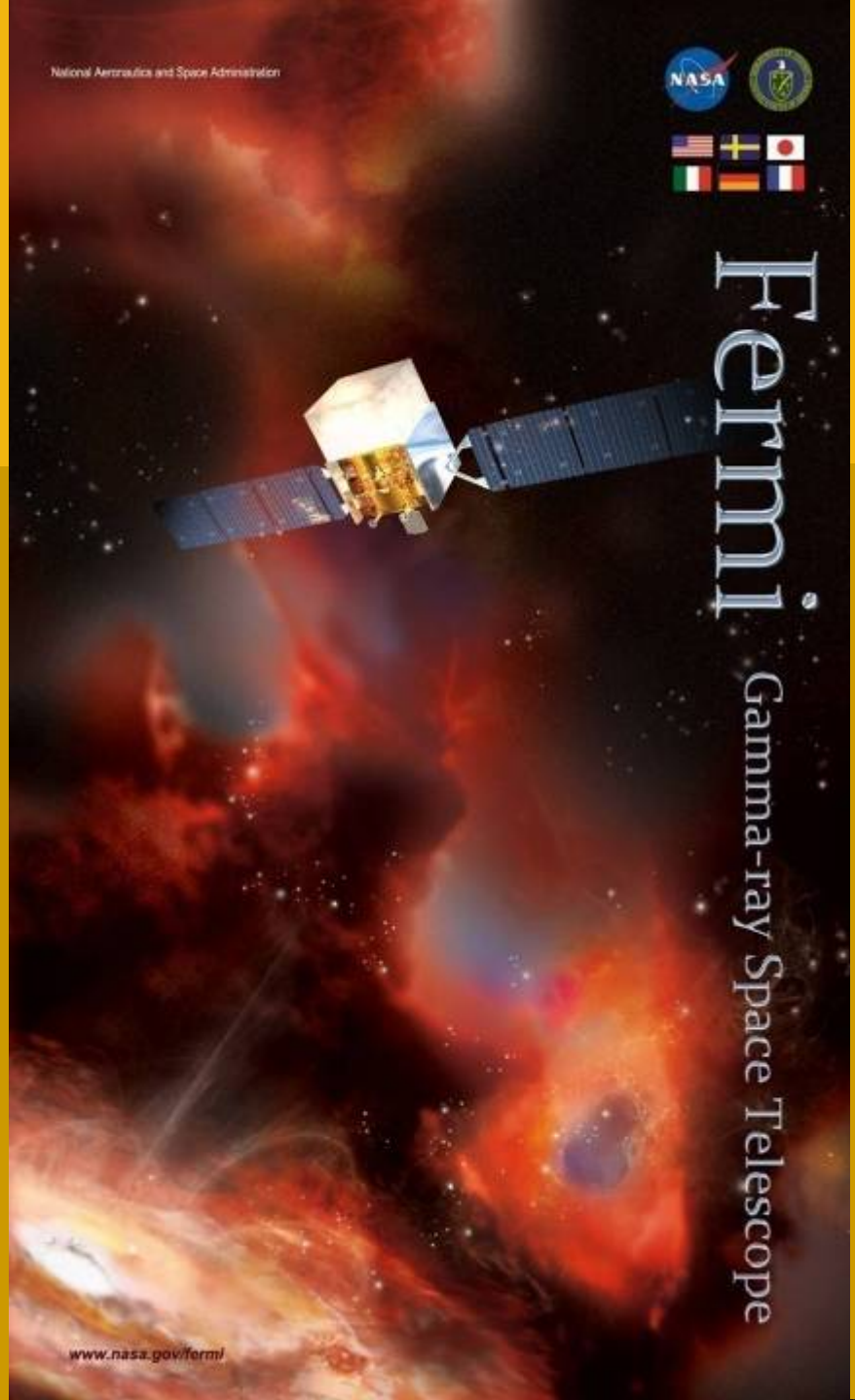
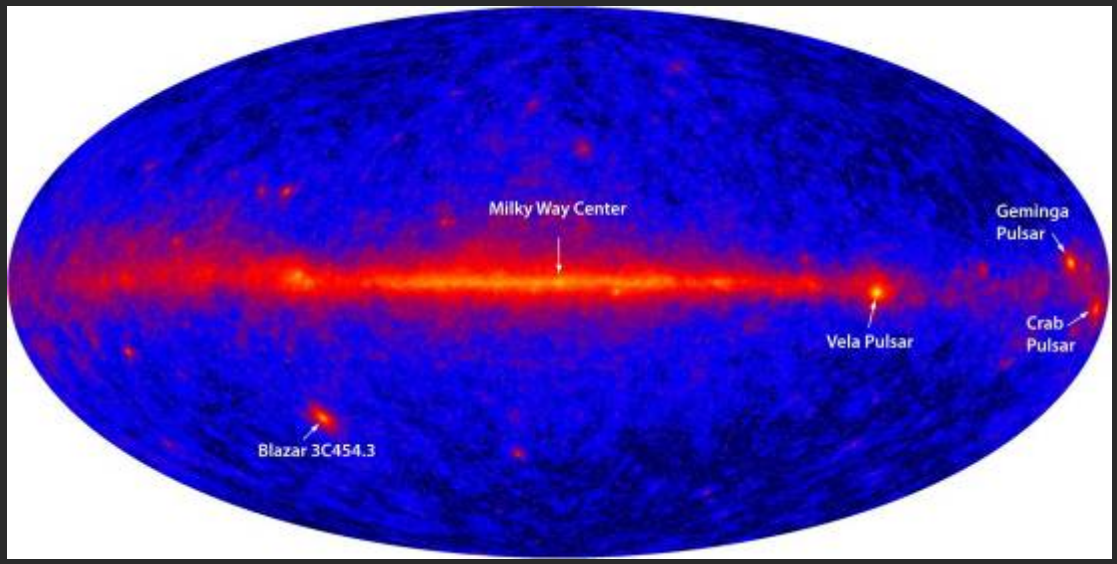


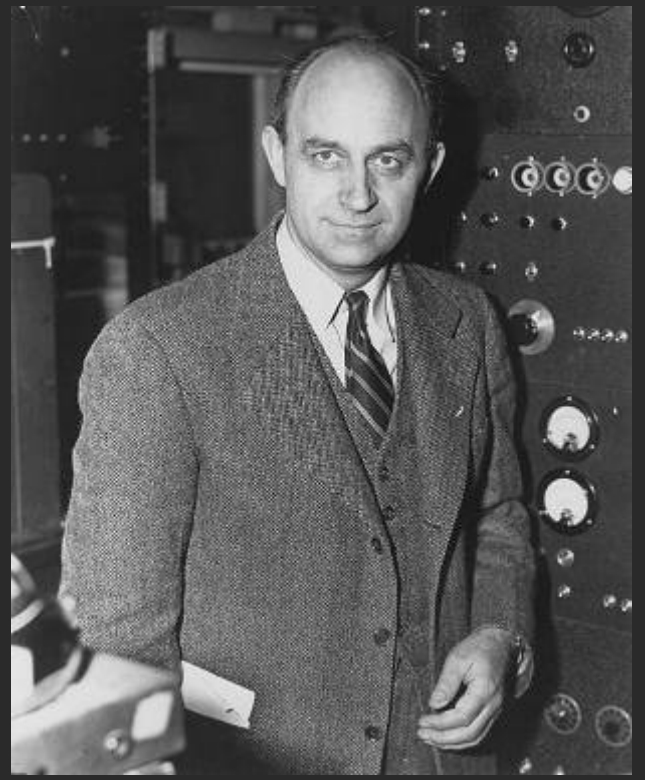
FGST
Science Highlights

Andreas von Kienlin (MPE)

First light and Observatory Renaming

- GLAST becomes Fermi Gamma-ray Space Telescope
  - "first light" 4 day sky map



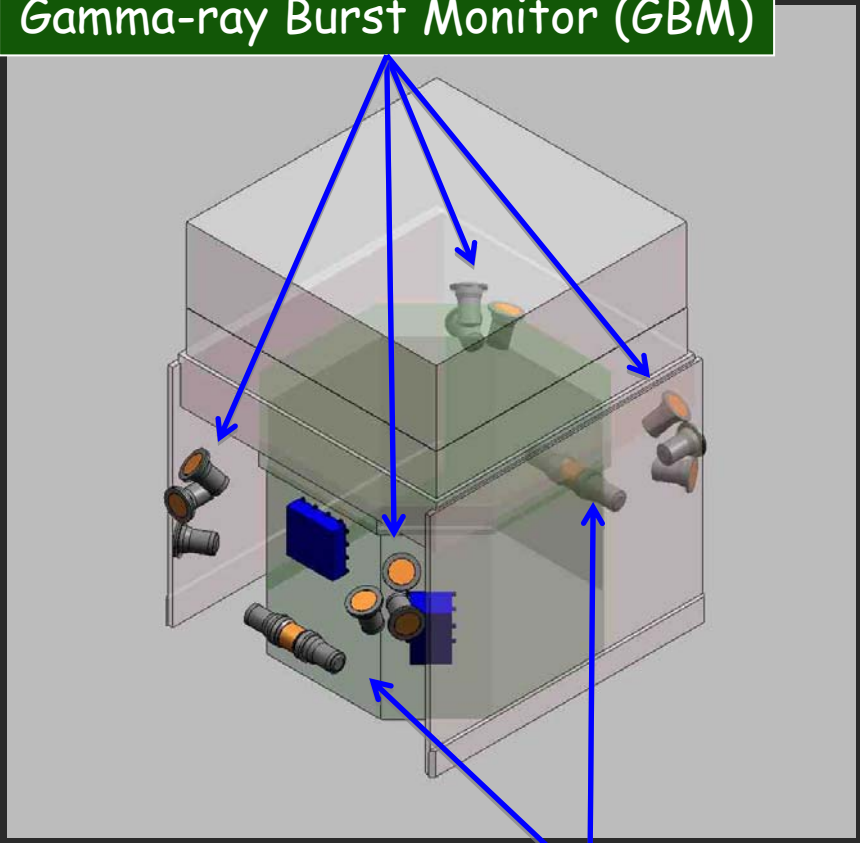


" Enrico Fermi (1901-1954) was an Italian physicist who immigrated to the United States. He was the first to suggest a viable mechanism for astrophysical particle acceleration. This work is the foundation for our understanding of many types of sources to be studied by NASA's Fermi Gamma-ray Space Telescope,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

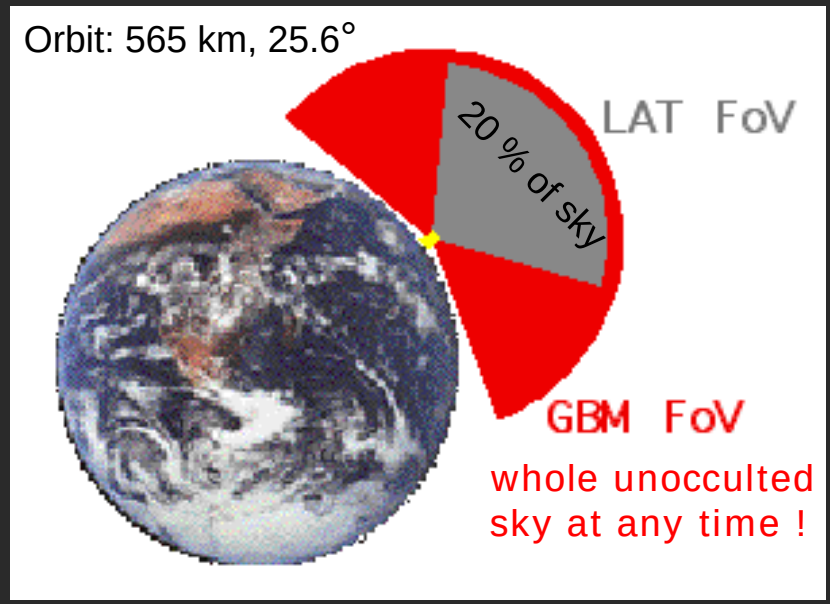
The Fermi Observatory

Large Area Telescope (LAT)

Gamma-ray Burst Monitor (GBM)

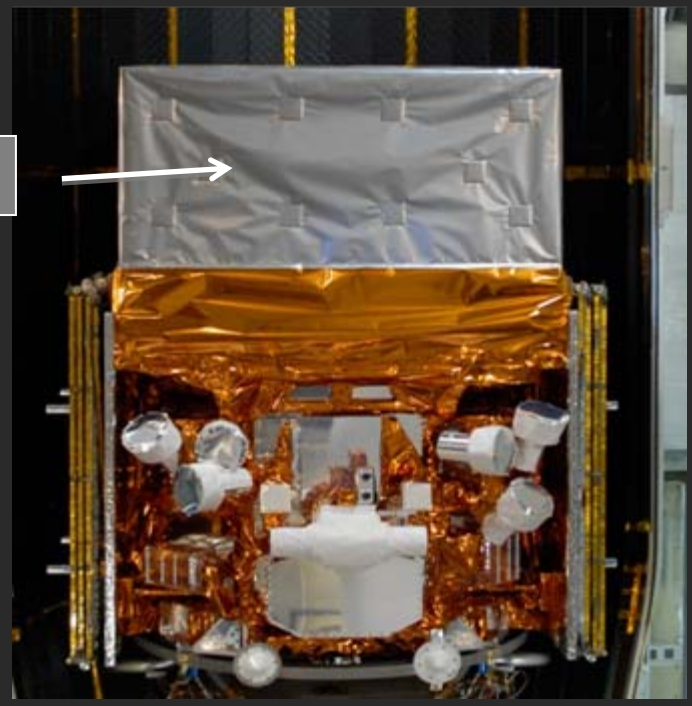


GBM BGO detectors

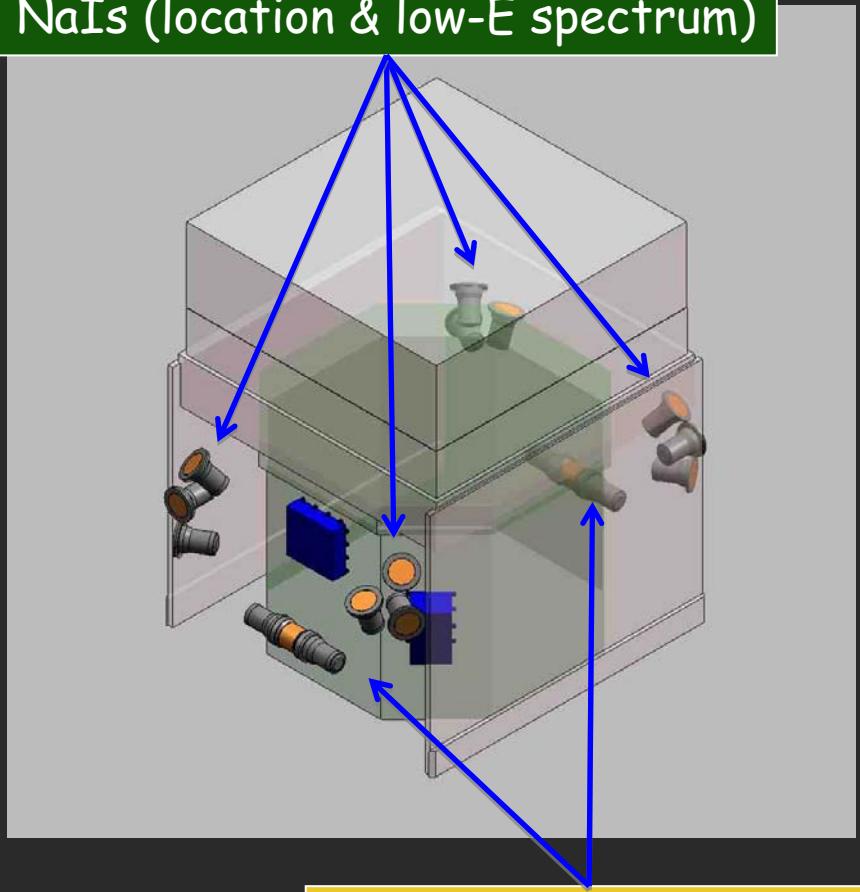


The Fermi Observatory

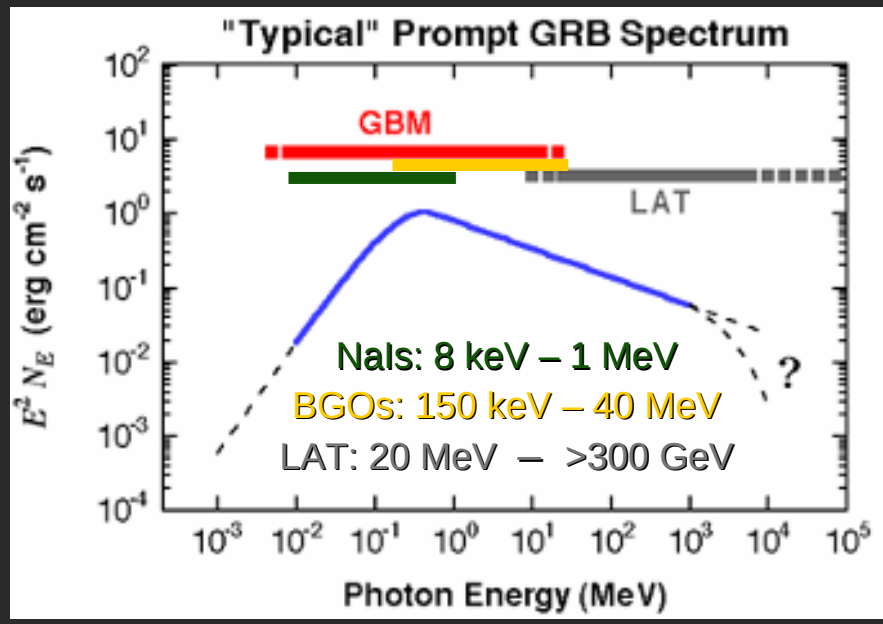
LAT (high-E spectrum)



