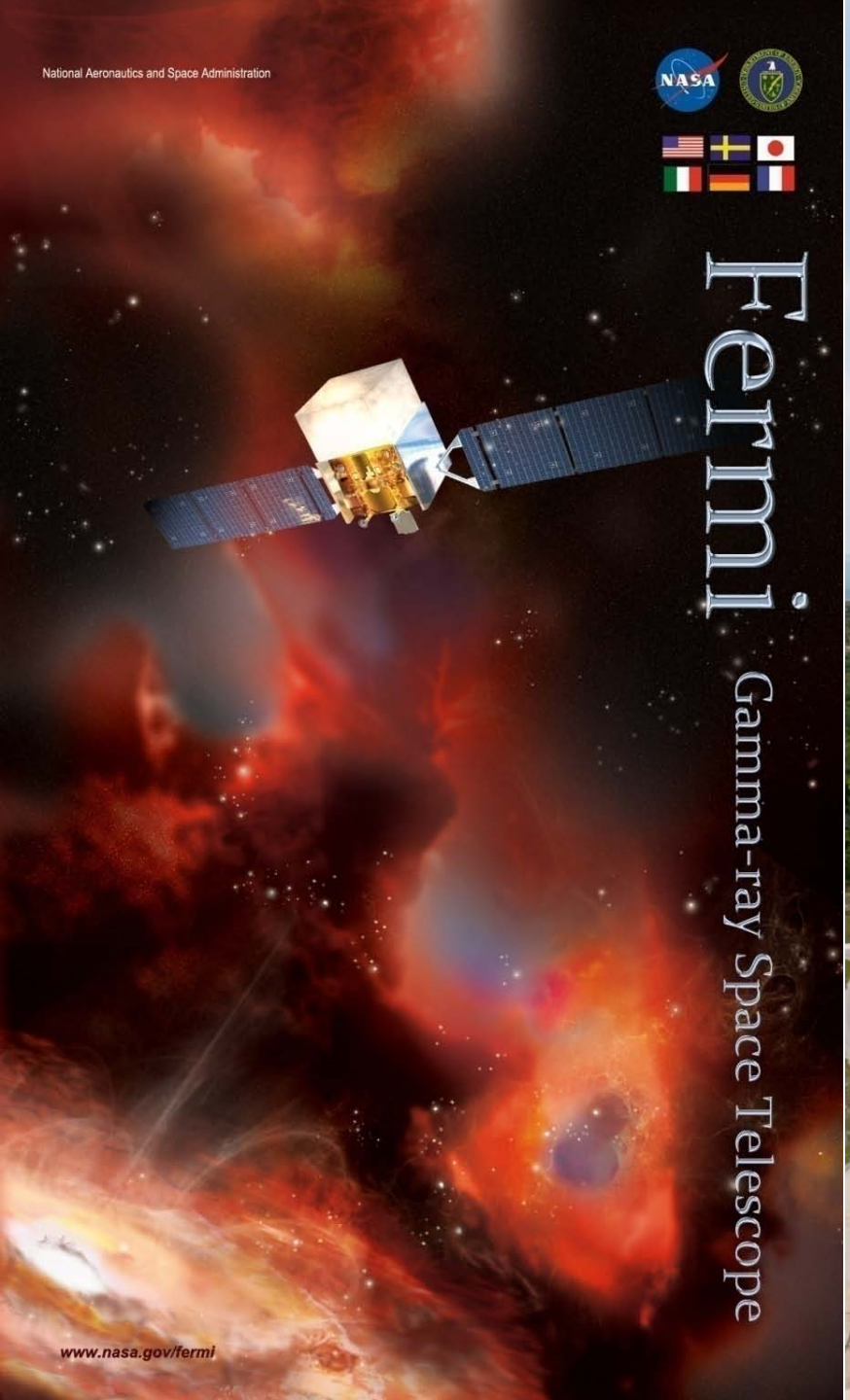

The VLBA and Fermi

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VLBA Workshop
NRAO, Charlottesville, VA
January, 2011

