GLAST Mission: Status and Science Opportunities

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Outline

• GLAST: An International Science Mission
  – Large Area Telescope (LAT)
  – GLAST Burst Monitor (GBM)
• mission operations plan
• highlights of science opportunities
• schedule highlights

LAT: 20 MeV – >300 GeV
GBM: 10 keV – 25 MeV
launch: February 2007
GLAST is an International Mission

NASA - DoE Partnership on LAT
LAT is being built by an international team
- Stanford University (SLAC & HEPL, Physics)
- Goddard Space Flight Center
- Naval Research Laboratory
- University of California, Santa Cruz
- University of Washington
- Ohio State University
- CEA/Saclay & IN2P3 (France)
- ASI & INFN (Italy)
- Hiroshima University, ISAS, RIKEN (Japan)
- Royal Inst. of Technology & Stockholm Univ. (Sweden)

GBM is being built by US and Germany
- MPE, Garching (Germany)
- Marshall Space Flight Center

Spacecraft and integration - Spectrum Astro

Mission Management: NASA/GSFC

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Gamma-ray Experiment Techniques

• Space-based:
  – use pair-conversion technique

• Ground-Based:
  – Airshower Cerenkov Telescopes (ACTs)
    image the Cerenkov light from showers induced in the atmosphere. Examples: Whipple, CANGAROO, HEGRA, STACEE, CELESTE, CELESTE, VERITAS, MAGIC, HESS
  – Extensive Air Shower Arrays (EAS)
    Directly detect particles from the showers induced in the atmosphere. Example: MILAGRO
The next-generation ground-based and space-based experiments are well matched.
Overview of LAT

- **Precision Si-strip Tracker (TKR)**
  18 XY tracking planes. Single-sided silicon strip detectors (228 µm pitch)
  Measure the photon direction; gamma ID.

- **Hodoscopic CsI Calorimeter (CAL)**
  Array of 1536 CsI(Tl) crystals in 8 layers.
  Measure the photon energy; image the shower.

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

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

**Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.**
LAT Status Summary

• Work by many people across institutions/countries:
  – subsystems completing testing their engineering model hardware; starting flight production and testing now

  – software tools shaping up well.
  First data challenge complete Feb 2004.
GLAST LAT High Energy Capabilities

- Huge FOV (~20% of sky)
- Broadband (4 decades in energy, including unexplored region > 10 GeV)
- Unprecedented PSF for gamma rays (factor > 3 better than EGRET for E>1 GeV)
- Large effective area (9x larger than EGRET @ 1 GeV)
- Results in factor > 30-100 improvement in sensitivity
- much smaller deadtime per event (25 µsec → factor 4,000 better than EGRET)
- No expendables  → long mission without degradation
High energy source sensitivity: all-sky scan mode

During the all-sky survey, GLAST will have sufficient sensitivity after $O(1)$ day to detect ($5\sigma$) the weakest EGRET sources.

EGRET Fluxes
- GRB940217 (100sec)
- PKS 1622-287 flare
- 3C279 flare
- Vela Pulsar
- 3EG 2020+40 (SNR γ-Cygni?)
- 3EG 1835+59
- 3C279 lowest 5σ detection
- 3EG 1911-2000 (AGN)
- Mrk 421

*zenith-pointed
GBM Detector

Bismuth Germanate (BGO) Scintillation Detector

Major Purpose

– Provide high-energy spectral coverage (150 keV – 25 MeV) to overlap LAT range over a wide FoV
Roles of the GBM

- provides spectra for bursts from 10 keV to 25 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;

  Simulated GBM and LAT response to time-integrated flux from bright GRB 940217

  Spectral model parameters from CGRO wide-band fit

  1 NaI (14°) and 1 BGO (30°)

- provides wide sky coverage (8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);

- GLAST observatory provides burst alerts to the ground.
Science Mission Elements

• Science Working Group (chair, S. Ritz, Project Scientist)
  – membership includes Interdisciplinary Scientists, instrument team PIs and instrument team representatives
  – bi-monthly telecons and ~bi-annual sit-down meetings, along with science symposia to engage the community.

• Users Committee (chair: J. Grindlay)
  – independent of the SWG. External review/feedback on science tools planning and progress.
  – includes members from both the astrophysics and high-energy particle physics communities who are likely users of GLAST data.

• GLAST Science Support Center (GSSC)
  – located at Goddard. Supports guest observer program, provides training workshops, provides data and software to community, archives to HEASARC, joint software development with Instrument Teams.
After the initial on-orbit checkout, verification, and calibrations, the first year of science operations will be an all-sky survey.

