

National Aeronautics and Space Administration



Fermi

Gamma-ray Space Telescope



www.nasa.gov/fermi

Fermi LAT

--≡ Gruppo 2 ≡--

Denis Bastieri
Sara Buson
Giovanna Pivato
Riccardo Rando

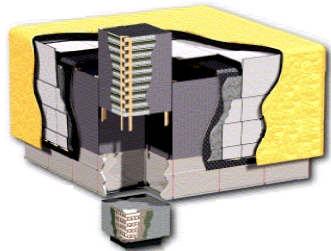
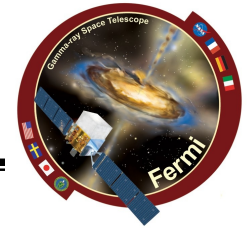
The Fermi observatory



- **Satellite gamma-ray telescope**
 - **Large Area Telescope (LAT)**
 - **20 MeV – > 300 GeV**
 - **Gamma Burst Monitor (GBM)**
 - **8 KeV – 40 MeV**
- **Key features**
 - **Huge field of view (2.4sr)**
 - **20% sky at any instant**
 - **Uniform coverage every 3h**
 - **Huge energy range**
 - **Including unexplored 10-100 GeV range**

Overview of the Large Area Telescope

Atwood, W. B. et al. 2009, ApJ, 697, 1071

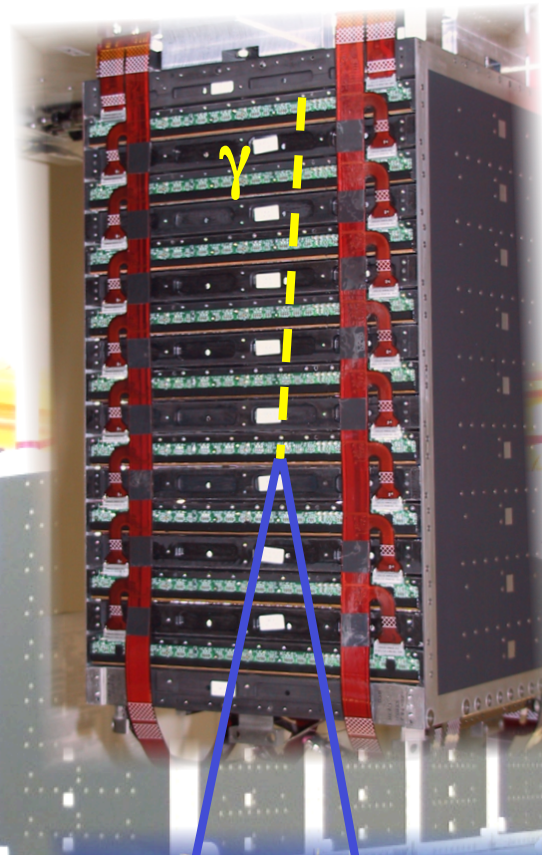
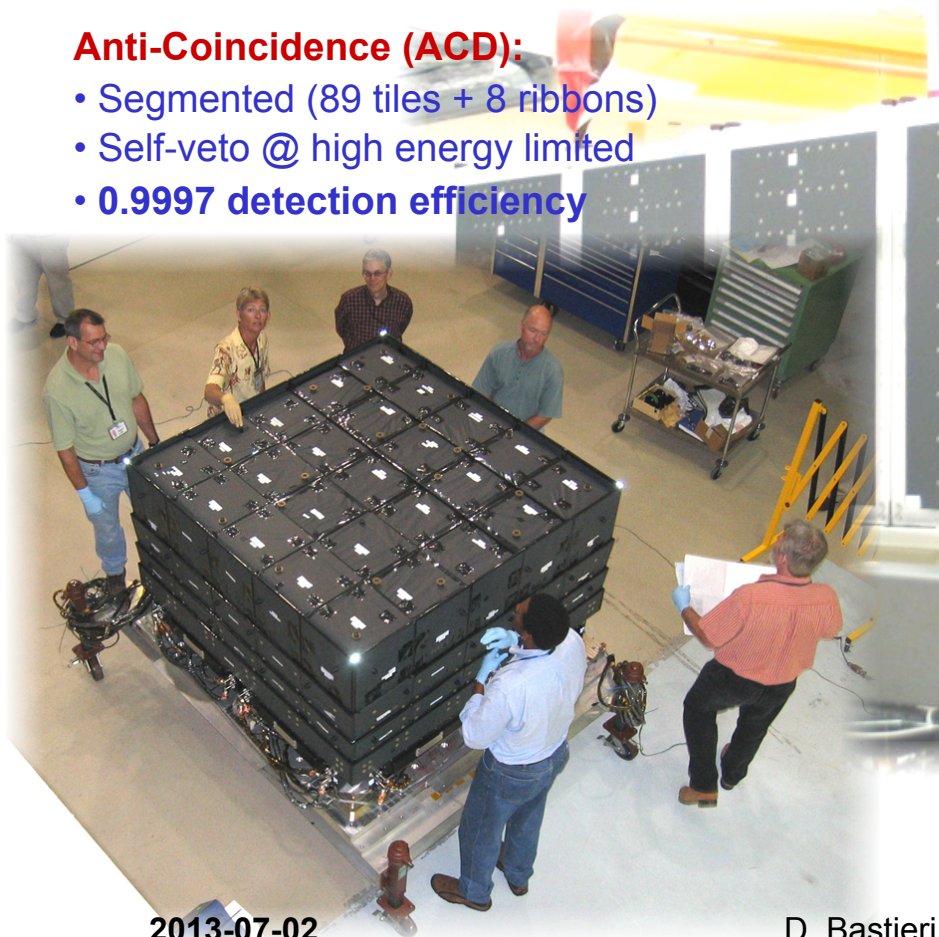


LAT:

- modular - 4x4 array
- 3ton – 650watts

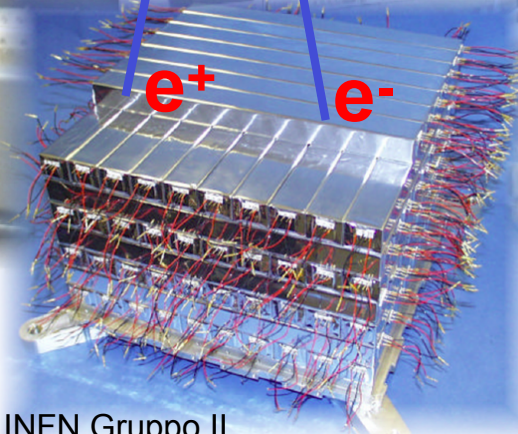
Anti-Coincidence (ACD):

- Segmented (89 tiles + 8 ribbons)
- Self-veto @ high energy limited
- **0.9997 detection efficiency**



