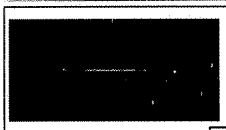
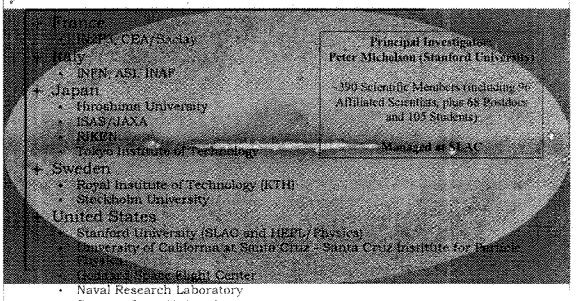


Recent Results on SNRs and PWNe from the Fermi Large Area Telescope

Elizabeth Hays
(NASA/GSFC)
On behalf of the Fermi LAT Collaboration

Fermi LAT Collaboration



Principal Investigator:
Peter Michelson (Stanford University)

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

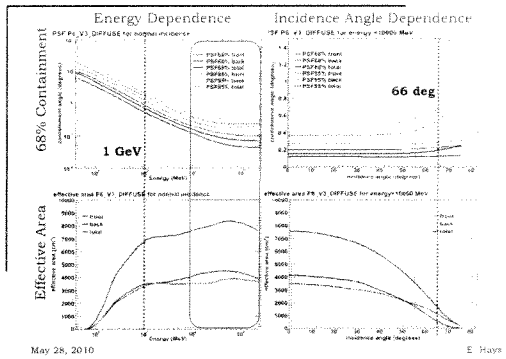
Managed at SLAC

- 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

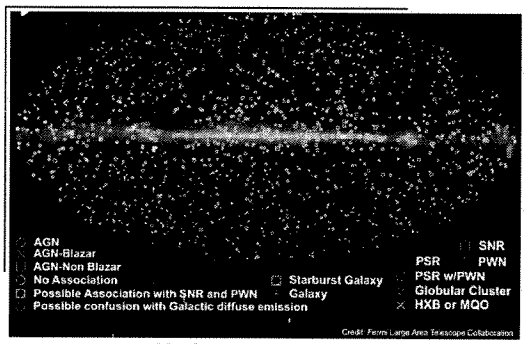
Galactic Results from LAT

- 1FGL Galactic populations
  - New GeV source classes in the Galaxy
- Recent Highlights
  - Pulsars and Pulsar Wind Nebulae
    - Which pulsars produce GeV nebulae and what are we learning from them?
  - Supernova Remnants
    - Solid detections, structure, and spectral features

