GLAST Large Area Space Telescope (LAT) and Gamma-Ray Bursts

GLAST LAT GRB Science Group

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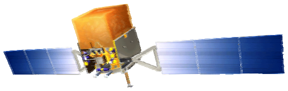
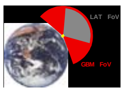
Abstract

The Large Area Telescope (LAT) of GLAST is the next generation satellite experiment for high-energy gamma-ray astronomy. It employs a pair conversion technique to record photons in the energy range from 20 MeV to 300 GeV and higher. Its modular design consists of sixteen towers made of silicon trackers followed by segmented CsI electromagnetic calorimeters. Towers are surrounded by plastic scintillators acting as an anticoincidence shield that rejects unwanted charge particle background. The LAT will follow the steps from its predecessor, EGRET, and will explore the high energy gamma-ray sky with unprecedented capabilities. The detection and observation of Gamma-Ray Bursts is one of the main scientific goals of the LAT. A full simulation chain has been developed by the LAT collaboration, starting from the simulation of the source to the detailed Monte Carlo simulation of the instrument, and to the full reconstruction software. Analysis tools dedicated to the GRB science have been developed, as well as the simulation of the GLAST Burst Monitor, the second instrument on-board GLAST, dedicated to GRB's. In this contribution we show the expected LAT sensitivity obtained with such simulations, as well as some results from spectral and temporal analysis.

GLAST Overview

The Gamma ray Large Area Space Telescope (GLAST) mission belongs to the next generation of satellite-based high energy gamma ray observatories. It consists of two instruments: the GLAST Burst Monitor (GBM) and the Large Area Telescope (LAT). The former will use NaI and BGO counters to record transient phenomena in the sky in the energy range from 10 keV to 30 MeV, while the latter will employ a pair-conversion technique to measure photons from 20 MeV to energies greater than 300 GeV.



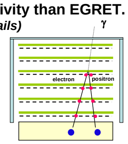


LAT Overview

The first all--sky survey above 50 MeV was performed by the CGRO--EGRET instrument. The Large Area Telescope (LAT) of GLAST will provide substantial overlap with ground-based gamma-ray telescopes to explore together a greatly expanded dynamic range compared to EGRET with well-matched capabilities. It will offer tremendous opportunities for discoveries in high-energy astrophysics with at least one order of magnitude better sensitivity than EGRET.
(See Poster 18.07 Atwood et al for more details)

Large Area Telescope

16 LAT Towers



Pair-conversion technique

LAT Instrument Science Operation Center and GRBs

The LAT Instrument Science Operations (LISOC) will oversee the health, safety and performance of the LAT. In addition it will monitor transient phenomena in the gamma ray sky and deliver science data products to the LAT Collaboration and the GLAST Science Support Center.
(See Posters 18.04 Borgland, 18.08 Chiang et al, 18.11 Cameron et al for more details on the ISOC and 18.06 Shrader for more details on GSSC)

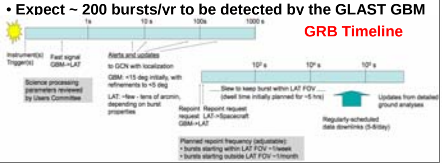
Operations

- **Full sky survey every 3 hours**
- **Downlink and Communications near real-time (TDRSS)**
- **Full science data ~ 6-8 times a day**
- **For intense bursts GLAST can repoint autonomously**
  - ➢**keeping LAT within the field-of-view**
  - ➢**Dwell time: 5 hr (adjustable)**
  - ➢**important for monitoring high energy afterglows**

GRBs

- **GRB locations determined onboard by either the GBM (several degrees) or the LAT (sub degree), depending on burst properties, are sent in near real time to GCN (~ 10 s)**
  - ➢**GBM localization: from < 15⁰ (on board) to 3⁰ (ground)**
  - ➢**LAT localization: > 10 arcmin (burst dependent)**
- **Expect ~ 200 bursts/yr to be detected by the GLAST GBM**