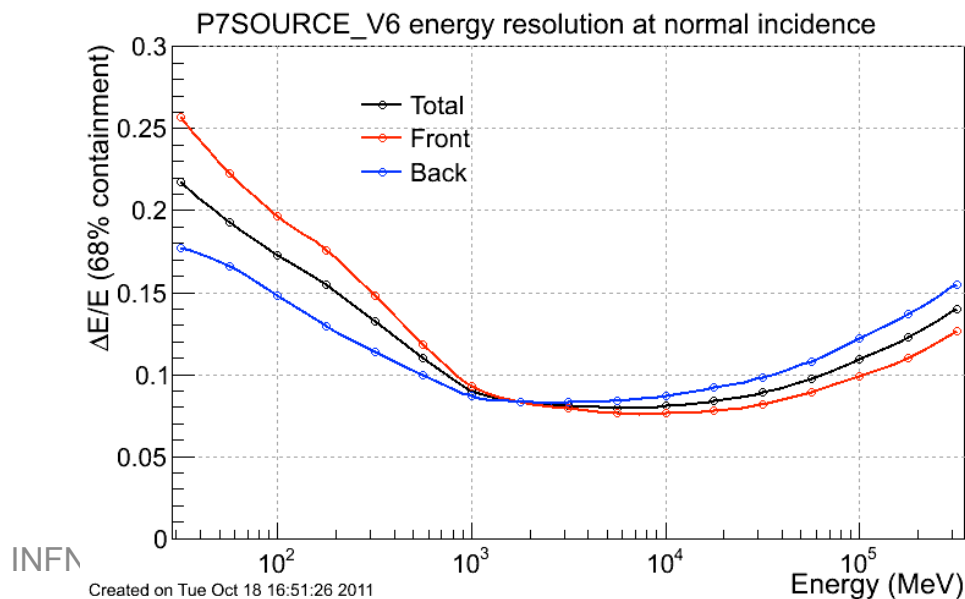
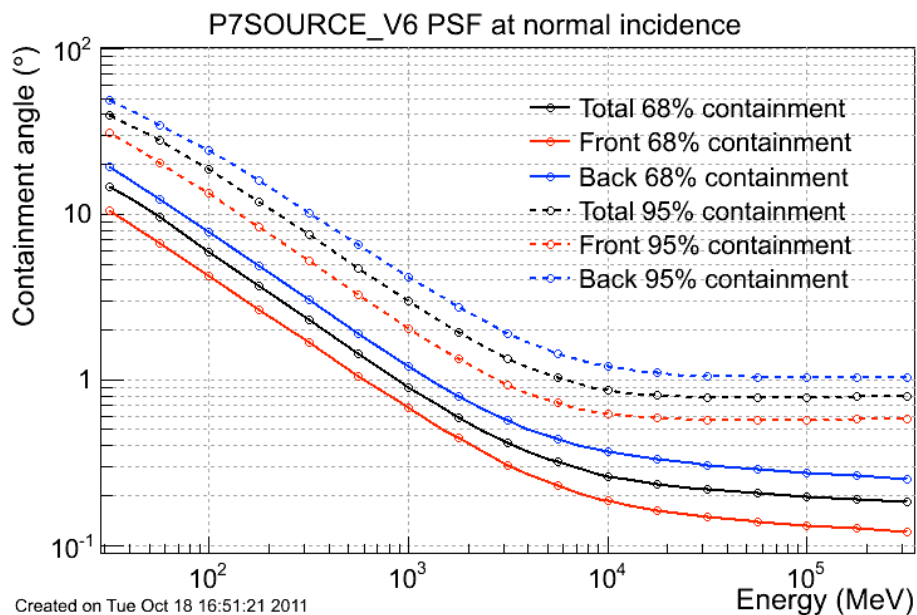
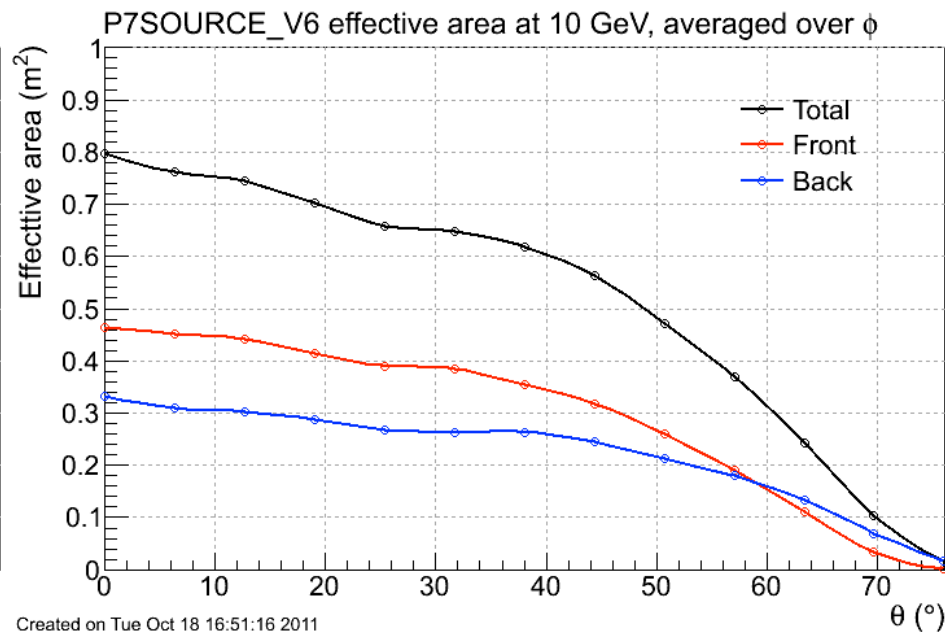
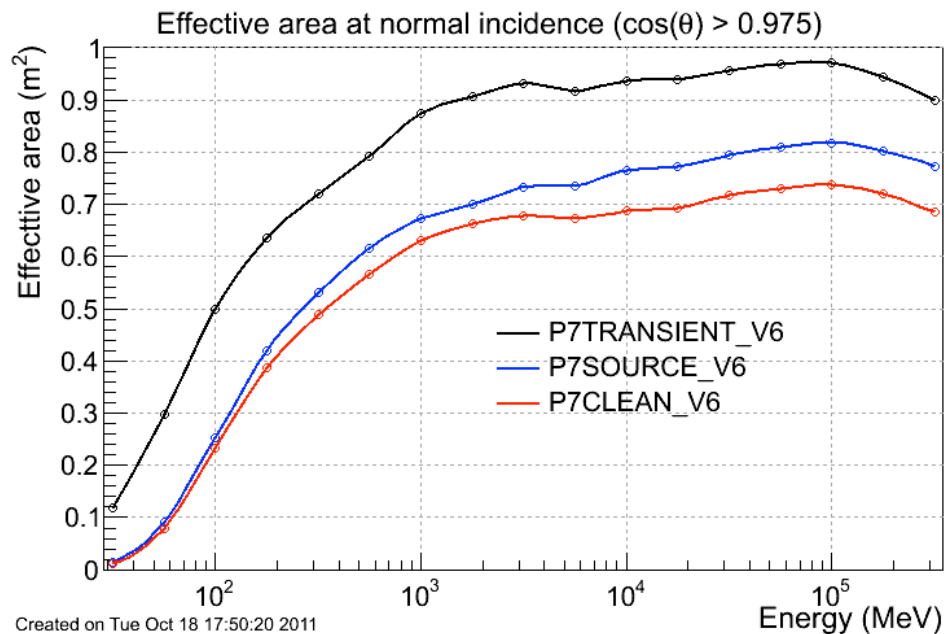
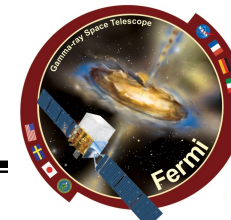
Tracker/Converter (TKR):

- Si-strip detectors
- ~80 m² of silicon (total)
- W conversion foils
- **1.5 X0 on-axis**
- 18XY planes
- ~10⁶ digital elx chans
- Highly granular
- High precision tracking
- Average plane PHA



Calorimeter (CAL):

- 1536 CsI(Tl) crystals
- **8.6 X0 on-axis**
- large elx dynamic range (2MeV-60GeV per xtal)
- **Hodoscopic (8x12)**
- Shower profile recon
- leakage correction
- EM vs HAD separation

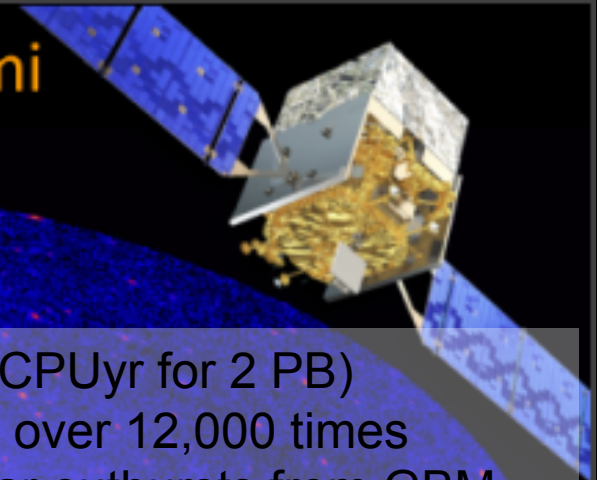




Fermi
Gamma-ray
Space Telescope

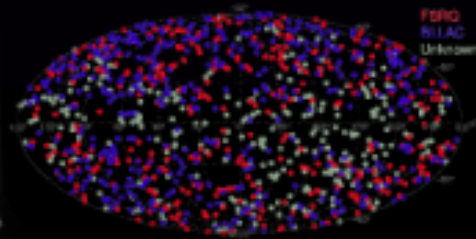
Happy 5th Birthday Fermi

Five spectacular years in orbit!

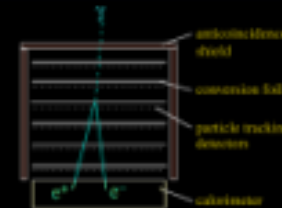
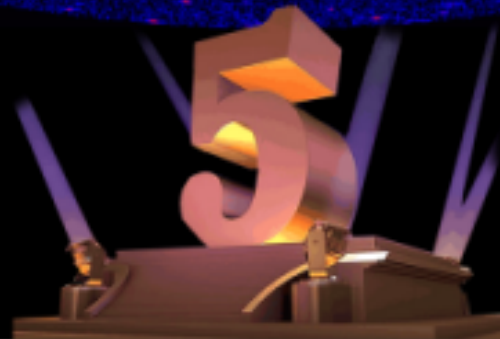


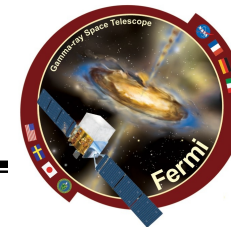
over 1.79 billion LAT events to the FSSC (1200 CPUyr for 2 PB)
242 LAT coll. papers (Cat I and Cat II) - been cited over 12,000 times
1151 GRB, 370 TGF, 522 solar flares and 192 magnetar outbursts from GBM

1130 ref. papers using Fermi data: cumulative 26038 citations
239 *ATeI*s issued by the LAT FA-GSW program
1269 individual guest investigators
42 press/web releases issued

