Fermi
The Gamma-ray Large Area Space Telescope

Mission Status

Julie McEnery
On behalf of the Fermi mission team

see http://fermi.gsfc.nasa.gov and links therein
Fermi instruments

Large Area Telescope (LAT):
- 20 MeV - >300 GeV (including unexplored region 10-100 GeV)
- 2.4 sr FoV (scans entire sky every ~3hrs)

Gamma-ray Burst Monitor (GBM)
- 8 keV - 40 MeV
- views entire unocculted sky

• Large leap in all key capabilities, transforming our knowledge of the gamma-ray universe. Great discovery potential.
• How do super massive black holes in Active Galactic Nuclei create powerful jets of material moving at nearly light speed? What are the jets made of?
• What are the mechanisms that produce Gamma-Ray Burst (GRB) explosions? What is the energy budget?
• What is the origin of the cosmic rays that pervade the galaxy?
• How does the Sun generate high-energy gamma-rays in flares?
• How has the amount of starlight in the Universe changed over cosmic time?
• What are the unidentified gamma-ray sources found by EGRET?
• What is the mysterious dark matter?
Launch! June 11, 2008

• 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.
Launch Day at GSFC
Launch Day in Florida
A few weeks later - instrument commissioning
First light and Observatory Renaming

- GLAST becomes Fermi Gamma-ray Space Telescope
Operations and observing modes

- Almost all observations in survey mode - the LAT observes the entire sky every two orbits (~3 hours), each point on the sky receives ~30 mins exposure during this time.
  - 35 deg rocking angle to Sept 2, 50 deg thereafter.
- 30 ARRs
  - 5 hour pointed mode observations in response to bright GBM detected GRB
- LAT Calibrations (13 hours), Engineering (5 days)
  - Very high ontime!

LAT sensitivity on 4 different timescales: 100 s, 1 orbit (96 mins), 1 day and 1 year.
LAT Collaboration

- France
  - CNRS/IN2P3, CEA/Saclay
- Italy
  - INFN, ASI, INAF
- Japan
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology
- Sweden
  - Royal Institute of Technology (KTH)
  - Stockholm University
- United States
  - Stanford University (SLAC and HEPL/Physics)
  - University of California, Santa Cruz - Santa Cruz Institute for Particle Physics
  - Goddard Space Flight Center
  - Naval Research Laboratory
  - Sonoma State University
  - The Ohio State University
  - University of Washington

PI: Peter Michelson
(Stanford)
~400 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.

Project managed at SLAC.
The Large Area Telescope

Si Tracker
pitch = 228 µm
8.8 \times 10^5 channels
18 planes

ACD
segmented scintillator tiles

CsI Calorimeter
hodoscopic array (8 layers)
6.1 \times 10^3 channels

LAT: 4 \times 4 modular array
3000 kg, 650 W
20 MeV – 300 GeV
LAT Data Collection and processing

- 80 B Events Trigger
- 15 B Events sent to ground (8 TB, 400 TB after processing)
- 200 M Gamma-Ray Candidate events sent to FSSC (50 GB)

• 160 cpu years worth of processing over 16 months
How many gammas?

Number of Gamma-rays

- **OSO-3**: 621
- **SAS-2**: 13000
- **COS-B**: 200000
- **EGRET**: 1500000
- **LAT**: 195000000

- **1967**
- **1972**
- **1975**
- **1991**
- **2008**
The Variable Gamma-ray Sky

Northern Galactic Hemisphere

Southern Galactic Hemisphere

Fermi LAT 05–AUG–2008

Julie McEnery

The LAT team releases flux/spectra as a function of time for all sources in a predefined list + flaring sources during flares.

- Modified data release after ~6 months:
  - Lowered flux threshold to release information on flaring sources by factor of 2.
  - Provided information continuously (not just during flares).
  - Started with 23 sources, now have >40

http://fermisky.blogspot.com
Leap in Capabilities: Implications

- **Dynamic Range Frontier; Variability Frontier** Whole-sky aperture for transients and variable sources: longterm, evenly sampled lightcurves; dynamic range of emission.
- **Depth Frontier** Deepening exposure over whole mission lifetime.
- **Energy Frontier** Discovering energy budgets and characteristics of wide variety of cosmic accelerator systems on different scales.
  - Getting to know 10 - 100 GeV sky
  - Connecting with TeV facilities: variability, spectral coverage
  - 7 decades of GLAST GRB energy coverage
- **Spatial Frontier** Breaking through to sub-arcmin point-source localizations (source dependent) -- ID the sources; PLUS starting to move beyond point sources: capabilities to resolve spatially, spectrally, and temporally.
- **Timing Frontier** Transient and periodic pulse profiles, searches.
- **Measurement Frontier** A rich data set to mine, touching many areas of science. Sources we know (AGN, SNR, XRBs, pulsars, PWN, galaxy clusters, solar flares, moon,...) and those awaiting discovery.

Even greater multiwavelength/multimessenger needs and opportunities
Breaking new ground!