A GeV, wide-field Instrument

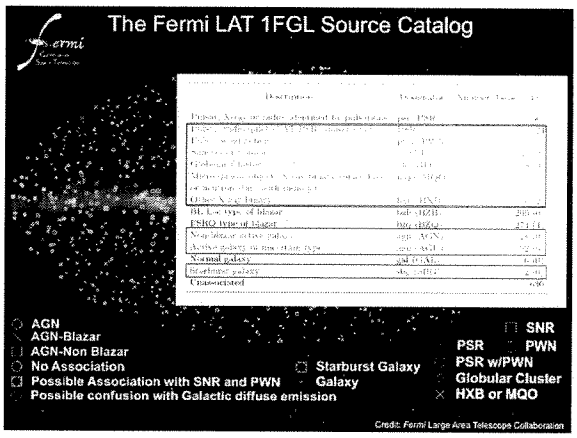


The 1FGL Catalog



May 28, 2010 *March 18 2010 Astro pic of the day* E. Hays

The Fermi LAT 1FGL Source Catalog

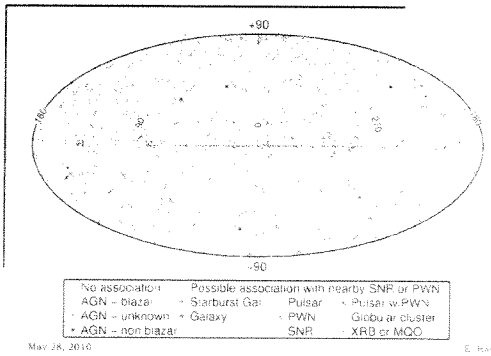


Unidentified Gamma-ray Sources

- Previous MeV-GeV energy gamma-ray missions left a legacy of "unidentified" sources (~2/3 of 3EG catalog)
  - Unidentified meant multiple possible candidates OR no plausible candidates (unassociated)
- LAT first catalog <50% unassociated
- LAT associations greatly aided by
  - Dramatically improved gamma-ray localization
  - Dedicated catalogs of potential gamma-ray counterparts
  - Multiwavelength searches
- LAT identifications from
  - Periodicity
  - Spatial morphology
  - Correlated variability with other observations

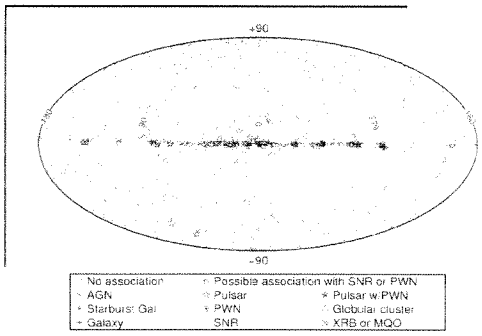
May 28, 2010 E. Hays

Variability in 1FGL Sources



May 28, 2010 E. Hays

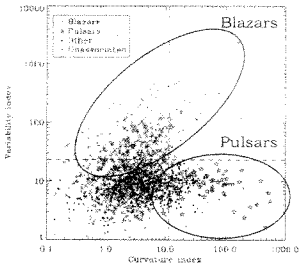
Curvature in 1FGL Sources



May 28, 2010 E. Hays

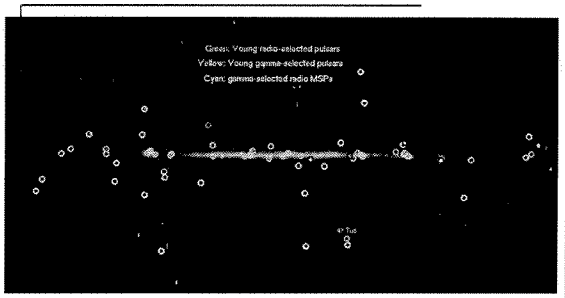
Spectral-Variability Classification

- Blazars and pulsars in the variability-spectral curvature plane



May 28, 2010 E. Hays

Gamma-ray Pulsars and MSPs



More than 56 gamma-ray pulsars in the first year
Plus gamma-selected MSPs

May 28, 2010 Abdo, A. A. et al. 2010, ApJS, 187, 460 E. Hays

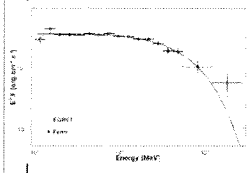
GeV PWN - where to look?

- Known high-energy PWNe
  - From X-ray and TeV observations
  - For example, Crab, Vela X, MSH 15-52
- Gamma-ray pulsars
  - PWN Catalog based on off-pulse searches from LAT team underway
- Young, energetic radio pulsars
- TeV nebula candidates

May 28, 2010

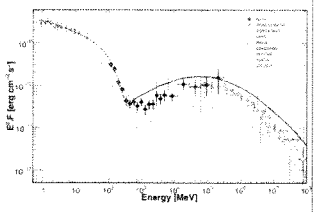
Crab Pulsar and Nebula

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

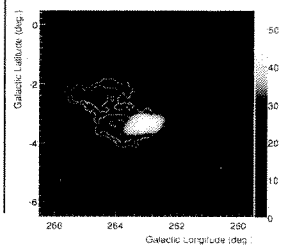


Inverse Compton emission consistent with mean magnetic field in nebula 100 μG < B < 200 μG

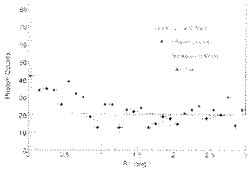
May 28, 2010 Abdo, A. A. et al. 2010, ApJ, 708, 1254 E. Hays

