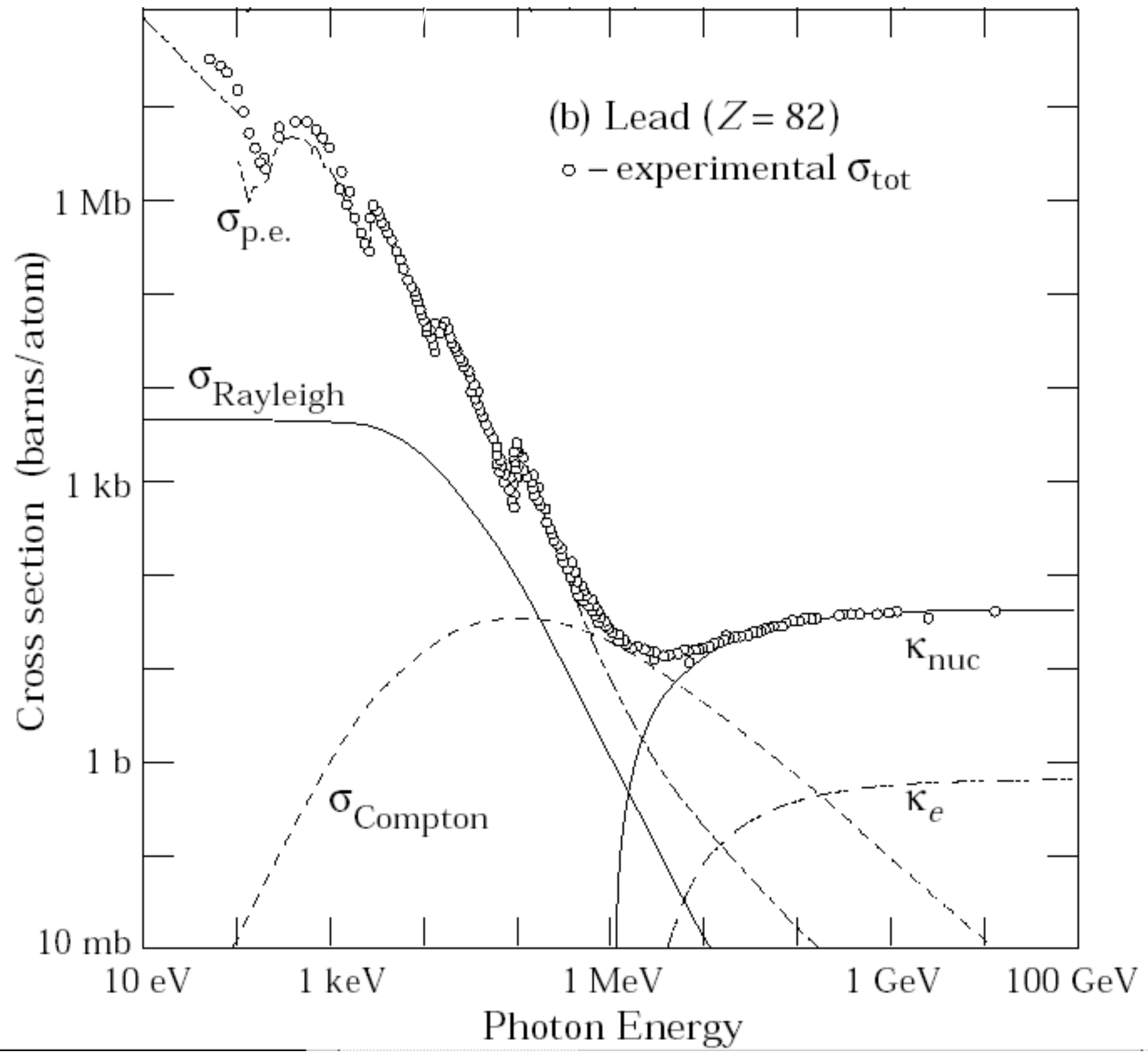
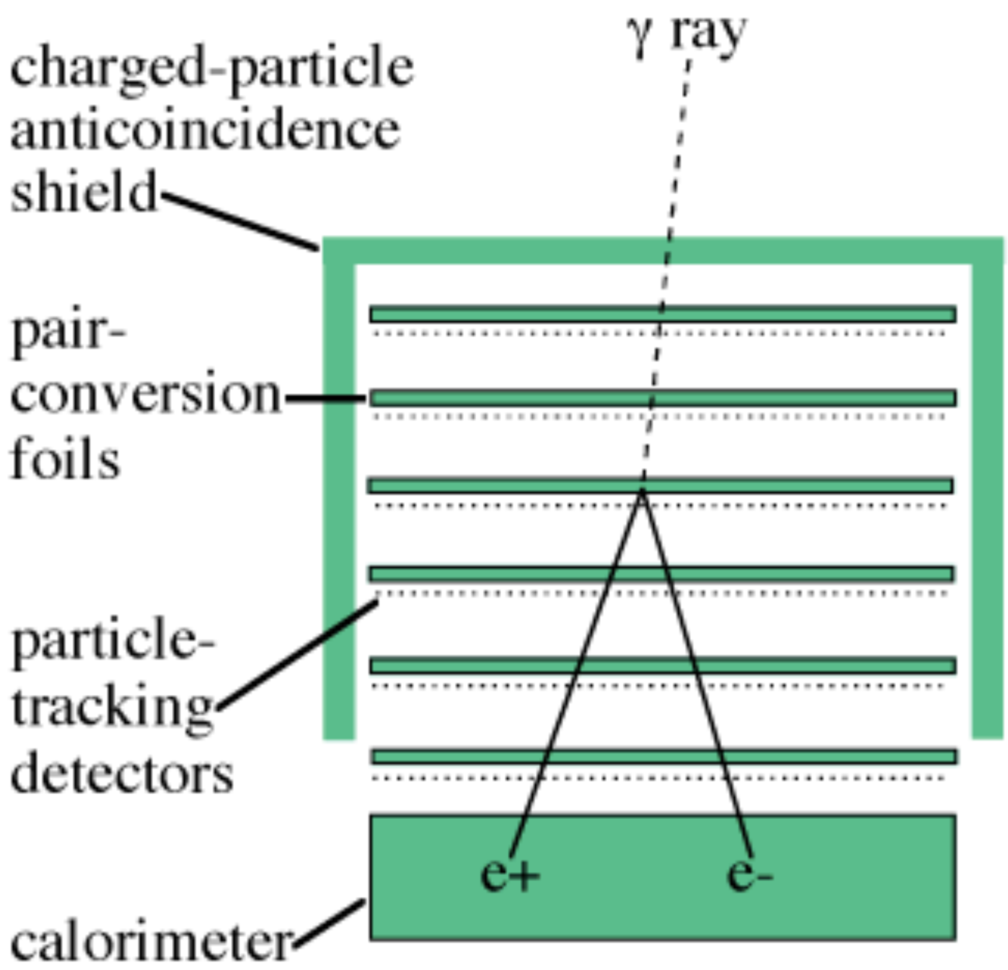
Astrofisica Nucleare e Subnucleare

GeV Astrophysics III

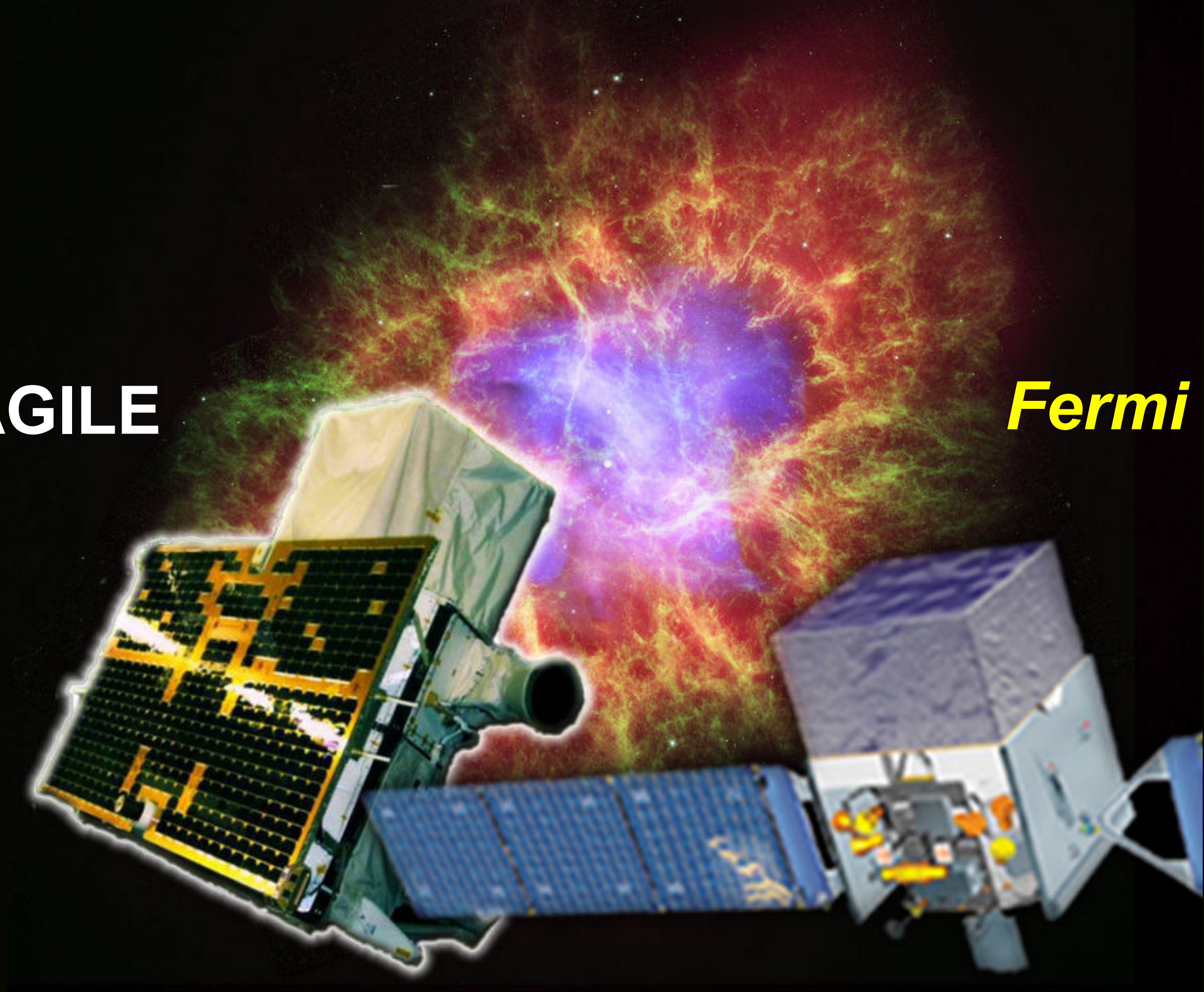
Photon Interactions



Detector Project

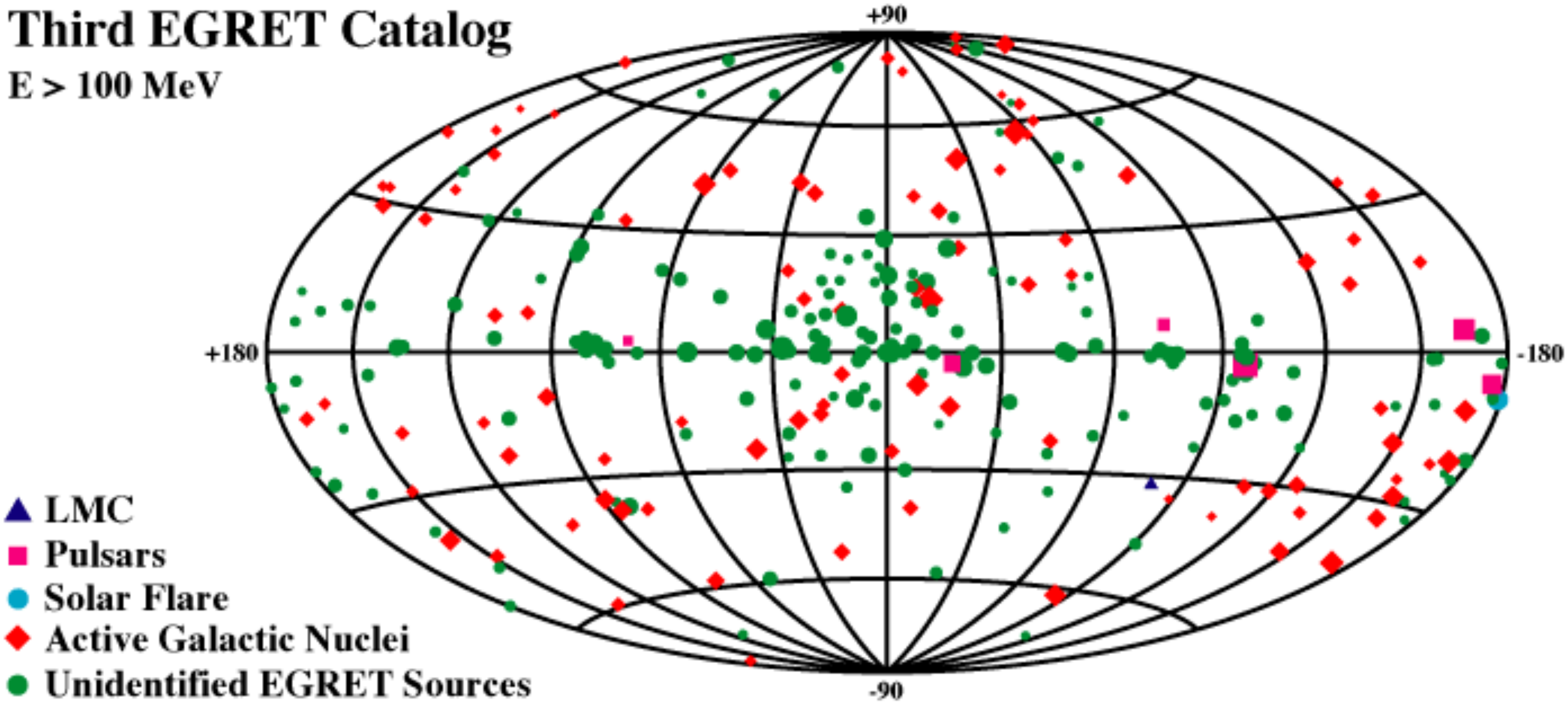


Gamma-ray astrophysics above 100 MeV



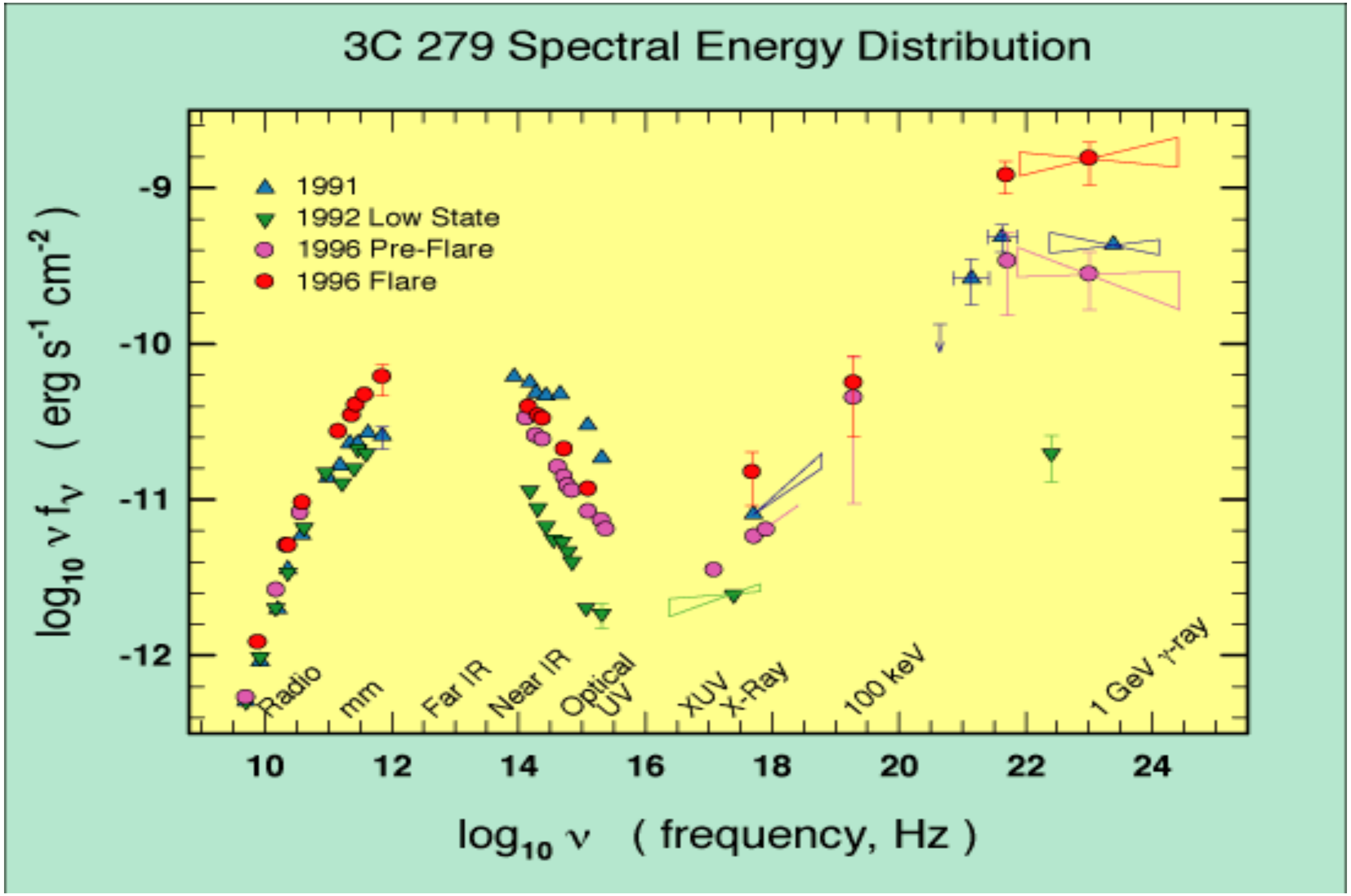
Picture of the day, Feb. 28, 2011, NASA-HEASARC

EGRET Gamma-ray Sources



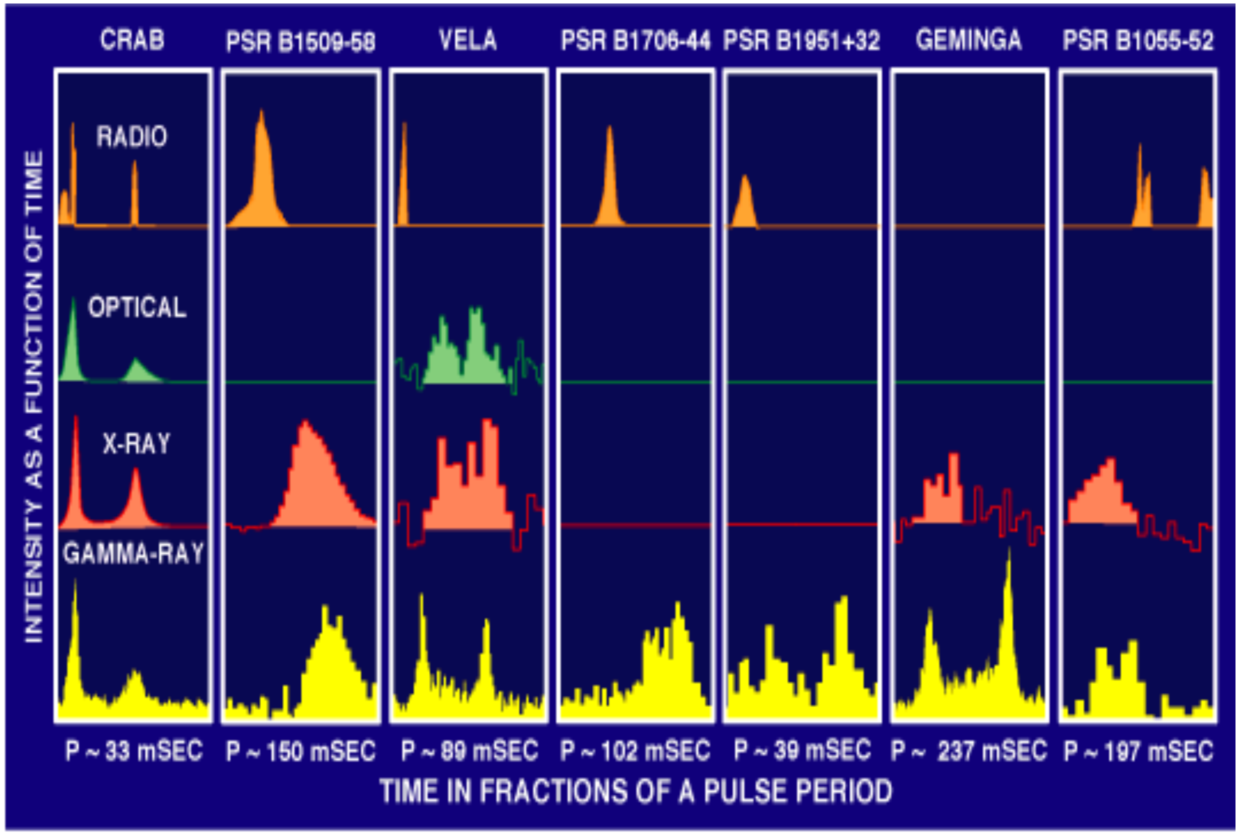
Challenge # 1

- Need simultaneous multiwavelength data to study variability and emission processes



Challenge # 2

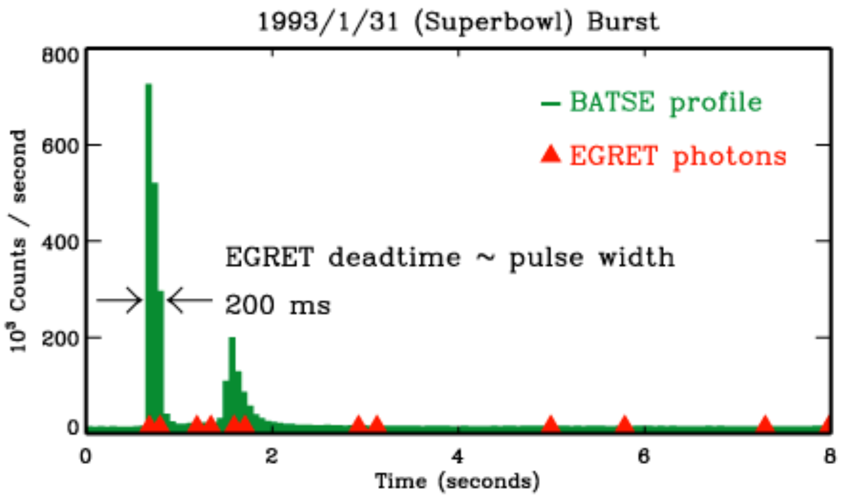
- Need more exposure and optimal timing (and radio monitoring) to discover more gamma-ray PSRs.



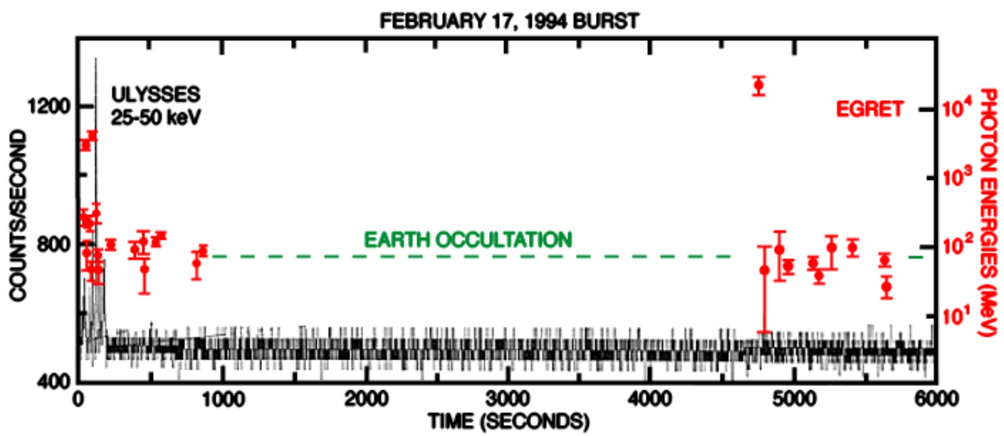
Challenge # 3

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

Prompt Emission (GRB 930131)

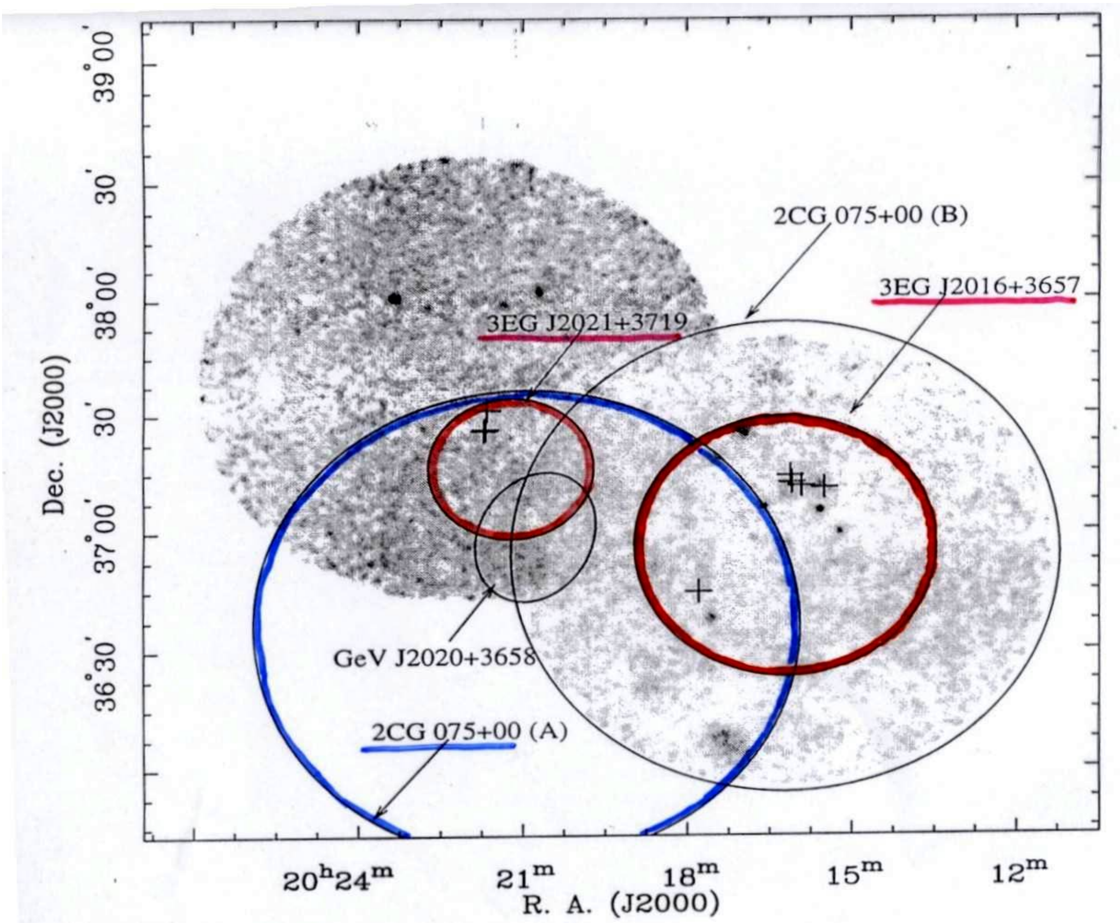


Delayed Emission (GRB 940217)



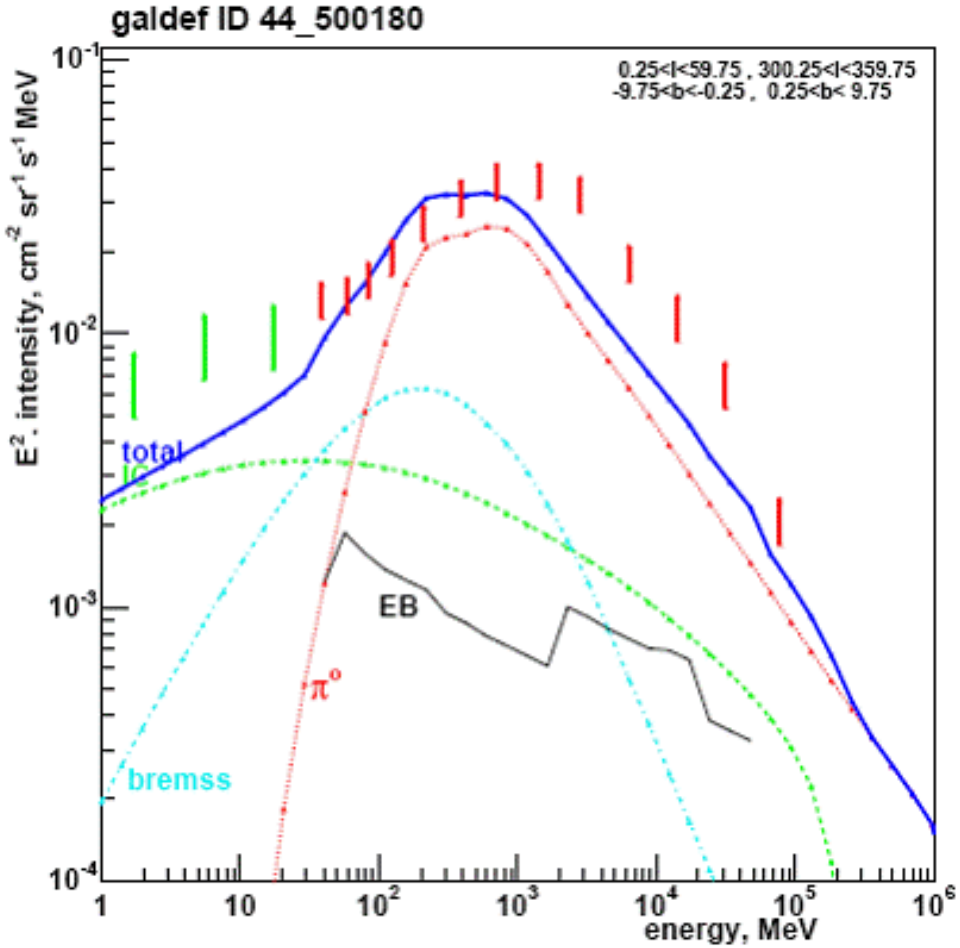
Challenge # 4

- Need arcminute positioning of gamma-ray sources (improving EGRET error box radii by a factor of 2-10).



Challenge # 5

- Need improvements in Spectral Resolution fo check for DM signals



AGILE

AGILE

agenzia spaziale italiana

INAF

INFN

CARLO GAVAZZI

Carlo Gavazzi Space SpA

OERLIKON CONTRAVES

ALCATEL ALENIA SPACE

An Alcatel/Finmeccanica company

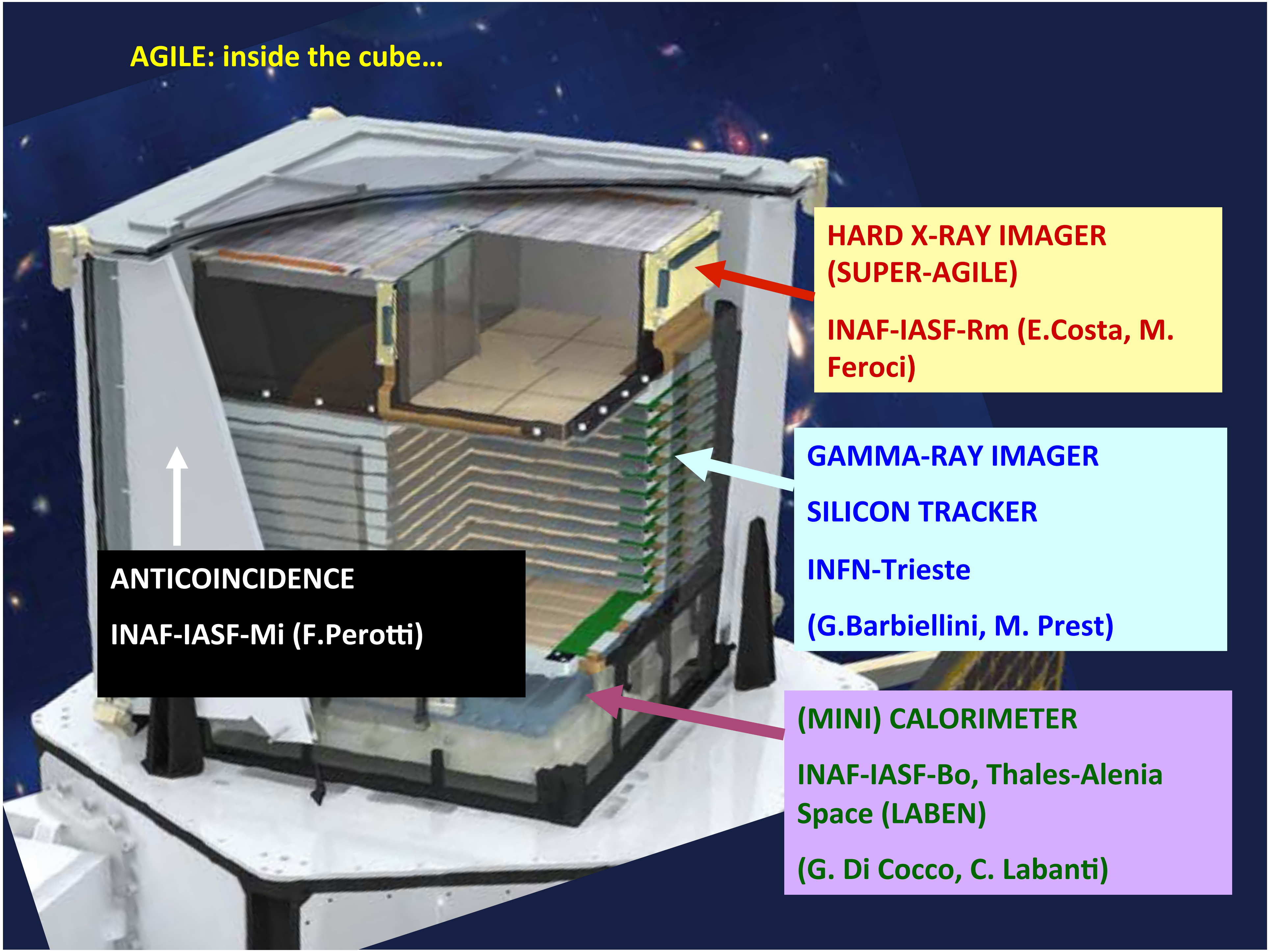
telespazio

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

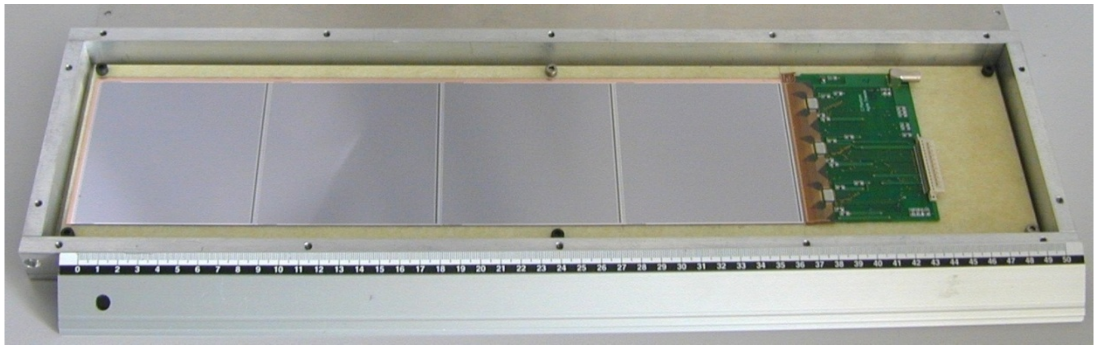
The AGILE silicon detectors

Detector specifications:

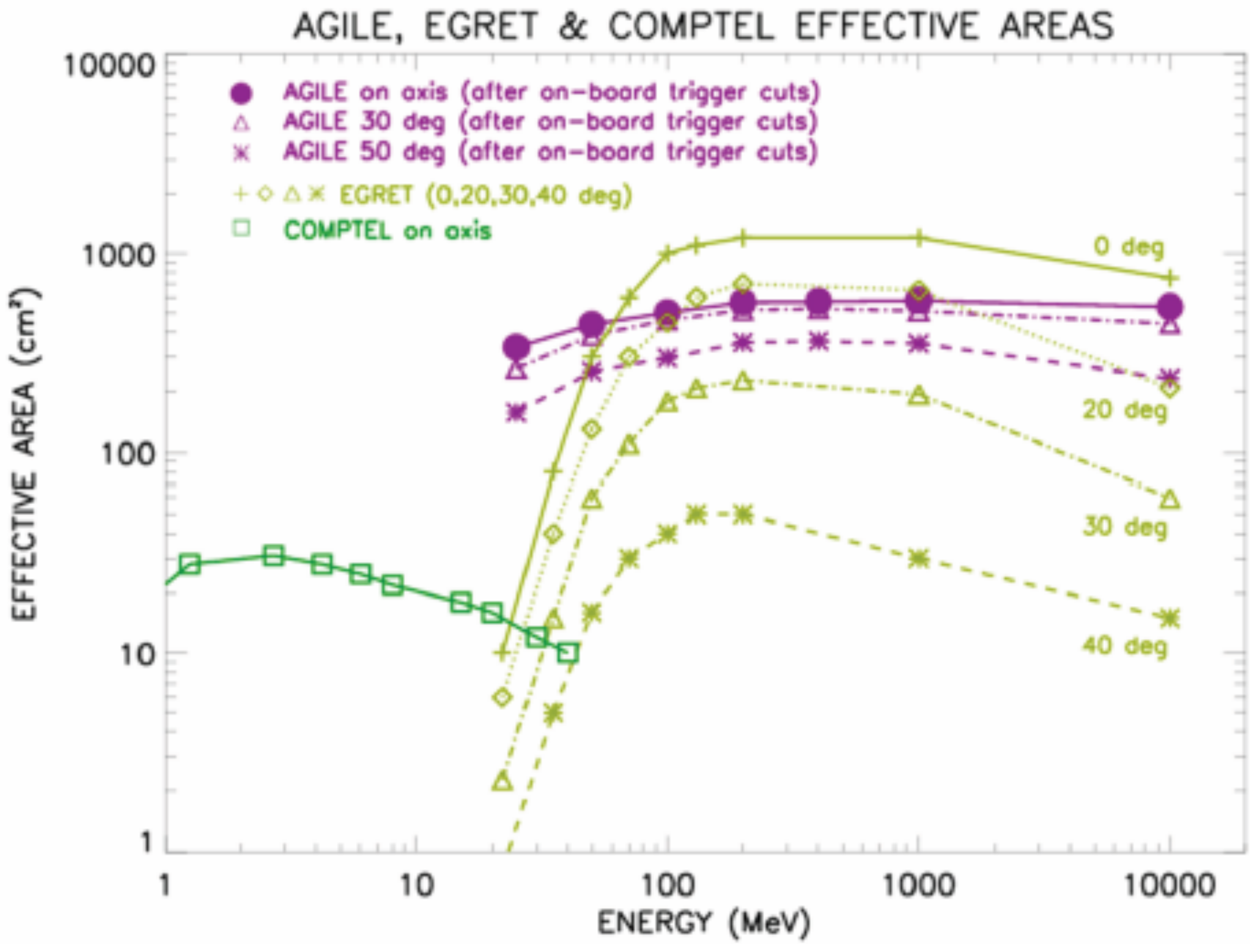
- dimension: 9.5x9.5 cm^2
- thickness: 410 μm (6 inch technology)
- readout pitch: 242 μm;
  physical pitch: 121 μm (one floating strip)
- number of strips/ladder: 384
- Single side and AC-coupled
- leakage current: 2 nA/cm^2 at Vbias=2.5*V_{FD} =200 V
- polarization resistor: 40 MΩ
- coupling capacitor: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

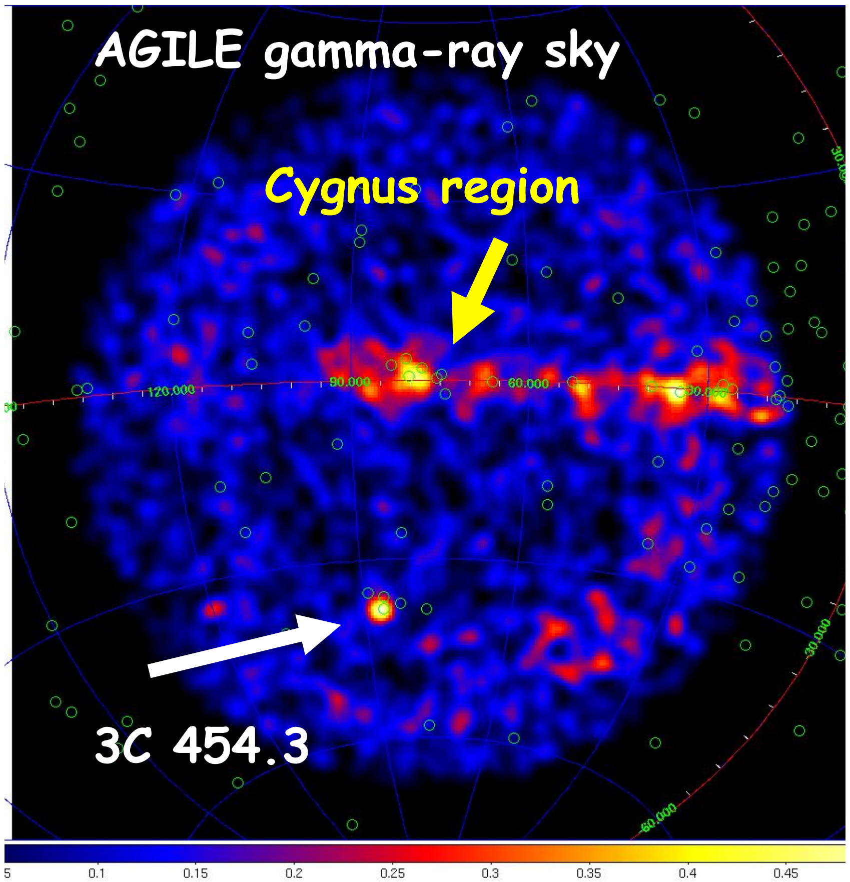
- low noise, low power, SELF-TRIGGERING
- technology: 1.2 μ CMOS, double poly, double metal (final: 0.8 μ BiCMOS on epitaxial layer)
- features:
  - 128 channels
  - gain: 25 mV/fC; range: 18 fC
  - noise (e^- rms): 165+6.1/pF for T_{peak}=2 μs
  - power: <0.4 mW/channel
  - power rails: ±2 V
  - readout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

