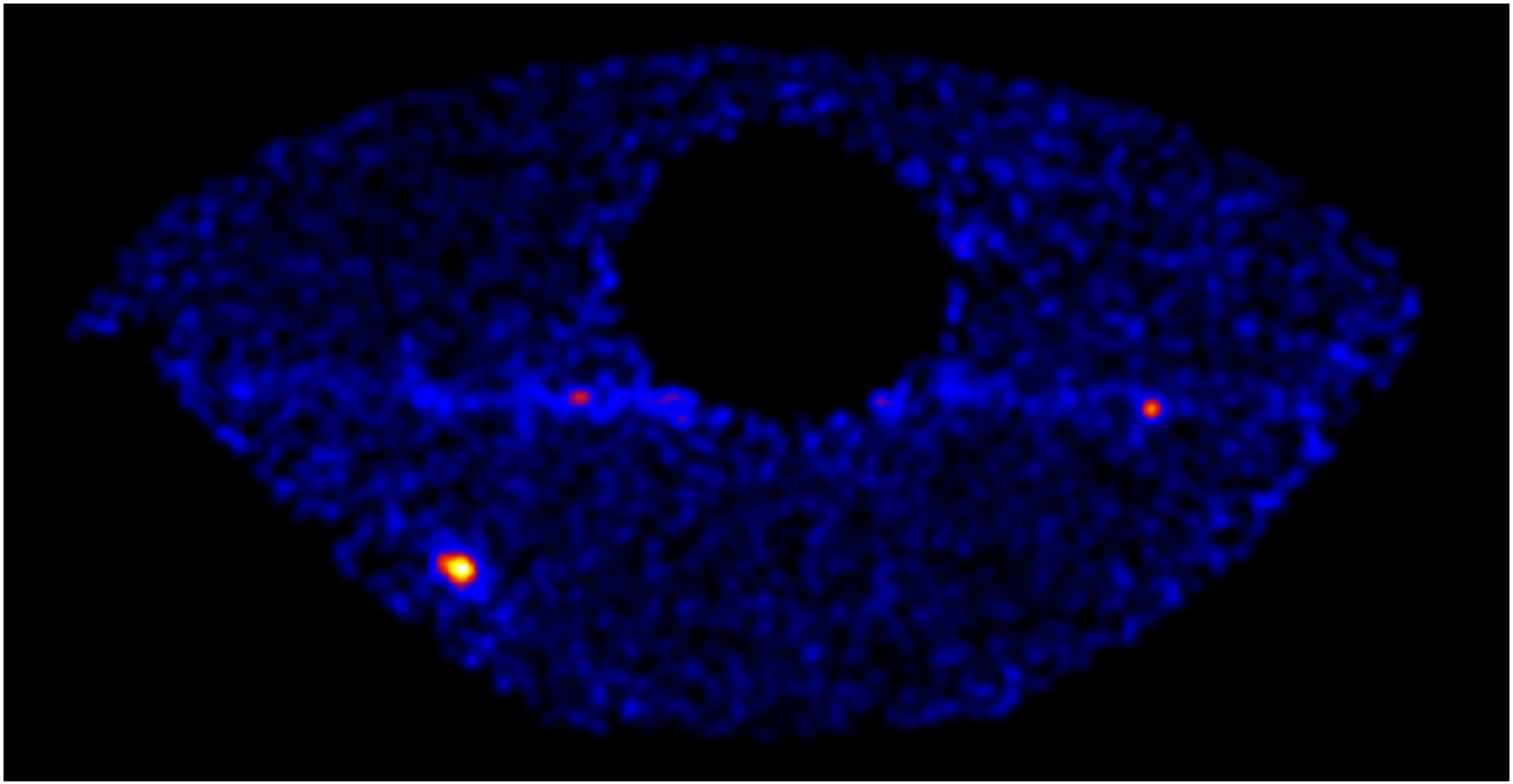
On Board AGILE Trigger



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)	~ $2\ 10^7$ (cm^2 sec)	(0.5-1) 10^7 (cm^2 sec)

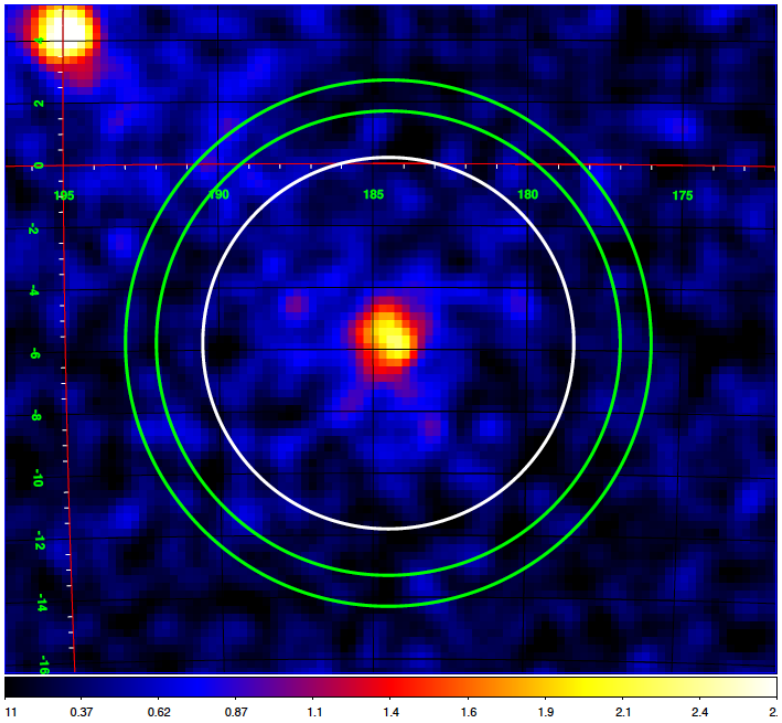
The sky in spinning mode

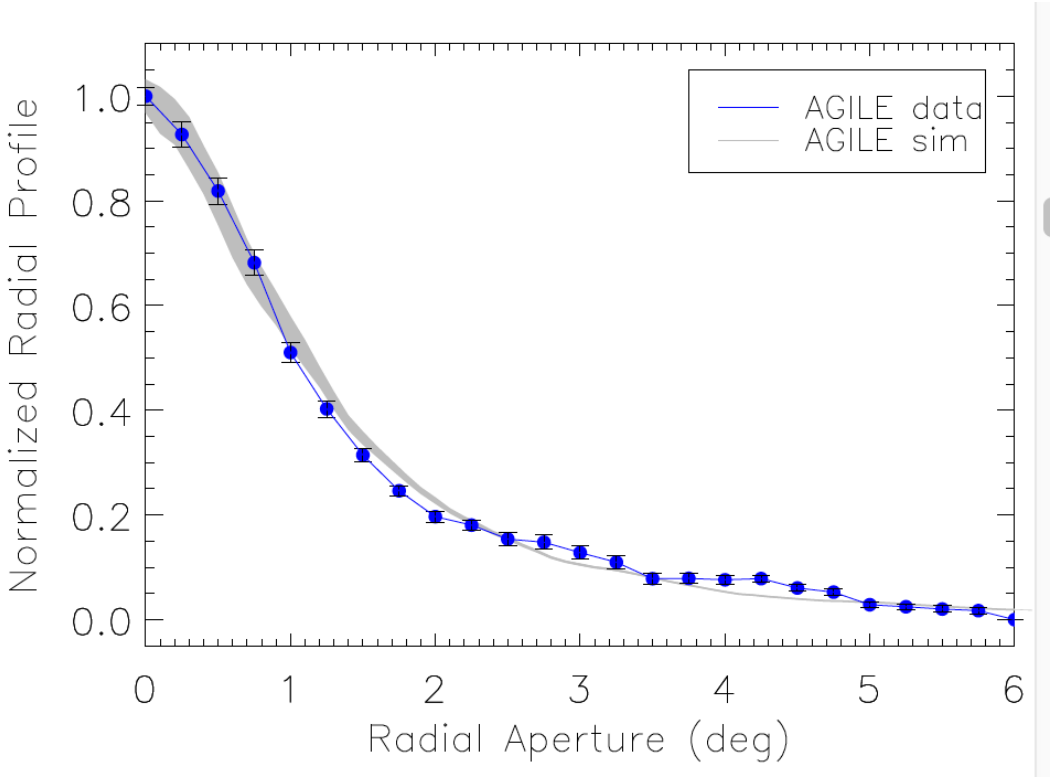


Vercellone et al. 2010

AGILE and Fermi/LAT common projects

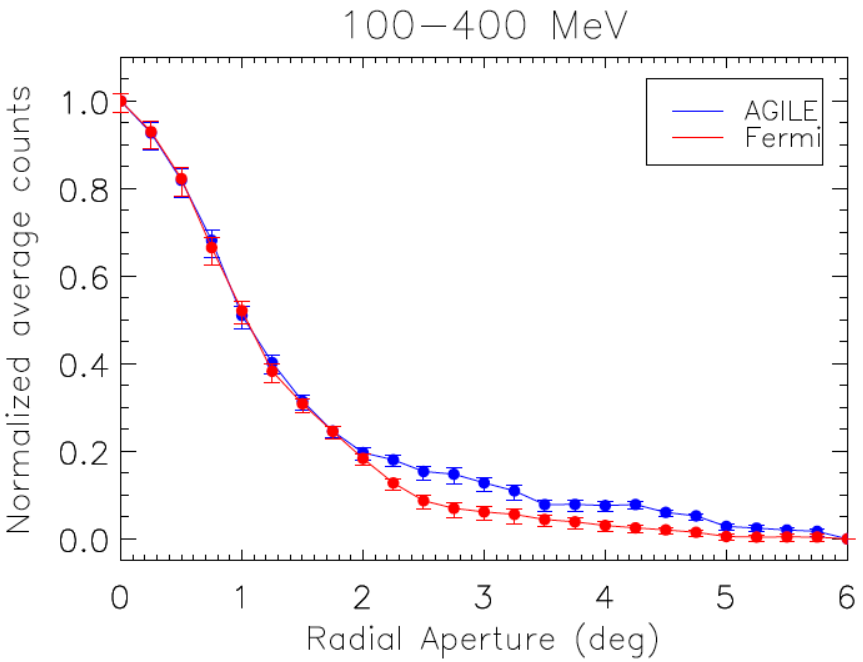
The AGILE PSF

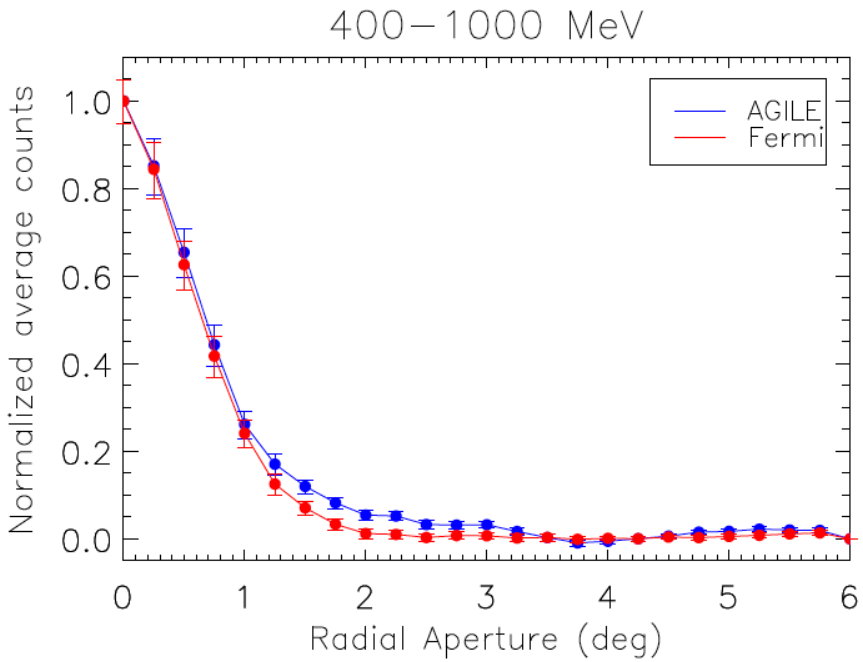




Sabatini et al. 2015

The AGILE PSF





Sabatini et al. 2015

Cross calibration

Fermi-AGILE Cross-calibration: First Steps

Andrew Chen (INAF - IASF Milano),
O. Celik-Tinmaz, F. Longo, D. Thompson, A. Trois, M. Pilia,
A. Pellizzoni

Fermi Collaboration Meeting, Abano Terme
March 7, 2012

Cross calibration

Vela light curves

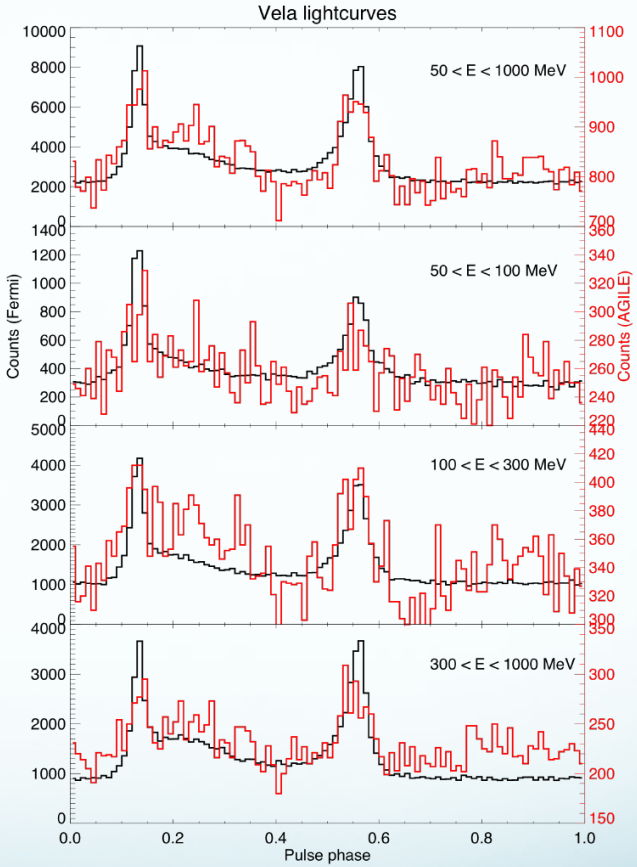
Aug 4, 2008 – Feb 26, 2008
(AGILE pointed mode)