NaIs (location & low-E spectrum)



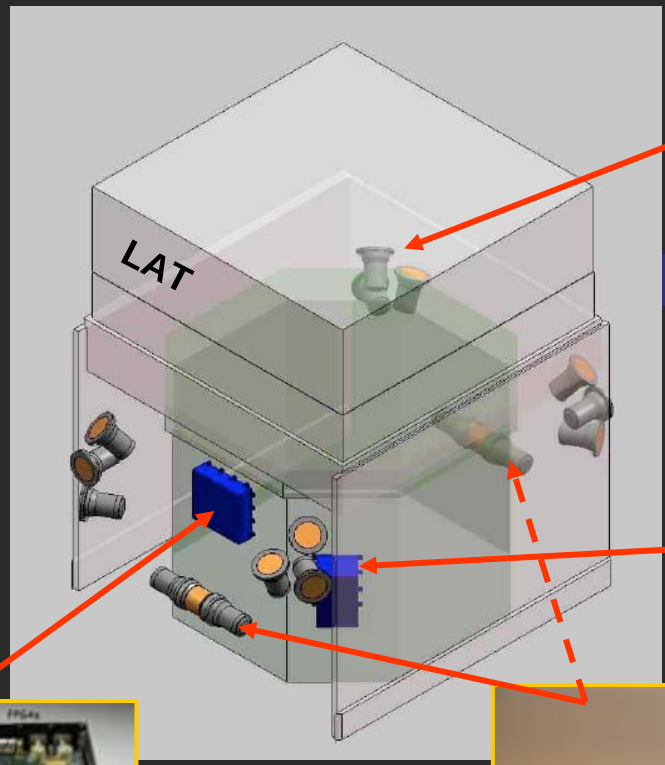
BGOs (mid-E spectrum)

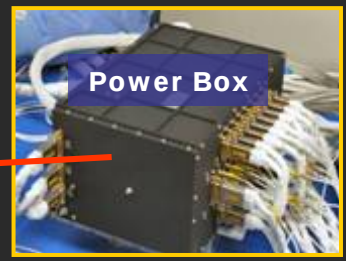


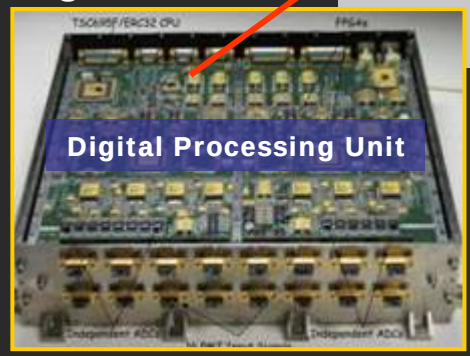
Fermi Gamma-Ray Burst Monitor

- 12 × Sodium Iodide NaI(TL) scintillation detectors
  - Wide Field of View
  - Burst Trigger
  - Coverage of typical GRB spectrum: 8 keV – 1 MeV
- 2 × Bismuth Germanate (BGO) scintillation detectors
  - Spectral overlap with the LAT: 150 keV-40 MeV
- 1 × Power Box (PB)
- 1 × Digital Processing Unit (DPU)

⇨ build by MPE + MSFC/UAH

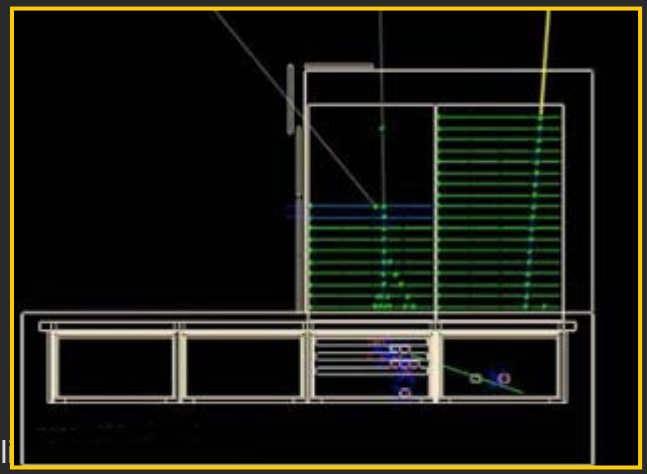


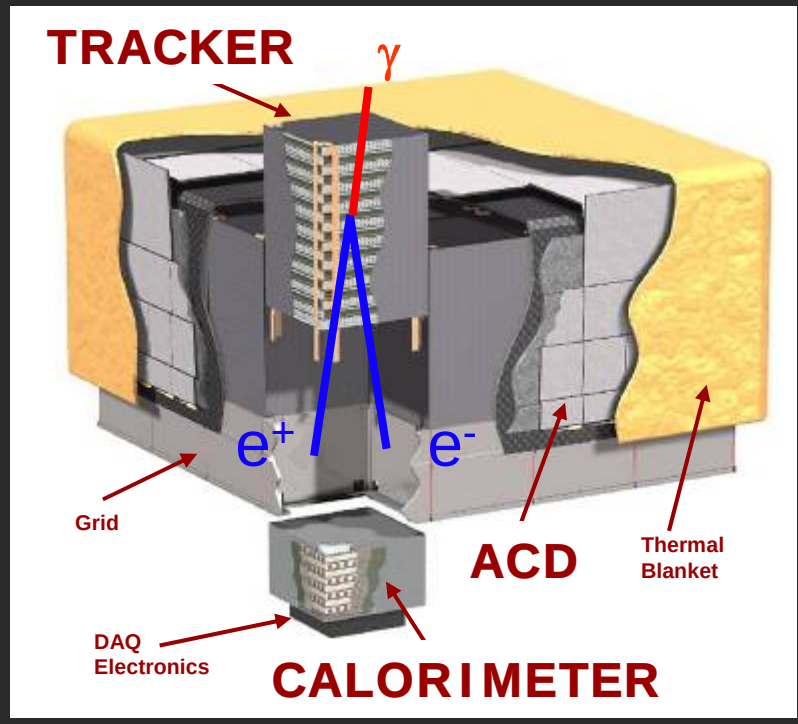




Fermi Large-Area Telescope (LAT)

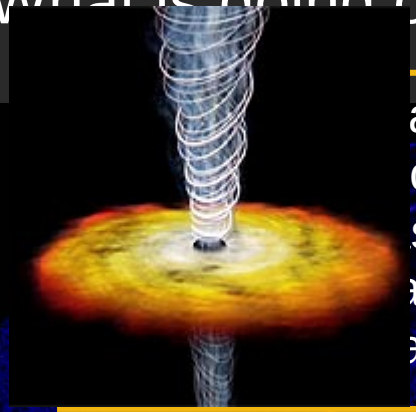
- Pair Conversion
  - 4 × 4 modular array, 3000 kg, 650 W
  - Detect photons between ~20 MeV - 300GeV
- Tracking system
  - Silicon-Strip Detectors (880000 channels)
- Calorimeter
  - CsI Crystals (8.4 r.l., hodoscopic array)
- Anticoincidence
  - Segmented ACD veto counters (tiles)





The Fermi Sky 100 MeV to 300 GeV

- What is going on in the gamma-ray sky?



amma rays
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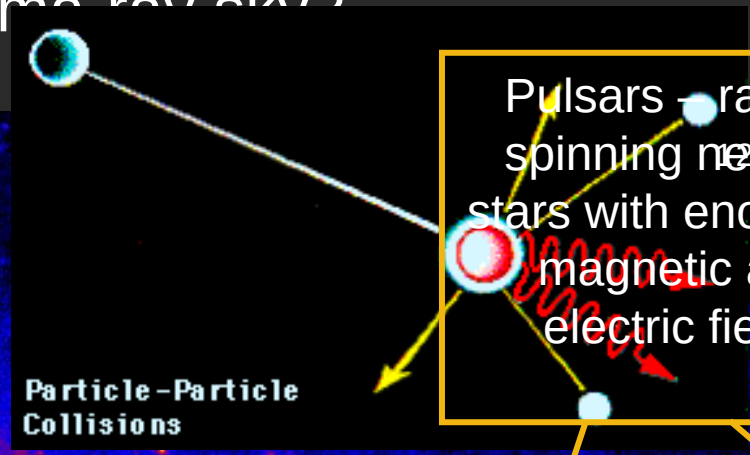
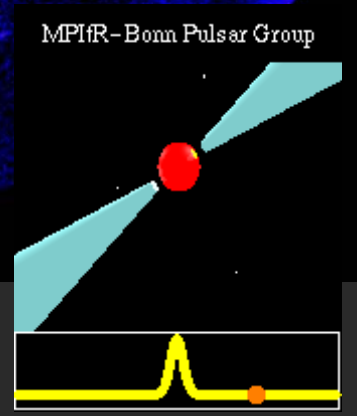
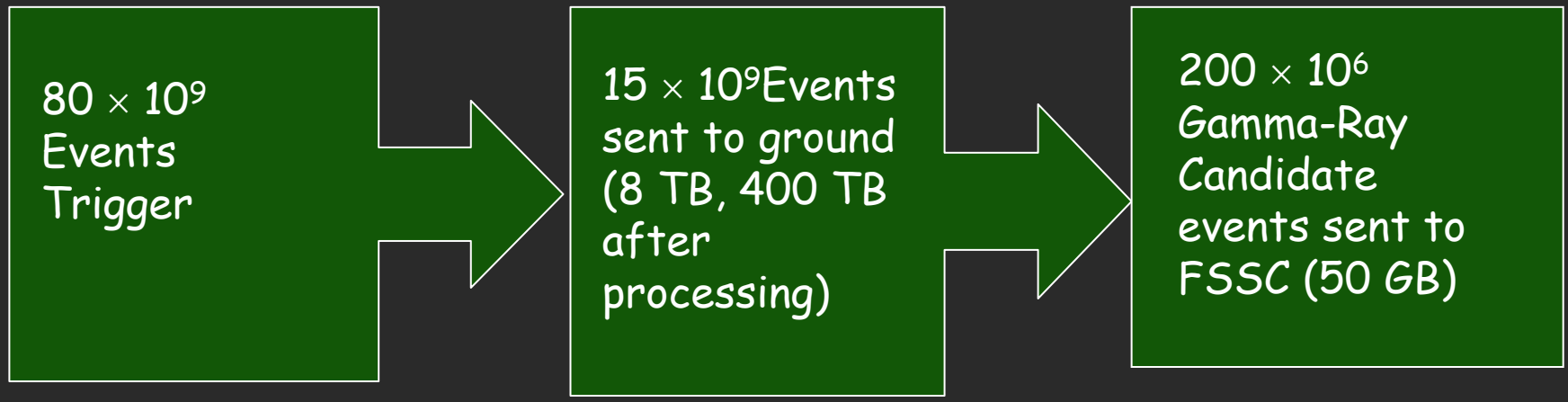


Pulsars – rapidly spinning neutron stars with enormous magnetic and electric fields

Blazars – supermassive black holes with huge jets of particles and radiation pointed right at Earth.