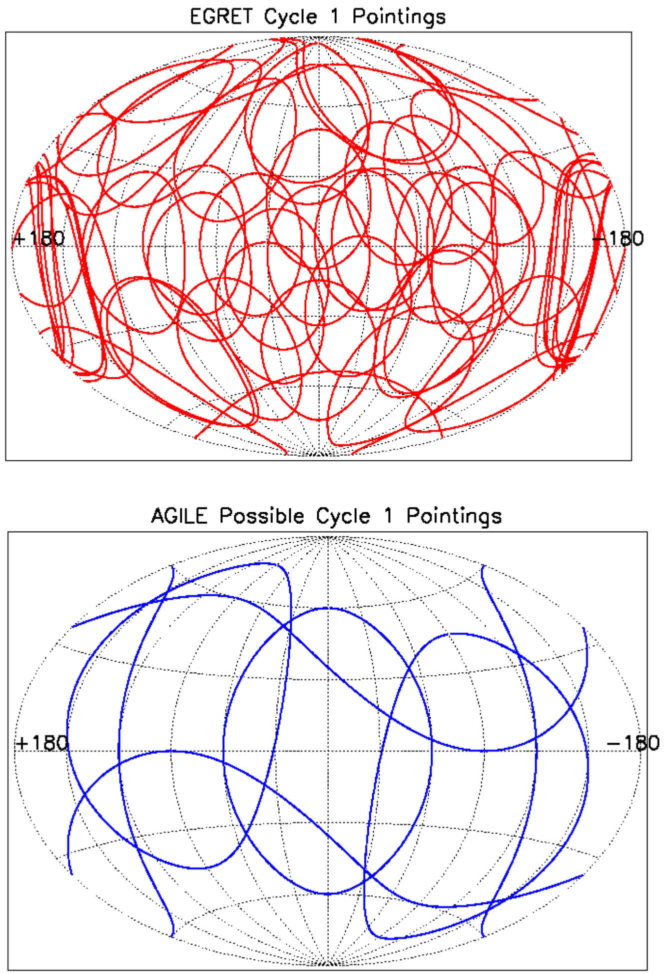


Performance

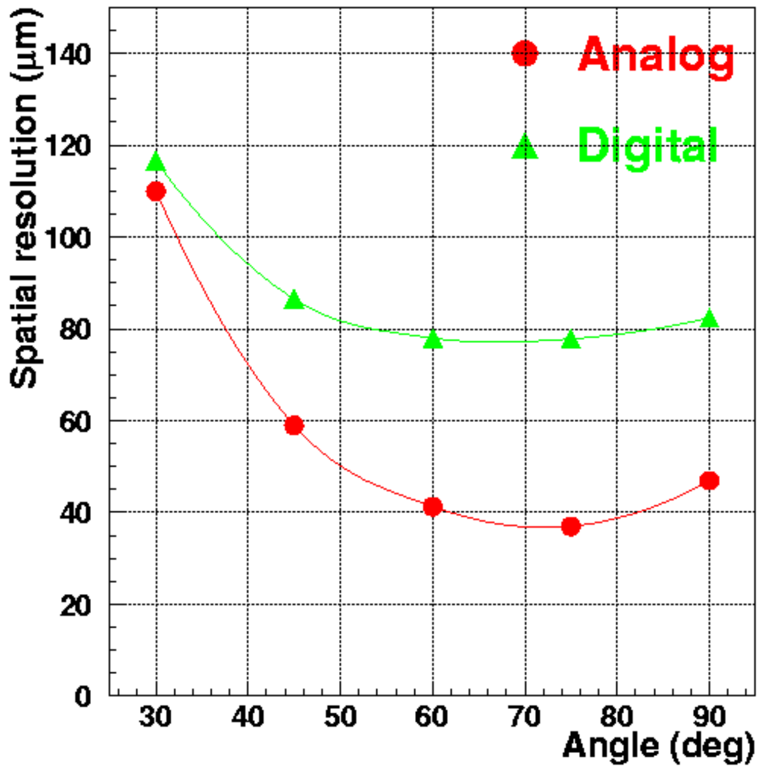


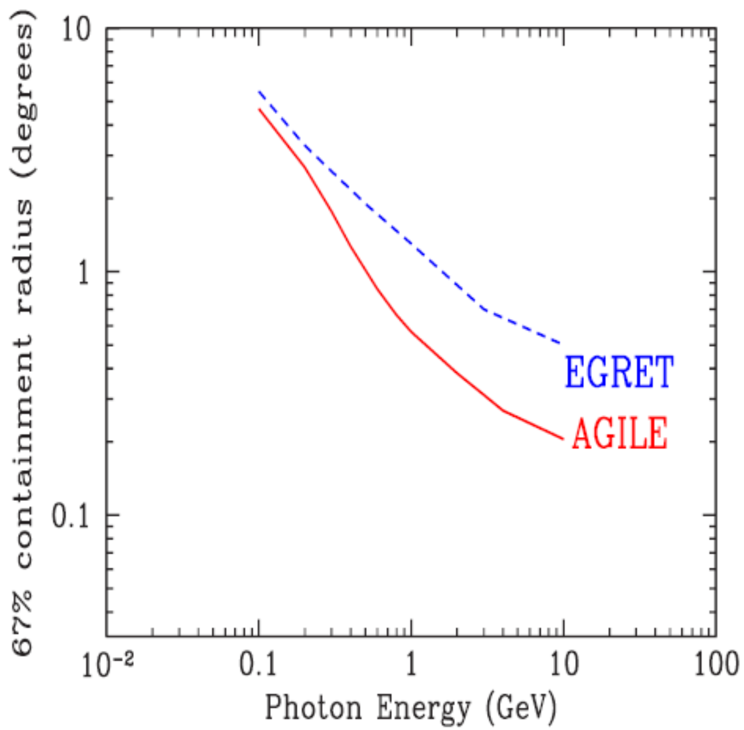
Si Self Trigger and FoV





Analog readout and PSF

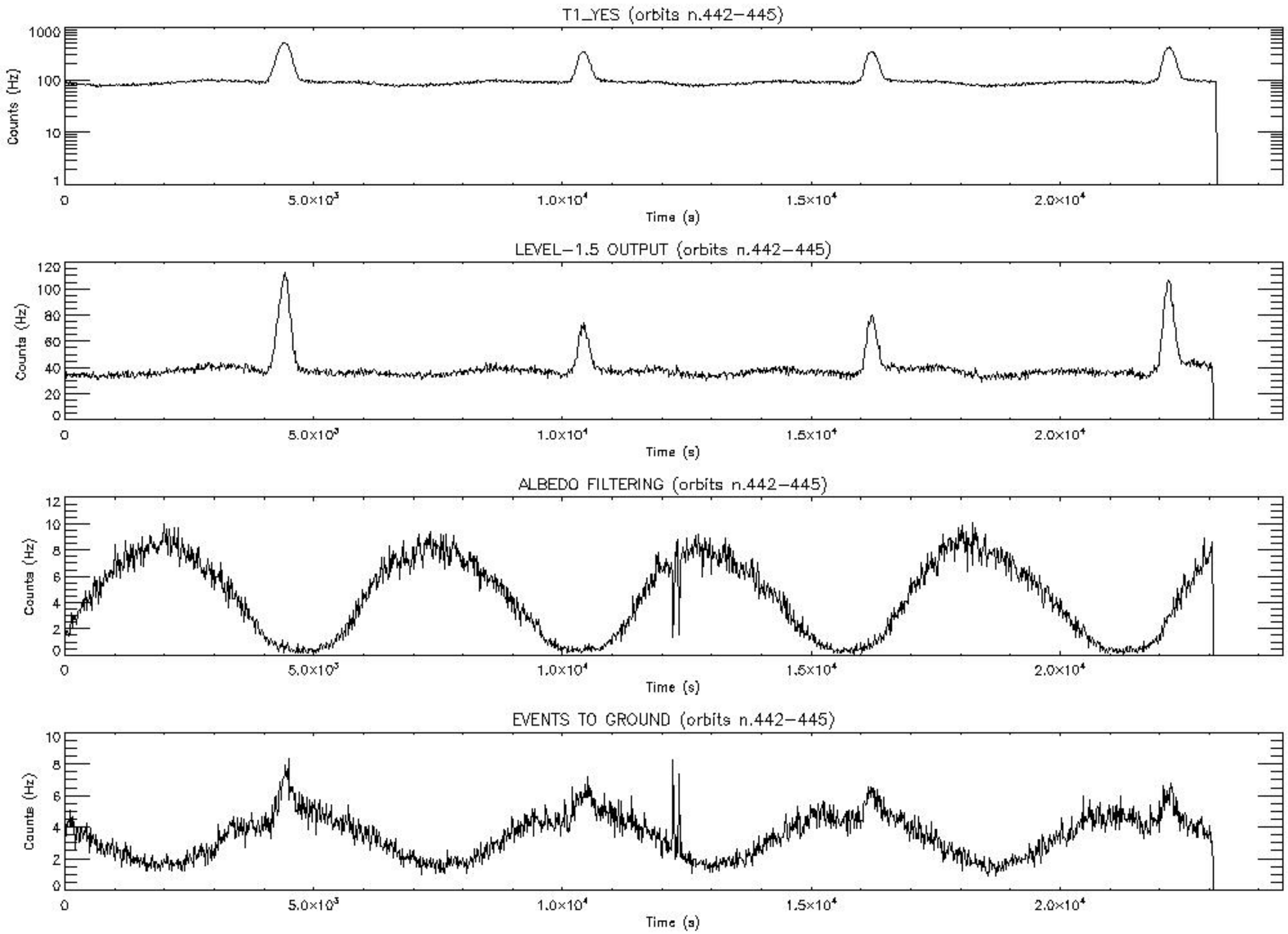




The AGILE launch

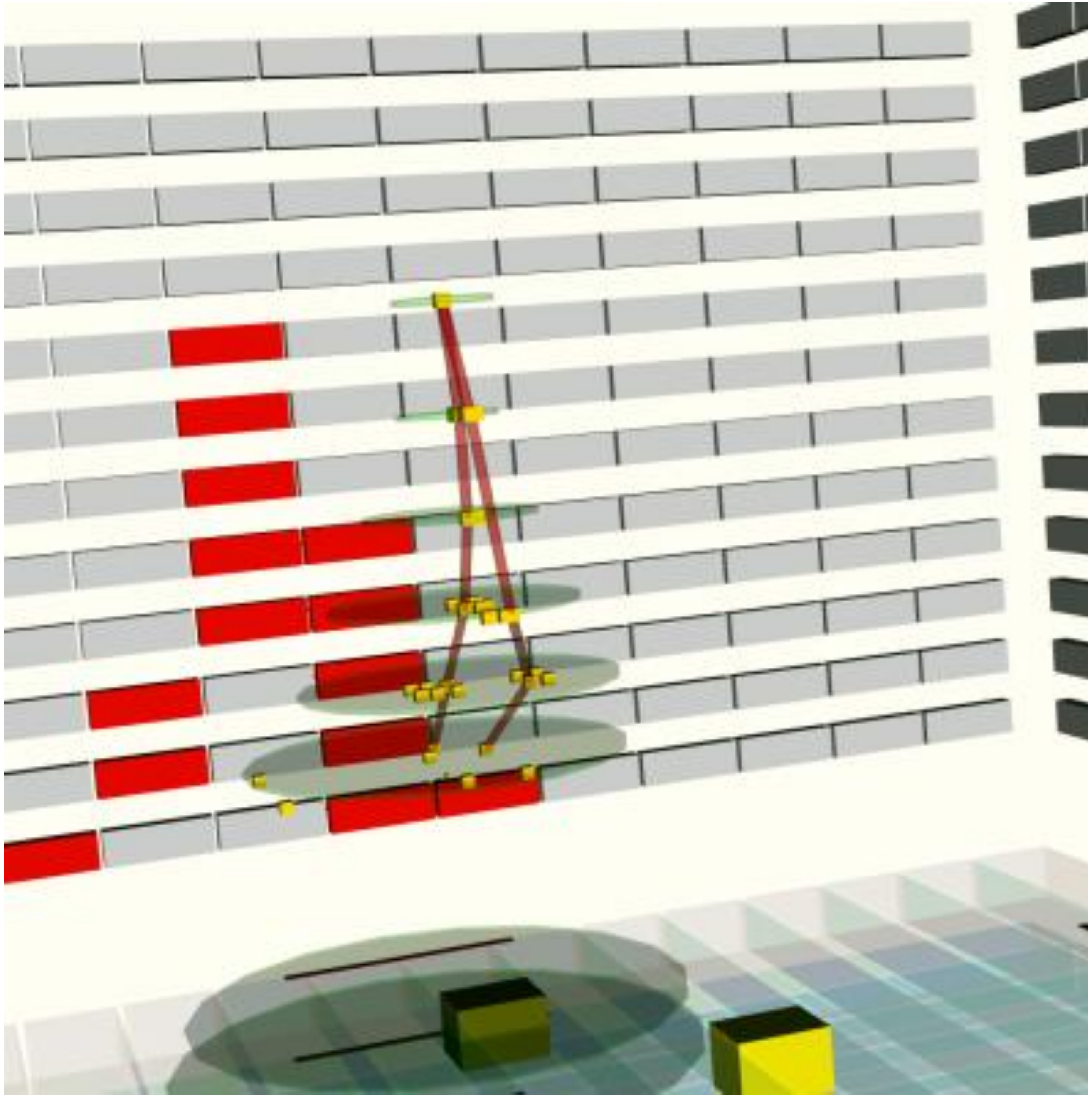
AGILE in orbit

AGILE in orbit

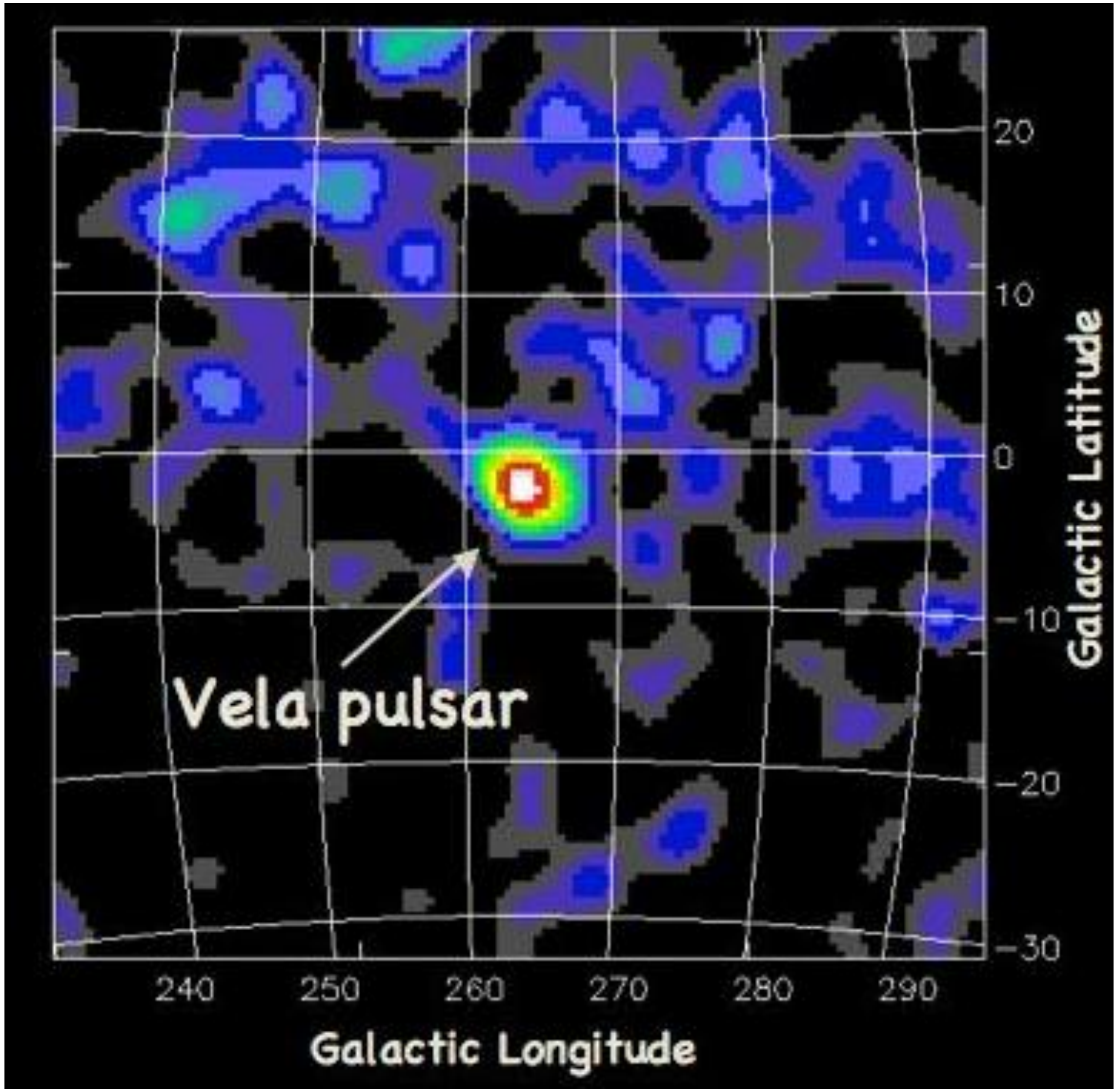


On Orbit Trigger Rates

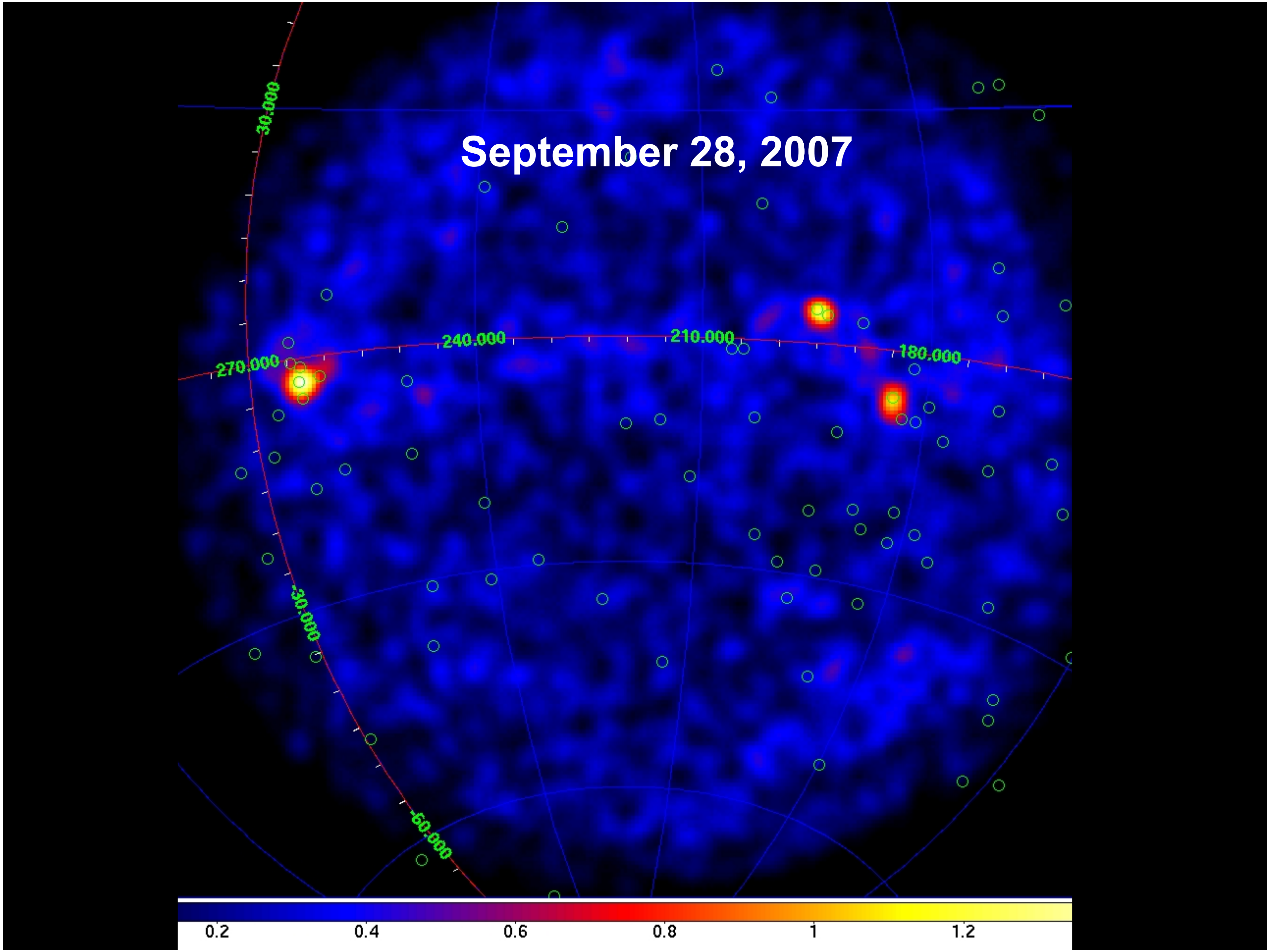
First gamma-ray detected in orbit with the nominal GRID trigger configuration (May 10, 2007)



First Light



Vela pulsar
20
10
0
−10
−20
−30
Galactic Latitude
240
250
260
270
280
290
Galactic Longitude

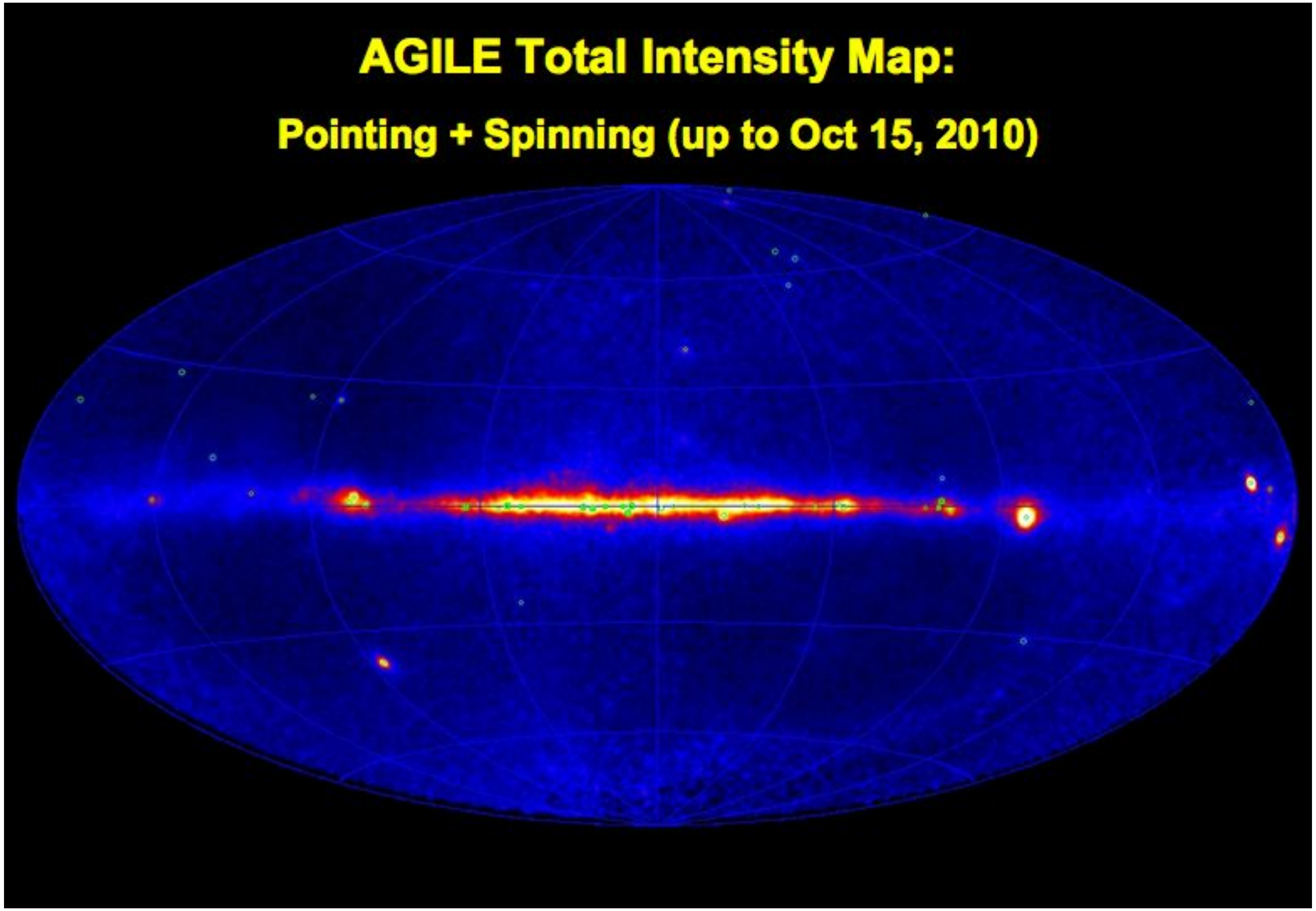


September 28, 2007
30.000
270.000
240.000
210.000
180.000
-30.000
-60.000
0.2
0.4
0.6
0.8
1
1.2

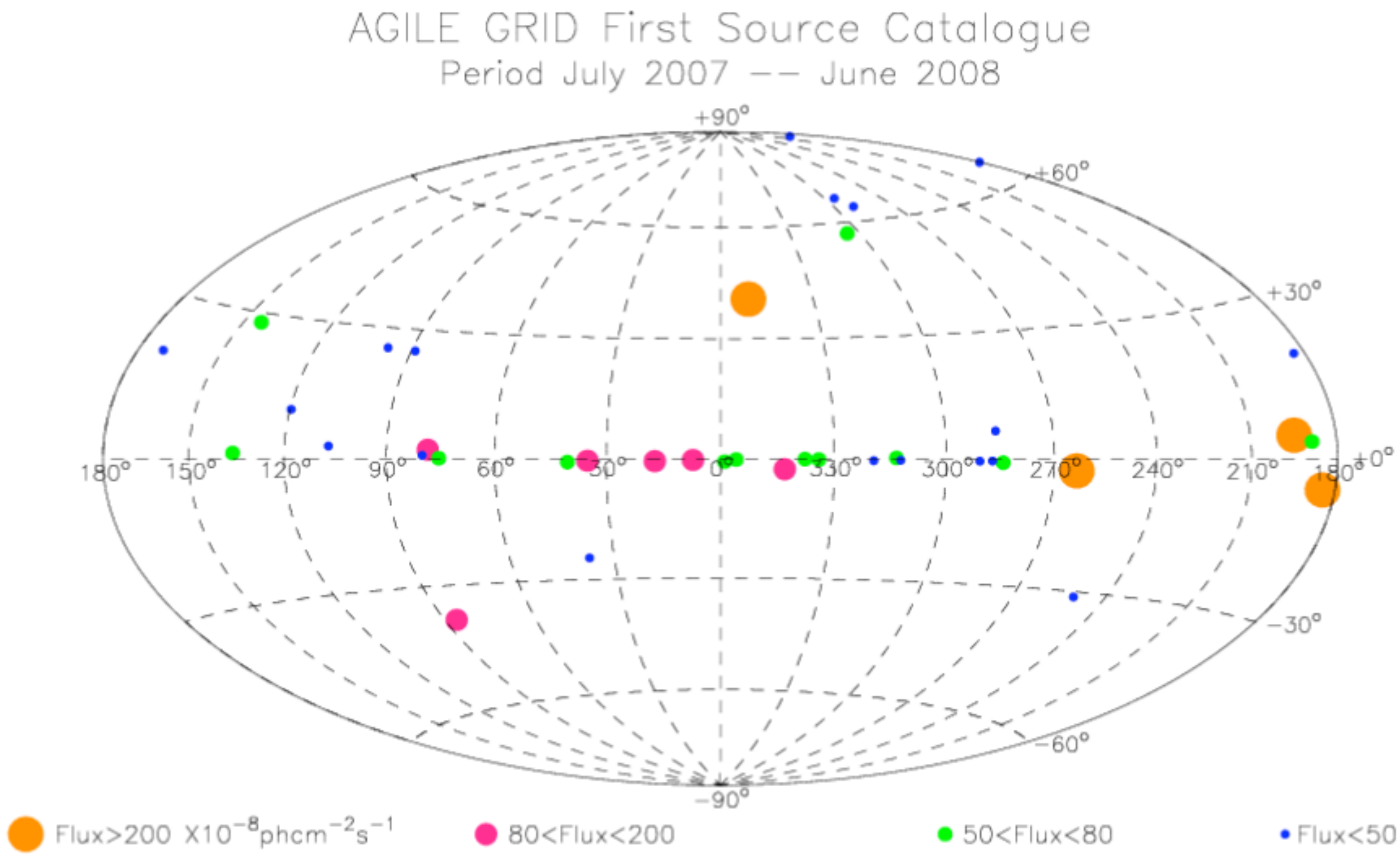
AGILE two lifes

	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 AGILE sky

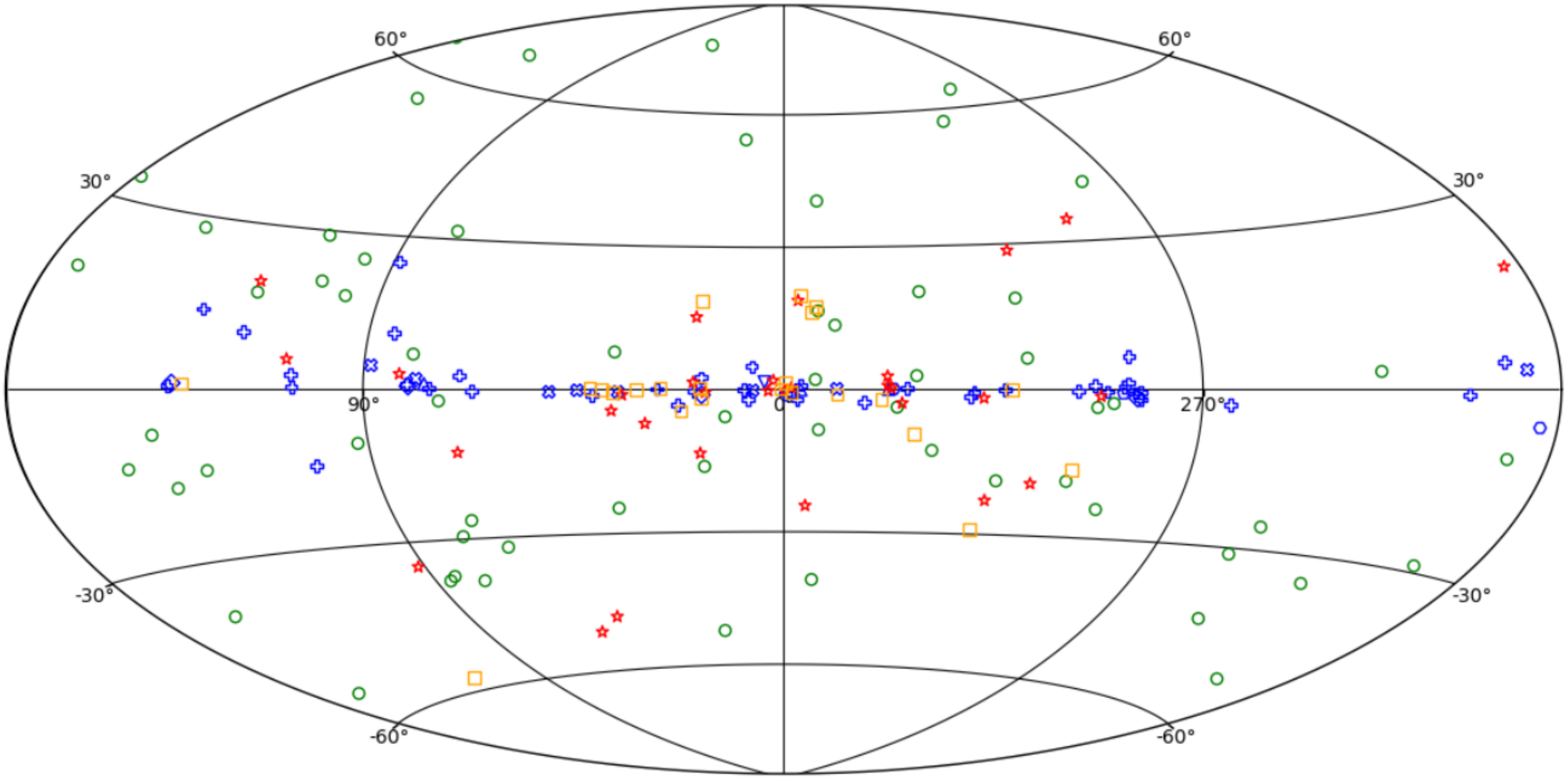


AGILE sources



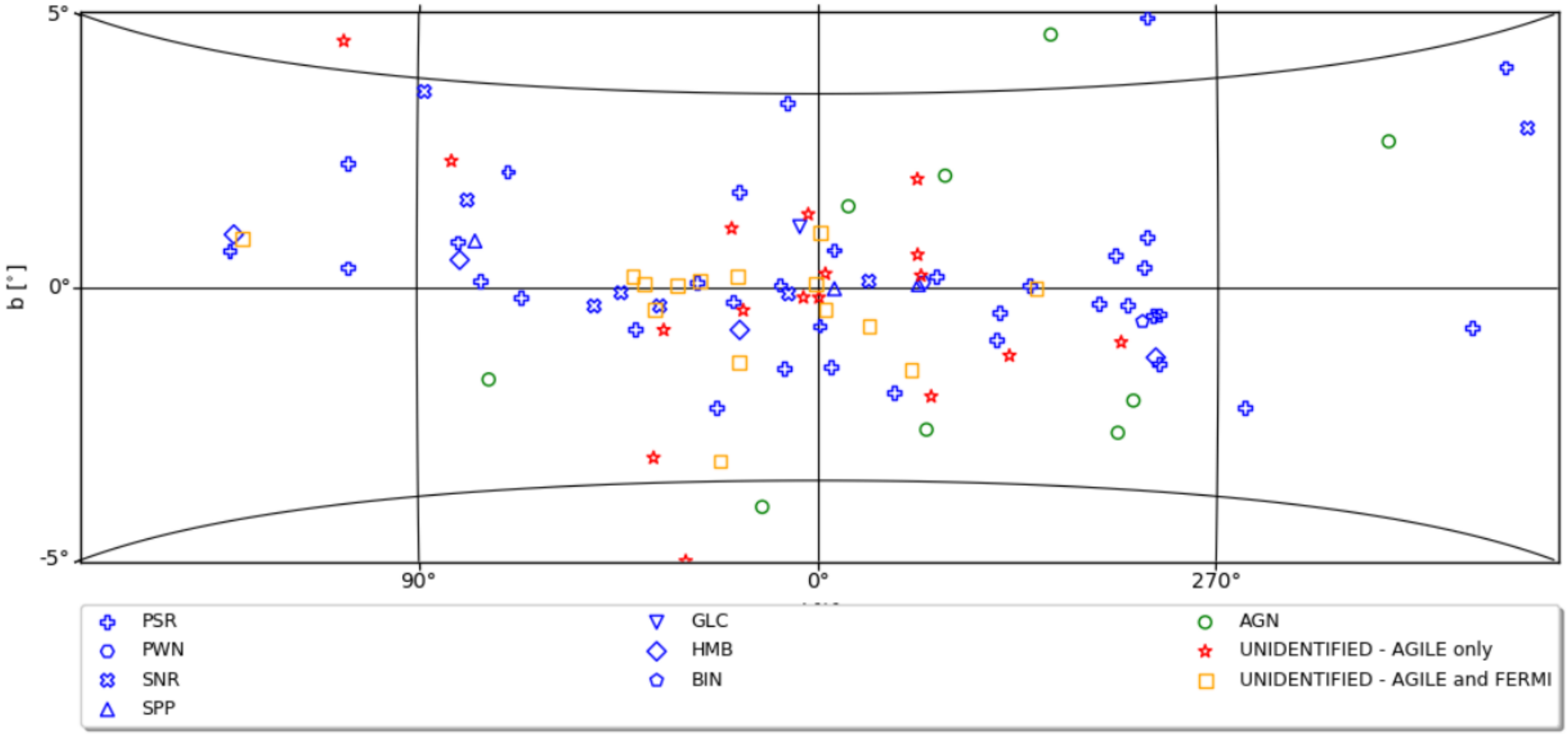
Pittori et al. 2009

AGILE sources



Bulgarelli et al. 2019

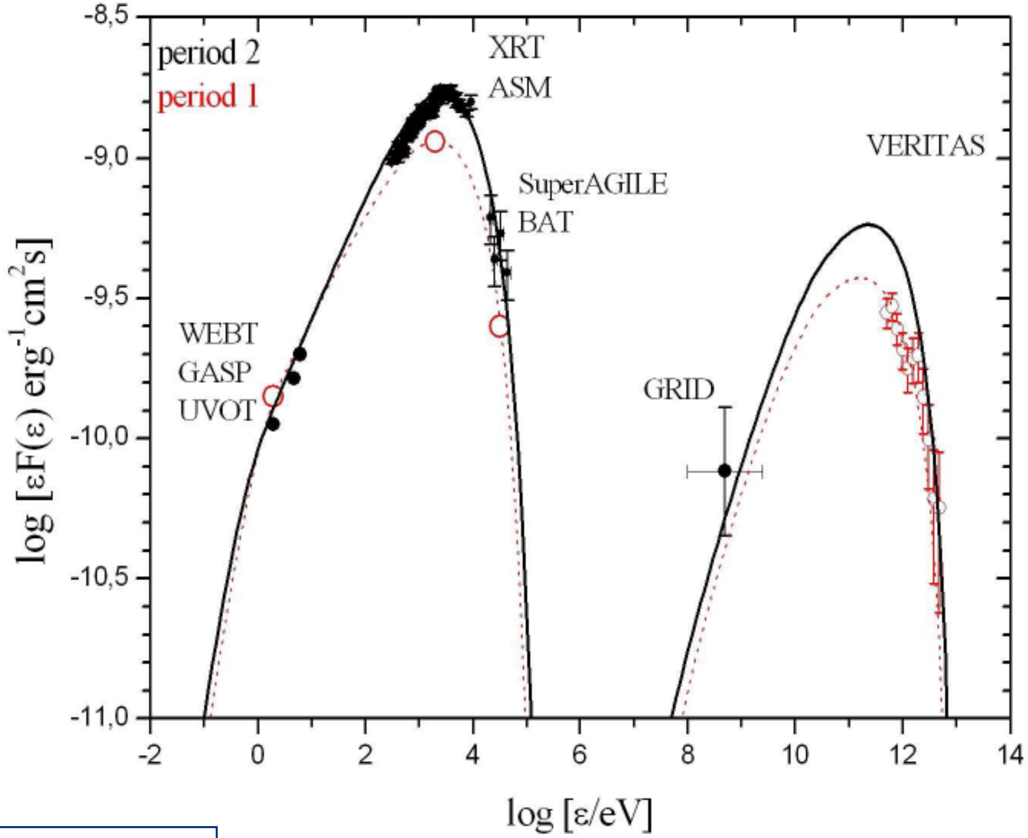
AGILE sources



Bulgarelli et al. 2019

Challenge # 1 – AGN

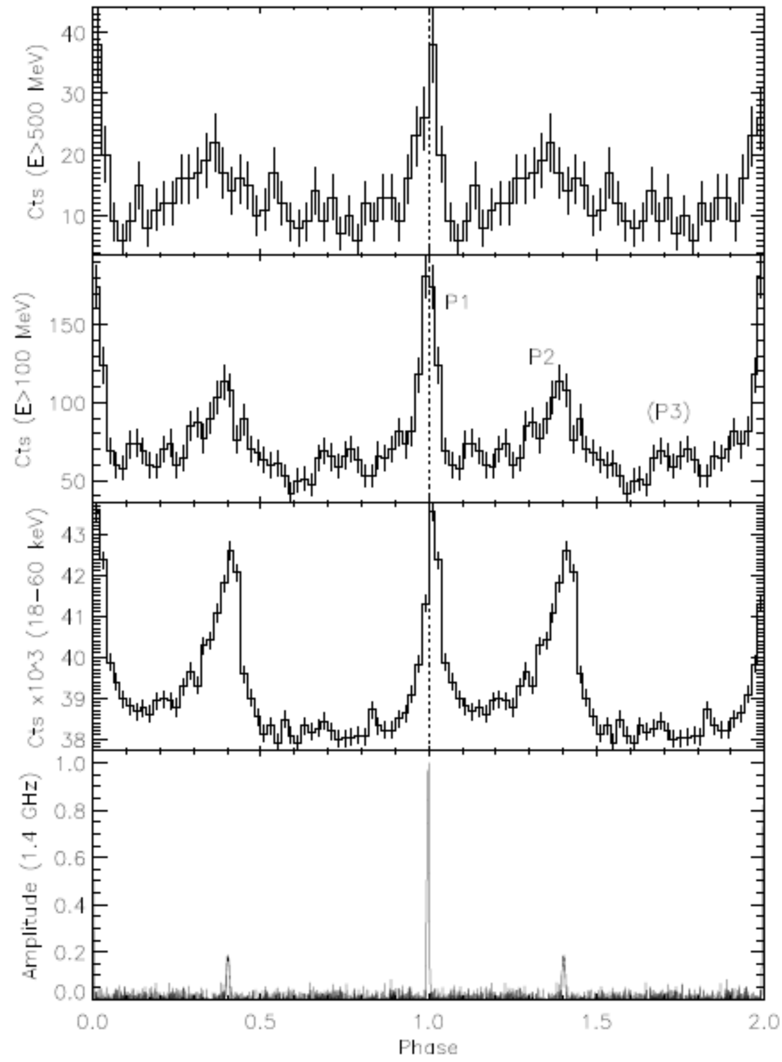
Joint campaign with MAGIC and VERITAS on Mkn 421



Donnarumma et al. 2009

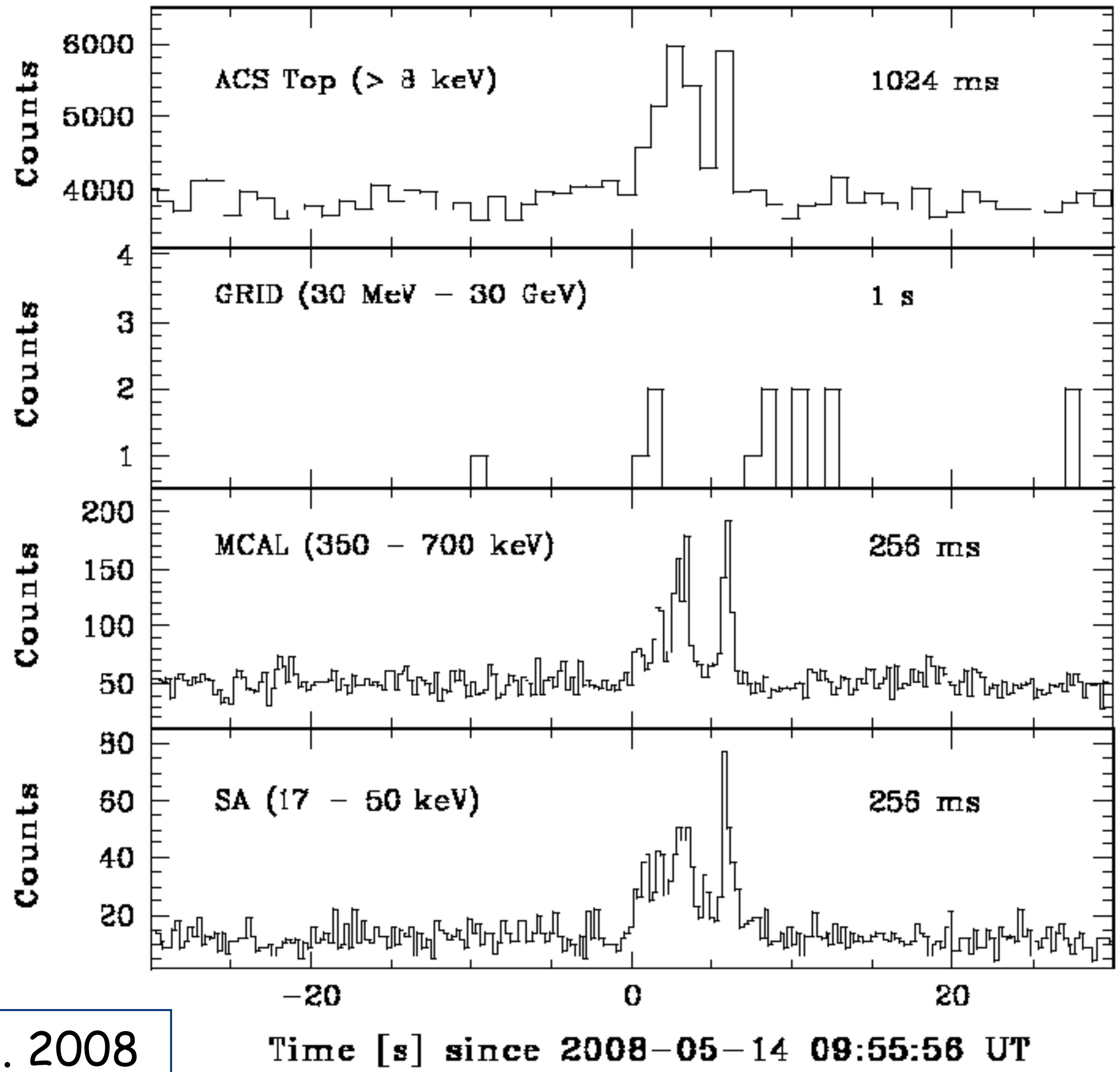
Challenge # 2 – Pulsar

High Precision Timing (eg. Crab PSR)