- first year data used for detailed instrument characterization, refinement of the alignment, and key projects (source catalog, diffuse background models, etc.) needed by the community
- data on transients will be released, with caveats
- repoints for bright bursts and burst alerts enabled
- extraordinary ToO’s supported
- limited first-year guest observer program
- workshops for guest observers on science tools and mission characteristics for proposal preparation

Observing plan in subsequent years driven by guest observer proposal selections by peer review. All data released through the science support center (GSSC).
GLAST E/PO Program

• Sonoma State University leads GLAST E/PO (Lynn Cominsky, et al)
• Use the observations and scientific discoveries of the GLAST mission to improve the understanding and utilization of science and mathematics concepts for grades 9-12.
  – collaborates with the OSS SEU Education Forum, other SEU missions, and other partners in the OSS Support Network.
• Web based materials and printed materials (now in the hands of over 10,000 teachers)
• Educator training
  – Educator Ambassador program (over 3000 teachers trained in 20 states)
  – workshops for AAVSO and at national, regional meetings
  – minority outreach workshops
• GLAST Telescope Network: partners scientists with high-school students and amateurs.
• PBS Nova show on High Energy Astronomy and Black Holes (Tom Lucas)
GLAST addresses a broad science menu

- Systems with supermassive black holes & relativistic jets
- Gamma-ray bursts (GRBs)
- Pulsars
- Solar physics
- Origin of Cosmic Rays
- Probing the era of galaxy formation
- Solving the mystery of the high-energy unidentified sources
- Discovery! Particle Dark Matter? Other relics from the Big Bang?
  Testing Lorentz invariance. New source classes

GLAST draws the interest of both the High Energy Particle Physics and High Energy Astrophysics communities.
Features of the gamma-ray sky

EGRET all-sky survey (E>100 MeV)

diffuse extra-galactic background (flux ~ 1.5x10^{-5} cm^{-2}s^{-1}sr^{-1})

galactic diffuse (flux ~ O(100) times larger)

high latitude (extra-galactic) point sources (typical flux from EGRET sources O(10^{-7} - 10^{-6}) cm^{-2}s^{-1}

galactic sources (pulsars, un-ID’d)

An essential characteristic: **VARIABILITY** in time!

wide field of view, and the ability to repoint, important for study of transients.
GLAST Survey: ~10,000 sources (2 years)
Anticenter Region
172 of the 271 sources in the EGRET 3rd catalog are “unidentified”

EGRET source position error circles are ~0.5°, resulting in counterpart confusion.

GLAST will provide much more accurate positions, with ~30 arcsec - ~5 arcmin localizations, depending on brightness.
AGN, the EBL, and Cosmology

IF AGN spectra can be understood well enough, they may provide a means to probe the era of galaxy formation:
(Stecker, De Jager & Salamon; Madau & Phinney; Macminn & Primack)

\[
\frac{\gamma eV}{E \times eV} = \frac{\gamma eV}{E}
\]

\[
\approx \frac{1}{3}
\]

No significant attenuation below 10 GeV

No significant attenuation below 10 GeV

\[
\begin{align*}
\text{opacity} & \text{ to source at redshift} \\
\text{gamma ray energy (GeV)}
\end{align*}
\]

GLAST Can Probe the Optical-UV EBL

- GLAST will see thousands of blazars - instead of peculiarities of individual sources, look for **systematic effects** vs redshift.
- key energy range for cosmological distances (TeV-IR attenuation more local due to opacity).

**Caveats**

- How many blazars have intrinsic roll-offs in this energy range (10-100 GeV)? (An important question by itself for GLAST!) **Power of statistics** is the key.
- Must measure the redshifts for a large sample of these blazars!

Unidentified Sources

- young population along Galactic plane
- intermediate latitude excess, especially in direction of Galactic bulge → older Galactic population
- possible Gould Belt association with ‘persistent’ sources; nearby population
- high latitude sources with no AGN identifications

3rd

AGN - blazars
unidentified
Northern Sky Survey
(D. Sowards-Emmerd, R. Romani, P. Michelson, J. Ulvestad)

- conduct systematic census of possible blazar counterparts in the Northern sky
  - Correlate flat-spectrum radio sources with EGRET sources (6 cm Greenbank, 21 cm VLA (NVSS), 3.5 cm CLASS surveys)
  - obtain optical IDs of suitable counterpart candidates with HET

- AGN - blazars
  - unidentified
  - pulsars
  - LMC
The gamma-ray source content of the northern sky

- AGNs - blazars
- NOT blazars
- unclassified (UnID)

- 70% of Northern EGRET sources have counterparts similar to bright EGRET blazars.
- Several more likely IDs than proposed 3EG IDs.
- 20 new IDs.
- Strong evidence for a set of 25 objects with NO possible counterpart like the known EGRET blazars.
  - Either a new extragalactic population or a population of Galactic objects with a large scale height.

![Graph showing distribution of objects with z values]

- Pulsars/plerions
- Unclassified (UnID)
GRBs are now confirmed to be at cosmological distances. The question persists: **What are they??**

EGRET detected very high energy emission associated with bursts, including a 20 GeV photon ~75 minutes after the start of a burst:

*Hurley et al., 1994*

**Future Prospects:** GLAST will provide definitive information about the high energy behavior of bursts: LAT and GBM together will measure emission over >7 decades of energy.
recent analysis by Gonzalez, et al.

Compare data from EGRET and BATSE: Distinct high-energy component has different time behavior!