Fermi Pass7_v6

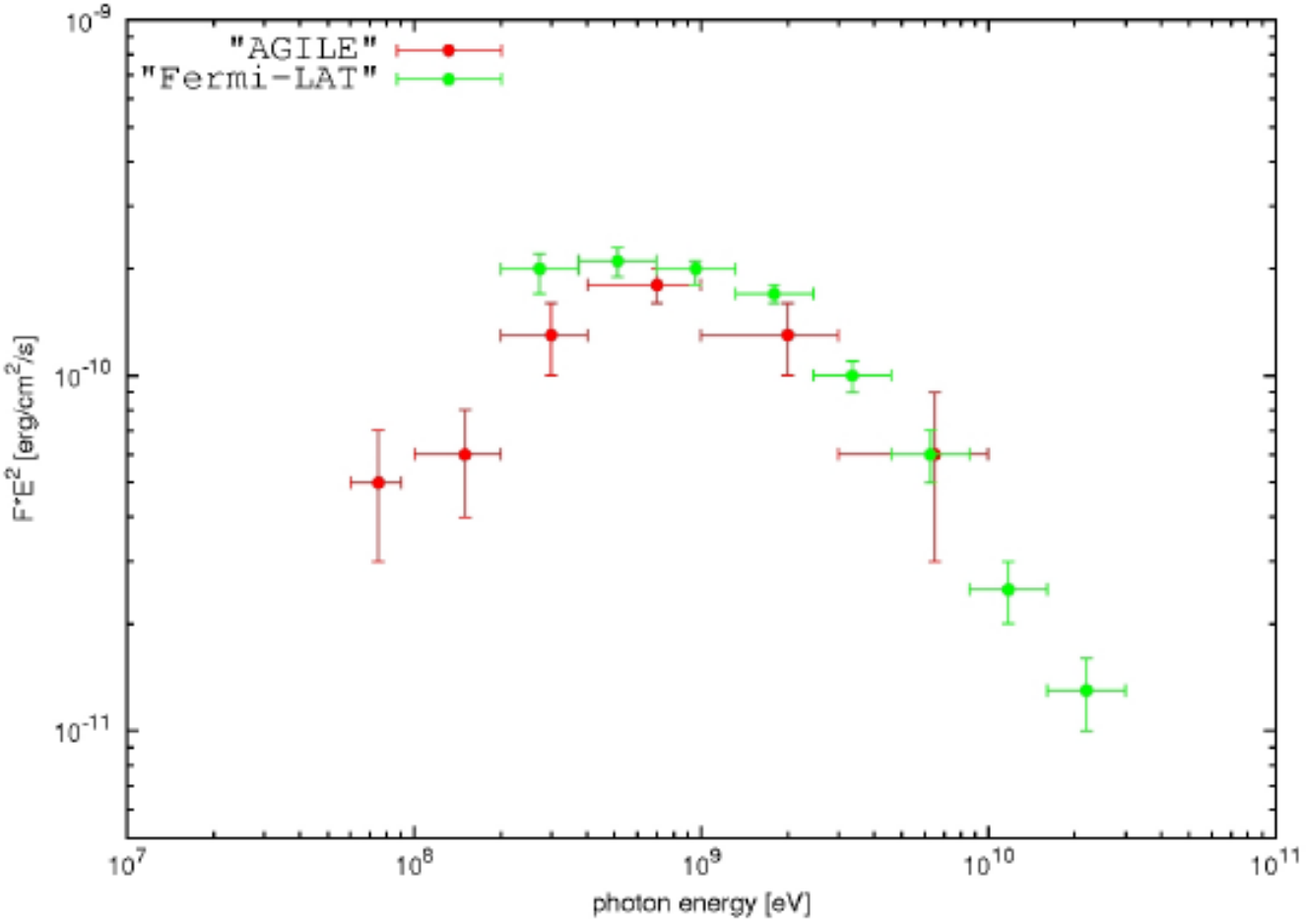
Photons within 10°

AGILE normalized to
Fermi [mean, max], offset by 0.5

On-pulse defined as
[0.05-0.4] + [0.5-0.65]

