Observation of High Energy Gamma Rays with the Fermi Observatory

N. Giglietto
(INFN and Politecnico of Bari) on behalf of the FERMI LAT Collaboration
The Observatory

**Large Area Telescope (LAT)**
- 20 MeV - >300 GeV

**Gamma-ray Burst Monitor (GBM)**
- NaI and BGO Detectors
- 8 keV - 30 MeV

**KEY FEATURES**

- **Huge field of view**
  - LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.

- **Huge energy range**, including largely unexplored band 10 GeV - 100 GeV. **Total of >7 energy decades!**

- **Large leap in all key capabilities. Great discovery potential.**
Overview of LAT: How it works

- **Precision Si-strip Tracker (TKR)**
  - 228 µm pitch, 8.8 \(10^5\) channels
  - Measure the photon direction; gamma ID.

- **Hodoscopic CsI Calorimeter (CAL)**
  - Measure the photon energy; image the shower. (8.6X0)

- **Segmented Anticoincidence Detector (ACD)**
  - Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.

- **Electronics System**
  - Includes flexible, robust hardware trigger and software filters.

- **3000 kg, 650 W**

**Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.**
Features of the EGRET 5 years gamma-ray sky

EGRET all-sky (galactic coordinates) E > 100 MeV

diffuse extra-galactic background (flux ~ 1.5x10^{-5} cm^{-2} s^{-1} sr^{-1})
galactic diffuse (flux ~30 times larger)
high latitude (extra-galactic) point sources

galactic sources (pulsars, un-ID'd)

An essential new characteristic: \( \text{\textit{Variability in time}} \)
Field of view important for study of transients.
Variability a 3 months look (north-south galactic emisphere)

E>100MeV, poles view, 1day time interval, extreme sensitivity to flux variations
Fermi Science

A very broad menu that includes:

• Systems with supermassive black holes (Active Galactic Nuclei)
• Gamma-ray bursts (GRBs)
• Pulsars
• Supernova remnants (SNRs), PWNe, Origin of Cosmic Rays
• Diffuse emissions
• Solar physics
• Probing the era of galaxy formation, optical-UV background light
• Solving the mystery of the high-energy unidentified sources
• Discovery! New source classes. Particle Dark Matter? Other relics from the Big Bang? Other fundamental physics checks.

Huge increment in capabilities.

Draws the interest of both the High Energy Particle Physics and High Energy Astrophysics communities.
The Accelerator
• Launch from Cape Canaveral Air Station 11 June 2008 at 12:05PM EDT
• Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination.
Operating modes

• Primary observing mode is Sky Survey
  
  Full sky every 2 orbits (3 hours)
  
  Uniform exposure, with each region
  
  viewed for ~30 minutes every 2 orbits
  
  Best serves majority of science, facilitates
  
  multiwavelength observation planning

• Pointed observations when appropriate (selected by peer review in later years) with automatic earth avoidance selectable. Target of Opportunity pointing
  
  Exposure intervals commensurate with
  
  **Autonomous repoints for onboard** GRB detections in any mode.
LAT Collaboration

- **France**
  - CNRS/IN2P3, CEA/Saclay

- **Italy**
  - INFN, ASI, INAF

- **Japan**
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology

**PI: Peter Michelson**
(Stanford)

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

**Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.**

**Managed at SLAC.**
LAT Working Very Well On Orbit!

- Total background rates very close to expectation (non-trivial!)

- Spectacular charged-particle hit efficiency:

- PSF on-orbit as expected (note intrinsic energy dependence => localization is source-dependent)
  - verify using on-pulse photons from Vela, compare with detailed MC simulation:

- On-orbit calorimeter calibration stable
  - use cosmic ray heavy ions:
Big Questions From EGRET Era

• **How and where do pulsars emit gamma rays? How common are radio-quiet pulsars?**
  – necessary clue to magnetic field configurations and dynamics

• **What are the EGRET Unidentified Sources?**
  – most of the EGRET source identifications are a mystery

• **What are the energy budgets of gamma-ray bursts? What are the temporal characteristics of the high-energy emission?**
  – not well characterized yet, key tests of models.