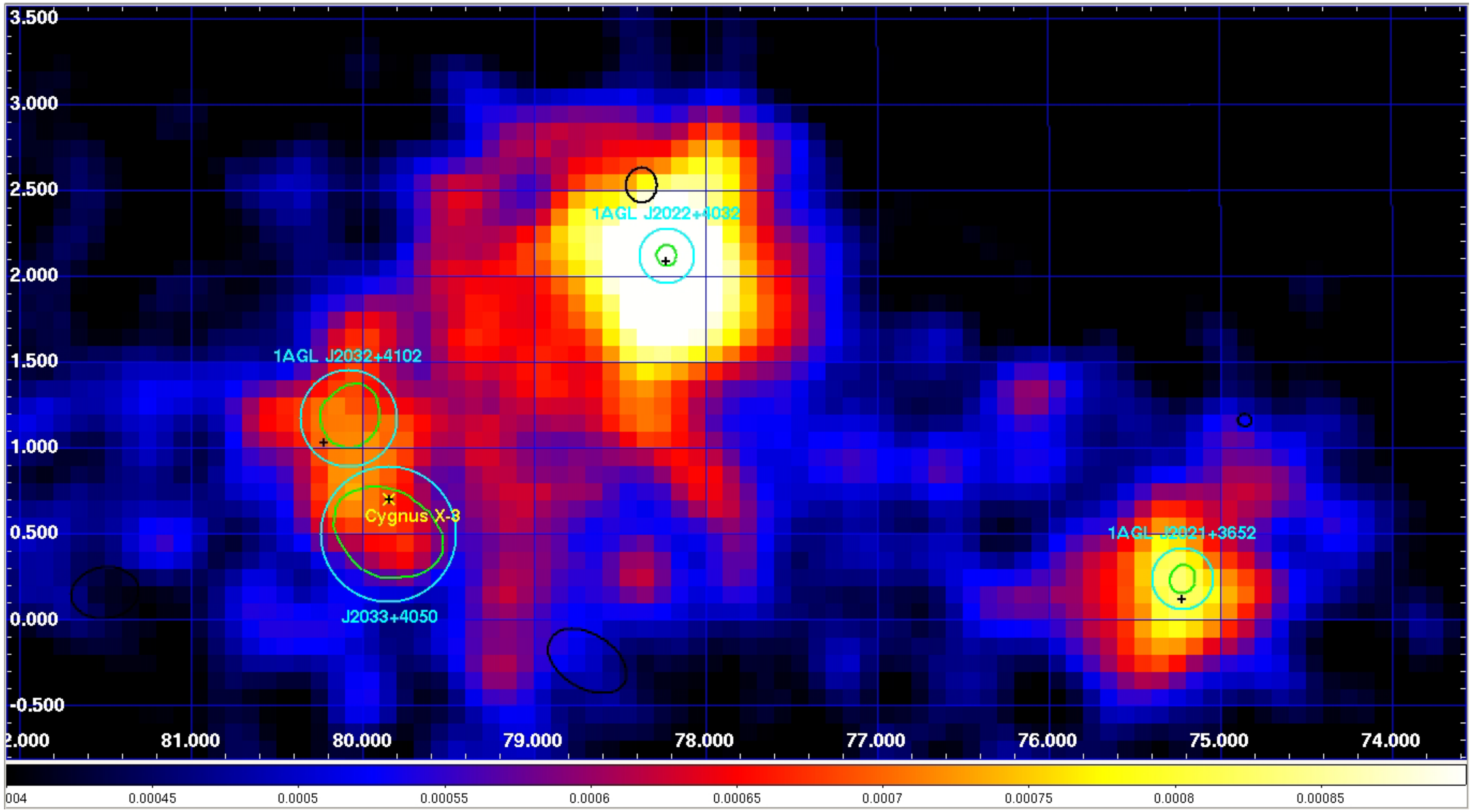
Pellizzoni et al. 2009

Challenge # 3 – GRB



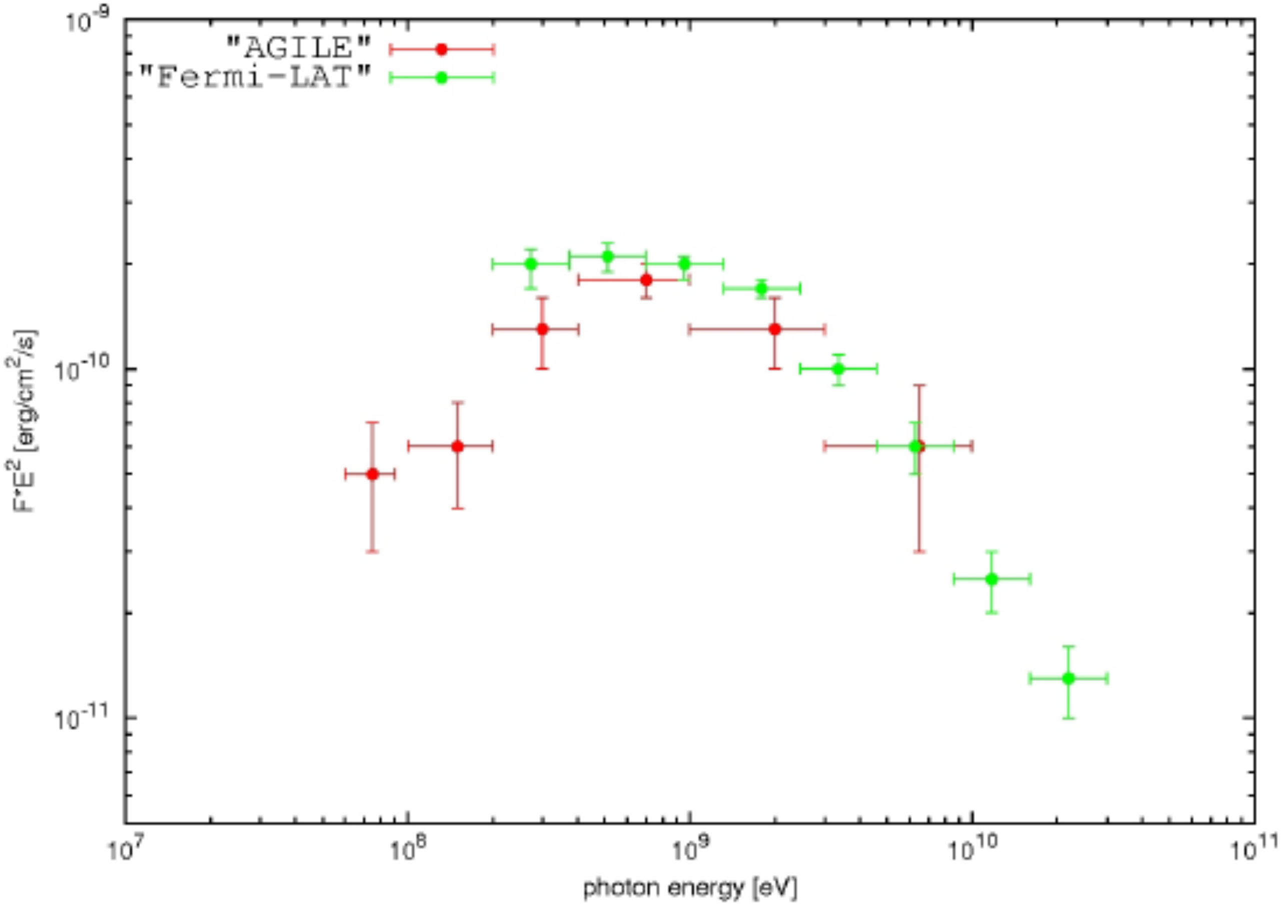
Giuliani et al. 2008

Challenge # 4 – Unidentified



Chen et al. 2011

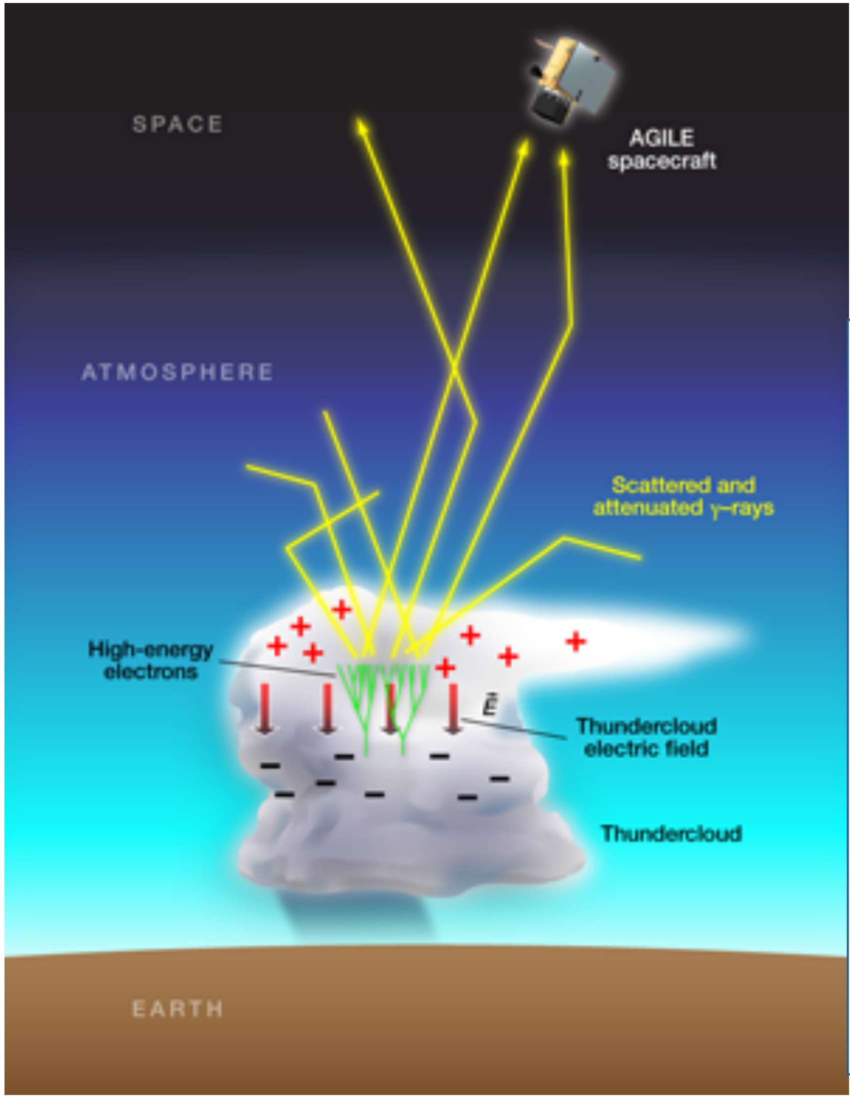
Challenge # 5 – Spectral resolution



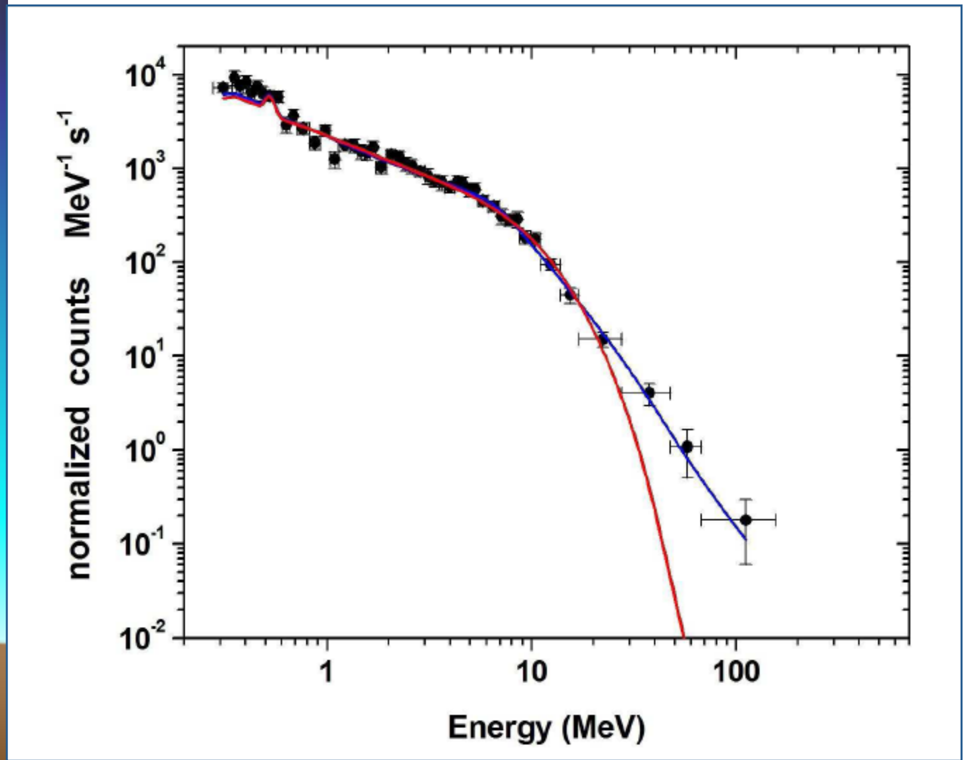
Giuliani et al. 2011

Key AGILE results

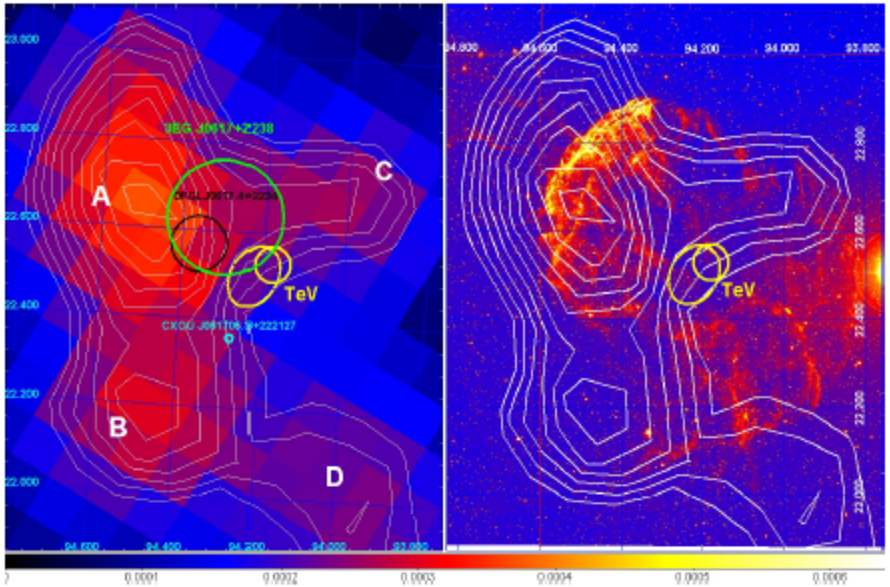
Terrestrial Gamma Ray Flashes



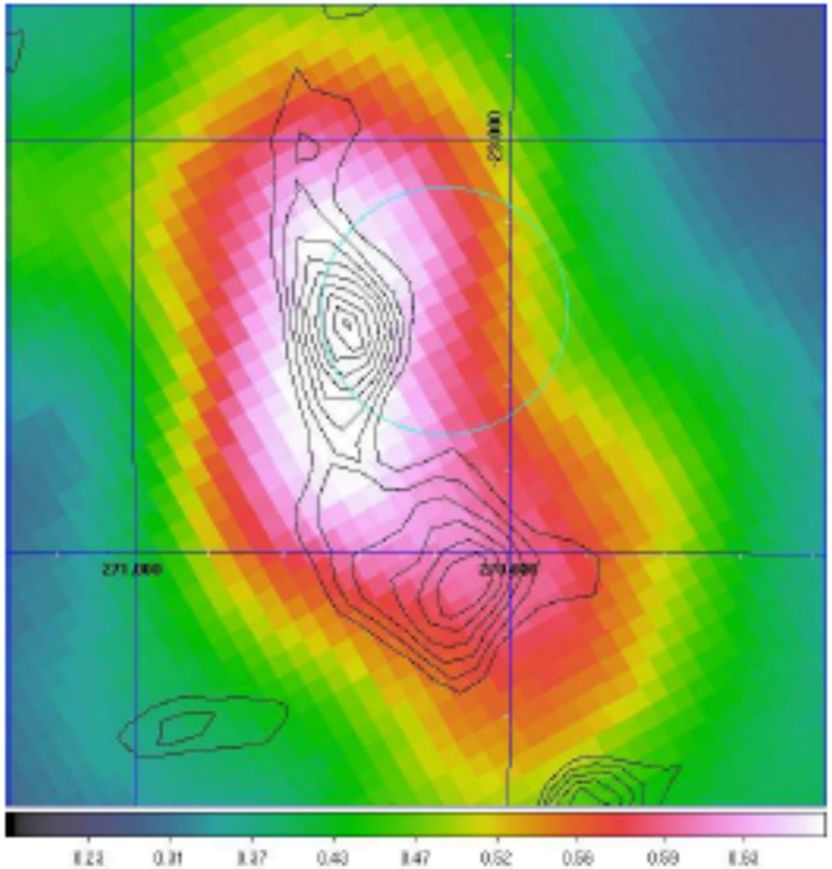
Marisaldi et al. 2010



Supernova Remnants

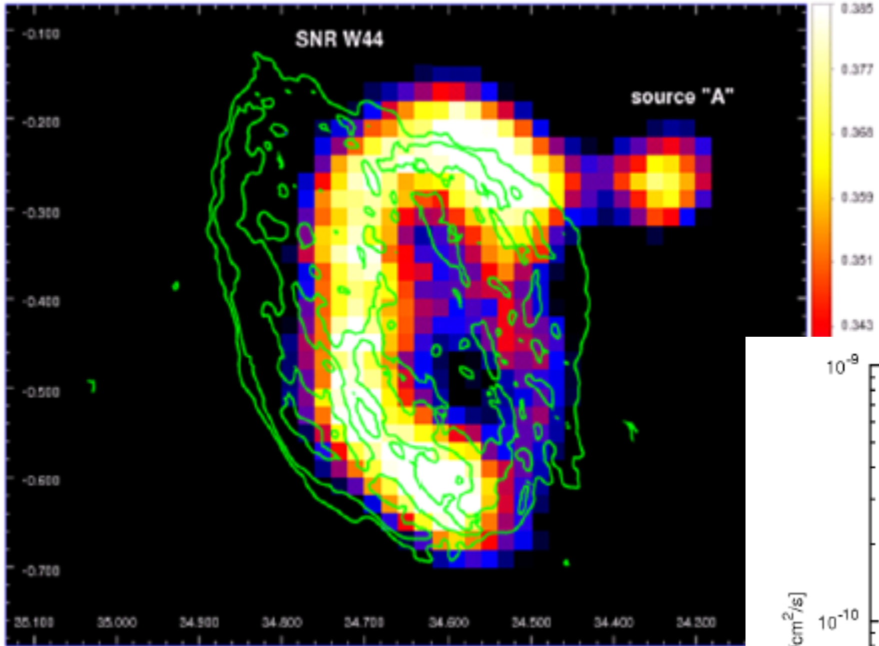


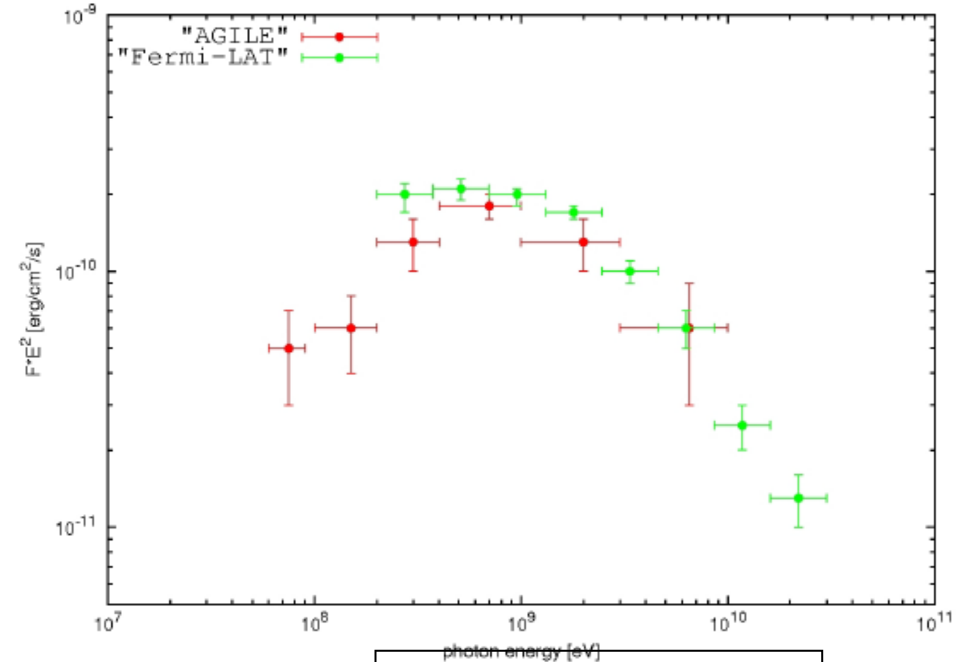
Tavani et al. 2010



Giuliani et al. 2010

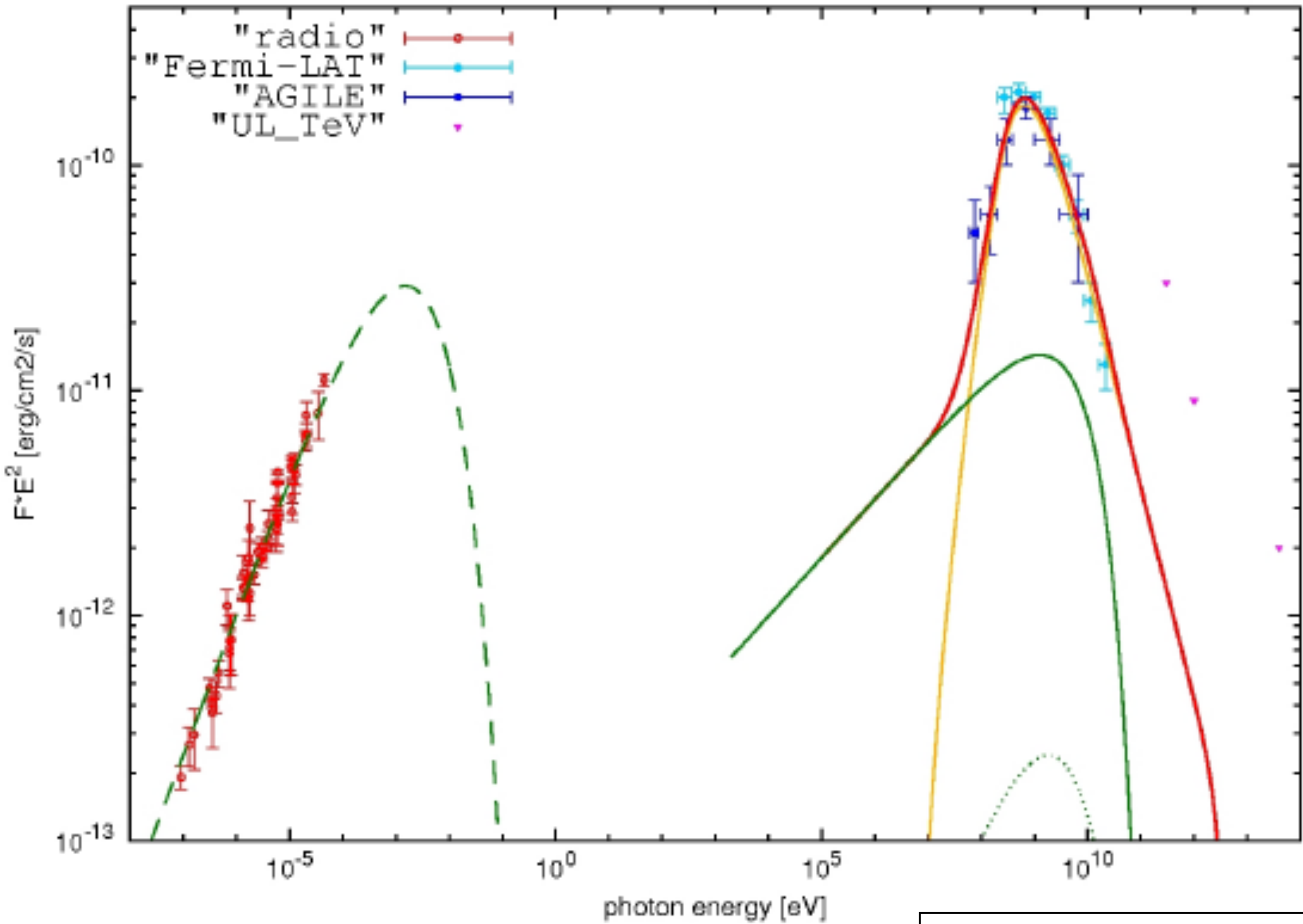
SNR W44





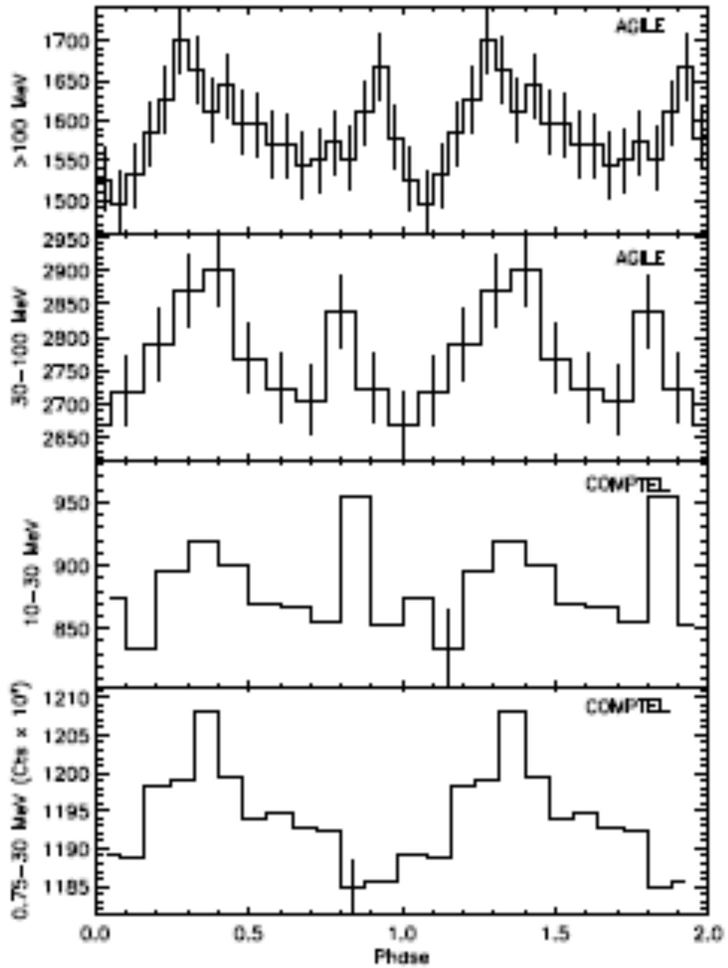
Giuliani et al. 2011

SNR W44

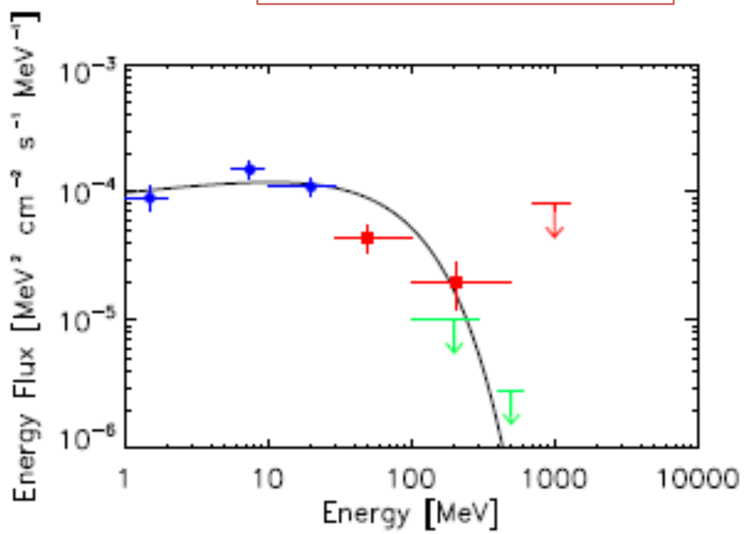


Giuliani et al. 2011

Low Energy Pulsars



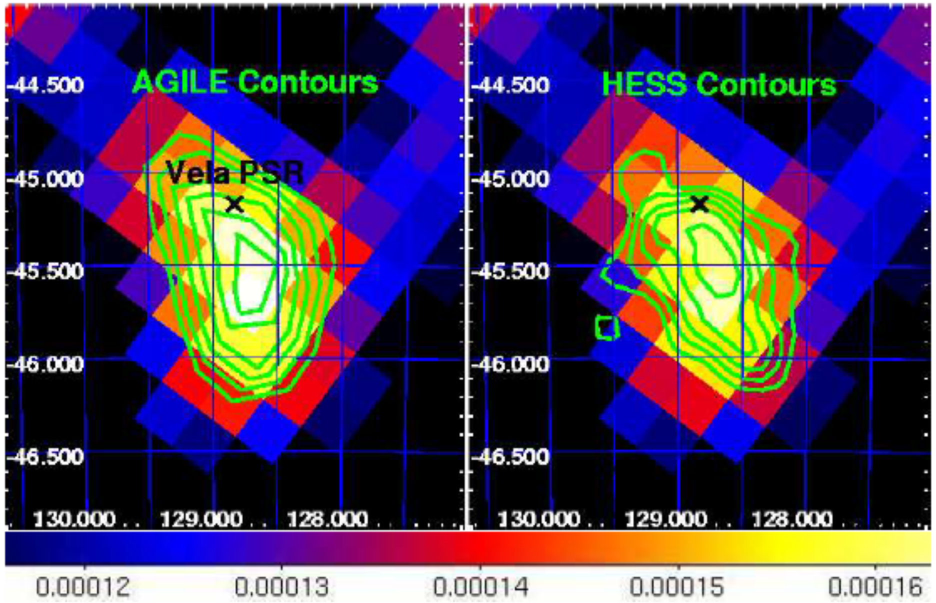
PSR B1509-58



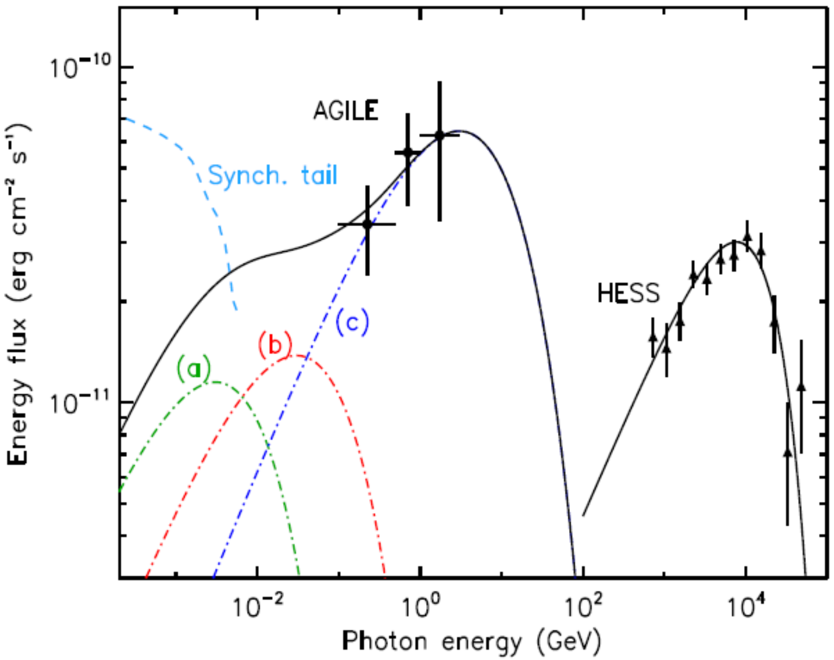
Pilia et al. 2011

Pulsar Wind Nebulae

Pellizzoni et al. 2010

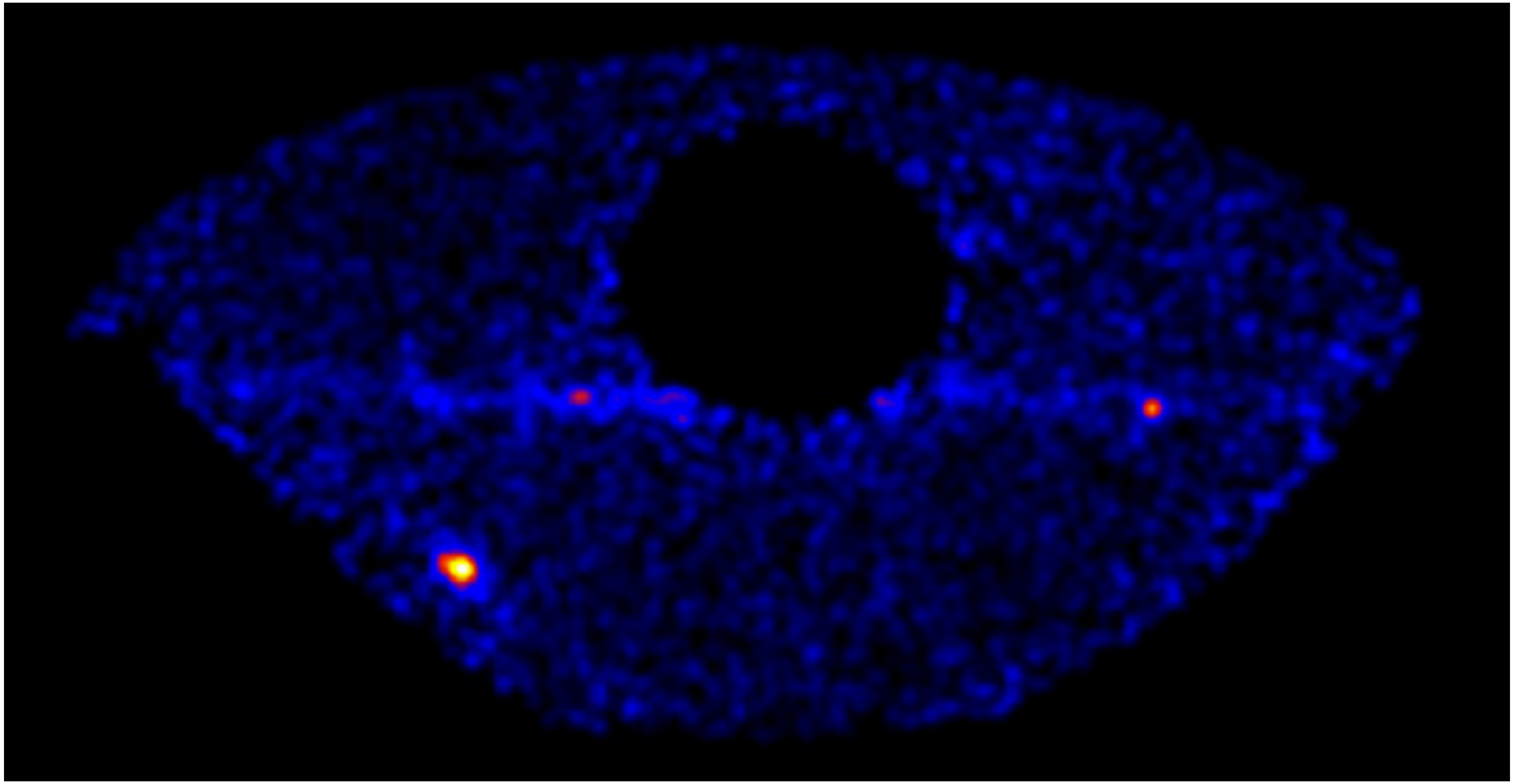


Vela X PWN



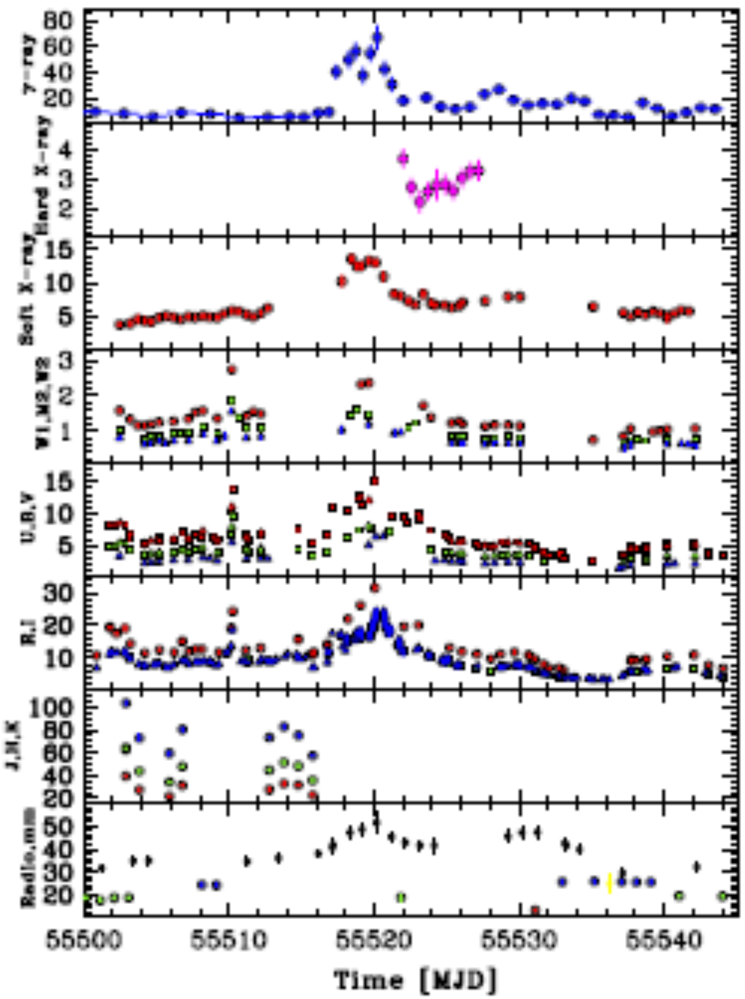
The Flaring 3C454.3

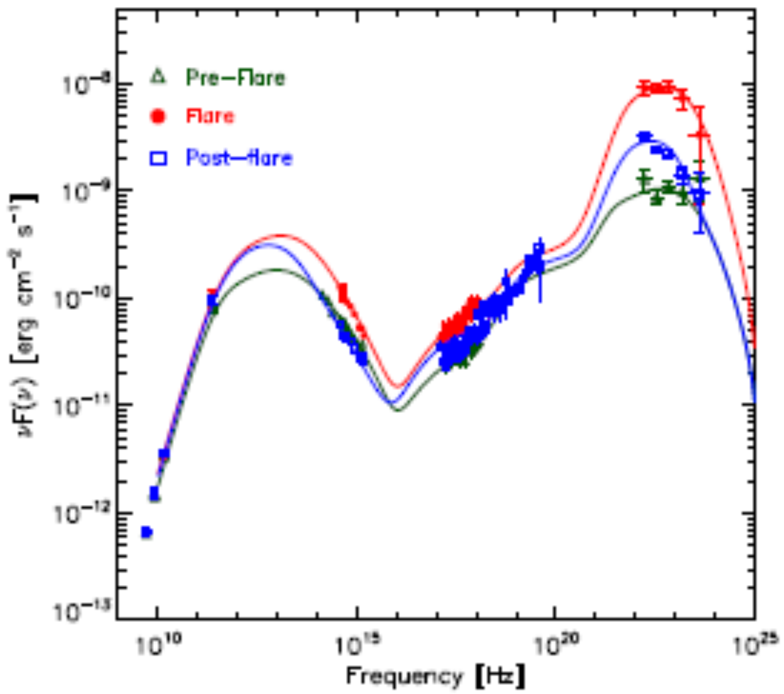
Vercellone et al. 2010



Blazar 3C454.3

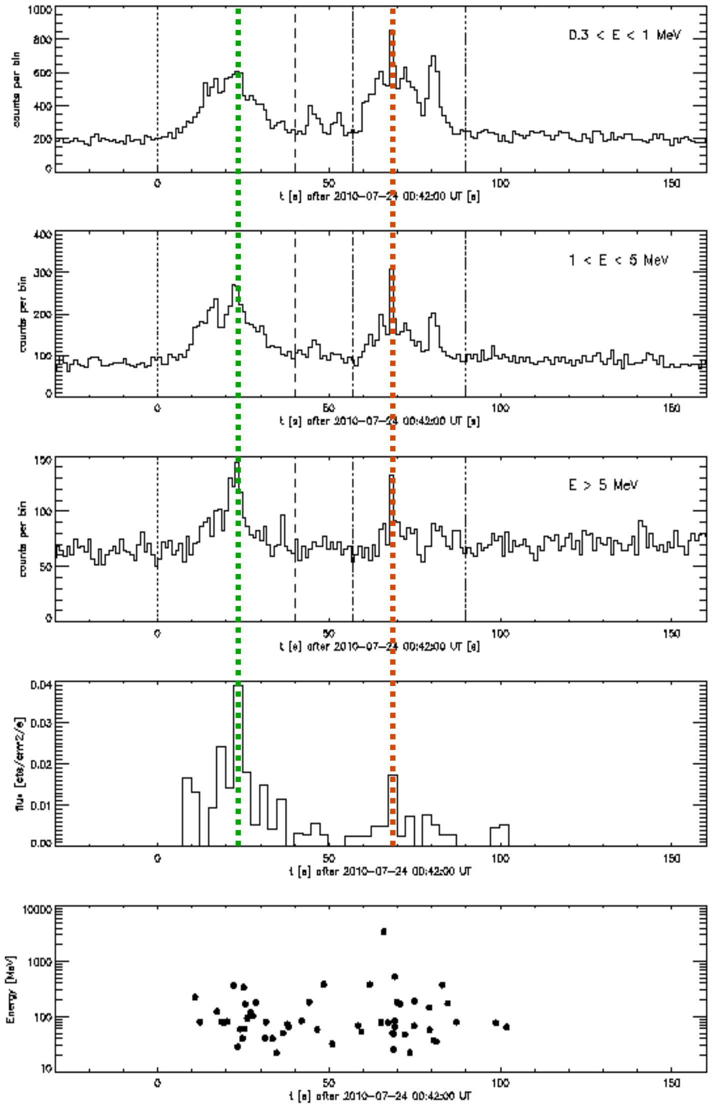
Vercellone et al. 2011





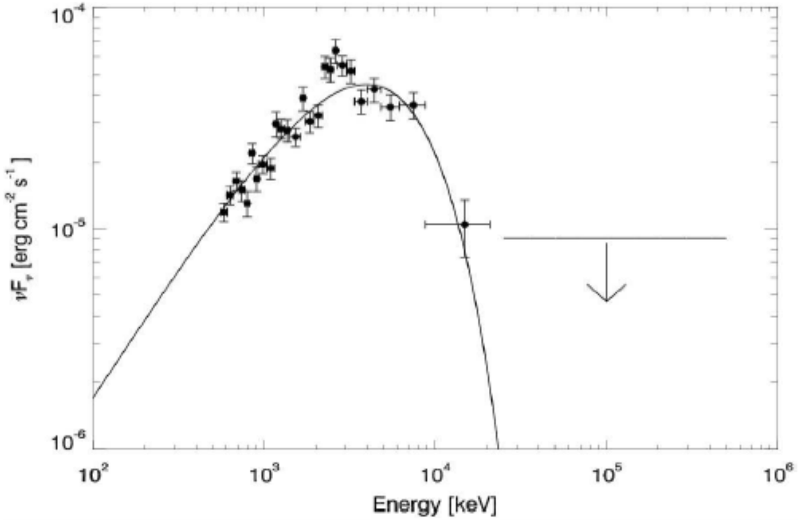
Gamma Ray Bursts

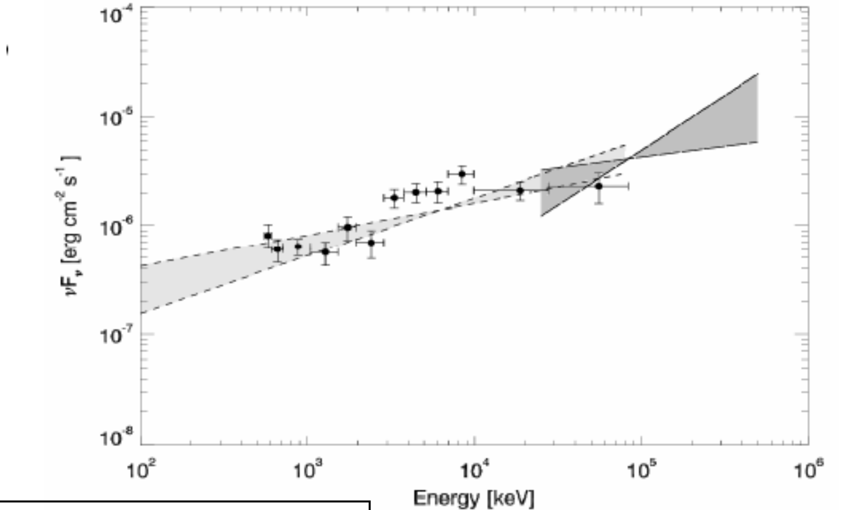
GRB 100724B



GRB 090510

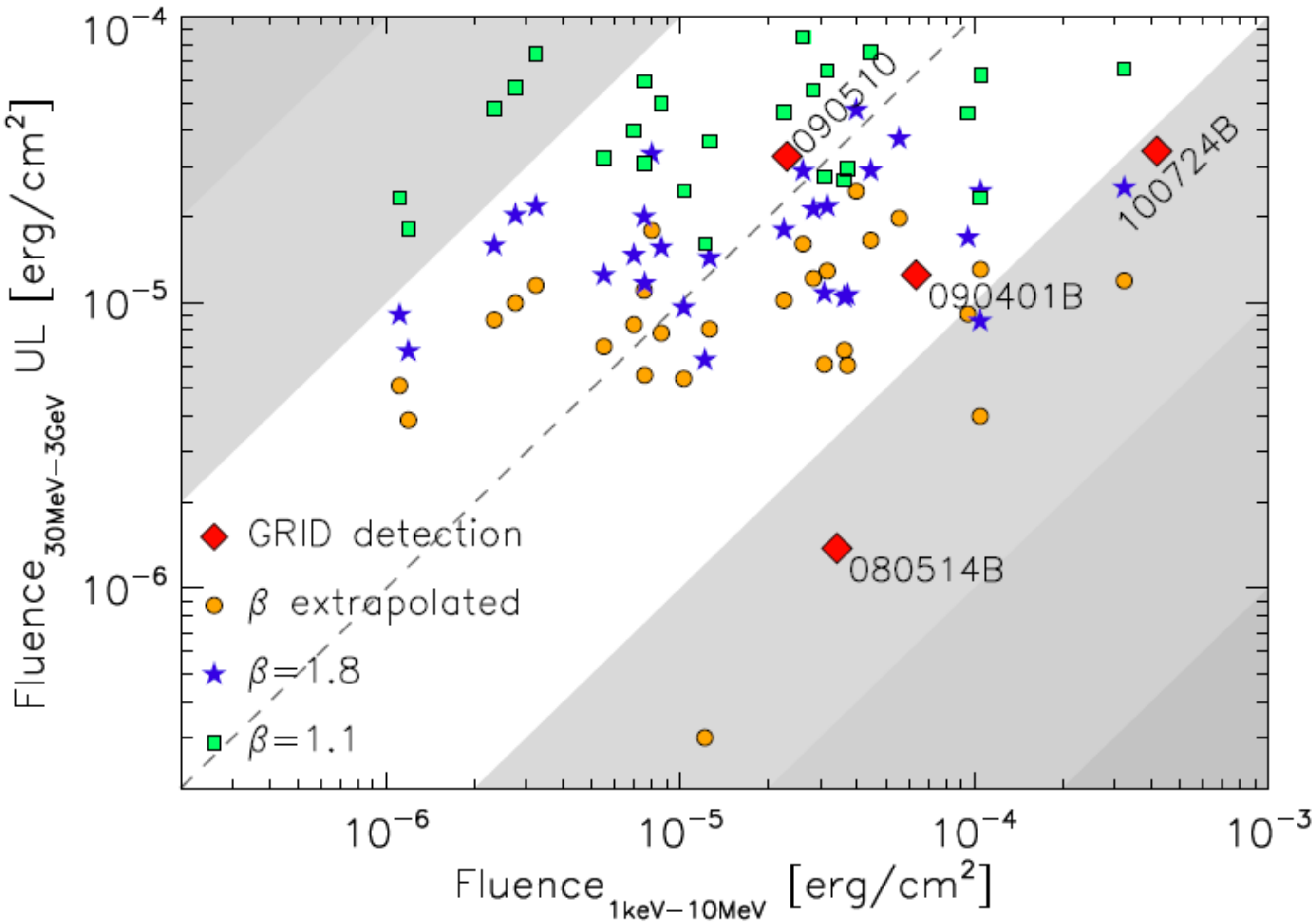
Giuliani et al. 2010





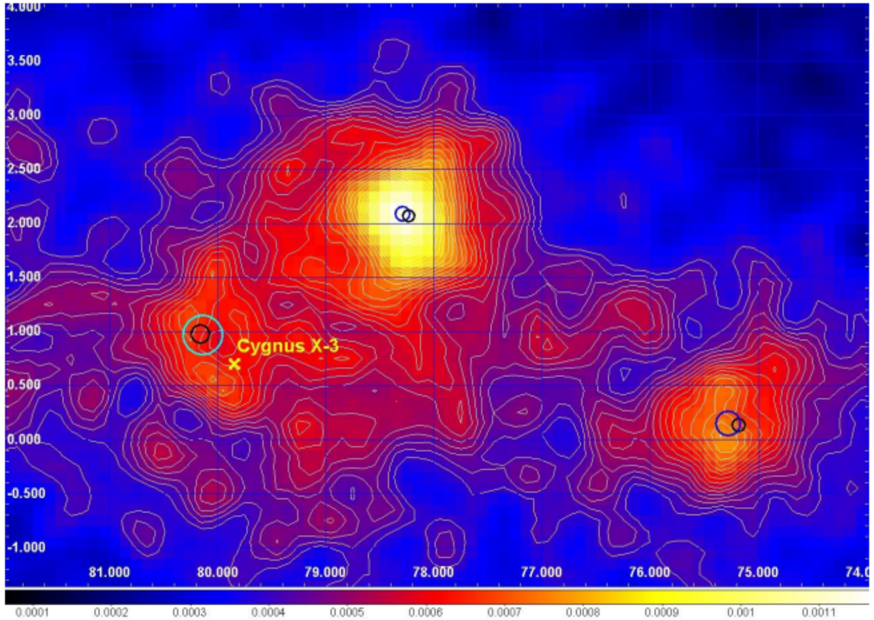
Del Monte et al. 2011

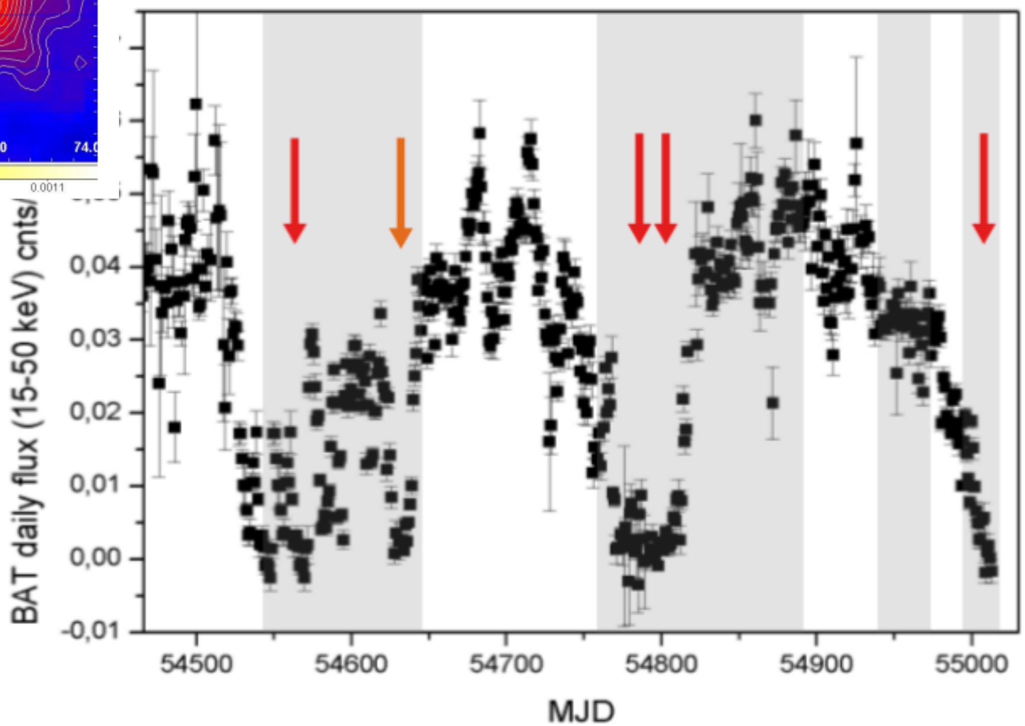
Upper limits in GRB



Longo et al. 2012

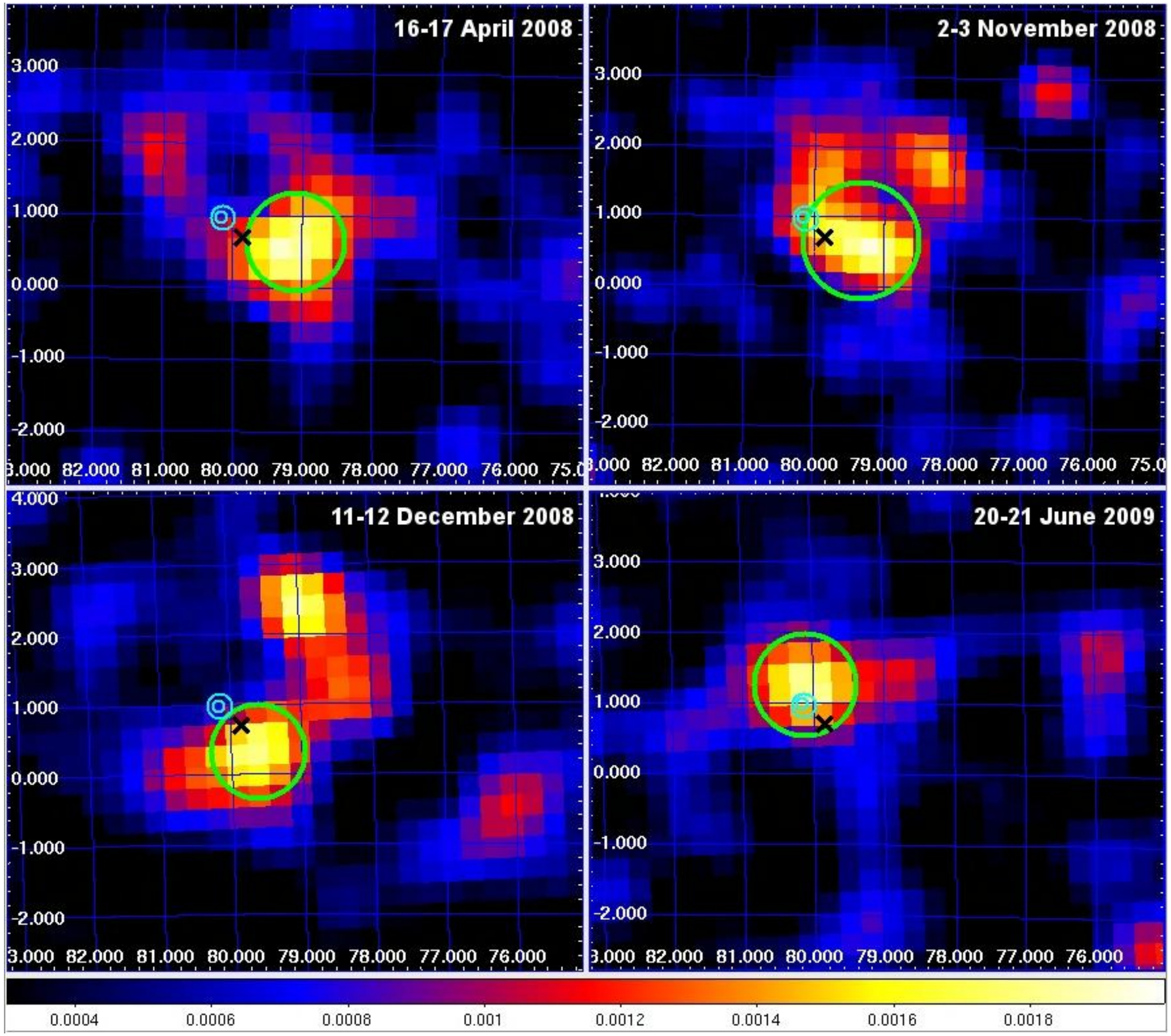
Galactic Transients: Cygnus X3





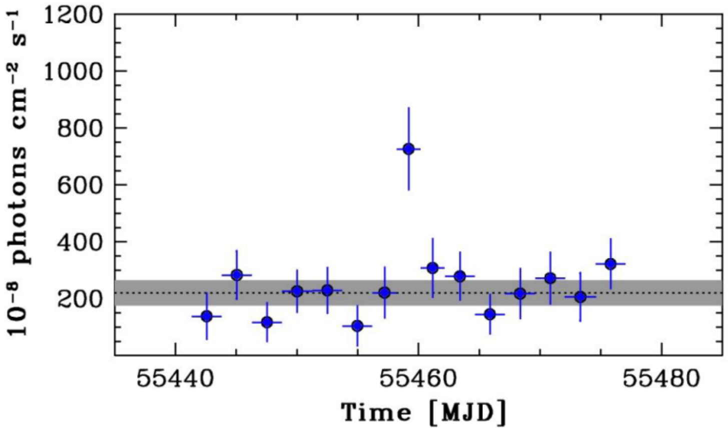
Tavani et al. 2009

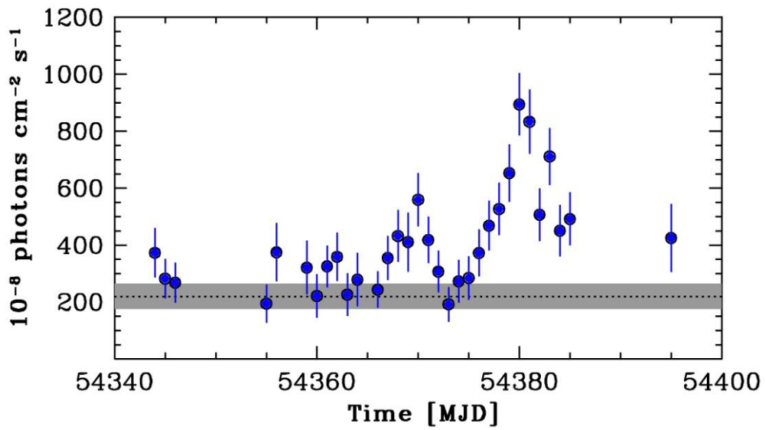
AGILE discovery of transient gamma-ray emission from Cygnus X-3