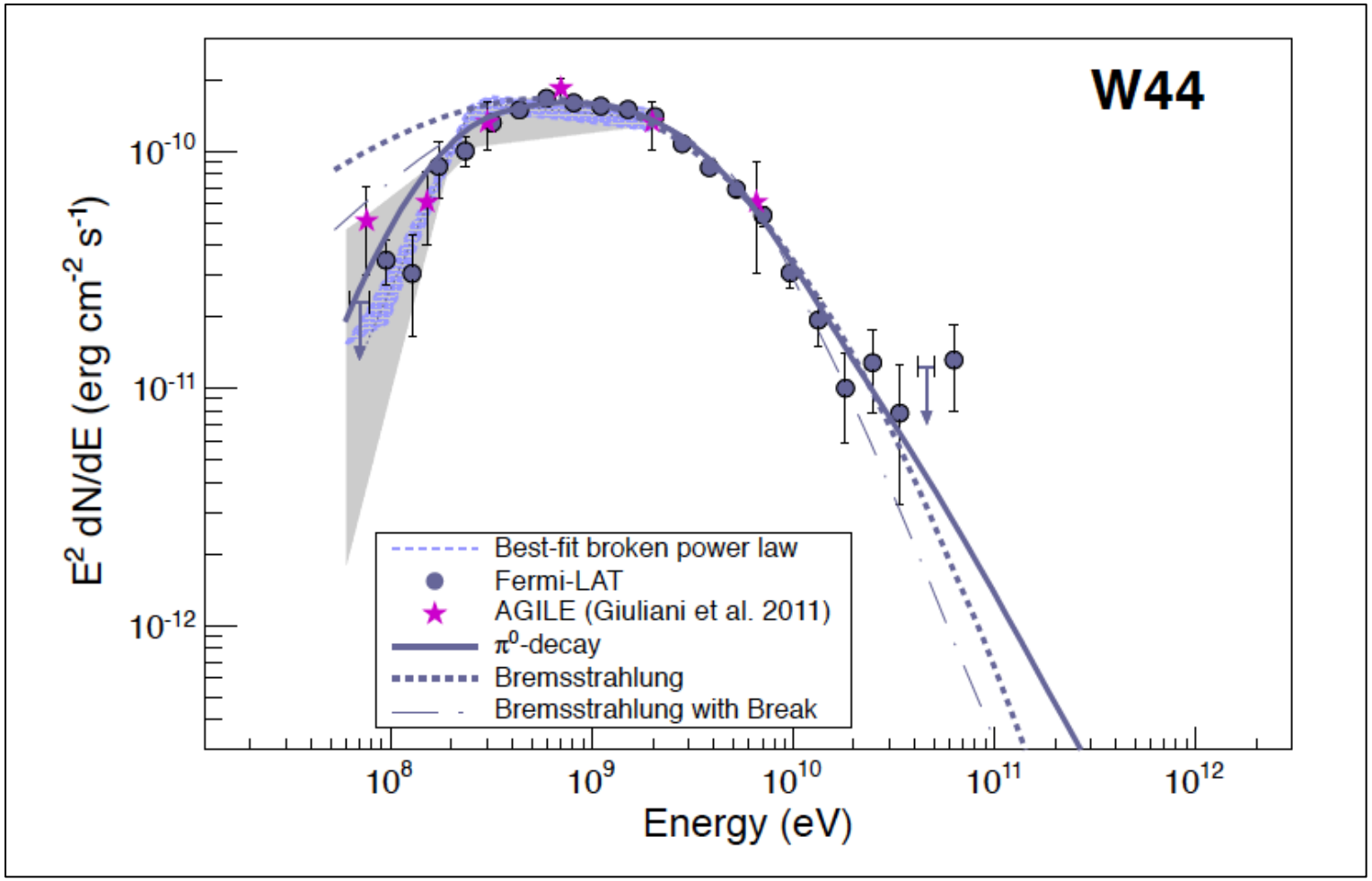


The SNR W44



Giuliani et al. 2011

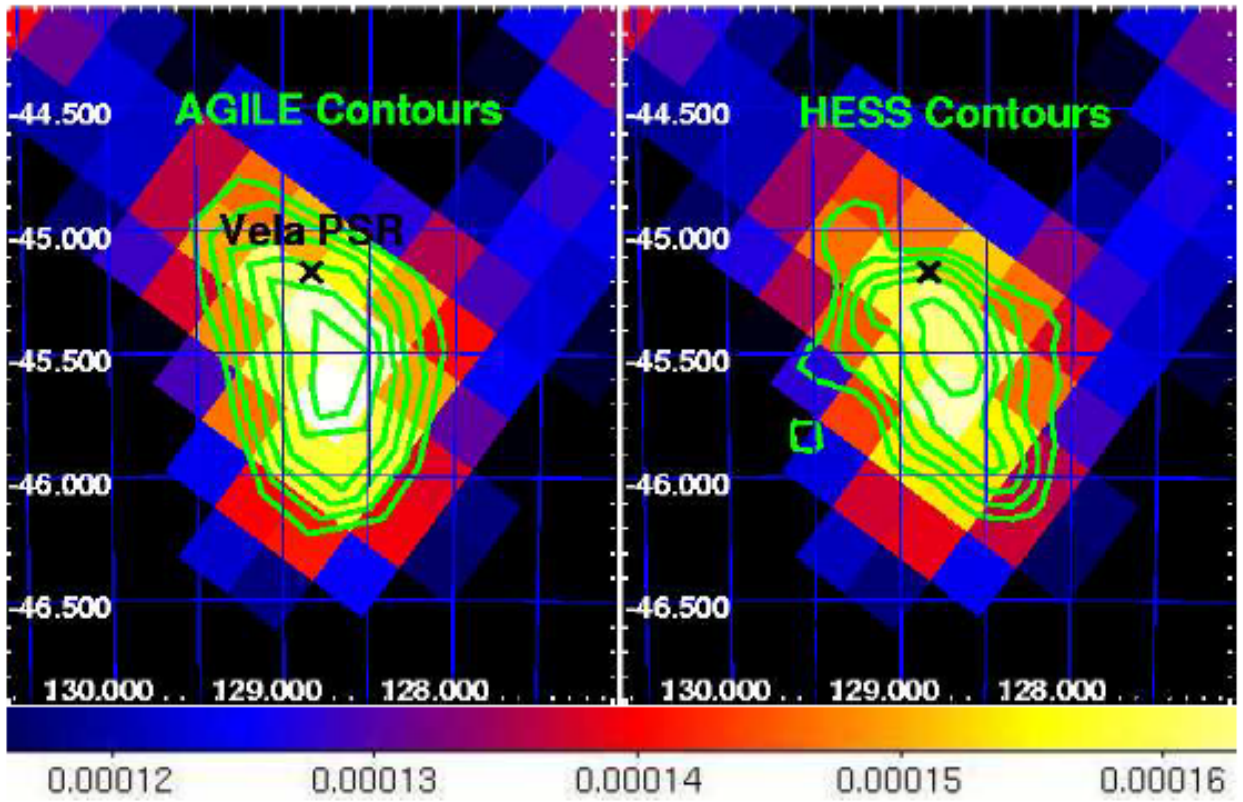
The SNR W44



Ackermann et al. 2013

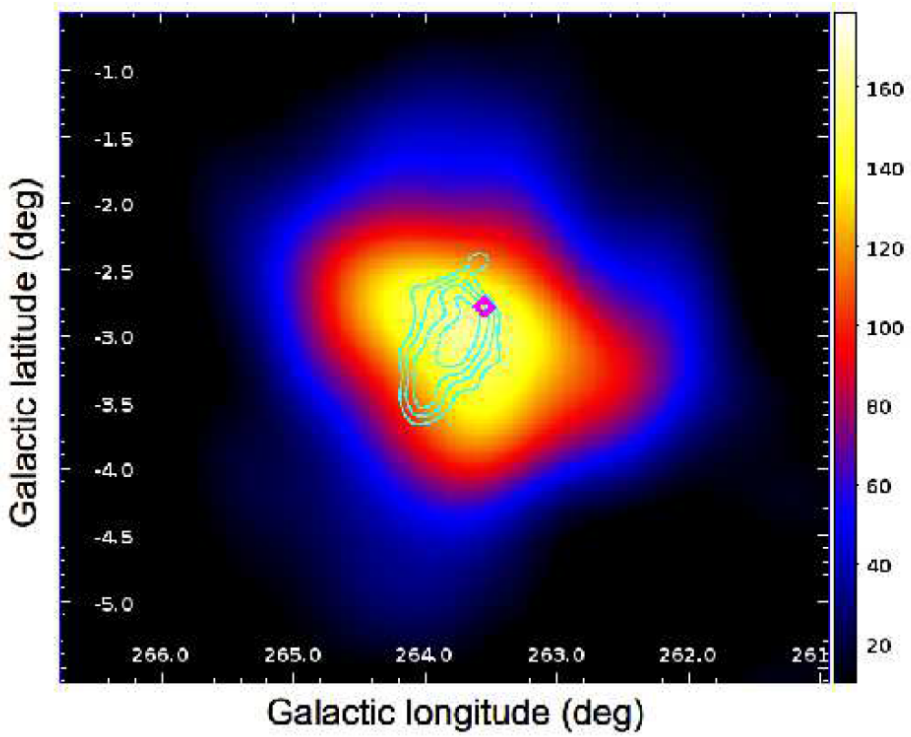
Pulsar Wind Nebulae

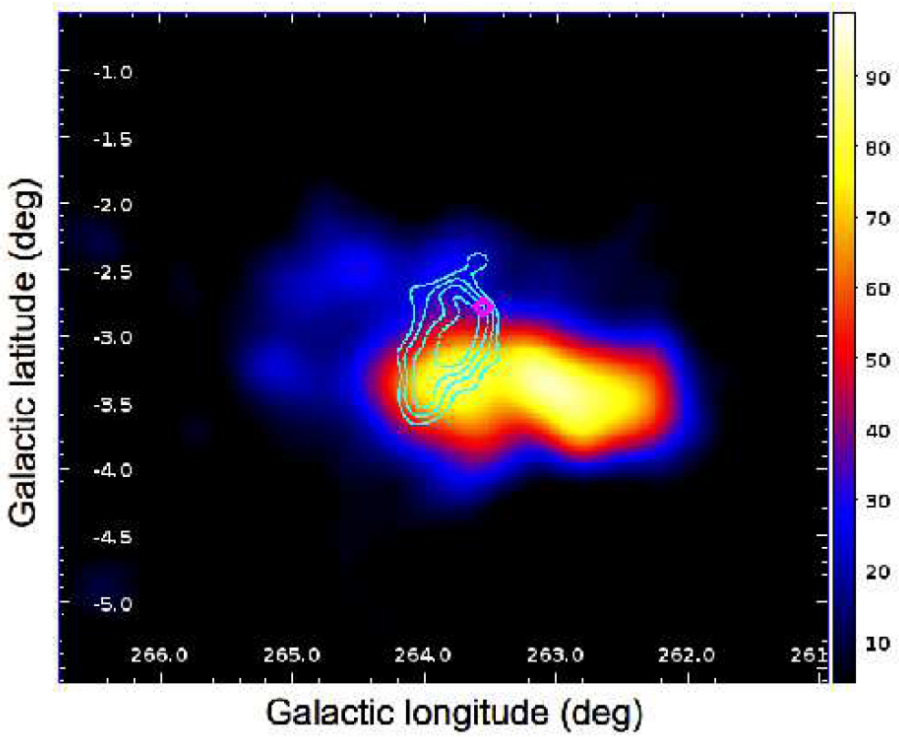
Pellizzoni et al. 2010



Vela X PWN

Pulsar Wind Nebulae





Grondin et al. 2013

The Flaring Crab

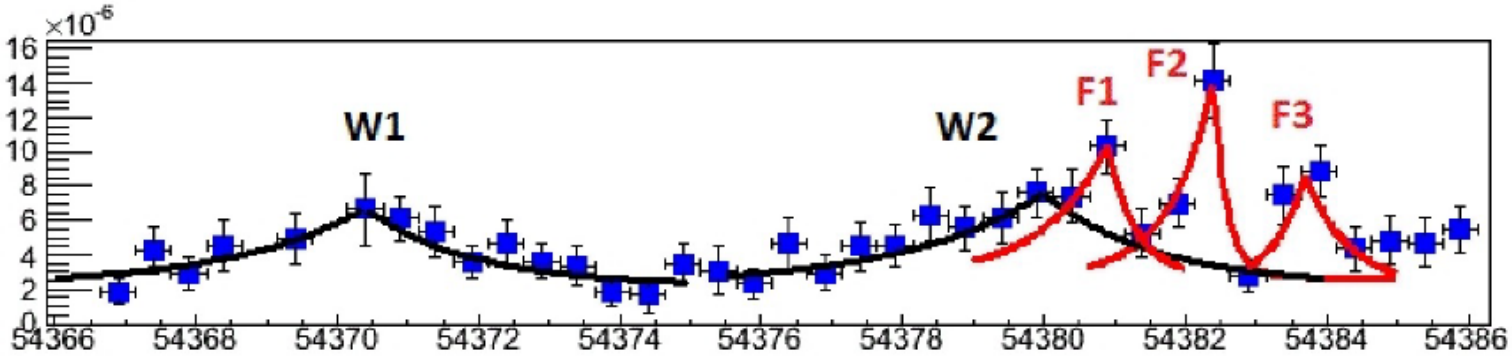


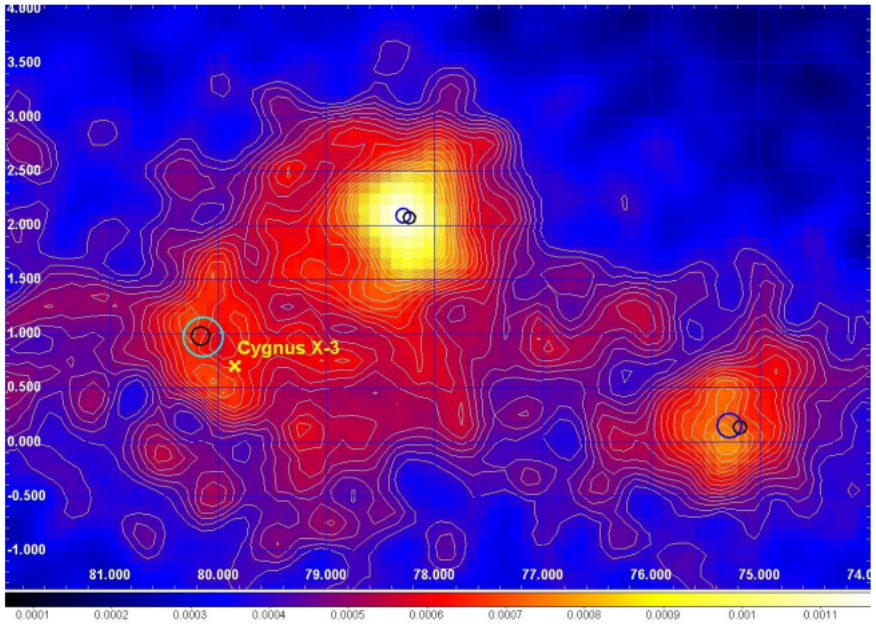
TABLE 1
TABLE OF THE *flares* ($F \geq 700 \times 10^{-8}$ ph cm^{-2} s^{-1}) OF THE CRAB NEBULA FOUND IN THE AGILE AND FERMI DATA FROM SEPT. 2007.

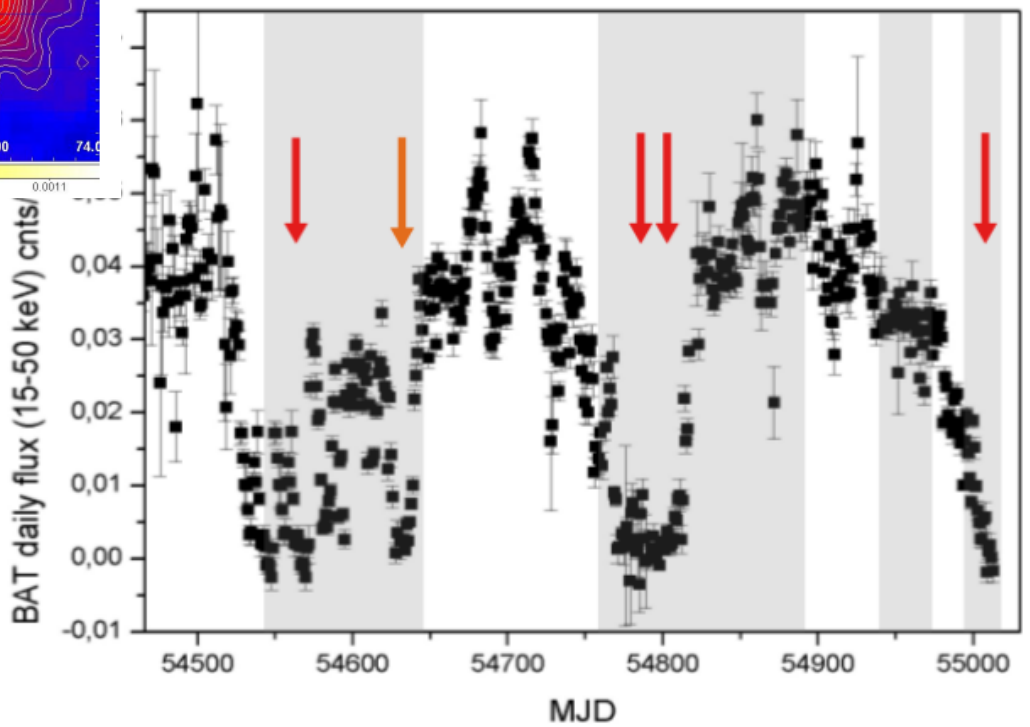
	Name	MJD	τ_1 (hr)	τ_2 (hr)	Peak Flux	$B(mG)$	γ^* (10^9)	l (10^{15} cm)
2007 (AGILE)	F_1	54381.5	22 ± 11	10 ± 5	1000 ± 150	$1.0 - 2.0$	$2.6 - 4.8$	$1.2 - 3.6$
	F_2	54382.5	14 ± 7	6 ± 3	1400 ± 200	$1.1 - 2.1$	$2.3 - 4.3$	$0.8 - 2.2$
	F_3	54383.7	11 ± 5	14 ± 7	900 ± 150	$1.0 - 2.0$	$2.6 - 4.8$	$0.8 - 1.7$
2009 (FERMI)	F_4	54865.8	10 ± 5	20 ± 10	700 ± 140	$0.7 - 1.3$	$2.6 - 4.8$	$0.6 - 1.6$
	F_5	54869.2	10 ± 5	22 ± 11	830 ± 90	$0.8 - 1.4$	$2.6 - 4.8$	$0.6 - 1.6$
2010 (AGILE & FERMI)	F_6	55457.8	8 ± 4	22 ± 11	850 ± 130	$0.7 - 1.3$	$2.5 - 4.7$	$0.5 - 1.3$
	F_7	55459.8	6 ± 3	6 ± 3	1000 ± 100	$1.4 - 2.6$	$2.6 - 4.8$	$0.3 - 0.9$
	F_8	55461.9	19 ± 10	8 ± 4	750 ± 110	$0.8 - 1.4$	$2.5 - 4.8$	$0.9 - 3.1$
2011 (FERMI & AGILE)	F_9	55665.0	9 ± 5	9 ± 5	1480 ± 80	$1.2 - 2.2$	$2.8 - 5.0$	$0.5 - 1.5$
	F_{10}	55667.3	10 ± 5	24 ± 12	2200 ± 85	$1.3 - 2.3$	$2.7 - 4.9$	$0.6 - 1.6$