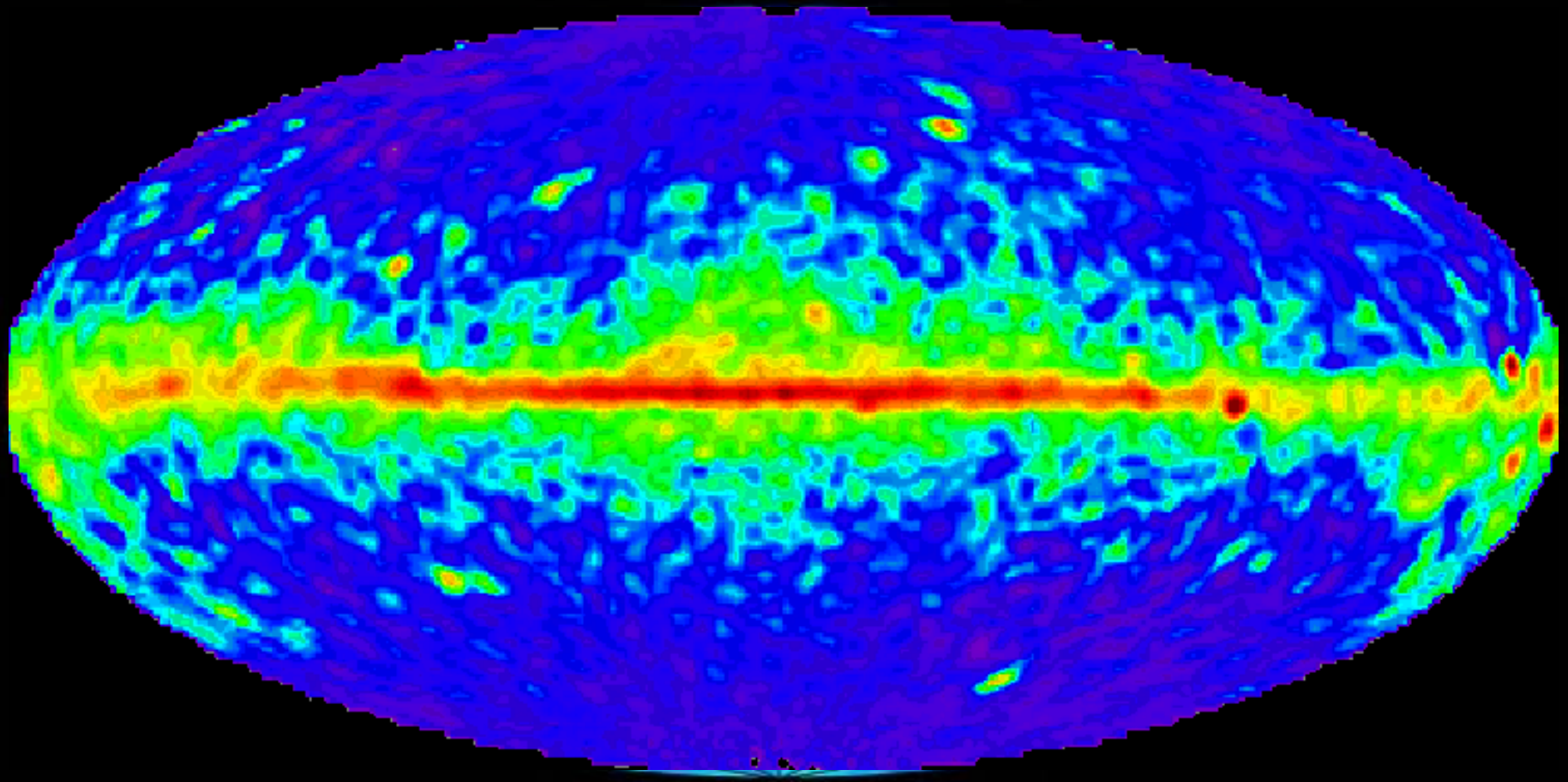
The Fermi Gamma-ray Space Telescope

Large Area Telescope (LAT)

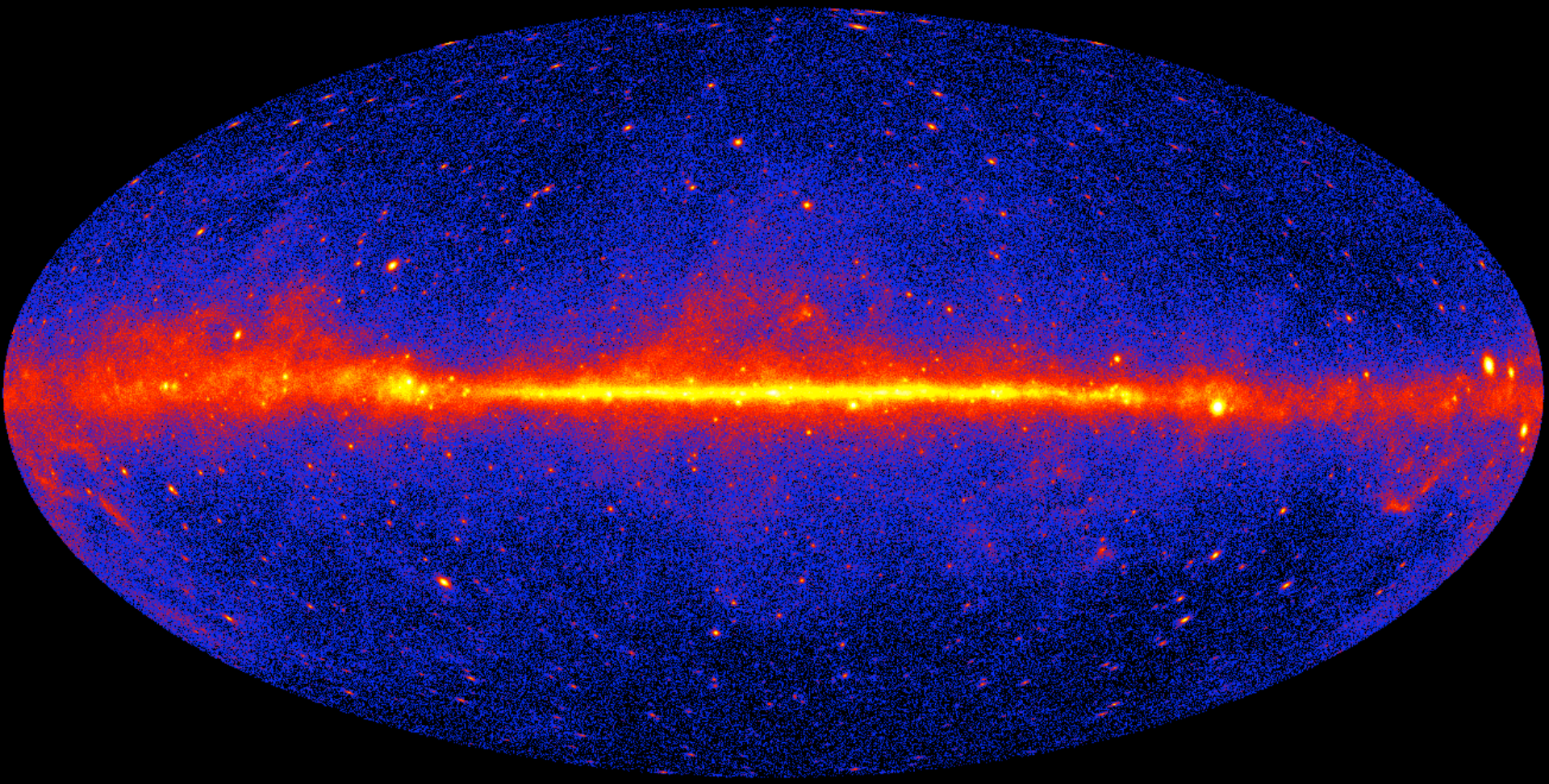
KEY FEATURES

- **20 MeV ➔ >300 GeV photon energies**
- **2.4 Steradian field of view**
- **Operated in scanning mode, so views the entire sky every 3 hours.**
- **Source location capability 1-10 arcmin.**

Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

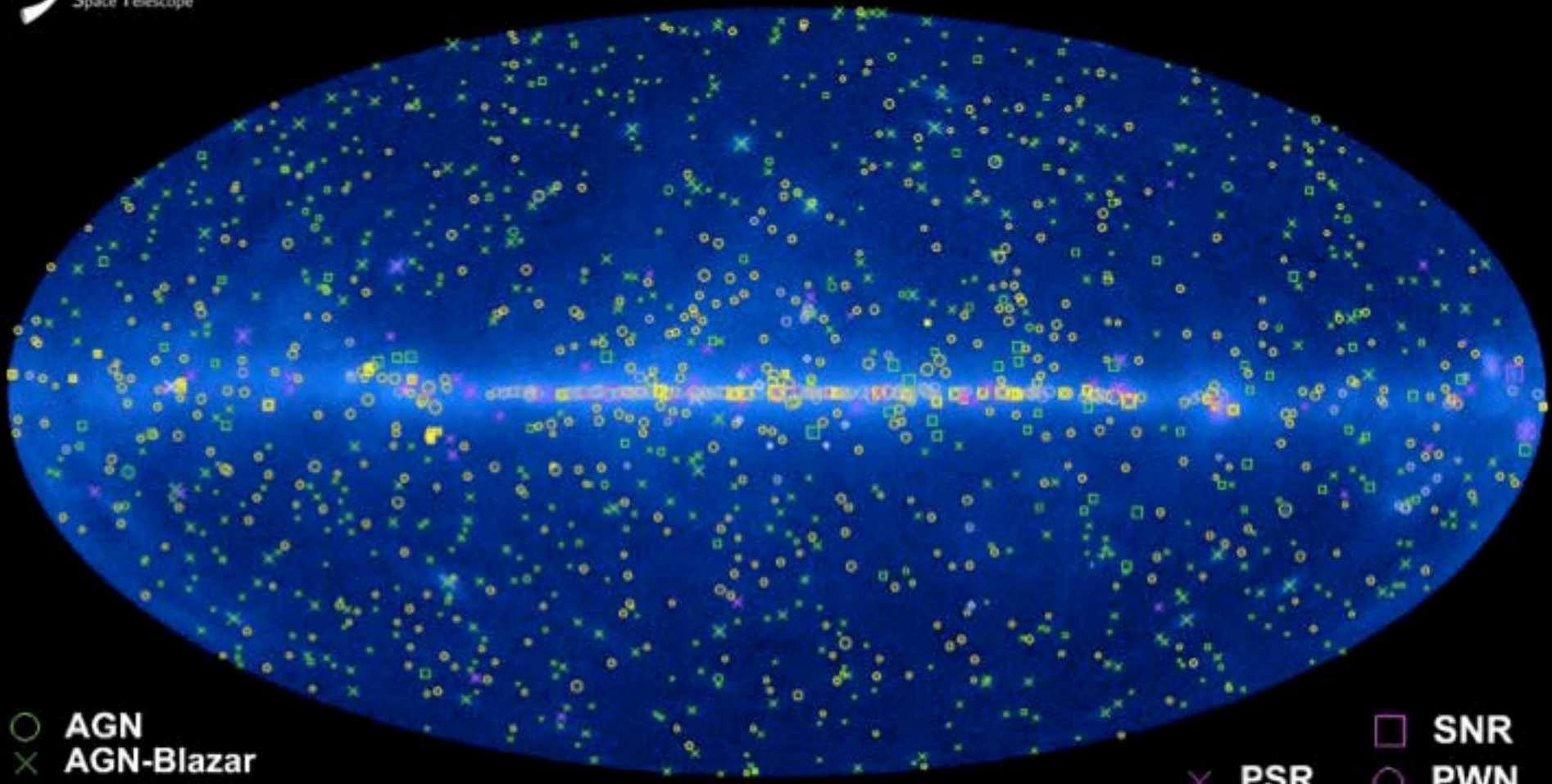


The Sky above 1 GeV Seen with the Fermi Large Area Telescope



The Fermi LAT 1FGL Source Catalog

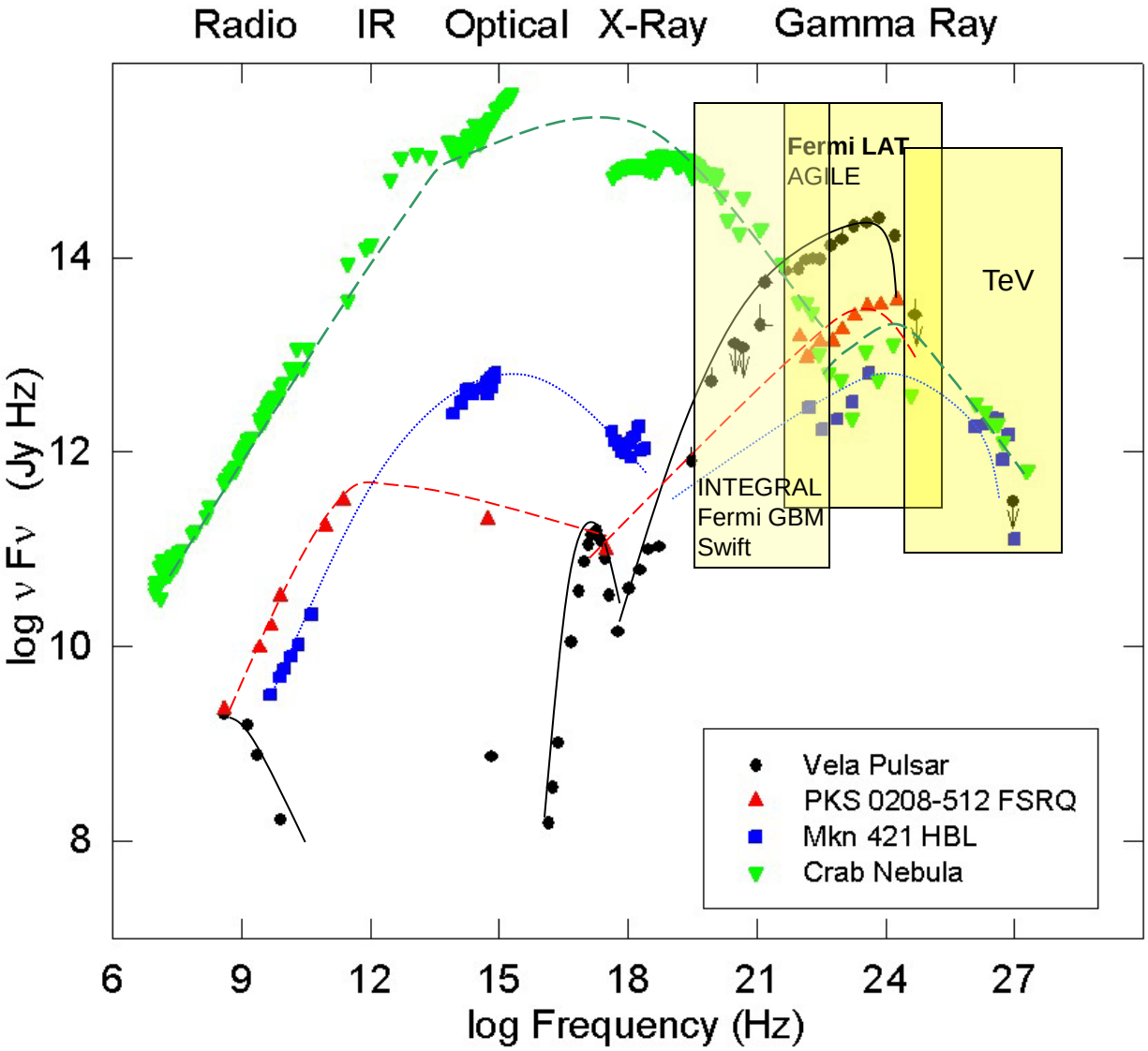
1451 Sources



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

Credit: *Fermi* Large Area Telescope Collaboration

Known Gamma-ray Sources – Multiwavelength Objects