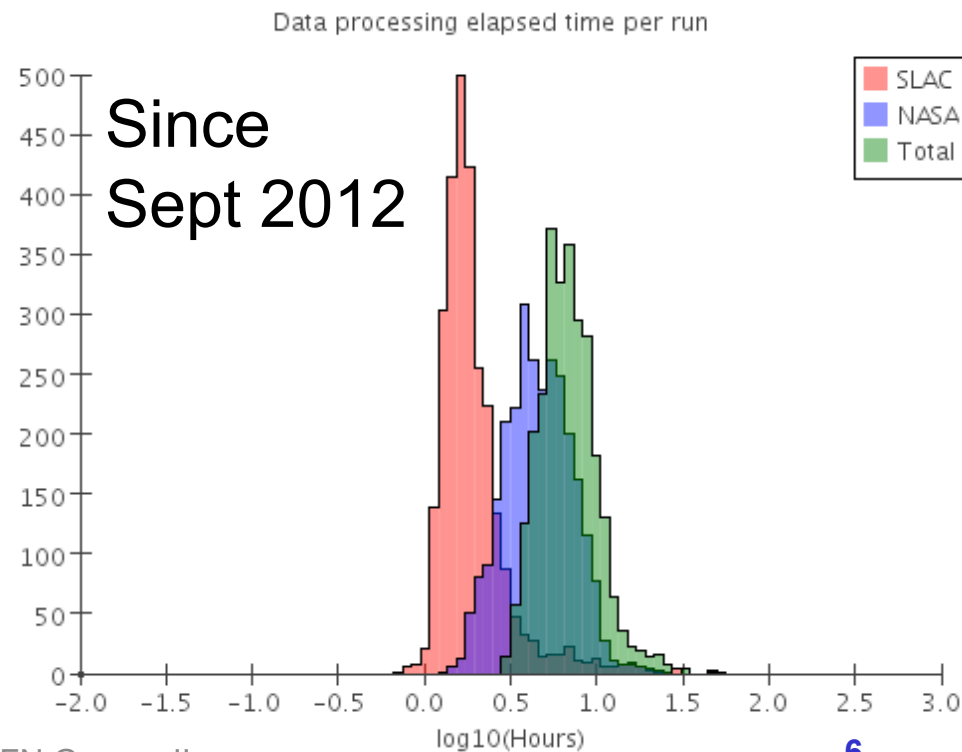
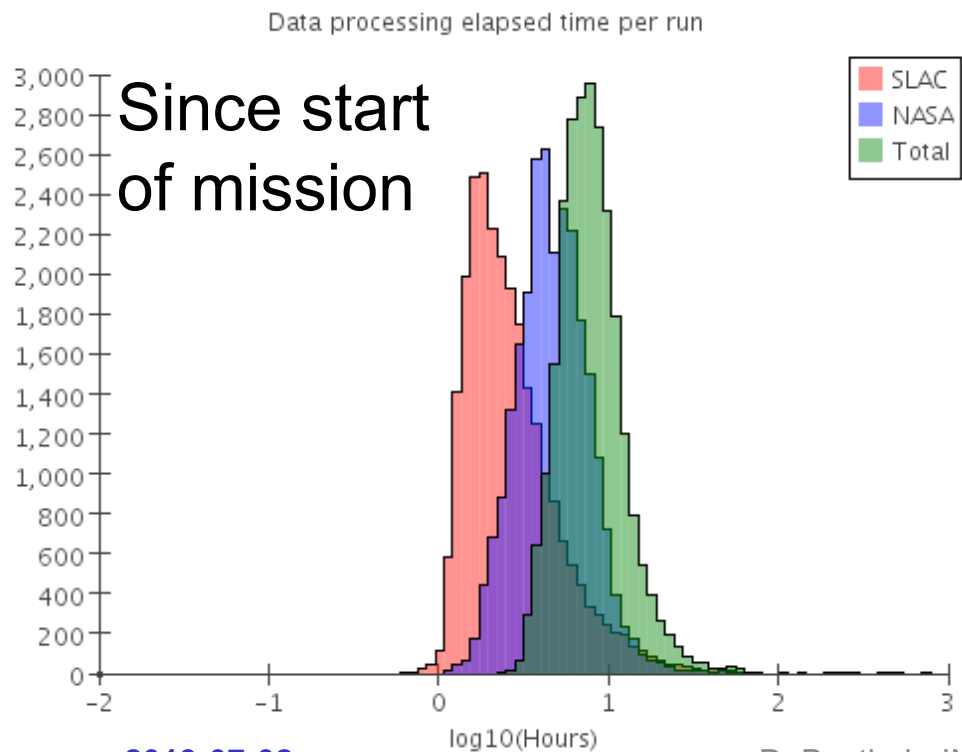


FERMI
RELIAC
Unknown

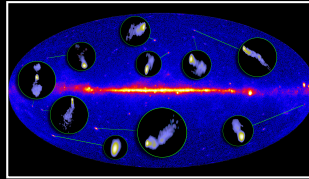
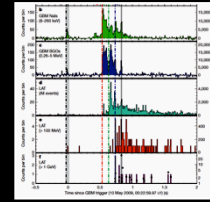
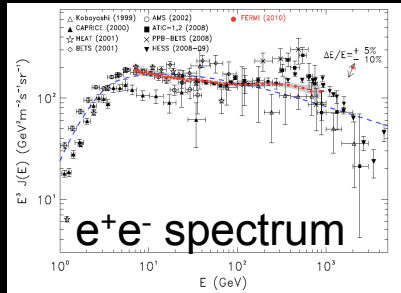




- ❑ 1666 days since 2008 August 4
- ❑ 99.7% uptime for the LAT
- ❑ 282.4 billion triggers on the LAT
 - 56.1 billion events downlinked and in the LAT catalog at SLAC
 - 1668 million transient events available at the FSSC
 - 246 million source photons available at the FSSC
 - » About 2 Hz detection rate

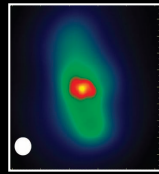


Fermi Highlights and Discoveries

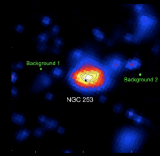


Blazars (782)

GRBs

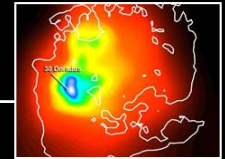


Radio Galaxies (12)



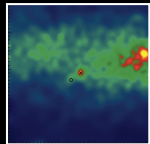
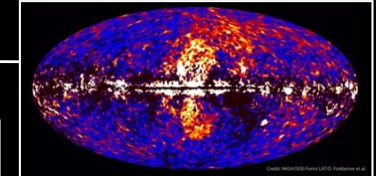
Star Burst Galaxies (4)

LMC & SMC



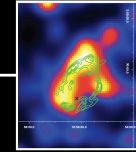
Globular Clusters (11)

Fermi Bubbles

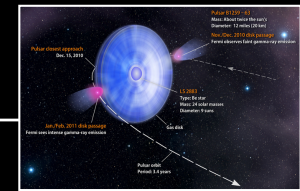


Nova (1)

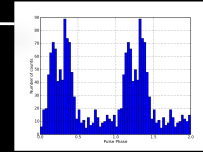
SNRs & PWN (68)



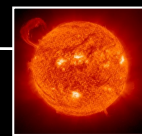
γ -ray Binaries (6)



Pulsars: isolated, binaries, & MSPs (122)