Tavani et al 2011
Abdo et al 2011

Striani et al. 2013

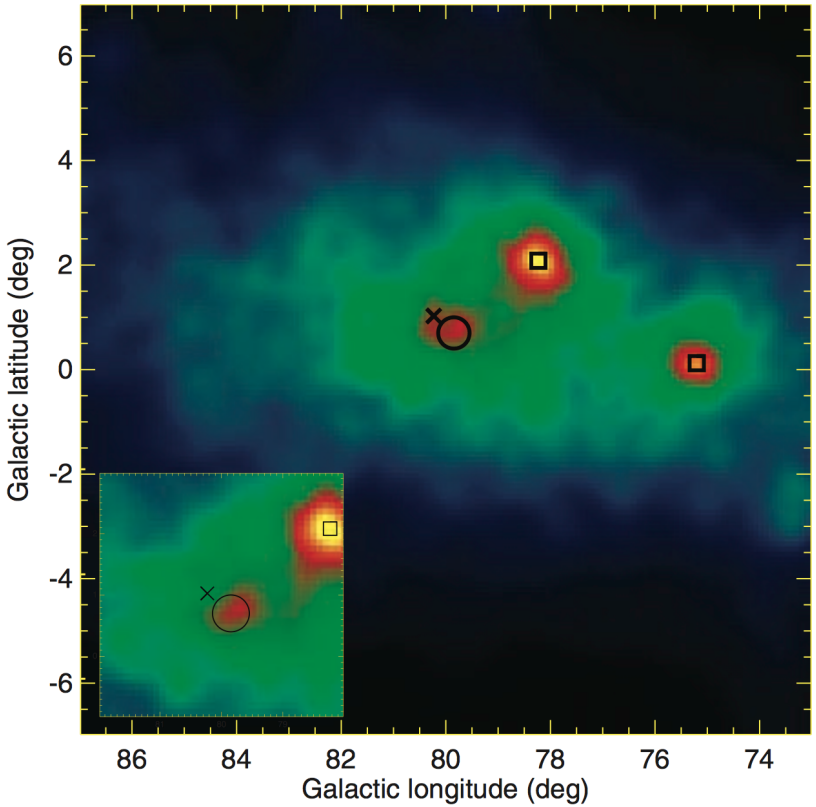
Cygnus X3

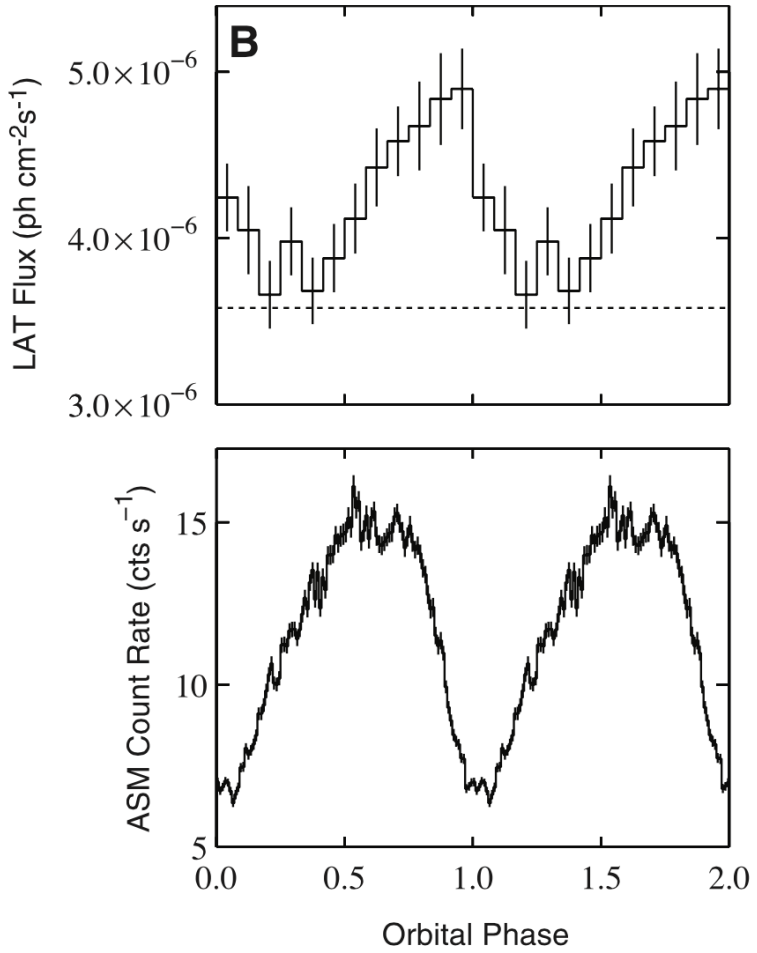




Tavani et al. 2009

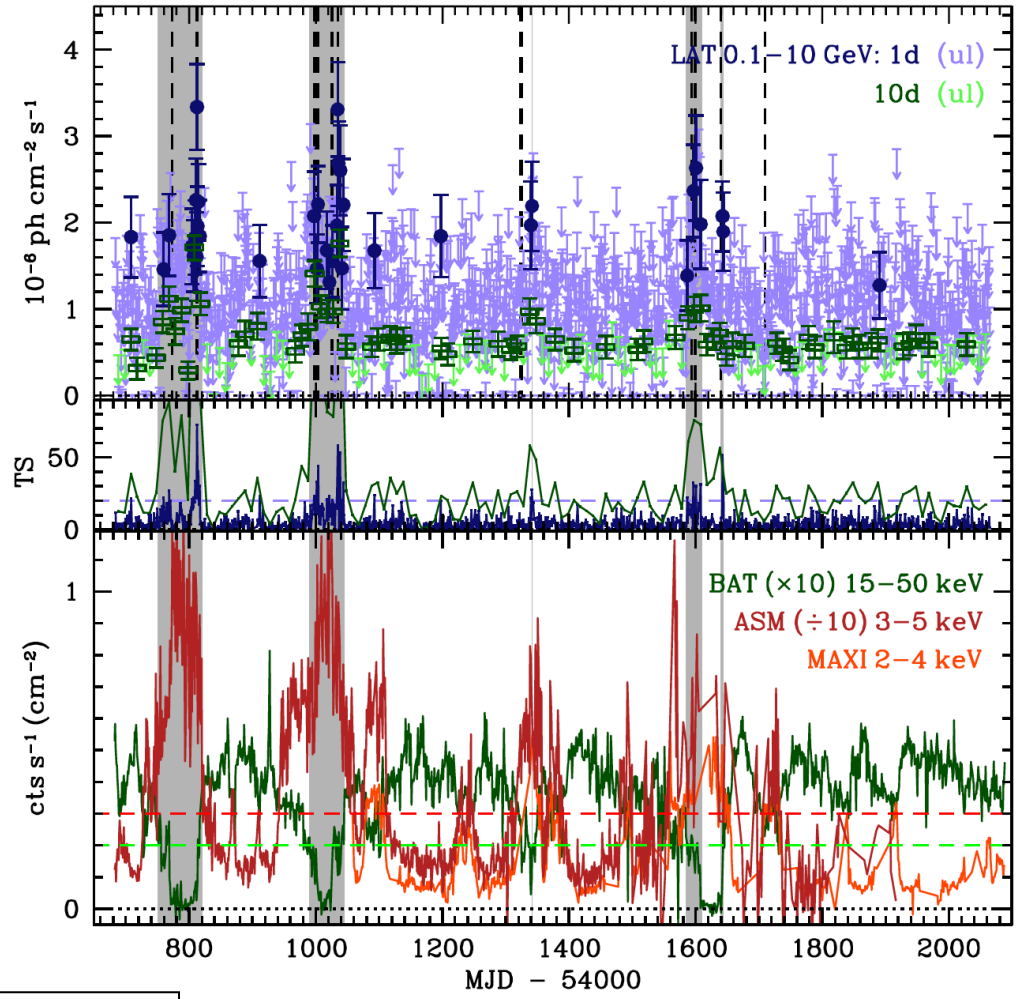
Cygnus X3





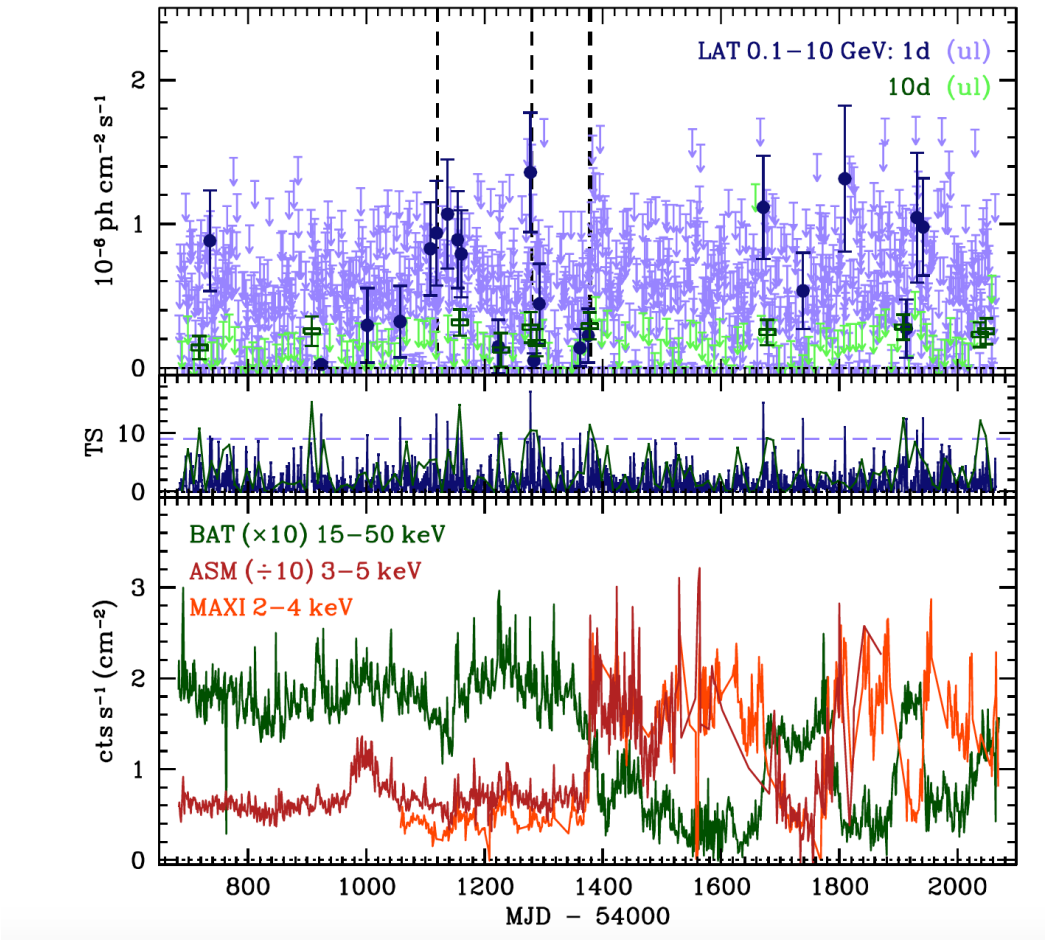
Abdo et al. 2009

Galactic Transients



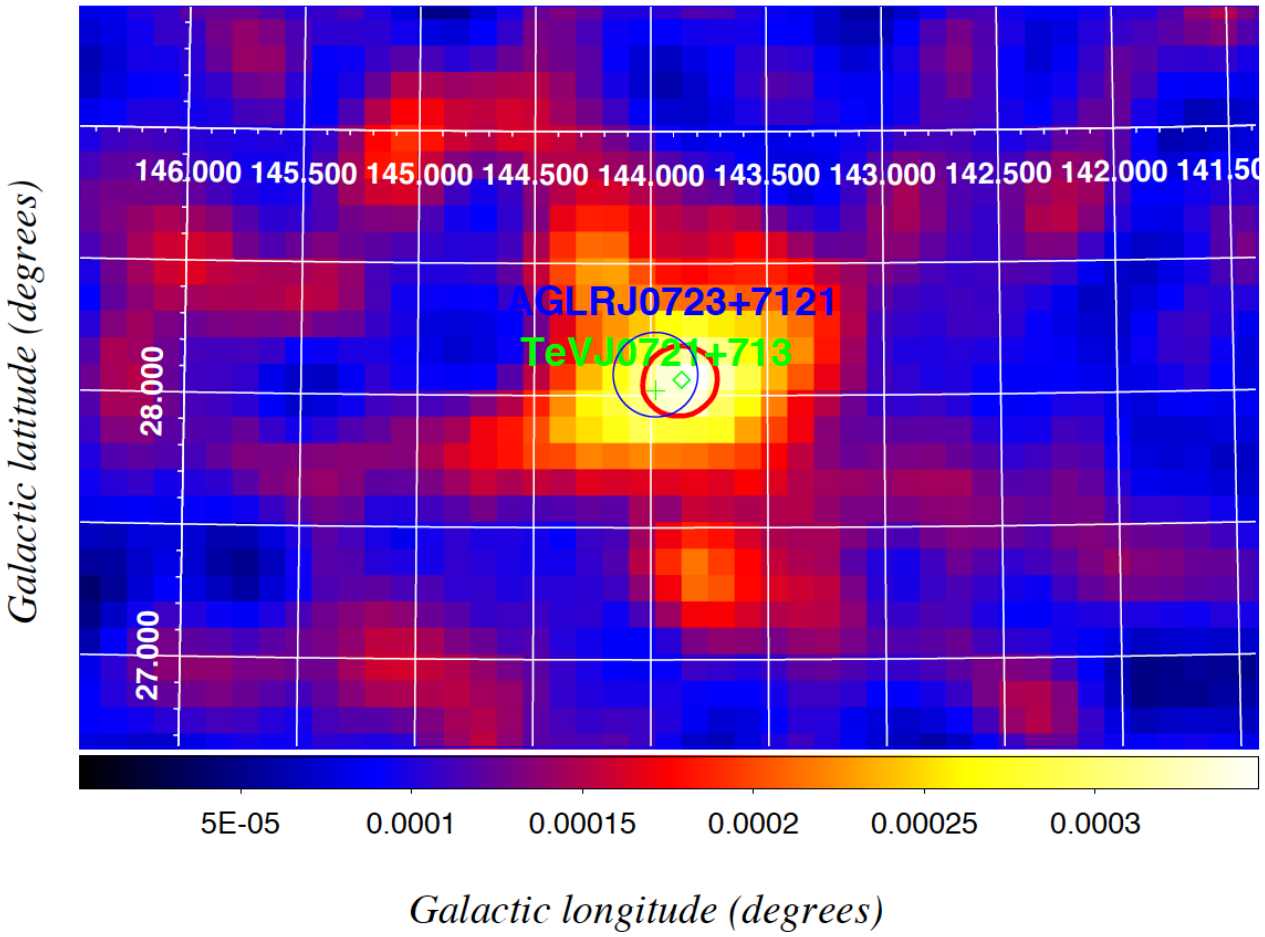
Bodaghee et al. 2013

Galactic Transients



Bodaghee et al. 2013

Galactic sources



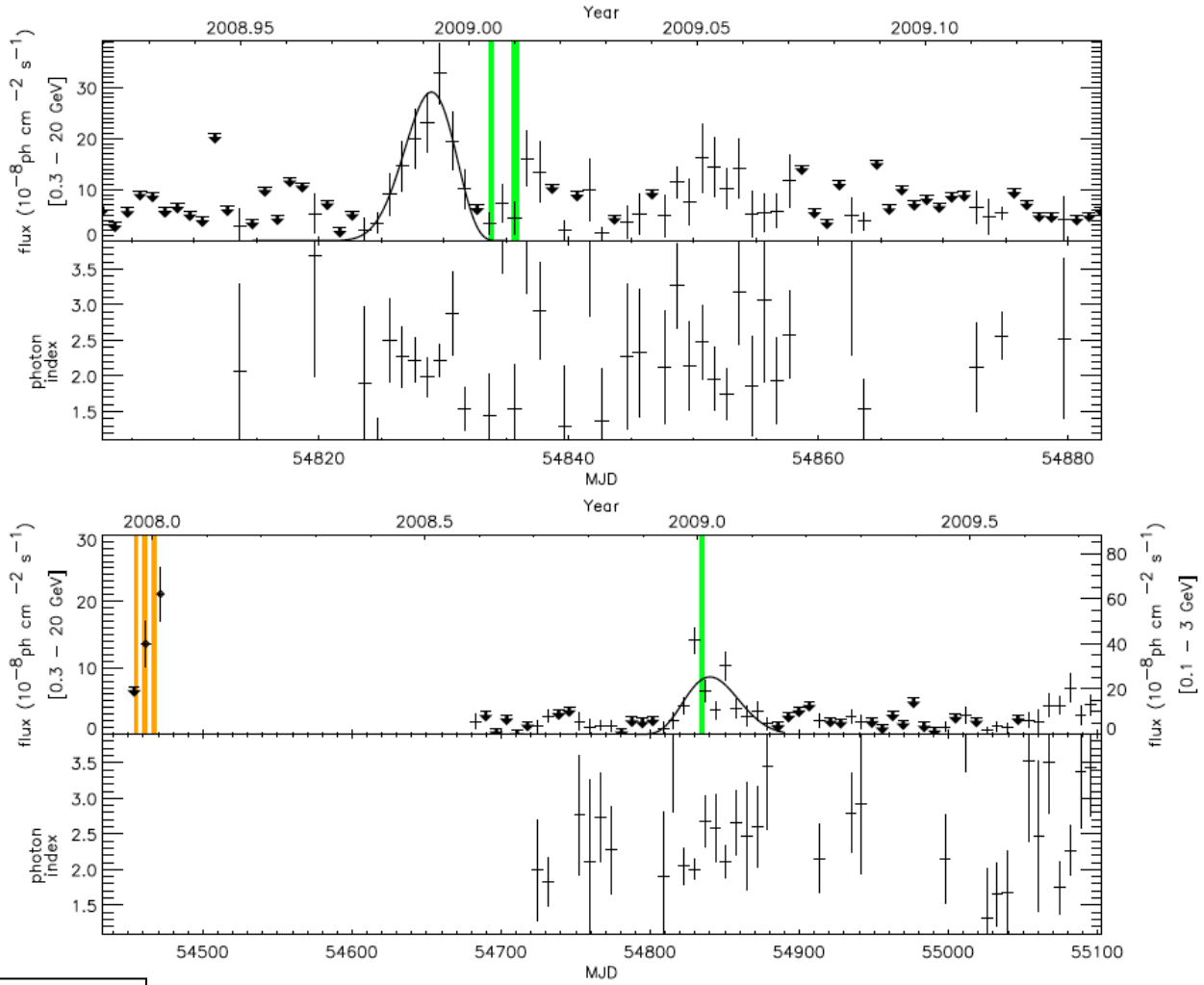
Rappoldi et al 2015

Galactic sources

ID	TeV Source	$\sqrt{(TS)}$	(l, b) [deg]	Error (95%)[19] [deg]	Flux (E>100 MeV) [10^{-7} ph cm^{-2} s^{-1}]	Dist. [deg]	AGILE Association	Fermi Association	Analysis Flag
1	TeVJ0006+727	21.6	119.66, 10.51	0.09	3.3 ± 0.2	0.1	1AGLR J0007+7307	3FGL J0007.0+7302 (E)	IN
12	TeVJ0222+430	8.1	140.0, -16.7	0.2	1.4 ± 0.2	0.1	1AGLR J0222+4305	3FGL J0222.6+4301 (P)	IN
14	TeVJ0232+202	4.2	152.9, -36.3	0.6	1.1 ± 0.3	0.4	-	3FGL J0232.8+2016 (P)	IN
15	TeVJ0240+612	27.1	135.5, 1.2	0.1	6.6 ± 0.3	0.2	1AGLR J0240+6115	3FGL J0240.5+6113 (P)	E
19	TeVJ0319+415	5.5	150.6, -13.2	0.4	1.0 ± 0.2	0.1	1AGLR J0321+4137	3FGL J0319.8+4130 (P)	IN
24	TeVJ0521+211	4.7	183.6, -8.6	0.5	1.7 ± 0.4	0.1	-	3FGL J0521.7+2113 (P)	IN
26	TeVJ0534+220	55.9	184.48, -5.81	0.06	26.7 ± 0.7	0.1	1AGL J0535+2205	3FGL J0534.5+2201 (P)	IN
30	TeVJ0616+225	13.2	188.9, 3.0	0.2	5.0 ± 0.5	0.2	1AGL J0617+2236	3FGL J0617.2+2234e (E)	O
32	TeVJ0632+173	82.6	195.09, 4.28	0.04	41.8 ± 0.9	0.6	1AGL J0634+1748	3FGL J0633.9+1746 (E)	IN
36	TeVJ0721+713	13.9	143.9, 28.1	0.1	2.6 ± 0.2	0.1	1AGLR J0723+7121	3FGL J0721.9+7120 (P)	IN
45	TeVJ1018-589	7.8	284.0, -2.0	0.3	2.6 ± 0.4	0.3	1AGLR J1018-5852	3FGL J1018.9-5856 (E) 3FGL J1016.3-5858 (E)	O
49	TeVJ1104+382	5.2	179.7, 65.0	0.2	1.6 ± 0.4	0.1	1AGLR J1105+3818	3FGL J1104.4+3812 (P)	IN
60	TeVJ1256-057	11.2	305.3, 57.1	0.2	4.2 ± 0.5	0.1	1AGL J1256-0549	3FGL J1256.1-0547 (P)	IN
66	TeVJ1418-609	13.5	313.2, 0.1	0.1	5.1 ± 0.4	0.1	1AGLR J1417-6108	3FGL J1418.6-6058 (E)	IN
75	TeVJ1459-608	5.8	317.6, -1.7	0.3	1.6 ± 0.3	0.1	-	3FGLJ1456.7-6046 (E) 3FGLJ1459.4-6053 (E)	IN
79	TeVJ1512-091	25.0	351.4, 40.1	0.1	8.2 ± 0.4	0.1	1AGLR J1513-0906	3FGL J1512.8-0906 (P)	IN
87	TeVJ1632-478	5.7	336.4, 0.0	0.4	2.2 ± 0.4	0.2	-	3FGL J1633.0-4746e (E)	IN
88	TeVJ1634-472	15.2	337.4, 0.1	0.2	5.1 ± 0.5	0.3	1AGL J1639-4702	-	O
95	TeVJ1708-443	42.3	343.12, -2.69	0.06	13.9 ± 0.4	0.3	1AGL J1709-4428	3FGL J1709.7-4429 (E)	O
109	TeVJ1747-248	5.9	4.0, 1.7	0.3	2.1 ± 0.4	0.2	-	3FGL J1748.0-2447 (E)	O
112	TeVJ1801-233	15.0	6.6, 0.1	0.2	6.8 ± 0.5	0.4	1AGL J1801-2317	3FGL J1801.3-2326e (E)	E
113	TeVJ1804-216	7.8	8.4, 0.2	0.3	3.5 ± 0.5	0.2	1AGLR J1805-2149	3FGL J1805.6-2136e (E)	O
116	TeVJ1813-178	4.8	13.0, 0.4	0.4	2.1 ± 0.5	0.4	1AGL J1815-1732	-	IN
125	TeVJ1841-055	14.0	26.3, 0.1	0.2	5.8 ± 0.5	0.6	1AGLR J1839-0550	3FGL J1840.9-0532e (E)	O
128	TeVJ1848-017	4.6	30.8, 0.1	0.2	1.8 ± 0.4	0.4	-	3FGL J1848.4-0141 (E)	O
132	TeVJ1907+062	13.3	40.4, -1.0	0.1	4.4 ± 0.4	0.2	1AGL J1908+0614	3FGL J1907.9+0602 (E)	O
133	TeVJ1911+090	7.8	43.3, 0.0	0.3	2.4 ± 0.3	0.2	-	-	IN
135	TeVJ1923+141	7.1	49.2, -0.5	0.3	2.1 ± 0.3	0.2	1AGL J1923+1404	3FGL J1923.2+1408e (E)	IN
142	TeVJ2019+368	25.5	75.17, 0.25	0.09	6.9 ± 0.3	0.2	1AGLR J2021+3653	3FGL J2021.1+3651 (E)	IN
144	TeVJ2032+415	8.0	80.3, 1.2	0.2	2.3 ± 0.3	0.1	1AGLR J2031+4130	3FGL J2032.2+4126 (E)	O
145	TeVJ2158-302	4.8	17.6, -52.0	0.6	1.4 ± 0.3	0.3	-	3FGLJ2158.8-3013 (P)	IN
147	TeVJ2227+608	16.7	106.7, 3.0	0.2	3.3 ± 0.2	0.4	1AGL J2231+6109	3FGL J2225.8+6045 (E)	E
152	TeVJ2359-306	4.0	12.6, -78.0	0.3	3.3 ± 1.0	0.1	-	3FGL J2359.3-3038 (P)	IN