Vela X Nebula of Vela Pulsar

LAT Test Statistic Map



Radial Profile above 800 MeV

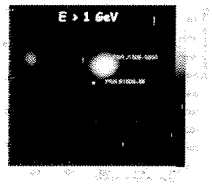


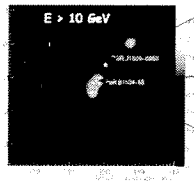
GeV significantly extended
Disk radius = 0.88° +/- 0.12

Better match to radio than TeV

May 28, 2010 Abdo, A. A. et al. 2010, ApJ, 713, 146 E. Hays

MSH 15-52





PSR J1509-5850

PSR B1509-58

HESS contours

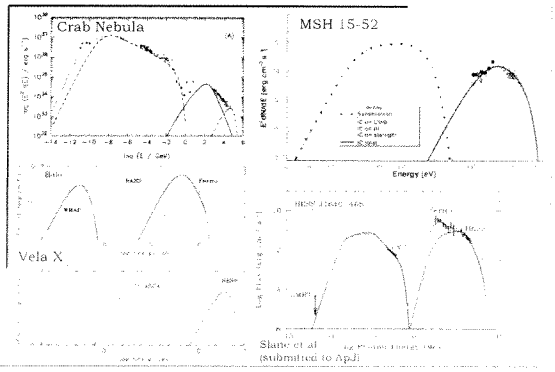
PSR B1509-58 only detected in timing analysis

LAT SED 1-100 GeV

Nebula not significant below ~1 GeV

May 28, 2010 Abdo, A. A. et al. 2010, ApJ, 714, 927 E. Hays

GeV PWNe Spectra



Slane et al. (submitted to ApJ)

GeV Nebula Limits

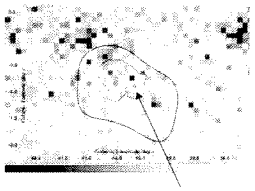
PSR J1907+0602
- Edot = 2.8 x 10^36 erg/s
- Char. Age = 19.5 kyr
- Distance estimate = 3 kpc

PSR J1907+0602

HESS J1908+063

MGRO J1908+06

LAT residual map
Off-pulse selection



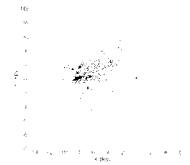
PSR J1907+0602

GeV upper limits require a low energy turnover between 20 and 300 GeV

Abdo, A. A. et al. 2010, ApJ, 711, 64

Nebula Search of LAT Pulsars

LAT is producing a more complete sample of young, energetic, nearby pulsars



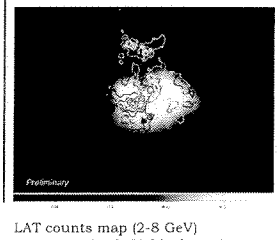
Catalog under development to characterize off-pulse nebula components for the LAT pulsars

Supernova Remnants

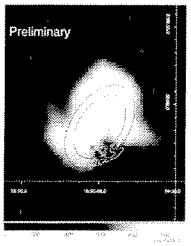
- Which remnants are GeV emitters?
- Where are the emission regions?
- What is producing the gamma rays?

SNR: GeV Morphology

SNRs W51C, W44, IC 443, W28 North source resolved by LAT.
Cas A unresolved.
Good agreement with shell structures.

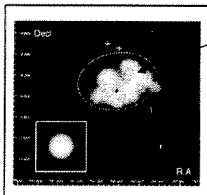


LAT counts map (2-8 GeV)
X-ray (0.1-2.4 keV, black) and radio (1.4 GHz, green) contours



LAT counts (2-10 GeV)
Infrared contours (4.5 um)