Gamma-ray sources are nonthermal, typically produced by interactions of high-energy particles.

With different interactions, the same particles produce radio emission.

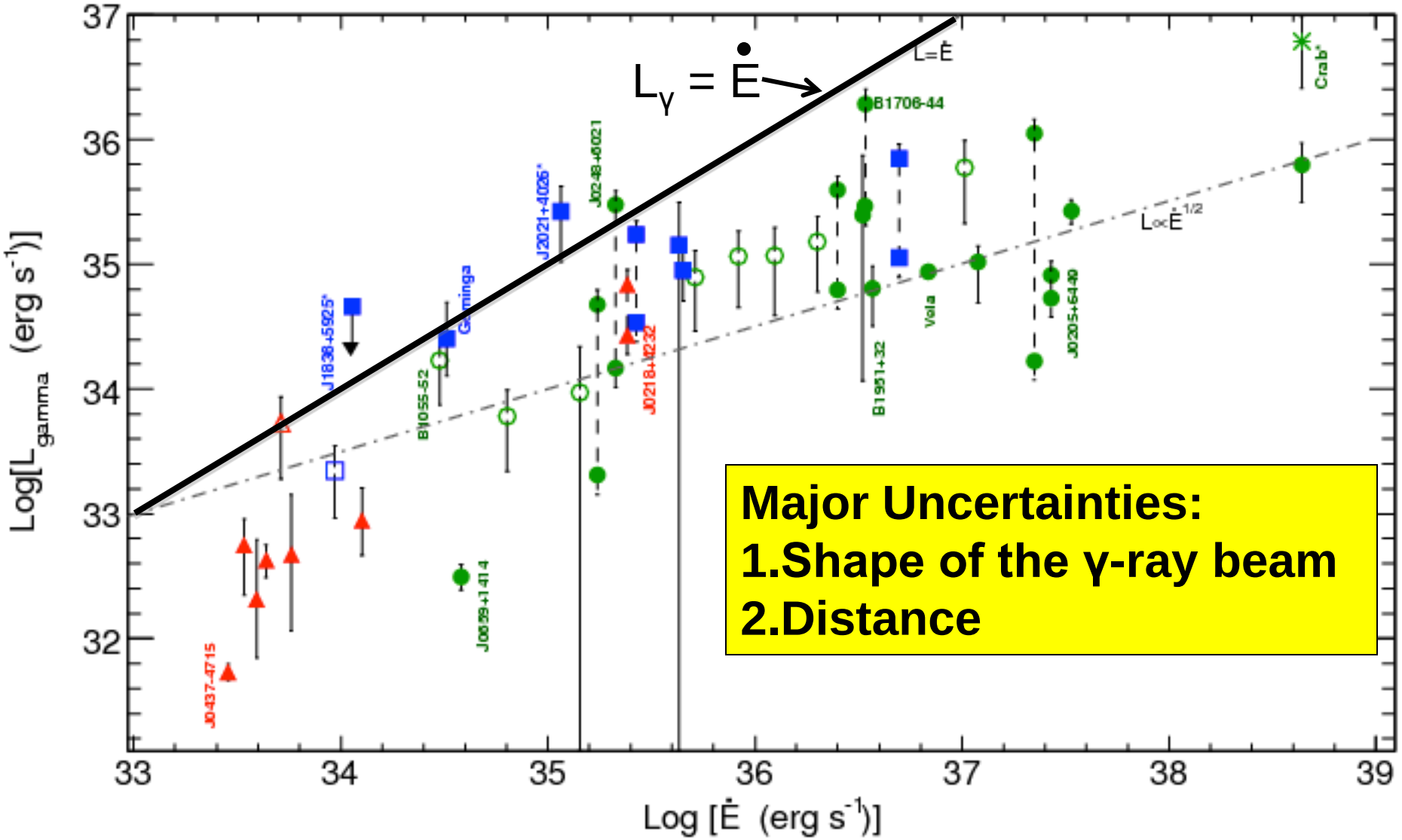
Gamma-Ray/Radio Synergy

Gamma rays often represent a significant part of the energy budget of a source; therefore, gamma-ray studies can be critical to understanding physical processes in such sources.