• **What are the origins of the diffuse emissions?**
  – galactic: cosmic-ray and matter distributions; sources
  – extragalactic: populations
  – new sources (Dark Matter annihilations, clusters, …)

• **How do the supermassive black hole systems of AGN work? Why do the jets shine so brightly in gamma rays?**
  – temporal and spectral variability over different timescales

• **What remains to be discovered with great new capabilities??**
  – **EGRET showed us the tip of the iceberg. New sources and probes for new physics.**
Discovery of First Gamma-ray-only Pulsar

A radio-quiet, gamma-ray only pulsar, in Supernova Remnant CTA1

Quick discovery enabled by
- large leap in key capabilities
- new analysis technique (Atwood et al)

Spin-down luminosity $\sim 10^{36}$ erg s$^{-1}$, sufficient to supply the PWN with magnetic fields and energetic electrons.

The $\gamma$-ray flux from the CTA 1 pulsar corresponds to about 1-10% of $E_{\text{rot}}$ depending

Age $\sim (0.5 - 1) \times 10^4$ years
Distance $\sim 1.4$ kpc
\[ N(E) = N_0 E^\Gamma e^{-(E/E_c)^b} \]

Consistent with \( b=1 \)

\[ \Gamma = -1.51^{+0.05}_{-0.04} \]

\[ E_c = 2.9 \pm 0.1 \text{ GeV} \]

\( b=2 \) (super-exponential) rejected at 16.5\( \sigma \)

No evidence for magnetic pair attenuation:
Near-surface emission ruled out
Summary: Fermi LAT Pulsar Discoveries

• In the first 4 months of the mission, over 3 dozen pulsars detected!

• Confirmed 6 known EGRET pulsars (and several EGRET candidates)

• Found 12 new young radio pulsars

• Found 13 young pulsars pulsing in Gamma-rays alone

• Found 7 ‘Millisecond’ Gamma-ray pulsars, establishing new class of gamma-ray pulsars (EGRET low-significance candidate, PSR J0218+4232, confirmed)

• 12 new pulsars found directly in the gamma-rays (blind searches) and

• 18 additional pulsars seen for the first time as gamma-ray emitters.
The Pulsing Sky

Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Confirmed pulsars seen by Compton Observatory EGRET instrument

Pulses at 1/10 true rate
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GBM Collaboration

National Space Science & Technology Center

University of Alabama in Huntsville

NASA Marshall Space Flight Center

Max-Planck-Institut für extraterrestrische Physik

Charles Meegan (PI)
Jochen Greiner (Co-PI)
Now have >129 GBM detected GRBs (200—250 per year). 5 GRBs with LAT.
GRB080916C

The first low-energy peak is not observed at LAT energies

14 events above 1 GeV

The bulk of the emission of the 2nd peak is moving toward later times as the energy increases

Clear signature of spectral evolution

new era of GeV GRB lightcurves!

GBM NaI + NaI (8 keV-260 keV)

8 keV – 260 keV

260 keV – 5 MeV

LAT raw

LAT (> 100 MeV)

LAT > 100 MeV

LAT (> 1 GeV)

LAT > 1 GeV

GROND optical follow up [GCN 8257, 8272]

Faint (21.7 mag at T +32h) and fading (T +3.3d) source

RA = 119.8472°, Dec = −56.6383° (±0.5” at 68% C.L.)
GRB summary

Updated on feb,20,2009: 129 bursts detected by the GBM, including 5 LAT detections
Nice joint GBM+LAT analyses

High-energy GRB observations:
Evidences for a delay between keV-MeV emission and >100MeV emission
All spectra consistent with a Band function
081024B : First >GeV observation from a short burst

080916C : Most energetic burst with a measured redshift $E \sim 8.8 \times 10^{54}$ ergs
Evidence for a temporally extended GeV emission: up to 23 min
090217: Last GRB detected, again evidences for a delayed emission between kev-MeV emission (GCN circulars 8902-03)

Consequences:
Narrow collimated relativistic jet
keV-GeV spectrum and variability: unique mechanism, same emission region
Leptonic or hadronic origin?