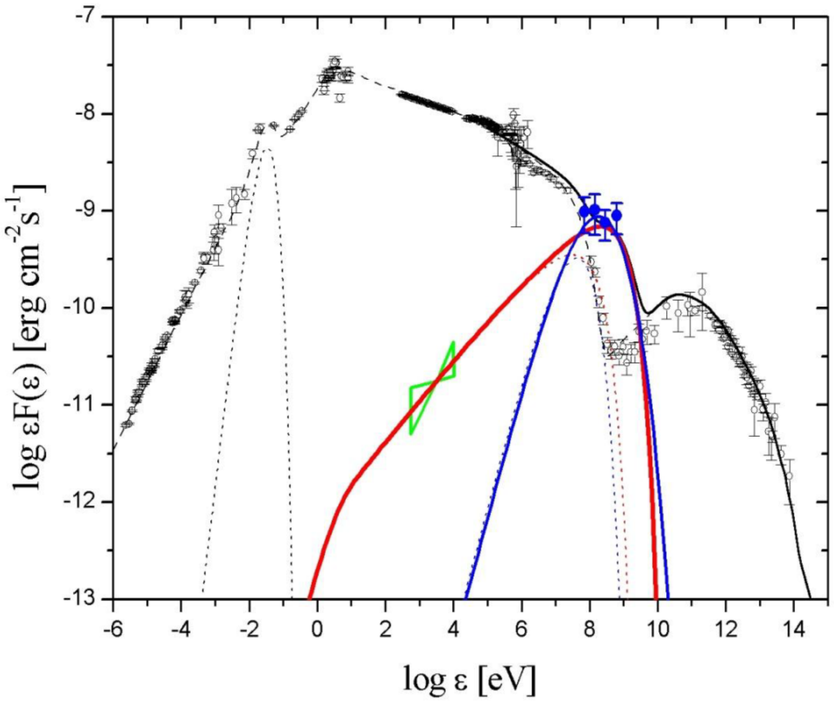


Galactic Transients: The Flaring Crab

Tavani et al. 2011







The Flaring Crab

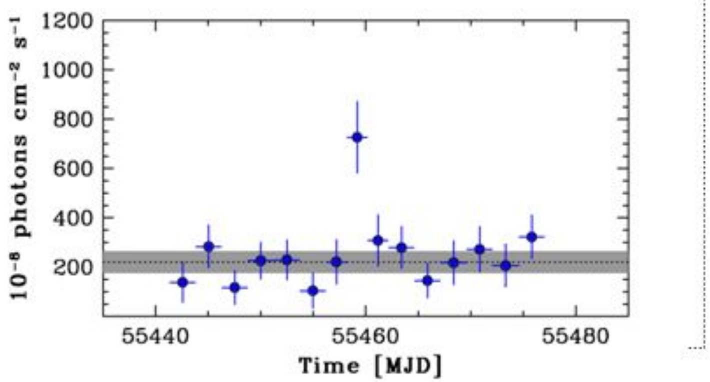
AGILE detection of enhanced gamma-ray emission from the Crab Nebula region

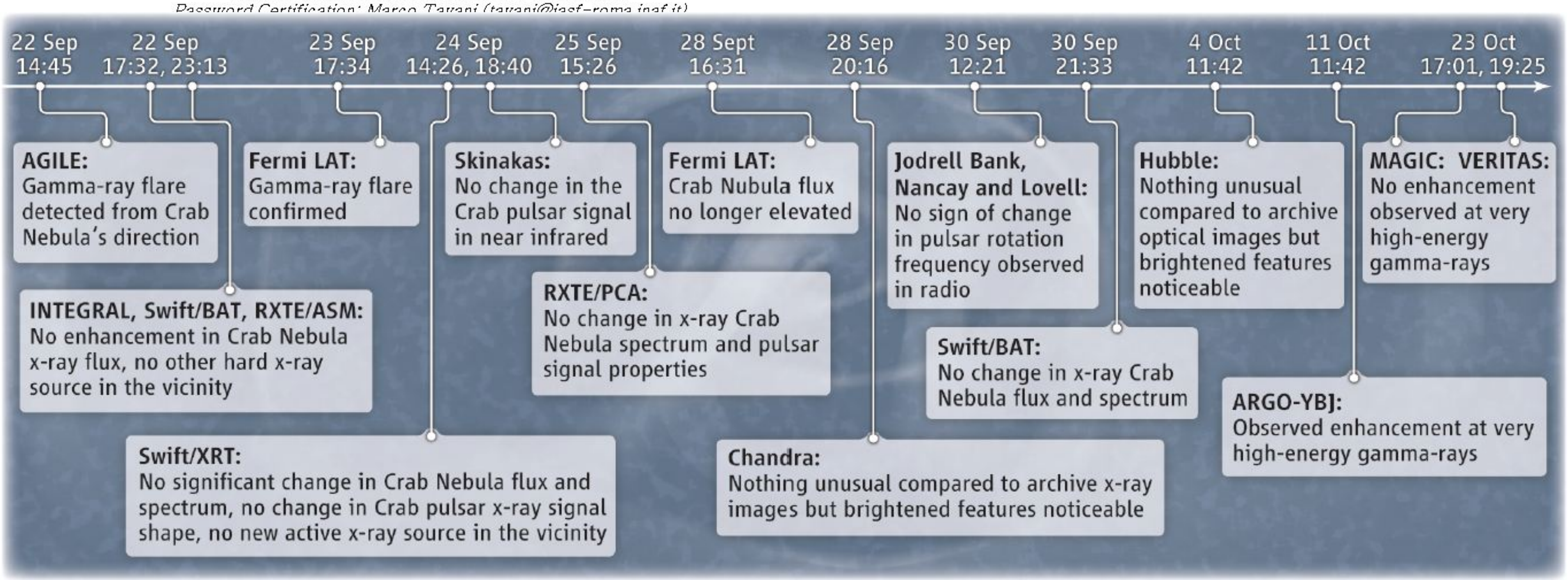
ATel #2855; M. Tavani (INAF/IASF Roma), E. Striani (Univ. Tor Vergata), A. Bulgarelli (INAF/IASF Bologna), F. Gianotti, M. Trifoglio (INAF/IASF Bologna), C. Pittori, F. Verrecchia (ASDC), A. Argan, A. Trois, G. De Paris, V. Vittorini, F. D'Ammando, S. Sabatini, G. Piano, E. Costa, I. Donnarumma, M. Feroci, L. Pacciani, E. Del Monte, F. Lazzarotto, P. Soffitta, Y. Evangelista, I. Lapshov (INAF-IASF-Rm), A. Chen, A. Giuliani(INAF-IASF-Milano), M. Marisaldi, G. Di Cocco, C. Labanti, F. Fuschino,M. Galli (INAF/IASF Bologna), P. Caraveo, S. Mereghetti, F. Perotti (INAF/IASF Milano), G. Pucella, M. Rapisarda (ENEA-Roma), S. Vercellone (IASF-Pa), A. Pellizzoni, M. Pilia (INAF/OA-Cagliari), G. Barbiellini, F. Longo (INFN Trieste), P. Picozza, A. Morselli (INFN and Univ. Tor Vergata), M. Prest (Universita` dell'Insubria), P. Lipari, D. Zanello (INFN Roma-1), P.W. Cattaneo, A. Rappoldi (INFN Pavia), P. Giommi, P. Santolamazza, F. Lucarelli, S. Colafrancesco (ASDC), L. Salotti (ASI)

on 22 Sep 2010; 14:45 UT

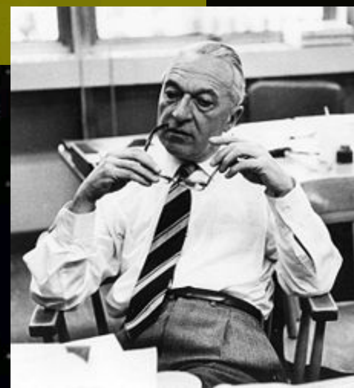
Distributed as an Instant Email Notice (Transients)

Password Certification: Marco Tavani (tavani@iasf-roma.inaf.it)



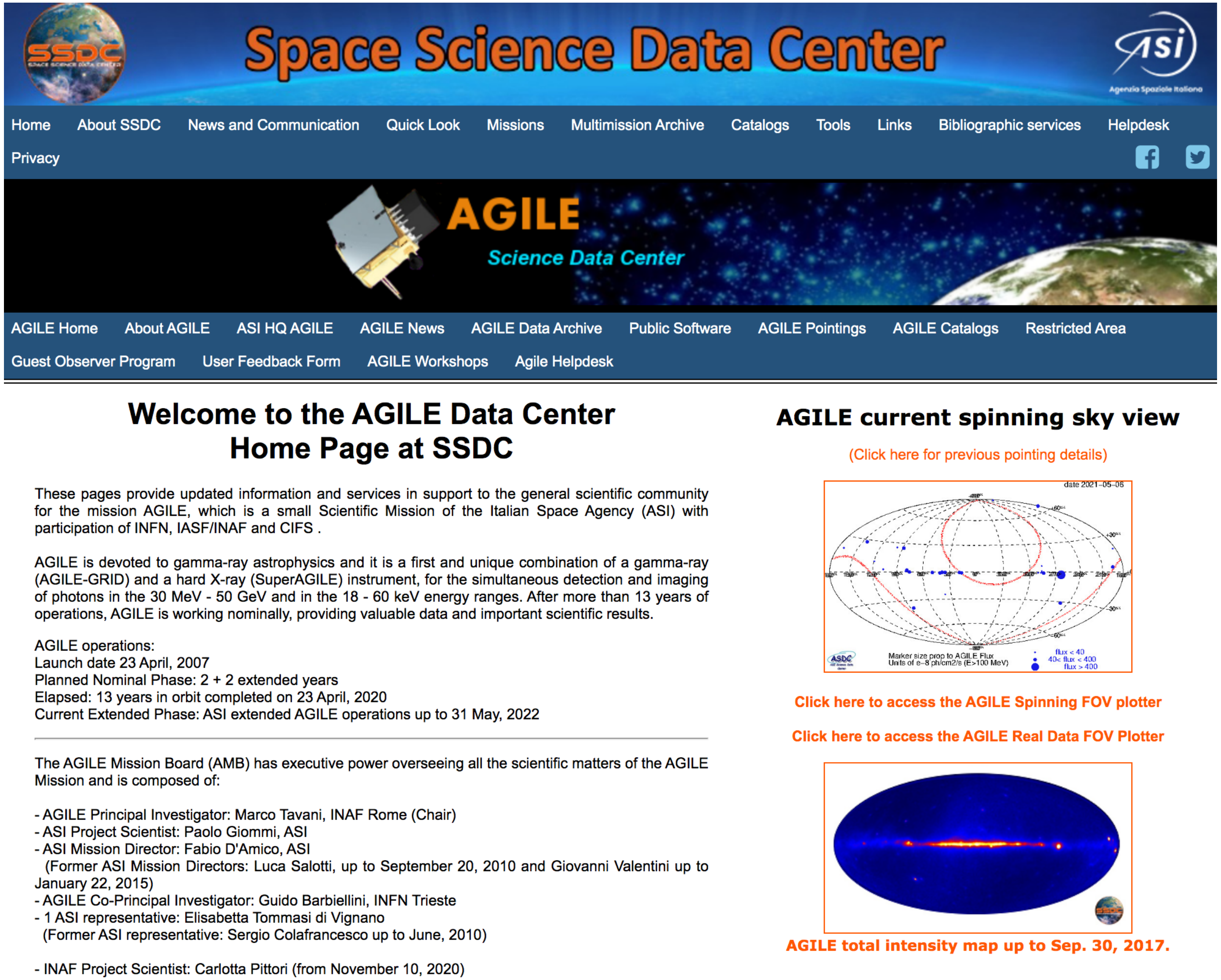


The Bruno Rossi Prize in High Energy Astrophysics awarded by AAS to astrophysicist Marco Tavani and the AGILE Team for the discovery of gamma-ray flares from the Crab Nebula (January 10, 2012).



Bruno B. Rossi

Where to find data?


Space Science Data Center

Home | About SSDC | News and Communication | Quick Look | Missions | Multimission Archive | Catalogs | Tools | Links | Bibliographic services | Helpdesk | Privacy

AGILE Science Data Center

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Welcome to the AGILE Data Center Home Page at SSDC

These pages provide updated information and services in support to the general scientific community for the mission AGILE, which is a small Scientific Mission of the Italian Space Agency (ASI) with participation of INFN, IASF/INAF and CIFS .

AGILE is devoted to gamma-ray astrophysics and it is a first and unique combination of a gamma-ray (AGILE-GRID) and a hard X-ray (SuperAGILE) instrument, for the simultaneous detection and imaging of photons in the 30 MeV - 50 GeV and in the 18 - 60 keV energy ranges. After more than 13 years of operations, AGILE is working nominally, providing valuable data and important scientific results.

AGILE operations:
Launch date 23 April, 2007
Planned Nominal Phase: 2 + 2 extended years
Elapsed: 13 years in orbit completed on 23 April, 2020
Current Extended Phase: ASI extended AGILE operations up to 31 May, 2022

The AGILE Mission Board (AMB) has executive power overseeing all the scientific matters of the AGILE Mission and is composed of:

- AGILE Principal Investigator: Marco Tavani, INAF Rome (Chair)
- ASI Project Scientist: Paolo Giommi, ASI
- ASI Mission Director: Fabio D'Amico, ASI
  (Former ASI Mission Directors: Luca Salotti, up to September 20, 2010 and Giovanni Valentini up to January 22, 2015)
- AGILE Co-Principal Investigator: Guido Barbiellini, INFN Trieste
- 1 ASI representative: Elisabetta Tommasi di Vignano
  (Former ASI representative: Sergio Colafrancesco up to June, 2010)

- INAF Project Scientist: Carlotta Pittori (from November 10, 2020)

AGILE current spinning sky view

(Click here for previous pointing details)

Click here to access the AGILE Spinning FOV plotter

Click here to access the AGILE Real Data FOV Plotter

AGILE total intensity map up to Sep. 30, 2017.

https://agile.ssdc.asi.it/

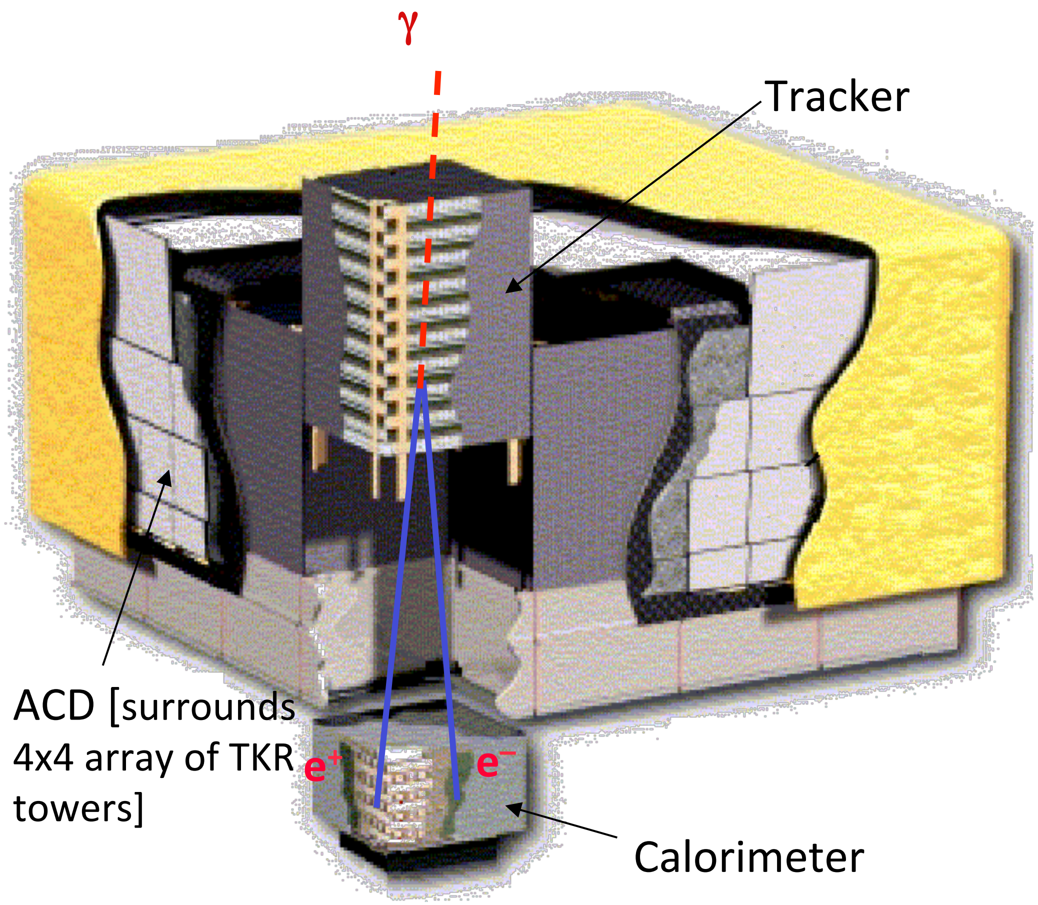
Conclusions

- 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

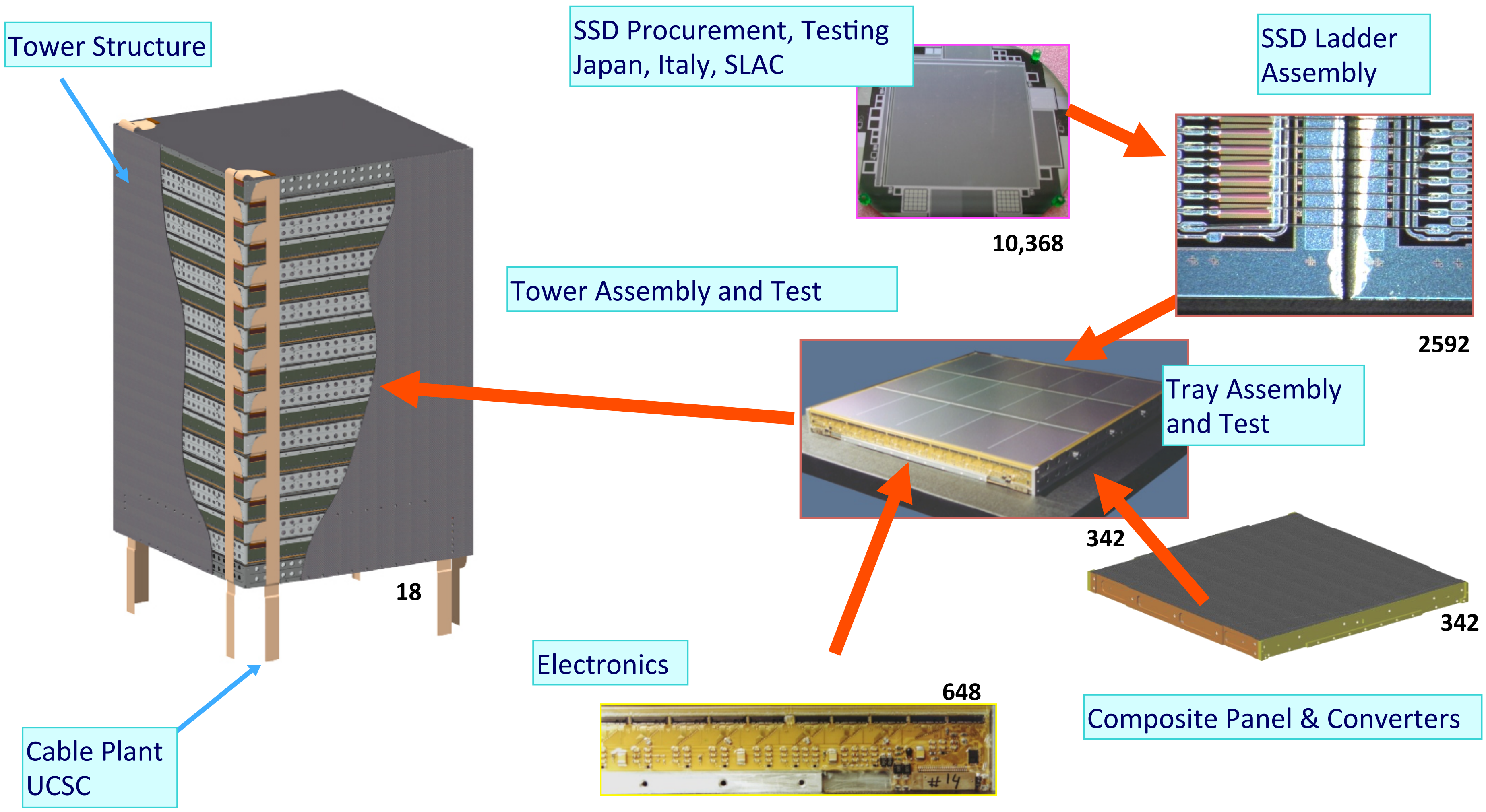
Fermi LAT

Overview of LAT

- Precision Si-strip Tracker (TKR) 18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID.
- Hodoscopic CsI Calorimeter(CAL) Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower.
- Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, robust hardware trigger and software filters.

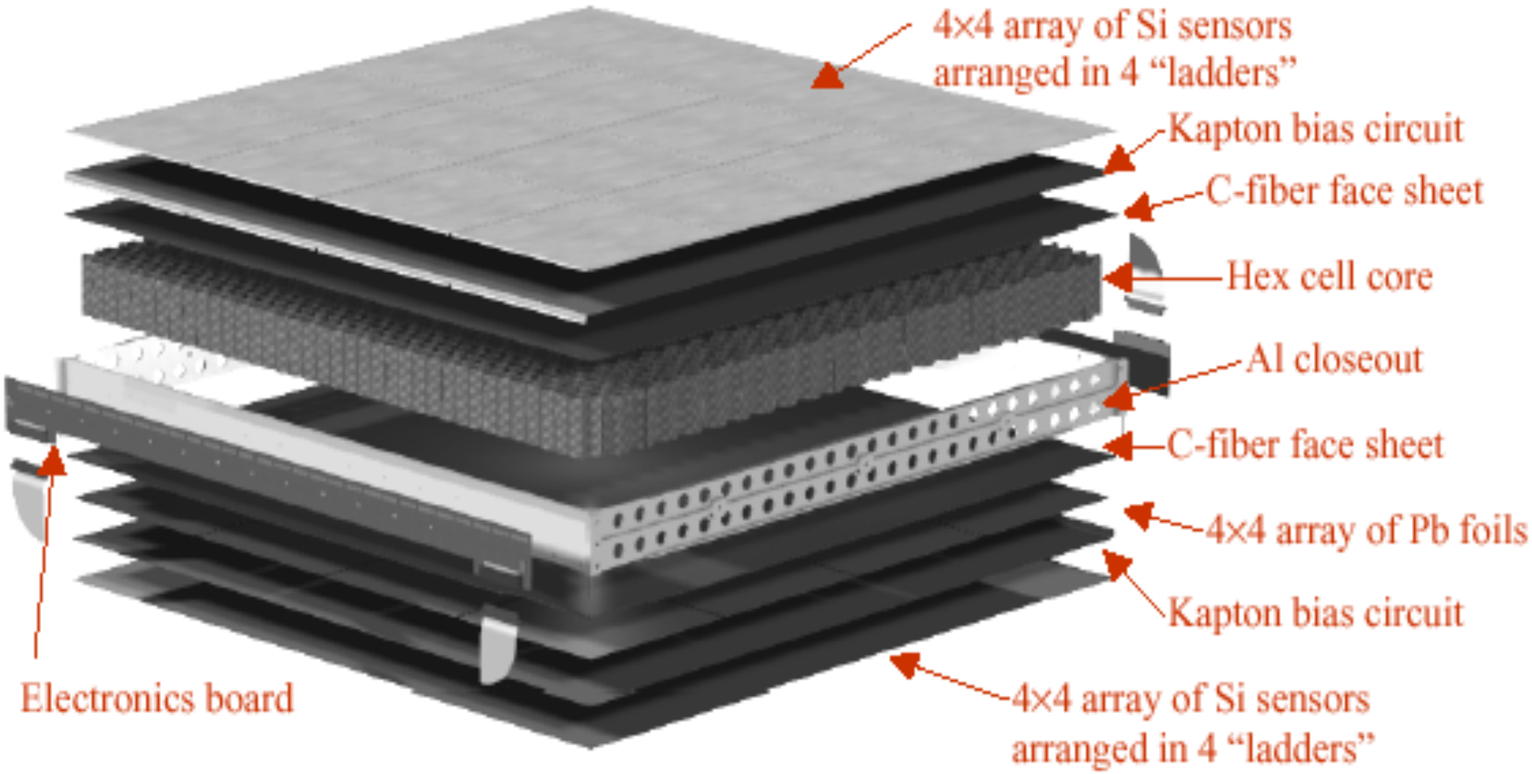


Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.



Tower Structure
SSD Procurement, Testing
Japan, Italy, SLAC
10,368
SSD Ladder
Assembly
2592
Tower Assembly and Test
Tray Assembly
and Test
342
342
18
Electronics
648
Composite Panel & Converters
Cable Plant
UCSC

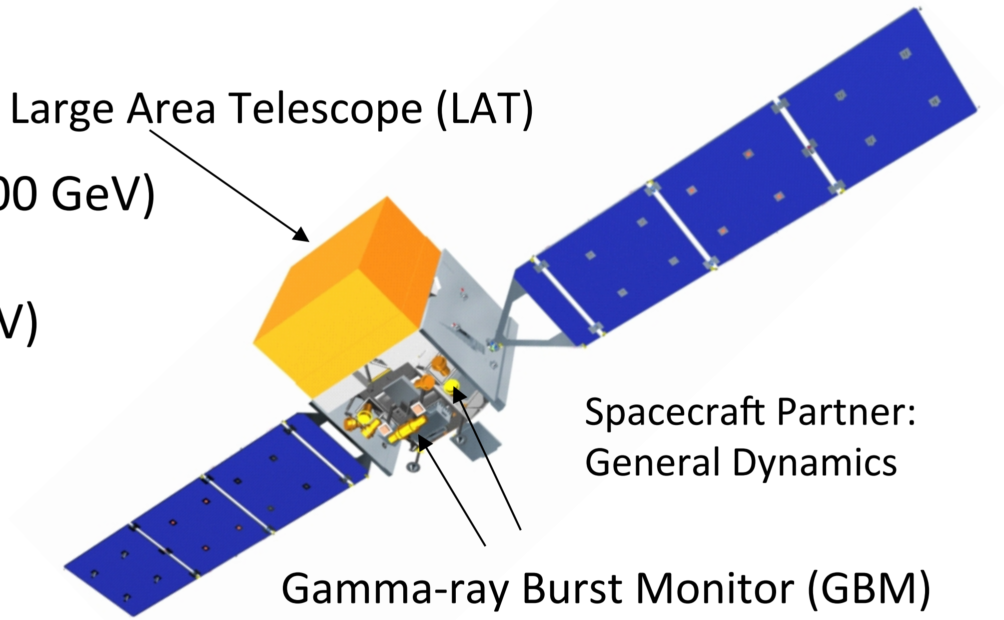
Silicon Detectors



GLAST silicon tracker tray

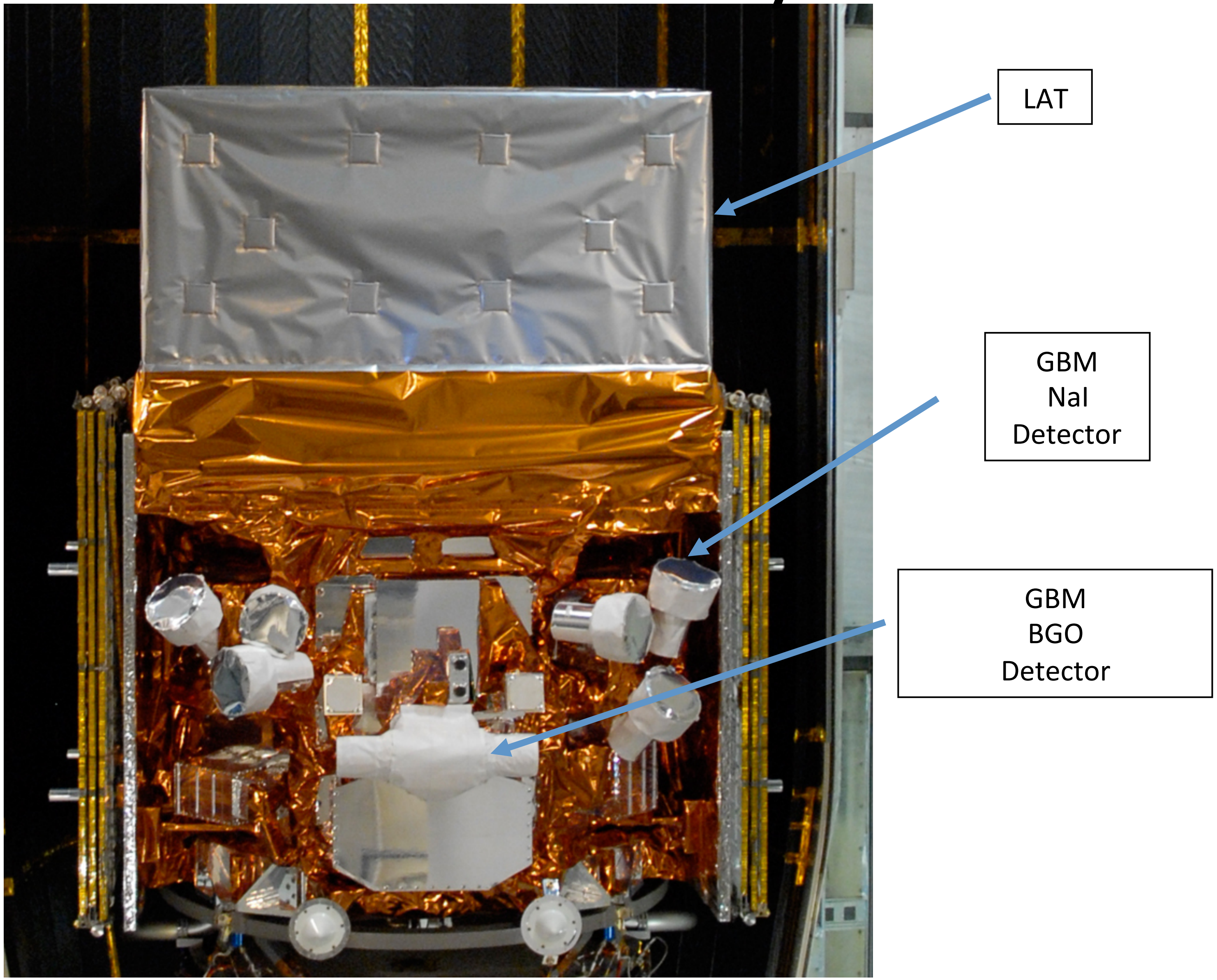
Key Features

- Two instruments:
  - LAT:
    - high energy (20 MeV – >300 GeV)
  - GBM:
    - low energy (8 keV – 40 MeV)



- Huge field of view
  - LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.
- Huge energy range, including largely unexplored band 10 GeV - 100 GeV
- Large leap in all key capabilities. Great discovery potential.

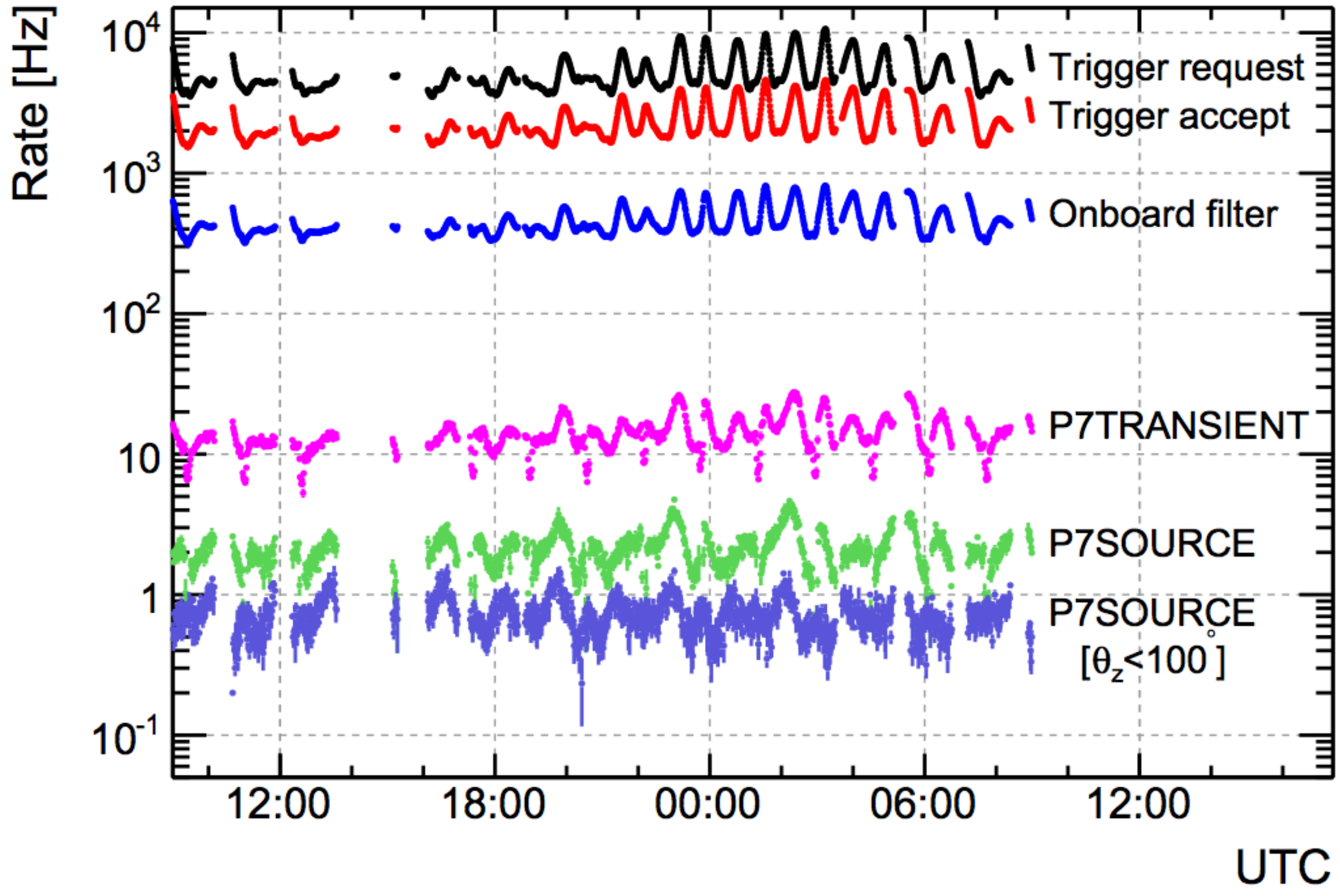
The Observatory



Launch!

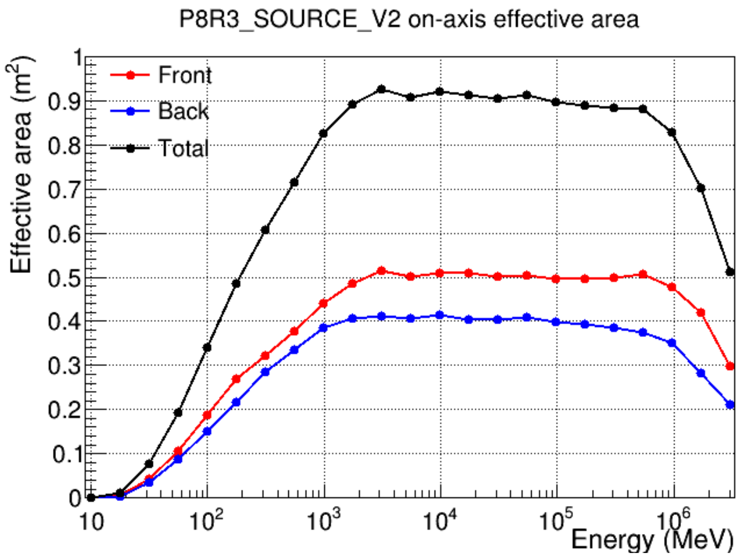
- Launch from Cape Canaveral Air Station 11 June 2008 at 12:05PM EDT
- Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination.

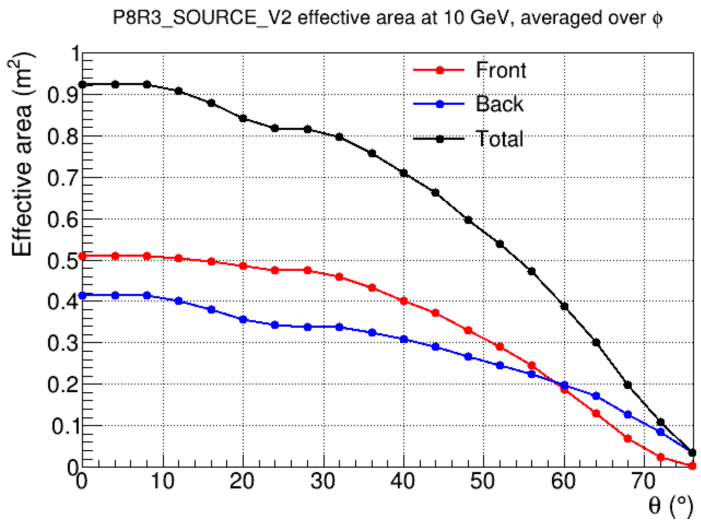
Fermi/LAT in orbit



On Orbit Trigger Rates

Effective Area (A_{eff})





< 100 MeV limited by 3-in a row requirement

< 1 GeV limited discriminating information

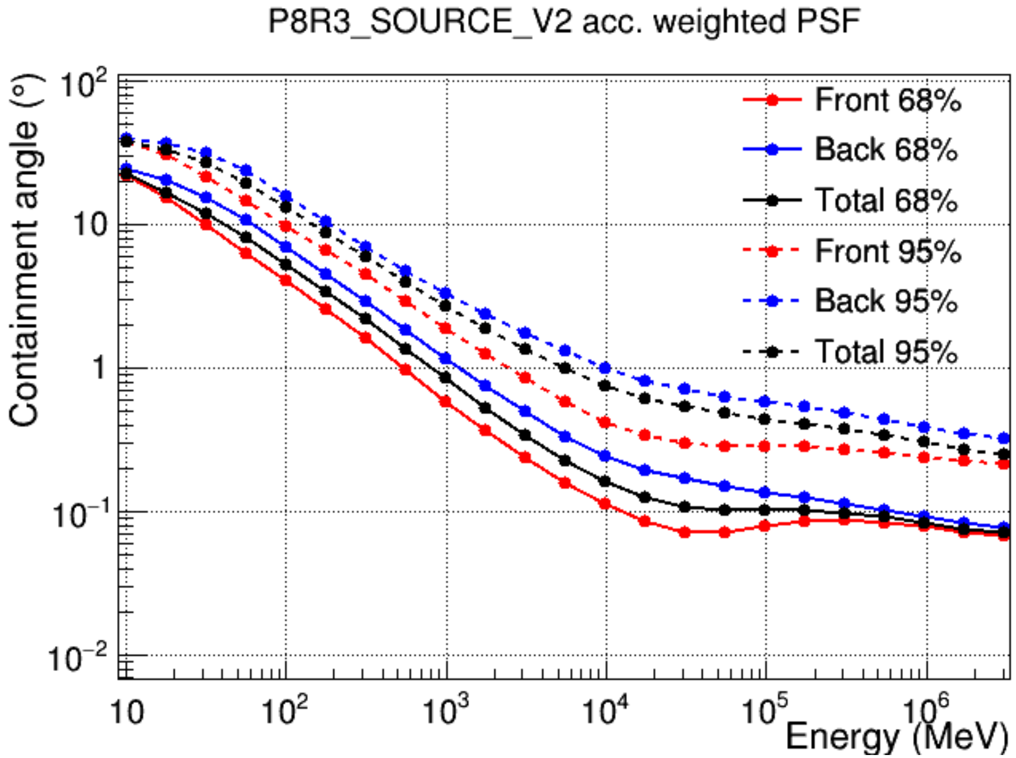
> 100 GeV self-veto from backsplash

Off-axis: more material, less cross section

Shift from front/back events as we go off-axis

http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

Point Spread Function (P)

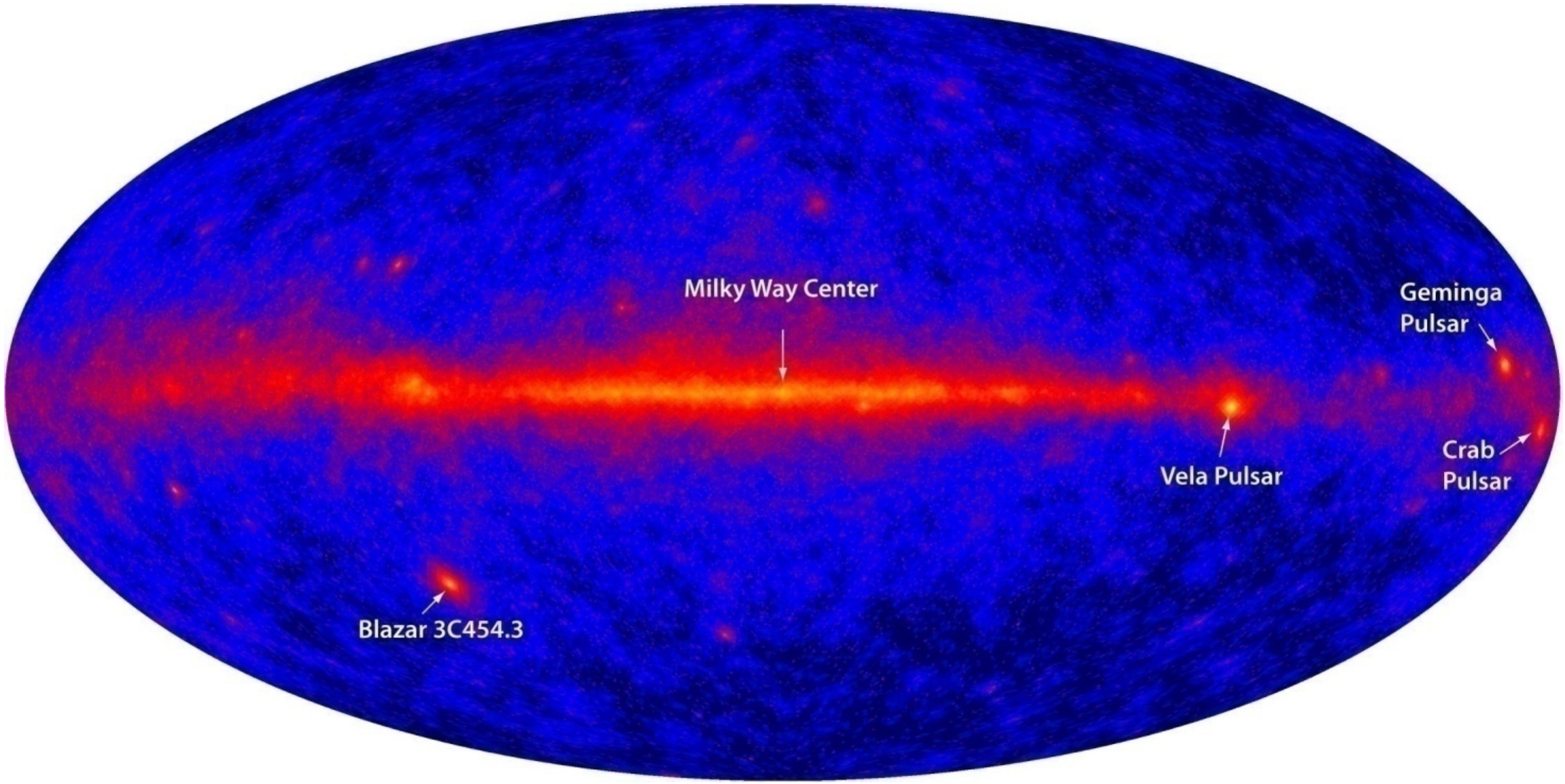


Low energy: dominated by MS

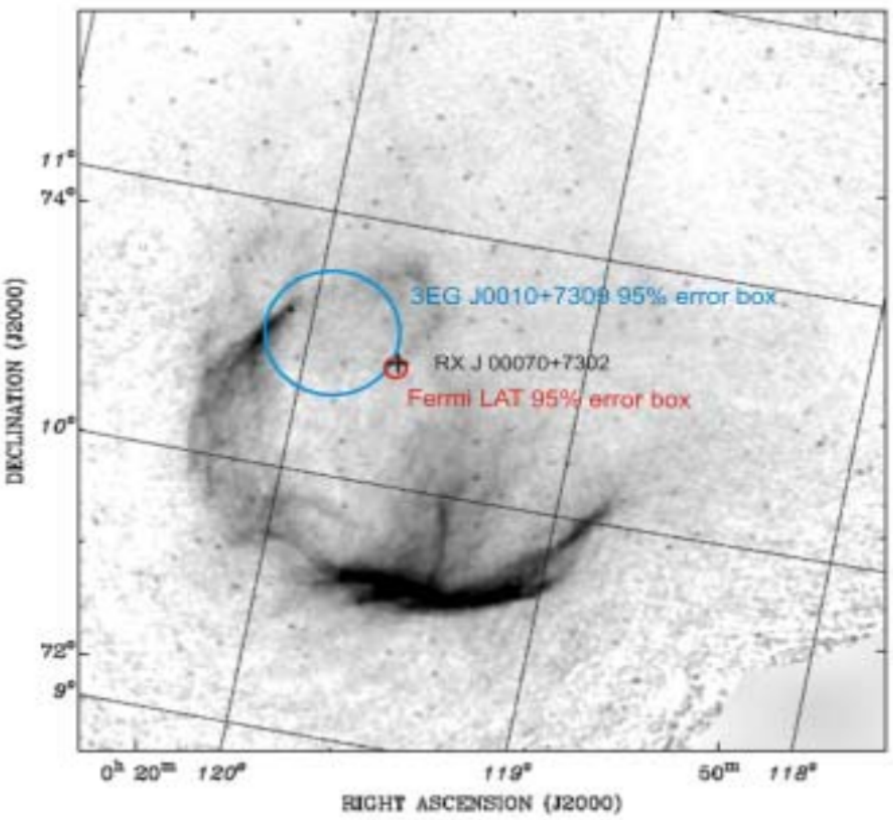
High energy: dominated by strip pitch

http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

LAT first light



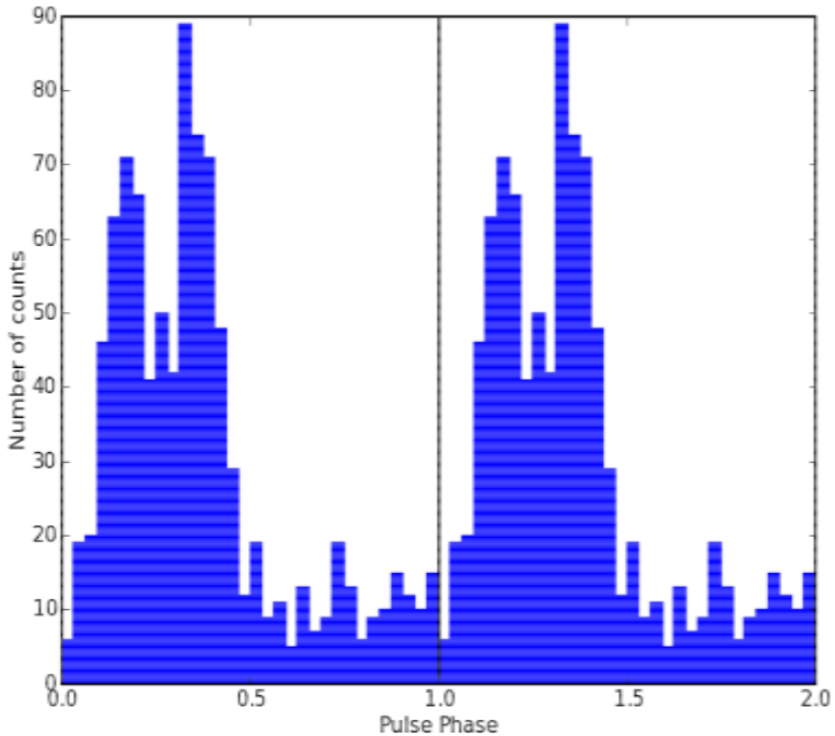
LAT discovers a radio-quiet pulsar!