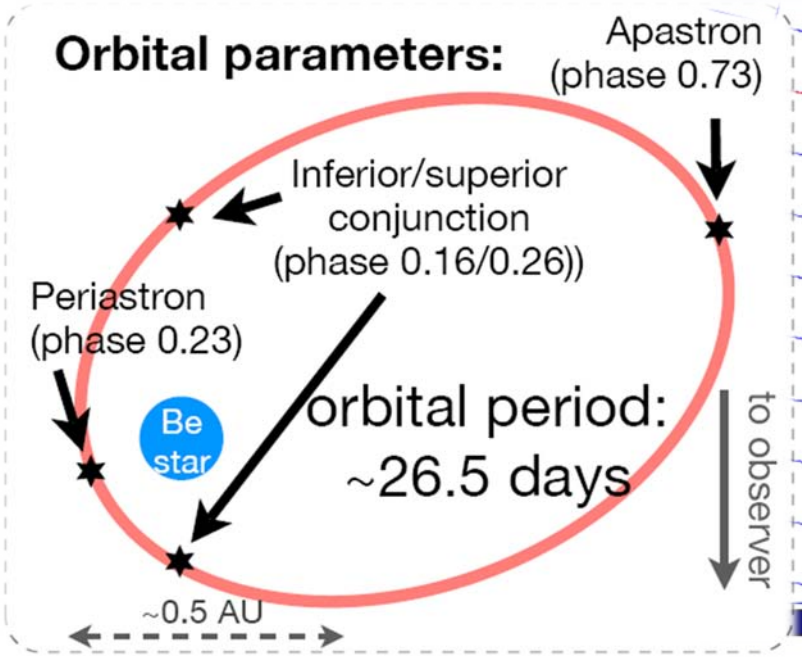
Radio observations offer timing and spatial resolutions vastly superior to anything possible with gamma-ray telescopes; therefore radio is often the key to understanding source structure.

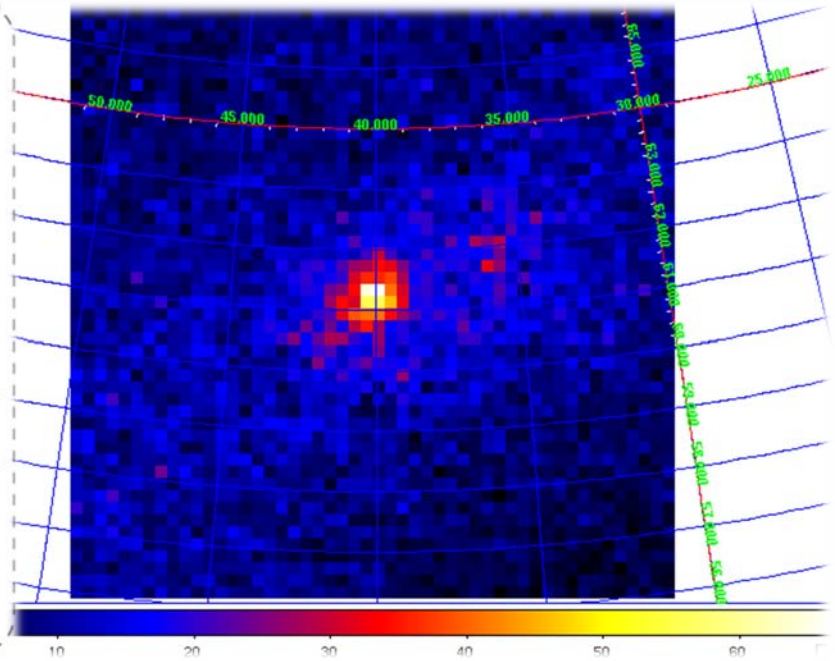
Gamma-ray and radio observations can complement each other, making a great team.