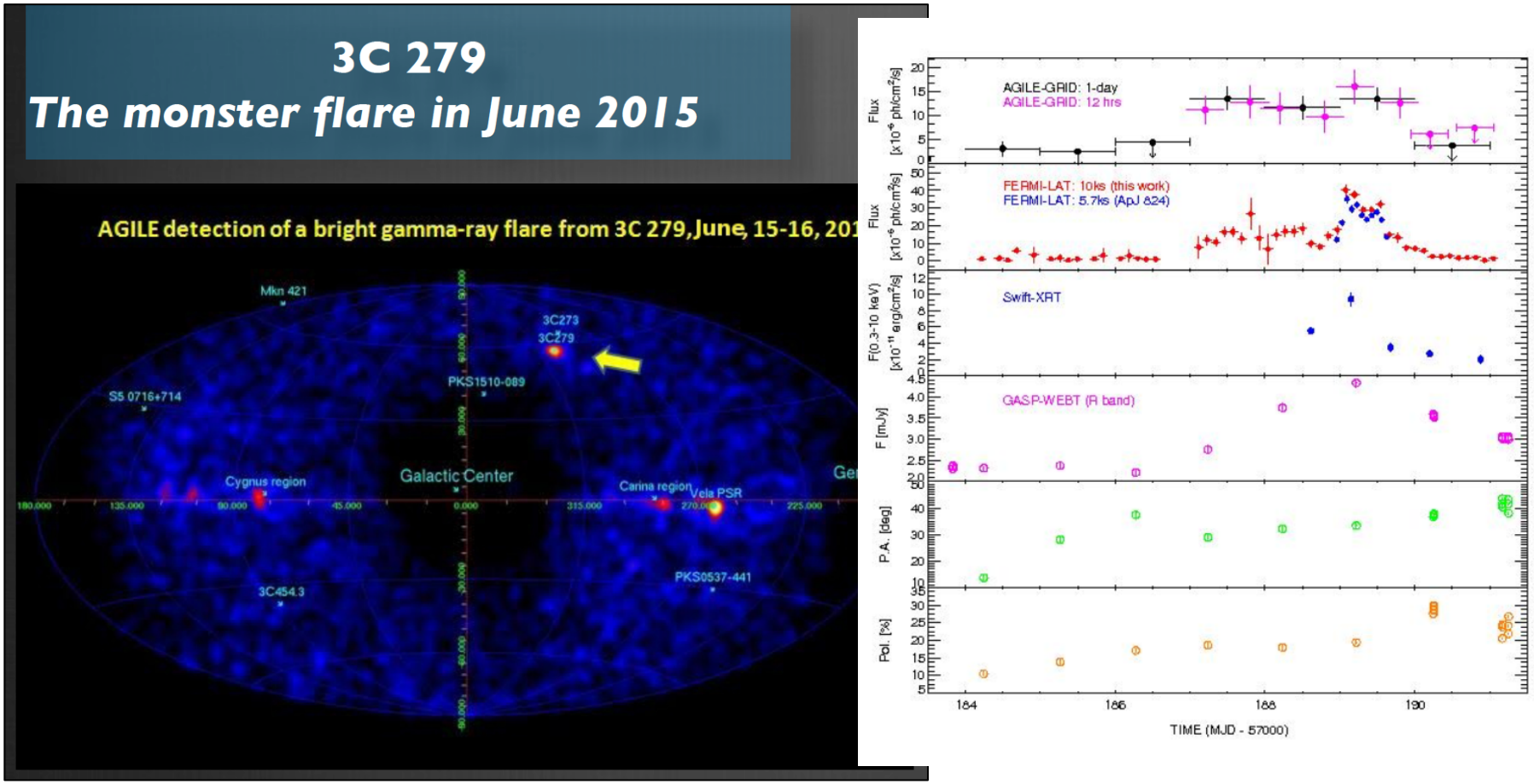
Rappoldi et al 2015

Joint campaigns on AGN



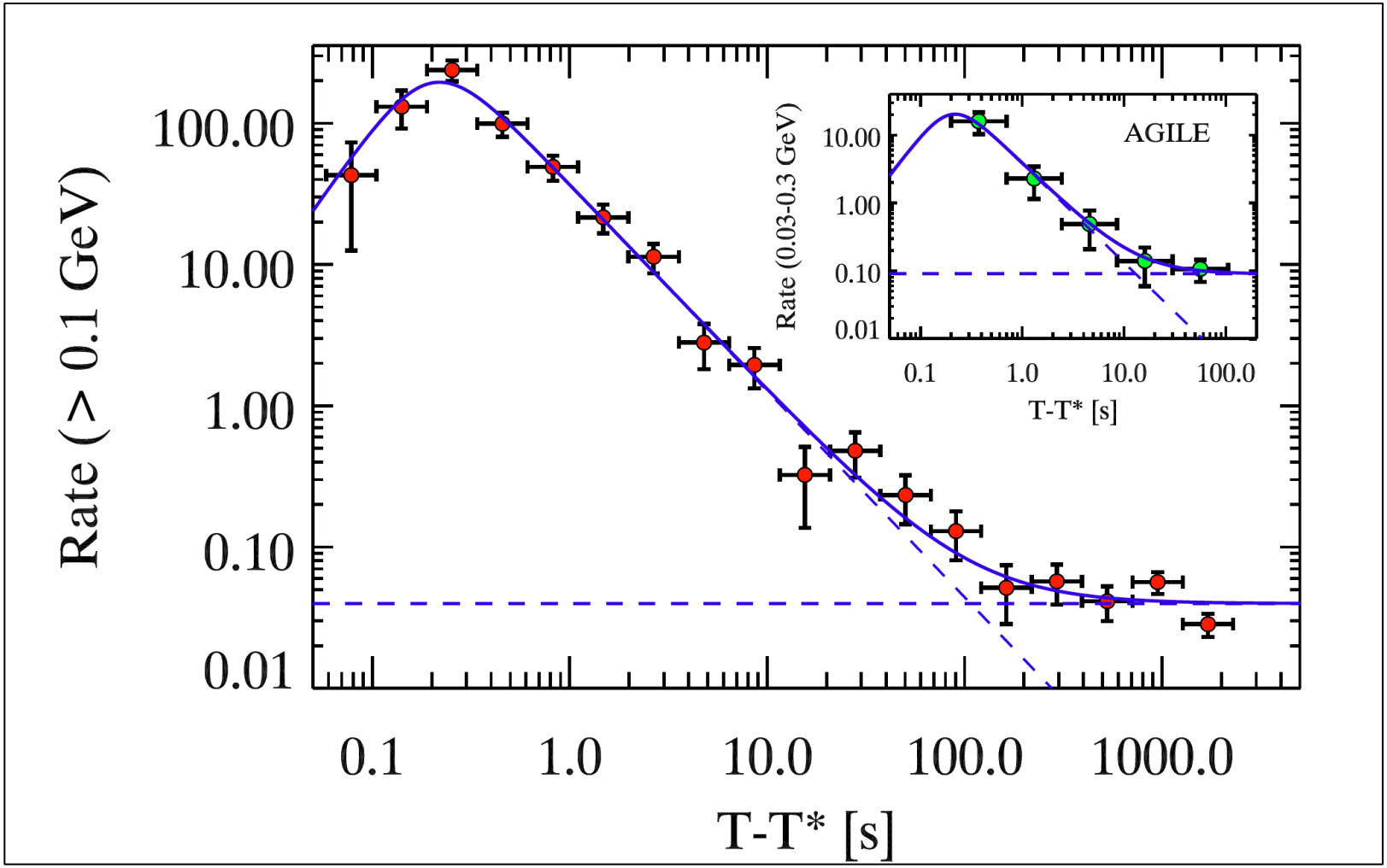
Pacciani et al. 2012

Flaring AGN



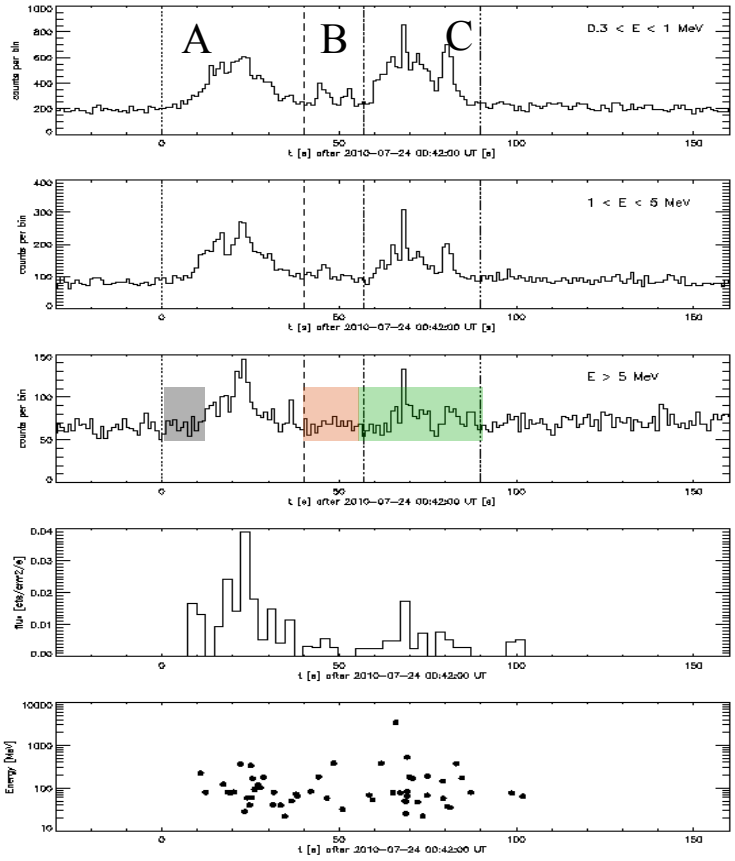
Pittori et al 2018

GRB 090510

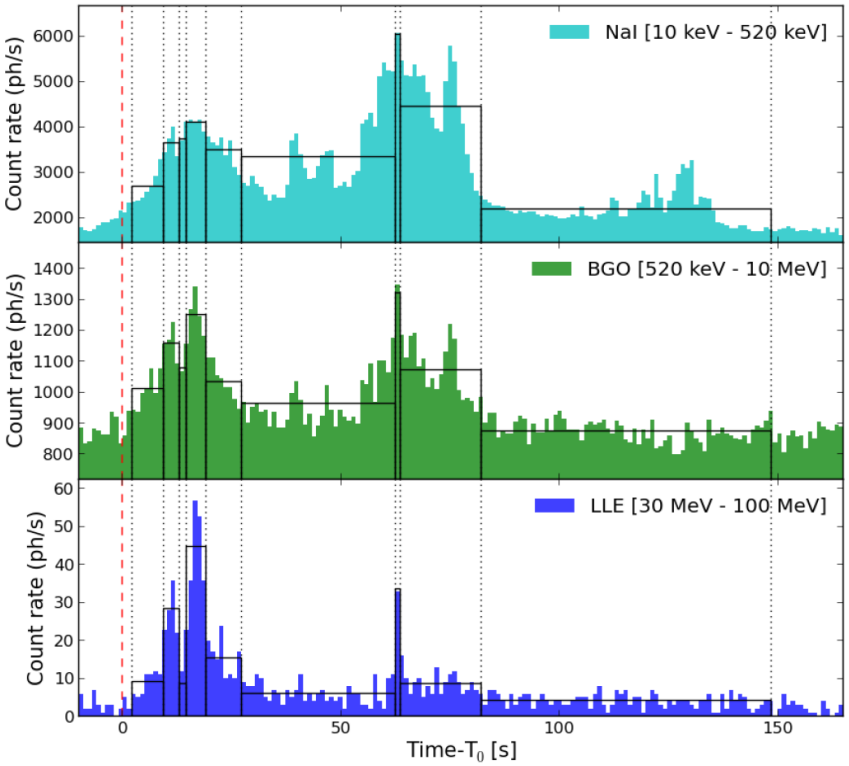


Ghirlanda et al. 2009

GRB 100724B

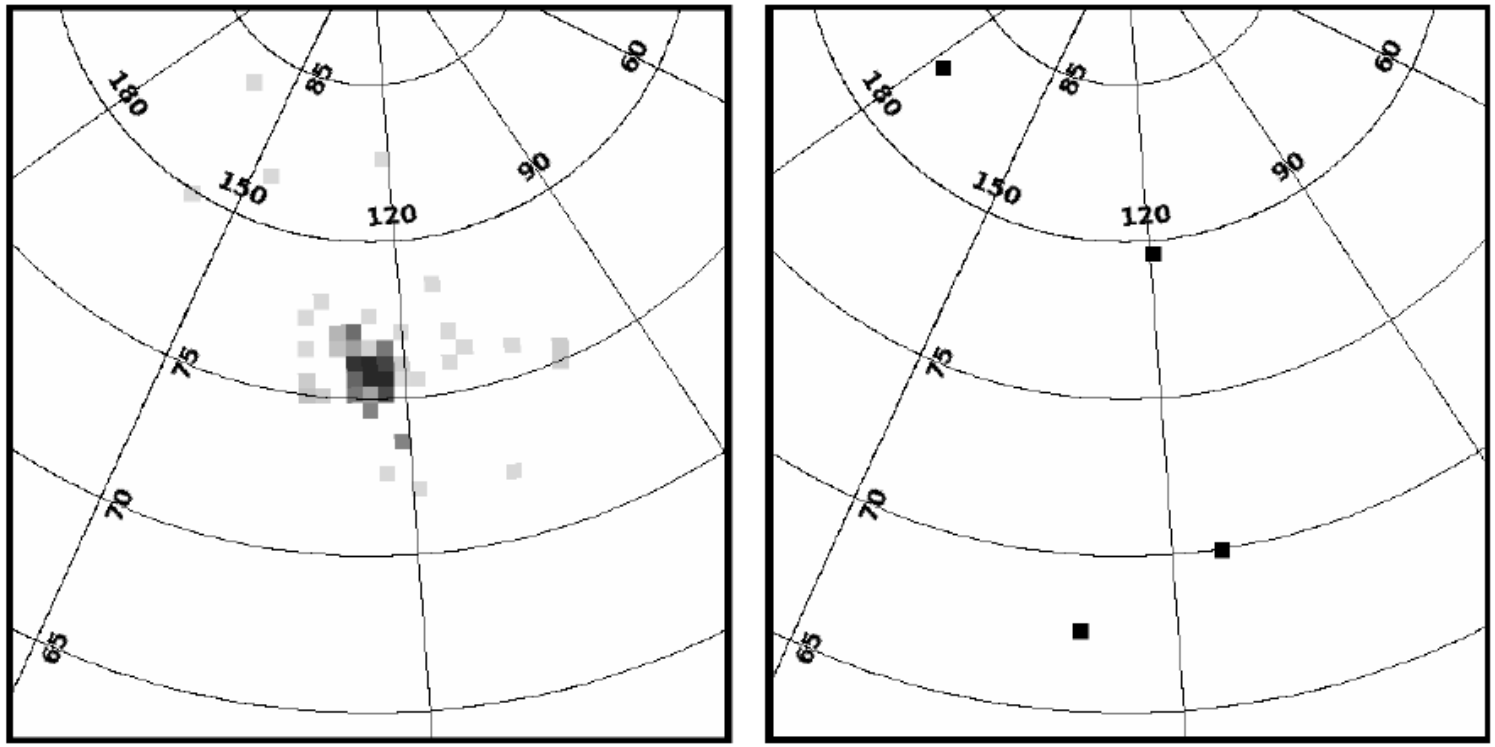


Del Monte et al. 2011



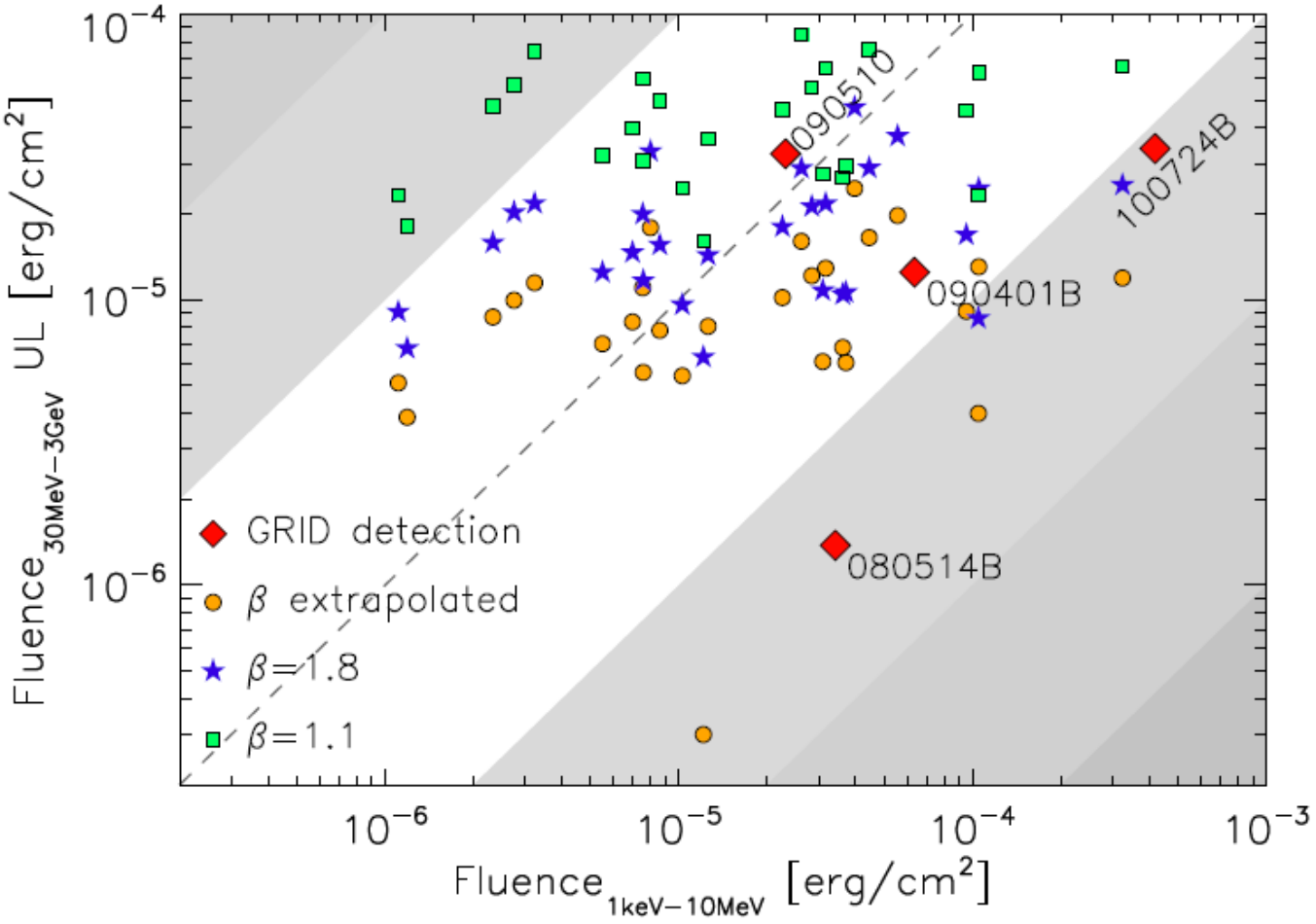
Vianello et al. 2018

GRB 100724B



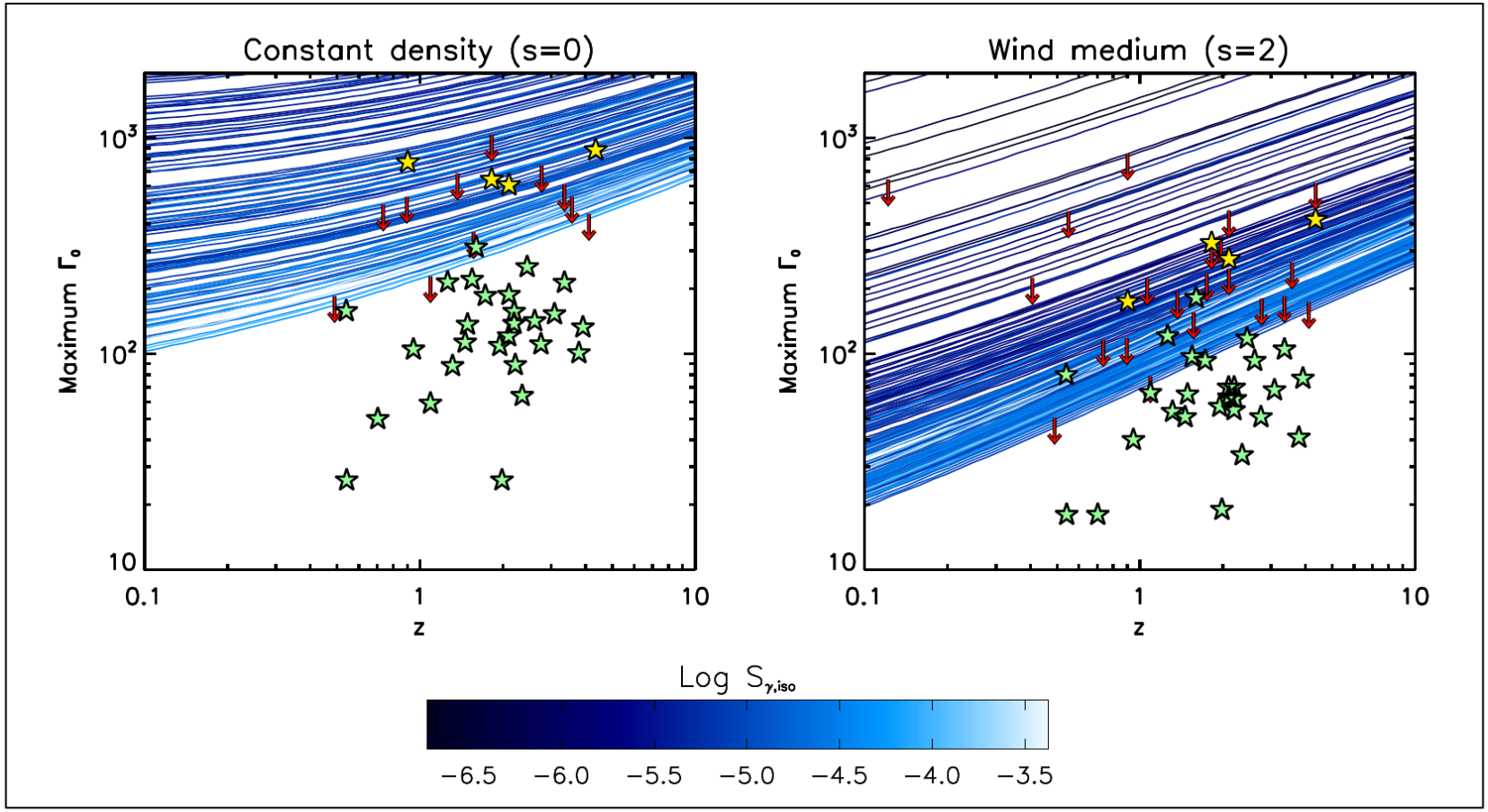
Vianello et al. 2018

Upper limits in GRB