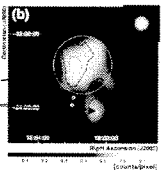
SNR: Molecular Connection

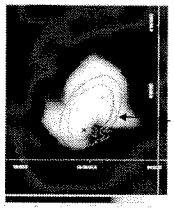


Shocked CO

CO (J=1-0) contours NANTEN

H II regions



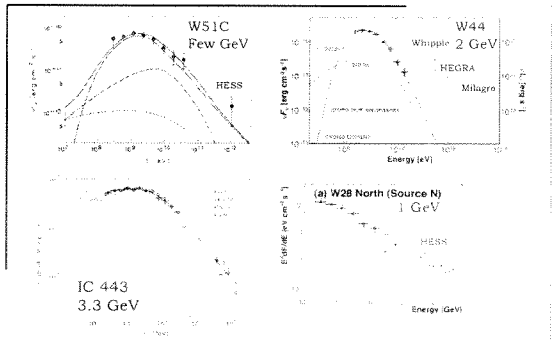


W44

Shocked H2

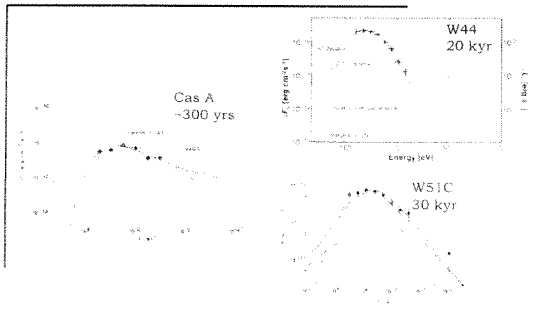
GeV emission from SNRs interacting with molecular clouds
IC 443, W51C, W44, W28...

SNR: GeV Breaks



IC 443
3.3 GeV

SNR: Young vs. Old



Summary

- GeV SNR population growing
  - Some preference for middle-aged remnants near dense regions (only young SNR at high significance is Cas A)
  - Pion decay scenarios generally favored; leptonic scenarios not completely ruled out
- GeV PWNe
  - Morphology and spectral studies for the bright elite
  - Multiwavelength context, particularly with TeV and radio/WMAP, probes electron populations
  - Population not well-defined yet
- Both of these classes benefit from additional LAT exposure

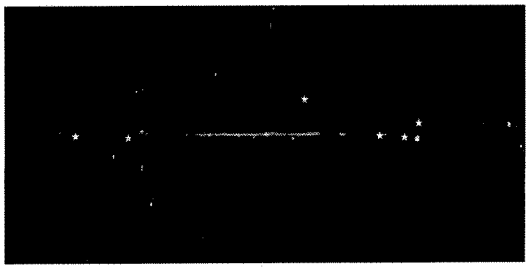
http://fermi.gsfc.nasa.gov

Extras

Pulsars everywhere...

- >50 gamma-ray pulsars so far
  - >40 young, energetic pulsars
  - 9 old, recycled millisecond pulsars
  - Identifying EGRET unidentifieds and LAT unidentifieds
- Gamma-ray beam is bigger than radio beam
- Pulsar spectra have exponential cutoffs in the GeV band
- Gamma rays from outer magnetosphere preferred
- Bonus: LAT unidentifieds also turning up new radio millisecond pulsars

LAT Unassociated Transient Detections



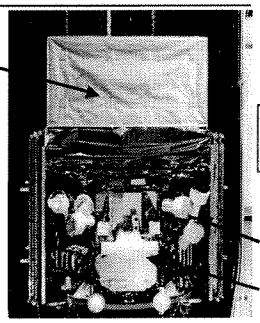
☆ Unassociated transients from daily search

○ Low latitude blazars from First LAT Catalog

The Fermi Observatory

Large Area Telescope (LAT)

- Large field of view (>2.4 sr)
- Entire sky every 3 hrs (every 2 orbits)
- Broad energy range (20 MeV - >300 GeV)



Gamma-ray Burst Monitor (GBM)

- Views entire unocculted sky
- **NaI:** 8 keV - 1 MeV
- **BGO:** 150 keV - 40 MeV

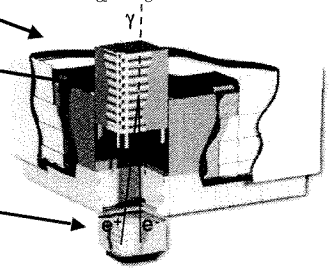
Large Area Telescope (LAT)

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



4x4 detector array

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