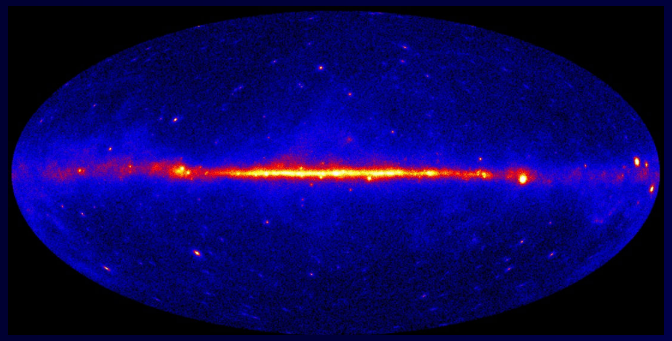


High Energy Astrophysics with the Fermi Large Area Telescope

Elizabeth Hays

(NASA/GSFC)

On behalf of the Fermi LAT Collaboration

Fermi LAT Collaboration

- France
  - IN2P3, CEA/Saclay
- Italy
  - INFN, ASI, INAF
- Japan
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology
- Sweden
  - Royal Institute of Technology (KTH)
  - Stockholm University
- United States
  - Stanford University (SLAC and HEPL/Physics)
  - University of California at Santa Cruz - Santa Cruz Institute for Particle Physics
  - Goddard Space Flight Center
  - Naval Research Laboratory
  - Sonoma State University
  - Ohio State University
  - University of Washington

Principal Investigator:
Peter Michelson (Stanford University)

~390 Scientific Members (including 96 Affiliated Scientists, plus 68 Postdocs and 105 Students)

Managed at SLAC

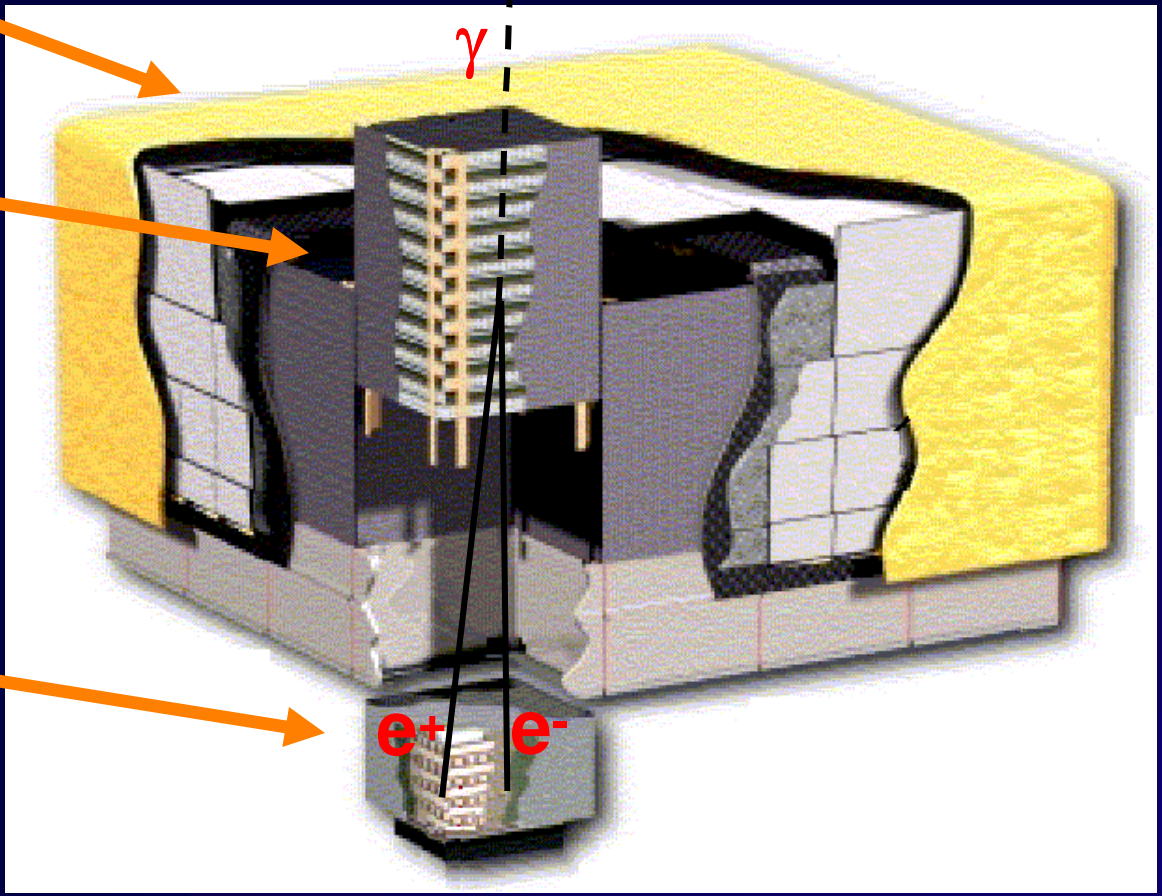
Large Area Telescope (LAT)

Large Field of View >2.4 sr
Broad Energy Range 20 MeV - >300 GeV

ACD
scintillator
89 tiles

Tracker
Si strip detectors
Tungsten foil converters
pitch = 228 um
8.8×10^5 channels
18 planes

Calorimeter
CsI crystals
hodoscopic array
6.1×10^3 channels
8 layers

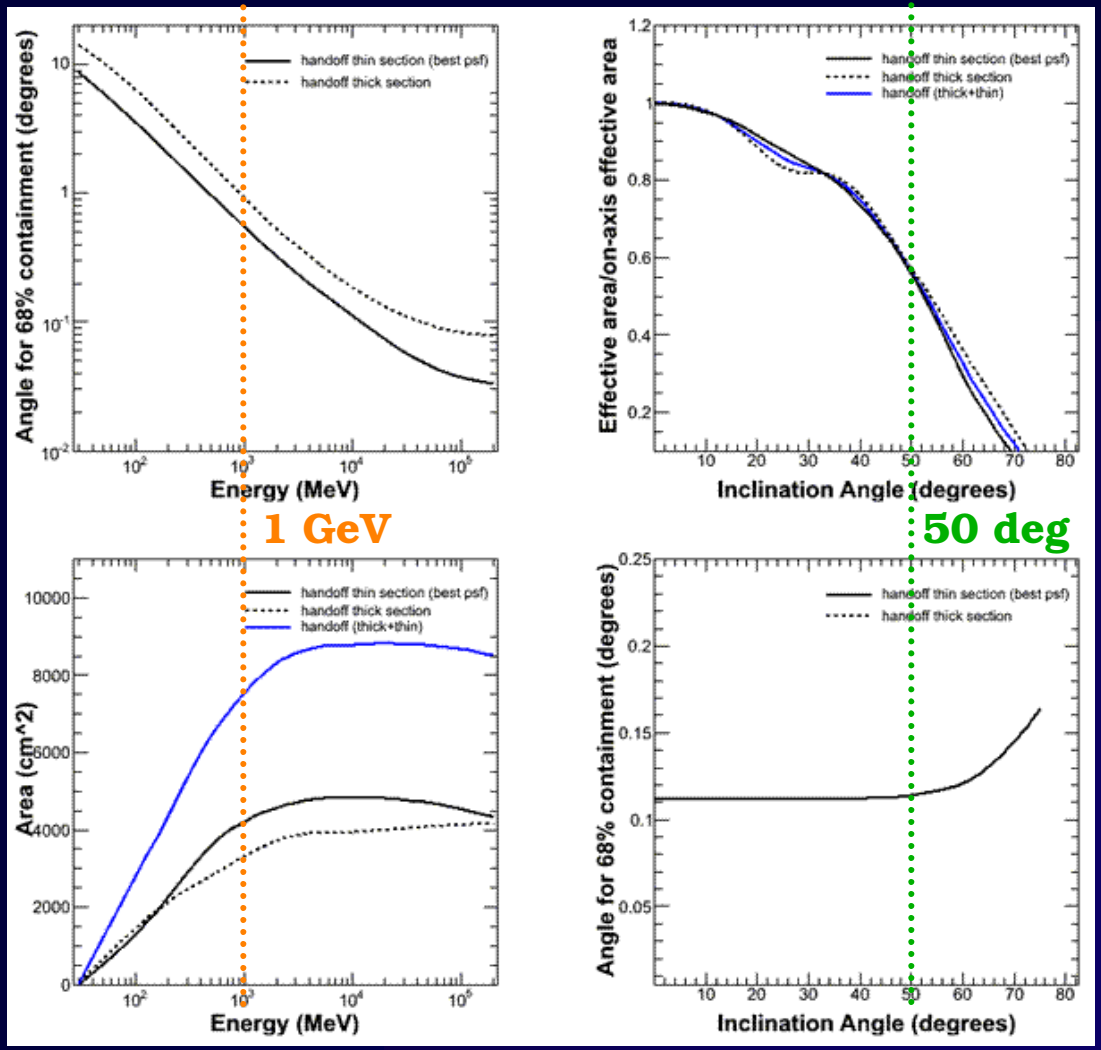


LAT Performance

A GeV, wide-field instrument

Energy dependence of PSF. 68% containment <0.5 deg above 1 GeV

Energy dependence of effective area. Peaks above 1 GeV



Dependence of effective area on inclination angle (10 GeV). ~50% efficiency at 50 deg.

PSF dependence on inclination angle (10 GeV). Resolution maintained to >50 deg.