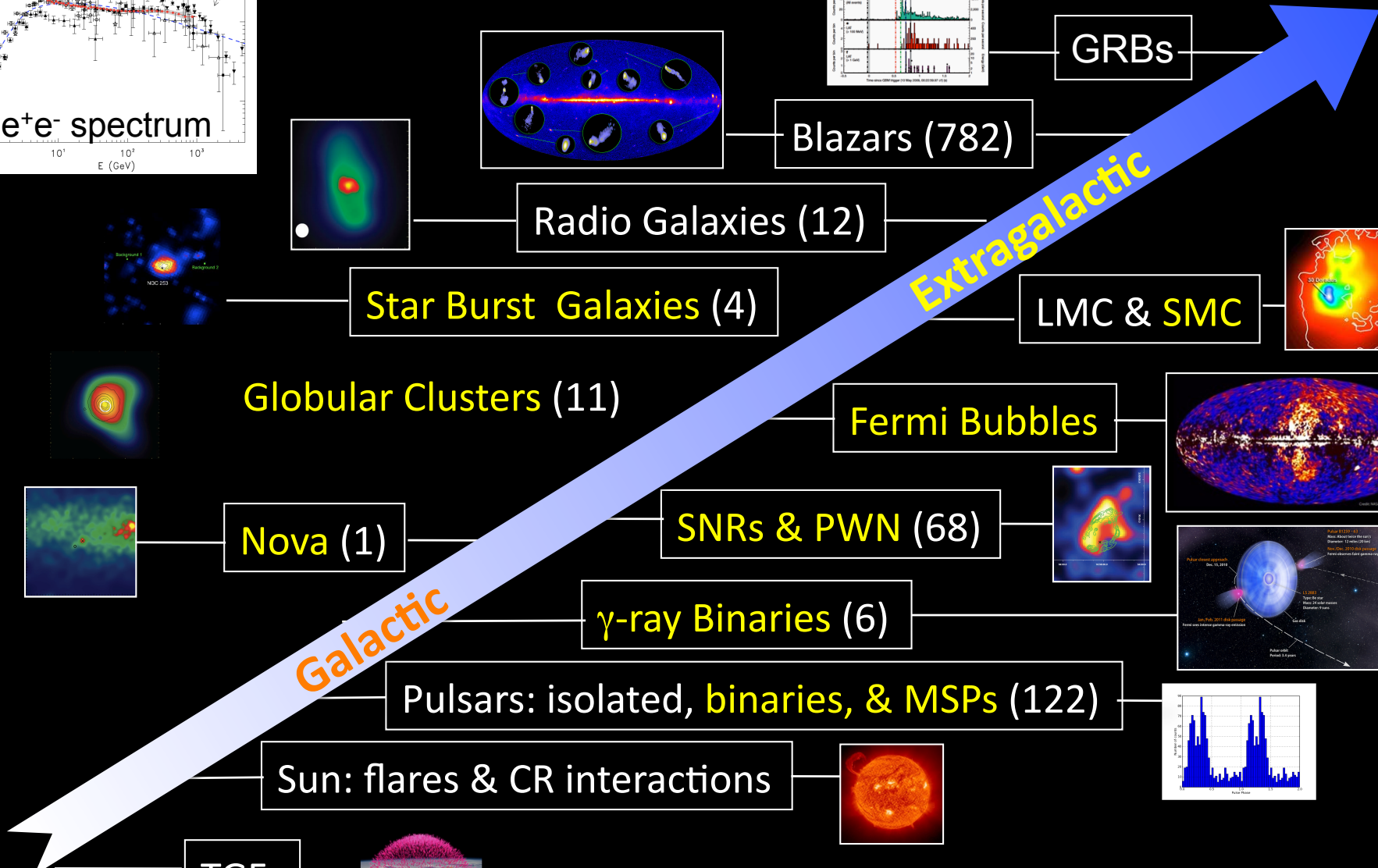
Sun: flares & CR interactions



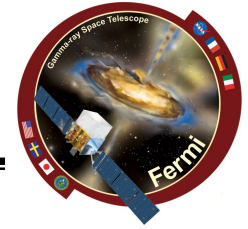
TGFs



Unidentified Sources (600)



Fermi LAT publications



Summary of Fermi LAT science publications

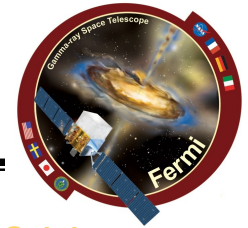
26 February 2013

Category I and II papers in refereed journals

Journal	Published	In press	Total
	0+1=1	-	1
Astronomical Journal	1+0=1	-	1
Astronomy and Astrophysics	6+16=22	-	22
Astroparticle Physics	2+3=5	-	5
Astrophysical Journal	72+37=109	0+1=1	110
Astrophysical Journal Letters	20+11=31	-	31
Astrophysical Journal Supplement	5+1=6	-	6
Journal of Cosmology and Astroparticle Physics	3+3=6	-	6
Monthly Notices of the RAS	0+13=13	-	13
Nature	2+1=3	-	3
Physical Review D	6+1=7	-	7
Physical Review Letters	6+0=6	-	6
Science	15+0=15	-	15
Total	138+87=225	0+1=1	226

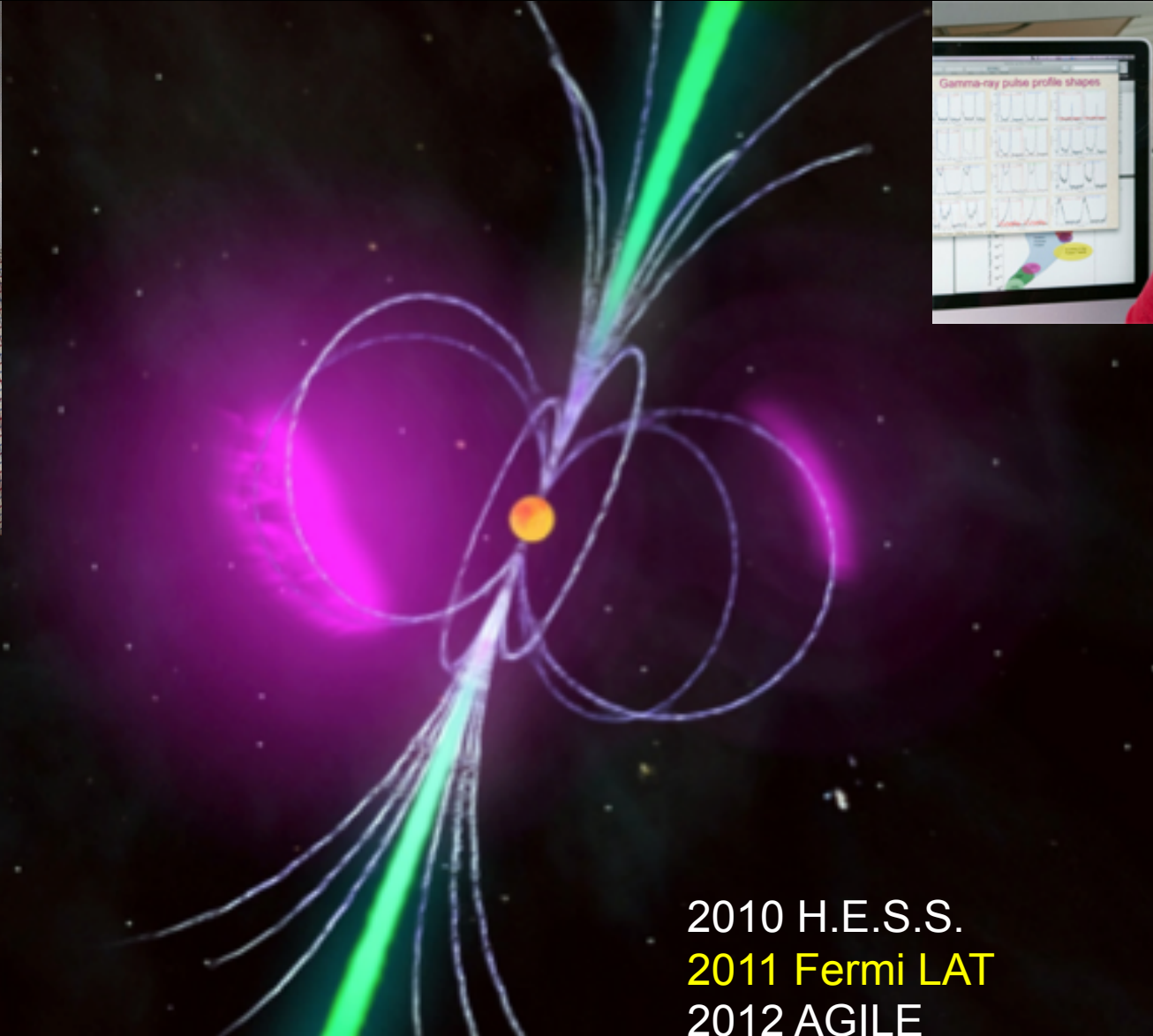
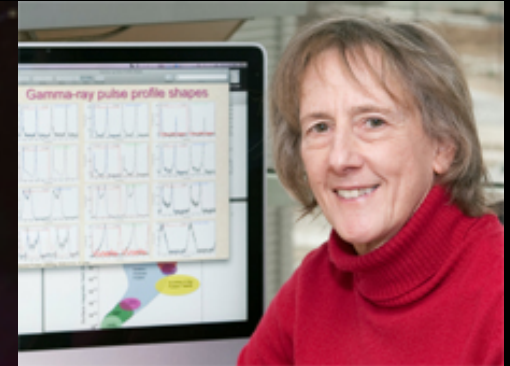
Total citations: 11,243

Most cited Fermi LAT papers



- “The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission” (06/2009) 844
- “Measurement of the Cosmic Ray $e^+ e^-$ Spectrum from 20 GeV to 1 TeV with the Fermi Large Area Telescope” (05/2009) 635
- “Fermi Large Area Telescope First Source Catalog” (06/2010) 445
- “Fermi/Large Area Telescope Bright Gamma-Ray Source List” (07/2009) 318
- “Bright Active Galactic Nuclei Source List from the First Three Months of the Fermi Large Area Telescope All-Sky Survey” (07/2009) 283
- “Fermi Observations of High-Energy Gamma-Ray Emission from GRB 080916C” (03/2009) 292
- “The First Fermi Large Area Telescope Catalog of Gamma-ray Pulsars” (04/2010) 286
- “Spectrum of the Isotropic Diffuse Gamma-Ray Emission Derived from First-Year Fermi Large Area Telescope Data” (11/2010) 242