Best constraints ever on $\Gamma$ (> 600 to 900) and $M$ (> 1.50e18 GeV/c ~0.1 M)
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GeV Galactic diffuse emission is non-thermal emission from interaction of CR with the interstellar medium

+ isotropic diffuse emission from unresolved AGN, star-forming galaxies, etc...

Dermer, 2007
The challenge of modeling the galactic diffuse γ-ray emission

- Cosmic-ray source distribution
- Cosmic-ray propagation

Inverse Compton π0-decay

Bremsstrahlung

Line-of-sight integration of produced gamma-ray intensities

Interaction with interstellar medium

HI 21cm LAB-survey
Kalberla et al. 2005

ISRF 0.1μm – 1mm

CO 1→0 (115GHz)
radial velocity/longitude profile

Dame et al., 2001

Pulsar distribution

SNR distribution

\[
\frac{\partial \psi}{\partial t} = q(r, p) + \nabla \cdot (D_{xx} \nabla \psi - V \psi) + \frac{\partial}{\partial p} \frac{p^2 D_{pp}}{p^2} \frac{\partial}{\partial p} \frac{1}{p} \psi
\]

\[
- \frac{\partial}{\partial p} \left[ p \psi - \frac{p}{3} (V \cdot V) \psi \right] - \frac{1}{\tau_f} \psi - \frac{1}{\tau_r} \psi
\]
Diffuse Emission, Nailing the EGRET “GeV Excess”

- Spectra shown for mid-latitude range → **GeV excess in this region of the sky is not confirmed.**
- Sources are **not** subtracted but are a minor component.
- LAT errors are dominated by systematic uncertainties and are currently estimated to be ~10% → this is **preliminary.**
- EGRET data is prepared as in Strong, et al. 2004 with a 15% systematic error assumed to dominate (Esposito, et al. 1999).
- EG + instrumental is assumed to be isotropic and determined from fitting the data at $|b| > 10^\circ$. 

N.Giglietto- High energy gamma rays observations with the Fermi Observatory-La Thuile 2009, March 12, 2009
Dark Matter searches with FERMI

\[ \frac{d\Phi_{\gamma}}{dE_{\gamma}} = \frac{1}{4\pi} \frac{\langle \sigma v \rangle}{2m_{\chi}^2} \sum_f \frac{dn_f}{dE_{\gamma}} \frac{B_f}{B_f} \int_{\Delta \Omega} \int_{l.o.s} \rho^2(\psi) d\psi \ d\Omega \]

Particle Physics

Astrophysics

J(\psi)

Gamma ray lines, the "smoking gun" signal of particle dark matter... but loop suppressed...

Continuum spectra

EGRET data ex

"GeV excess"

DM contribution

Annihilation channel b\bar{b} m_{\chi} = 50 \text{ GeV}

Background

WIMP annihilation

Total contribution

N. Giglietto - High energy gamma rays observations with the Fermi Observatory - La Thuile 2009, March 12, 2009
<table>
<thead>
<tr>
<th>Search Technique</th>
<th>advantages</th>
<th>challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galactic center</td>
<td>Good Statistics</td>
<td>Source confusion/ Diffuse background</td>
</tr>
<tr>
<td>Satellites, Subhalos, Point Sources</td>
<td>Low background, Good source id</td>
<td>Low statistics</td>
</tr>
<tr>
<td>Milky Way halo</td>
<td>Large statistics</td>
<td>Galactic diffuse background</td>
</tr>
<tr>
<td>Extra-galactic</td>
<td>Large Statistics</td>
<td>Astrophysics, galactic diffuse background</td>
</tr>
<tr>
<td>Spectral lines</td>
<td>No astrophysical uncertainties, good source id</td>
<td>Low statistics</td>
</tr>
</tbody>
</table>

Sensitivity map for GC with FERMI

above 3 σ EGRET observation

\[ E_\gamma > 1 \text{ GeV} \]