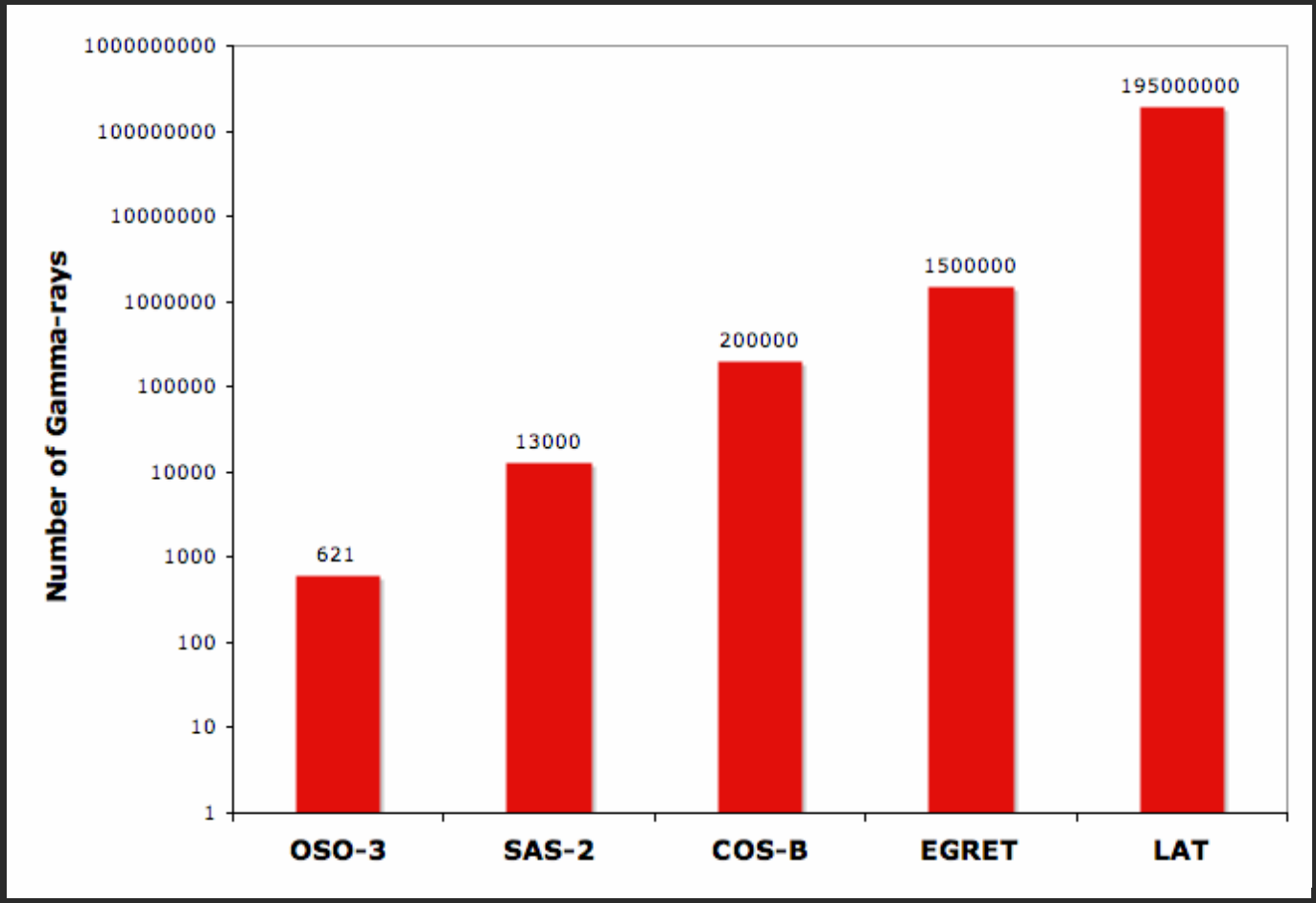


Fermi/LAT: data volume & processing

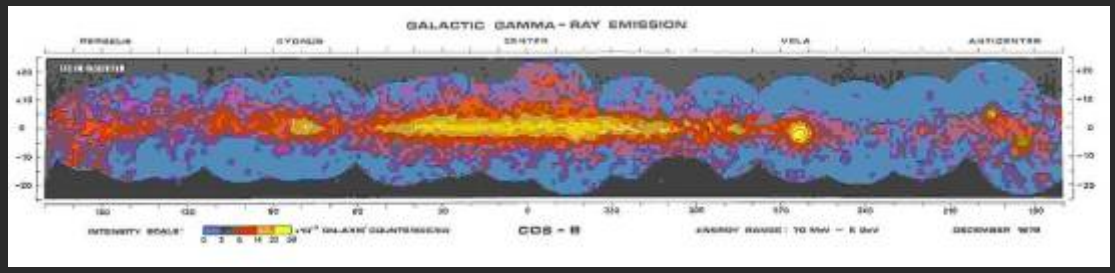


⇨ 160 CPU years in the last 16 months

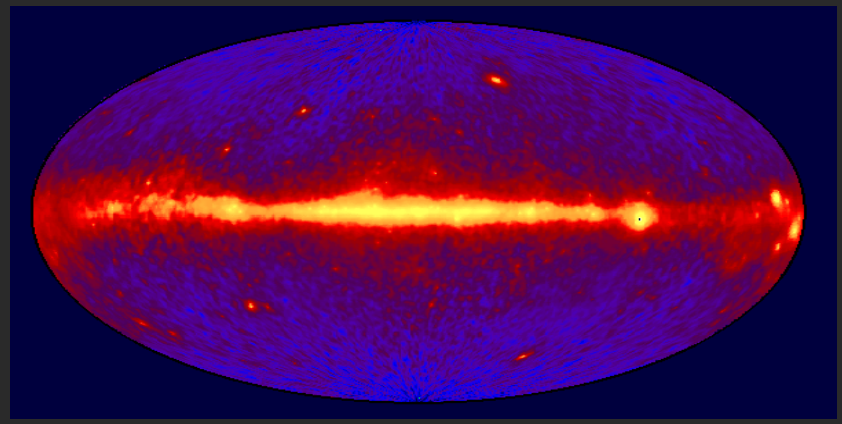
Number of Gamma-photons



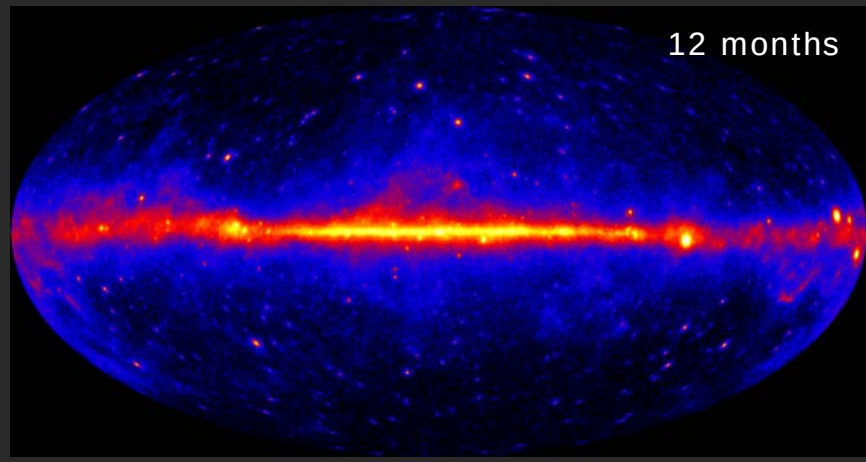
The Milky Way at Eγ > 100 MeV



COS-B: 1975-82



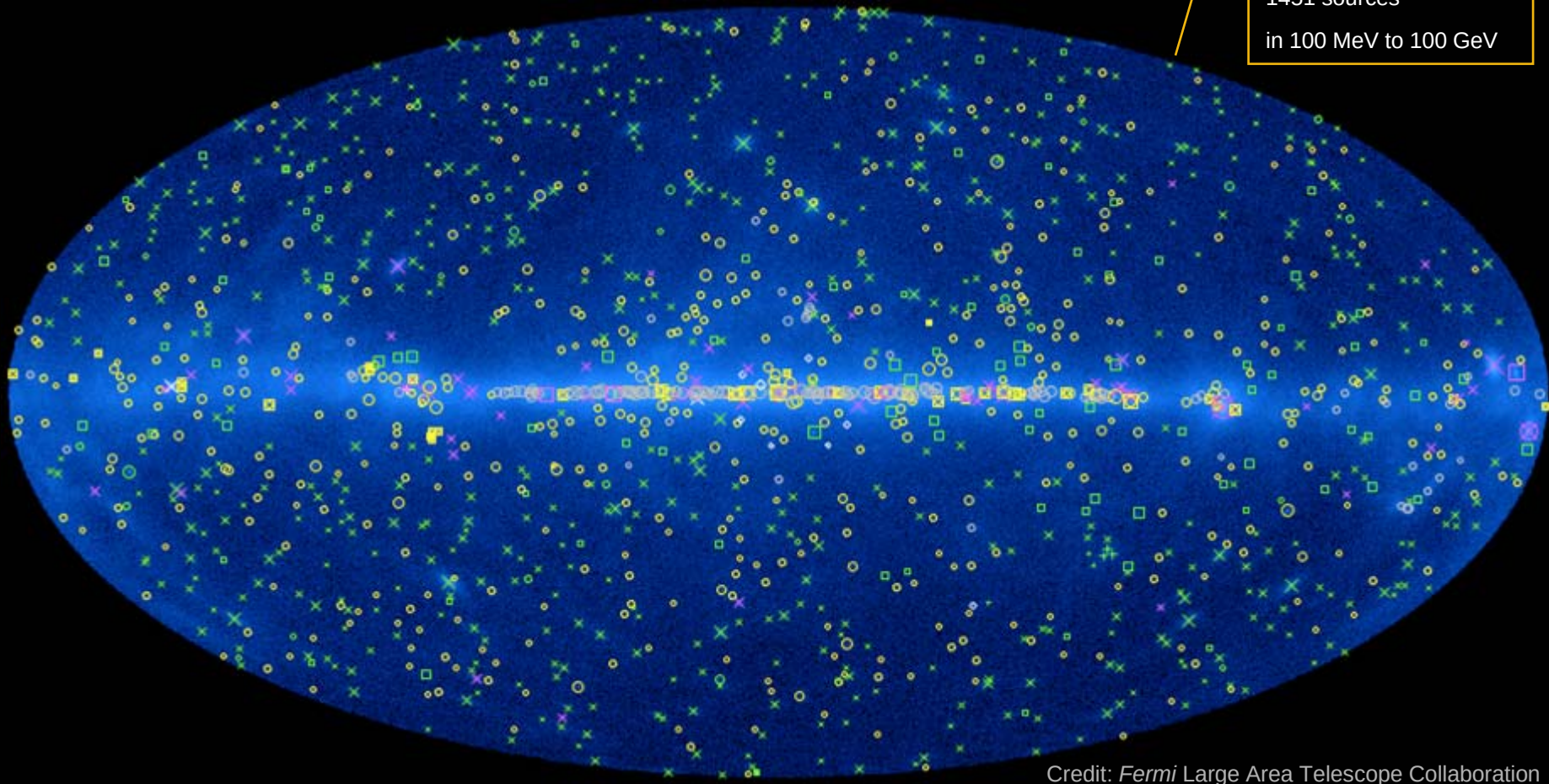
EGRET: 1991-2000



Fermi: Juli 2009

The Fermi LAT 1FGL Source Catalog

First 11 months:
1451 sources
in 100 MeV to 100 GeV



Credit: *Fermi* Large Area Telescope Collaboration

- AGN
- AGN-Blazar
- AGN-Non Blazar
- No Association
- Possible Association with SNR and PWN
- Possible confusion with Galactic diffuse emission
- Starburst Galaxy
- Galaxy
- PSR w/PWN
- Globular Cluster
- HXB or MQO
- SNR
- PWN
- PSR

The First LAT AGN catalog (1LAC)

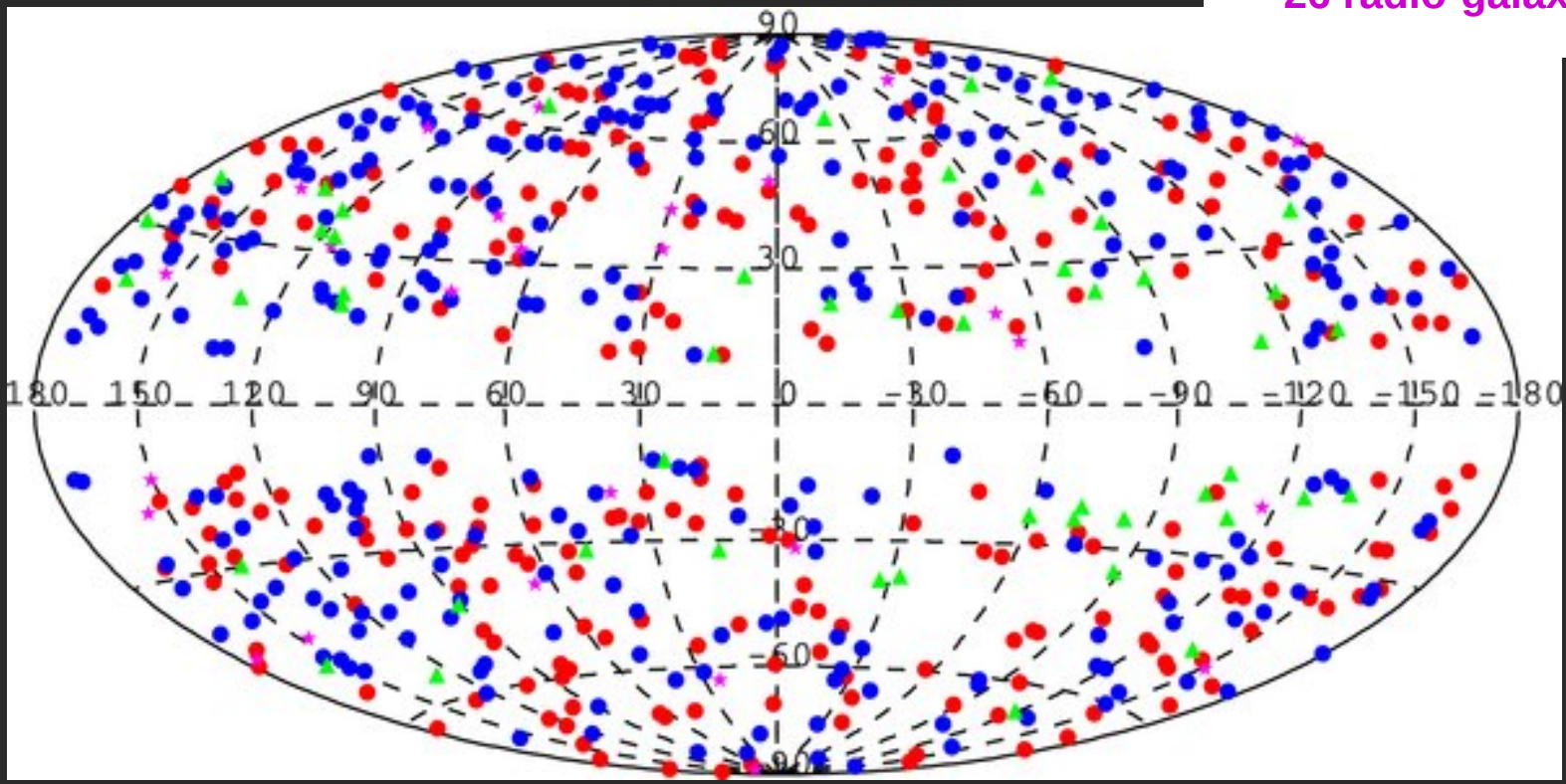
- 599 AGNs (+ ~100 candidates)
  - 11 month data set ("clean sample", |b|>10°)

248 FSRQs

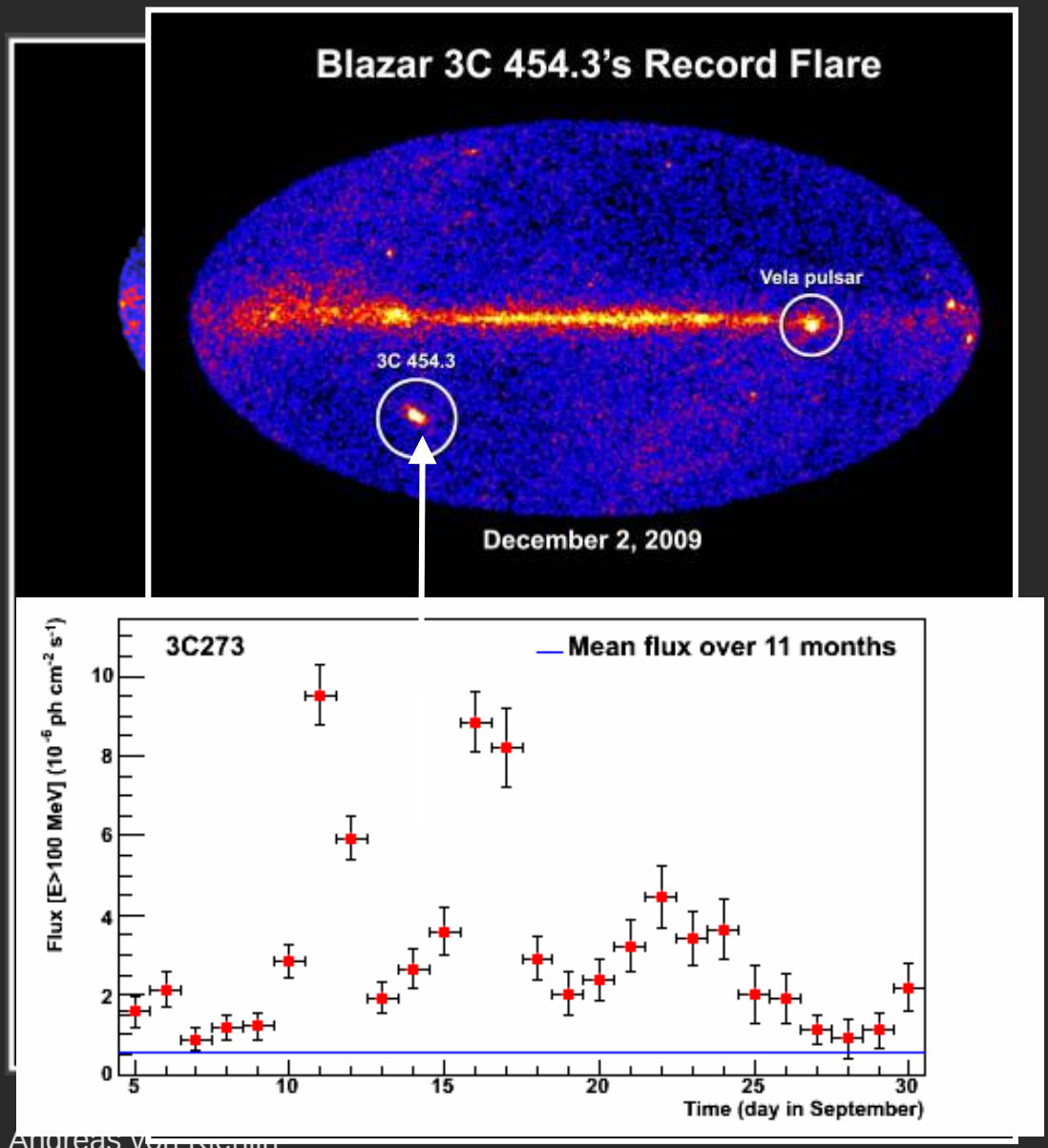
275 BLLacs

50 of unknow type

26 radio-galaxies



The flaring and variable sky



~50 Astronomers telegrams

- Discovery of new gamma-ray blazars:
  - PKS 1502+106,
  - PKS 1454-354
- Flares from known gamma-ray blazars:
  - 3C454.3, PKS 1510-089,
  - 3C273, AO 0235+164,
  - PSK 0208-512, 3C66A,
  - PKS 0537-441.
- Galactic plane transients:
  - J0910-5041,
  - 3EG J0903-3531