Location of EGRET source 3EG J0010+7309, the Fermi-LAT source, and the central X-ray source RX J0007.0+7303

Published in Science Express October 16, 2008

P ~ 317 ms
Pdot ~ 3.6E-13
Characteristic age ~ 10,000 yrs



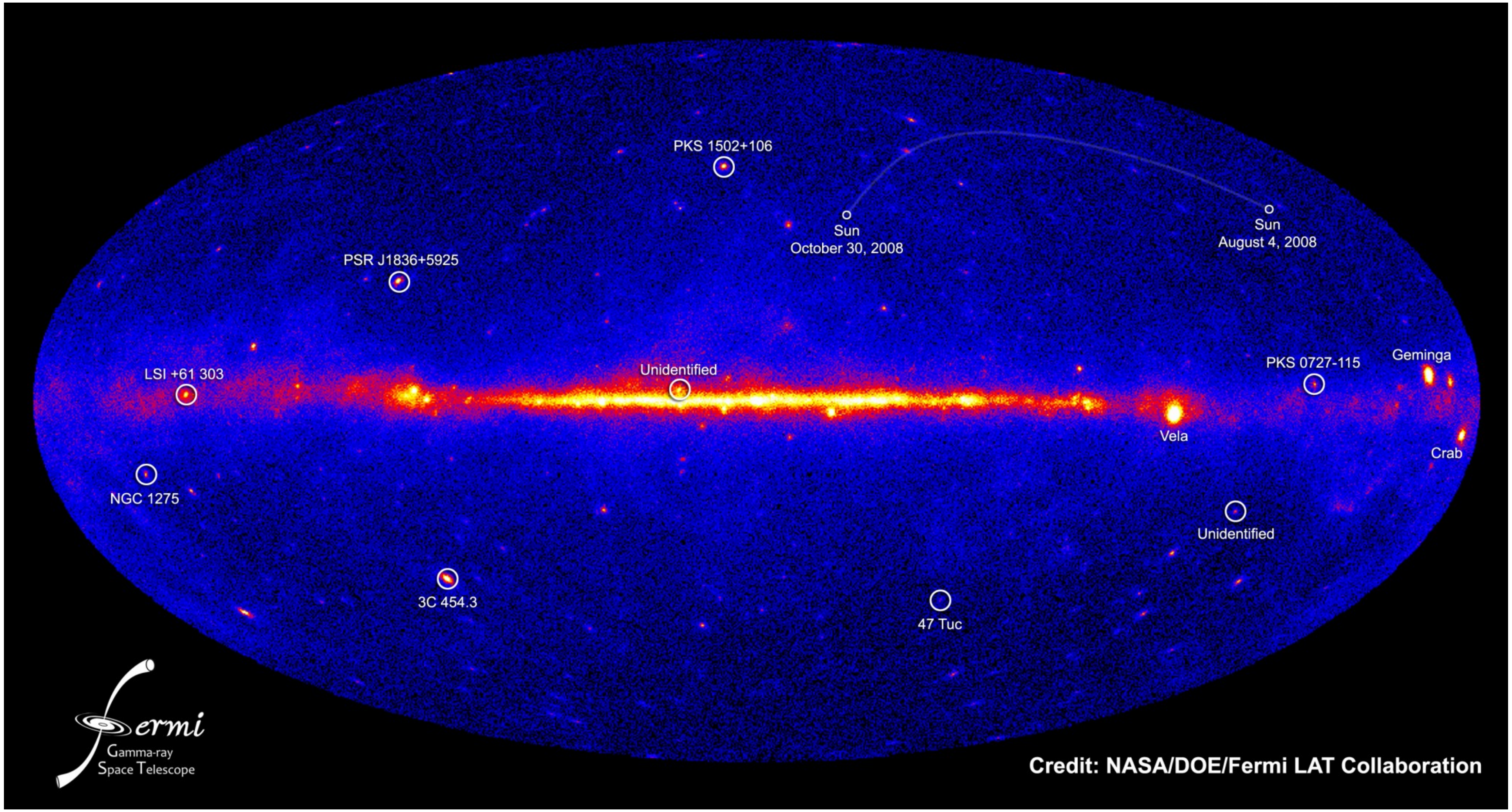
Fermi Gamma-ray Space Telescope

GLAST renamed *Fermi* by NASA on August 26, 2008

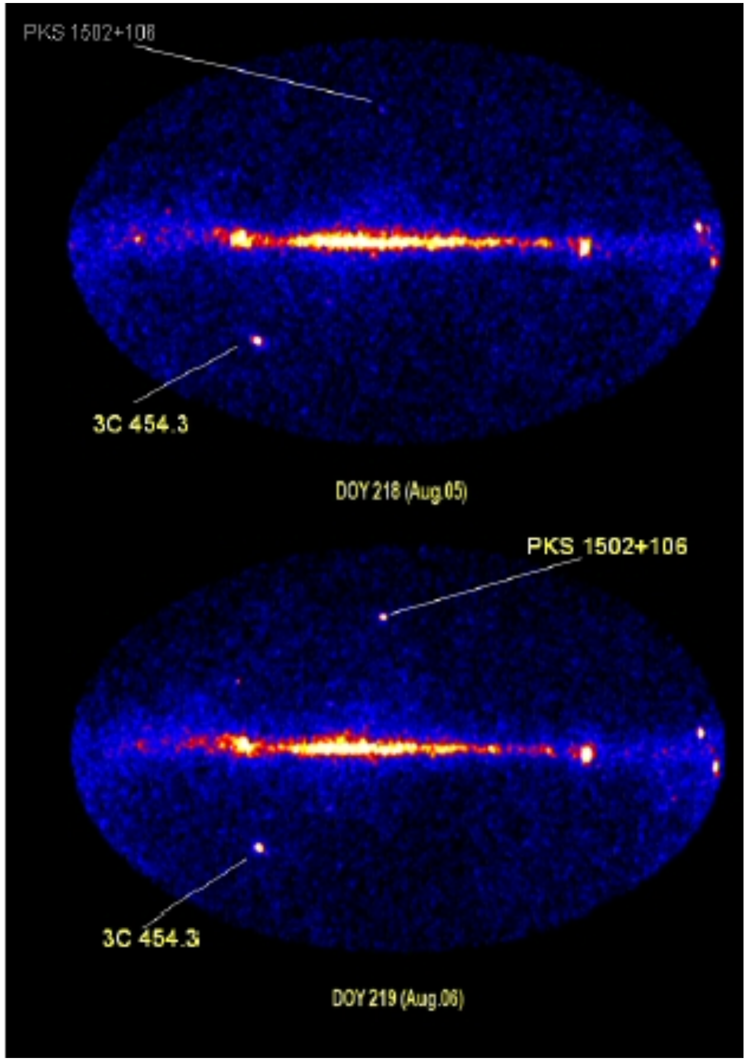
http://fermi.gsfc.nasa.gov/

“ Enrico Fermi (1901-1954) was an Italian physicist who immigrated to the United States. He was the first to suggest a viable mechanism for astrophysical particle acceleration. This work is the foundation for our understanding of many types of sources to be studied by NASA’s Fermi Gamma-ray Space Telescope, formerly known as GLAST. ”

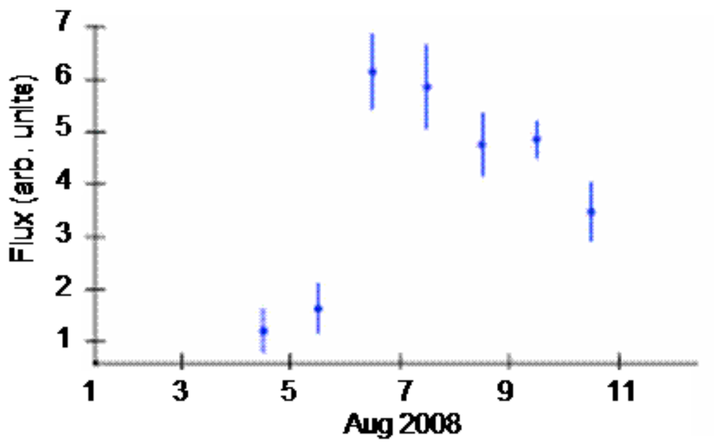
Fermi LAT 3 months sky



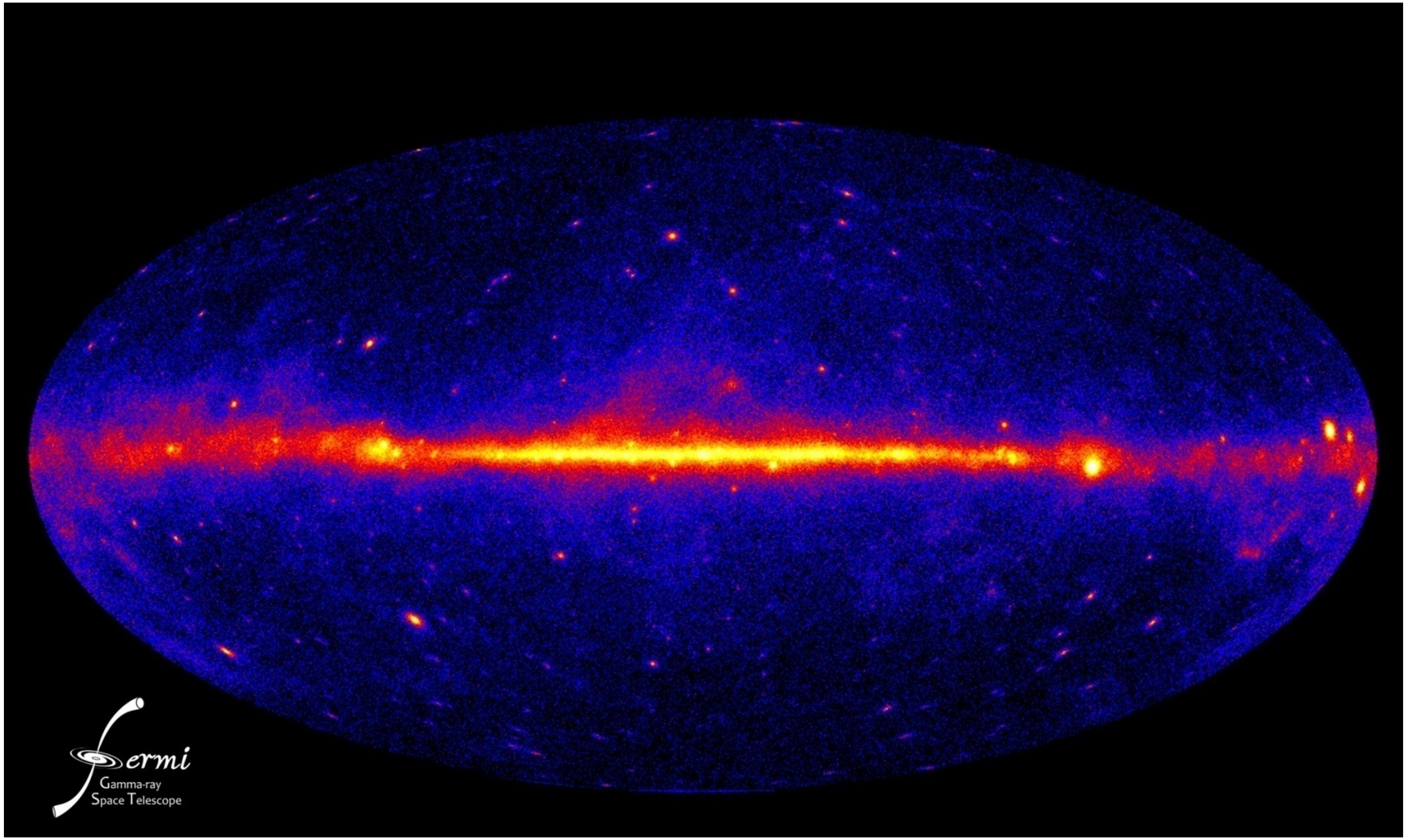
PKS 1502-106 and 3C454.3



- The sky is dynamic, Fermi is monitoring the sky, catching flaring sources over different time scales.
- Atel #1628 (3C454.3) and #1650 (PKS 1502-106) issued to announce these flares.



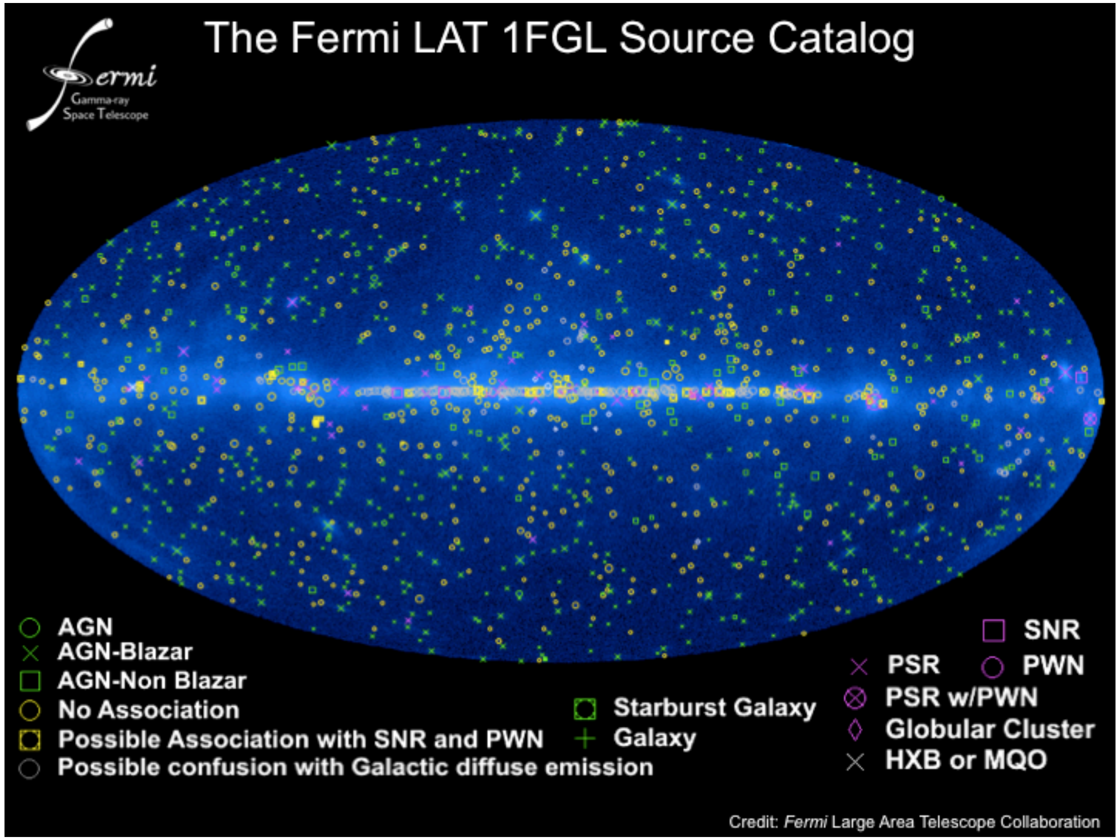
Fermi 1 yr sky



Fermi Year One Catalog

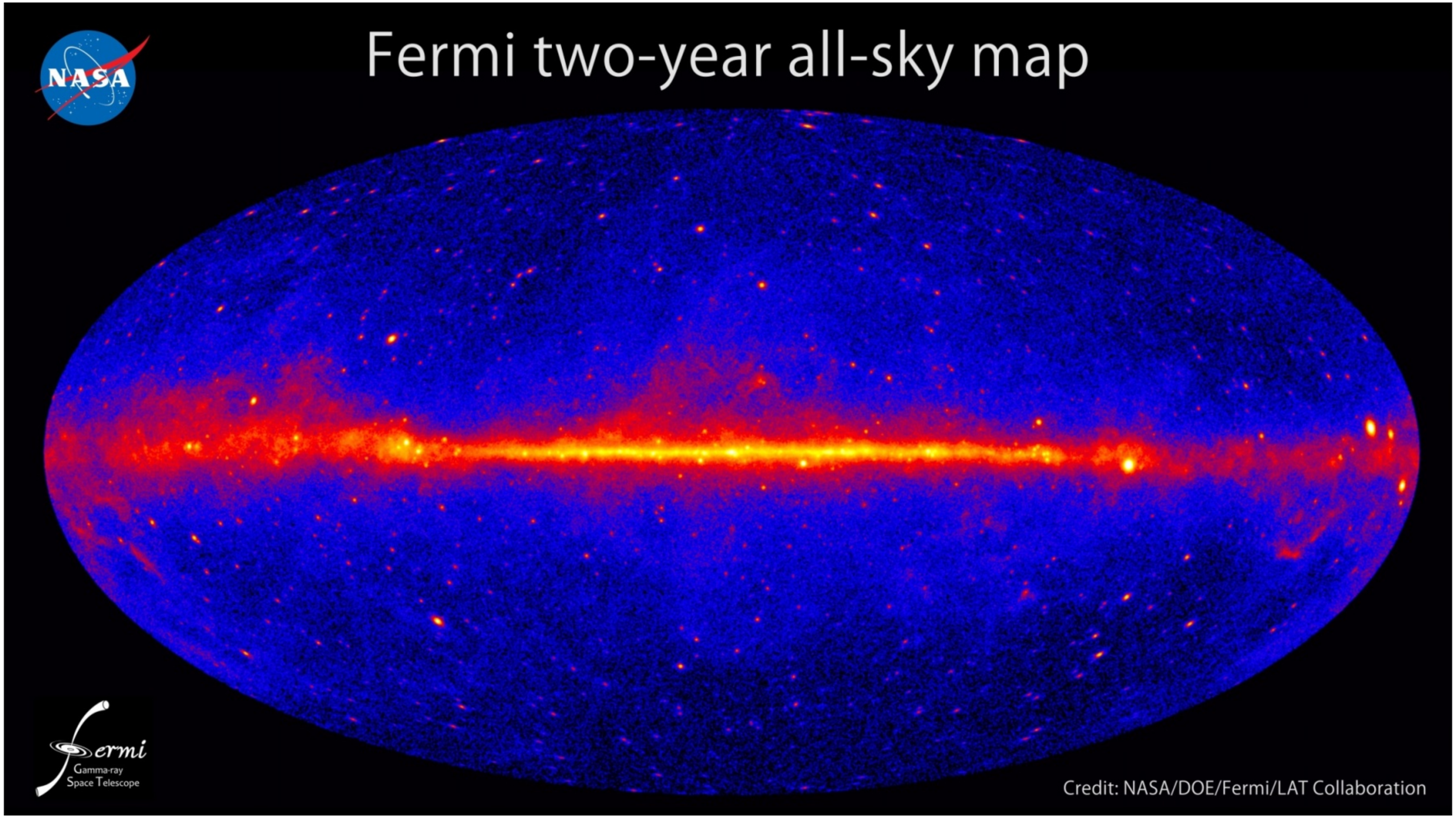
http://fermi.gsfc.nasa.gov/ssc/data/access/lat/1yr_catalog/

More than 1000 sources in year one catalog !



- About 250 sources show evidence of variability
- Half the sources are associated positionally, mostly blazars and PSRs
- Other classes of sources exist in small numbers (XRB, PWN, SNR, starbursts, globular clusters, radio galaxies, narrow-line Seyferts)
- Uncertainties due to the diffuse model, particularly in the Galactic ridge

2 year sky

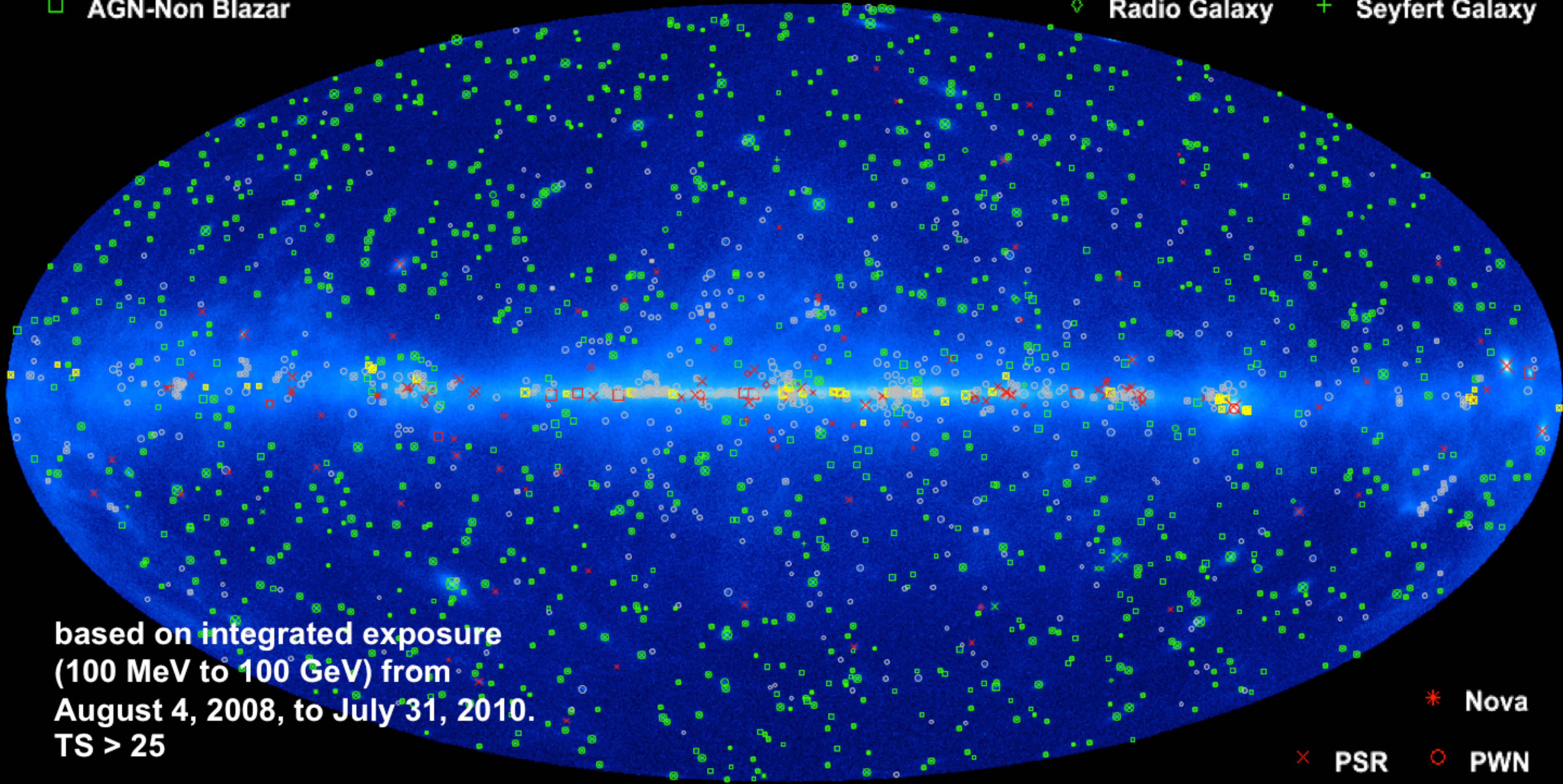


Fermi two-year all-sky map
NASA
Fermi
Gamma-ray
Space Telescope
Credit: NASA/DOE/Fermi/LAT Collaboration

2FGL Catalog

1,873 sources

- ○ AGN
- ⊗ AGN-Blazar
- □ AGN-Non Blazar
- × Galaxy
- ✳ Starburst Galaxy
- ◊ Radio Galaxy
- + Seyfert Galaxy

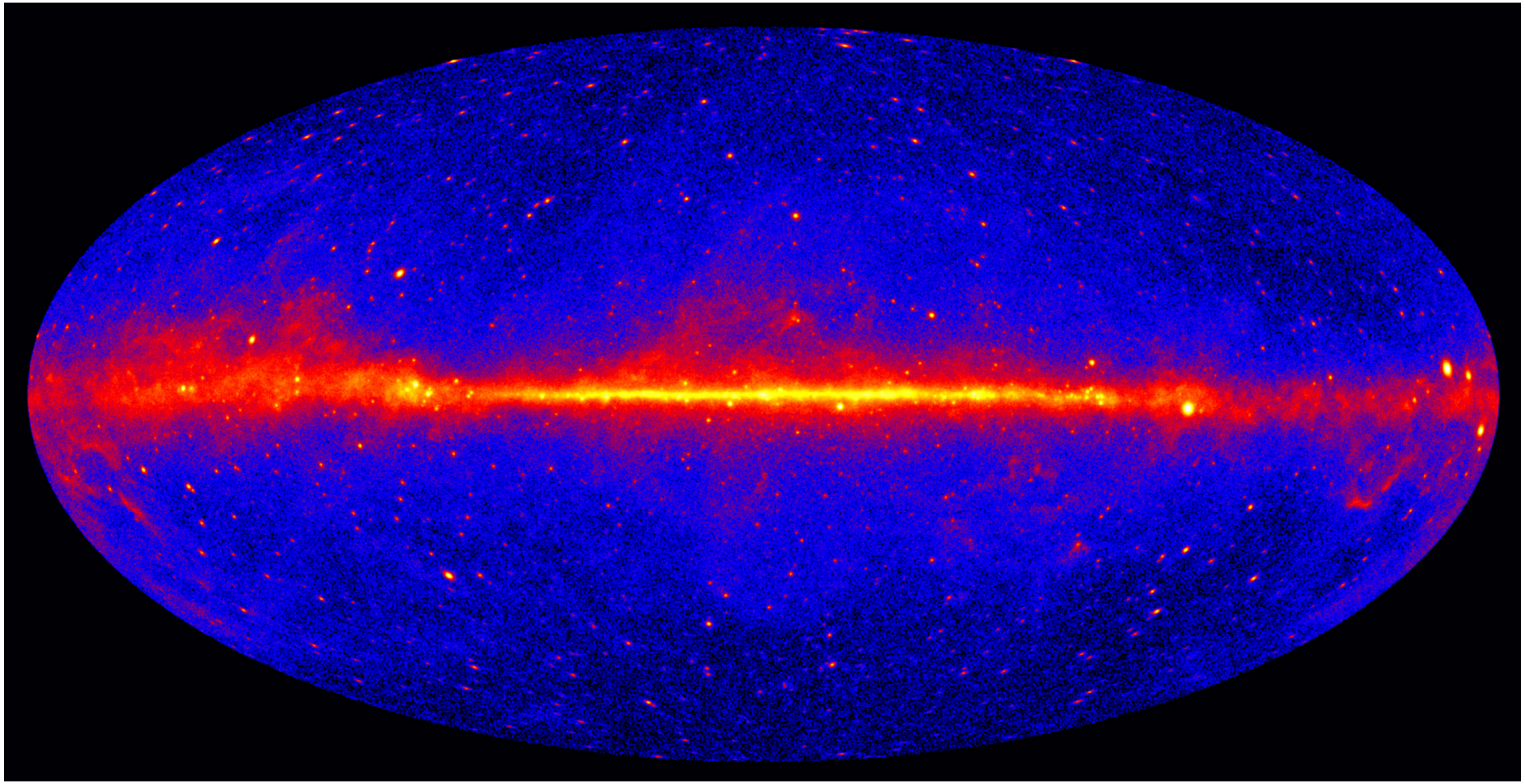


based on integrated exposure (100 MeV to 100 GeV) from August 4, 2008, to July 31, 2010.
TS > 25

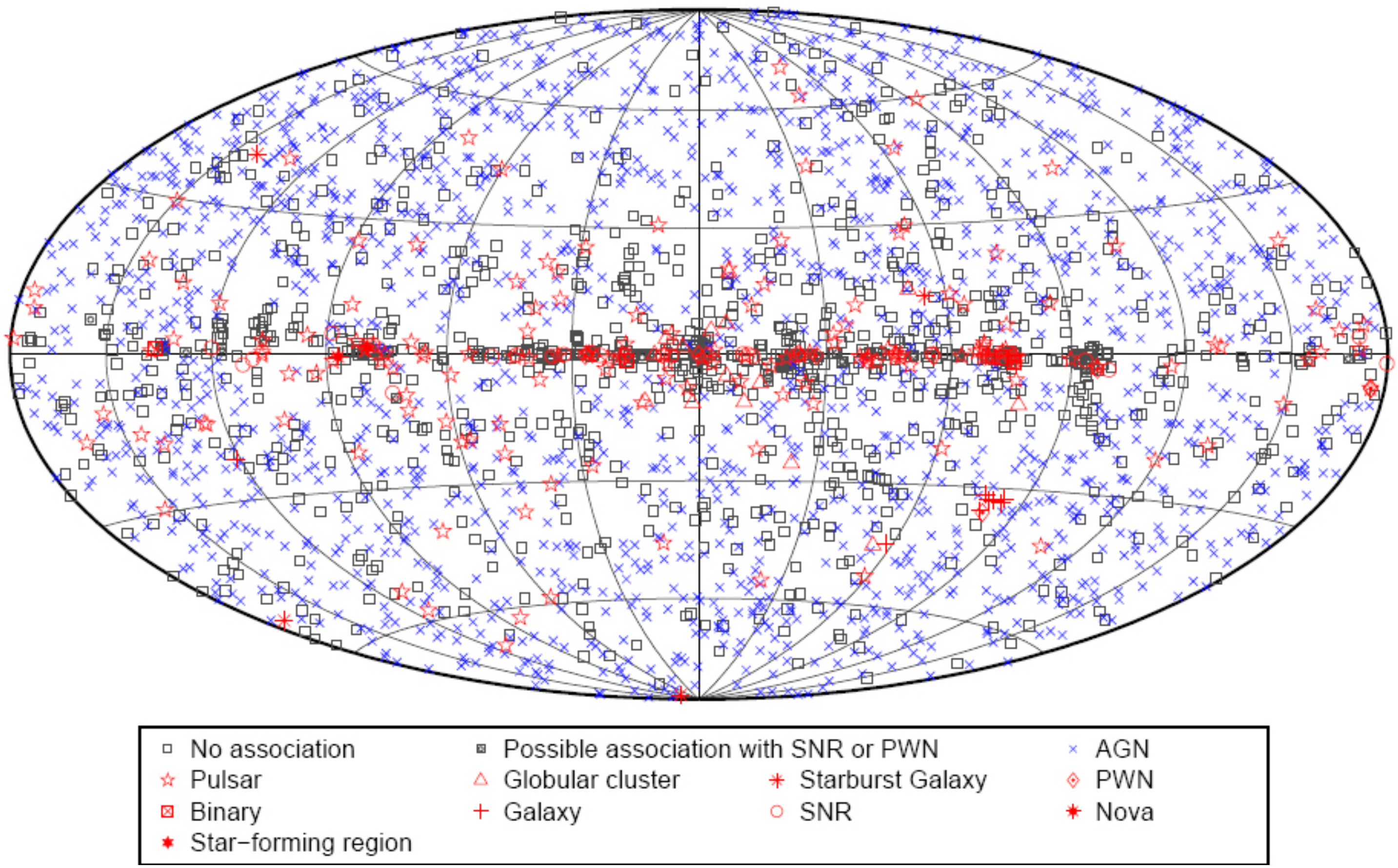
- ○ Unassociated
- □ Possible Association with SNR and PWN
- ✳ Nova
- × PSR
- ○ PWN
- ⊗ PSR w/PWN
- □ SNR
- ◊ Globular Cluster
- + HMB

Credit: Fermi Large Area Telescope Collaboration

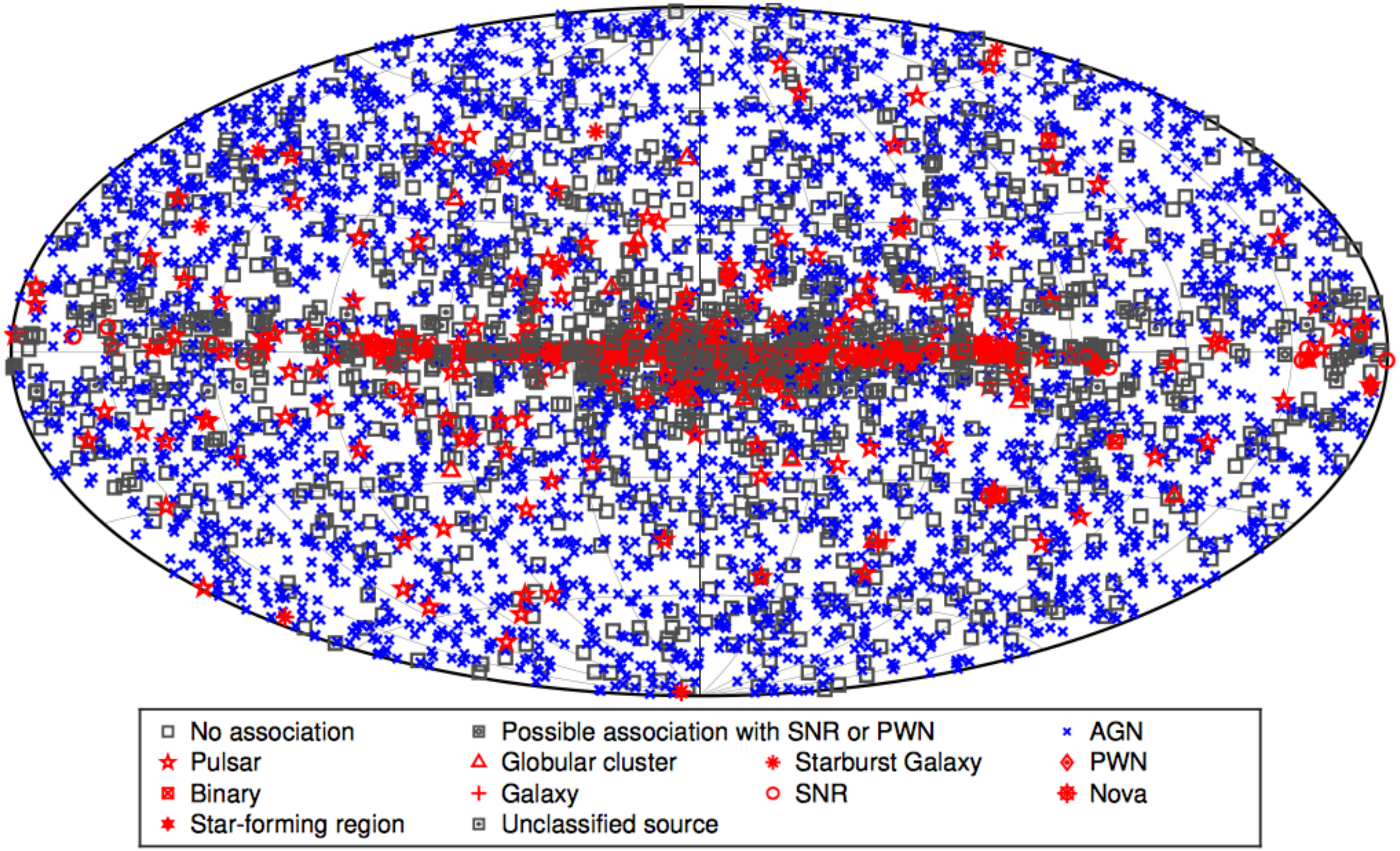
4 years sky



3FGL catalog – 3033 sources

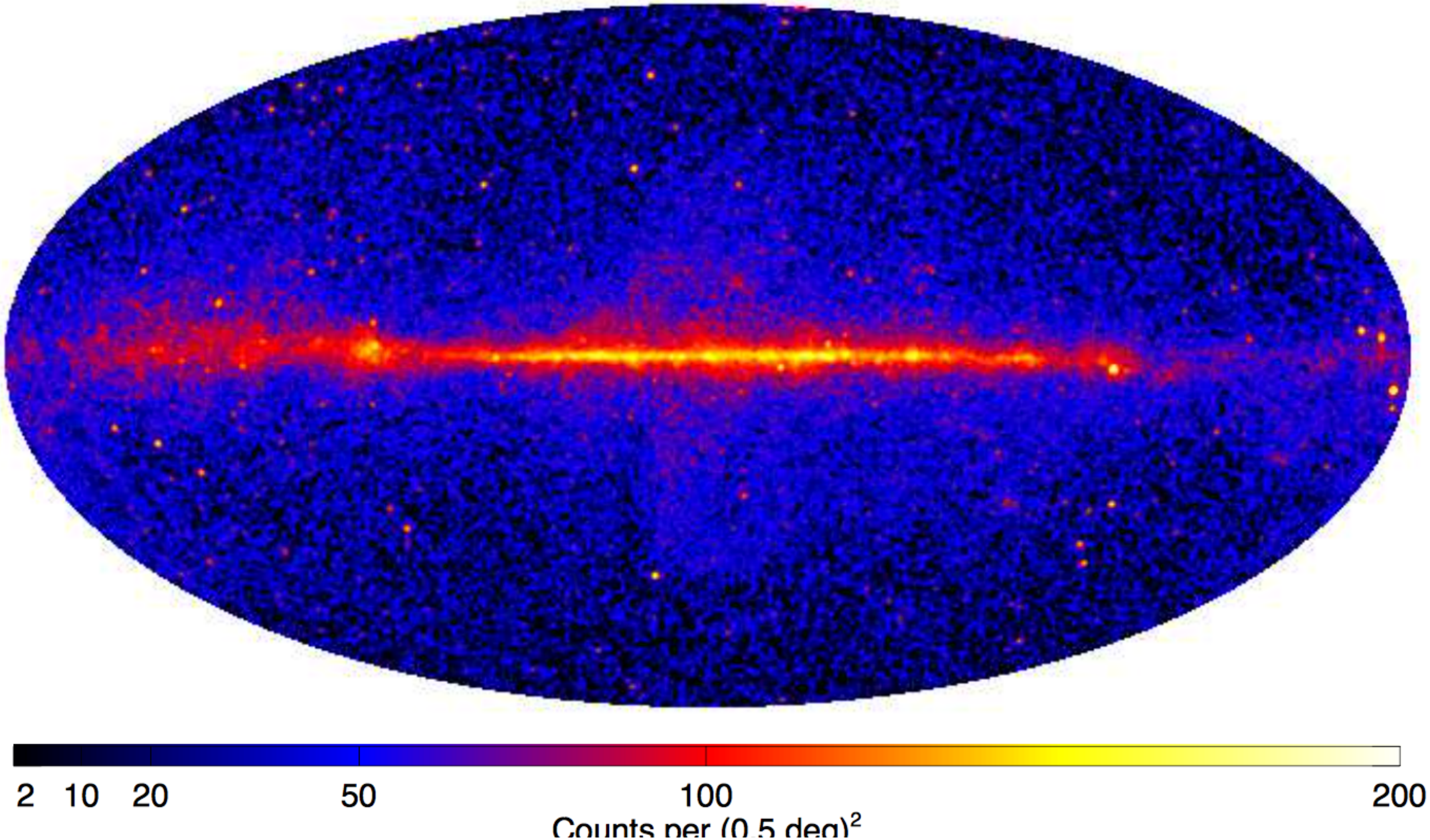


4FGL catalog

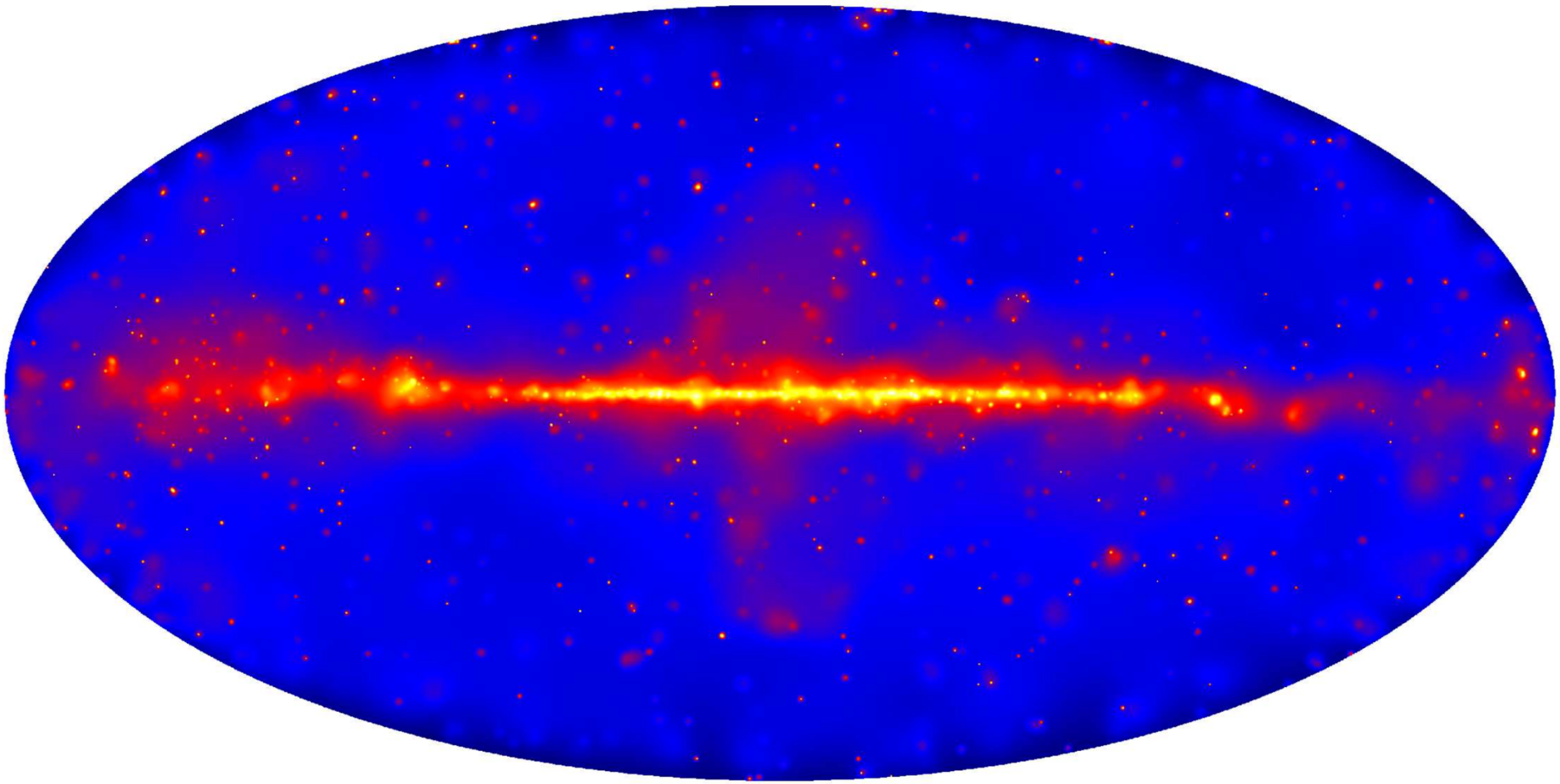


Abdollahi et al 2020

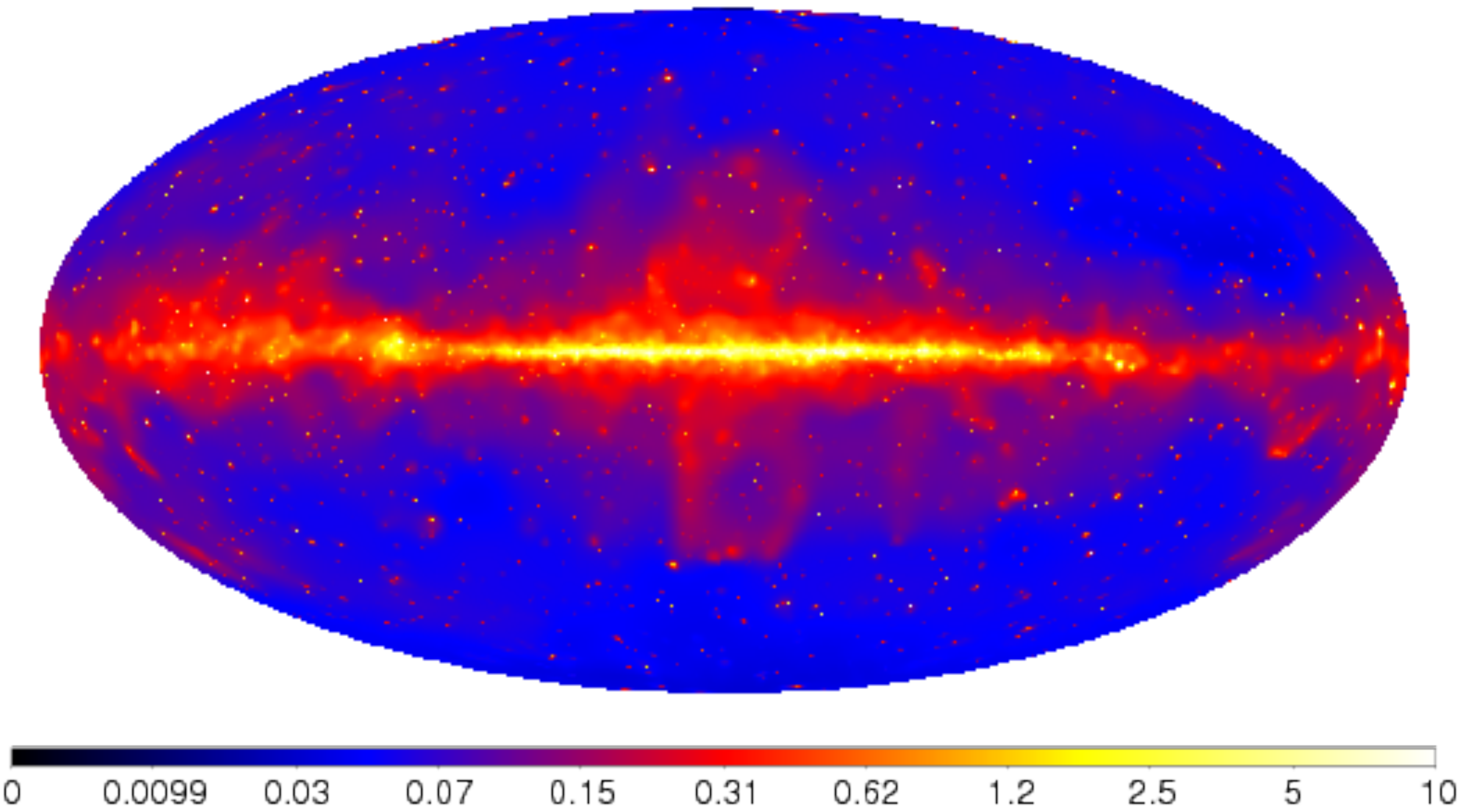
1 FHL (3 years, Pass7, E>10 GeV)