LAT Sensitivity with Time

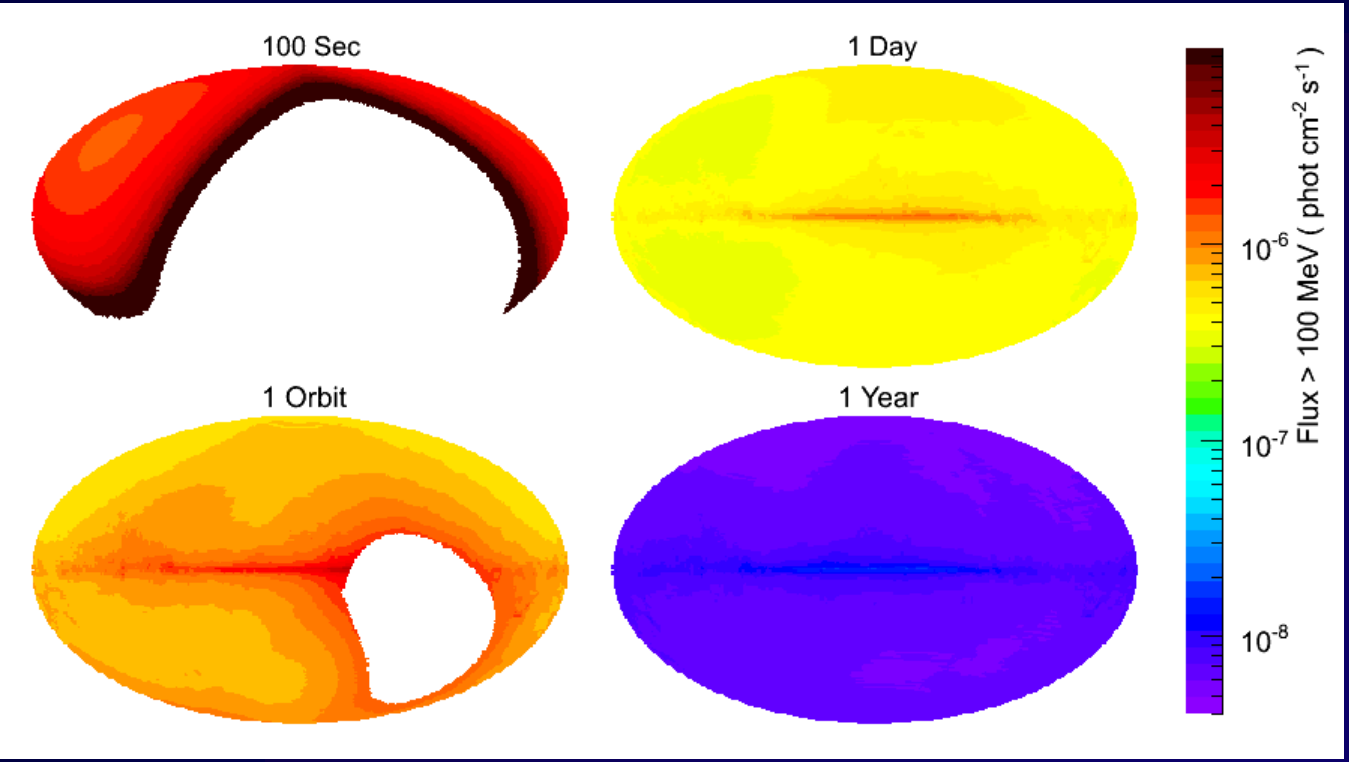
Transient Science: Flares, bursts, multiwavelength campaigns, unidentified transients

Accumulated Science: New source types, populations, long-term monitoring, spatially extended and diffuse studies

Deepest and most uniform survey of the sky at these energies

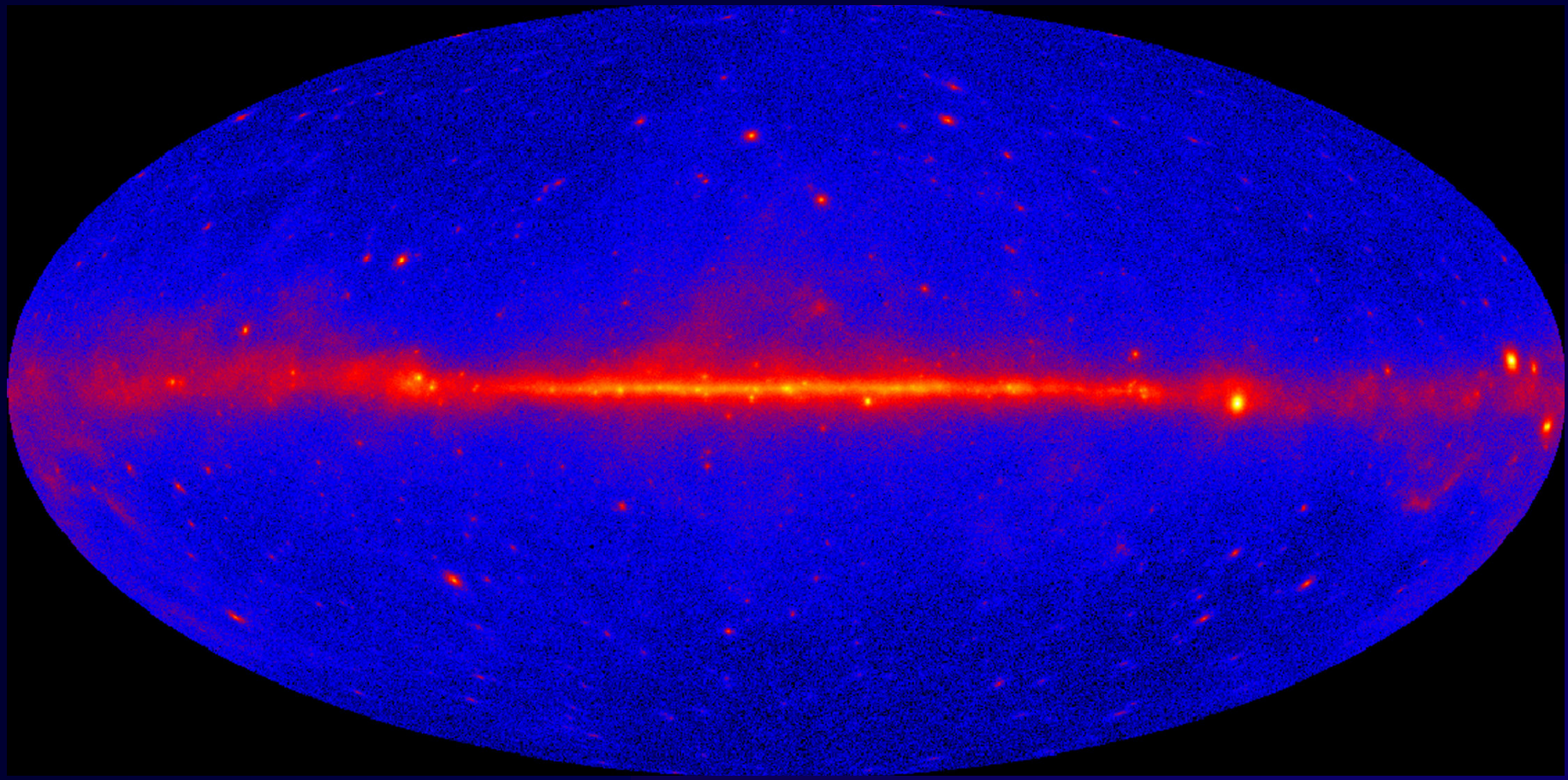
All sky coverage in ~3 hrs (2 orbits)