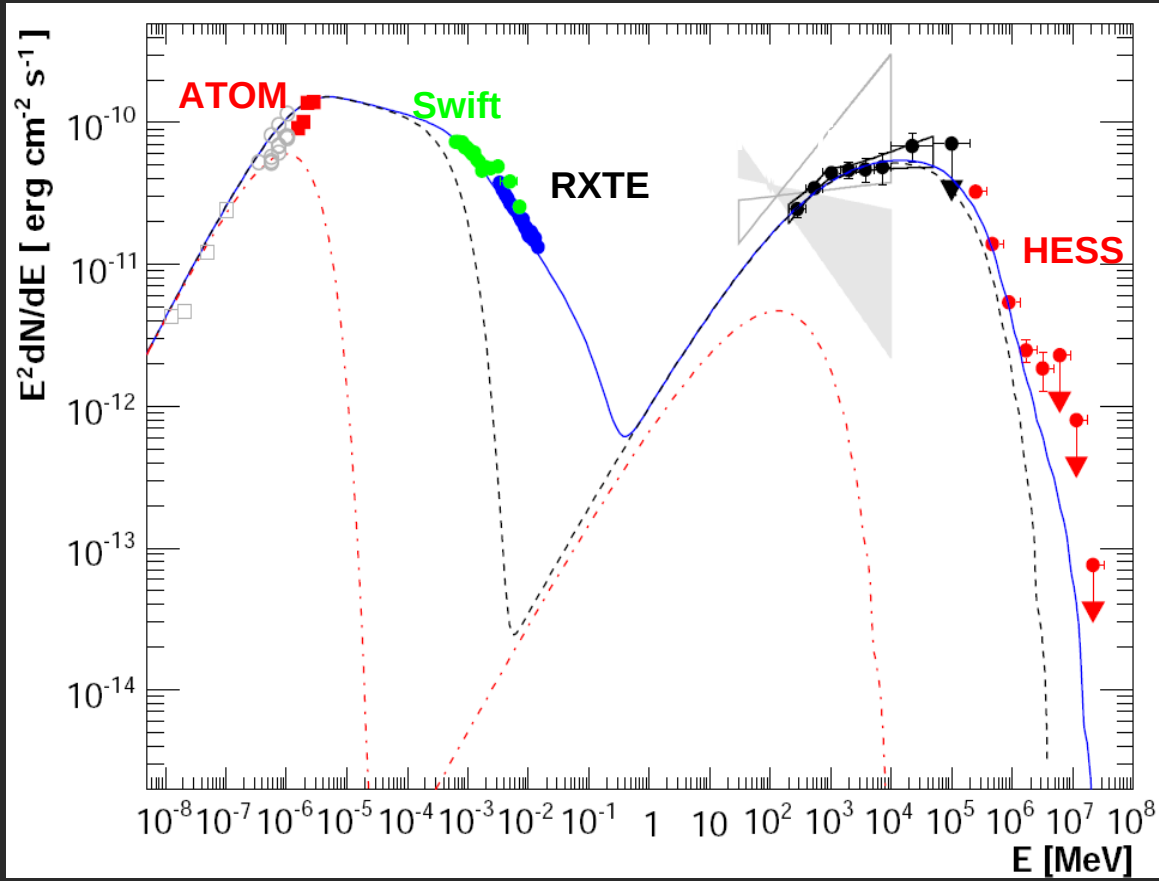
MW campaign on PKS 2155–304 (with HESS)

HSP-BLLac, z=0.116 nonflaring, low/quiescent state

First simultaneous SED including GeV-TeV

Unexpected correlations:

- strong correlation between optical and TeV fluxes
- X-ray flux varies independently of TeV flux
- correlation between X-ray flux and GeV photon index
- Challenge simple SSC models

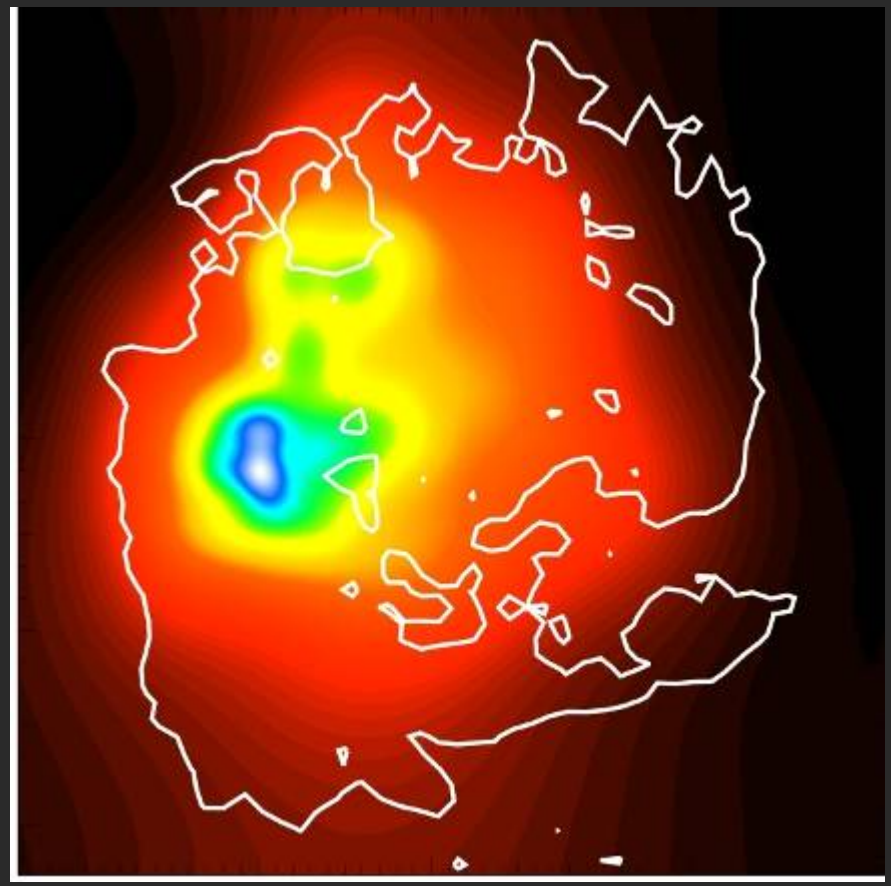


Aharonian, F. et al. 2009, ApJL, 696 L150
contact authors: B. Giebels & J. Chiang

New category of Gamma-sources

- Large Magellanic Cloud (LMC) for the first time resolved in gamma rays

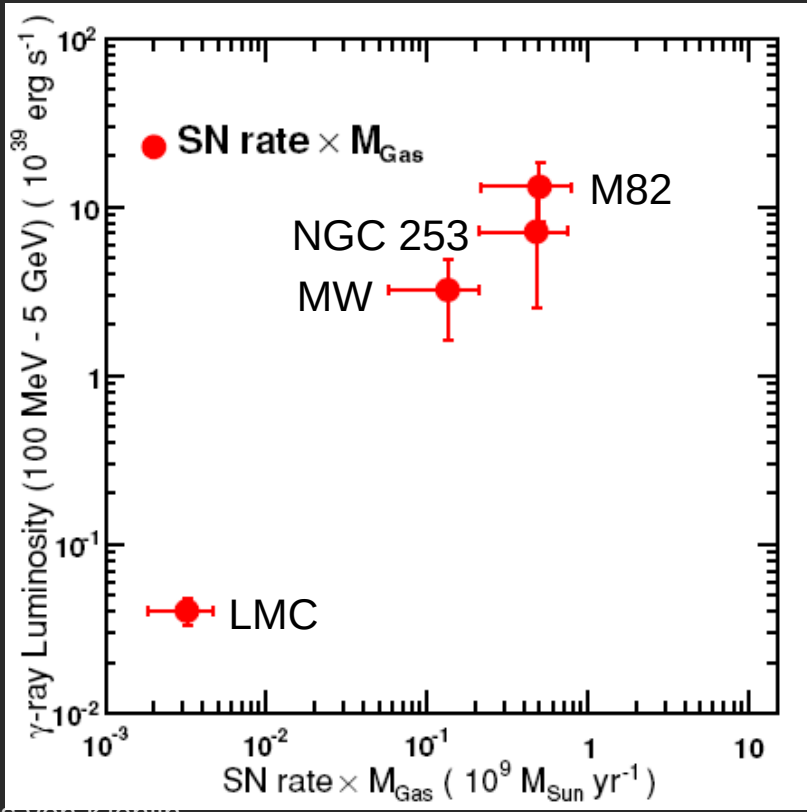
  - 30 Doradus star forming region is a bright source of gamma rays and very likely a powerful cosmic-ray accelerator
  - Gamma-ray emission correlates well with massive star forming regions
  - CR interaction with interstellar medium and radiation field
  - Compactness of emission regions suggests little CR diffusion length

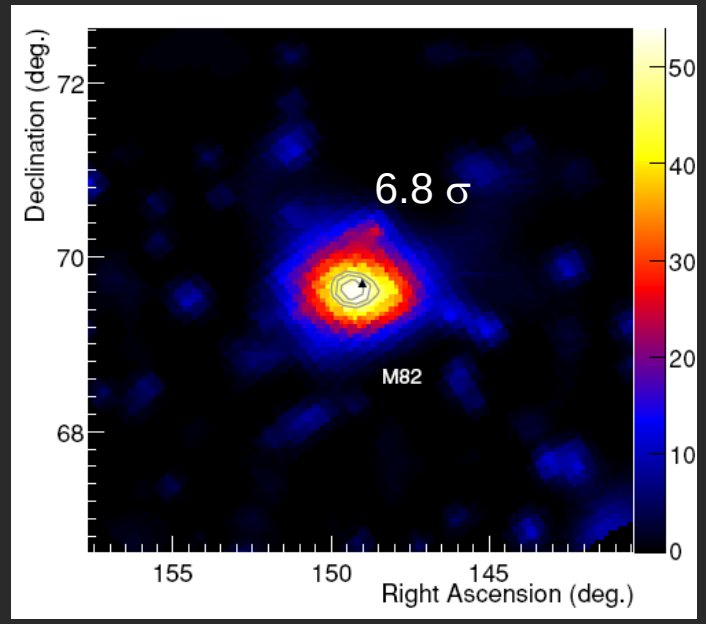


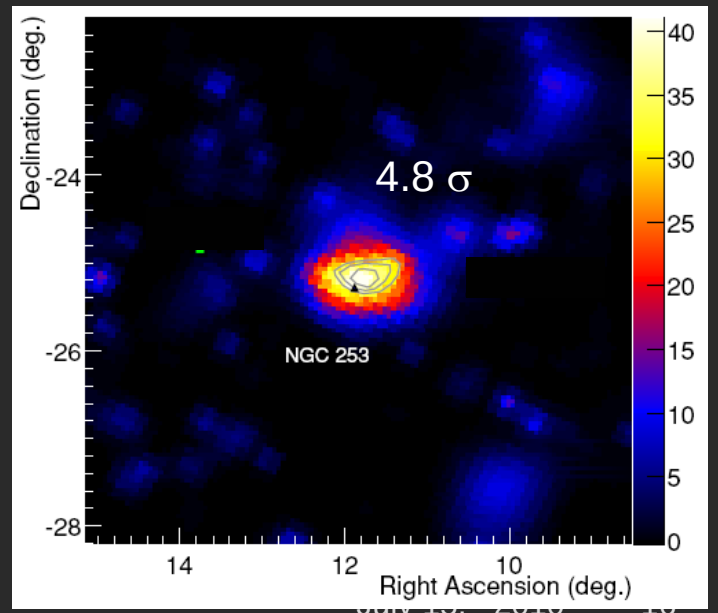
astro-ph, 1001.3298

New category of Gamma-sources

- HE γ-ray emission from starburst galaxies
  - from interaction of CRs with local interstellar gas and radiation fields
  - depends on SN rate and large quantities of target gas