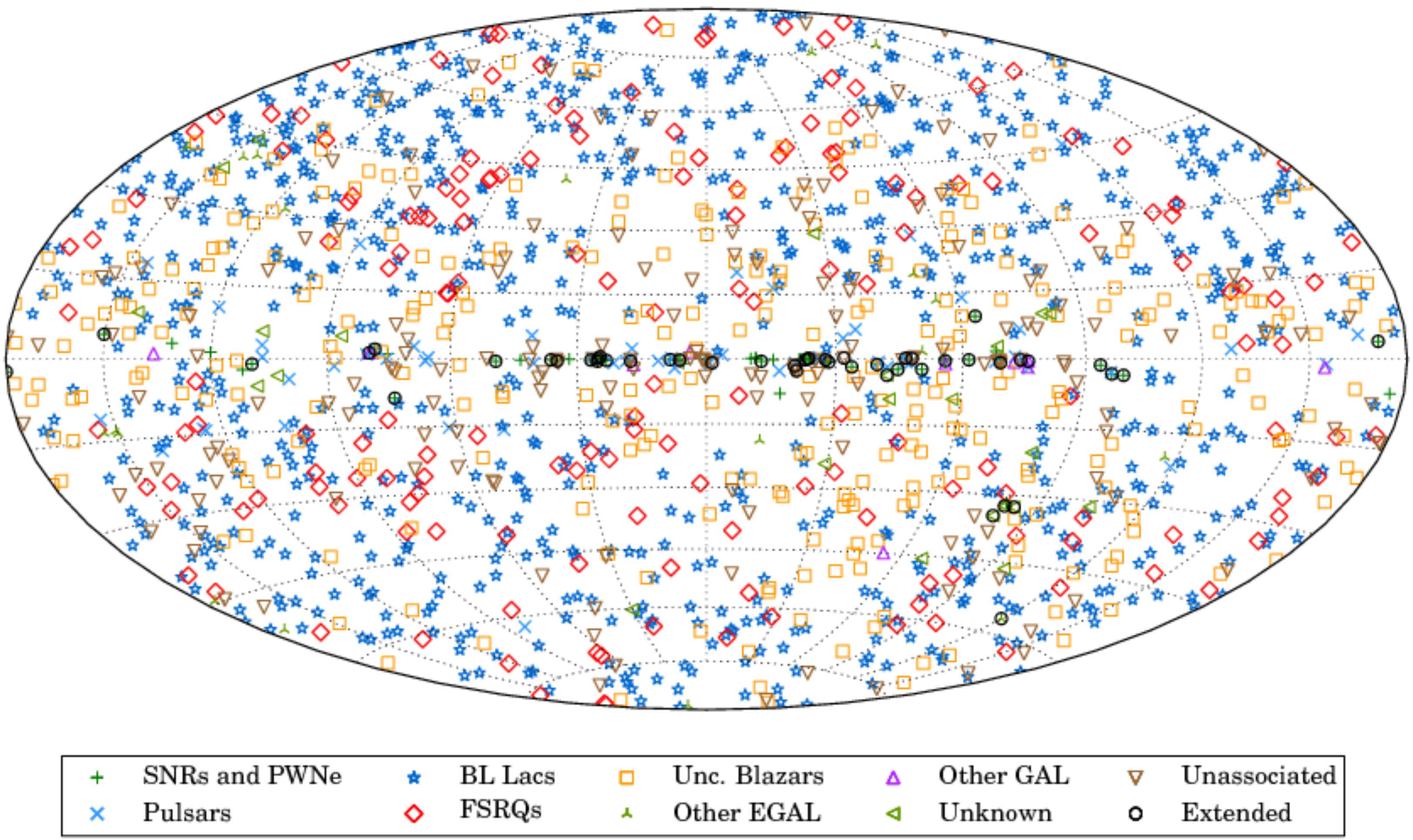
2FHL (P8 data >50 GeV) – 80 months



3FHL (E>10 GeV – P8)



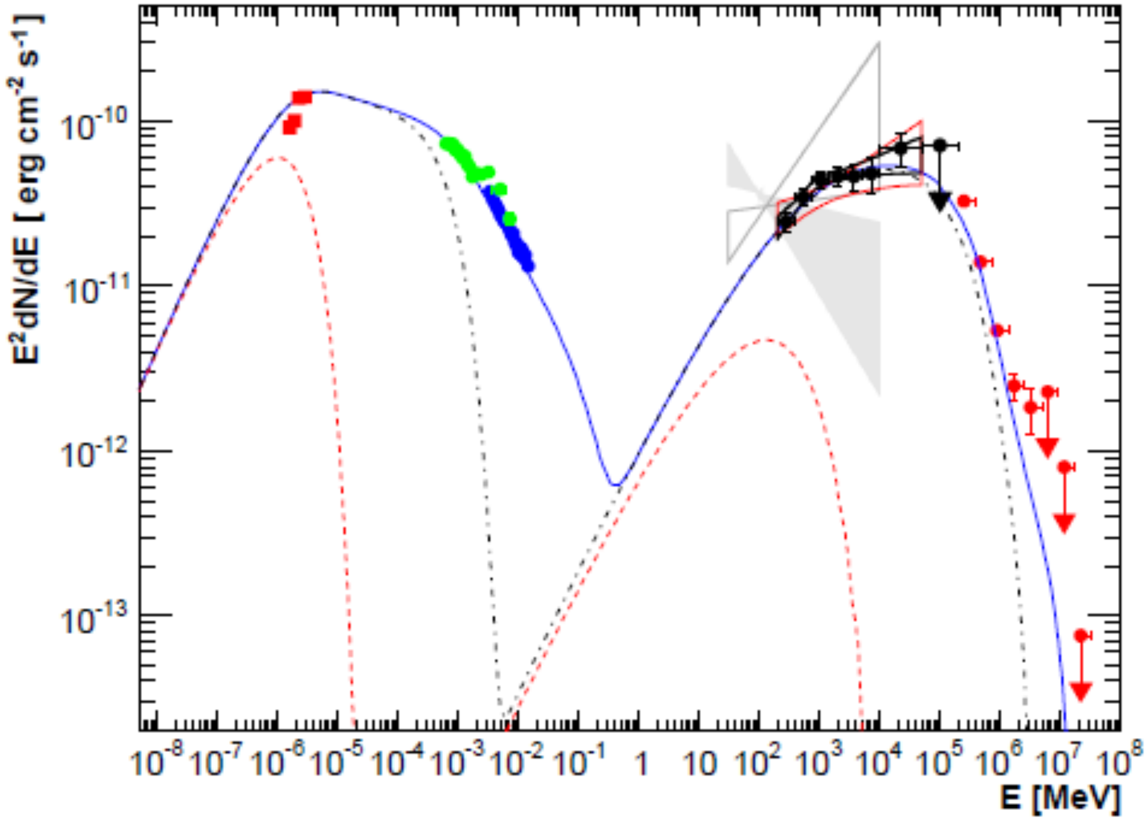
3 FHL



SNRs and PWNe
Pulsars
BL Lacs
FSRQs
Unc. Blazars
Other EGAL
Other GAL
Unknown
Unassociated
Extended

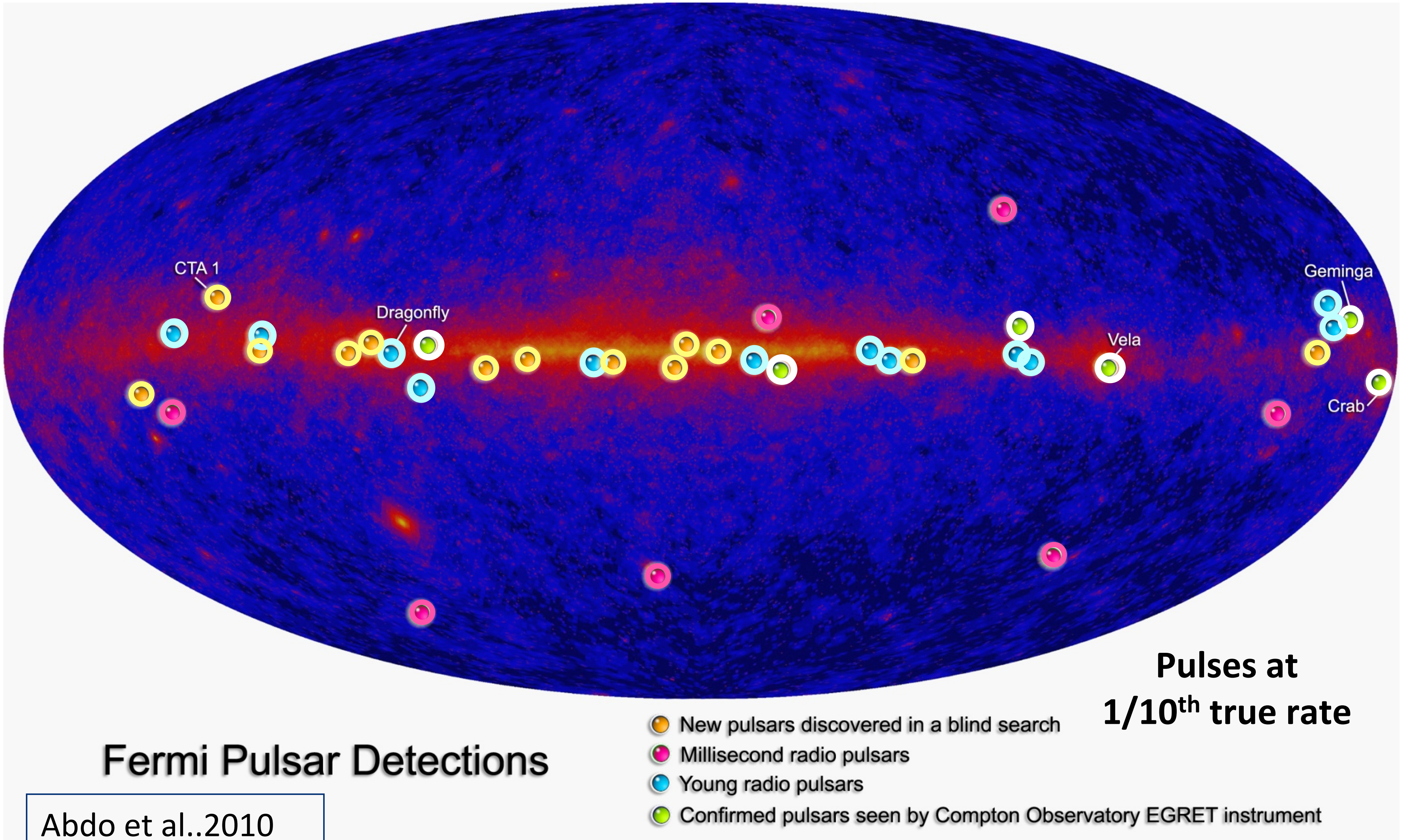
Challenge # 1 – AGN

Joint campaign on PKS 2155 with HESS



Aharonian et al. 2009

Challenge # 2 – Pulsars Blind Search



Pulses at 1/10th true rate

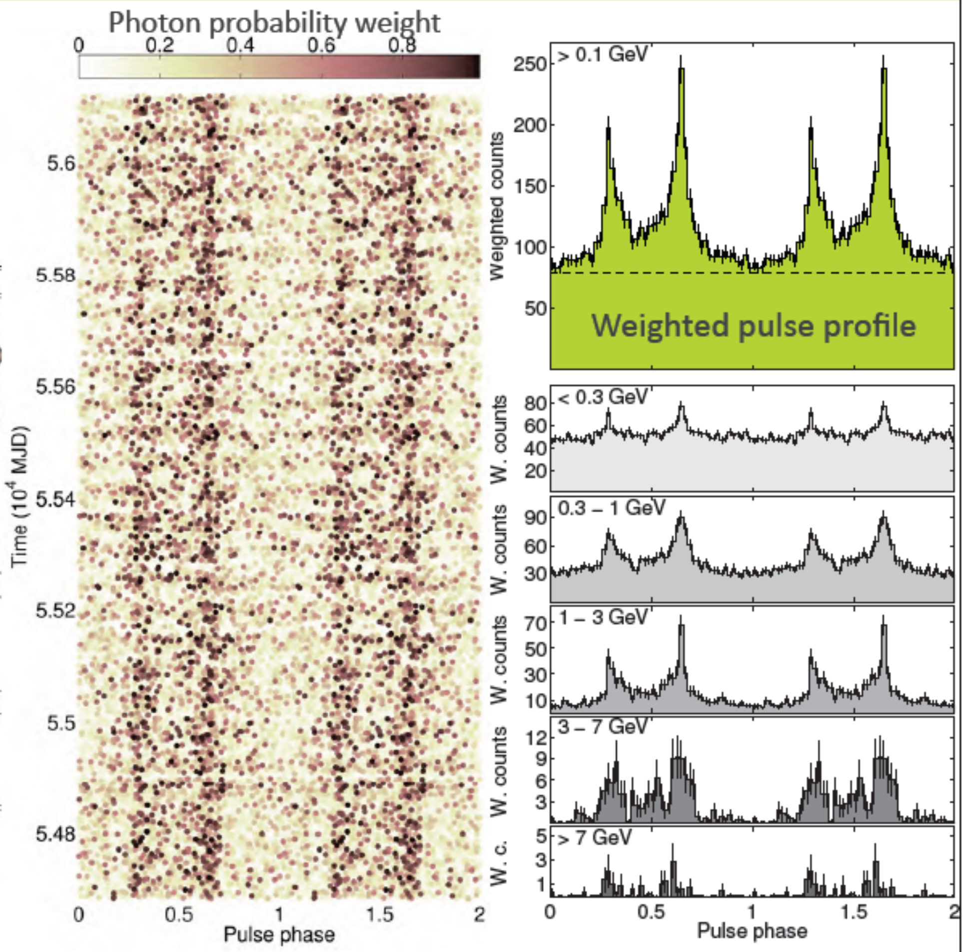
Abdo et al..2010

The first blind ms Pulsar

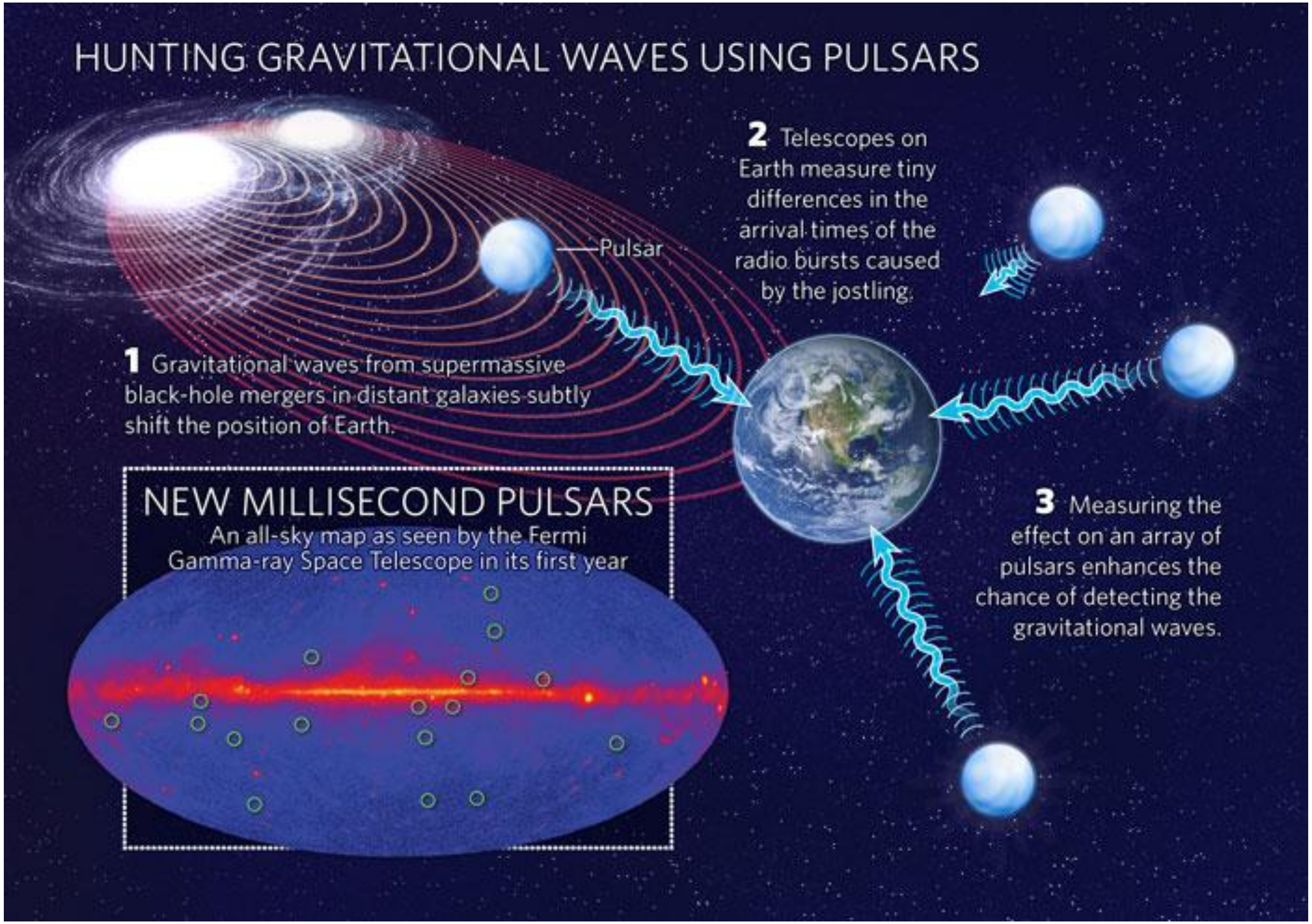
The PSR J1311-3430 system (1/2)

- Following the discovery:
  → pulsar timing to precisely measure the system parameters (▬)

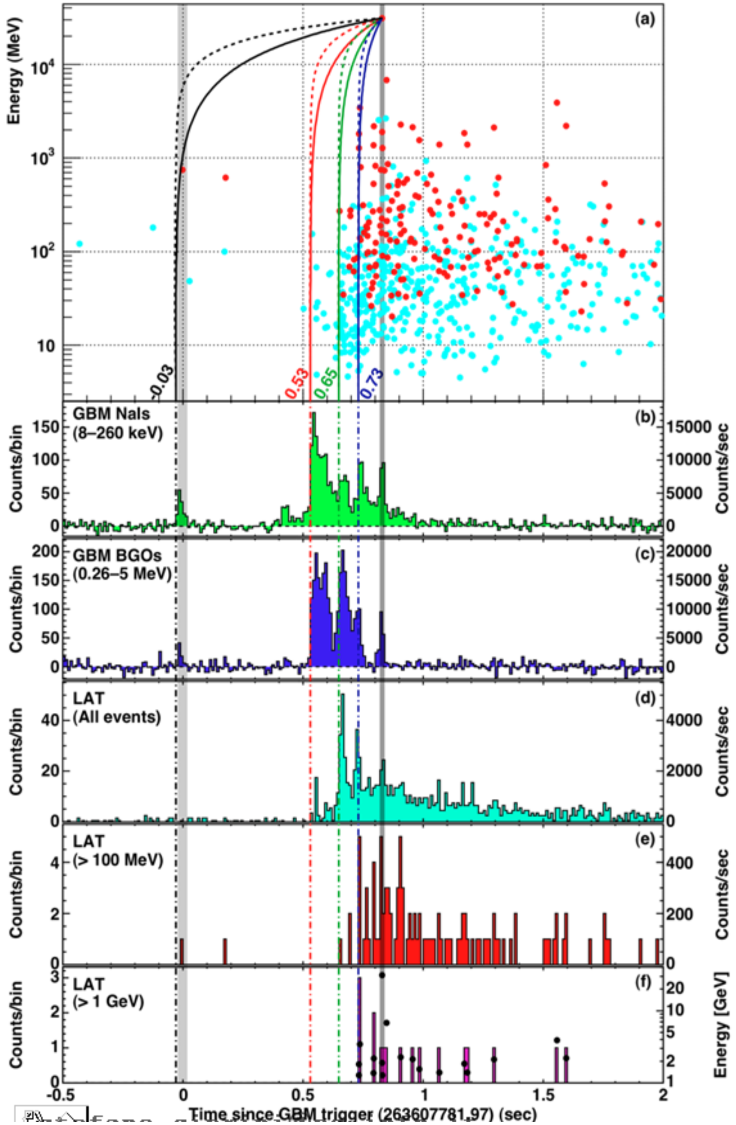
Parameter	Value
Right ascension (J2000.0) (hh:mm:ss)	13:11:45.7242(2)
Declination (J2000.0) (dd:mm:ss)	−34:30:30.350(4)
Spin frequency, f (Hz)	390.56839326407(4)
Frequency derivative, $\dot{f}$ (Hz s^{-1})	$-3.198(2) \times 10^{-15}$
Reference time scale	TDB
Reference time (MJD)	55266.90789575858
Orbital period P_{orb} (d)	0.0651157335(7)
Projected pulsar semi-major axis x (lt-s)	0.010581(4)
Time of ascending node T_{asc} (MJD)	56009.129454(7)
Eccentricity e	< 0.001
Data span (MJD)	54682 - 56119
Weighted RMS residual (μs)	17
Derived Quantities	
Companion mass m_c ($M_\odot$)	> 0.0082
Spin-down luminosity $\dot{E}$ (erg s^{-1})	4.9×10^{34}
Characteristic age τ_c (yr)	1.9×10^{9}
Surface magnetic field B_S (G)	2.3×10^{8}
Gamma-Ray Spectral Parameters	
Photon index, Γ	1.8 ± 0.1
Cutoff energy, E_c (GeV)	3.2 ± 0.4
Photon flux above 0.1 GeV, F (10^{-8} photons cm^{-2} s^{-1})	9.2 ± 0.5
Energy flux above 0.1 GeV, G (10^{-11} erg cm^{-2} s^{-1})	6.2 ± 0.2



New MSP and GW detection



Challenge # 3 – GRB



- This GRB is a perfect case for studying Lorentz Invariance Violation
  - z = 0.9 (5.381 Gyr)
  - Emission of 31 GeV photon after 859 ms since the trigger
- Only conservative assumption!
  - the HE photon is not emitted *before* the LE photons, at different events.

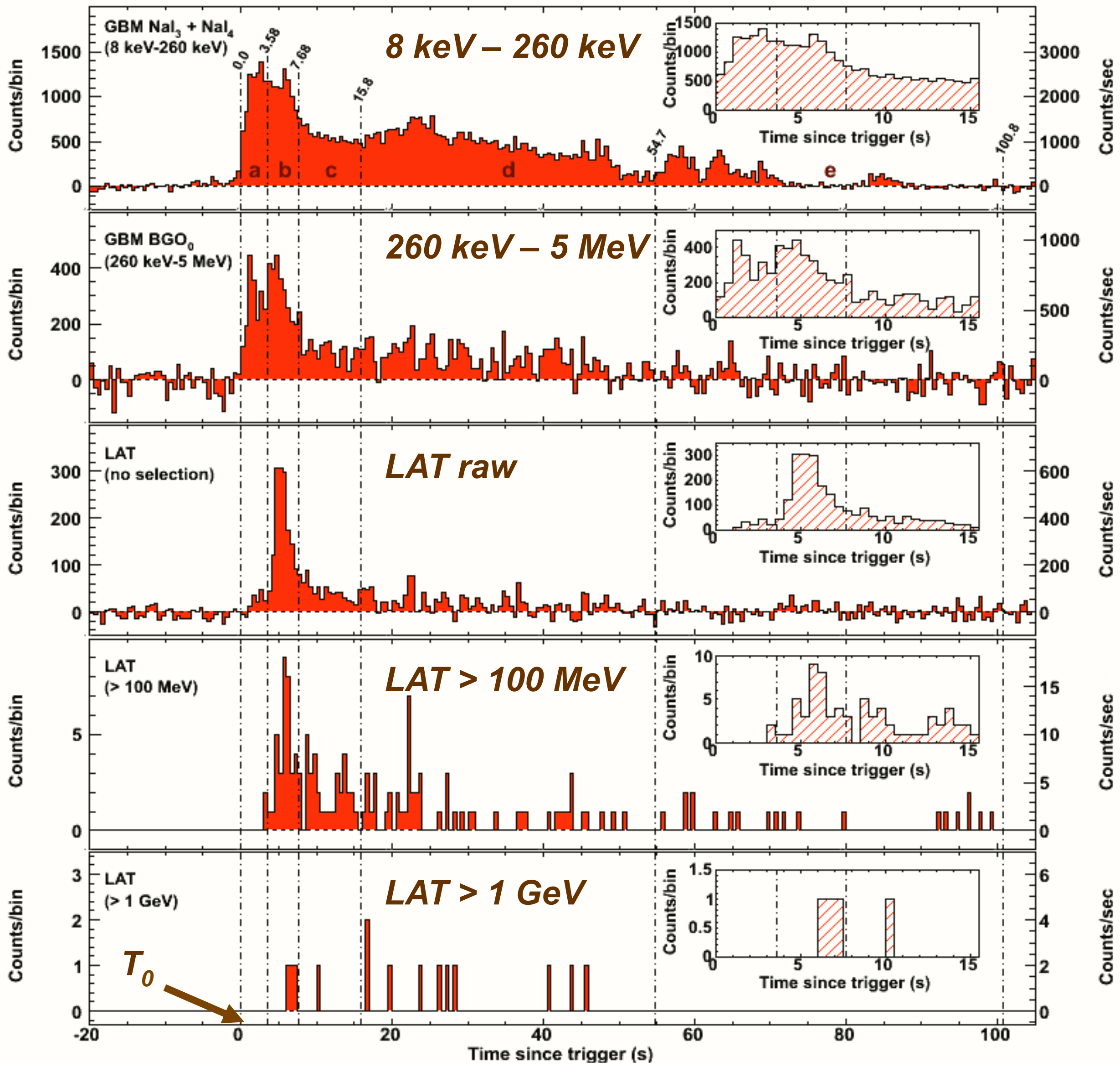
$$v = \frac{\partial E}{\partial p} \approx c\left(1 - \xi \frac{E}{E_{QG}}\right) \qquad \Delta t \approx \xi \frac{E}{E_{QG}} \frac{L}{c}$$

Amelino-Camelia et al 1998

Table 2 | Limits on Lorentz Invariance Violation

#	$t_{start} - T_0$ (ms)	Limit on $\|\Delta t\|$ (ms)	Reasoning for choice of t_{start} or limit on Δt or $\|\Delta t/\Delta E\|$	E_l † (MeV)	Valid for s_n*	Lower limit on $M_{QG,1}/M_{Planck}$
(a)✧	−30	< 859	start of any < 1 MeV emission	0.1	1	> 1.19
(b)✧	530	< 299	start of main < 1 MeV emission	0.1	1	> 3.42
(c)✧	*648*	< 181	start of main > 0.1 GeV emission	100	1	> 5.63
(d)✧	730	< 99	start of > 1 GeV emission	1000	1	> 10.0
(e)♦	—	< 10	association with < 1 MeV spike	0.1	±1	> 102
(f)♦	—	< 19	If 0.75 GeV‡ γ-ray from 1st spike	0.1	−1	> 1.33
(g)♠	$\|\Delta t/\Delta E\| < 30$ ms/GeV		lag analysis of > 1 GeV spikes	—	±1	> 1.22

GRB080916C - Multiple detector light curve



First 3 light curves are background subtracted

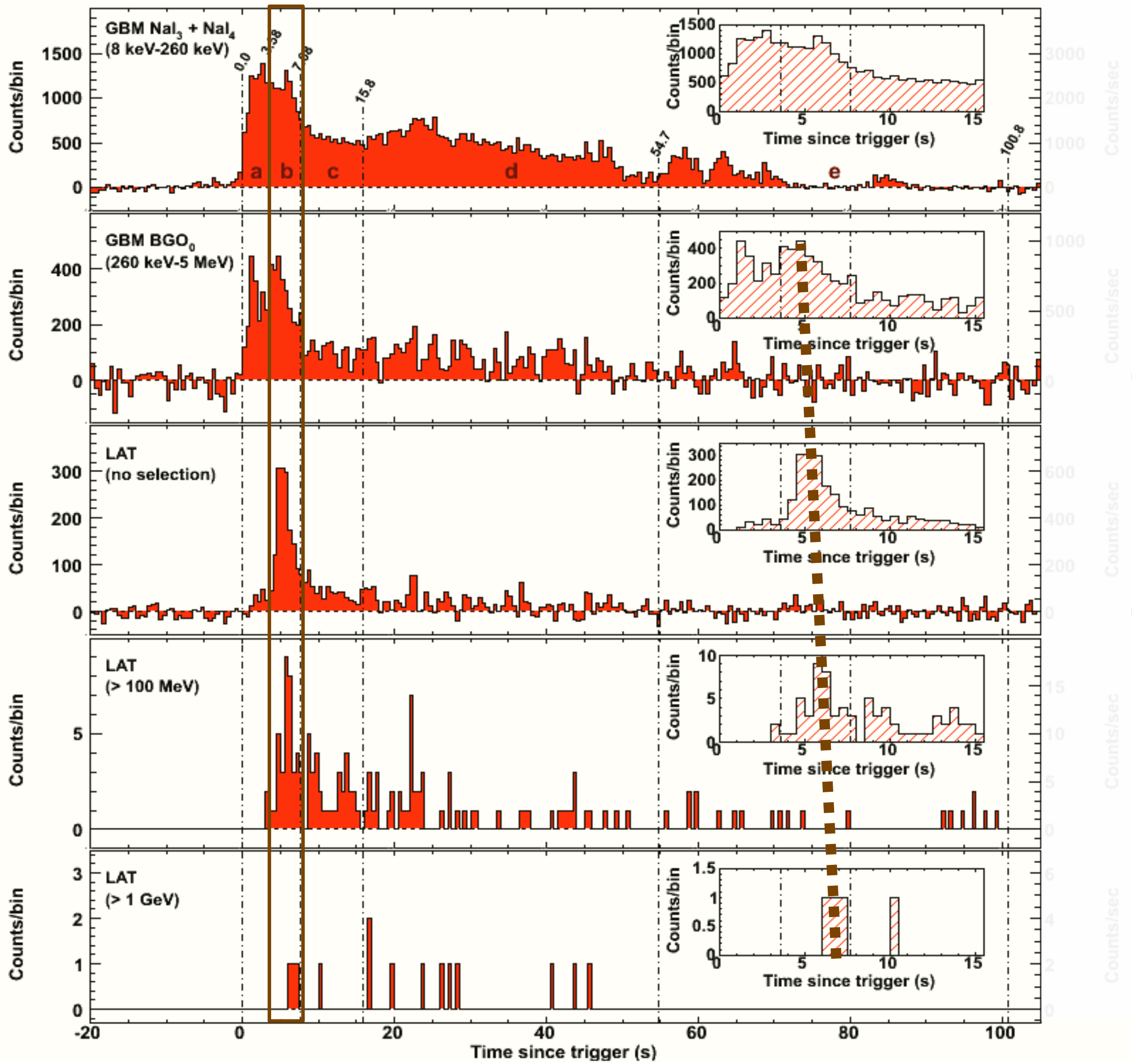
The LAT can be used as a counter to maximize the rate and to study time structures above tens of MeV

- **The first low-energy peak is not observed at LAT energies**

Spectroscopy needs LAT event selection (>100 MeV)

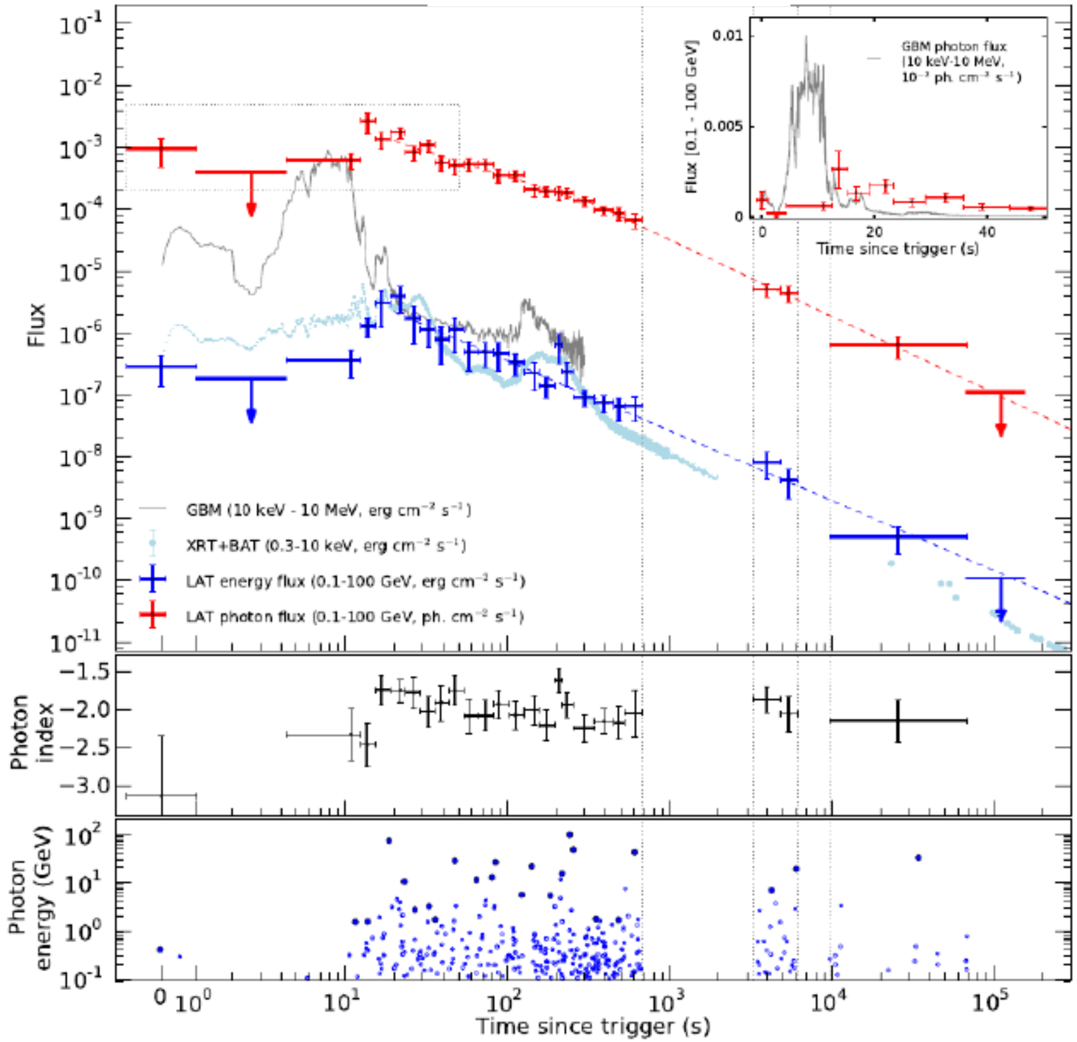
- **14 events above 1 GeV**

Multiple detector light curve



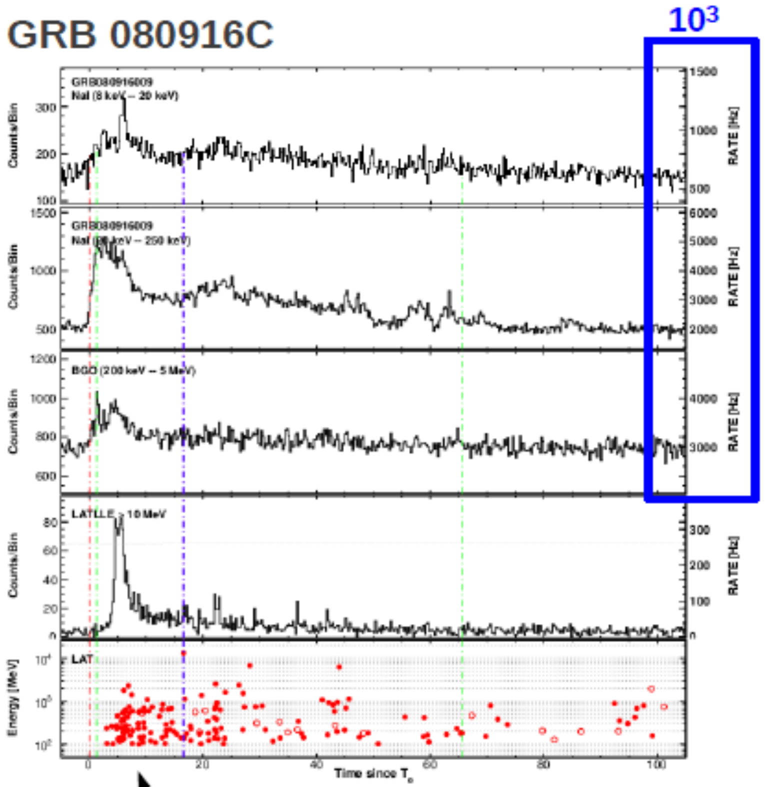
- The bulk of the emission of the 2nd peak is moving toward later times as the energy increases
- Clear signature of spectral evolution

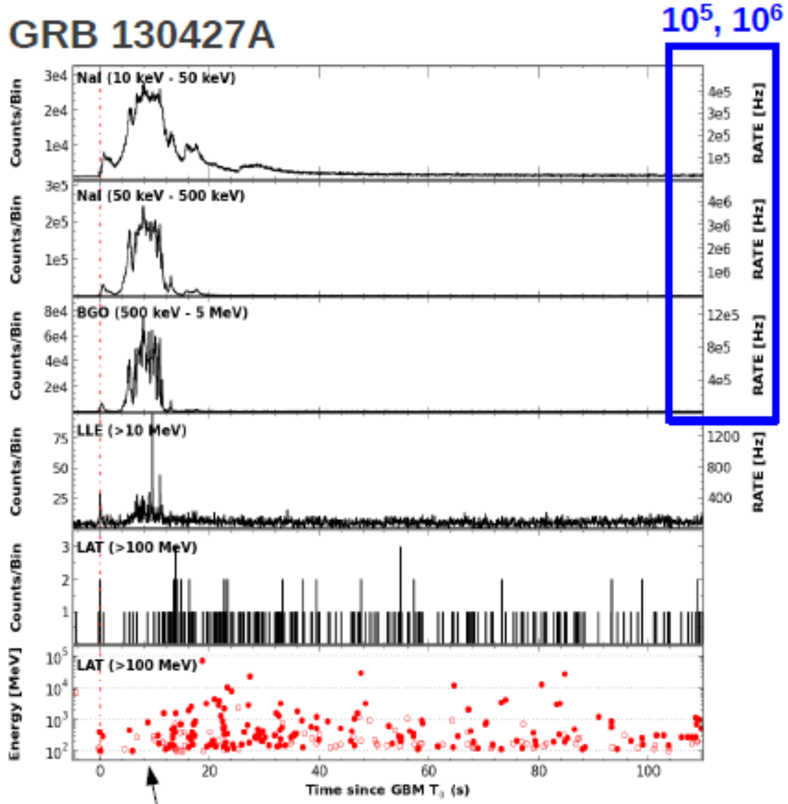
GRB 130427A



(Ackermann et al., Science, Vol. 343 no. 6166 pp. 42-47)