5 years operation

Others annihilating channels have been investigated: \( t \bar{t}, W^+ W^-, \tau^+ \tau^- \), ...
Fermi covers electrons energy measurements 20GeV-1000GeV

excess at about 300-600 GeV by ATIC and PPB-BETS

Big Questions From EGRET Era

- How and where do pulsars emit gamma rays? How common are radio-quiet pulsars?
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Models of AGN Gamma-ray Production

(from Sikora, Begelman, and Rees (1994))

(credit: J. Buckley)
3C454.3 with LAT

- Well-known radio source, identified with an OVV quasar at $z = 0.859$; also detected by EGRET, AGILE

- Not a simple power law

  - Can describe as a broken power law with a break, $\Gamma_1 \sim 2.3$ to $\Gamma_2 \sim 3.5$ at $E_b \sim 2$ GeV
LAT studies EBL cutoff

Probe history of star formation to $z \sim 4$ by determining spectral cutoff in AGN due to EBL
Summary

• Fermi is off to a great start!
  Instruments are beautiful. The gamma-ray sky is keeping its promise. Great cooperation across the international team.

• Already addressing many important questions from EGRET era
  New analysis techniques and approaches are essential -- new topics!
  EGRET GeV excess excluded
  Many variable sources discovered
  Many pulsars discovered
  The challenge of great discovery potential

Sign up for newsletters:
http://fermi.gsfc.nasa.gov/ssc/resources/newsletter/
Sources in Solar System

“\( \gamma \)-ray albedo” due to CR interactions with surface material

Moving sources:
The Moon (albedo)
The Sun (albedo + inverse Compton)
The Earth

Potential Sources:
Asteroids in different populations:
Main Asteroid Belt (MBAs)
Jovian and Neptunian Trojans (Trojans)
Kuiper Belt Objects (KBOs)
Other planets
The Quiet Sun: first 6 months of observation

Source Flux (>100 MeV) ~ $4 \times 10^{-7}$ cm$^{-2}$ s$^{-1}$ (albedo+IC, preliminary)

Expected IC Flux (>100 MeV) ~ $4.3 \times 10^{-7}$ cm$^{-2}$ s$^{-1}$ (@ solar min, IM+’06)
**GBM Detector**

MSFC, MPE PI: Chip Meegan

**Bismuth Germanate (BGO) Scintillation Detector**

**Sodium Iodide (NaI) Scintillation Detectors**

LAT
diffuse EBL contains unique information about the epochs of formation and the evolution of galaxies and in what environments the stars of the universe formed.

direct EBL measurements require accurate model-based subtraction of bright foregrounds (e.g., zodiacal light).

alternative approach: extract imprint of EBL absorption, as function of redshift, from high-energy spectra of extragalactic sources.

\[ \gamma \gamma \rightarrow e^+ e^- , \text{ maximum when } \epsilon \sim \frac{1}{2} \left( \frac{1000 \text{ GeV}}{E} \right) \text{ eV} \]

no significant attenuation below 10 GeV

N.Giglietto- High energy gamma rays observations with the Fermi Observatory-La Thuile 2009, March 12, 2009
Pulsars (using early engineering data)

Geminga: $P=237 \text{ ms}$

Vela: $P=89.3 \text{ ms}$

Crab: $P=33 \text{ ms}$
Solar system sources

- Quiet Sun and Moon contribute to the diffuse background
- Sun is now at the minimum solar activity but going to increase its activity: search for Solar flares, studies in connection with other observatories
- FERMI will operate during the entire 24 solar cycle
Light curves (daily and weekly integrations) in energy bands.

PLUS, same for any source flaring above $2 \times 10^{-6}$ ph/cm$^2$/s until the flux drops below $2 \times 10^{-7}$ ph/cm$^2$/s (two additional sources thus far: PKS 1454 and PKS 1502)

A “quicklook” analysis to get the results out as soon as possible. Tables may be updated as analysis and calibrations improve.
205 Preliminary LAT Brightest Sources

- EGRET on the Compton Observatory found fewer than 30 sources above 10 \( \sigma \) in its lifetime.

- Typical 95\% error radius is less than 10 arcmin. For the brightest sources, it is less than 3 arcmin. Improvements are expected.