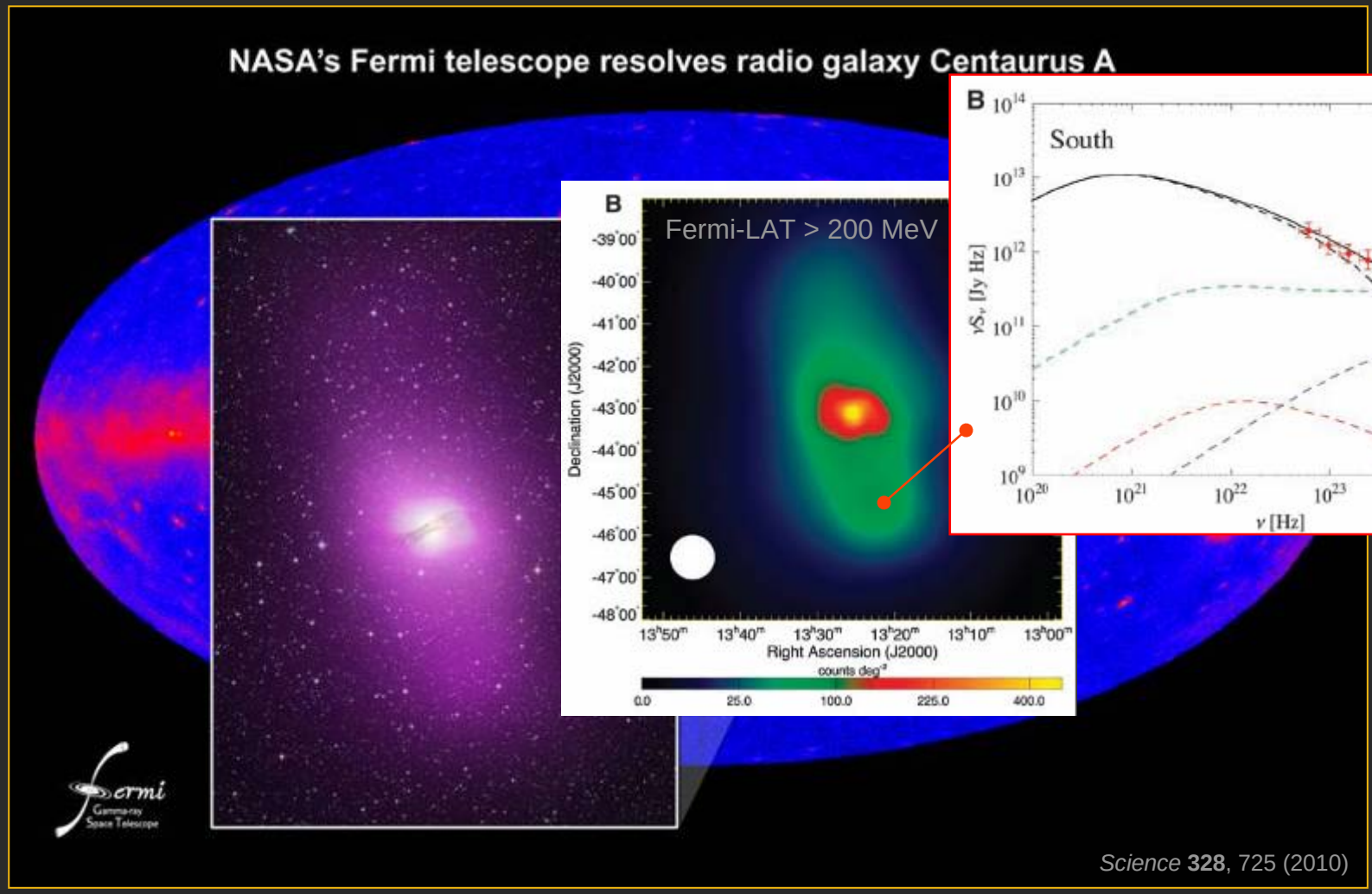






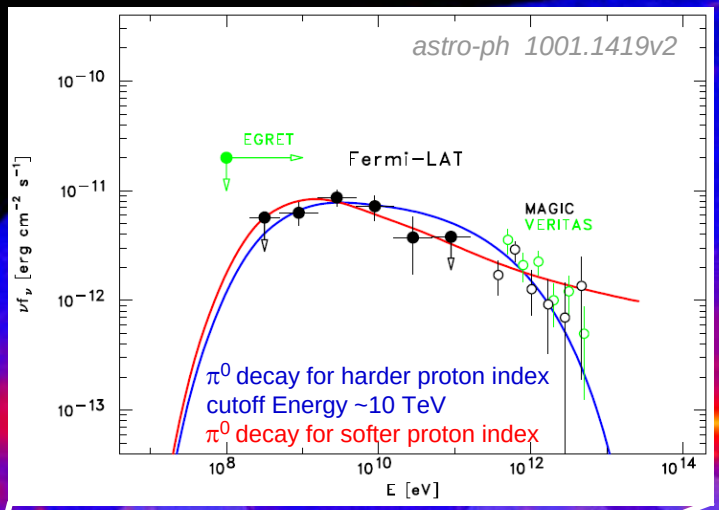
Imaging of a Radio Galaxy: Centaurus A

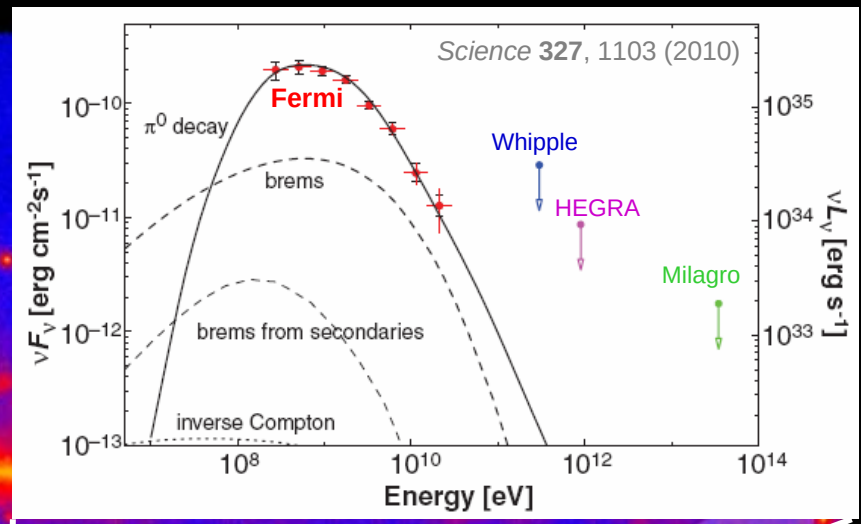
- Gamma-ray emission from the lobes:
  - Inverse Compton-scattered relic radiation from the CMB

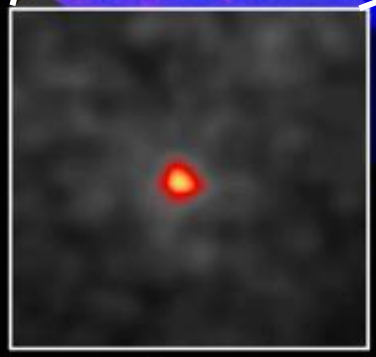


Science **328**, 725 (2010)

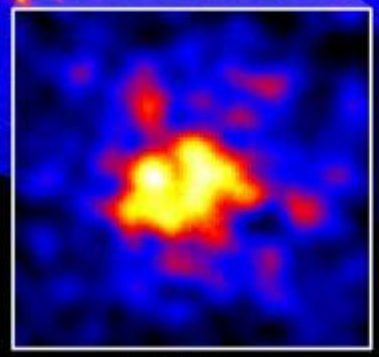
NASA's Fermi telescope resolves supernova remnants at GeV energies



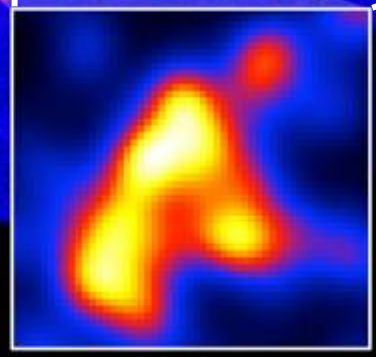




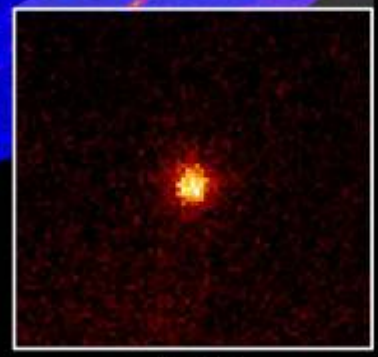
Cas A



W51C



W44



IC 443

young SNR ⟵ middle-aged SNRs ⟶

6-Month Pulsar catalog:
the blinking Gamma-ray sky

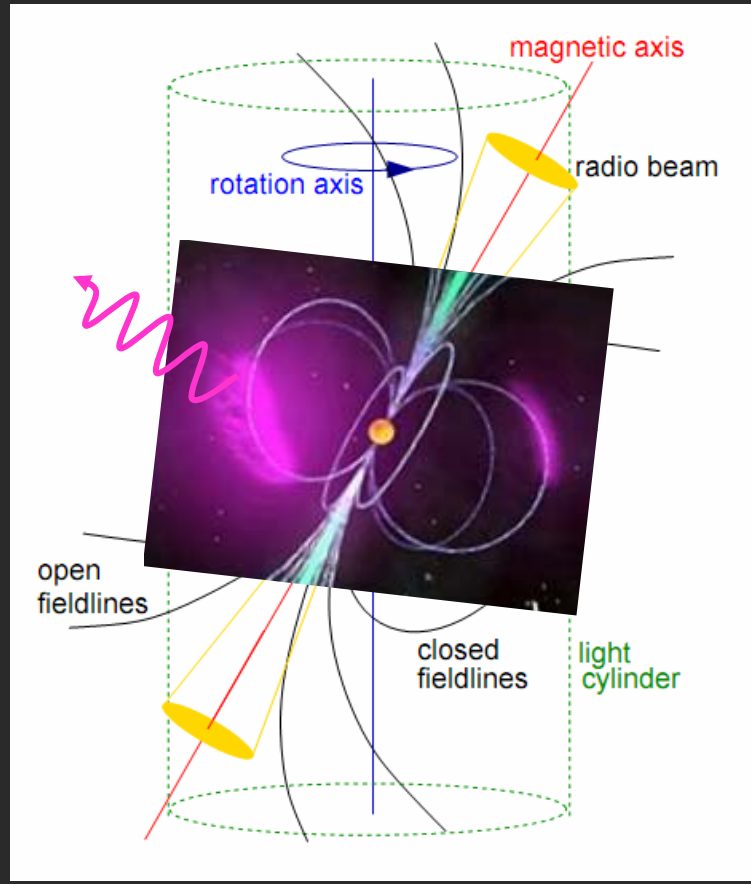
Pulses at
1/10th true rate

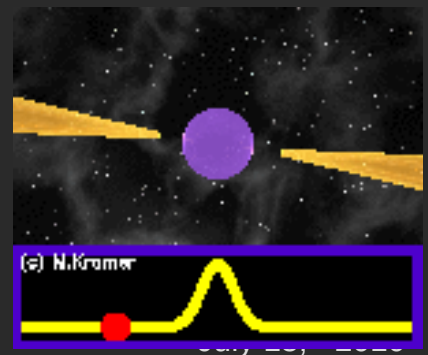
Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument

High-energy emission of Pulsars

- Fermi detects 16 new Pulsars
  - GeV photons are produced with a very high efficiency and into ‚wide-angle' beams
  - Gamma-ray emission beam is much wider than radio emission
  - Most (but perhaps not all) observed light-curves can be reproduced in the outer-gap / TPC model

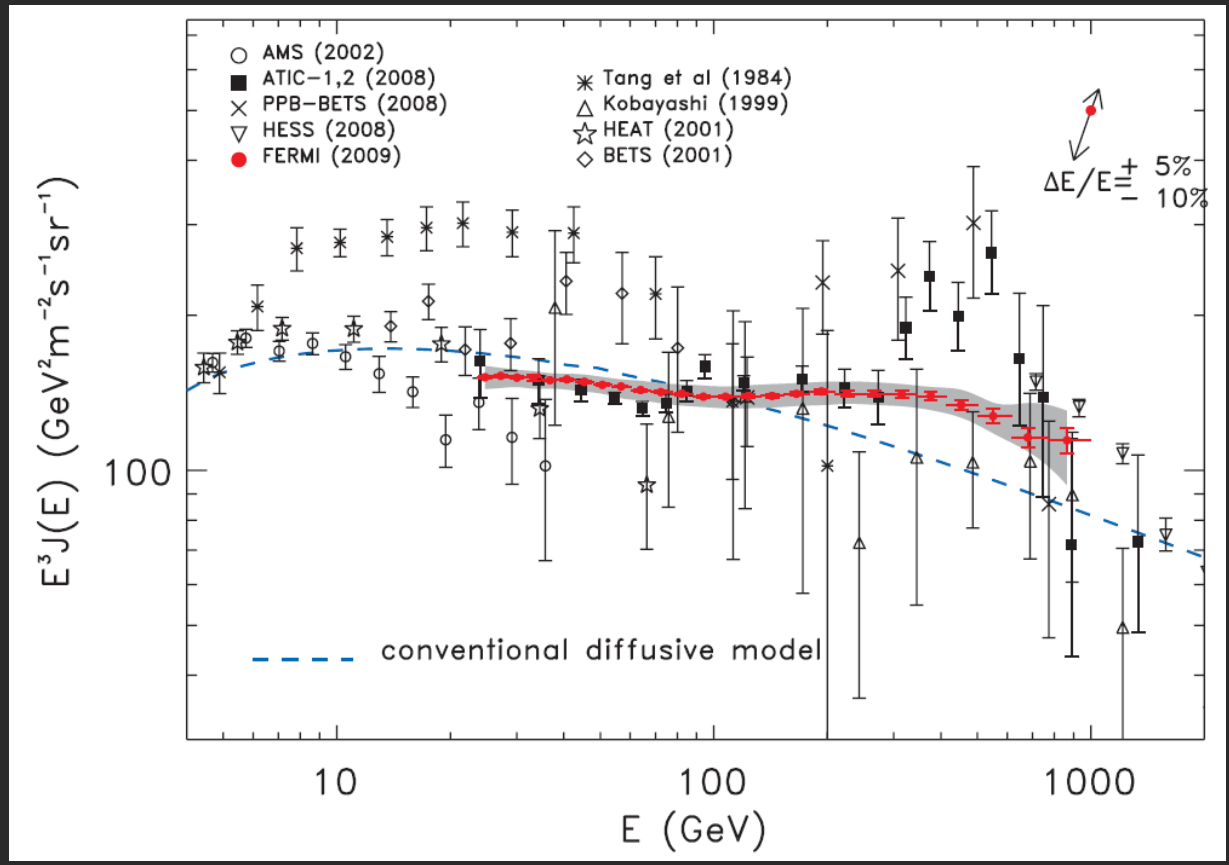




Cosmic Ray Electron Spectrum

- Fermi measures cosmic ray $e^- + e^+$ with >2 m^2sr acceptance (need to reject CR proton background)
- CR electron spectrum $E^{-3.04}$ between ~25 and 900 GeV
  - featureless; consistent with power law

- harder than predicted by GALPROP
- Local sources?
- Dark matter?

