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

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

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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

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A GeV, wide-field Instrument

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Fermi LAT Collaboration
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

Variability in 1FGL Sources

The Fermi LAT 1FGL Source Catalog
Curvature in 1FGL Sources

Spectral-Variability Classification

- Blazars and pulsars in the variability-spectral curvature plane

Gamma-ray Pulsars and MSPs

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


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
Crab Pulsar and Nebula

**Pulsar** 100 MeV to 20 GeV

**Nebula** from MeV to TeV

Hyper-exponential cutoff excluded at -5 sigma. Consistent with emission well above the neutron star surface.

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


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.


MSH 15-52

PSR B1509-58 only detected in timing analysis.

Nebula not significant below ~1 GeV.


GeV PWNe Spectra

Crab Nebula

MSH 15-52
GeV Nebula Limits

PSR J1907+0602
- \( E_{\text{diss}} = 2.8 \times 10^{36} \text{ erg} \)
- Chirp Age = 19.5 kyr
- Distance estimate = 3 kpc

LAT residual map
Off-pulse selection

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


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 (8.0 \mu m)
SNR: Molecular Connection

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

SNR: GeV Breaks

- IC 443: 3.3 GeV
- W44

SNR: Young vs. Old

- 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

Summary

- Both of these classes benefit from additional LAT exposure

http://fermi.gsfc.nasa.gov
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

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LAT Unassociated Transient Detections

- Unassociated transients from daily search
- Low latitude blazars from First LAT Catalog

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The Fermi Observatory

- Large field of view (12 sr)
- Entire sky every 3 hrs
- Broad energy range (20 MeV - 300 GeV)

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Gamma-ray Burst Monitor (GBM)

- Views entire unexposed sky
- NaI: 8 keV
- BGO: 150 keV
- 1 MeV
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
8.0x10^9 channels
1.6 planes

Calorimeter
CsI crystals
hodoscopic array
6.2x10^9 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