- About 1/3 of the sources show definite evidence of variability.

- More than 30 pulsars are identified by gamma-ray pulsations.

- Over half the sources are associated positionally with blazars. Some of these are firmly identified as blazars by correlated multiwavelength variability.

- Over 40 sources have no obvious associations with known gamma-ray emitting types of astrophysical objects.

Crosses mark source locations, in Galactic coordinates.

A list, not a catalog!
CTA 1 pulsar (2 cycles, P=315.86 ms)

Vela (2 cycles, P=89.3 ms)

Geminga (2 cycles, P=237.1 ms)

PSR B1706-44 (2 cycles, P=102.4 ms)

PSR B1055-52 (2 cycles, P=197 ms)

Crab pulsar (P=33.4 ms)


N. Giglietto- High energy gamma rays observations with the Fermi Observatory-La Thuile 2009, March 12, 2009
**Gamma-Ray Bursts observed by LAT**

LAT has reported 3 high-energy bursts since launch.

<table>
<thead>
<tr>
<th>GRB 080916C: Fermi LAT observation</th>
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<td><strong>DATE:</strong> 08/09/16 18:25:23 GMT</td>
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<td><strong>FROM:</strong> Nicola Omodei at INFN(Pisa)/GLAST <a href="mailto:nicola.omodei@pi.infn.it">nicola.omodei@pi.infn.it</a></td>
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<td><strong>FROM:</strong> Aurelien Bouvier at Stanford <a href="mailto:bouvier@stanford.edu">bouvier@stanford.edu</a></td>
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</table>

First detection of short-duration burst at high energy.

<table>
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<td><strong>SOURCE:</strong> GCN</td>
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**EBL spectral energy distribution**

HESS upper limit derived from observed hard spectra of blazars at $z = 0.165$ and $0.186$

Reference EBL SED, matches direct measurements at 2.2 and 3.5 $\mu$m.

**- lower limits on HST galaxy counts combined with HESS upper limit on EBL imply that any unresolved component is no more than $\sim 1/3$ of the total.**
3C 454.3:

- Supermassive black hole
- 8 billion light-years from us

**GLAST-LAT detection of extraordinary gamma-ray activity in 3C 454.3**

ATel #1628: G. Tosti (Univ/INFN-Perugia), J. Chiang (SLAC), B. Lott (CENBG/Bordeaux), E. do Couto e Silva (SLAC), J. E. Grove (NRL/Washington), J. G. Thayer (SLAC) on behalf of the GLAST Large Area Telescope Collaboration

on 24 Jul 2008; 14:25 UT

Password Certification: Gino Tosti (tosti@pg.infn.it)

Subjects: Gamma Ray, > GeV, AGN, Quasars

The Large Area Telescope (LAT), one of two instruments on the Gamma-ray Large Area Space Telescope (GLAST) (launched June 11, 2008), which is still in its post-launch commissioning and checkout phase has been monitoring extraordinarily high flux from the gamma-ray blazar 3C454.3 since June 28, 2008. This confirms the bright state of the source reported by AGILE (see ATel #1592) and by the optical-to-radio observers of the GASP-WEBT Project (ATel #1625).

3C 454.3 has been detected on time scales of hours with high significance (> 5 sigma) by the LAT Automatic Science Processing (ASP) pipeline and the daily light curve (>100 MeV) indicates that the source flux has increased from the initial measurements on June 28. Although in-flight calibration is still ongoing, preliminary analysis indicates that in the period July 10-21, 2008 the source has been in a very high state with a flux (>100 MeV) that is well above all previously published values reported by both EGRET (Hartman et al. 1999, ApJS, 123, 79) and AGILE (see e.g. ATel #1592 and Vercellone et al. 2008, ApJ, 676, L13).

Because GLAST will continue with calibration activities, regular monitoring of this source cannot be pursued. Monitoring by the LAT is expected to resume in early August. In consideration of the ongoing activity of this source we strongly encourage multiwavelength observations of 3C 454.3.