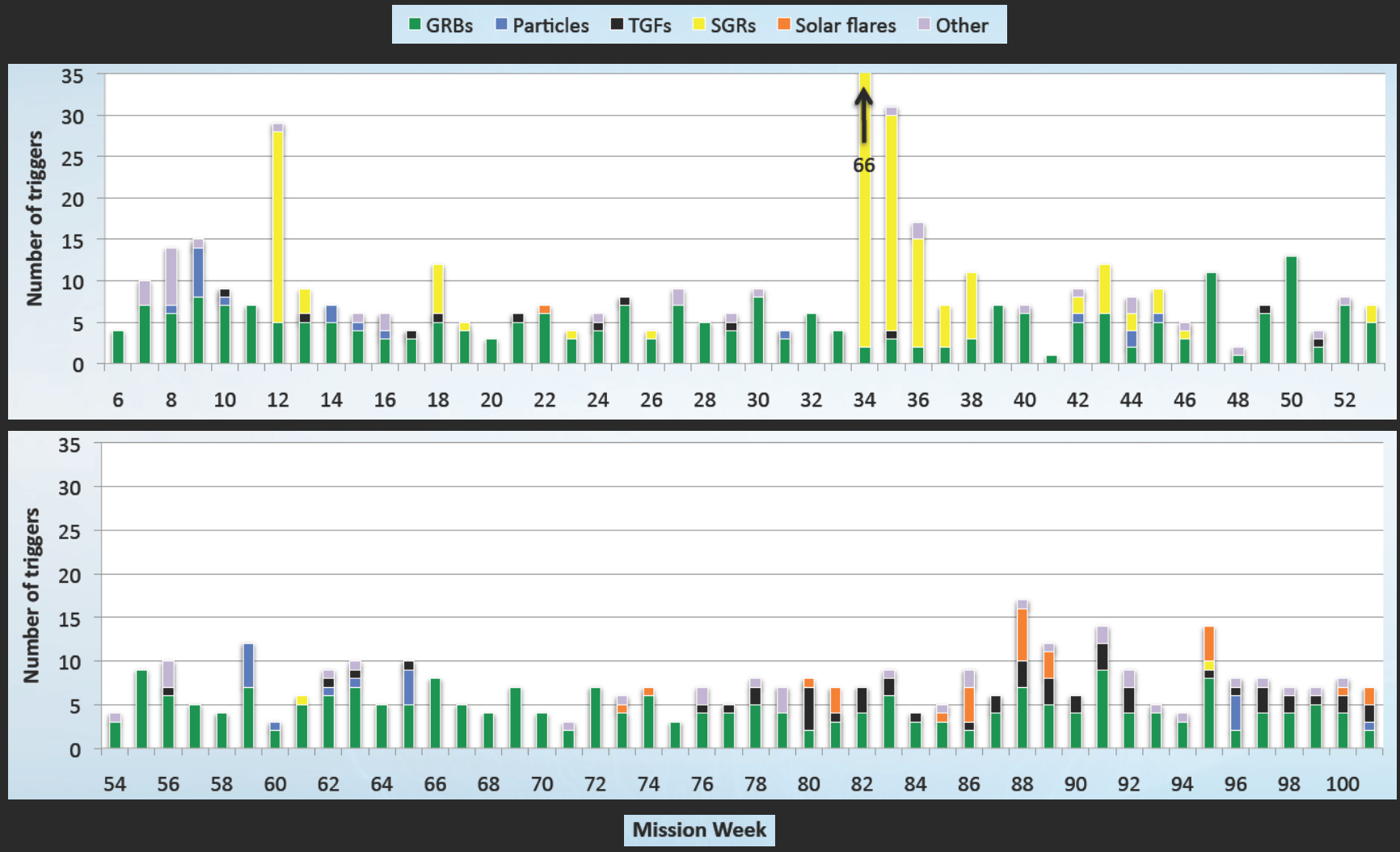


PRL 102, 181101 (2009)

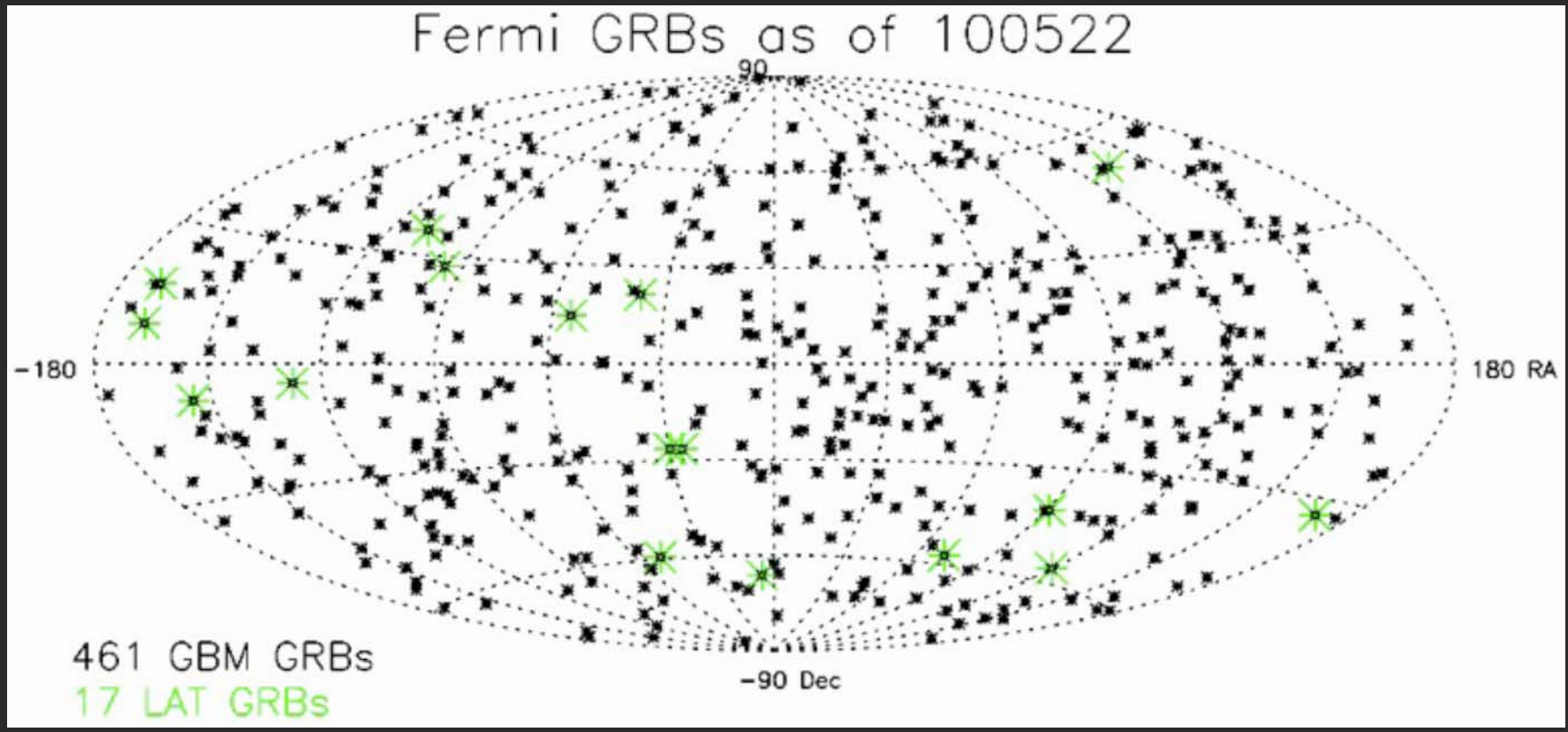
Gamma-ray Burst Monitor Science Highlights

- Gamma-Ray Bursts (GRBs)
- Soft Gamma Repeaters (SGRs)
- Terrestrial Gamma-ray Flashes (TGFs)
- Solar Flares (SFs)

GBM Trigger History



Fermi GRBs

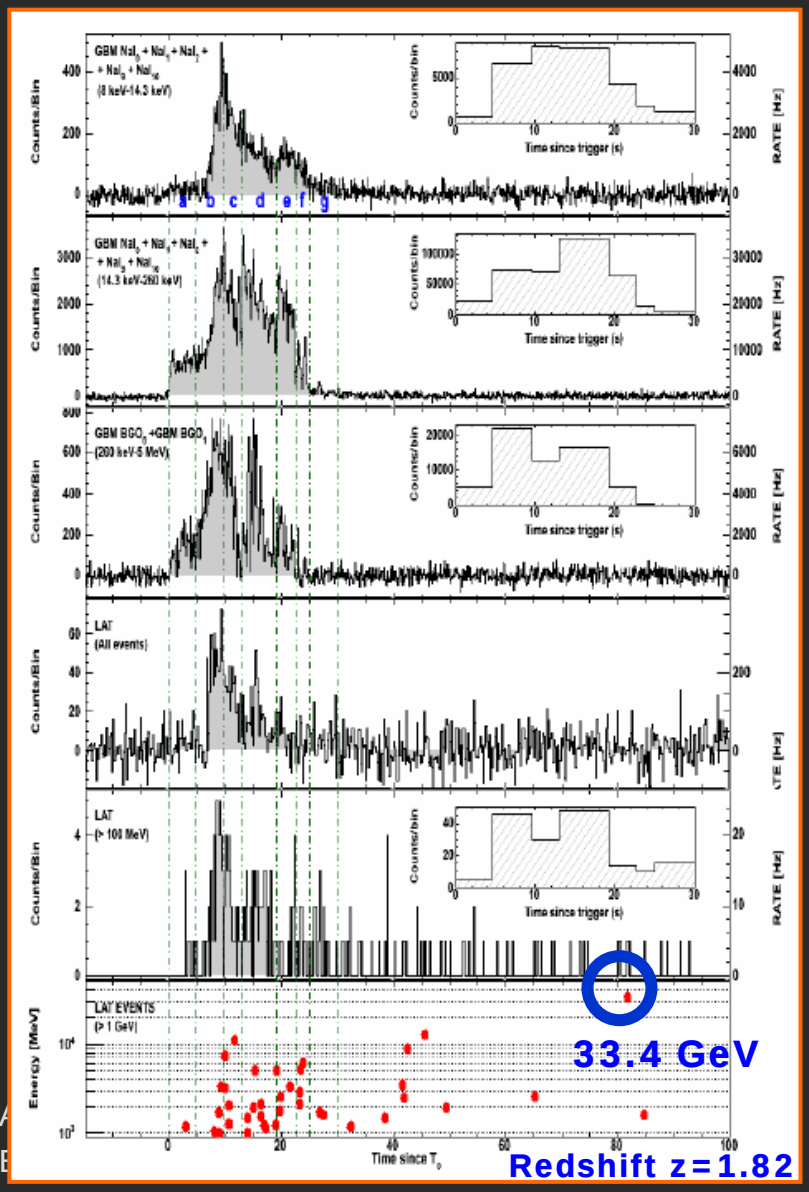


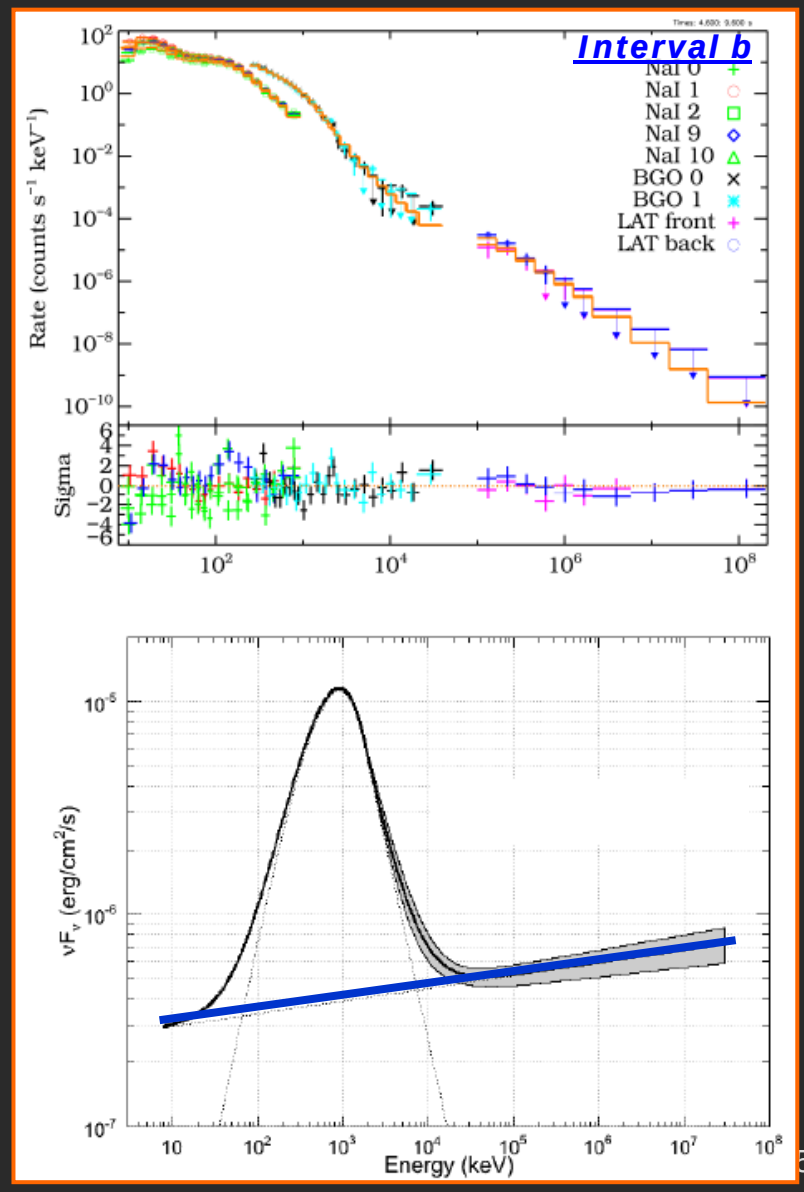
- 10 of 17 LAT bursts were observed (followed up) with Swift XRT, and all but 2 of these were detected by XRT.
- All XRT-detected LAT bursts were seen to have an optical counterpart, with a redshift measured in each case.

Fermi Observations of GRB 090902B

"A distinct spectral Component in the Prompt and Delayed emission"

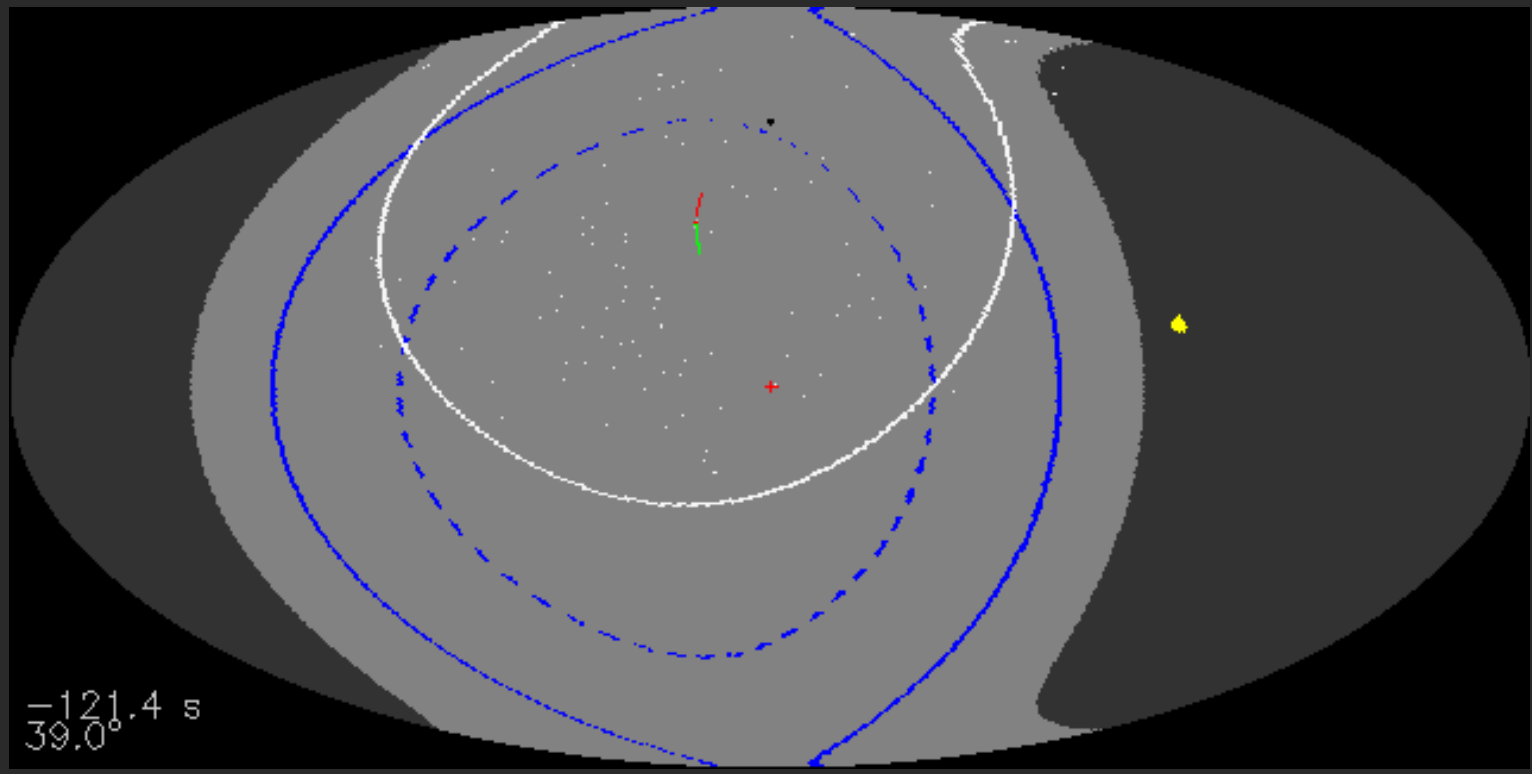
Bissaldi, dePalma, Chiang & McBreen on behalf of the GBM and LAT Collaborations, ApJL submitted





