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 unocculted 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

Orbit poles are exposed every other orbit
Long term 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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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?

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!

The Pulsing Sky

Fermi Pulsar Detections

Pulses shown at 1/10th true rate

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

*Science Express* October 16
Abdo et al., 2008, Science

1420 Hz radio map

LAT 95% error radius = 0.038 deg

**Vela Pulsar Lightcurve**

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
(confirm EGRET)
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

Pulse undetected in radio/X-ray

Power Law

Φ(E) ~ E^{−α}

Pdot = 3.6 x 10^{-12} ± 1.1 E dot

Flux (100 MeV) = 3.8 ± 0.2 x 10^{-7} ph cm^{-2} s^{-1}

Radio

\text{P1} \quad \text{P2} \quad \text{P3} \quad \text{Observed}

0 0.3 1 1

Rotational Phase
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, $\frac{\text{EFlux}_{\gamma}}{\text{E_dot}} \sim 10\%$

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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 081224B - 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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3 Month Daily Movie

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

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Fermi Gamma-Ray Bursts
How Relativistic is the Jet?

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

GRB 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
  - >100 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

GRB 080916C lightcurve

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GRB 080916C Spectrum

- Spectrum for main peak in LAT (3.6 - 7.7 s)
- Compatible with a single component from 10 keV to 10 GeV

Abdo et al. 2009, Science, 323, 1688
Test of Quantum Gravity

+ Test for energy dispersion of photons (higher energy arrive later)
  + $\Delta T \approx \Delta E / M_{QG}$
+ Strong limit on Lorentz invariance violation
  + Highest E photon $13.2 \text{ GeV} (1+z) = 70.6 \text{ GeV}$
  + Arrived 16.5 sec after T0
  + $\Rightarrow M_{QG} > 1.3 \times 10^{18} \text{ GeV}/c^2$
  + $\sim 0.1 M_{\text{planck}}$

LAT Transients in the Galactic Plane

+ 2 -day flares detected in the plane without obvious blazar counterpart
  + ATel #1771
    - Spatially coincident with 3EG J0903-3531
    - Variable EGRET source appearing in several viewing periods
    + 68% error radius 0.11 deg
    + No firm identification
  + ATel #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