The GLAST LAT is a pair conversion telescope designed to cover the energy band from 20 MeV to greater than 300 GeV. It is the product of an international collaboration between NASA and DOE in the U.S. and many scientific institutions across France, Italy, Japan and Sweden.
Constructing the LAT Bright Source List

• Maximum likelihood analysis.
In the simplest model, the emission should depend on 4 parameters: spin period, magnetic field, magnetic dipole inclination, and viewing angle.

- Luminosity derived from rotational energy:
  \[ E = \frac{1}{2} I \Omega \]

- Energy:
  \[ E = -B R \Omega / c \]

- Derived parameters:
  - Rotational age: \( \tau = \Omega / 2\Omega \)
  - B field: \( B = 3.2 \times 10^{19} \) G

\( \gamma \)-ray emission fan beam
Earth albedo $\gamma$-rays
The interstellar medium

Interstellar gas

Atomic hydrogen (HI)
Column density and spatial distribution from 21cm line measurement
Molecular hydrogen (H₂)
Column density and spatial distribution from 2.6mm CO 1→0 transition measurement
CO→H₂ conversion via X factor

Ionized hydrogen (HII)
Small contribution but scale height ~ 1 kpc
present at higher latitudes

Interstellar radiation field
Starlight (~ 0.1 um – 10 um)
Dust (~ 10 um – 300 um)
Cosmic Microwave Background

Moskalenko, 2002
Moskalenko, Porter & Strong, 2006
Moskalenko, 2002
Moskalenko, Porter & Strong, 2006
GRB080916C Spectroscopy of the Main LAT peak

- Consistent with Band function from 10 keV to 10 GeV
- No evidence for any other component
- No evidence for any roll-off

### Alpha
-1.02 \pm 0.02

### Beta
-2.21 \pm 0.03

### Epeak
1170 \pm 142 keV

### Amp.
0.0354 \pm 0.001 photons/s-cm^-2-keV

### Reduced Chi-Square
0.963

### Probability
0.698
Photons with $E > 10$ GeV are attenuated by the diffuse field of UV-Optical-IR extragalactic background light (EBL)

EBL over cosmological distances is probed by gammas in the 10-100 GeV range. Important science for GLAST!

In contrast, the TeV-IR attenuation results in a flux that may be limited to more local (or much brighter) sources.
**Millisecond pulsars detected by Fermi**

<table>
<thead>
<tr>
<th>PULSAR</th>
<th>PERIOD (ms)</th>
<th>PERIOD DERIV. $(10^{-20} \text{s/s})$</th>
<th>D (kpc)</th>
<th>Edot (erg/s)</th>
<th># PHOTONS</th>
<th>H-TEST TS</th>
<th>CHANCE PROB</th>
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<tbody>
<tr>
<td>J0030+0451</td>
<td>4,86</td>
<td>1</td>
<td>0,32</td>
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<td>&lt; 4e-08</td>
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<tr>
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<td>7,74</td>
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<td>0,96</td>
<td>0,48</td>
<td>1,32E+34</td>
<td>549</td>
<td>60</td>
<td>&lt; 4e-08</td>
</tr>
<tr>
<td>J1024-0719</td>
<td>5,16</td>
<td>1,85</td>
<td>0,53</td>
<td>5,31E+33</td>
<td>135</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>J1744-1134</td>
<td>4,07</td>
<td>0,89</td>
<td>0,48</td>
<td>5,21E+33</td>
<td>1014</td>
<td>25,1</td>
<td>5,04E-05</td>
</tr>
<tr>
<td>J2124-3358</td>
<td>4,93</td>
<td>2,1</td>
<td>0,25</td>
<td>6,91E+33</td>
<td>277</td>
<td>57,7</td>
<td>&lt; 4e-08</td>
</tr>
</tbody>
</table>

*Which kind of MSP? The far, high Edot, and the close, intermediate Edot MSPs are detected.*

=> *high spin-down flux MSPs (Edot / d)*

*Many intermediate distance MSPs should be detected with time.*
Cygnus region

3 months, $E > 450$ MeV

PRELIMINARY!
• Intermediate latitude γ-ray spectra can be explained by cosmic-ray propagation models based on local cosmic-ray nuclei and electron spectra.