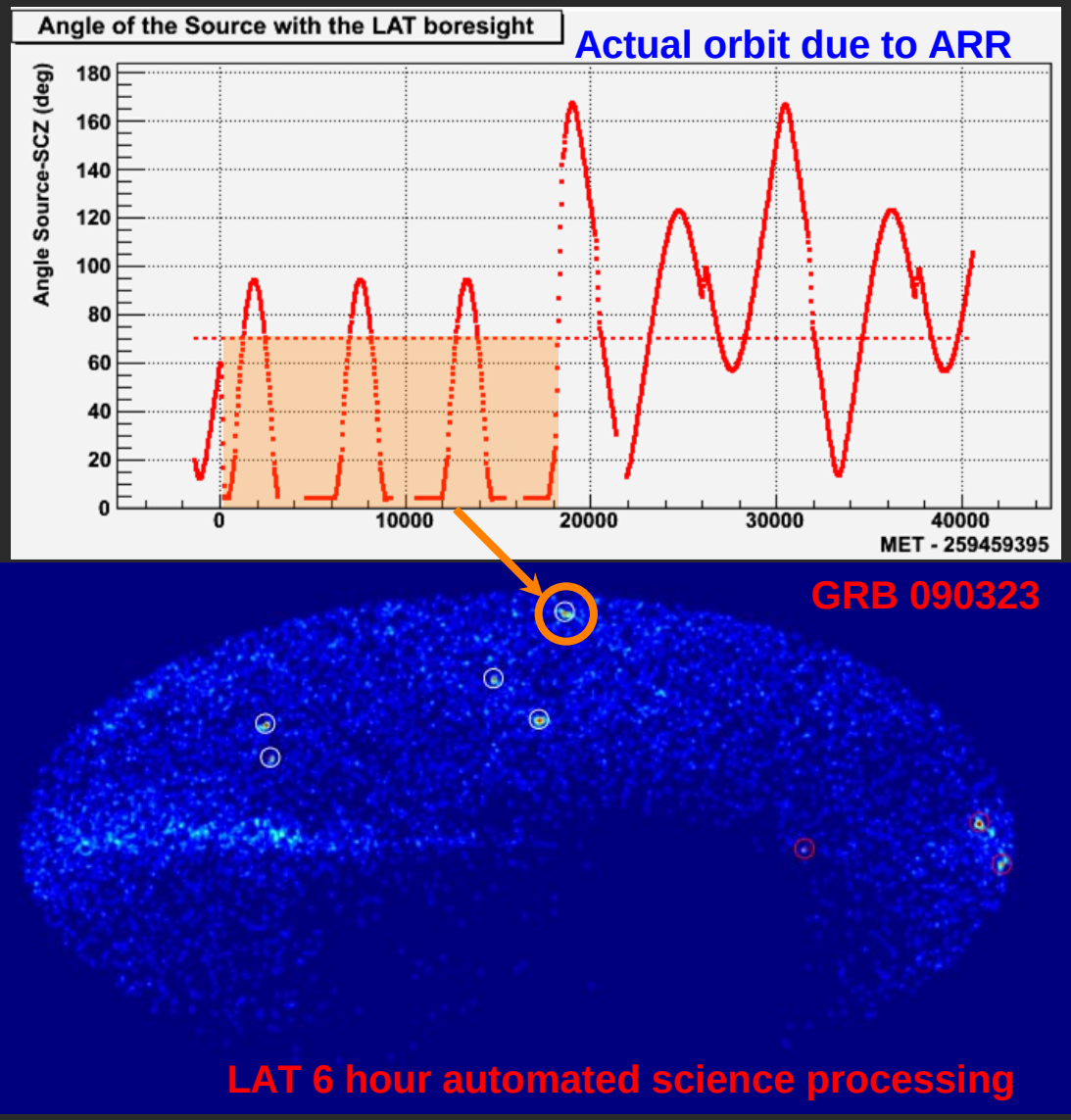
Autonomous Repoint Request (ARR)

- ARR for GRB 090902B



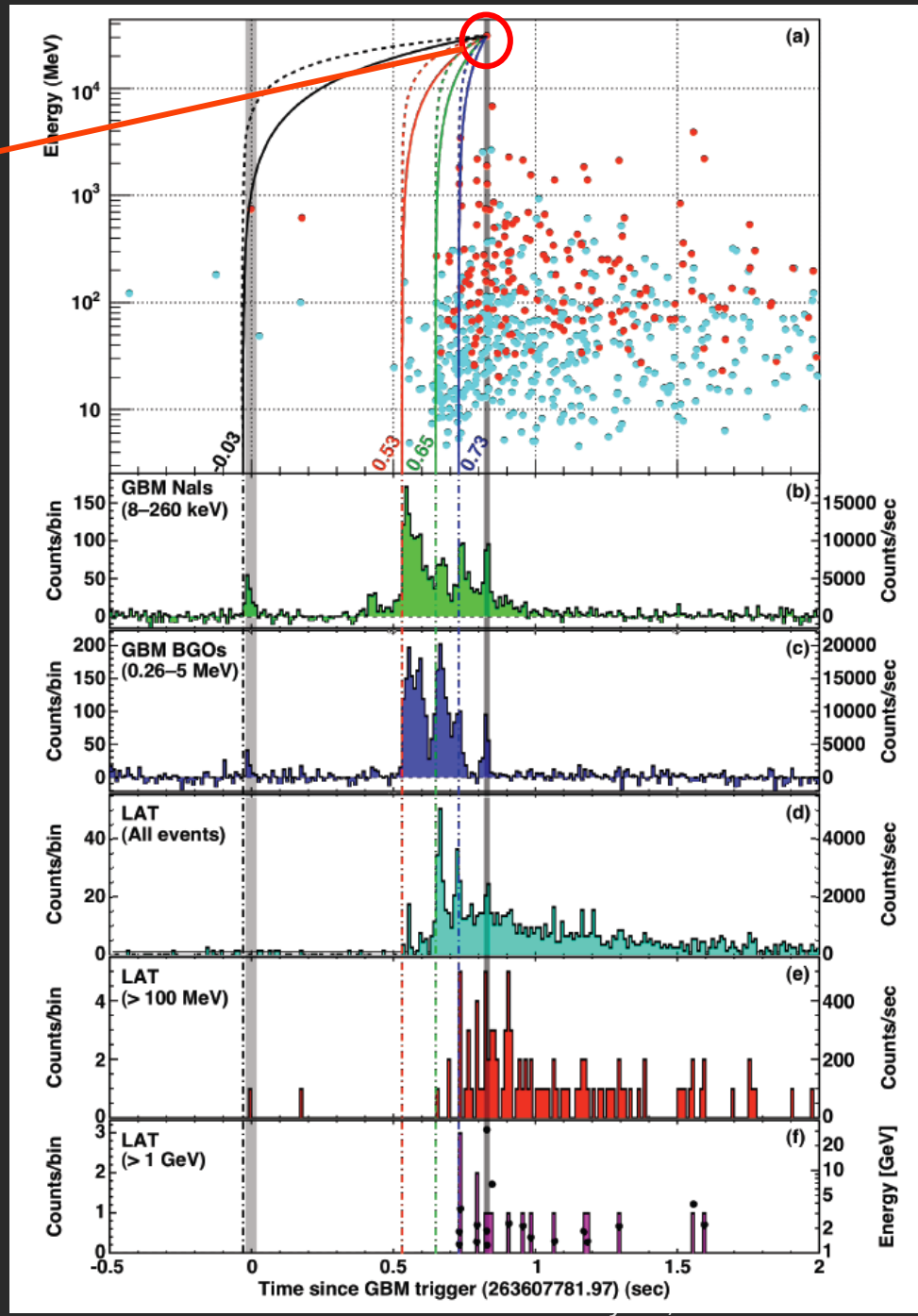
Long-Lived HE Emission in Other LAT GRBs

- GRB 090323
  - HE emission up to a few GeV lasted ~2000 s.
  - Made possible by ARR (autonomous repoint recommendation) by GBM
    - Otherwise GRB would have been out of FOV
- GRB 090328
  - HE emission lasted ~900 s
  - ARR was also issued



GRB 090510

- 31 GeV photon: 0.83 s after the trigger
- This is the highest energy observed from short GRB
  - z = 0.9 / 7.3 billion ly
- Thus, this photon can be used to constrain both the bulk Lorentz factor of the relativistic jet and Lorentz Invariance Violation (LIV)
- GRB 080916C:
  - $M_{QG} > 0.1\ M_{Planck}$
  - where $M_{Planck} \sim 10^{19}$ GeV
- GRB 090510 (short-hard burst):
  - $M_{QG} >$ a few M_{Planck}
- At the fundamental length scale (Planck-scale of 1.62×10^{-33} cm) one expects that quantum effects affect nature of Space/Time



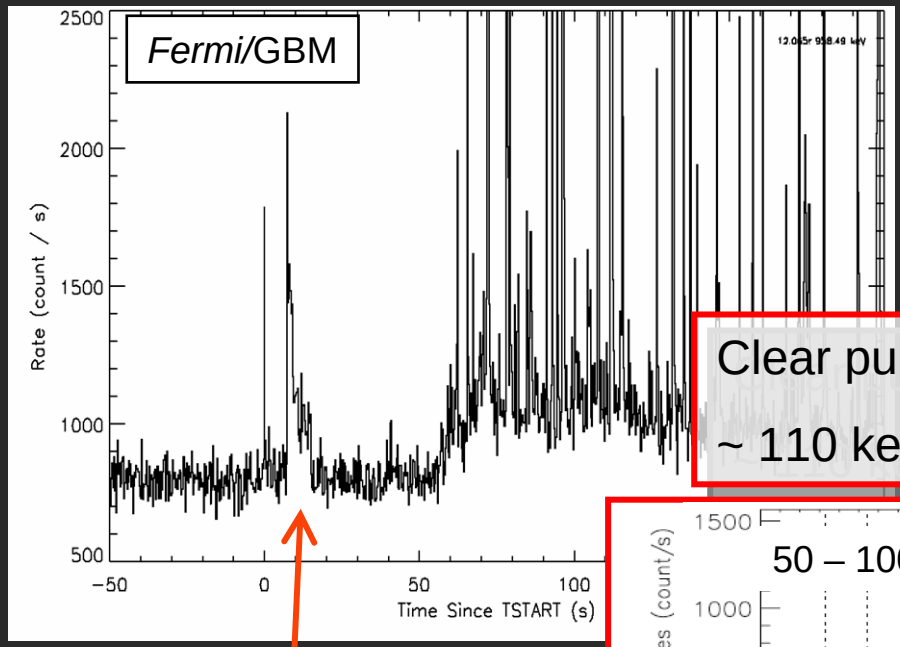
SGRs & AXPs in the *Fermi* era

SGR Source	Active Period	Triggers		Comments
J0501+4516	22 Aug – 03 Sep 08	26		New source at Perseus arm
1806-20	29 Nov 2008	1		Old source - reactivation
J1550-5418	03 - 20 Oct 08 22 Jan - 24 Feb 09 22 Mar – 17 Apr 09	7 117 14		Known source – first time exhibiting burst active episodes
J0418+5729	05 Jun 2009	2		discovered with GBM ! new source at Perseus arm
1833-0832	19 Mar 2010			discovered with Swift and RXTE – no GBM detection

- GBM Magnetar Key Project (PI: Chryssa Kouveliotou)
  - http://gammaray.nsstc.nasa.gov/gbm/science/magnetars

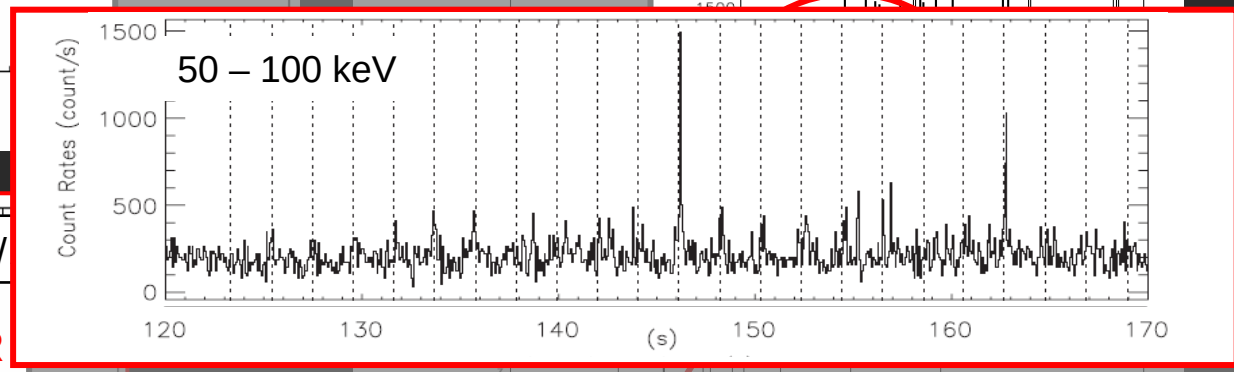
Observations of the Magnetar SGR J1550-5418
with *Fermi* /GBM and *INTEGRAL* SPI/ACS

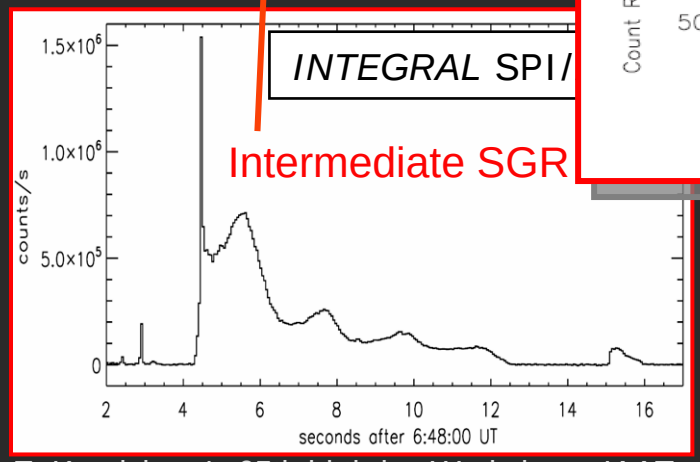
- 3activity periods: Oct 08, Jan 09, March & April 09
  - About 500 bursts detected
  - Two intermediate flares
  - Enhanced persistent emission with pulsations at the NS spin period

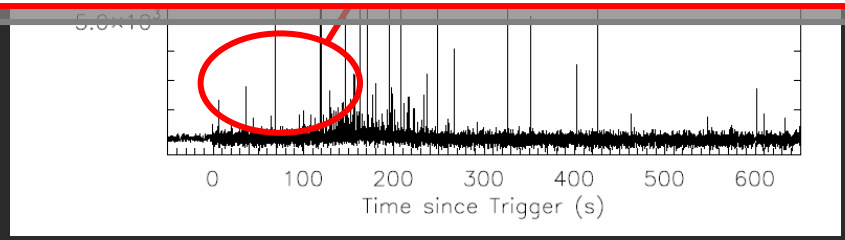


Clear pulsation up to

~ 110 keV seen!