2013 Rossi Prize



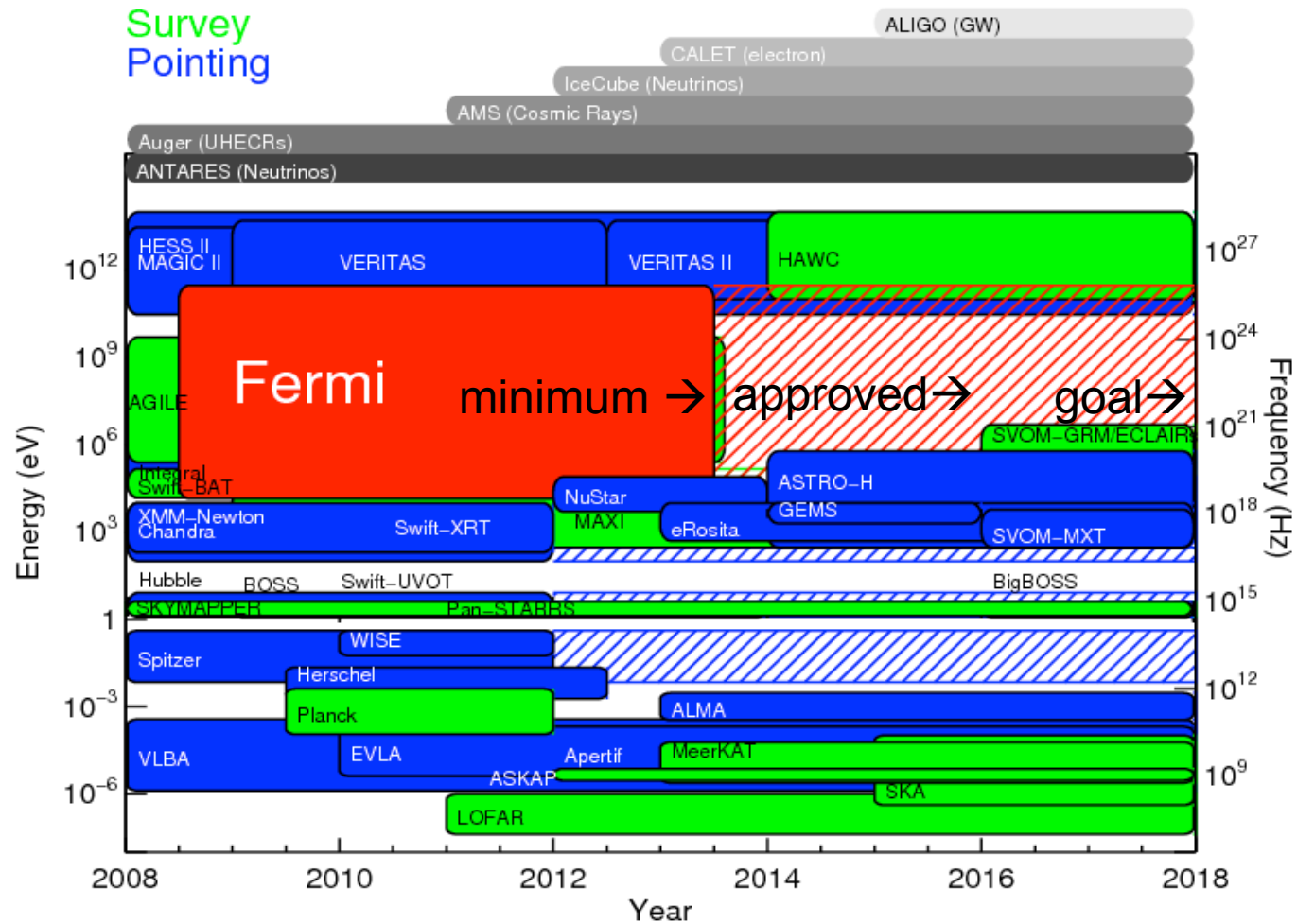
2010 H.E.S.S.

2011 Fermi LAT

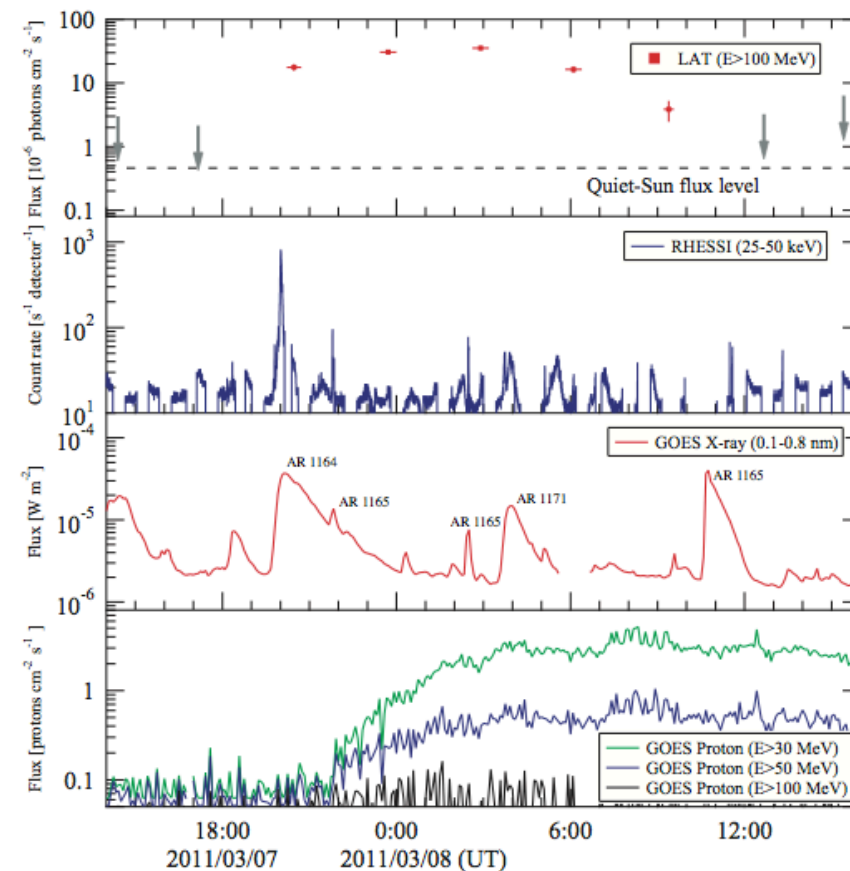
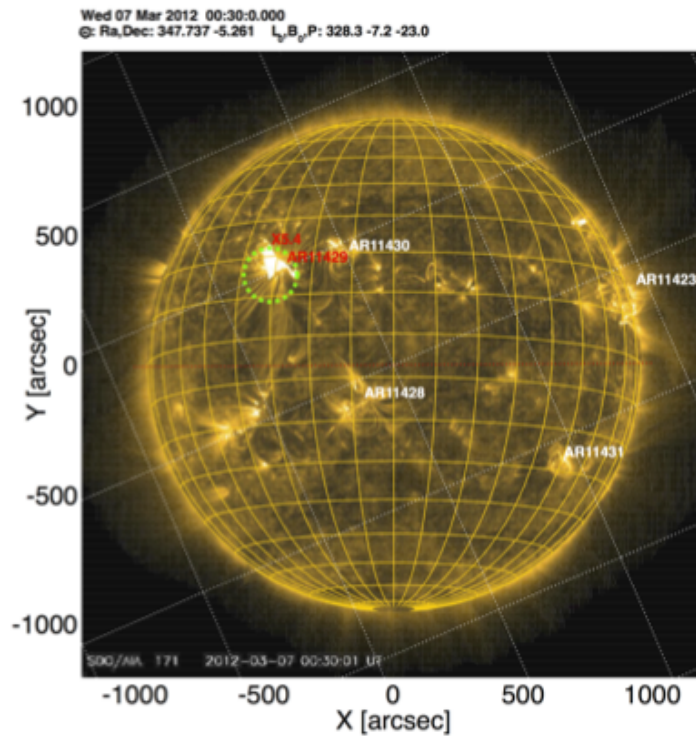
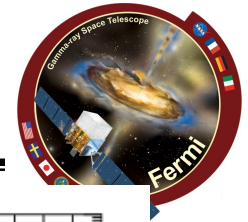
2012 AGILE

2013 R.W. Romani & Alice Harding

Fermi mission status



- ❑ NASA 2012 Senior Review recommended extended operations
 - <http://science.nasa.gov/astrophysics/2012-senior-review/>
- ❑ NASA HQ will extend the mission to at least 2016

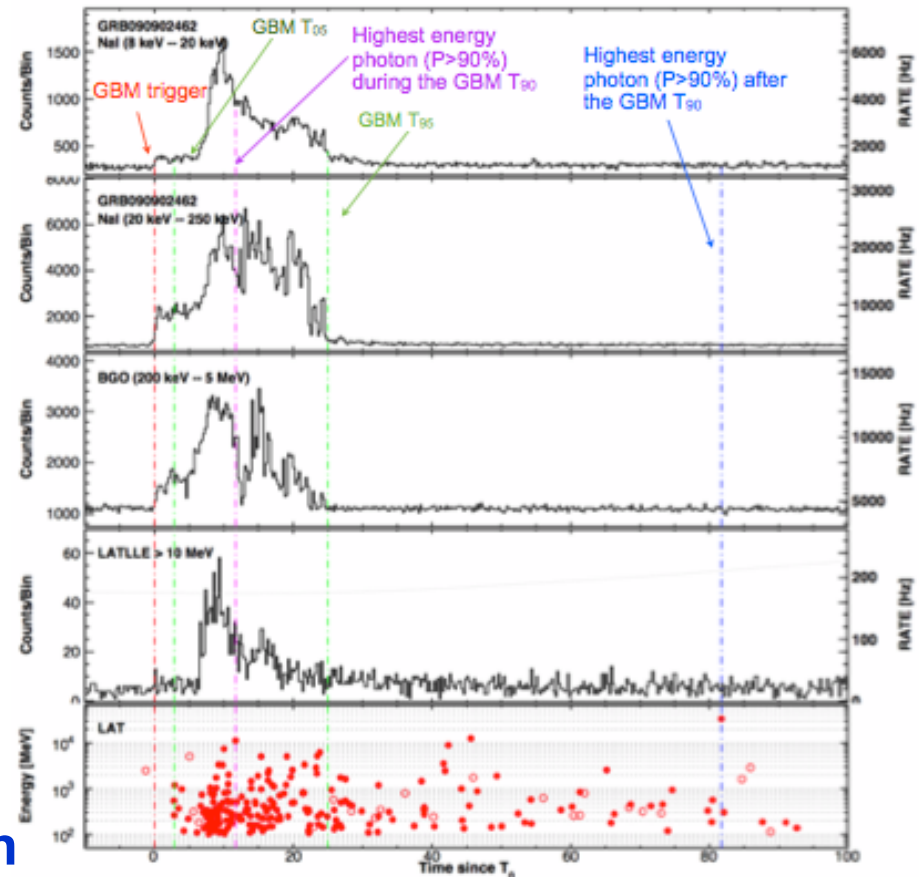


□ Full list of LAT solar flares

- 16 in total
- analysis of bright long flares
 - γ -rays localized on x-ray emission region for 1st time