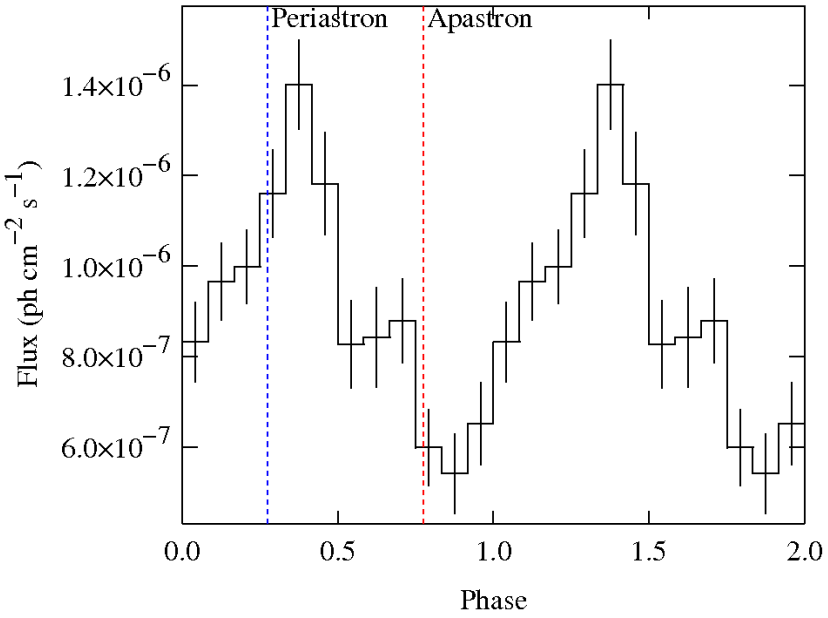
Gamma-Ray Pulsars



High-Mass X-ray Binary – LSI +61°303

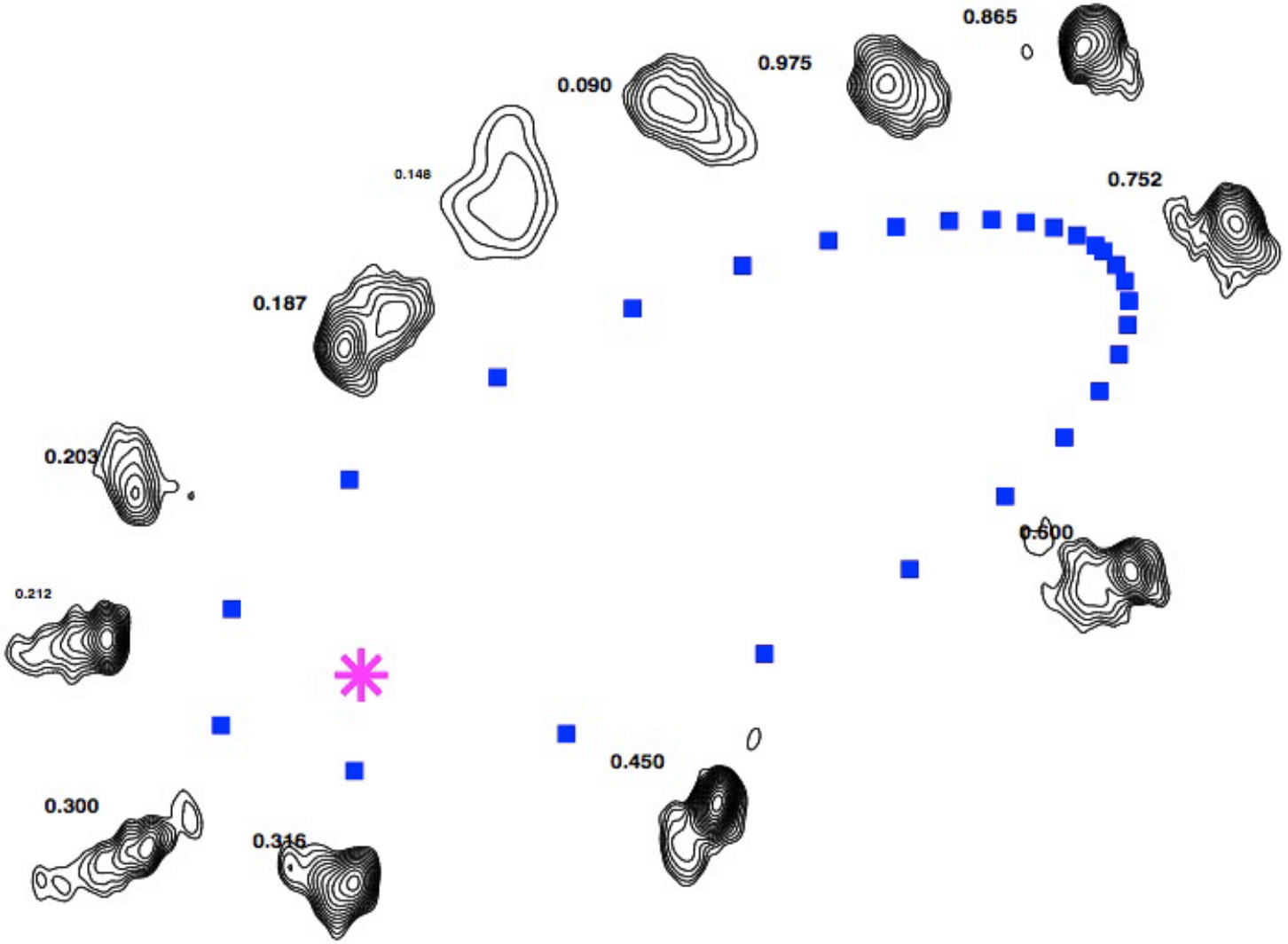






Fermi LAT observations showed a clear 26-day modulation.

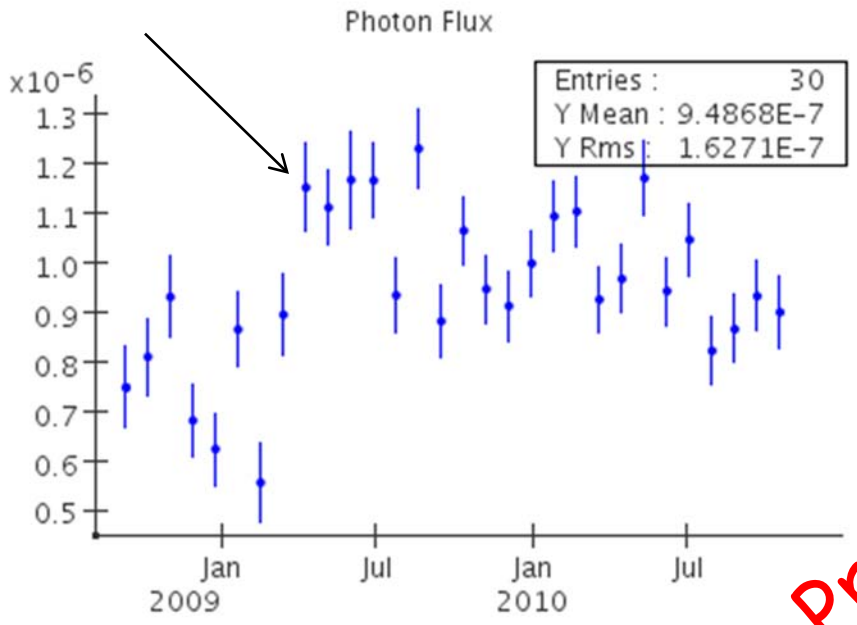
High-Mass X-ray Binary – LSI +61°303



VLBA observations by Vivek Dhawan, Amy Mioduszewski, & Michael Rupen (2006) suggest that it is a pulsar in orbit around the Be star. The Fermi LAT spectrum also appears pulsar-like.