Minor asymmetry due to passages through South Atlantic Anomaly



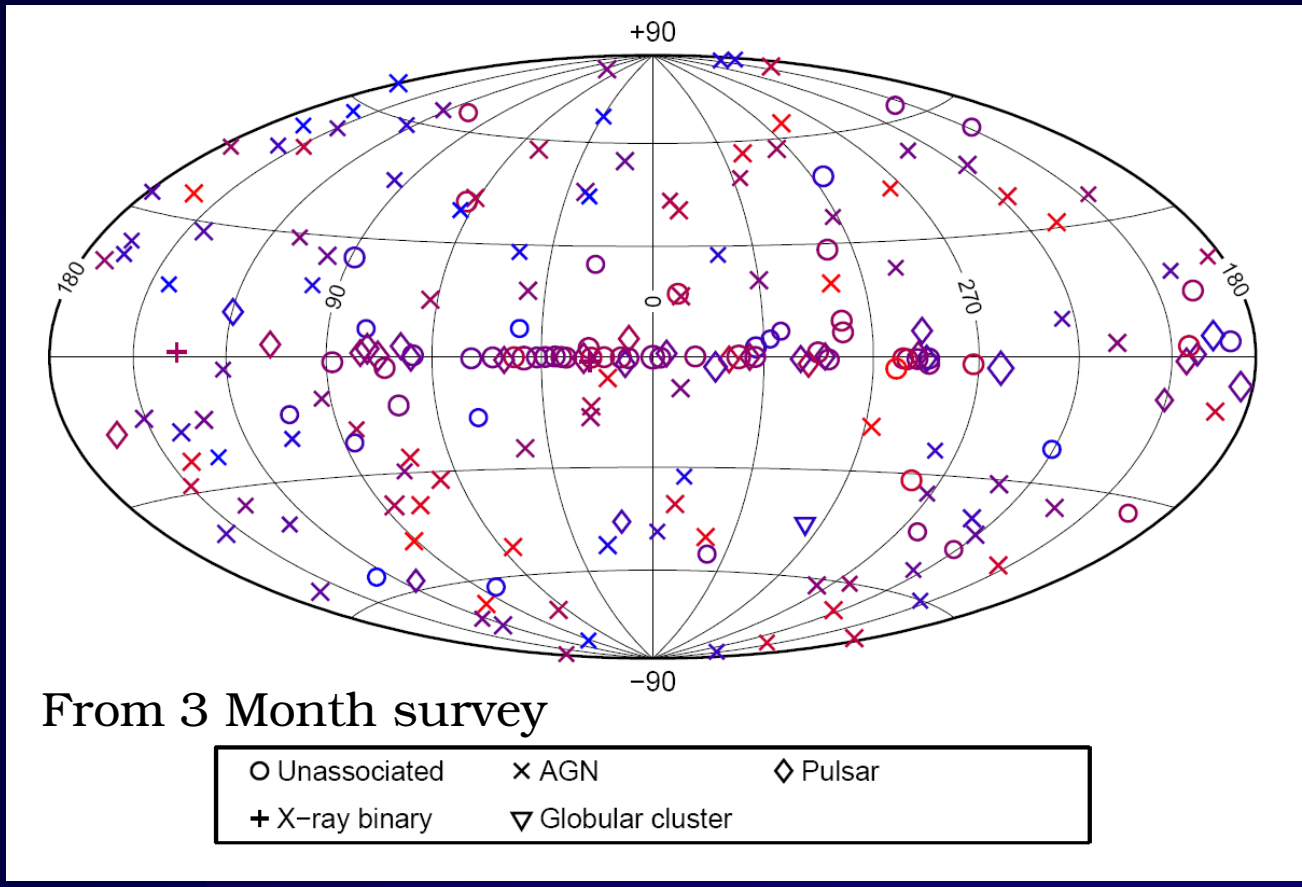
Fermi LAT 9-Month Skymap

Full sky in Galactic Coordinates



Extragalactic Highlights

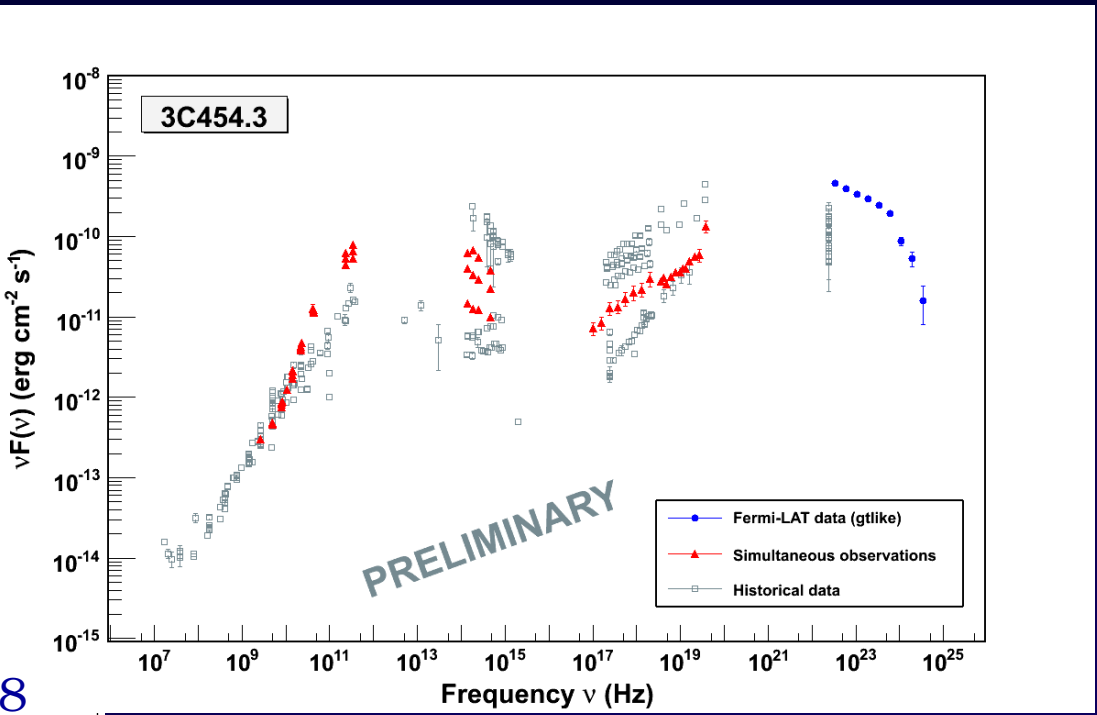
- First 3 Months
- 206 bright sources (>10 σ)
- 1/3 variable
- 106 spatially associated with active galactic nuclei (AGN)
- 2 radio galaxies

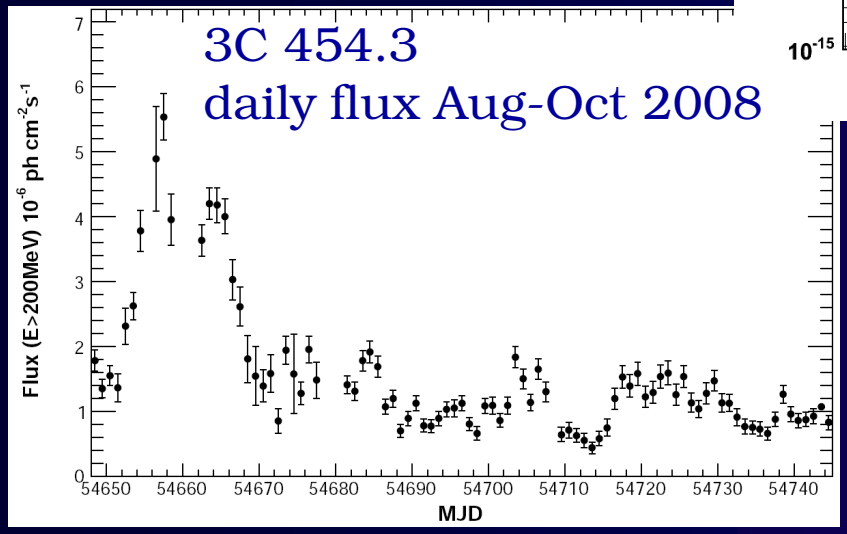


Abdo et al. 2009, ApJS, 183, 46
Abdo et al. 2009, ApJ, 700, 597

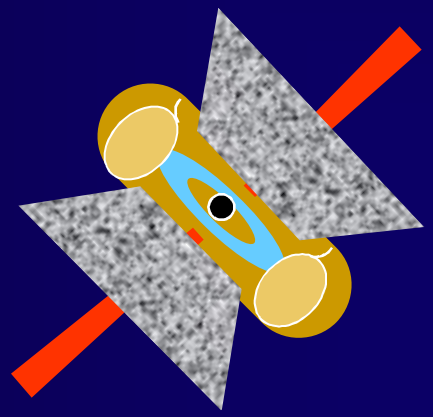
Blazar Galaxies

- Looking down relativistic particle jets from galaxy cores
- Extremely variable
- Broadband emission from radio to gamma-ray wavelengths