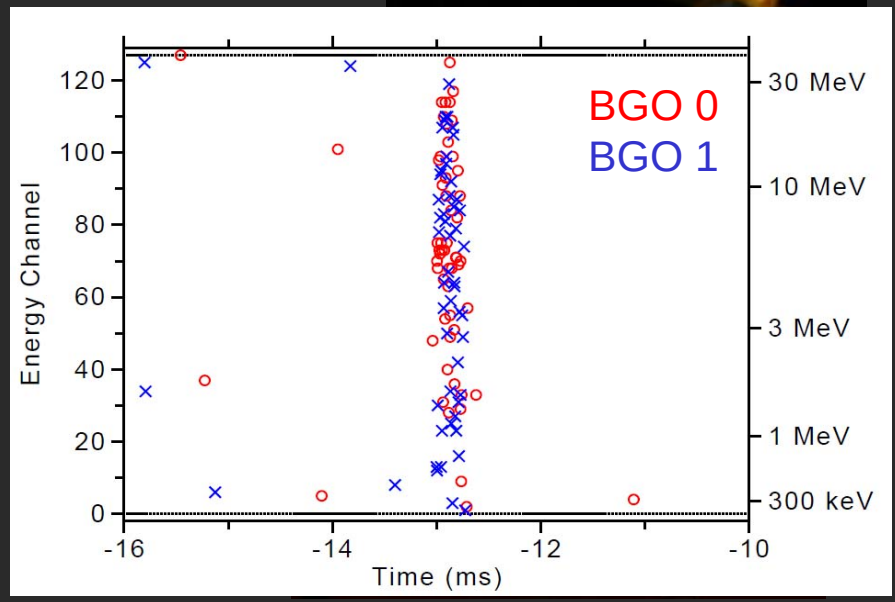


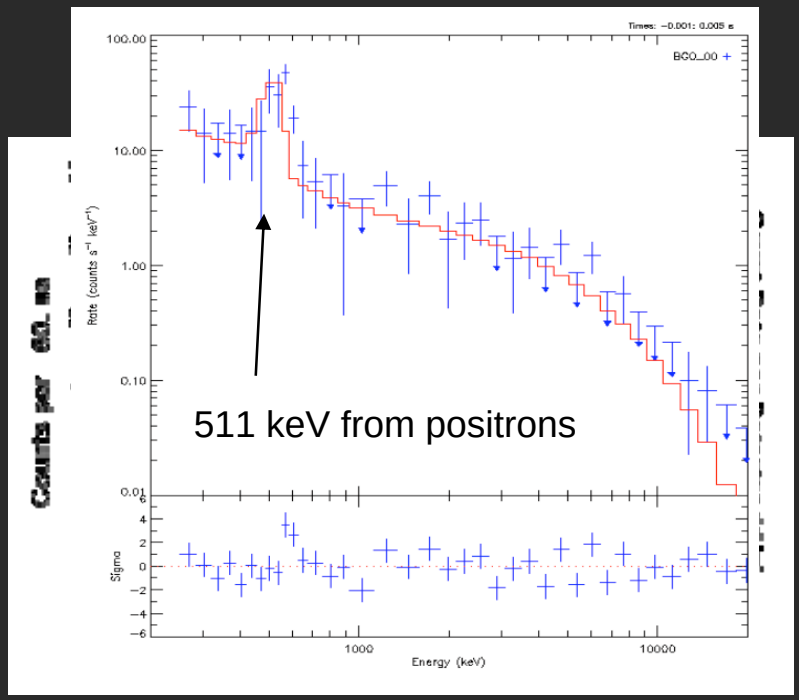


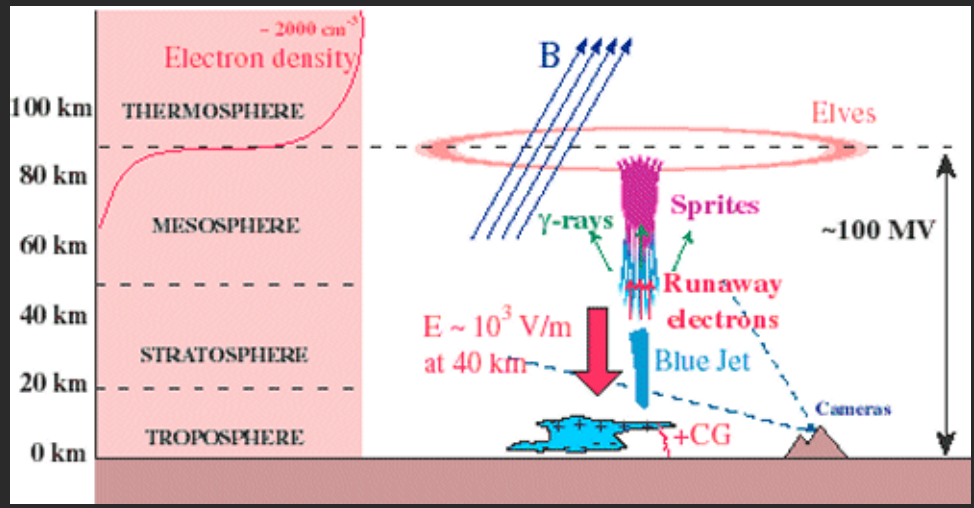
Kaneko et al. 2010

Terrestrial Gamma-ray Flashes (TGFs)

- GBM triggered on 79 TGFs
- Two types of TGFs:
  - Short (~0.1 ms) γ-ray TGFs
  - Long (~1 ms) electron/positron TGFs

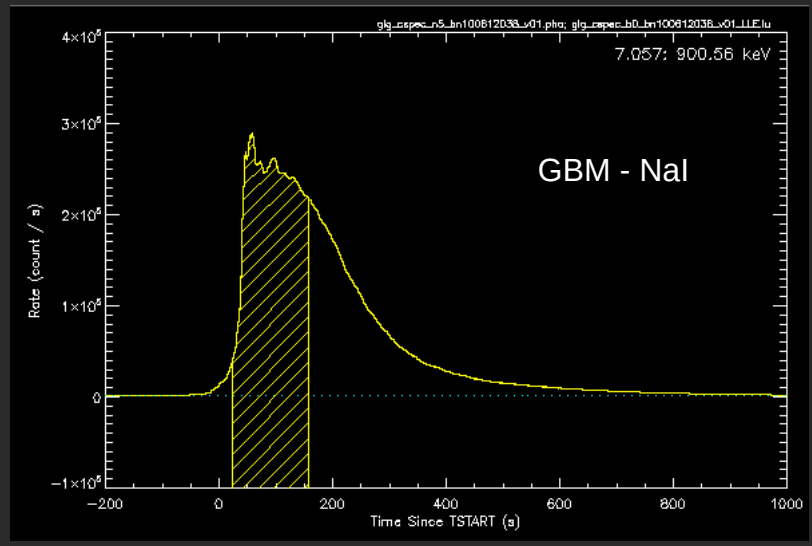


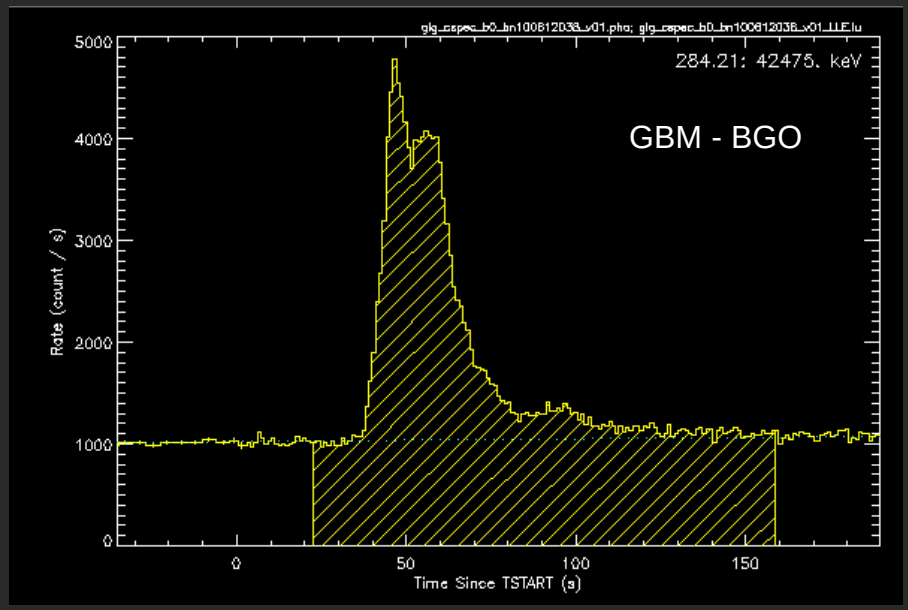


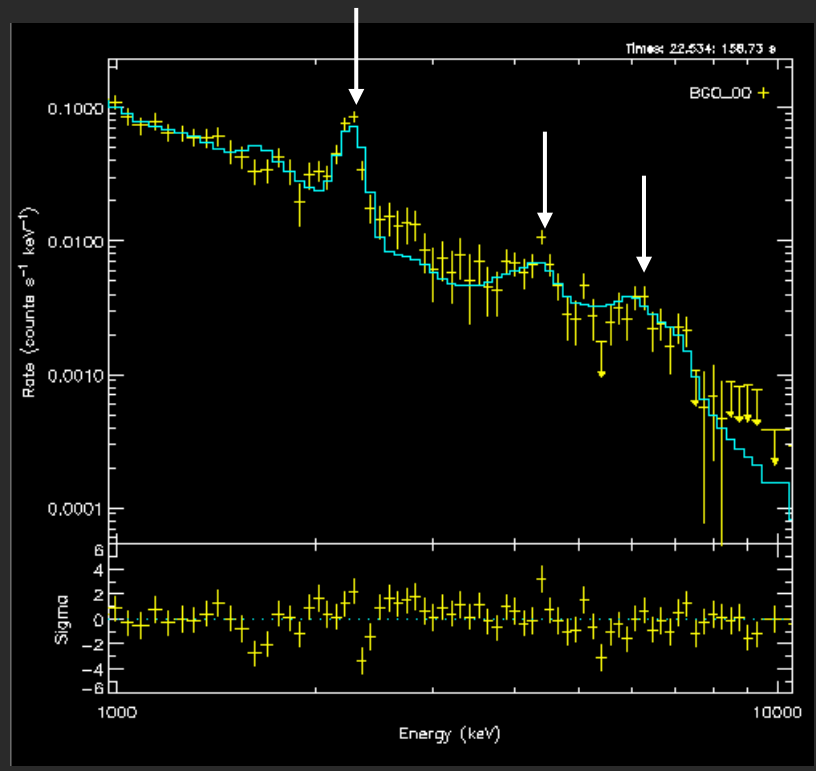


Solar Flares (GBM)

- June 12, 2010: First solar flare with nuclear lines
  - 2.2 MeV ^{1}H neutron capture line
  - 4.4 MeV $^{12}C^{*}$ nuclear interaction line
  - 6.1 MeV $^{16}O^{*}$ nuclear interaction line





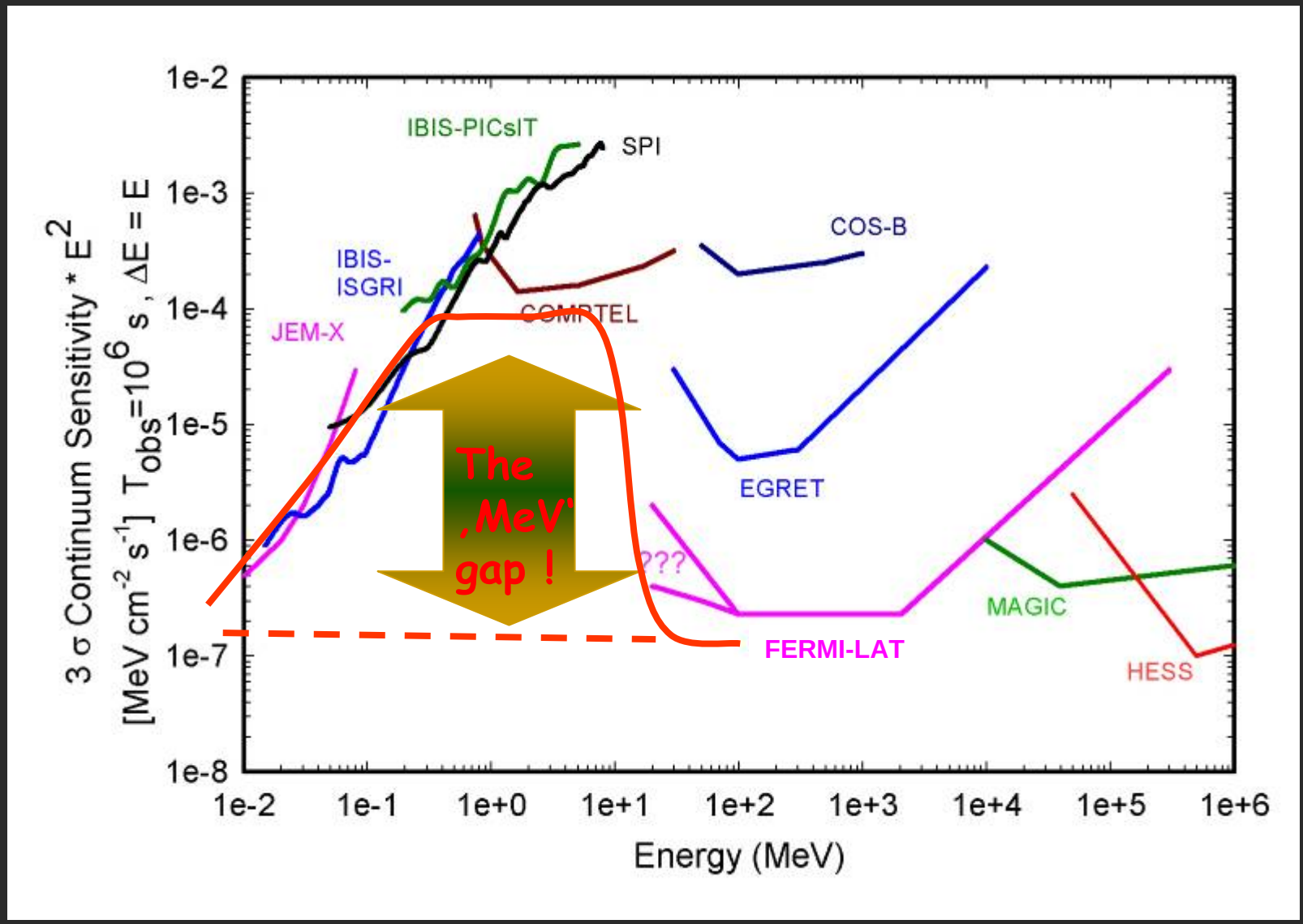


Highlights Summary

- Large Area Telescope (*Fermi*-LAT):
  - 1st Fermi LAT Source catalog (1451 sources)
  - Observes flaring and variable source
  - Starburst galaxies + LMC detected in GeV γ-rays
  - Multiwavelength Campaigns
  - Resolves SNRs at GeV energies
  - γ-ray emission from Cen A's radio lobes
  - LAT detects many pulsars and constrains emission mechanism
- Gamma-ray Burst Monitor (*Fermi*-GBM)
  - 500 GRBs in 2 years
  - 17 LAT GRBs ⇨ extra emission component, delayed onset, LAT/GBM constrain LIV
  - Burst from 4 SGRs detected
  - TGFs
  - 1st Solar Flare with nuclear lines

…exciting progress in many more topics!

Outlook: Future Mission in the Gamma-ray regime ?



Outlook: Future Mission in the Gamma-ray regime ?

- Advanced Compton Telescope (ACT)
- GRIPS