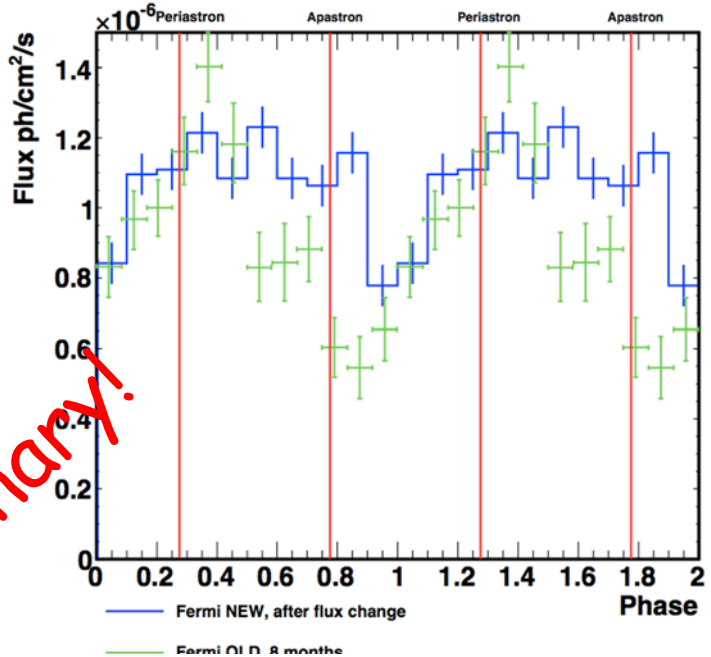
High-Mass X-ray Binary – LSI +61°303

40% flux rise in March 2009

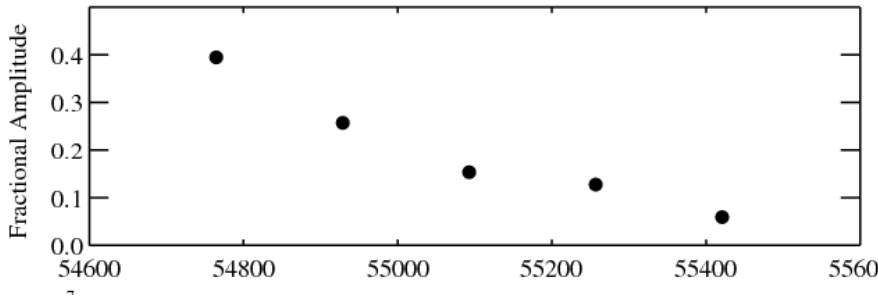


LSI Flux per Week

Flux vs Orbital Phase



Preliminary!



Modulation Fraction vs Time

Gamma-ray pulsars are generally stable emitters, but this source is not. The flux has changed, and the modulation has almost disappeared. We have not solved all the mysteries of this system yet.

The Fermi Guest Investigator (GI) Program Key Points

Primary role of the GI program is to provide financial support for Fermi studies

Limited resource for Fermi is funding, not observing time.

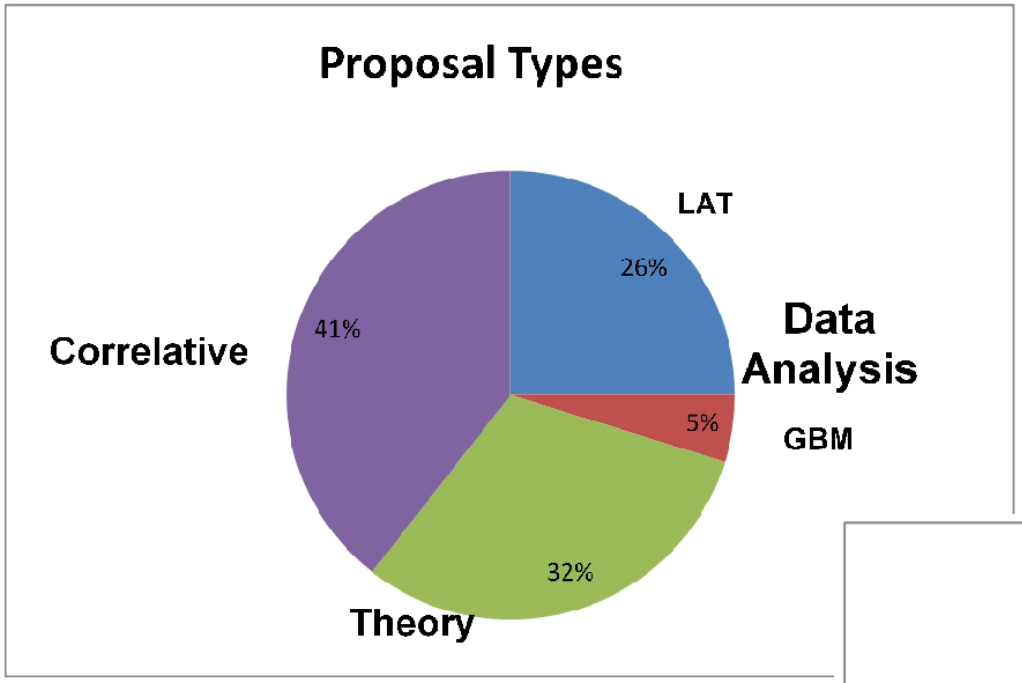
Operations

- Fermi operates almost exclusively in survey mode
- All Fermi gamma-ray data are immediately made public
  - No proprietary gamma-ray data for GIs or instrument team.