GRB 130427A





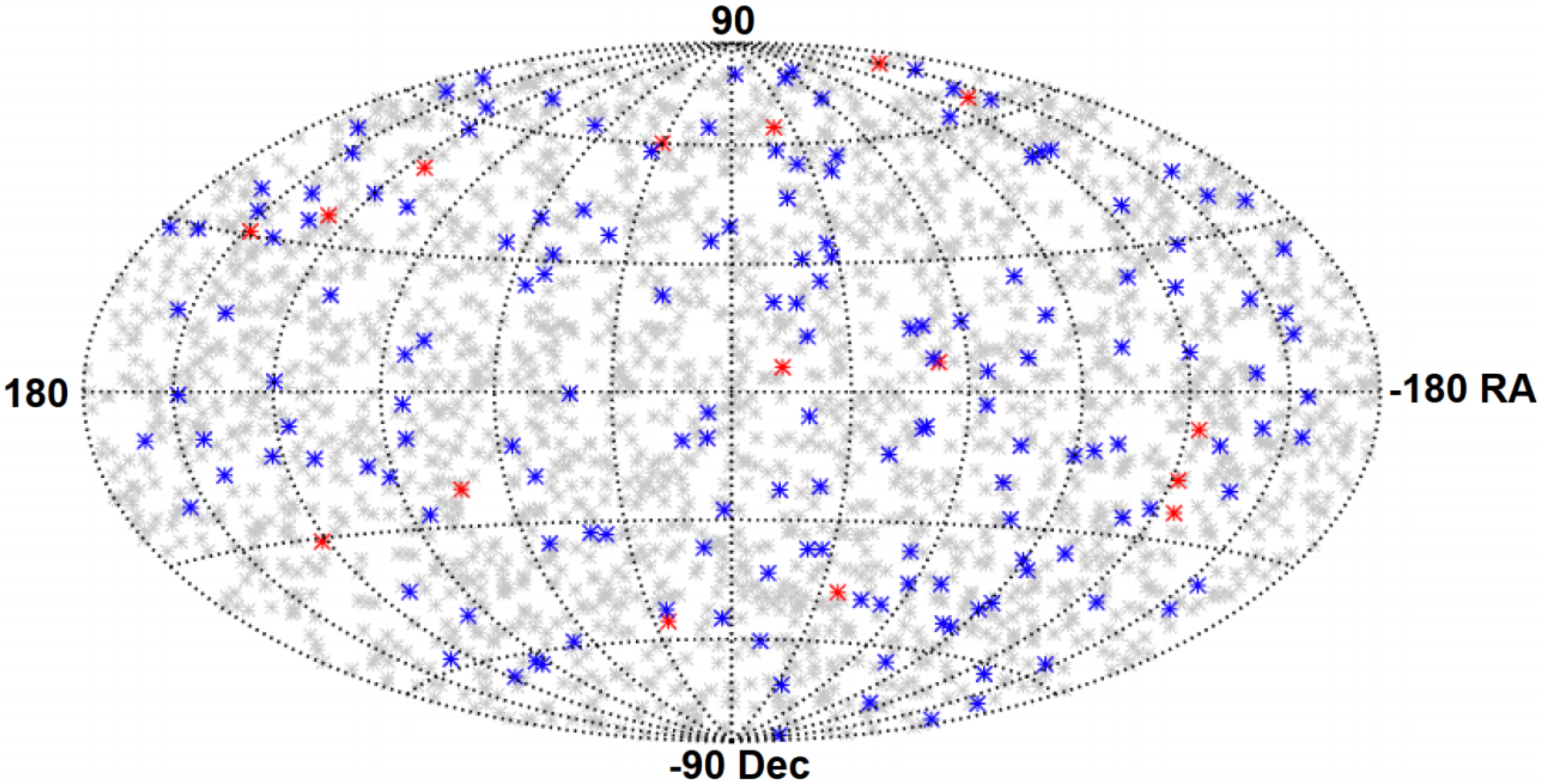
LAT emission dying down

LAT emission still going

Very little LAT emission when GBM emission is bright

LAT and GBM are bright at the same time

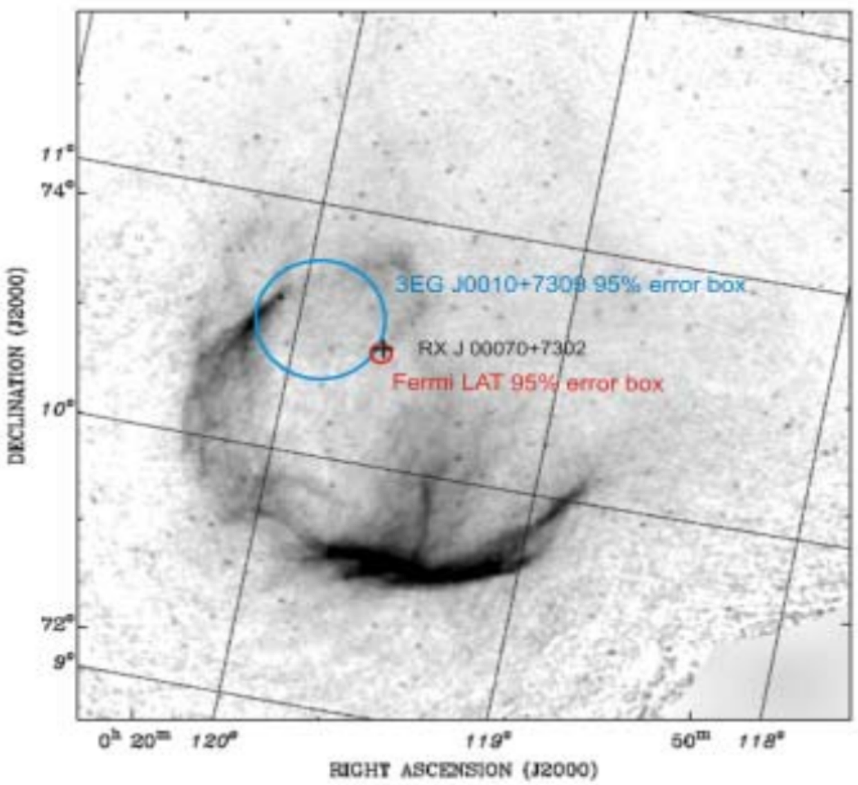
Gamma Ray Bursts

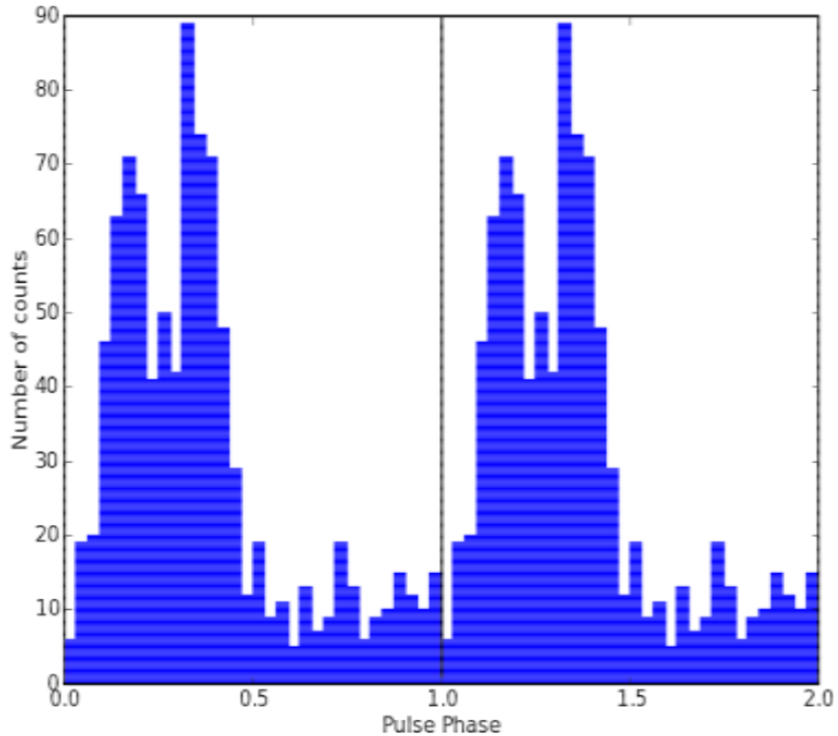


Ajello, M. et al. 2019

Challenge # 4 – Unidentified

CTA 1 Discovery

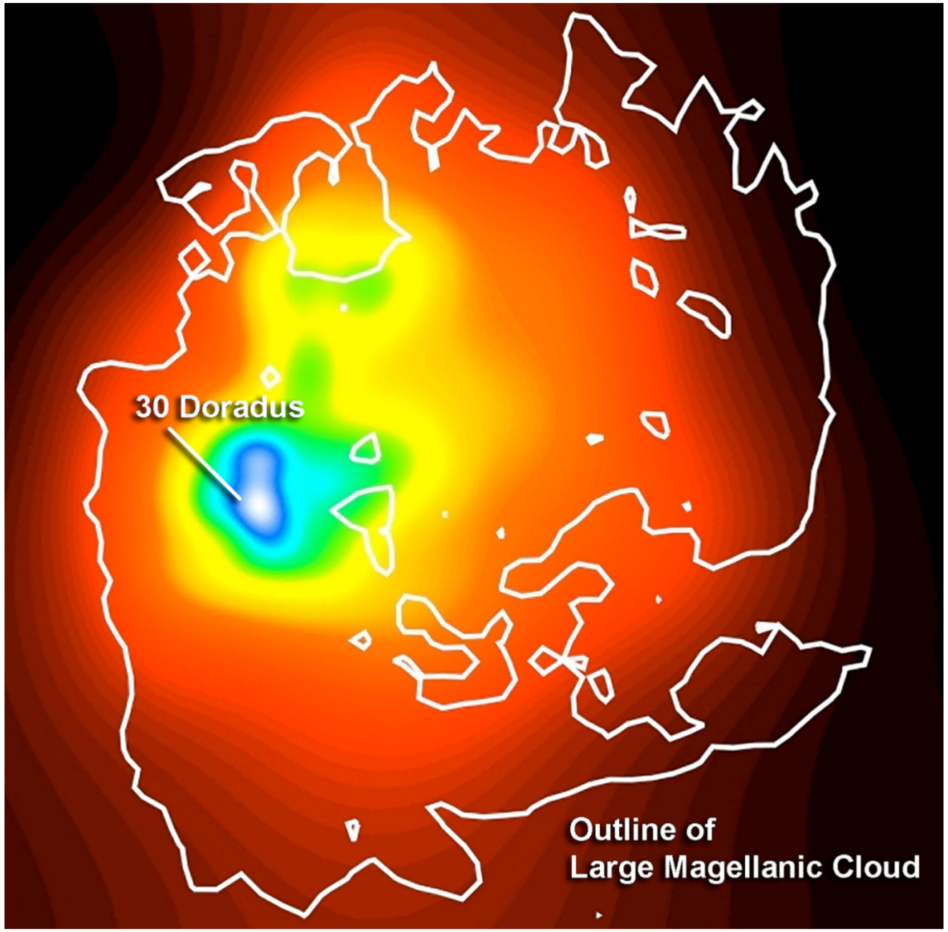




Abdo et al. 2008

Challenge # 4
Location of Gamma-ray emission

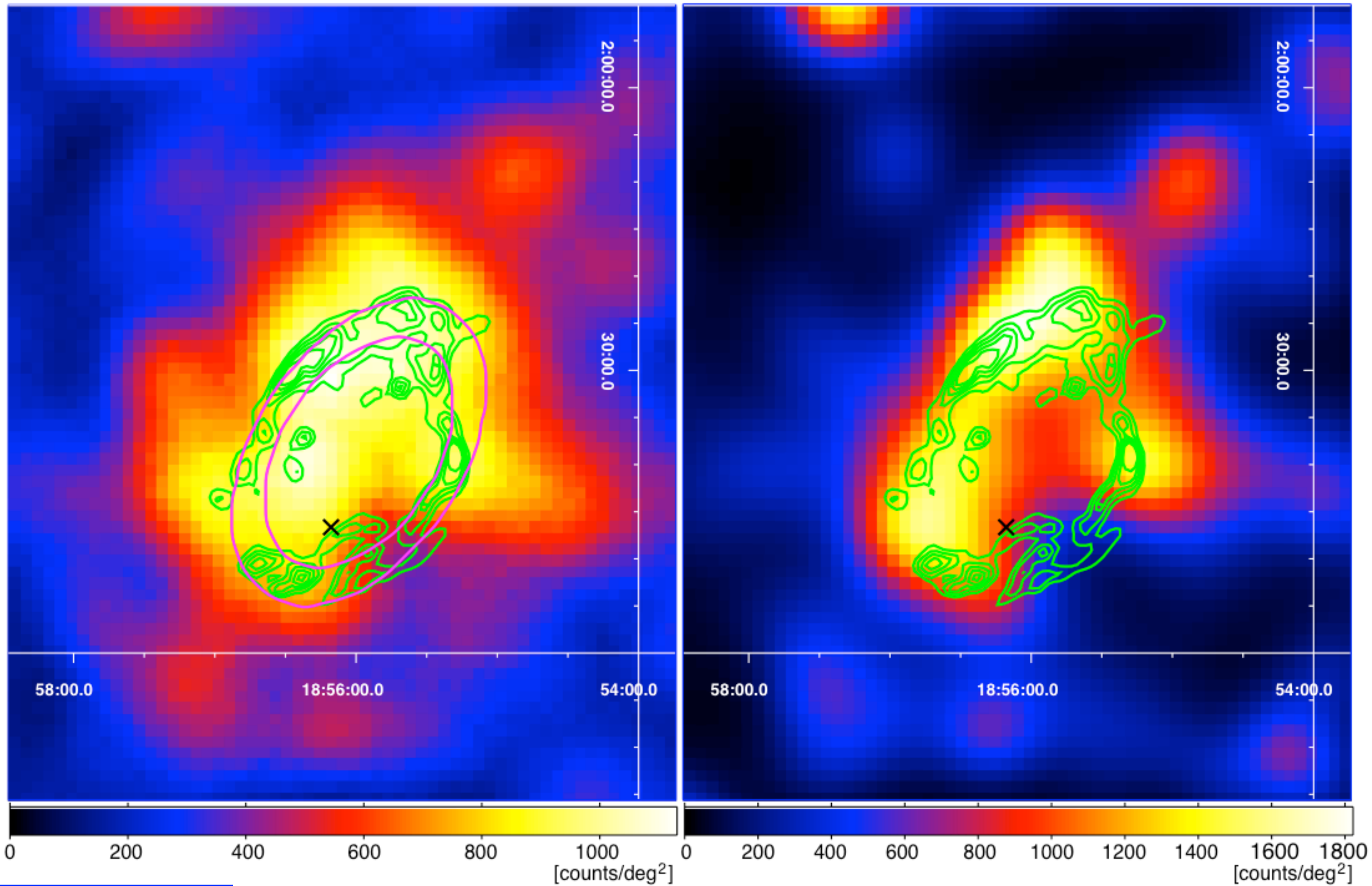
Observations of the Large Magellanic Cloud with *Fermi*



Abdo, A. A. et al. 2010

Challenge # 4
Location of Gamma-ray emission

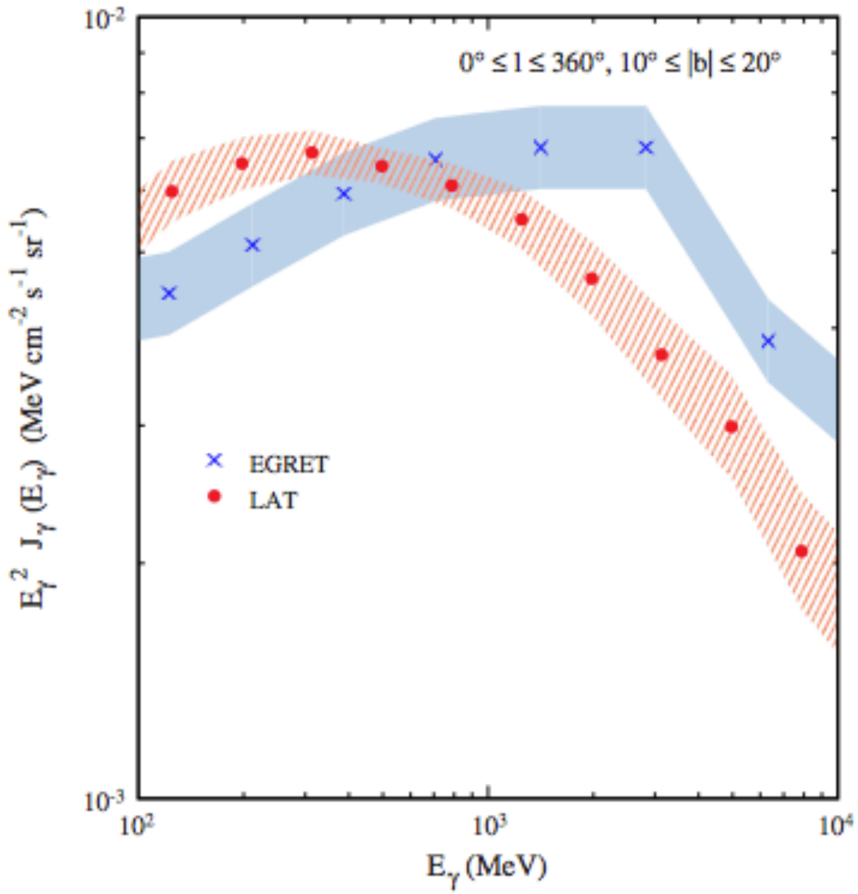
Gamma-Ray Emission from the Shell of Supernova Remnant W44 Revealed by the Fermi LAT

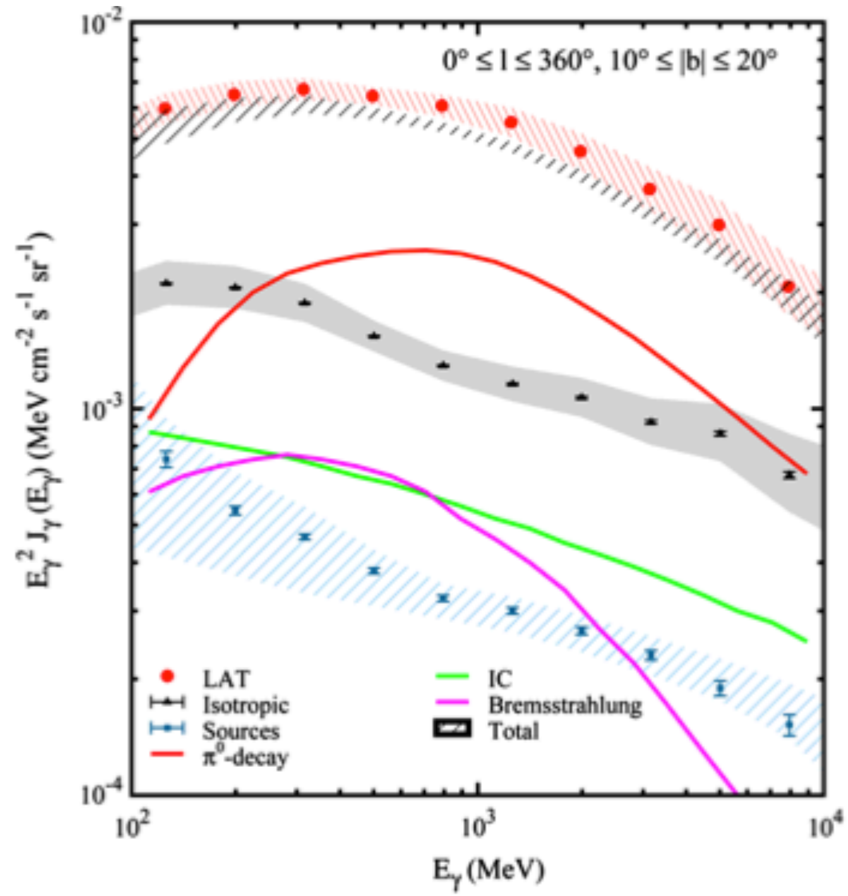


Abdo, A. A. et al. 2010

Challenge # 5 – Spectral Resolution

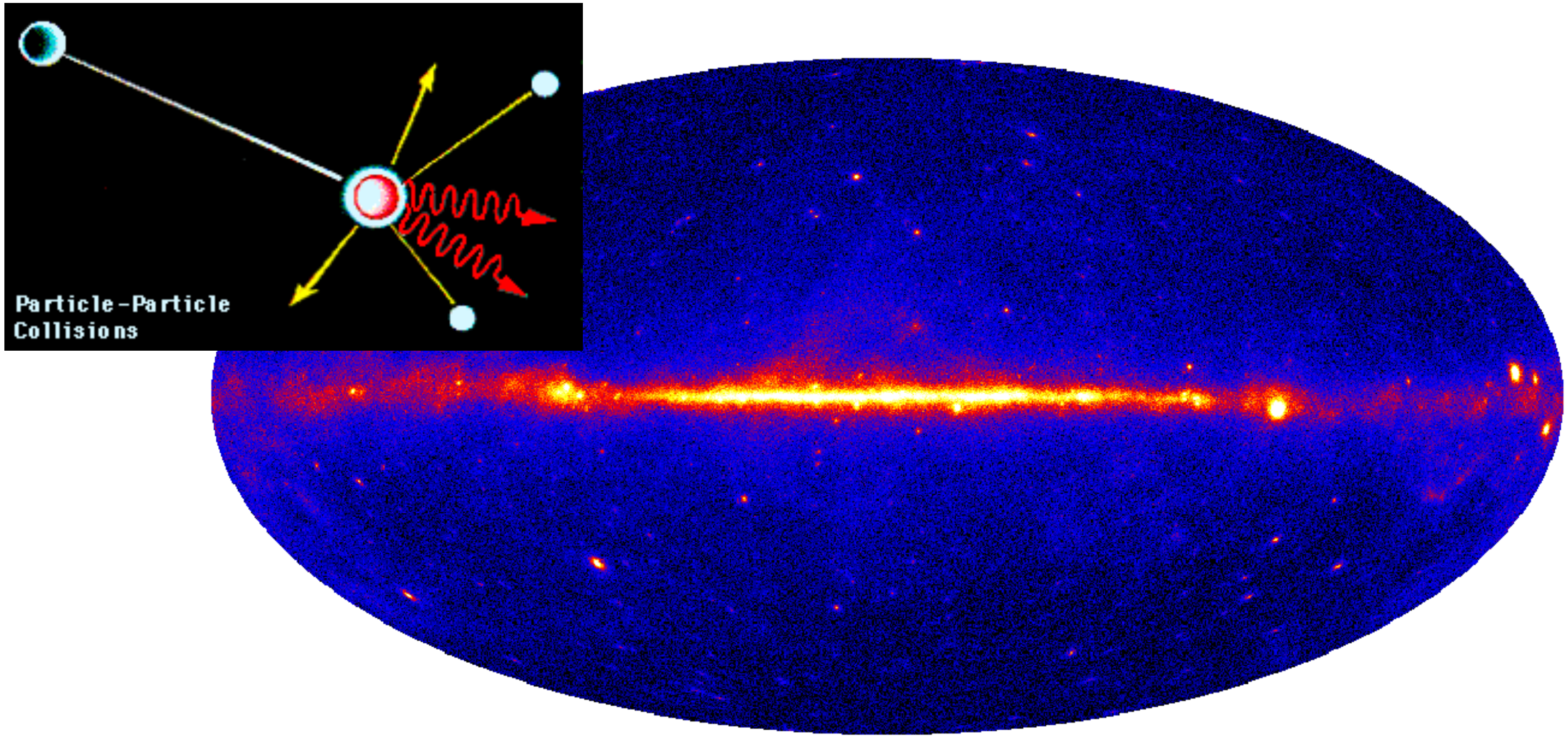
Fermi Large Area Telescope Measurements of the Diffuse Gamma-Ray Emission at Intermediate Galactic Latitudes





Abdo, A. A. et al. 2009

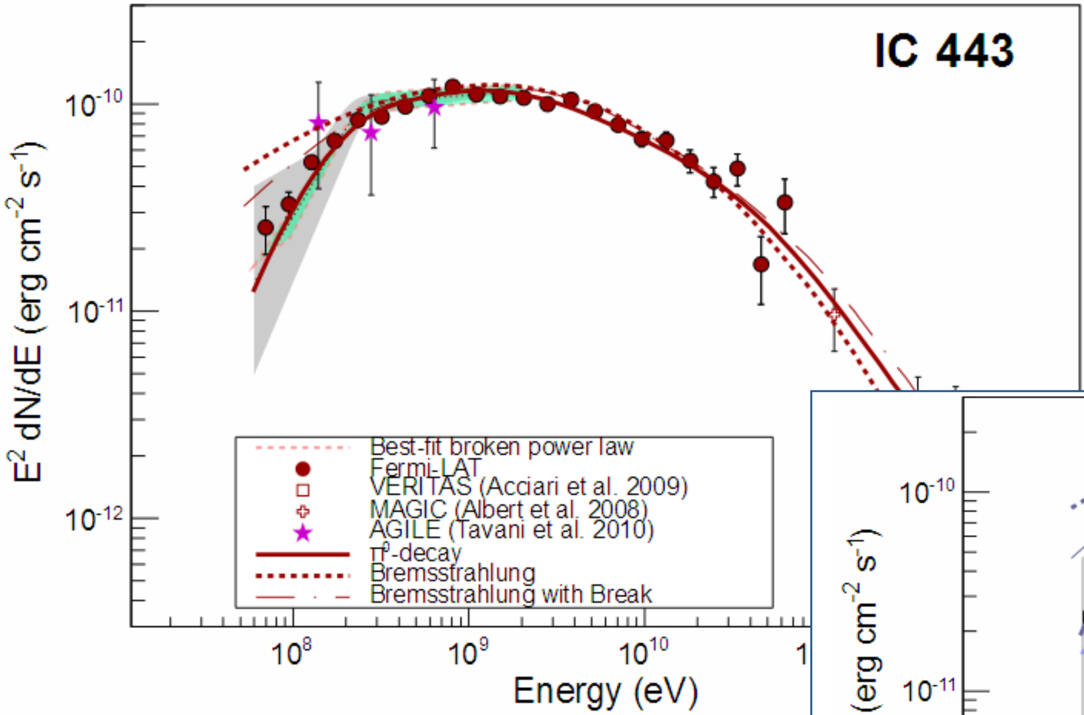
Cosmic Rays – Gamma-rays connection

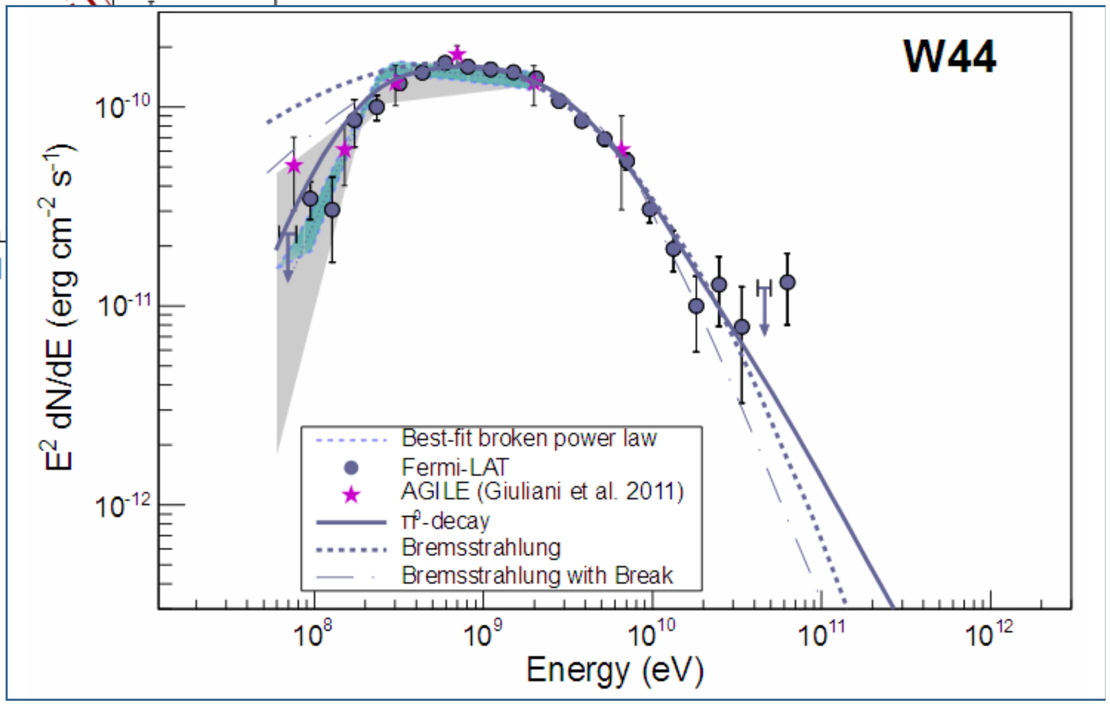


- **Galactic gamma rays trace cosmic-ray proton interactions (cosmic-ray acceleration sites & propagation)**
- **Observations of nearby galaxies provide an outside view**
- **Primary targets: galactic plane, starburst galaxies, LMC, SNR**
- **Direct CR observations**

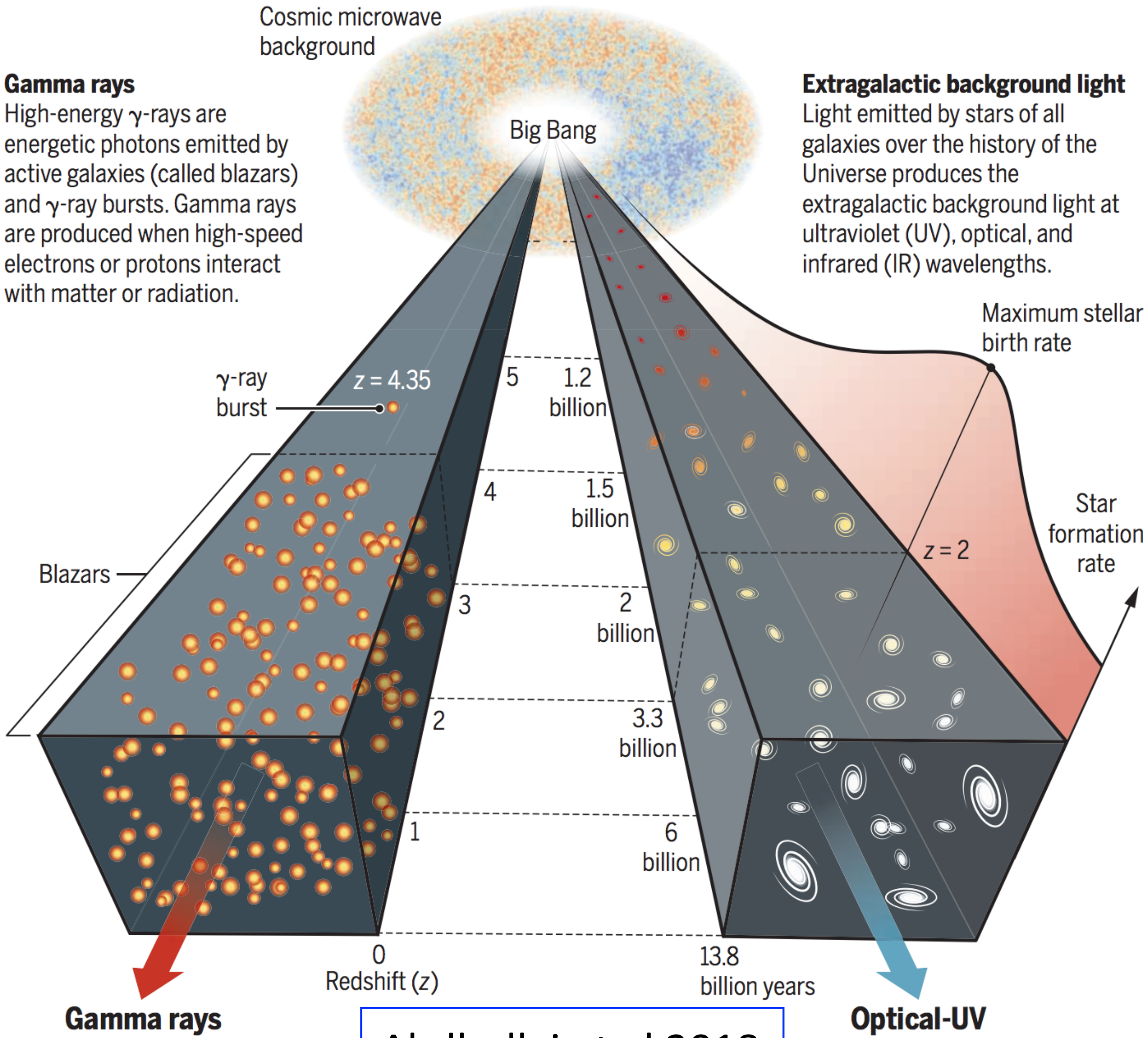
Supernova Remnants

Ackermann et al. 2013



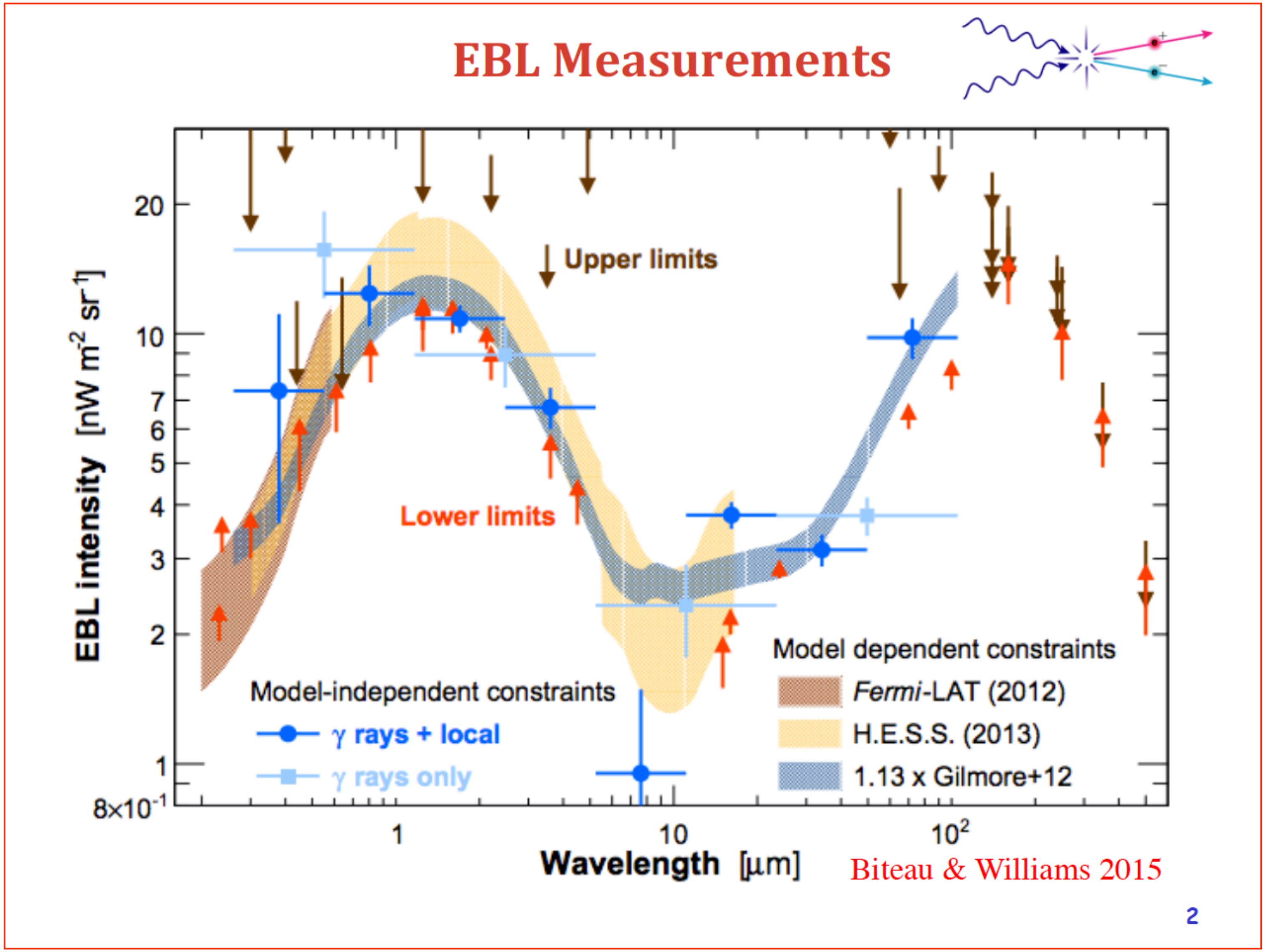


The EBL



Abdhollai et al 2018

The Extragalactic Background Light



Dark Matter Searches

Gamma-ray indirect emission

Galactic Center

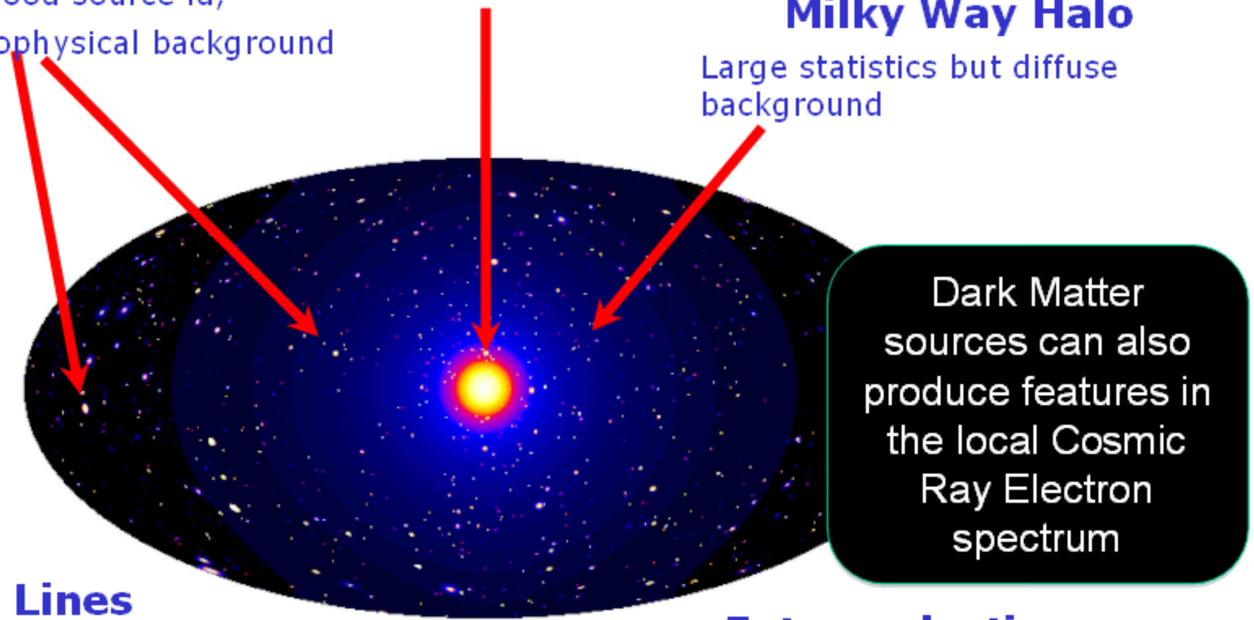
Good Statistics but source confusion/diffuse background

Satellites

Low background and good source id, but low statistics, astrophysical background

Milky Way Halo

Large statistics but diffuse background



All-sky map of simulated gamma ray signal from DM annihilation (Baltz 2006)

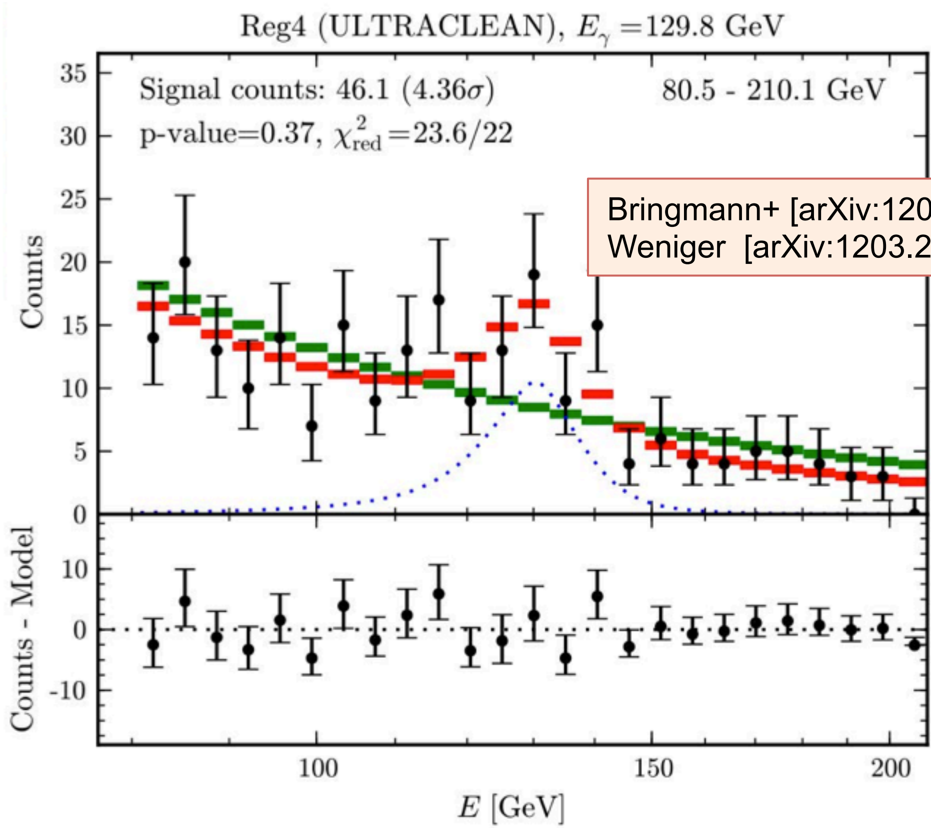
Spectral Lines

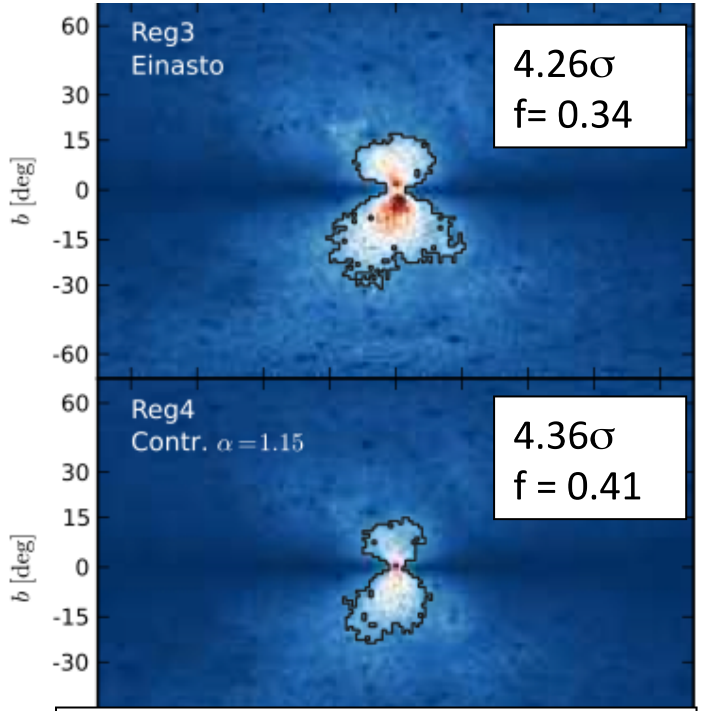
No astrophysical uncertainties, good source id, but low sensitivity because of expected small BR

Extra-galactic

Large statistics, but astrophysics, galactic diffuse background

Narrow Spectral Feature at 130 GeV



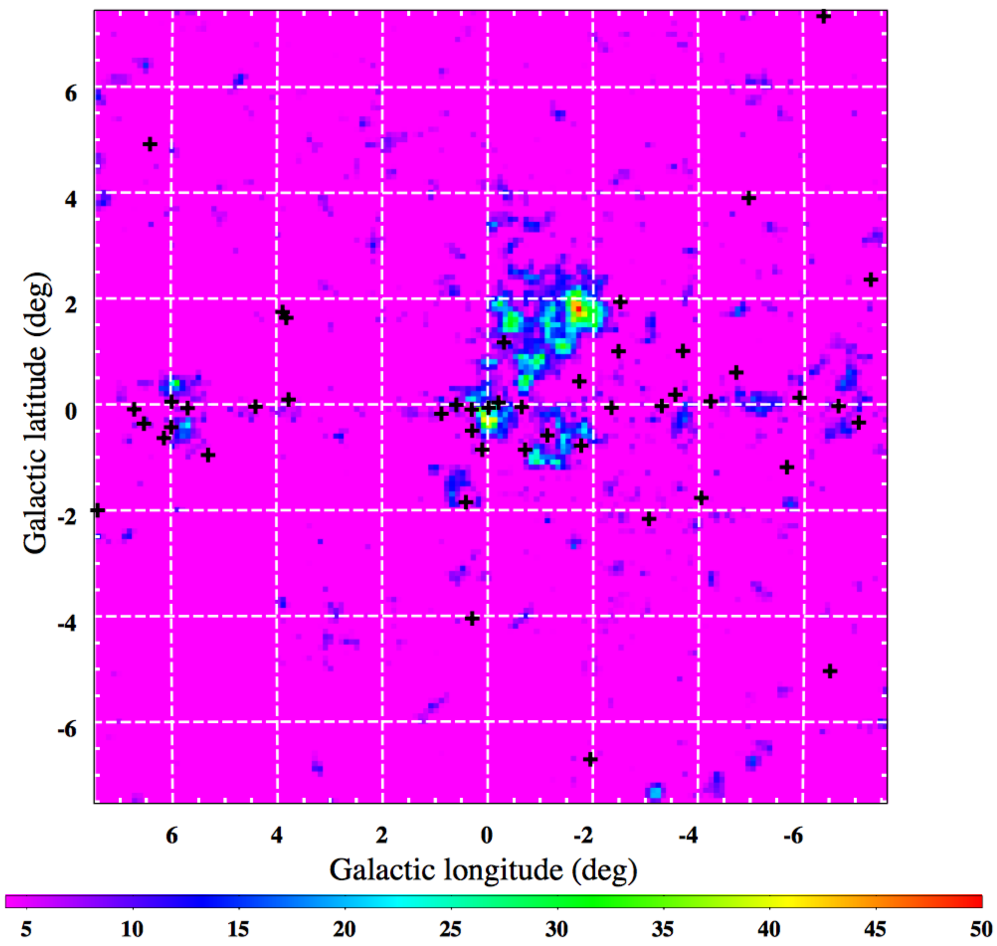


Fractional Residual (i.e., S/N):
$f = s^2 / n_s$

Bringmann et al. and Weniger showed evidence for a narrow spectral feature near 130 GeV near the Galactic center (GC) in the LAT data.

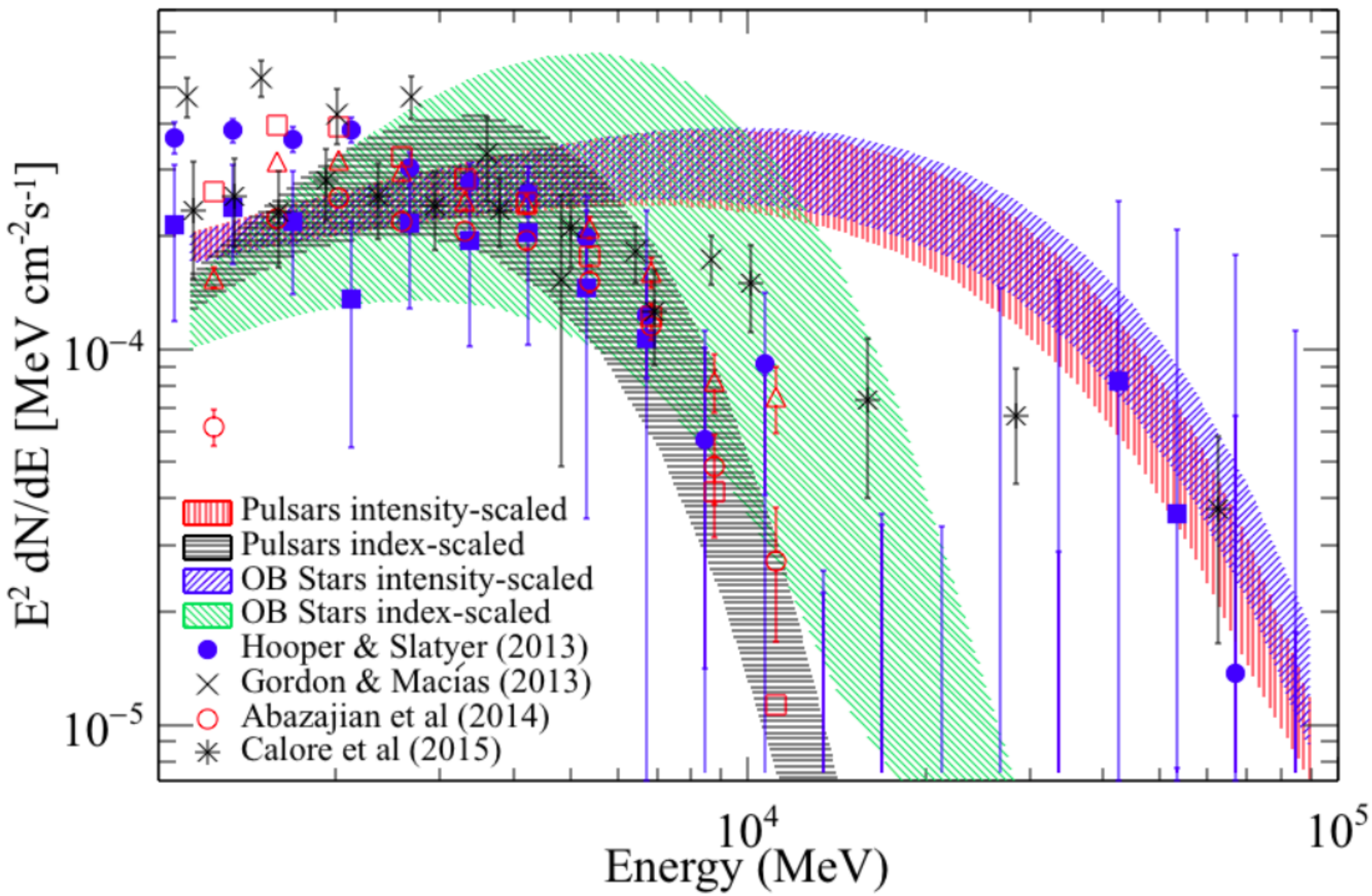
- Signal is particularly strong in 2 out of 5 test regions, shown above.
- Over 4σ local significance with S/N > 30%, up to ~60% in optimized ROI.
- Some indication of double line (111 &130 GeV).