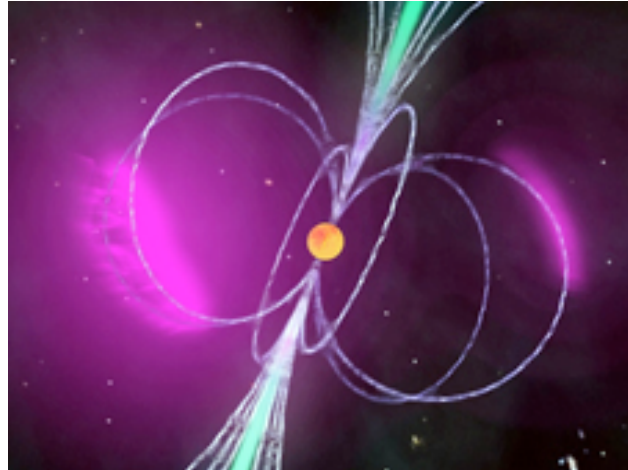


- ❑ Individual bursts plus LAT GRB catalog
- ❑ Common properties in the sample
 - Delayed HE emission
 - Longer HE duration
 - Evidence for multi-component spectra
- ❑ Emission mechanism
 - And connection to Cosmic Rays
- ❑ Fundamental physics
 - Lorentz Invariance Violation
 - Limits on Extra Galactic Background Light from single high energy photons



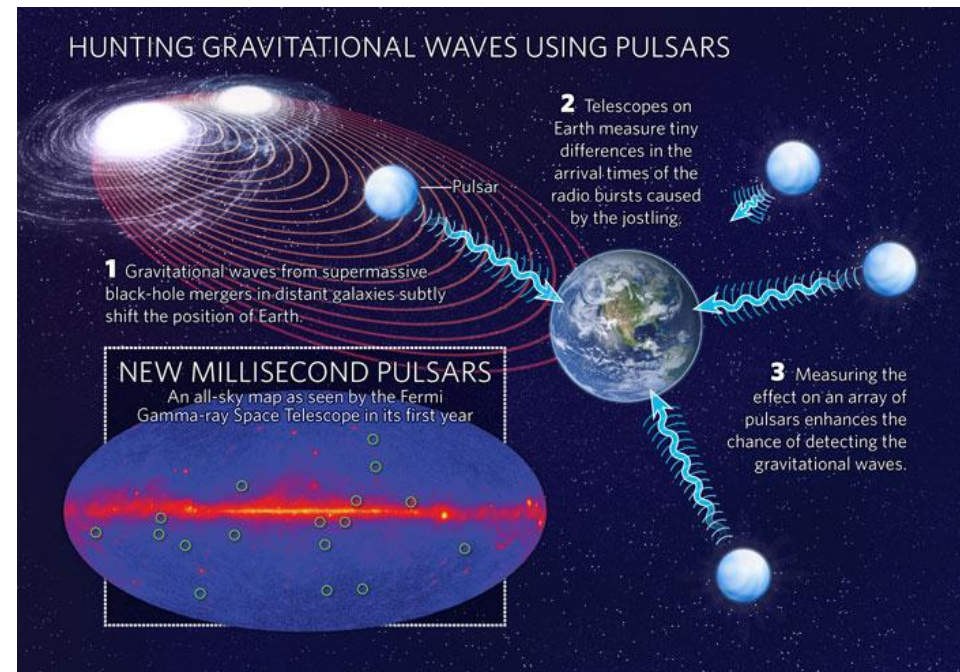
Abdo, A. A. et al. 2009, Nature, 462, 331
 Abdo, A. A. et al. 2009, Science, 323, 1688
 The First LAT GRB Catalog, arxiv 1303.2908,
 Submitted to ApJS

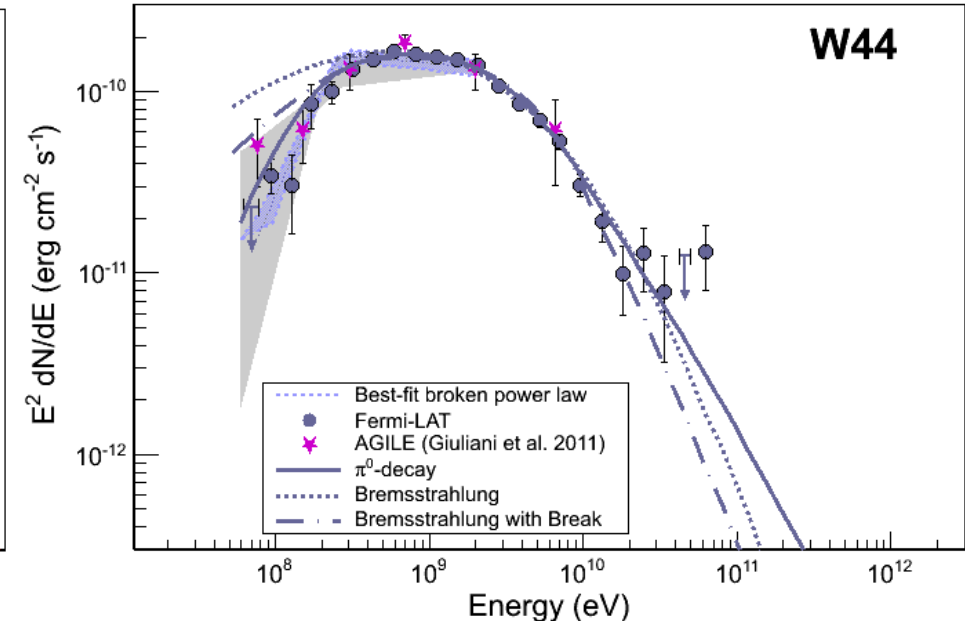
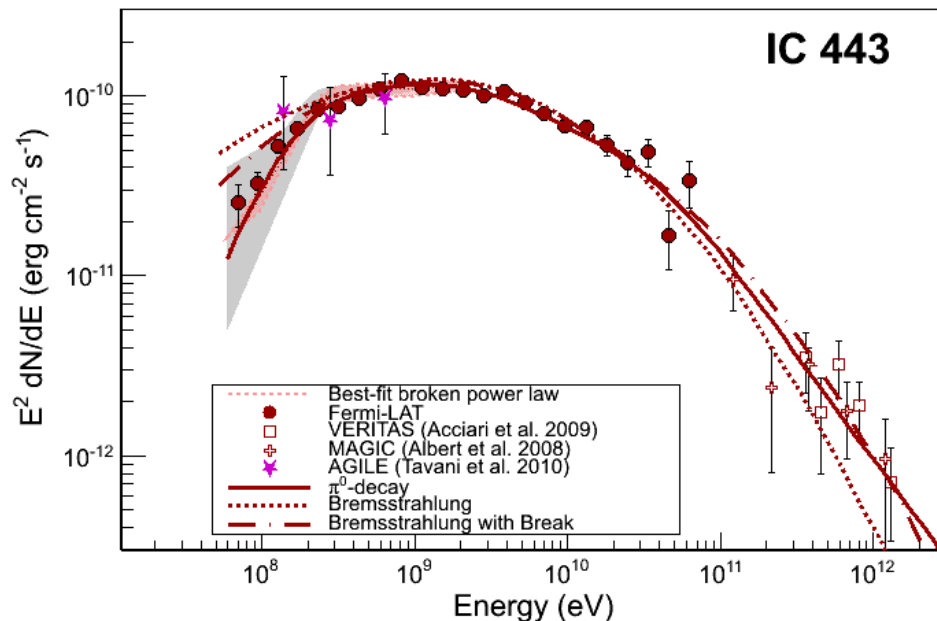
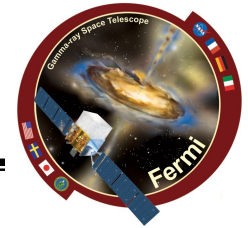
A new picture for pulsars



- Emission mechanism away from star
- Many γ -ray only PSR
- mPSR in γ -ray
 - Pulsar timing array
- mPSR in globular clusters