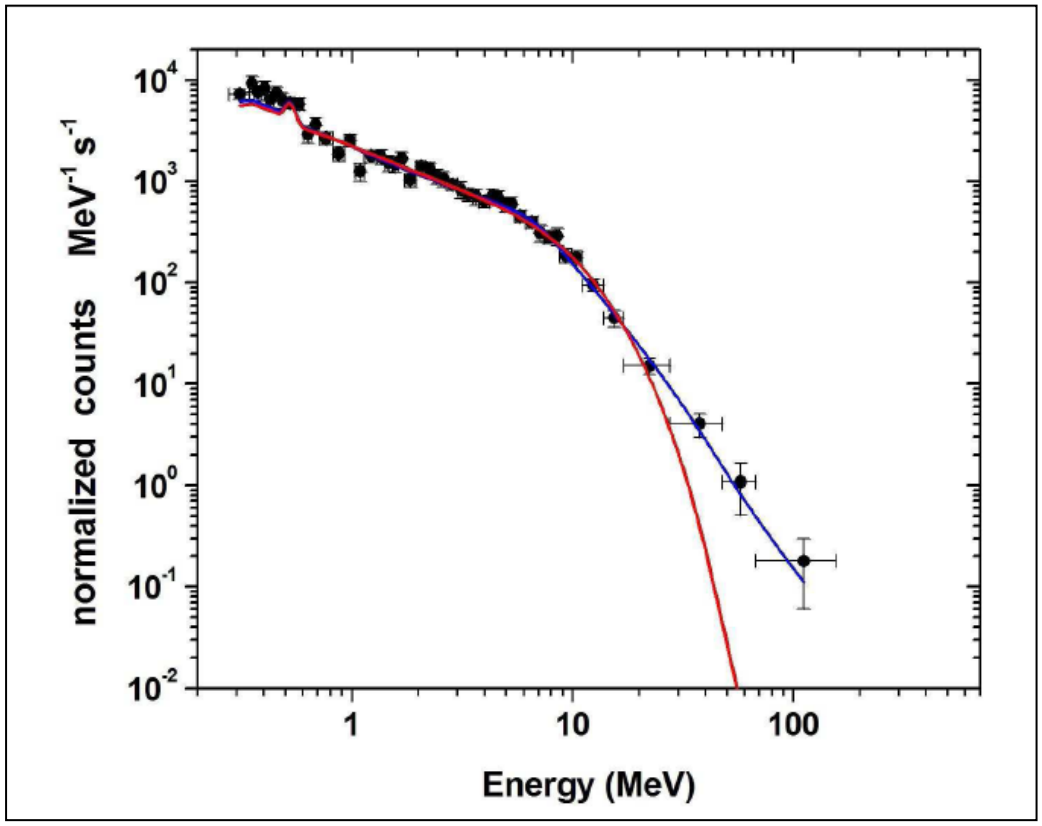
Longo et al. 2012

Upper limits in GRB



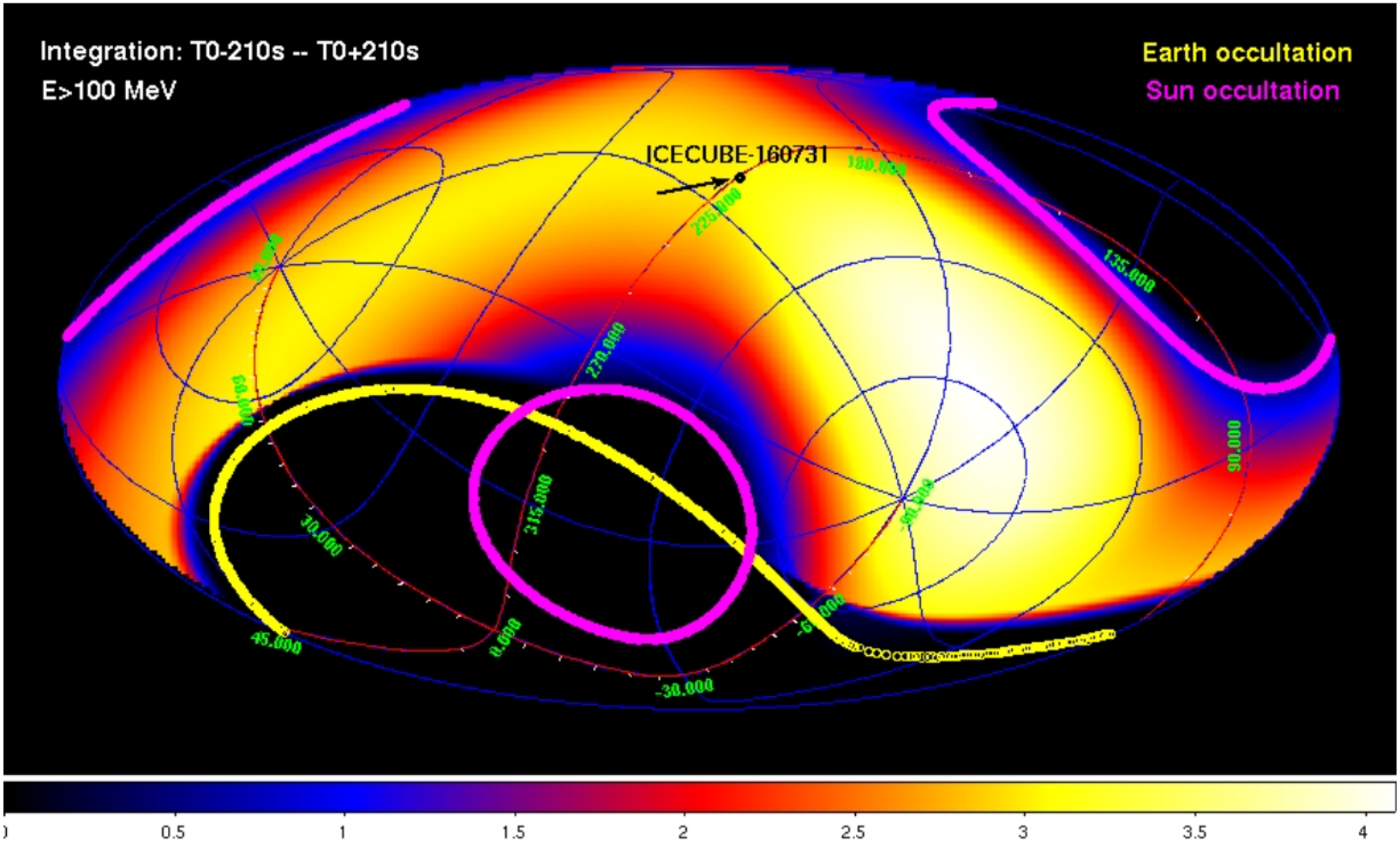
Nava et al. 2016

Terrestrial Gamma Ray Flashes



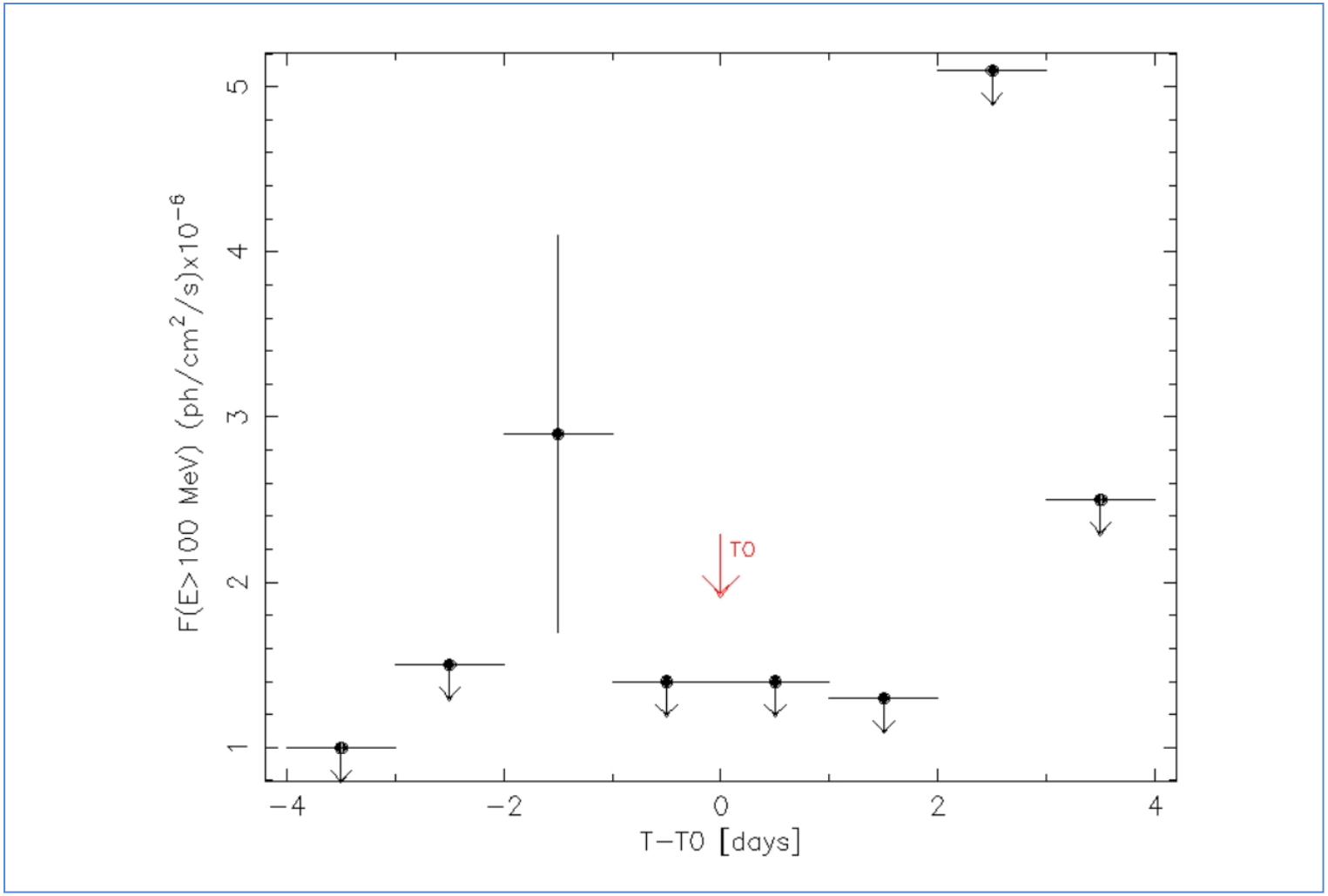
Marisaldi et al. 2010

Follow up of Neutrino events



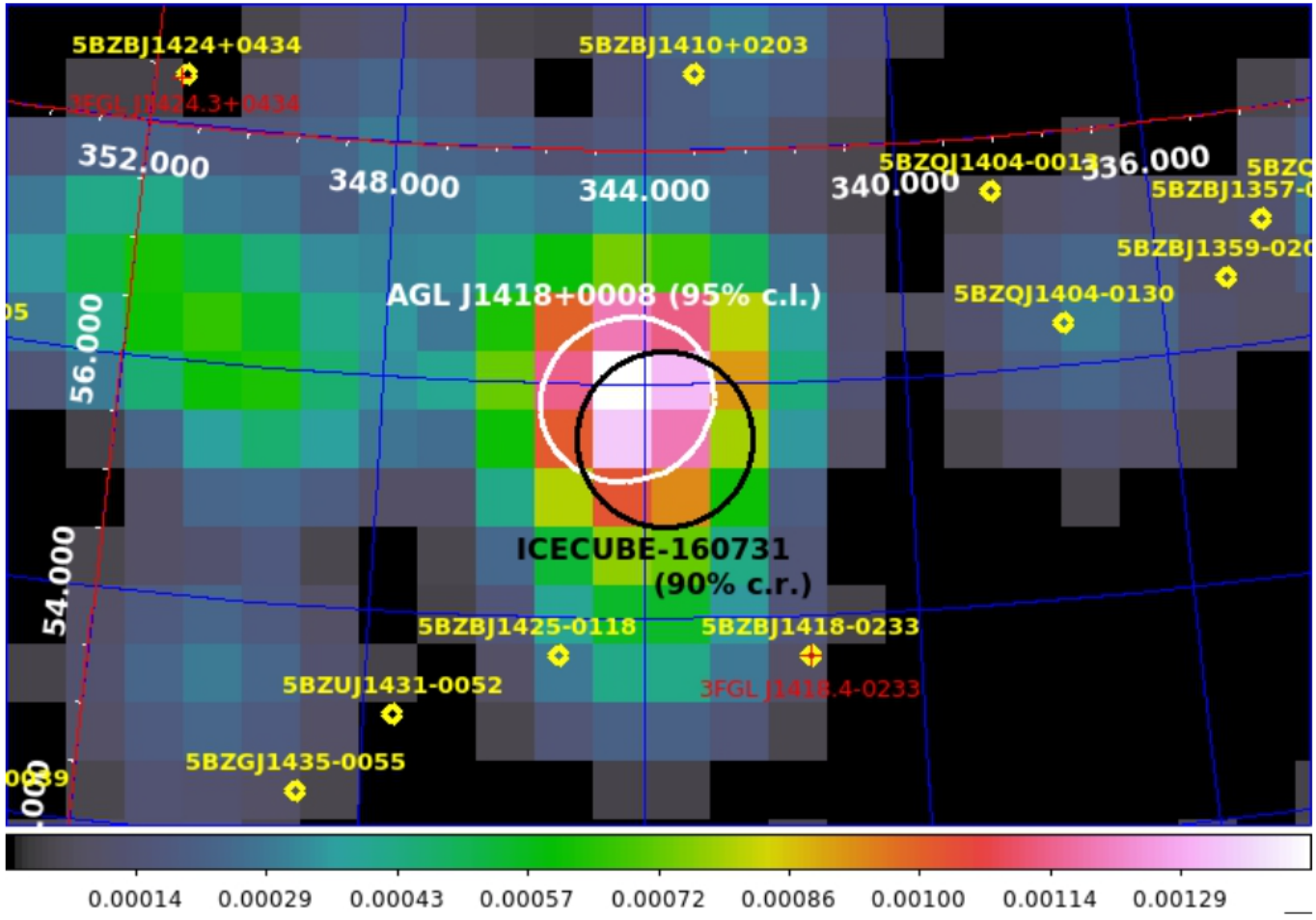
Lucarelli et al 2017

Follow up of Neutrino events



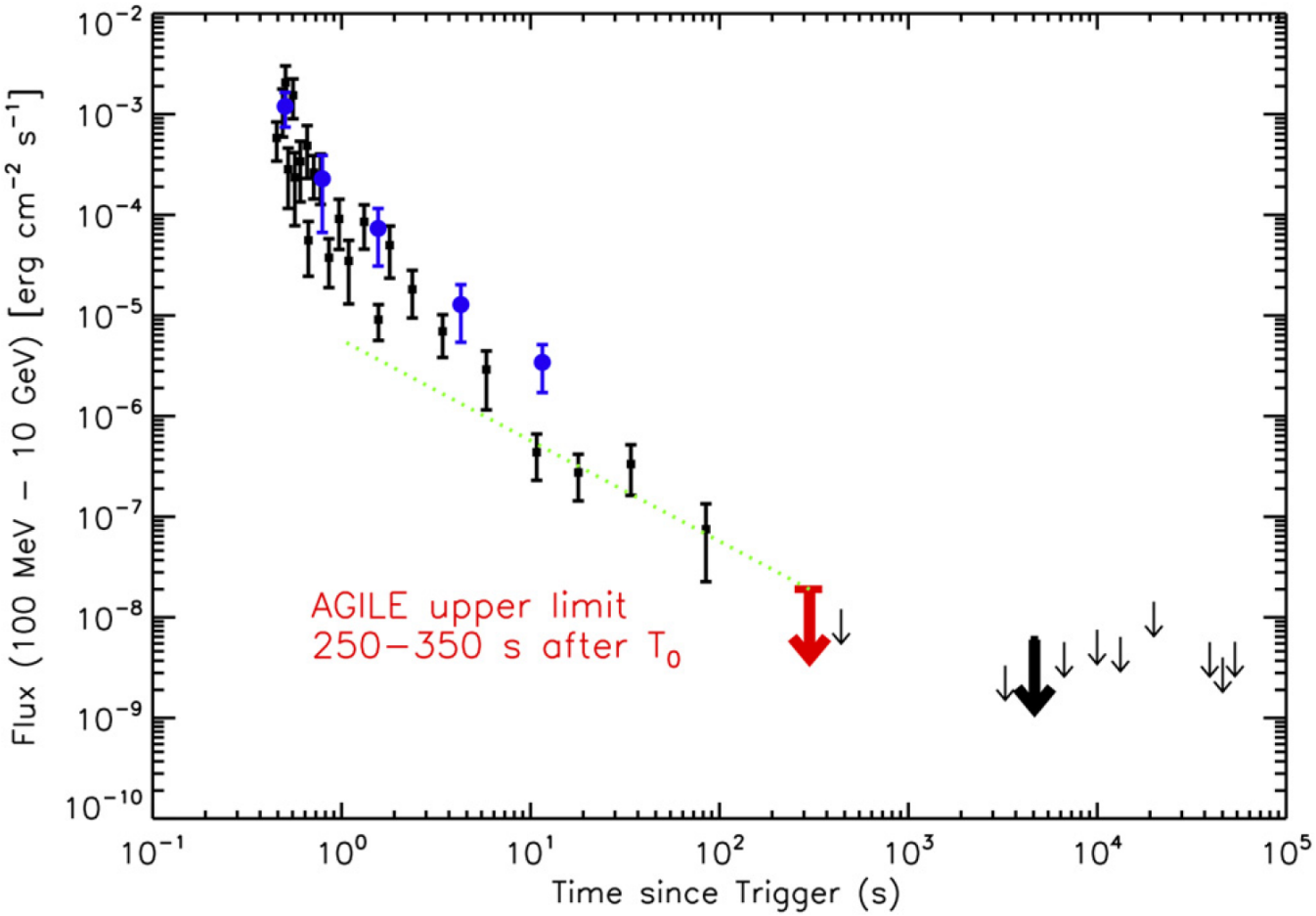
Lucarelli et al 2017

New!! Follow up of Neutrino events



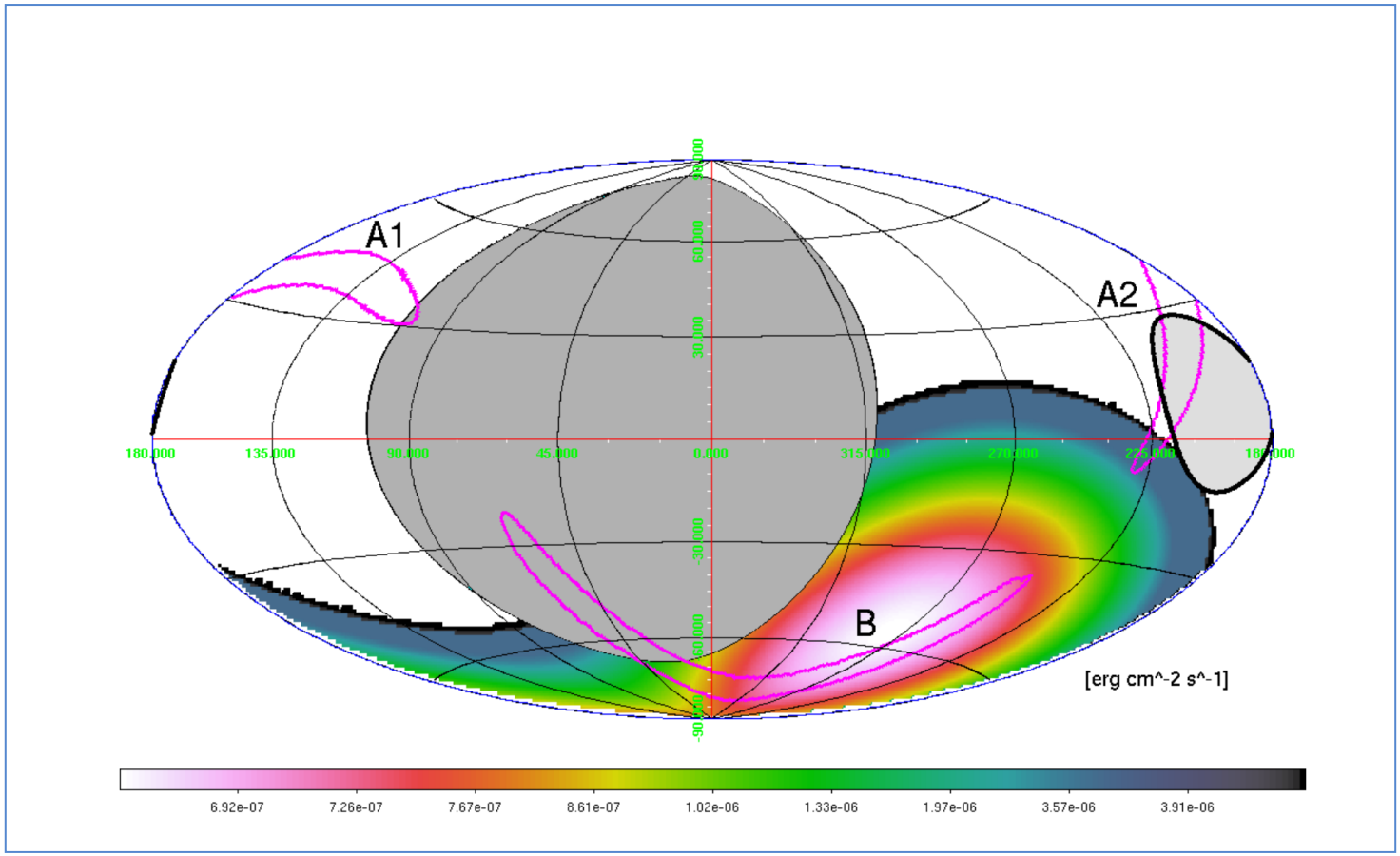
Lucarelli et al 2017

Follow-up of GW events



