High Energy Astrophysics with the Fermi Large Area Telescope

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On behalf of the Fermi LAT Collaboration

The Fermi Observatory

Large Area Telescope (LAT)
- Large Field of View (>2.4 sr)
- Views entire sky every 3 hrs (every 2 orbits)
- Broad Energy Range (20 MeV - >300 GeV)

Gamma-ray Burst Monitor (GBM)
- Views entire un occulted sky
- NaI: 8 keV - 1 MeV
- BGO: 150 keV - 30 MeV

Candidate Gamma-ray Events - Flight Data

LAT Performance from Ground Simulations

The LAT is a GeV, wide-field instrument

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

Dependence of effective area on inclination angle (10 GeV): >50% efficiency at 50 deg.
The 9 Month Skymap

LAT Sensitivity with Time

From simulations: 5r integral flux assuming a power law with index -2.0.

Orbit poles are exposed every other orbit
Long time scale asymmetry due to SAA passages

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The Sun and the Moon

Detection of the quiet Sun in gamma rays!
Fluxes consistent with model expectations. Moon flux agrees with EGRET.

RHESSI observes to -20 MeV
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Fermi LAT Collaboration

Principal Investigator:
Peter Michelson (Stanford University)

construction managed by
Stanford Linear Accelerator Center (SLAC), Stanford University

France
+ IN2P3, CEA/Saclay
+ INP, IRFU
+ IN2P3, CEA/Saclay
+ INP, IRFU
+ Japan
+ Hiroshima University
+ BAS/LAXA
+ 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

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EGRET Legacy: GeV Excess

- Extra gammas at ~1 GeV disagree with models based on local cosmic rays
- Spatial variation in cosmic ray spectra?
- Unresolved sources?
- Dark matter?
- Instrument calibration issue?

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Diffuse Emission from the Galaxy

- EGRET GeV excess not confirmed by LAT for this part of the sky
- Conventional model (local CR) in good agreement
- All-sky measurements ongoing - stay tuned!

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The Pulsing Sky

Pulses shown at 1/10th true rate

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Rotation Powered Pulsars

- Electrons (positrons) accelerated to relativistic speeds, emit synchrotron radiation
- Radio emission along magnetic axis
- >1500 radio pulsars catalogued
- Rotational periods from msec to secs, increasing over time

Neutron star ~1.4 x Mass Sun

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**New Gamma-ray Pulsar in CTA 1**

**Science Express** October 16
Abdo et al., 2009, Science

1420 Hz radio map

LAT 95% error radius = 0.038 deg

**Vela Pulsar Lightcurve**

100 MeV - 10 GeV
Timestamps accurate to 300 ns
Phase analysis accurate to ~1 us
Abdo et al. 2009

**Vela Pulsar Energy Dependence**

Peak 1 (P1) stronger at low energy.
Peak 2 (P2) stronger at higher energy.
NEW: Peak 3 evolves with energy

**Vela Pulsar Spectrum**

Consistent with simple exponential cutoff
Super-exponential rejected at 16.5σ
Excludes emission near neutron star surface
47 Tucanae (4.5 kpc) contains at least 23 ms pulsars

New class of gamma-ray emitter! Combined emission from ms pulsars in the cluster? Consistent with average efficiency, \( \text{EFlux}_{\gamma}/\text{Edot}_{\gamma} \approx 10\% \)

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Globular Star Clusters

Active Galactic Nucleus

3C 273 X-ray image

Relativistic Jet

Clouds of gas

Supermassive Black Hole

Accretion Disk

Dusty Torus

Fermi Gamma-Ray Bursts

- GBM
  + >115 bursts
  + 20 are short GRBs
  + 5 GBM bursts detected by LAT

- LAT
  + GRB 080825C - the first one
  + >10 events above 100 MeV
  + GRB 080916C - the long, bright ('') one
  + GRB 081024E - the short one
  + detected >1 GeV photons
  + GRB 081215A - 86 deg. from on-axis - rate only, not imaged
  + GRB090217 - another delayed LAT burst

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How Relativistic is the Jet?

- High redshift and high fluence implies strongly collimated jet
- No spectral cut off ($z \approx 4.35$)

Gravitational Radiation Burst 080916C - the long bright one

- 2nd GRB detected by LAT
- 1st since EGRET with imaged photons and $E > 1$ GeV!
- Brightest burst with a measured redshift
- GROND measurement of redshift, $z = 4.3$

Prompt emission
- >3000 LAT events in first 100 seconds
- >140 LAT events for spectral analysis (>100 MeV)
- Time-resolved spectroscopy over 6 decades in energy (10 keV to 10 GeV)
- High-energy emission peaks at later times
- LAT photons up to 23 min after the trigger time
- Abdo et al. 2009, Science, 323, 1688
Test of Quantum Gravity

- Test for energy dispersion of photons (higher energy arrive later)
- \( \Delta T = \Delta E / M_{QG} \)
- Strong limit on Lorentz invariance violation
  - Highest E photon 13.2 GeV \((1+z) = 70.6 \text{ GeV}\)
  - Arrived 16.5 sec after T0
  - \( M_{QG} > 1.30 \times 10^{18} \text{ GeV}/c^2 \)
  - \( \{-0.1 \text{ M}_{\text{planck}}\} \)

LAT Transients in the Galactic Plane

- 2-day flares detected in the plane without obvious blazar counterpart
- ATeI #1771
  - Spatially coincident with 3EG J0903-3531
  - Variable EGRET source appearing in several viewing periods
  - 68% error radius 0.11 deg
  - No firm identification
- ATeI #1788
  - New GeV source, Fermi J0910-5041
  - 68% error radius 0.07 deg

Summary

- The LAT is a powerful pulsar detector
  - Already influencing pulsar emission models
  - And a great flare monitor
  - Ideal for multiwavelength campaigns (always on!)
  - Excellent performance for GRBs bright above 100 MeV
- The Bright Source List is similar in size to entire EGRET catalog (at only 3 months)
- The Gamma-Ray sky is dynamic
- Lots more Fermi science to come!

www.fermi.gsfc.nasa.gov