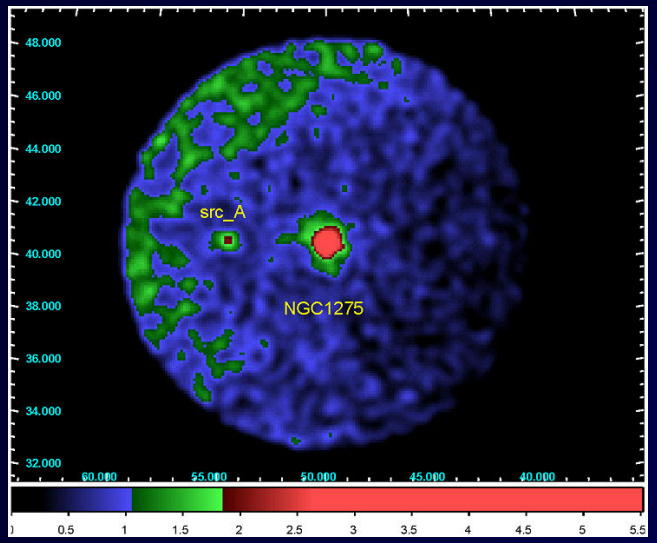


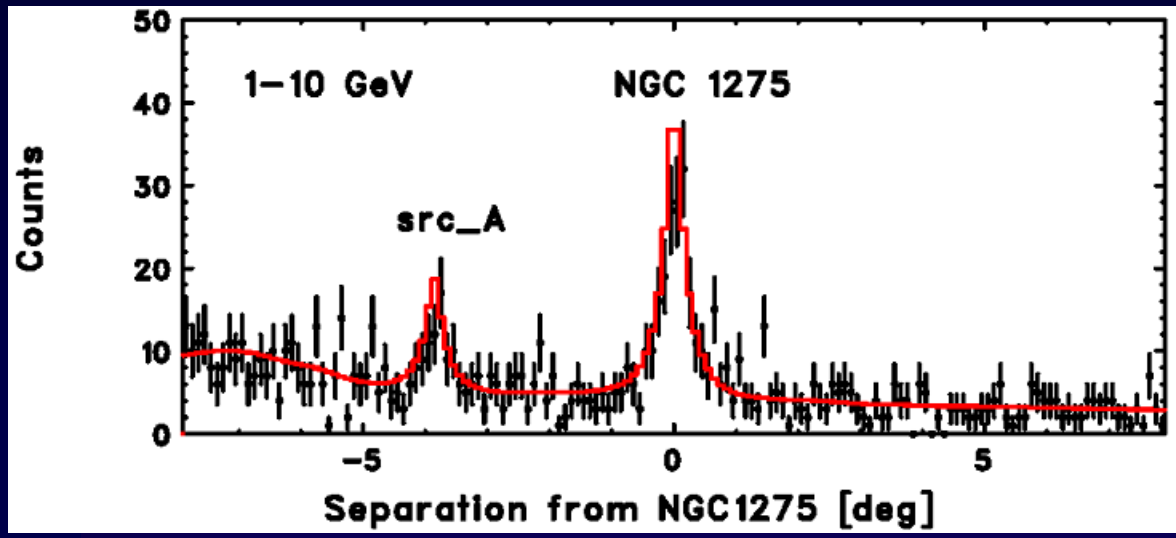


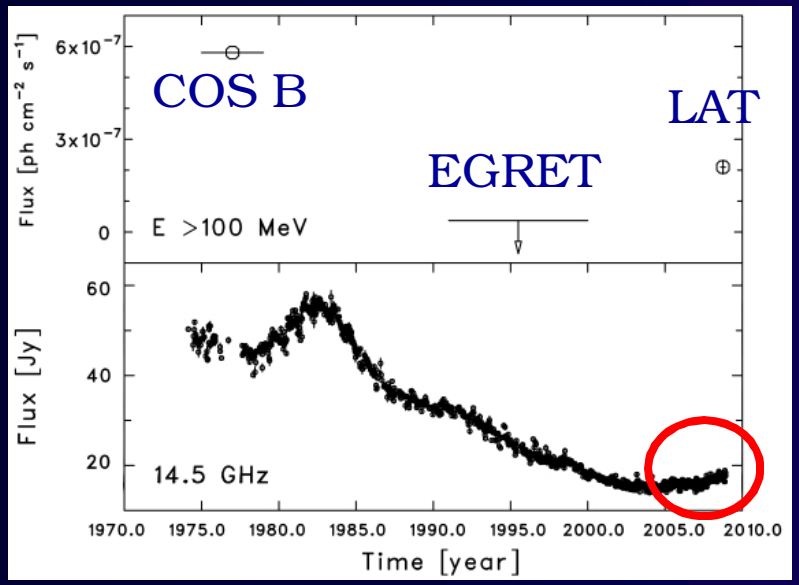
Abdo et al. 2009, ApJ, 699, 817



LAT Detection of Perseus A







First new LAT radio galaxy

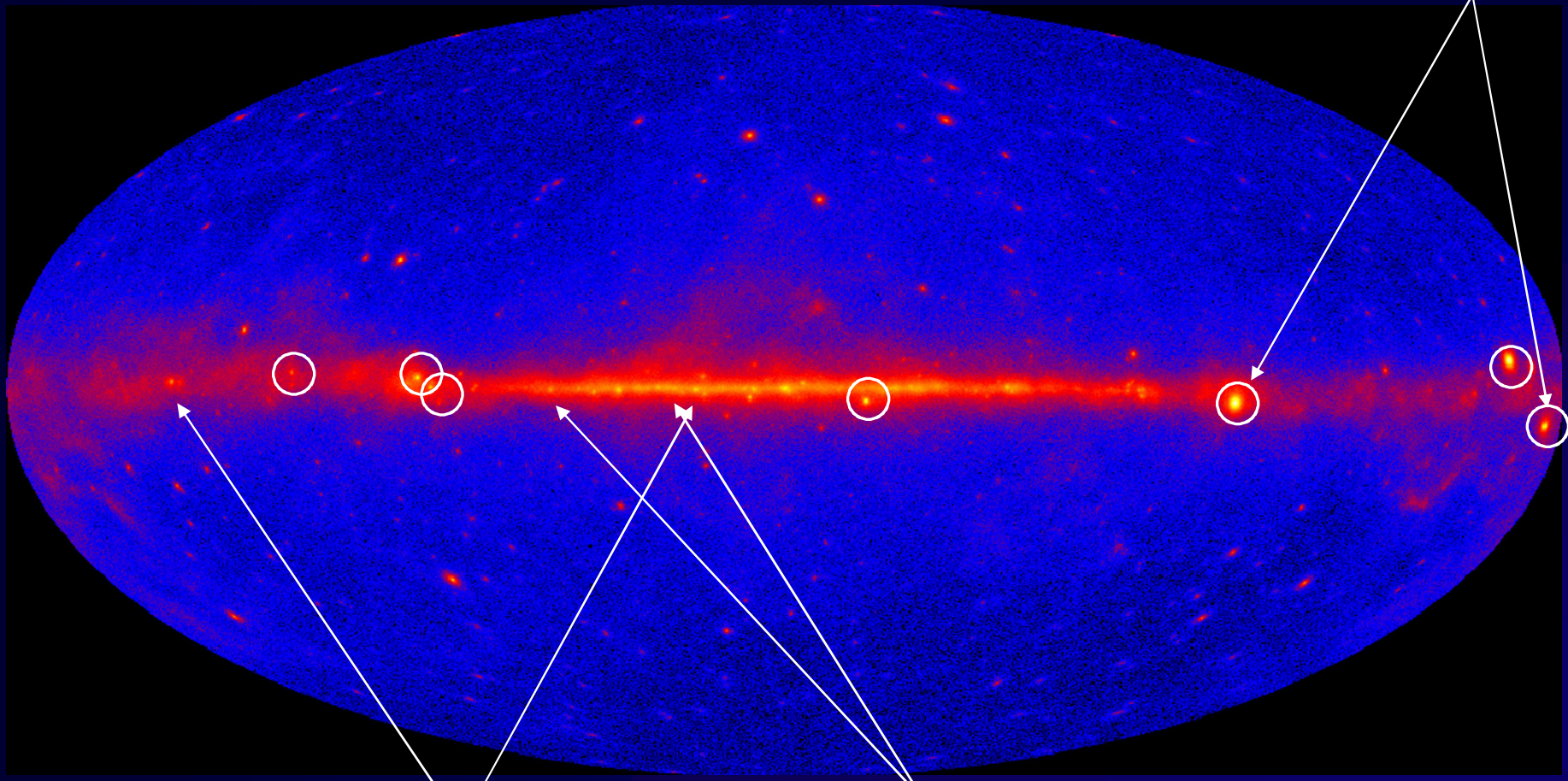
- NGC 1275 = Perseus A = 3C84
- In galaxy cluster at D~75 Mpc
- No previous detection with EGRET
- Consistent with a point source
- Long-term variability

Abdo et al. 2009, ApJ, 699, 31

Galactic Highlights

Pulsars (47+)
And nebulae

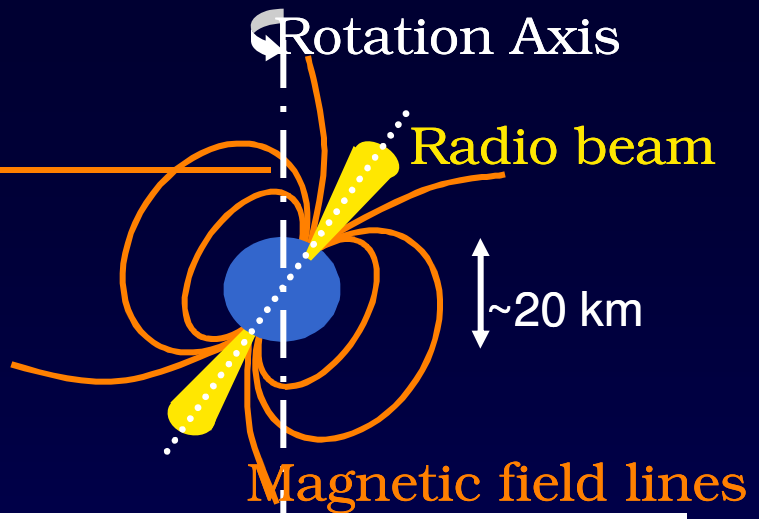
Unidentifieds ?