Pletsch, H. J. et al. 2012, ApJ, 744, 105
 Saz Parkinson, P. M. et al. 2010, ApJ, 725, 571
 Abdo, A. A. et al. 2010, ApJS, 187, 460
 Abdo, A. A. et al. 2009, Science, 325, 840
 Abdo, A. A. et al. 2009, Science, 325, 845
 Abdo, A. A. et al. 2009, Science, 325, 848
 Abdo, A. A. et al. 2008, Science, 322, 1218
 plus many other
 2013 AAS/HEAD Rossi Prize





- ❑ Unambiguous and robust detection of pion decay bump in W44 and IC443 (thanks to increased low energy Pass7 acceptance)
- ❑ Proof that SNR accelerate protons

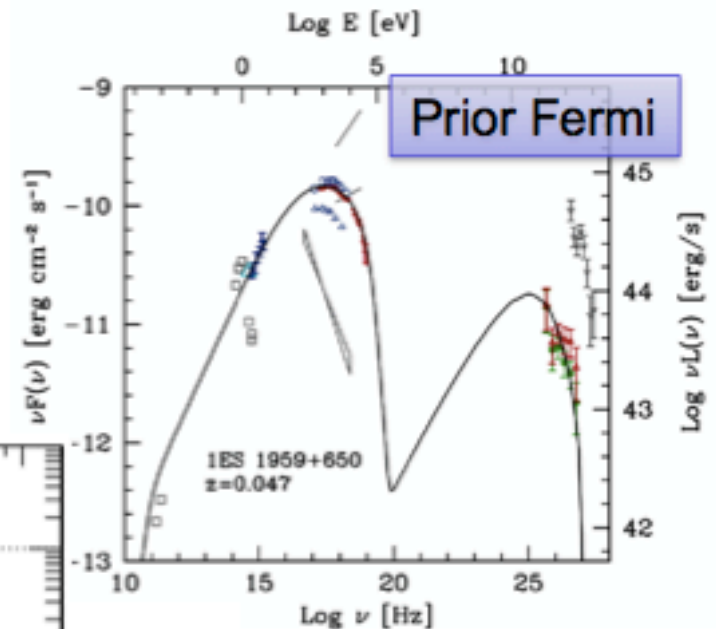
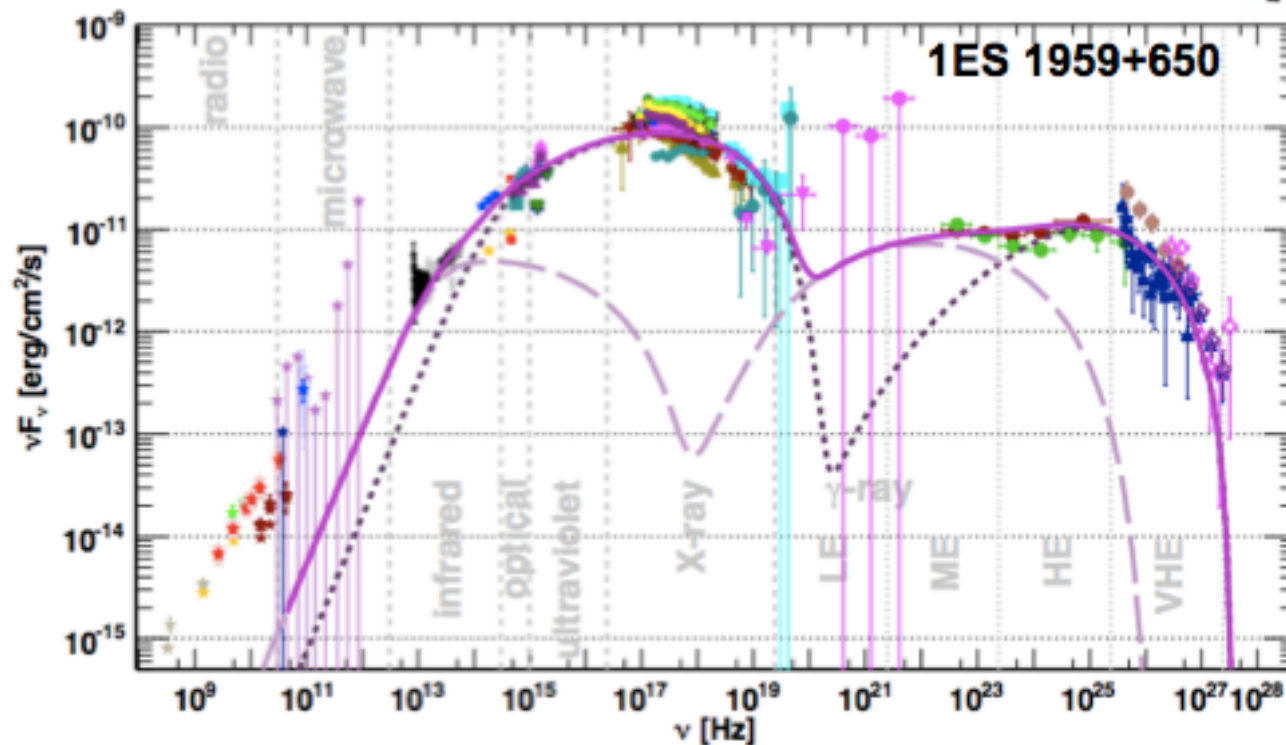
Detection of the pion-decay cutoff in Supernova remnants



Challenging the one zone leptonic model:
Flat VHE spectrum

A “standard” blazar (no EBL, no hard TeV,...)

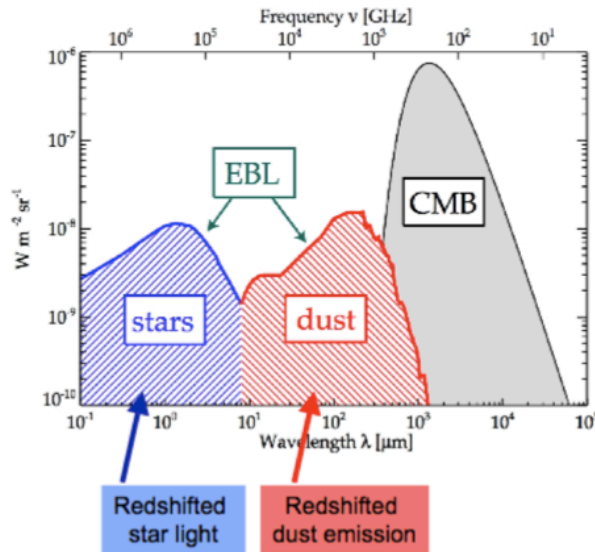
- A HSP with an hadronic VHE bump?
- Leptonic Multi-zones emission?



Tagliaferri+ 2009

M. Backes,
 PhD thesis

The Extragalactic Background Light

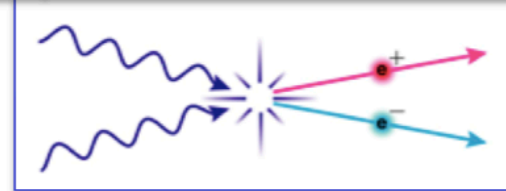


EBL studies central to:

- put constraints on galaxy evolution, star formation activity, dust extinction processes
- understanding cosmic structure formation and evolution

2 Photons convert into an electron-positron pair if :

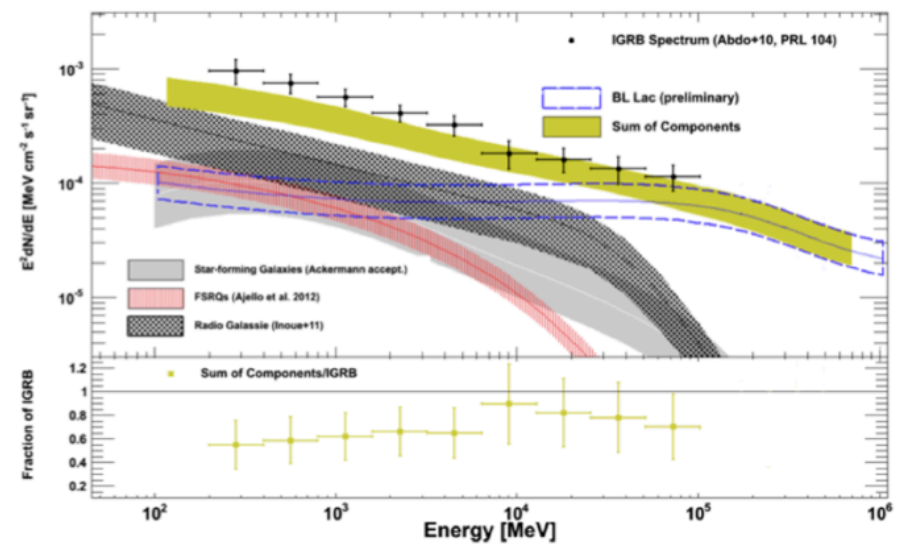
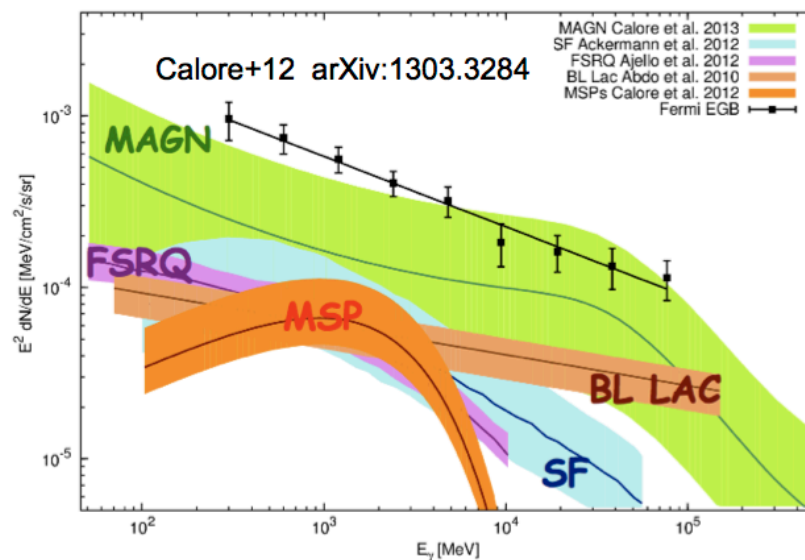
$$E_\gamma \times E_{\text{EBL}} \geq 2(m_e c^2)^2$$