What is the high-energy break and total luminosity?

Need GLAST
Particle Dark Matter

Particle physics models with SUSY could also solve the dark matter problem. If correct, these new particle interactions could produce an observable flux of gamma rays.

\[ \chi \rightarrow q \quad \text{inclusive flux,} \quad \text{or } \gamma \gamma \text{ or } Z \gamma \text{ “lines”?} \]

Observations of the galactic center are intriguing:

- EGRET detected a gamma-ray source near the galactic center, with a small excess GeV flux.
- Hints of a TeV galactic center source from Whipple [K. Kosack et al., astro-ph/0403422]

Contributions to extragalactic diffuse flux from dark matter haloes also possibly observable. [Ullio et al, astro-ph/0207125]

Just an example of what might be waiting for us to find!
theories with large (submillimeter) extra dimensions: alternative way to solve the hierarchy problem of particle physics

- move the Planck scale to near the weak scale
- observed weakness of gravity due to presence of \( n \) new spatial dimensions large compared to electroweak scale (Arkani-Hamed, Dimopoulos & Dvali 1998)

Recently, Hannestad & Raffelt (2002) pointed out that SNe would produce Kaluza-Klein gravitons that are generic for these theories

- produced non-relativistically, so many are gravitationally bound to SN core (i.e, neutron star) \( \rightarrow \) KK particle halo
- KK gravitons decay \( (\tau \sim 10^9 \text{ years}) \) to \( \nu\nu, e^+e^-, \text{ and } \gamma\gamma \)
discovery potential: large extra dimensions

- Constraints from EGRET observations (Hannestad & Raffelt 2002):
  
  $\gamma$-ray flux limits for nearby NS limit compactification scale
  
  $\geq 500$ TeV (n=2)
  
  $\geq 30$ TeV (n=3)

- GLAST will have point source sensitivity of $\sim 1.5 \times 10^{-9}$ ph cm$^{-2}$ s$^{-1}$

  corresponds to $f_{\text{KK}} = 10^{-7}$, where $f_{\text{KK}}$ is the fraction of SN energy emitted as KK gravitons

other exotic possibilities

Lorentz Invariance breaking models can lead to different maximum velocities by particle type (Stecker&Glashow, Coleman&Glashow):

\[ c_e \equiv c_\gamma (1 + \delta), \quad 0 < |\delta| \ll 1 \]

For \( _- < 0 \), photons can decay to e+e- pairs if \( E_\gamma > m_e \sqrt{2/|\delta|} \)
Observation of the Crab (E>50 TeV) implies \( _- \sim \leq 2 \times 10^{-16} \)

For \( _+ > 0 \), superluminal electrons will emit vacuum Cerenkov radiation and the threshold for pair creation will be altered. Cosmic ray data and inferred information from Mrk501 blazar observations \( \Rightarrow _+ \leq 3 \times 10^{-14} - 1.3 \times 10^{-15} \).

Some classes of QG models imply a linear photon velocity dispersion (Amelino-Camelia et al., Ellis, Mavromatos, Nanopoulos):

\[ V = c \left( 1 - \xi \cdot \frac{E}{E_{QG}} + \ldots \right) \]

Use GRBs! Effects could be measurable using GLAST data alone. But ?? effects intrinsic to bursts?? Representative of window opened by measurements at such large distance and energy scales.
GLAST Master Schedule

- **Launch**: February 2007
- **Observatory I&T starts**: December 2005
- **GBM I&T starts**: September 2004
- **LAT ready for Environmental Test**: July 2005
- **First flight hardware deliveries to SLAC for I&T**: late summer 2004

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**GLAST Master Schedule**

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**Project Milestones**

- **Gamma-2001**: 2001
- **PDR/NAR**: 2002
- **CDR**: 2003
- **MOR**: 2004
- **PER**: 2005
- **ORR**: 2006
- **Launch 2/20**: 2007

**LAT Instrument**

- **Balloon Launch**: 2004
- **Delta LAT**: 2005

**GBM Instrument**

- **PDR**: 2003
- **DPF/SWR**: 2004

**Spacecraft**

- **S/C Accom Study**: 2002
- **RFO**: 2003
- **SR**: 2004
- **CDR**: 2005

**Ground System**

- **OC PEER Rev**: 2002
- **MOC Dec**: 2003
- **MOC Pnt Peer Rev**: 2004
- **MOC SW Release 1**: 2005
- **MOC SW Release 2**: 2006

**DLV Launch Services**

- **Advance Support**: 2003
- **Kickoff GOM**: 2004

**Education and Public Outreach**

- **Ambassador Training**: 2004
- **TOPS #1**: 2005
- **TOPS #2**: 2006
- **Space Mys Mod #2**: 2007
Through most of history, the cosmos has been viewed as eternally tranquil.
During the 20th century, the quest to broaden our view of the universe has shown us the vastness of the Universe and revealed violent cosmic phenomena and mysteries.

**GLAST**: Exploring Nature’s Highest Energy Processes

launch: February 2007