• The Vela spectrum shows similar discrepancies, indicating that the GeV excess is instrumental.

• Work to analyse and understand diffuse emission over the entire sky is in progress.
**ms γ-ray pulsars**

- Very different characteristics from the normal γ-ray pulsars:
  - Spinning 100 times faster
  - Magnetic fields ~10,000 times lower
  - ~10,000 times older

- “Recycled” pulsars spun-up by binary companion stars (movie)
  - Old recycled pulsars can accelerate particles to very high (TeV) energies
  - *Fermi* is seeing so far the nearby ms pulsar population
  - This may be the tip-of-the-iceberg
GRB080916C Spectral evolution

Soft-to-hard, then hard-to-soft evolution

N.Giglietto- High energy gamma rays observations with the Fermi Observatory-La Thuile 2009, March 12, 2009
Summary: Gamma-ray Bursts Thus Far

- LAT detections:
  - [GCN 8183 – Bouvier, A. et al., GCN 8141, 8184 – van der Horst, A. et al.]
  - [GCN 8246 – Tajima, H. et al., GCN 8245, 8278 – Goldstein, A. et al.]
  - [GCN 8246 – Tajima, H. et al., GCN 8245, 8278 – Goldstein, A. et al.]
GRB080916C Interpretation

Redshift measurement:

- Fluence (10 keV - 10 GeV) ~ 2.4 x 10^{-4} ergs.cm^{-2} \text{ & } z \approx 4.35 \Rightarrow E_{\text{iso}} \approx 8.8 \times 10^{54} \text{ ergs}

  strongly suggests narrow jet collimation

- highest energy photon in src frame: 13.2 GeV \times (1+z) = 70.6 \text{ GeV}
- delayed arrival (16.5s) of this photon

  puts a constraint on Lorentz invariance violation:

$$MQG > 1.50e18 \text{ GeV/c} \approx 0.1 \text{ MPlanck}$$

No spectral cutoff:

- high-energy delay a priori not due to pair-production opacity

- bulk Lorentz factor: $\Gamma_{\text{min}} = 600 \text{ (bin d)}, \Gamma_{\text{min}} = 890 \text{ (bin b)}$

No extra spectral component (≠ Gonzalez et al., 03):

- leptonic model: IC peak $>> 10 \text{ GeV}$
clump at 100 pc,

\[ D_0 = 1028 \text{ cm}^2/\text{s} \]

for a NFW DM distribution with boost factor of 5 and \( \rho_{\text{local}} = 0.4 \text{ GeV cm}^{-3} \)

Fermi measurements of the total lepton flux with large statistics will be able to explore this energy region and distinguish a slope change with a sharp cutoff with high confidence level.
GLAST/LAT performance

- Energy Resolution: ~10% (~5% off-axis)
- PSF (68%) at 100 MeV ~ 5°
- PSF (68%) at 10 GeV ~ 0.1°
- Field Of View: 2.4 sr
- Point Source sens. (>100 MeV): 3x10^{-9} cm^{-2}s^{-1}
Year 1 Science Operations Timeline Plan

LAUNCH

- spacecraft turn-on checkout
- LAT, GBM turn-on checkout
- "first light" whole sky
- "first light" pointed + sky survey tuning
- Observatory renaming
- Initial tuning/calibrations
- Sky survey + ~weekly GRB survey tuning + sky repoints + extraordinary TOOs

+60 days

- 12 months

Start Year 1 Science Ops
- sky survey + ~weekly GRB
- in-depth instrument studies

Start Year 2 Science Ops
- Release Flaring and Monitored Source Info
- Release GI Cycle 1 Funds Release
- Fellows Year 1 Start
- LAT 6-month high-confidence source release, GSSC science tools advance
- GI Cycle 2 Proposals
- LAT Year 1 photon data release PLUS LAT Year 1 Catalog and Diffuse Model
- 2nd Symposium 2-5 Nov.

continuous release of new photon data
First Light!

Four days of all-sky survey engineering data.