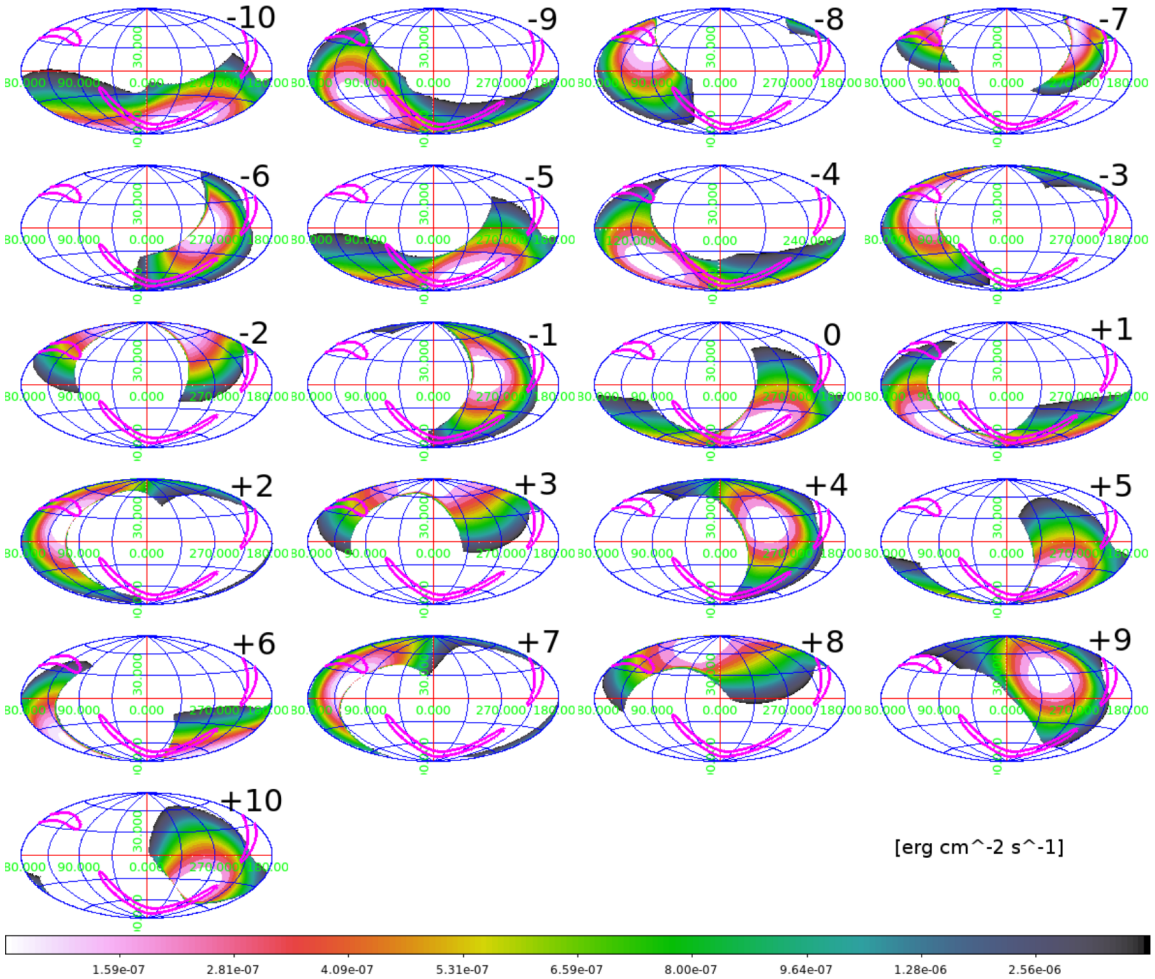
Tavani et al 2016

Follow up of GW events



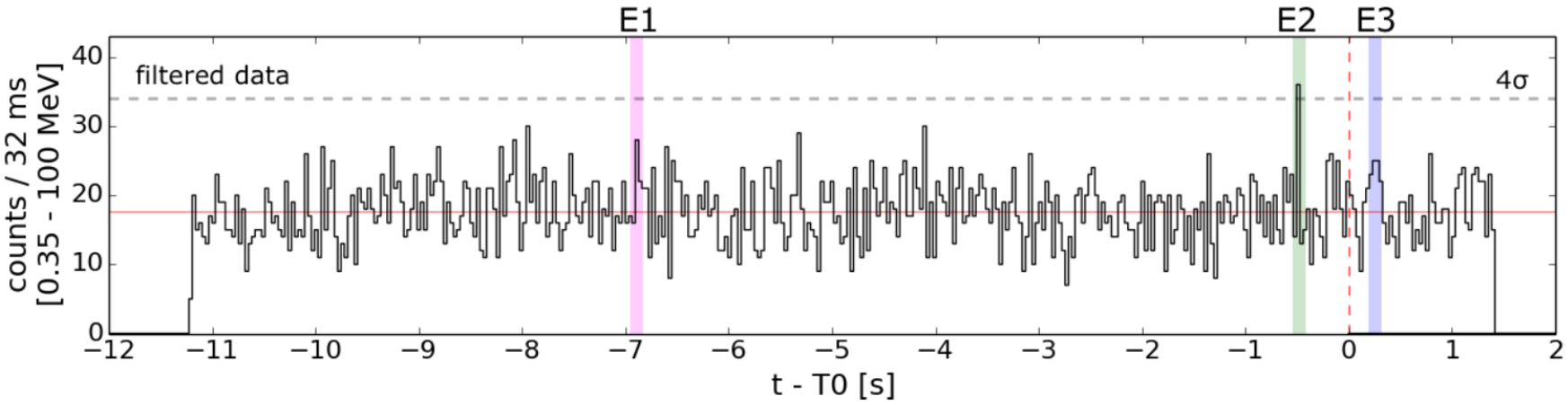
Verrecchia et al 2017

Follow up of GW events



Verrecchia et al 2017

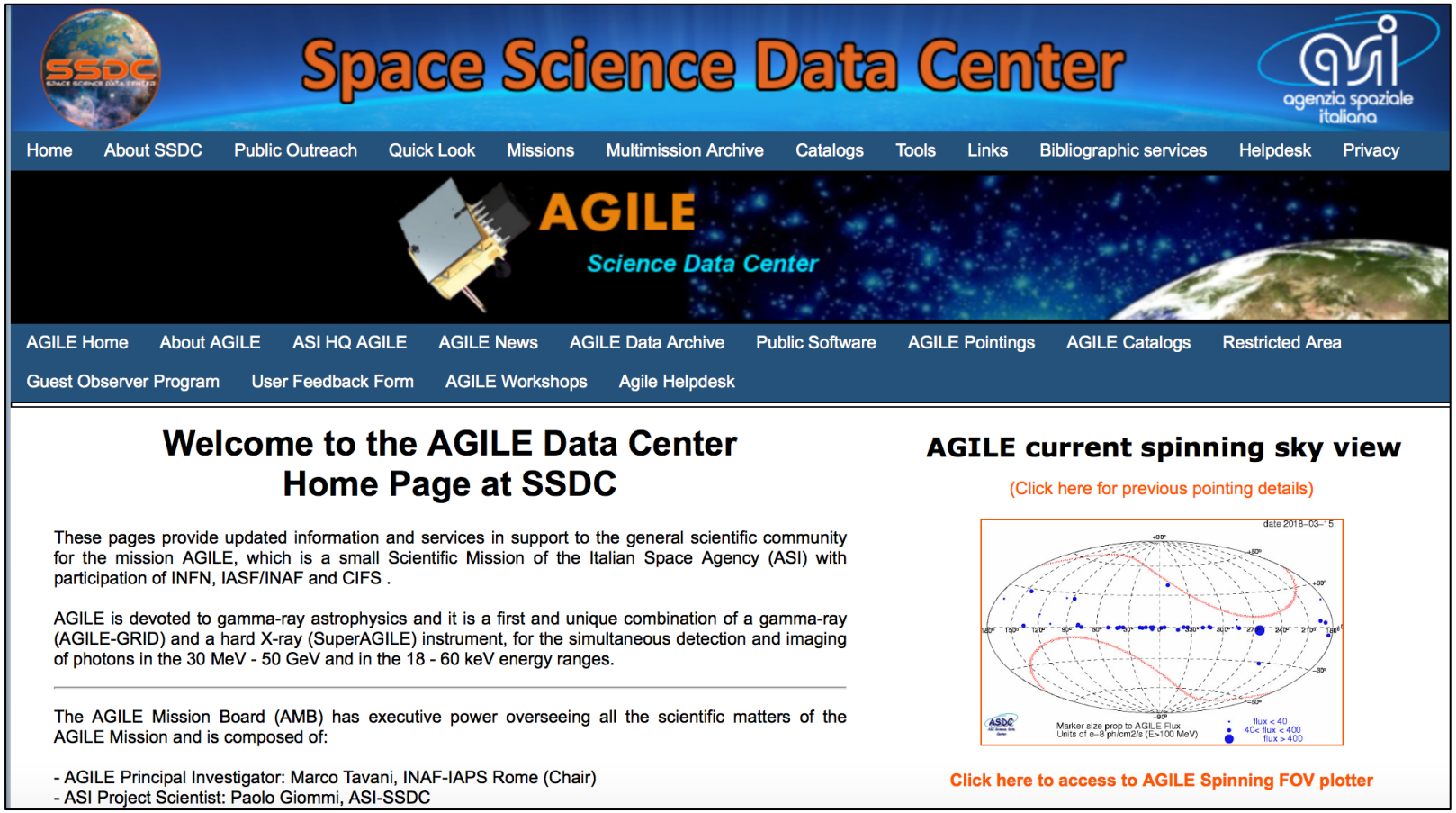
Follow-up of GW events



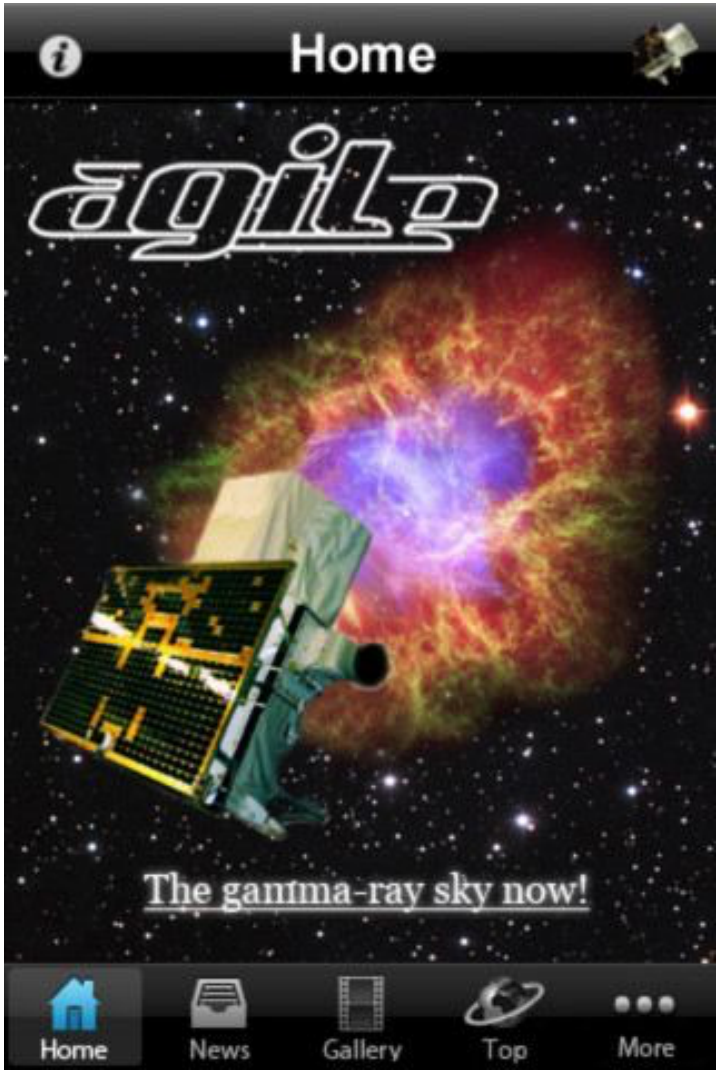
Verrecchia et al 2017

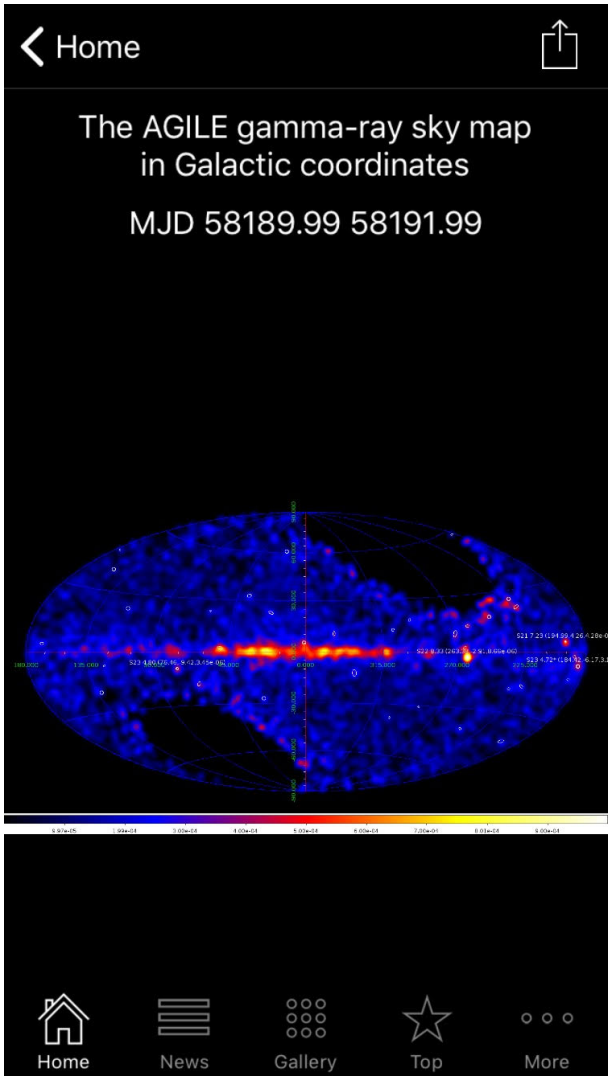
Where to find data?

http://agile.ssdc.asi.it



The AGILEScience App





Issues & Opportunities

- Transient sources detected by AGILE and not confirmed by Fermi
  - Not in all cases … why ?
  - Different effective areas
- Soft spectra and AGILE energy resolution
  - Different Energy bands ?
- Transient short events
  - Different exposure to source regions?
- Different but Similar Analysis methods
- Some common areas of interest
  - Transients sources
- Not yet fully explored
  - Cross working group on Galactic model

Conclusions

- **AGILE and Fermi are operative since 2007 and 2008**
  - **We are still in the Golden era for Gamma-ray Astrophysics from space**
  - **Don't miss the opportunity of having cross check and confirmation from two different instruments**