Dark Matter searches – Galactic Center



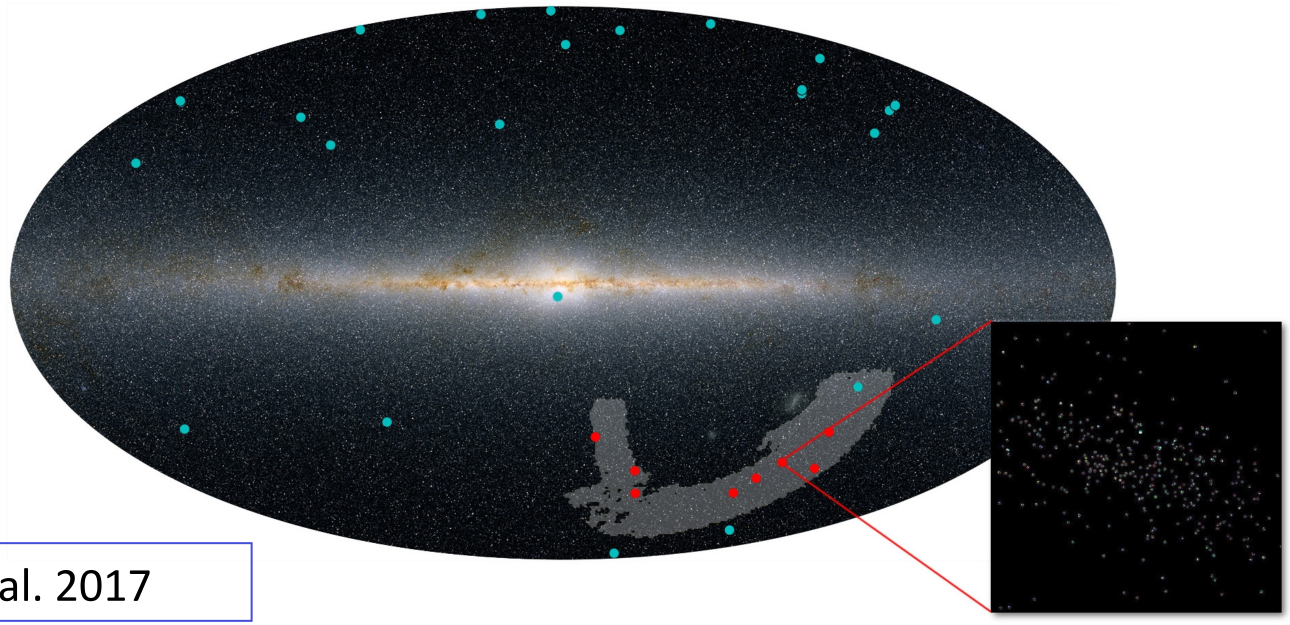
Ackermann, M. et al. 2017

Dark Matter searches – GC

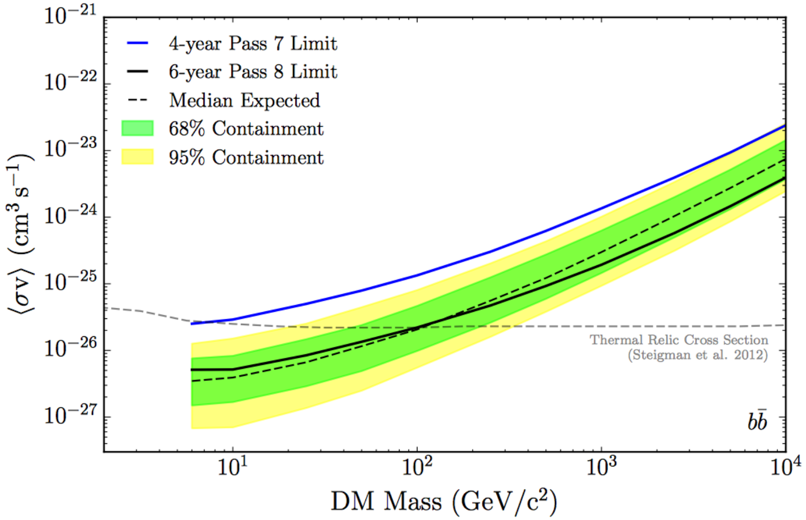


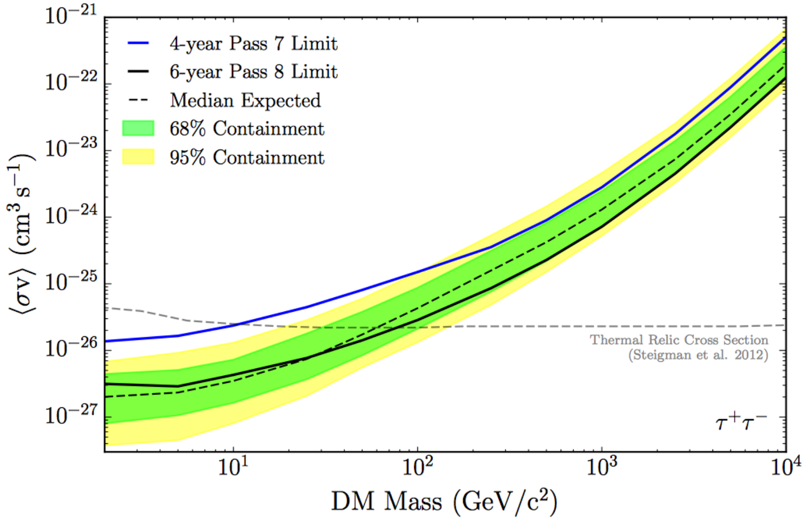
Ackermann, M. et al. 2017

Dark Matter searches – Dwarfs Galaxies



Albert, A. et al. 2017





How the LAT detects electrons

Trigger and downlink

Very versatile and configurable

- Triggering on ~ all particles that cross the LAT
  - Including electrons (8M/yr)

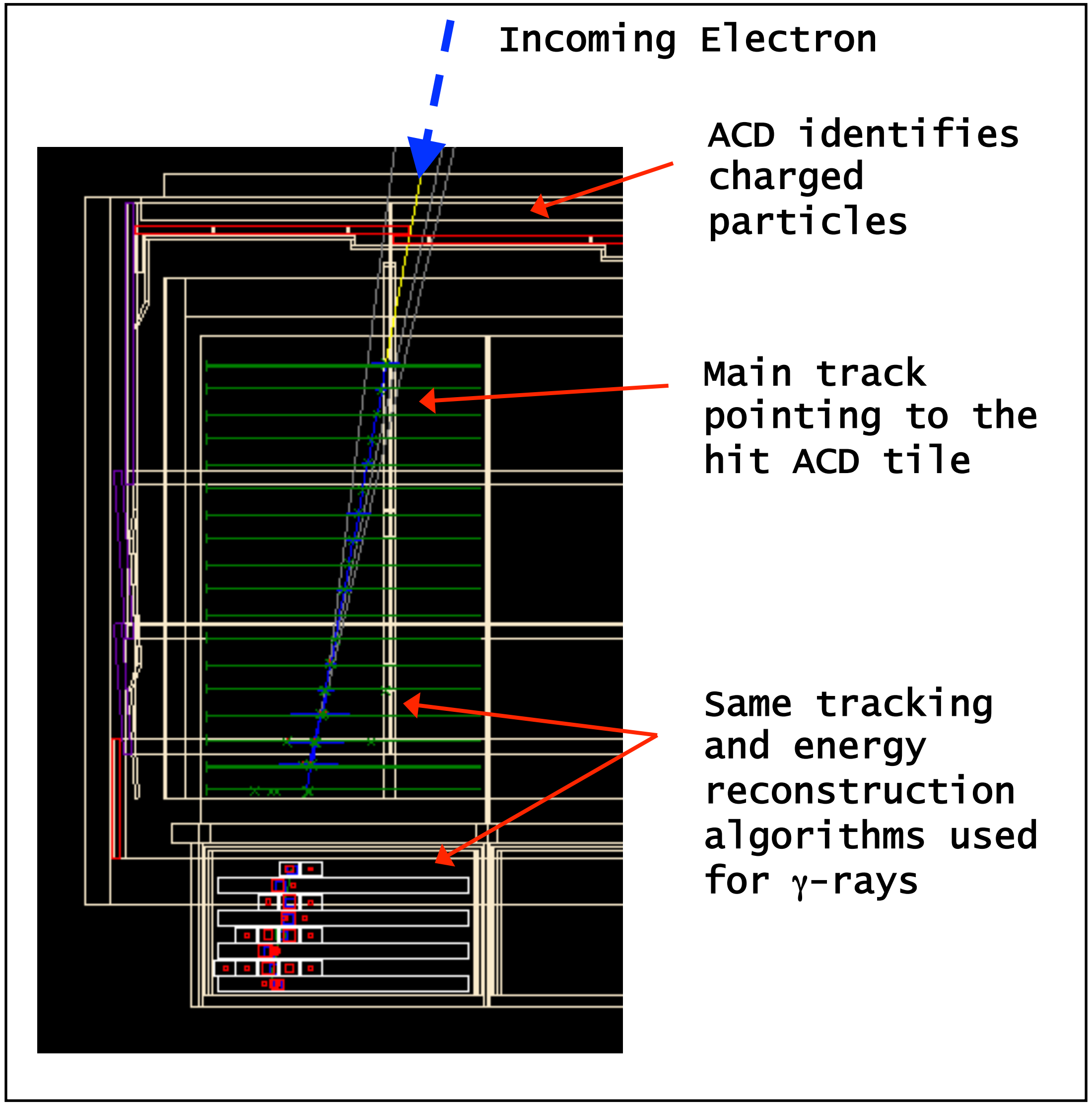
On board filtering to fit bandwidth

- Remove many charged particles
- Keeps all events with more than 20 GeV in the CAL (HE)
- Prescaled (1:250) sample of unfiltered triggers (LE)

Electron identification

The challenge is identifying the good electrons among the proton background

- Rejection power of $10^3 - 10^4$ required
- Can not separate electrons from positrons
- → Dedicated high energy electron event selection



Importance of a direct CRE measurement

- Probe CR models
  - Sources (including DM), interactions, propagation, diffusion
- Probe CR targets (ISM, ISRF)
  - Propagation and diffusion
  - Strong connection with diffuse gamma-ray radiation
- Probe possible nearby sources
  - limited electron lifetime within Galaxy
- Answers to long-standing questions and vast literature

THE ASTROPHYSICAL JOURNAL, 162:L181–L186, December 1970

PULSARS AND VERY HIGH-ENERGY COSMIC-RAY ELECTRONS

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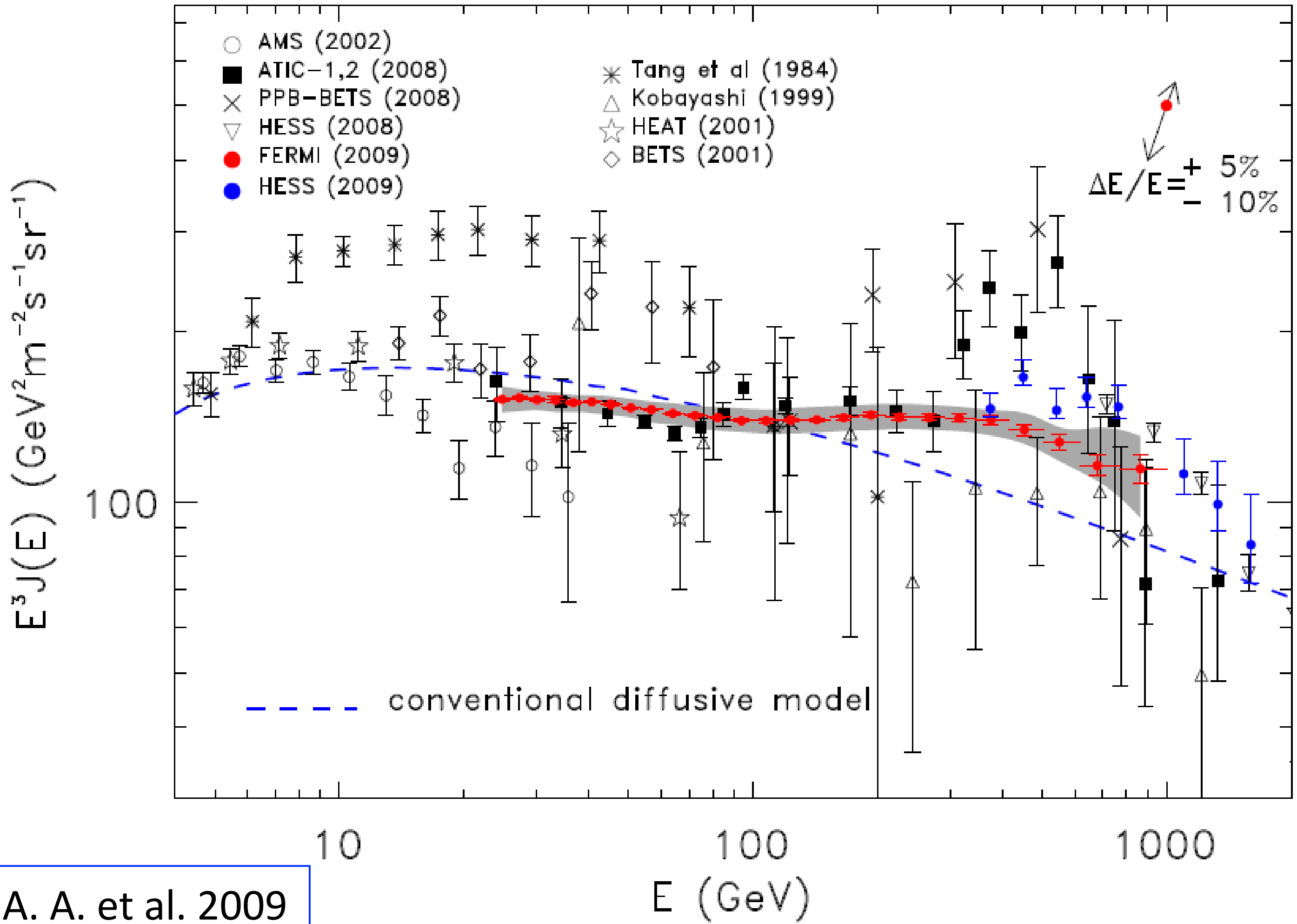
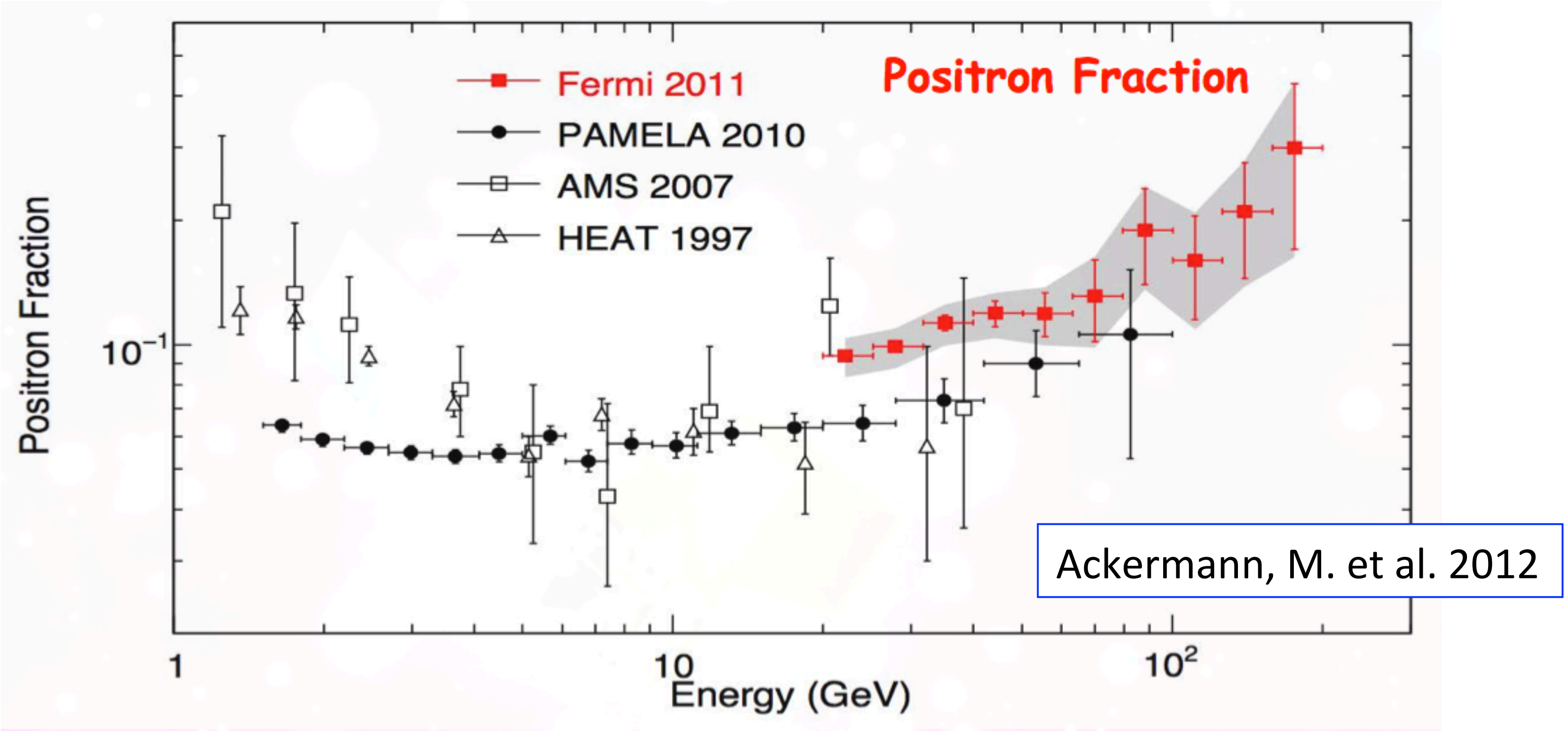
PRL **102,** 181101 (2009) PHYSICAL REVIEW LETTERS week ending 8 MAY 2009

Measurement of the Cosmic Ray $e^+ + e^-$ Spectrum from 20 GeV to 1 TeV with the Fermi Large Area Telescope



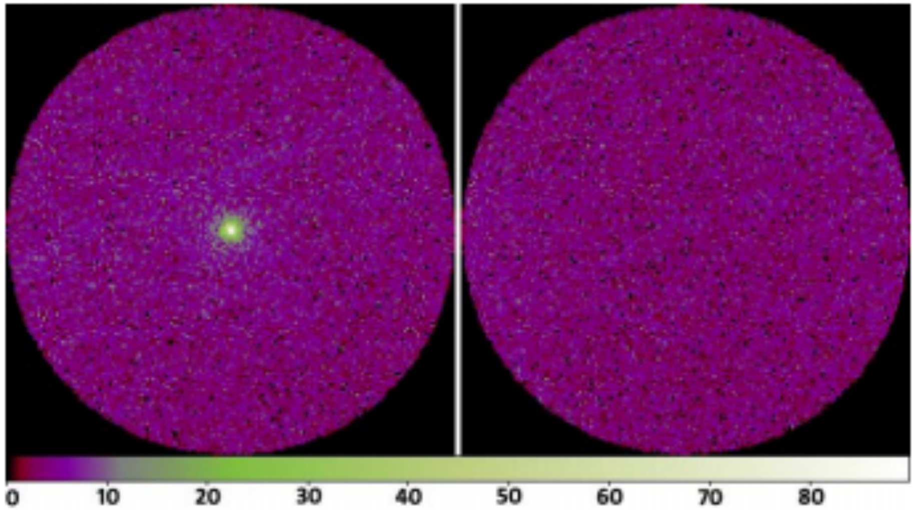
Abdo, A. A. et al. 2009

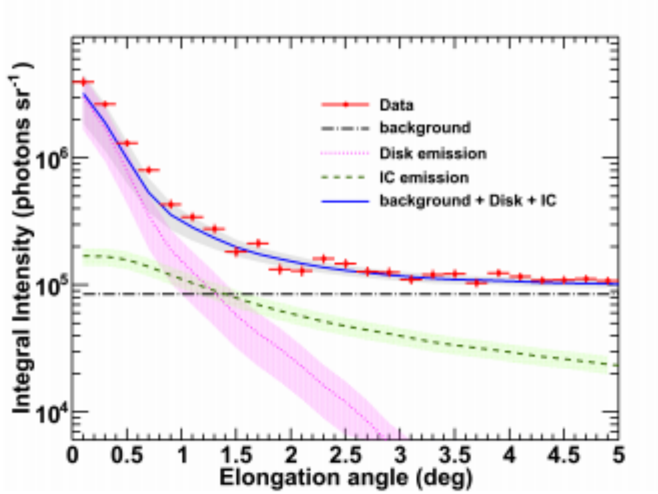
Positron Fraction Measurements

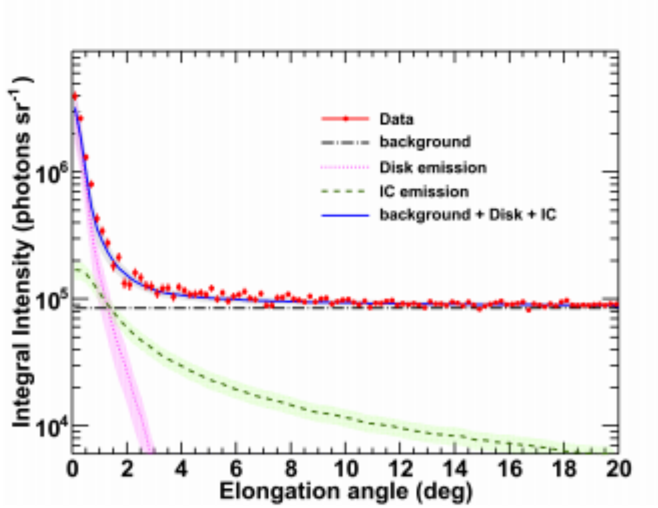


- PAMELA and Fermi-LAT observe a rise in local e^+ fraction above ~10 GeV
- This disagrees with conventional models (e.g., GALPROP) for cosmic rays (secondary e^+ production only)
- No similar rise is seen in anti-proton fraction

The Quiet Sun

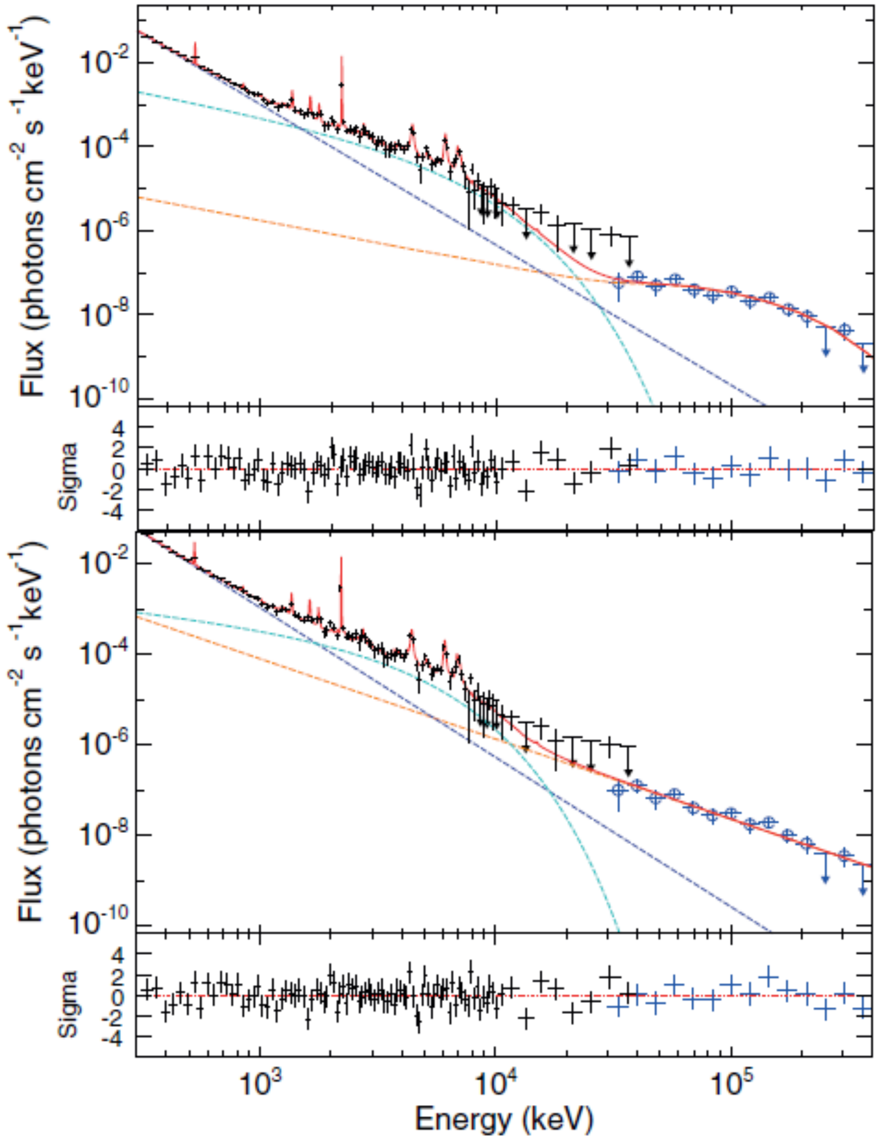






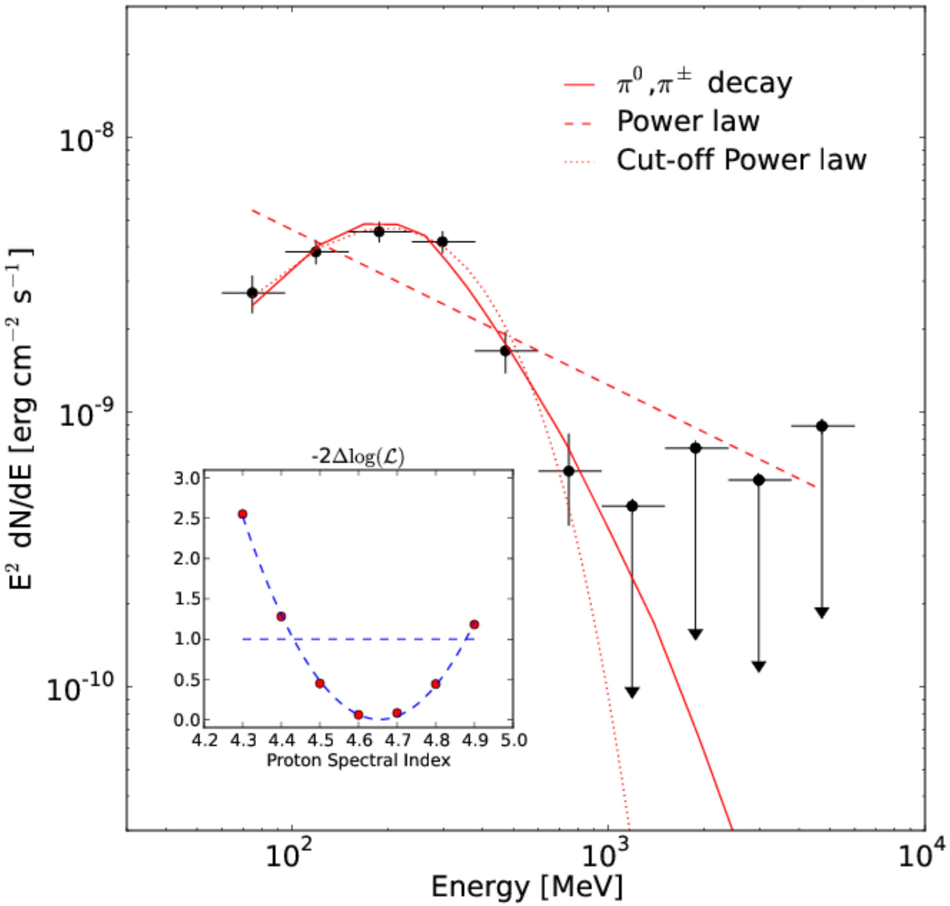
Abdo, A. A. et al. 2011

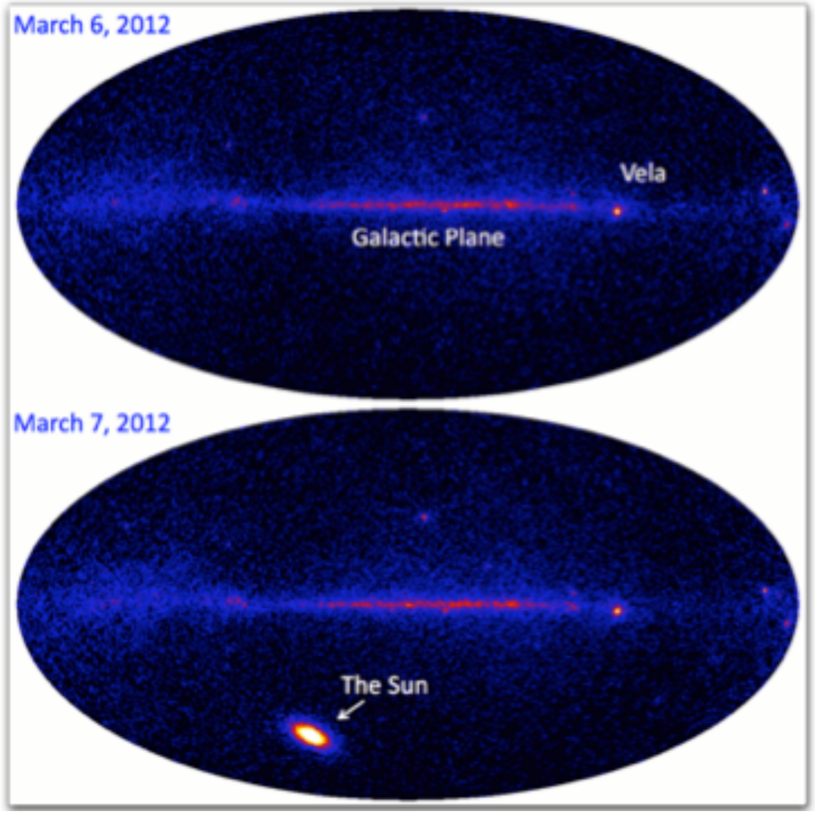
Challenge #5: Flaring Sun



Ackermann, M. et al 2012

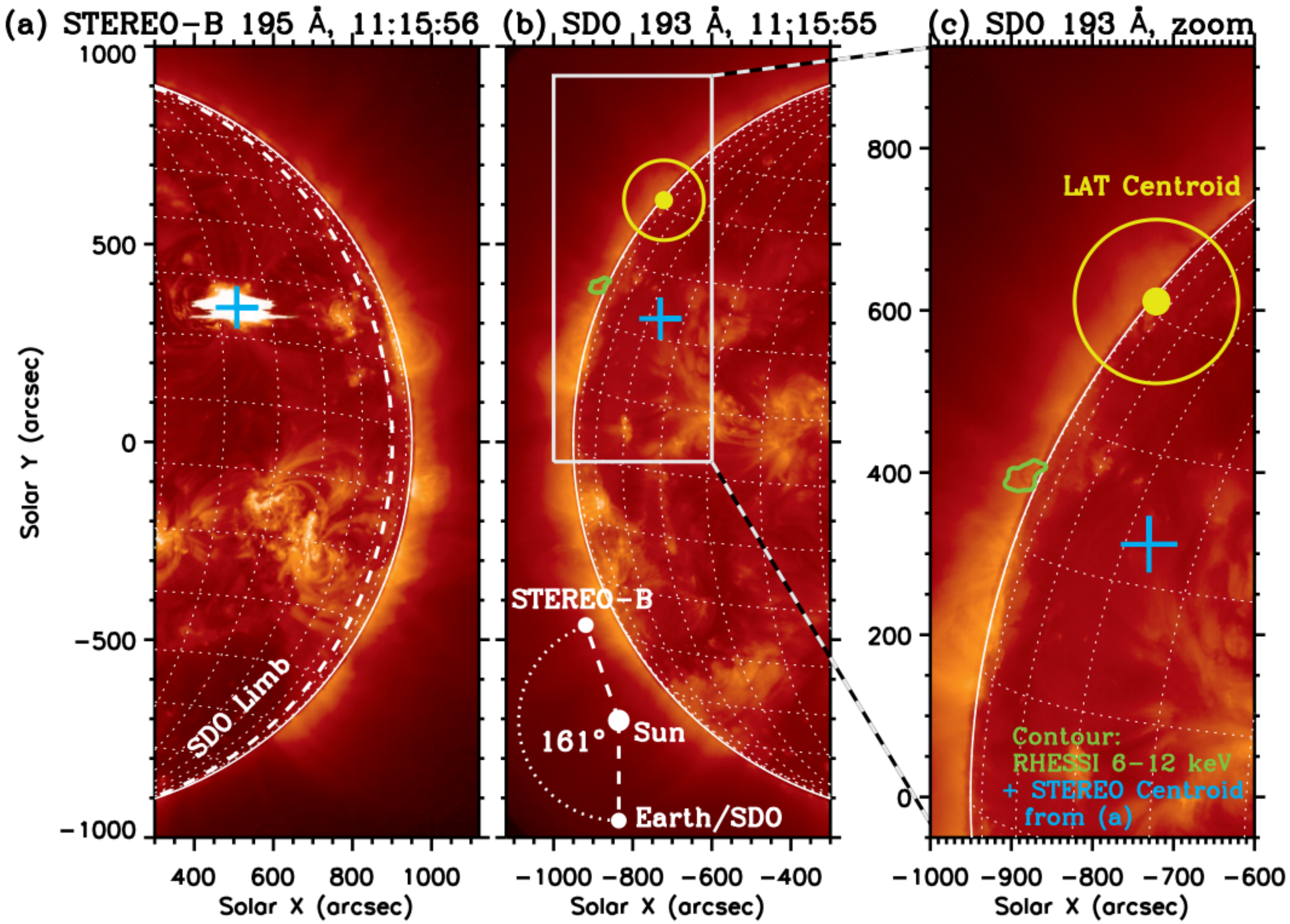
Solar Flares





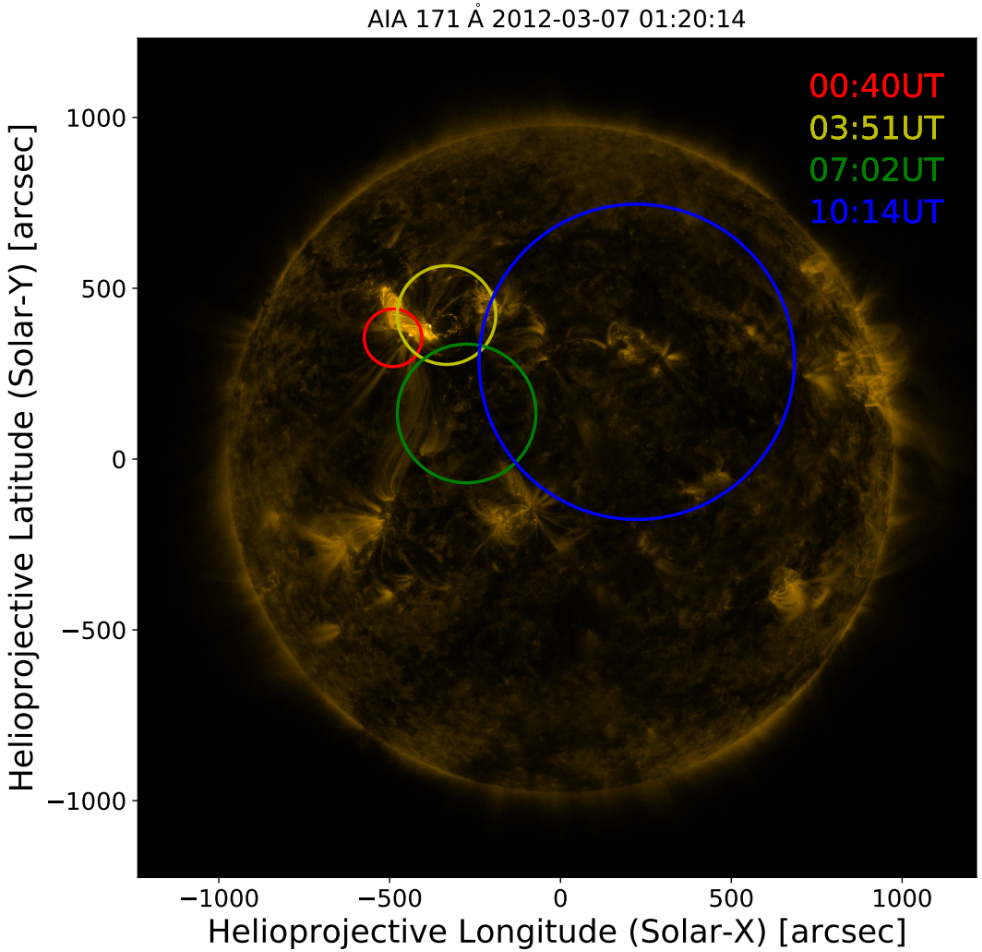
Ajello, M. et al. 2014

Solar Flares



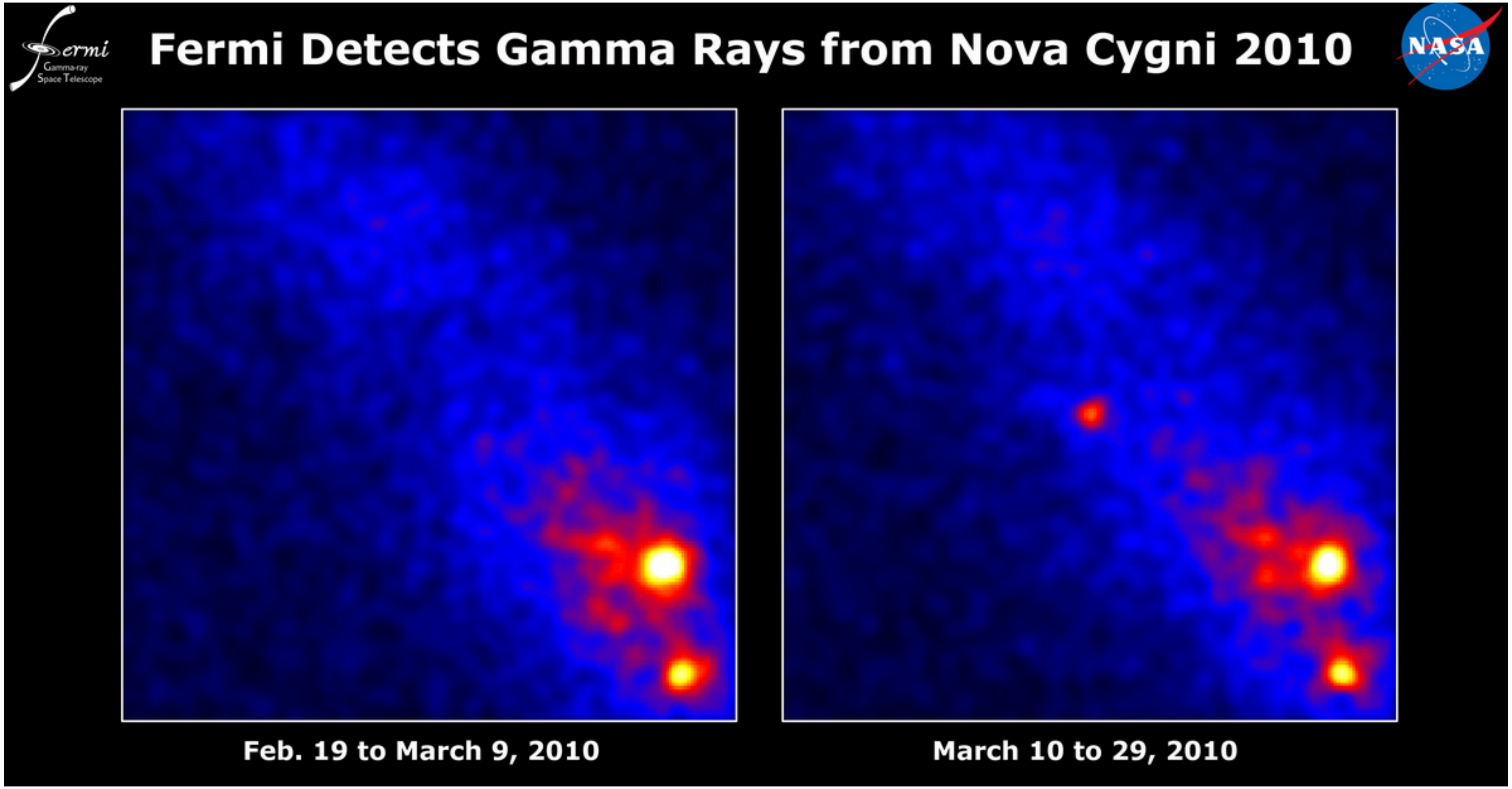
Ackermann M et al, 2017

Solar Flares



Ajello, M. et al. 2021

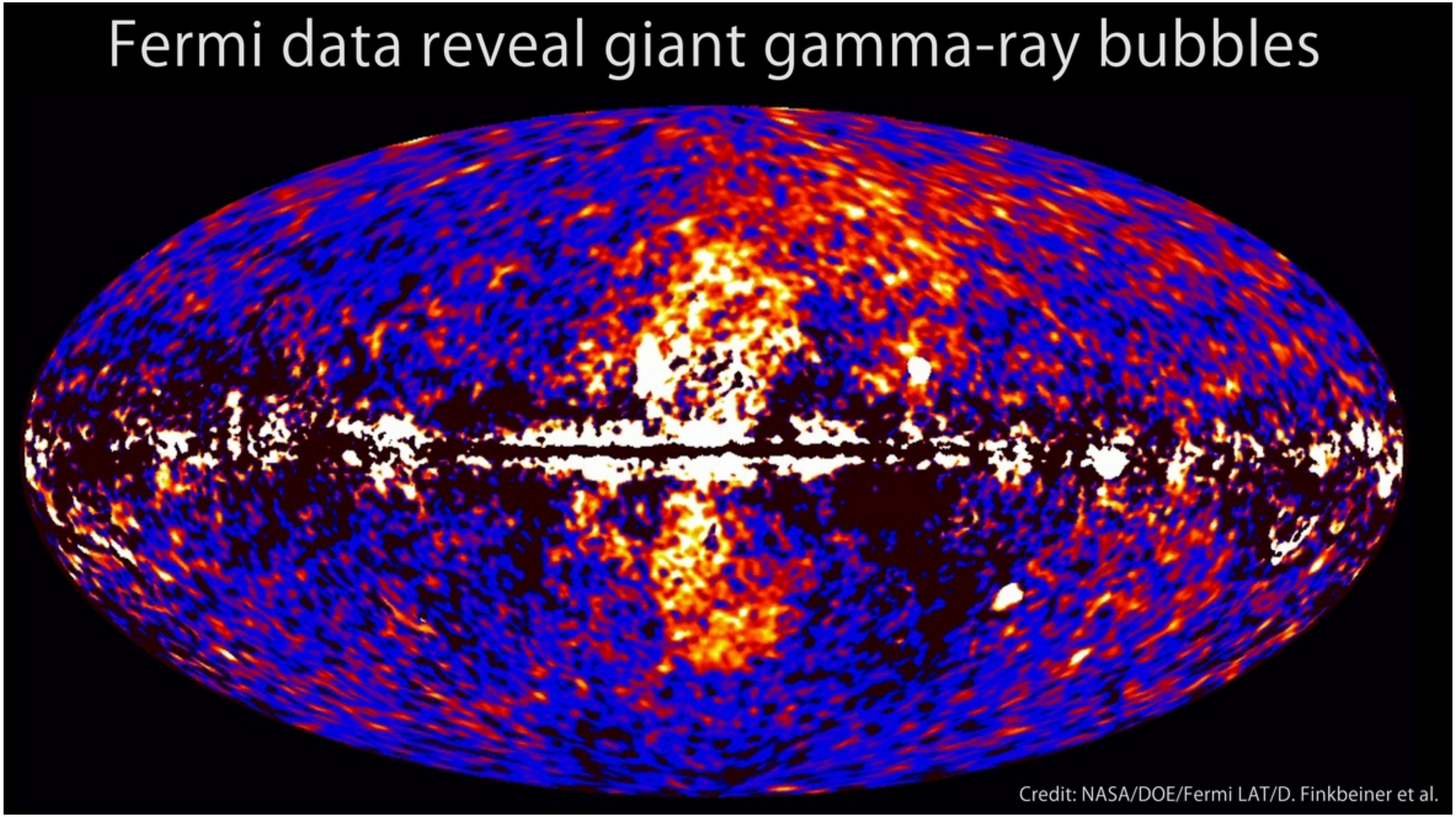
Surprise! Nova emitting in Gamma Rays!



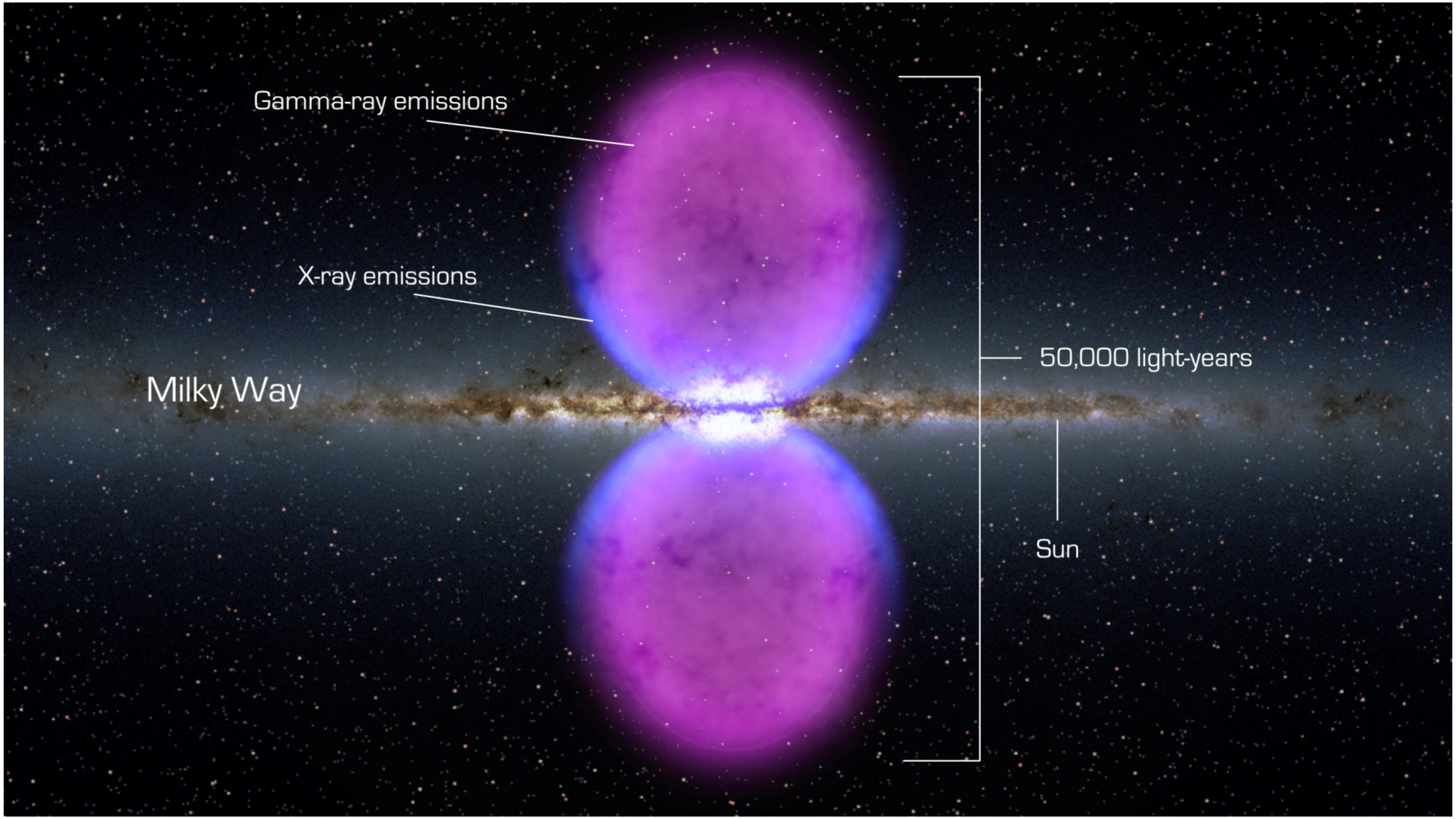
Abdo, A. A. et al. 2010

Gamma Ray Novae

Surprise! The Fermi Bubbles



Fermi bubbles



LAT team analysis: Ackermann, M. et al. 2017