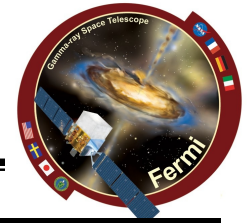




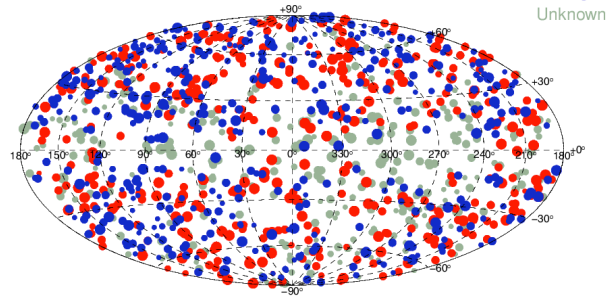
- Star forming: 13% ($\pm 9\%$)
 - FSRQs : 9.3% ($\pm 5\%$)
 - Radio galaxies: 20%-30% (+58%/-16%)
 - BL Lacs (to be refined) : 10-15%
- TOTAL : 60%

Contributions from unresolved sources of known source classes can account for some or most of Isotropic background.

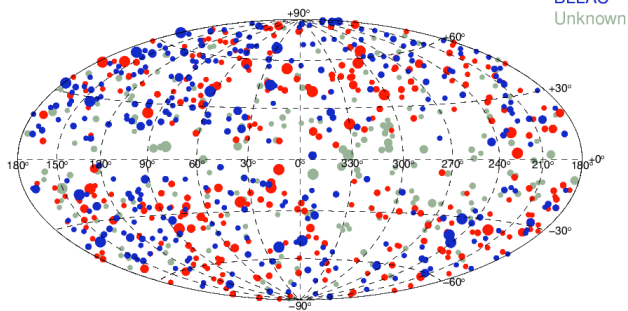




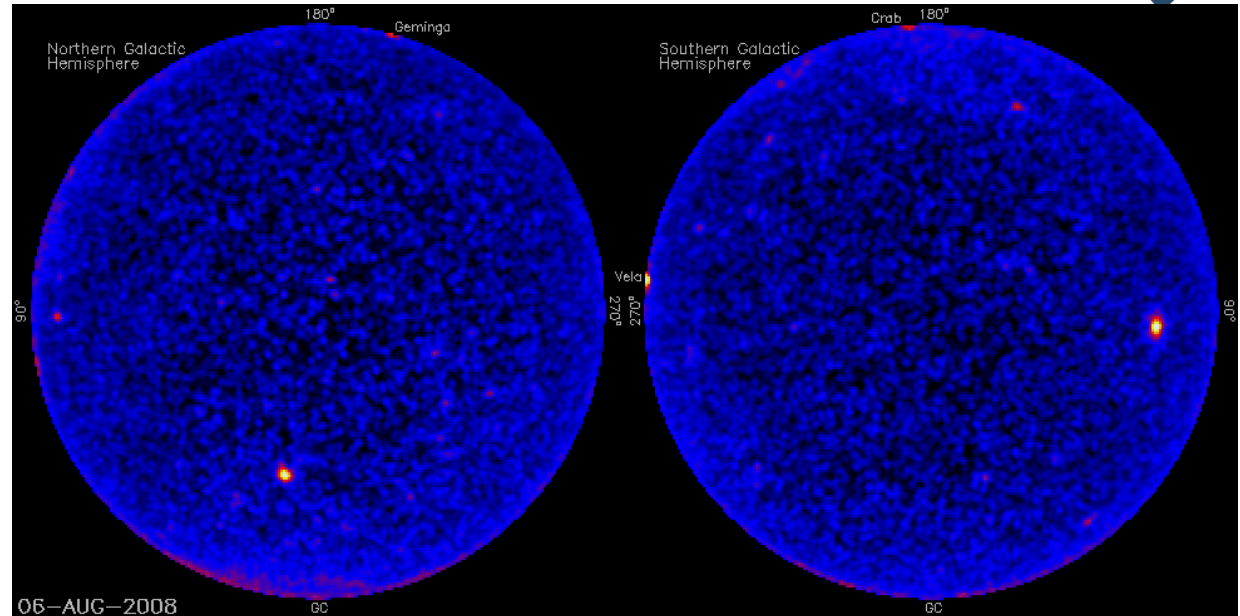
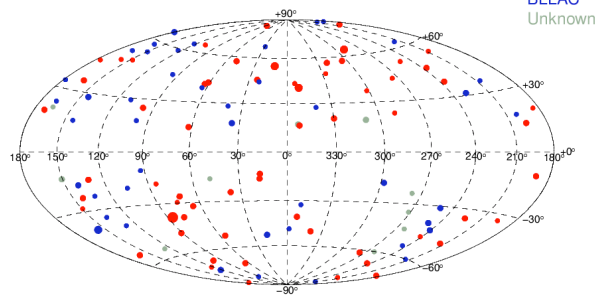
Second LAT Catalogue (2LAC)
TS>25, August 2008 – August 2010



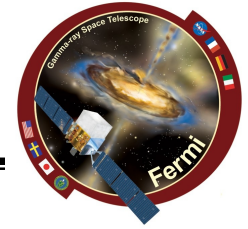
First LAT AGN Catalogue (1LAC)
TS>25, August 2008 – July 2009



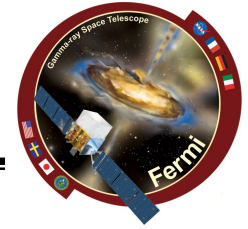
LAT Bright AGN Source List (LBAS)
TS>100, August 2008 – October 2008



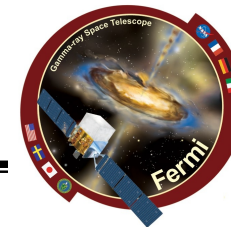
- ❑ Most numerous Fermi sources (~60%)
- ❑ Highly variable
 - Require multi-wavelength campaigns for modeling
- ❑ Simple Self-Synchrotron Compton not adequate to explain variety of AGNs



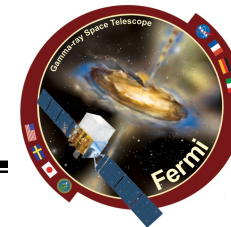
- ❑ **AGN and multiwavelength campaigns:**
 - **Denis Bastieri & Sara Buson**
 - **+ Graziano Chiaro, Giacomo Principe, ...**
- ❑ **Galactic plane sources**
 - **Giovanna Pivato**
- ❑ **AGN and extragalactic sources (coordinator)**
 - **Denis Bastieri**
- ❑ **Instrument Response Functions**
 - **Riccardo Rando**
- ❑ **Flare Advocate/Gamma-ray Sky Watcher**
 - **Denis Bastieri (sw) & Sara Buson (analysis)**
- ❑ **Parallel computing**
 - **Denis Bastieri**
 - **+ Andrea Pigato, Max Fatica & N. Juffa**
- ❑ **Public outreach**
 - **Denis Bastieri & Giacomo Saccardo**



- ❑ Denis Bastieri (1 cat I + 3 cat II + 1 cat III) AGN
- ❑ Sara Buson (2 cat I + 10 cat II) AGN
- ❑ Giovanna Pivato (1 cat II) HB 21
- ❑ Riccardo Rando (1 cat I) IRFs pass 7
- ❑ TOTALE (3 cat I + 11 cat II + 1 cat III)



Denis Bastieri	RU	100%
Sara Buson	Assegnista	100%
Giovanna Pivato	PhD	100%
Riccardo Rando	RU	70%
...		
TOTALE	4	3.7 FTE



- Missioni Estere**
 - **Attività ISOC (1m/u)** **8 k€**
 - **Riunioni Analysis/Science Working Group (3 missioni da 7 gg)** **9 k€**
 - **Collab. Meeting (6 missioni da 7 gg)** **18 k€**
- Missioni Interne**
 - **riunioni software + Collab. italiana** **5 k€**
 - **riunioni resp locale con referees e/o CSN2** **2 k€**
- Materiale di Consumo (metabolismo)** **3 k€**
- Totale** **45 k€**

- Servizio calcolo: ordinaria manutenzione < 1 mese/uomo**