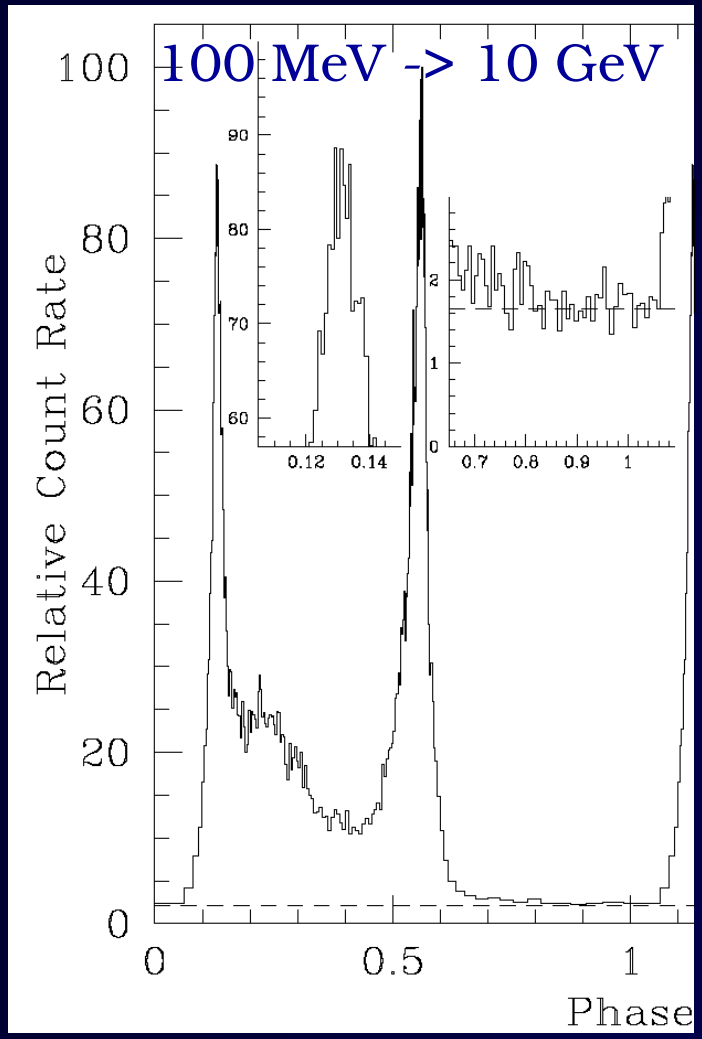


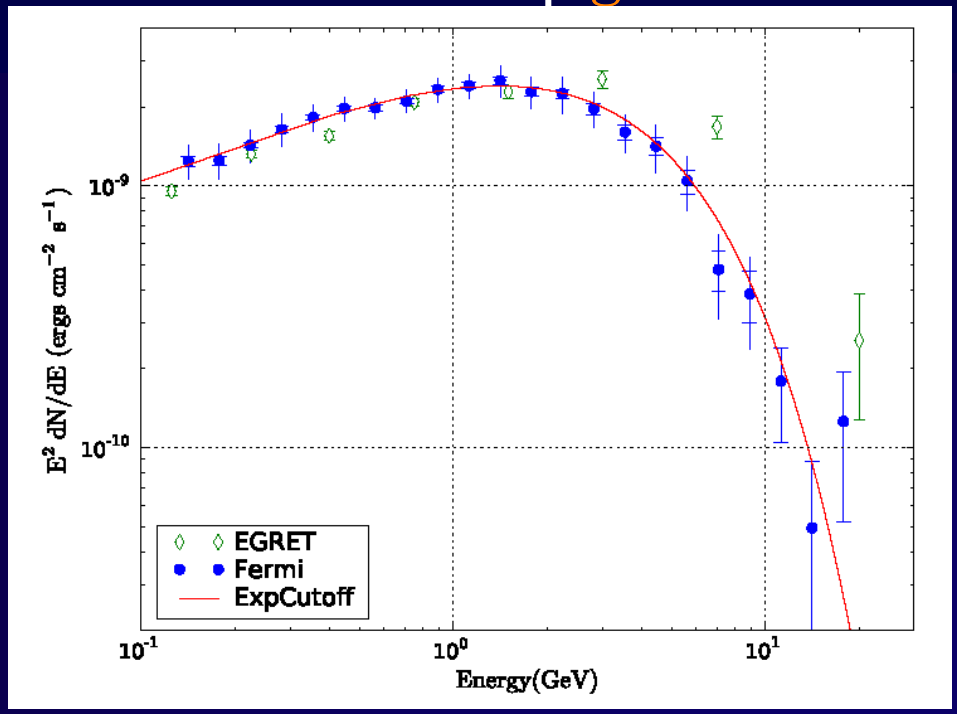
X-ray Binaries

Supernova Remnants

Vela Pulsar





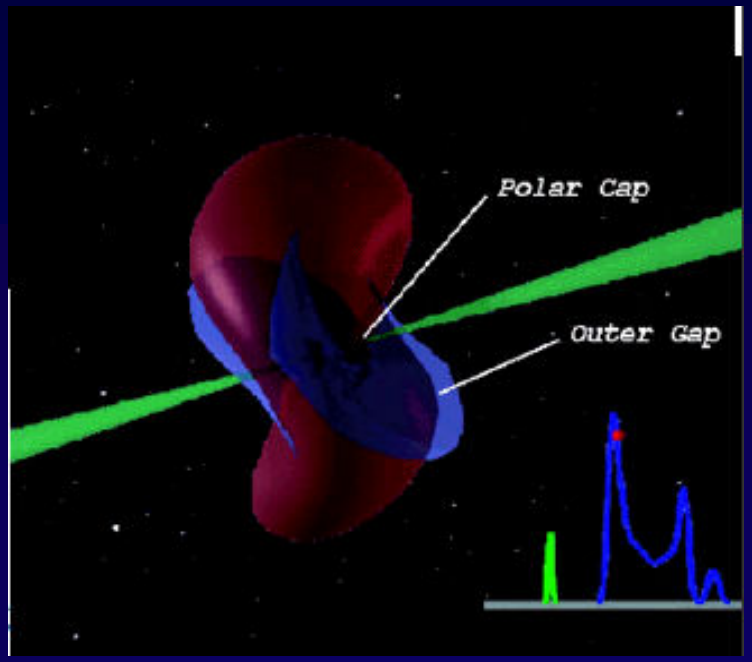


Accurate LAT timestamps plus accurate radio timing solutions

Abdo et al. 2009, ApJ

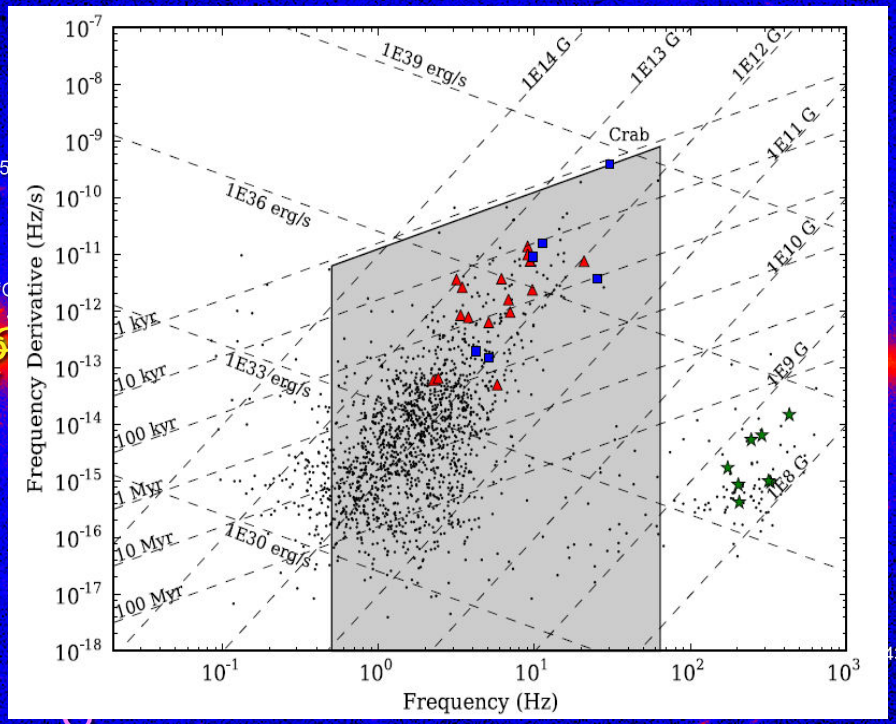
Gamma-ray Pulsar Discoveries

- Pre-LAT: 1 radio-quiet gamma-ray-loud pulsar detected with EGRET
- Blind search for periodicity at known locations of interest
  - ~4 months of data
  - ~100 "interesting" locations
  - ~200 unidentified LAT sources
  - Time-differencing technique applies FFT to time differences not event times (Atwood et al. 2006, Ziegler et al. 2008)
    - Saves in trials and computation
- NEW: 13 of 16 radio-quiet LAT pulsars associated with unidentified EGRET sources



Credit: Yadigaroglu & Romani

New Gamma-ray Pulsars

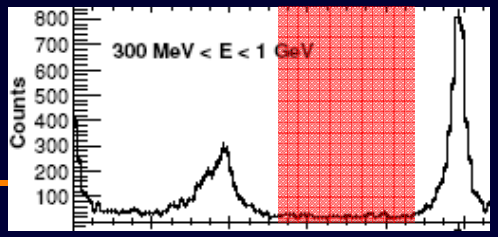


"CTA 1"
J0007+7303
J1836+5
J2238+59
J2032+4127
J0357+32
J0218+4232
J0030+0451
J0751+1807
Geminga
J0633+0632
Vela
Crab
J0613-0200
437-4715

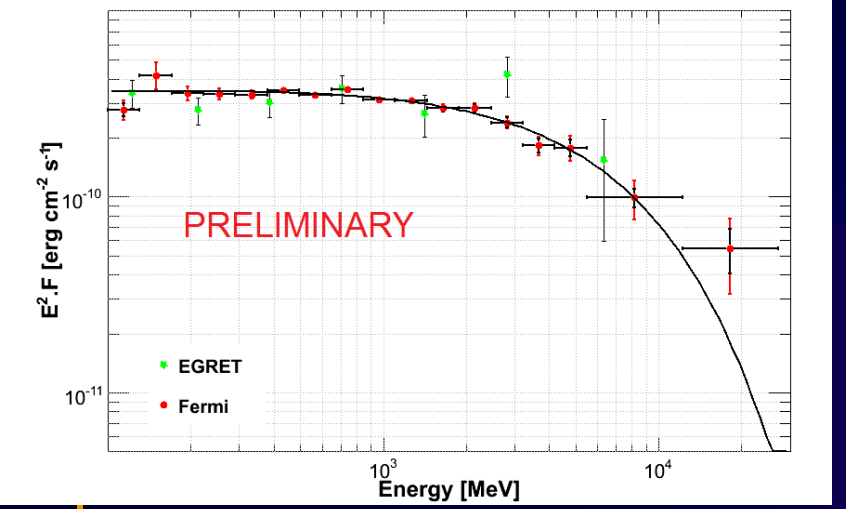
New pulsars found in a blind search
Millisecond radio pulsars