W44

Crab Nebula

3C454.3

Populations

GRB090902

All sources

Blazars

PRELIMINARY

PRELIMINARY

PRELIMINARY
Since July 2008, GBM has detected over 260 GRB (250/year c.f. 200/year predicted)
  – Benefited from flexible onboard triggering algorithms
Also has seen 4 SGRs, >10 TGFs and 2 solar flares.
Recent flight software updates to improve reliability of autonomous repoint requests (to more reliably slew only to bright GRB)
GBM - not just transients

GBM Pulsar Project

<table>
<thead>
<tr>
<th>Source Name</th>
<th>l (deg)</th>
<th>b (deg)</th>
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<tbody>
<tr>
<td>GX 1+4</td>
<td>1.94</td>
<td>4.79</td>
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<tr>
<td>HX 1</td>
<td>58.20</td>
<td>37.50</td>
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<td>Cap X-4</td>
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<td>1RX J1816-395,5</td>
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<td>V 0332+53</td>
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<td>A0535+26</td>
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<td>MXB 0656-072</td>
<td>220.20</td>
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<td>Vela X-1</td>
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<td>A 1118-615</td>
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<td>GO 301-2</td>
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<td>4U 1626-67</td>
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<td>4U 1538-52</td>
<td>327.42</td>
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<tr>
<td>OAO 1657-415</td>
<td>344.40</td>
<td>0.31</td>
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</table>

GBM Accreting Pulsar Histories

For each source we plot the history of pulse frequency and pulsed flux measured using the Fermi Gamma Ray Burst Monitor (GBM) NaI detectors. For these measurements we use the CTTIME data which normally has 0.256 s time bins, and eight energy channels. Our analysis normally uses channels 1 (10-25 keV) and 2 (25-55 keV). The integration intervals used varies from source to source, ranging from one to four days. For eclipsing systems each egress interval is divide into an integral number of equal parts, with no measurement made during the eclipse. The measured frequencies are barycentered. For sources where the binary orbit is known the frequencies are corrected for the binary motion. The R.M.S. pulsed flux is given in the energy band that the pulse search was made. This usually includes only the first and second harmonics. These results are preliminary. Please contact Mark Finger for further information.

Please return to GBM Science or the GLAST Burst Monitor or the Gamma Ray Astrophysics Home Page.

Modification date: 06 Jul, 2009

Author: Valerie Contini

http://gamma-ray.nsstc.nasa.gov/gbm/science/pulsars/lightcurves/VelaX1_Fig1.png

GBM team have made non-GRB high level data/results available.
Two instruments together - Autonomous repoints

- LAT pointing in celestial coordinates from -120 s to 2000 s
  - Red cross = GRB 090902B
  - Dark region = occulted by Earth
  - Blue line = LAT FoV (±66°)
  - White points = LAT events (no cut on zenith angle)
Fermi Science Support Center (FSSC)

- Supports guest investigator program (Cycle 3 deadline Feb 4)
- Provides training workshops
- Provides data, software, documentation, workbooks to community
- Archives to HEASARC
- Joint software development with Instrument Teams, utilizing HEA standards
- Located at Goddard
  - see http://fermi.gsfc.nasa.gov/ssc/
  - and help desk
  - http://fermi.gsfc.nasa.gov/ssc/help/
Data Releases

- Beginning of science operations: GBM data + LAT high level data from start of science operations
- Feb 6, 2009: LAT bright source list, first LAT analysis software release
- Aug 25, 2009: low level LAT data, second LAT analysis software release

~400 queries in first day, many requesting the entire dataset.
Made link to weekly all-sky files more obvious (so number of queries dropped)
LAT Data Latency

- Typical turnaround is less than 10 hours (time to get data off spacecraft, processed and back to FSSC)
The FSSC is holding a sequence of regional data analysis workshops.

First workshop on Oct 1 at GSFC.

1-day, focus on hands-on activities.

~<25 participants
- Larger group limits 1-on-1 interactions.

Future workshops
- Venues chosen based on community feedback.
- May try internet conferencing analysis workshops.

Please drop by the FSSC station for help with analysis topics, software installation and data access.
Fermi Users Group Members

• Alan Marscher (Chair)
• Matthew Baring
• Pat Slane
• Buell Januzzi
• Don Kniffen
• Henric Krawczynski
• Jamie Holder
• Wei Cui
• Scott Ransom
• Jim Ulvestad
• Alicia Soderberg

Plus

• Neil Gehrels
• Ilana Harrus
• Julie McEnery
• Bill Paciesas
• Peter Michelson
• Steve Ritz
• Chris Shrader
• Dave Thompson
• Kathy Turner
• Lynn Cominsky

http://fermi.gsfc.nasa.gov/ssc/resources/guc/
Conclusions

• The LAT and GBM are both working well
• First LAT GeV catalog contains over 1000 gamma-ray sources!
  – New classes of gamma-ray sources (millisecond pulsars, gamma-ray binaries, globular clusters, starburst galaxies…)
    • field of gamma-ray astrophysics is rapidly expanding
• GBM is detecting many kinds of MeV transients
  – >300 GRB/year, 4 SGRs, >10 TGFs and 2 solar flares.
• Science returns in solar system studies, Galactic astrophysics, extragalactic astrophysics, cosmic-ray physics and fundamental physics.
• The full data release since Aug 25, software to assist with data analysis is also available.
  – http://fermi.gsfc.nasa.gov/ssc
• Lots more science to come…