GI Program

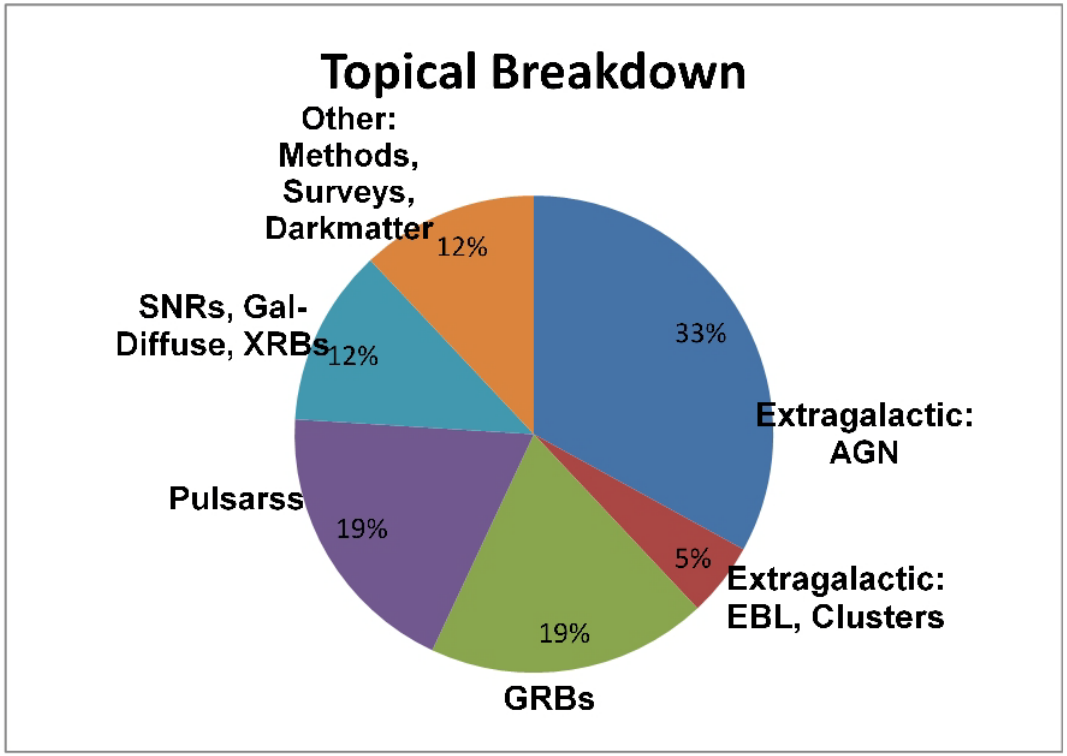
- Funding for analysis of Fermi data and/or correlative observations
- Funding for theoretical studies related to Fermi
- Pointed mode or ToO observations (no accepted proposals in first 3 cycles)
- NRAO, NOAO or Suzaku observations related to Fermi science
- $8M/year disbursed through GI program (1/3 of total mission budget)
- Funds are dispersed to GIs as soon as they are available

Summary of Cycle-3 Program



Topical breakdown of approved Cycle-3 Guest Investigations. Note that No a priori topical prioritizations are imposed.

Breakdown by proposal types. Note that “correlative” includes the joint NOAO & NRAO programs. Joint NRAO programs comprised about 15% of approved Cycle-3 programs.



Summary of Cycle-3 Program

- **Limited resource is $$**
  - **Observations - NRAO, NOAO, Fermi-pointed not oversubscribed**

- **192 proposals received, $16.6M requests**
  - **Includes 10 "Progress Reports"**
  - **77 new grants issued, 10 continuations approved**
- **2 multi-year "Large Projects" selected**
  - **Down from 8 selections in Cycle-1, 3 in Cycle-2**
- **Average grants: $174k (multi-year) $78k (regular)**
- **NRAO: ~850 hours awarded**
  - **~55% of requested total**
  - **~50% of allotted time**
  - **Comprises 15% of all approved Fermi proposals**
- **NOAO: ~60 hrs awarded of ~80 requested**
  - **~60% of allotted time.**

Last week: 210 proposals received for Fermi Cycle 4.

Leveraging GI program to provide MW resources

http://fermi.gsfc.nasa.gov/ssc/observations/multi/programs.html

Multiwavelength Observing - Support Programs

A number of observing programs have been established to provide either regular monitoring or targeted observations specifically designed to help support the *Fermi* science effort. Many of the programs listed below provide their datasets publicly as a service to the science community. These data are not part of the *Fermi* public dataset, so their use should be coordinated directly with the project leads. Please refer to each site for data usage and/or attribution information. For more information on coordinated observations with the LAT, please contact the LAT Multiwavelength Coordinating Group.

Blazar Monitoring

The Radio/Gamma-ray AGN Working Group Home Page provides more information on ongoing science and data acquisition activities in support of *Fermi* AGN Science.

- Owens Valley Radio Observatory (OVRO) Monitoring of *Fermi* Blazars
  40M Radio telescope (15 GHz) monitoring more than 1200 blazars about twice per week.
- MOJAVE/2cm Survey Data Archive
  An imaging survey of compact radio sources at 15 GHz. Many sources are from the *Fermi*-LAT First Point Source Catalog
- University of Michigan Radio Astronomy Observatory
  Tabulated daily averages for flaring gamma-ray blazars.
- TANAMI (Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry)
  Tracking the jets of flaring *Fermi* blazars south of -30 degrees declination at 8.4GHz and 22GHz
- Boston University Blazar Group
  Provides monthly Images of gamma-ray blazars with the VLBA at 43 GHz
- SMARTS Optical/IR Observations of LAT Monitored Blazars
  Uses three telescopes at CTIO to monitor all blazars on the LAT Monitored Sources List that are viewable from Chile

Summary

The nonthermal nature of high-energy gamma-ray emission almost assures that gamma-ray sources will be radio sources.

The VLBA/Fermi cooperative effort has already produced some excellent science, and more is anticipated from ongoing programs.

The Fermi Guest Investigator program will continue to fund scientists to observe with the VLBA. We look forward to more cooperative work involving Fermi and the VLBA.