Appeared in Science Express July 2

Crab Pulsar and Nebula



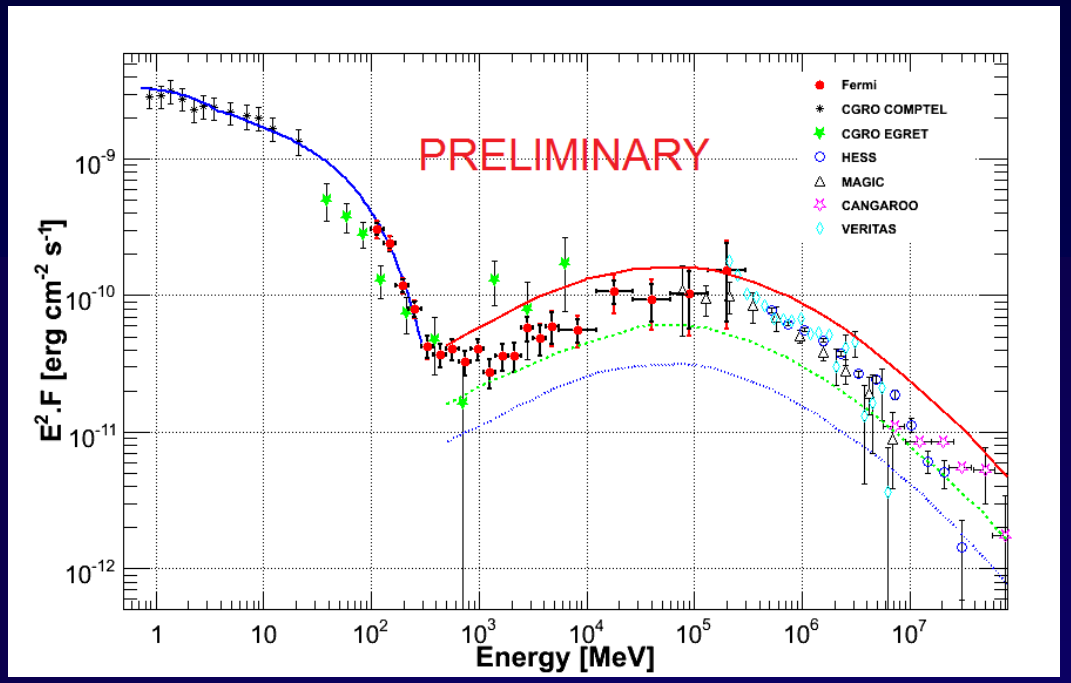
Pulsar 100 MeV to 20 GeV



Hyper-exponential cutoff excluded at ~5 sigma

Consistent with emission well above the neutron star surface

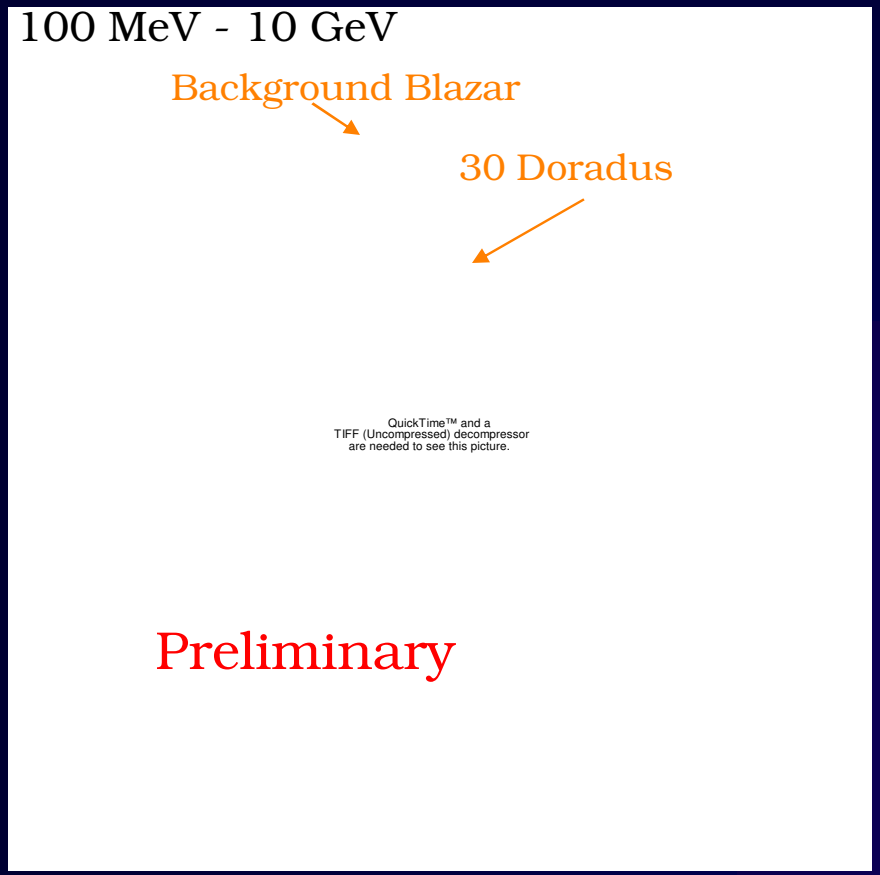
Nebula from MeV to TeV



Inverse Compton emission consistent with mean magnetic field in nebula 100 μG < B < 200 μG

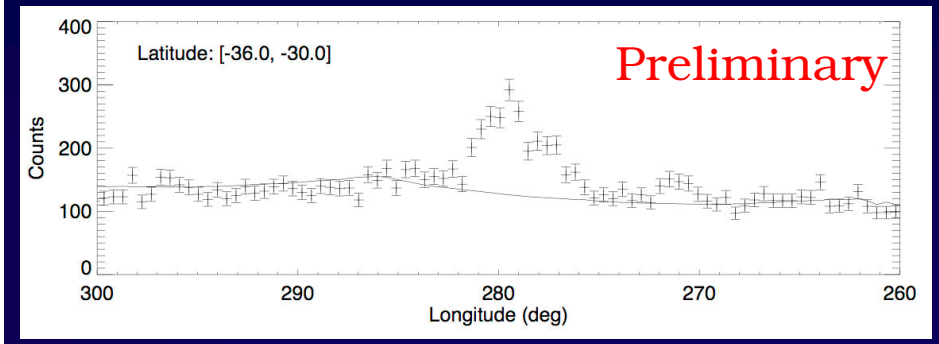
LAT Resolves a Nearby Galaxy

Large Magellanic Cloud



Adaptively smoothed LAT count map with dust map contours from infrared observations

- D~50 kpc (~180 kly)
- Active star forming regions, massive stars and supernova remnants

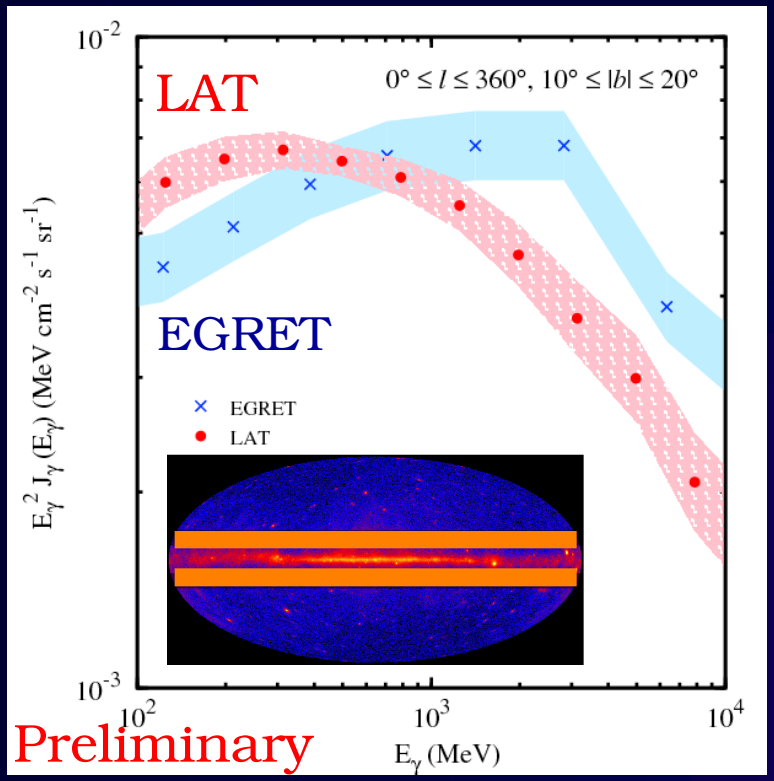


LAT resolves galaxy plus a source consistent with 30 Doradus (Tarantula nebula, HII region)

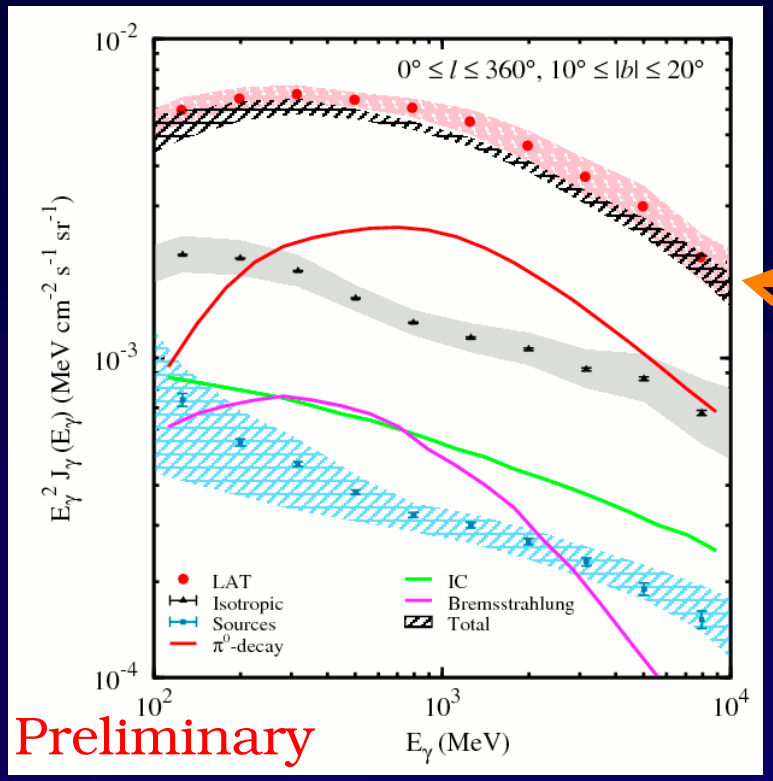
- 50% from 30 Doradus
- 50% from LMC

Diffuse Emission from the Galaxy

LAT/EGRET comparison



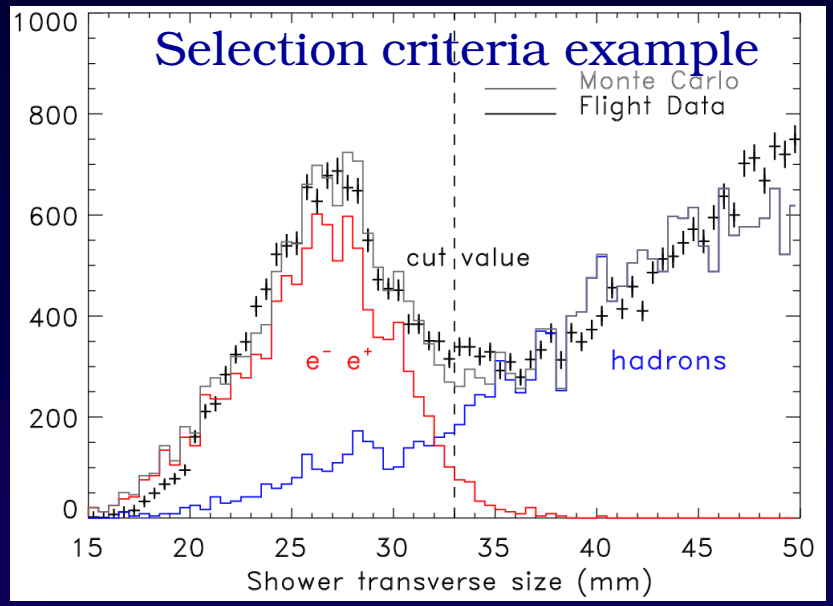
LAT/CR Model comparison

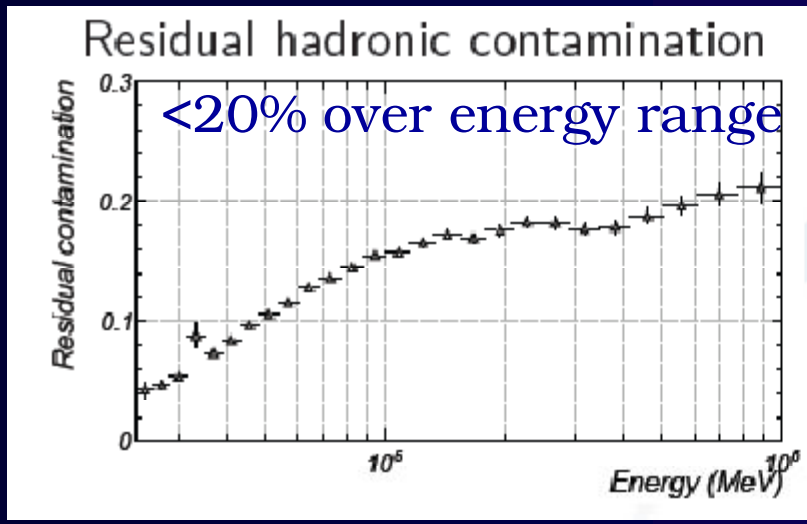


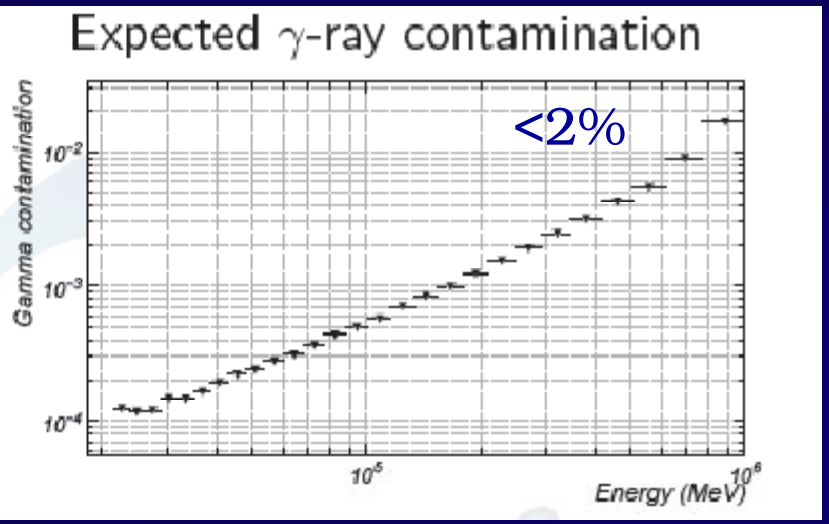
- LAT and EGRET measurements dominated by systematics
- EGRET GeV excess not confirmed by LAT for intermediate latitudes
- Model based on local cosmic-ray measurements (pre-Fermi) in good agreement

LAT as an Electron Detector

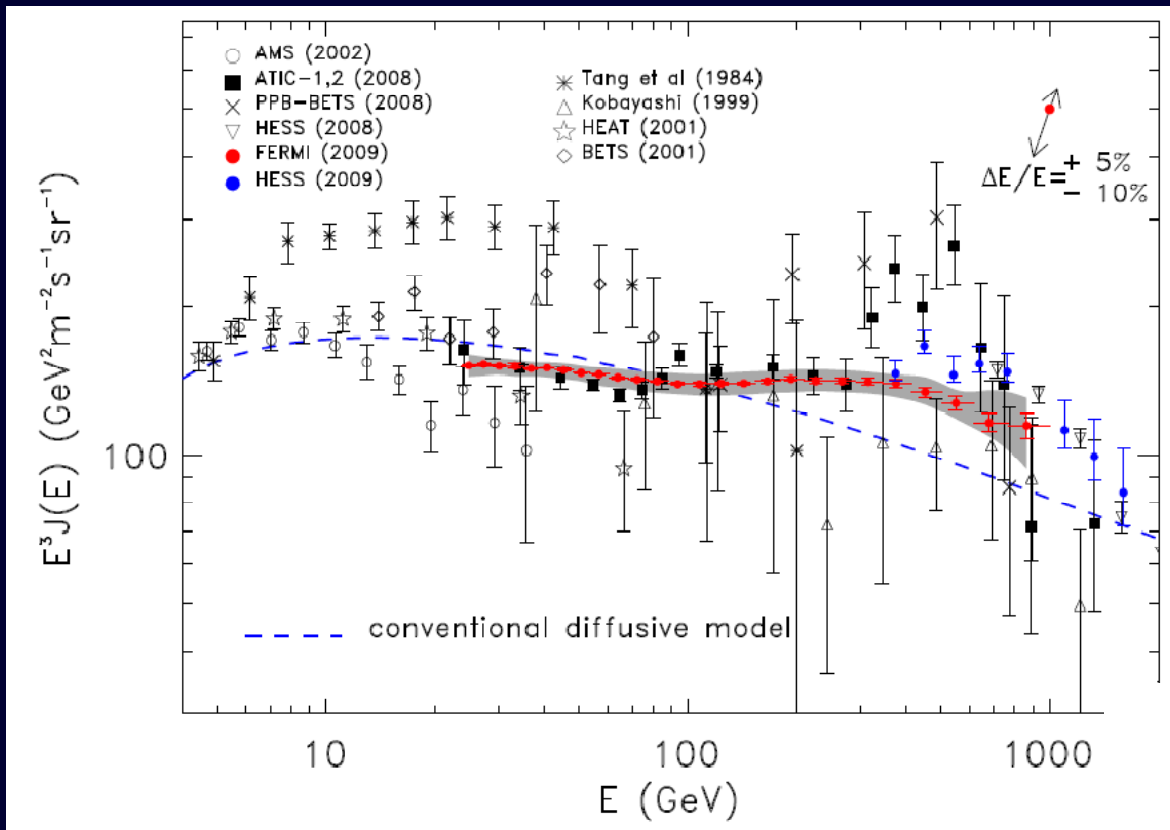
- ~100% efficient for E>20 GeV
- Good hadron rejection (up to 1:10^4 at 1 TeV)
- Detailed simulations and comparisons with data
- Systematics <20%
  - MC-data, acceptance, proton spectrum, energy calibration







Cosmic-ray $e^+ + e^-$ spectrum from 20 GeV to 1 TeV



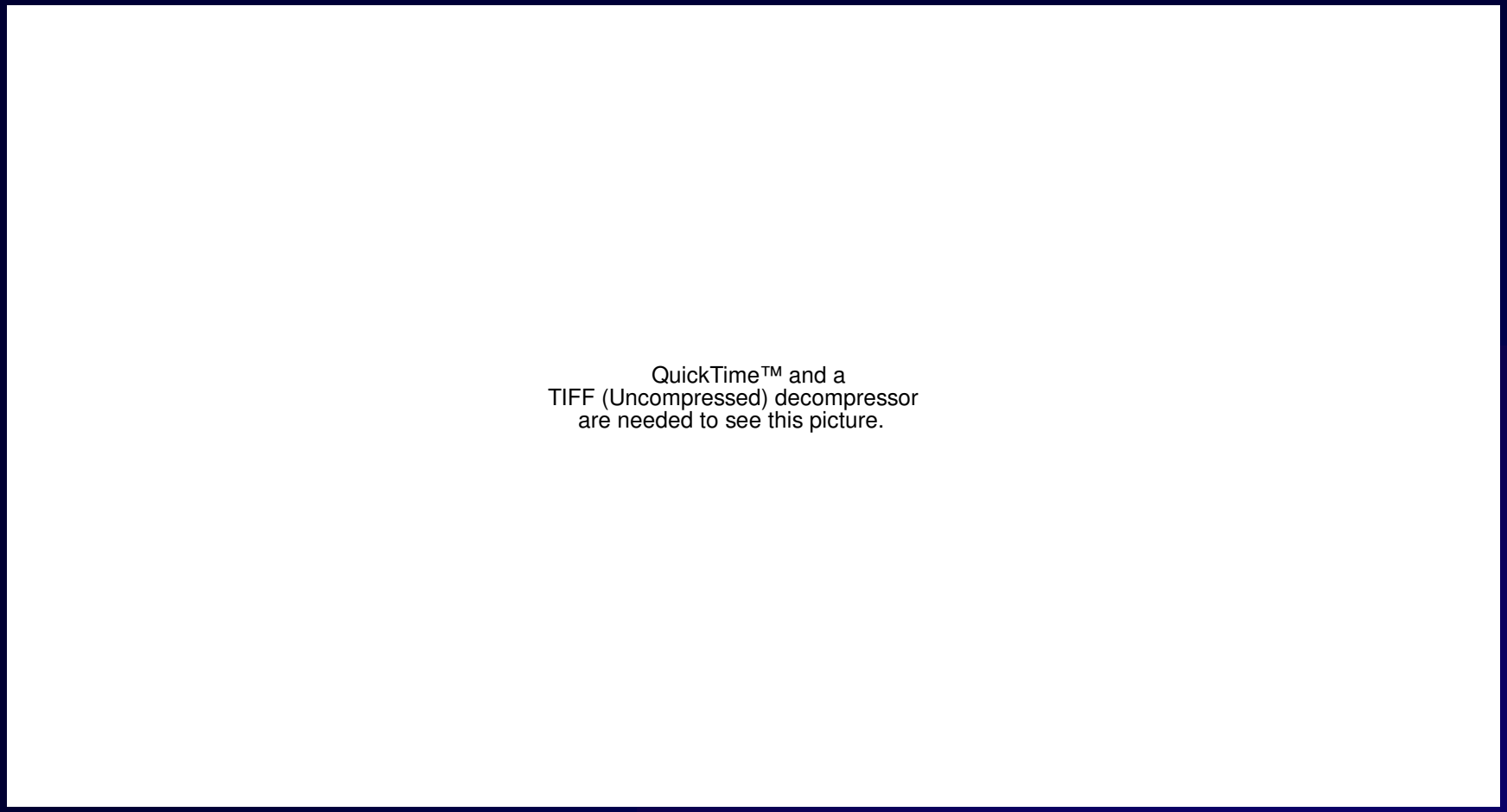
- LAT error band includes systematics
- Model assumes standard CR injection and propagation

Energy Resolution

Abdo et al. 2009, Physical Review Letters, 102, 181101

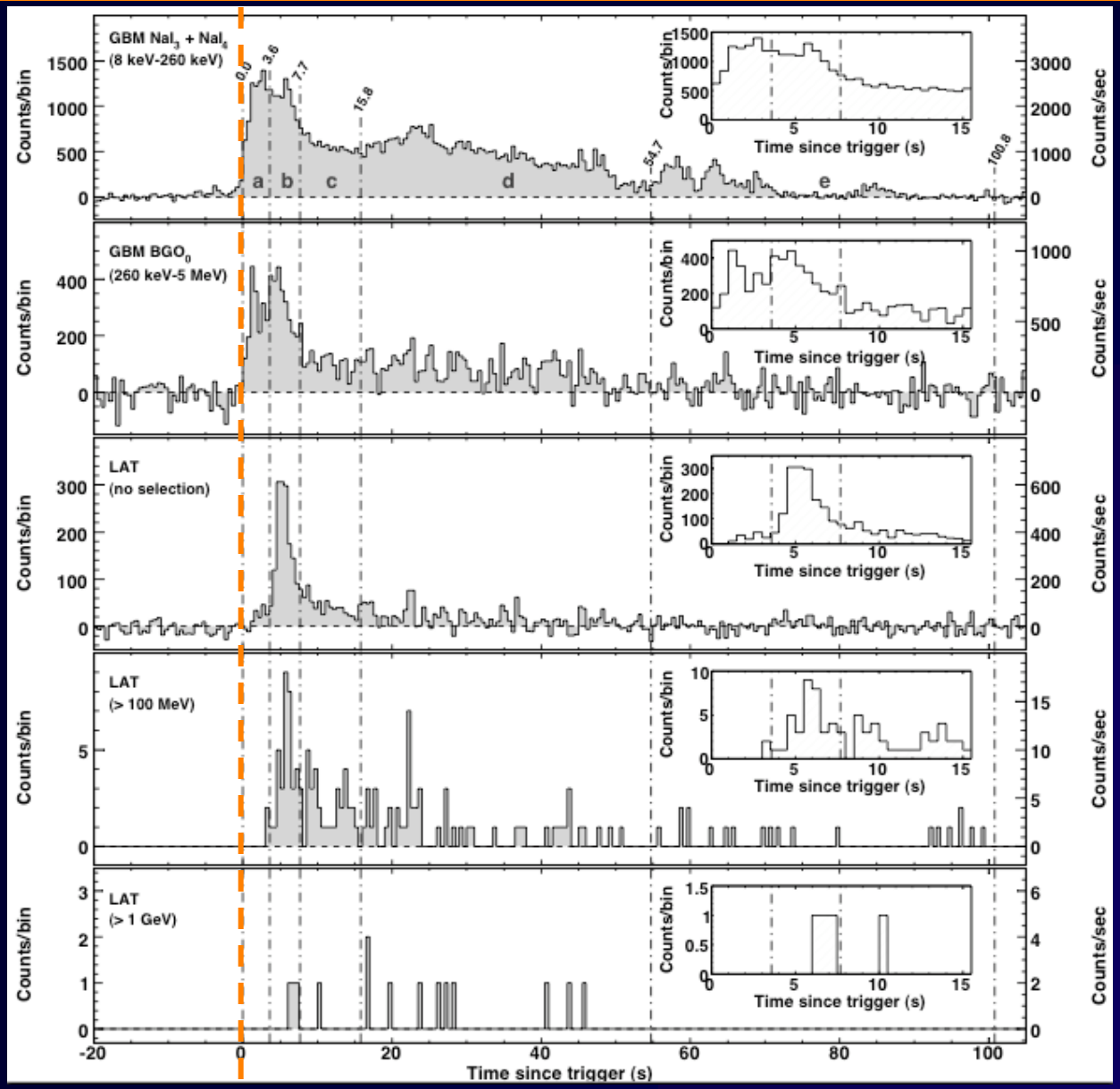
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Fermi Gamma-ray Bursts



9 LAT GRBs (2x pre-Fermi for E>100 MeV)
2 short GRBs detected by LAT

GRB 080916C keV to GeV Lightcurve



NaI
8 keV - 260 keV

BGO
260 keV - 5 MeV

LAT All

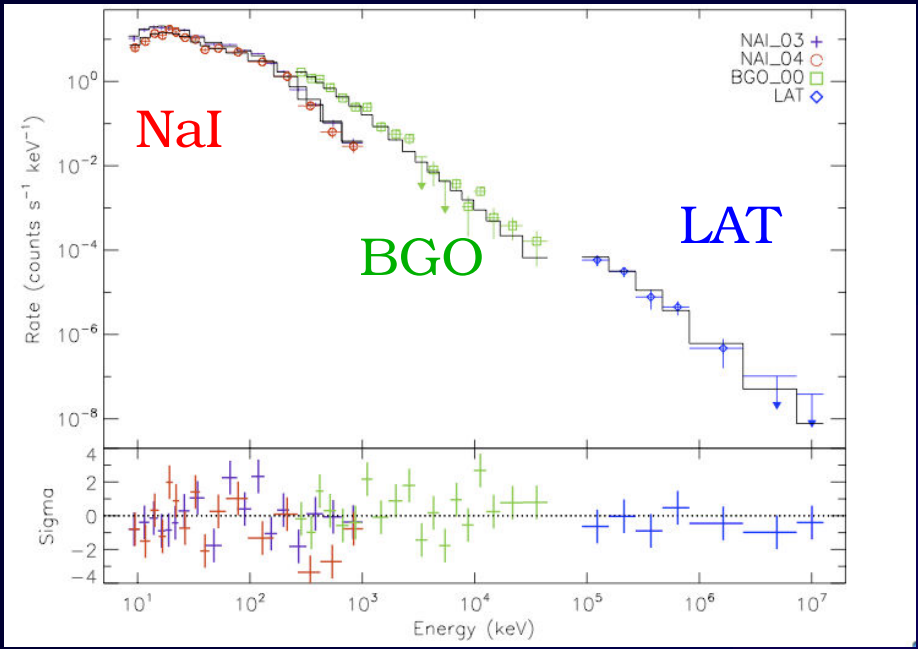
LAT >100 MeV

LAT >1 GeV

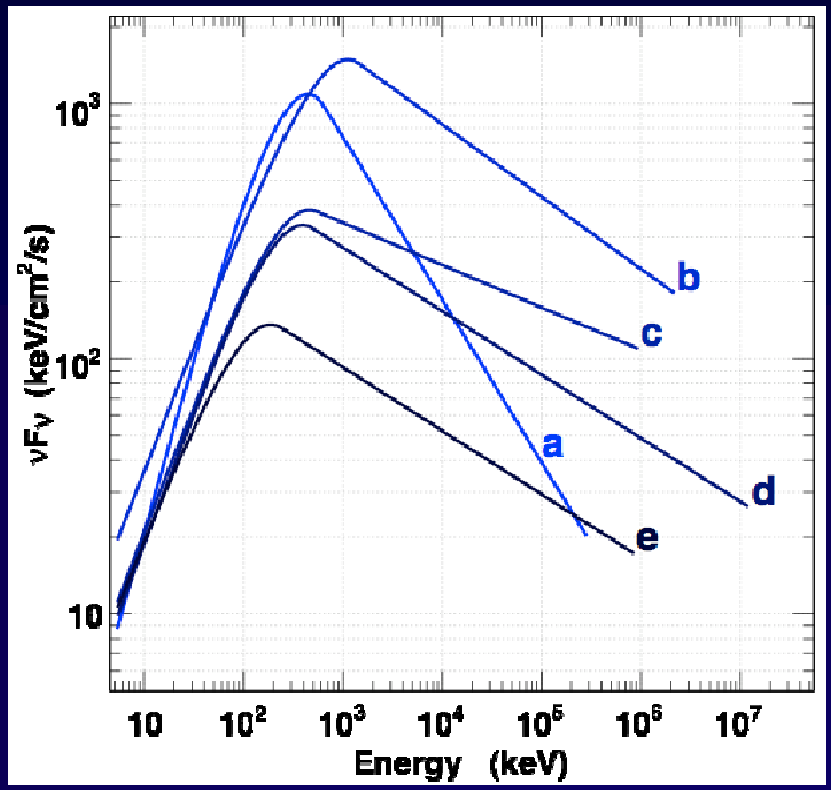
Abdo et al. 2009, Science, 323, 1688

E. Hays

GRB 080916C Spectral Evolution



Spectrum for (b) 3.6 - 7.7 s
compatible with a single component



Rapid soft to hard evolution in (a) to (b)

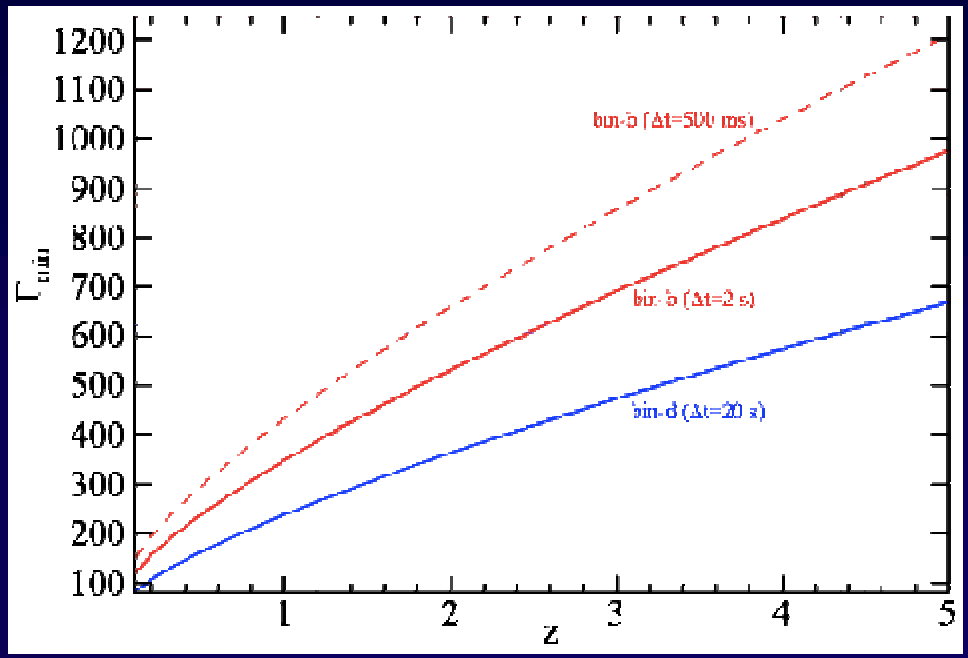
Gradual decrease of Epeak from (b) to (d)

Abdo et al. 2009, Science, 323, 1688

Implications of High Redshift

- E_{iso} ~8.3 x 10^{54} ergs
  - Largest energy release ever observed
- High redshift and high fluence imply strongly collimated jet
- No cutoff => bulk Lorentz factor >890±21
  - Also constrain Lorentz invariance violation
  - 13.2 GeV @ T_0+16.5 s
  - M_{QG} > 1.3 x 10^{18} GeV/c^2

Z = 4.35 +/- 0.15 (GROND)



Summary

- LAT is an excellent gamma-ray (and electron) detector
- Explaining previously unidentified gamma-ray emitters
- Monitoring the entire gamma-ray sky, catching flares from blazars and gamma-ray bursts - some very far away!
- Detecting new pulsars and probing the emission zones and mechanisms
- Measuring diffuse gamma-ray emission from the Galaxy and beyond
- Exploring new territory - more science to come!

First year of science Aug. 11 - data release soon!
First Fermi Symposium Nov 2-5, Washington, D.C.

http://fermi.gsfc.nasa.gov