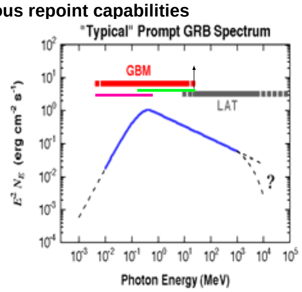
GRB Timeline



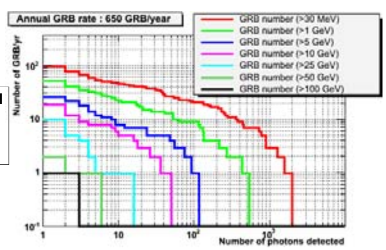
GRB Science with GLAST

- **Explore the high-energy behavior of GRBs up to > 300 GeV**
  - ➢**Little is known about GRB emission in the >50 MeV energy regime.**
  - ➢**LAT will have the sensitivity to detect a possible gamma-ray afterglow in GeV energies**
  - ➢**Extended or delayed GeV emission may require more than one emission mechanism, and remains one of the unsolved problems in GRB science.**
- **Unprecedented energy coverage during GRB prompt phase**
  - ➢**10 keV to >300 GeV**
  - ➢**EGRET detected few high-energy bursts**
  - ➢**Prompt GeV emission with no high-energy cutoff (combined with rapid variability) implies highly relativistic bulk motion at source: $\Gamma > 10^2 - 10^3$**
  - ➢**A high energy spectral component has been observed in the prompt phase** ***(Gonzàlez et al 2003, Nature 424, 749)***
- **LAT improvement with respect to EGRET**
  - ➢**Wider field-of-view (> 2 sr)**
  - ➢**Shorter deadtime (~25 μs)**
  - ➢**Autonomous repoint capabilities**

Typical prompt GRB spectrum



Estimated annual rate of GRBs versus number of LAT counts

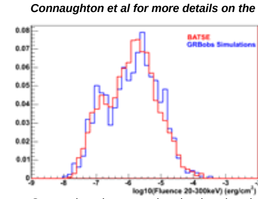


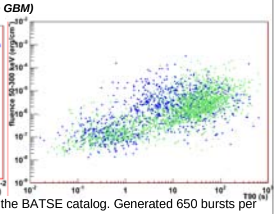
- **Assumptions and Modeling**
  - ➢ **Rate of 650 bursts/yr over the full sky, each burst is described by a phenomenological model, which assumes a Band spectral function** *(Band et al. 1993, ApJ, 413, 281-292.)* **and an universal pulse shape** *(Norris et al. 1996 ApJ, 459, 393)*.
  - ➢**Parameters are sampled from the observed BATSE distributions** *(Preece et al. 2000 ApJS, 126, 19 and Norris et al. 1996 ApJ, 459, 393)*
  - ➢ **Includes EBL effect** *(Primack & Bullock and Sommerville 2005 AIPC, 745, 23)* **and redshift distribution for long bursts** *(Porciani & Madau 1999 ApJ, 548, 522),* **and for short bursts** *(Fryer & Heger 2005 ApJ, 623, 302)*

(See Poster 13.18 Band for more on GLAST's Sensitivity to Gamma-Ray Bursts)

GRB LAT Monte Carlo Simulations

- **Physical Model (Fireball: Piran,1999)**
  - ➢**shells emitted with relativistic Lorentz factors**
  - ➢**internal shocks (variability naturally explained)**
  - ➢**acceleration of electrons between with a power law initial distribution, between γ_{min} and γ_{max}**
  - ➢**Non-thermal emission (Synchrotron and Inverse Compton) from relativistic electrons**
- **Phenomenological approach**
  - ➢ **Parameters from observed distributions (BATSE)**
  - ➢ **Different GRB light curves can be obtained.**
  - ➢ **Fluxes are normalized to the BATSE observed fluence distribution (use BATSE catalog)**
  - ➢**LAT flux is obtained by extrapolating the BATSE flux to LAT energies**
- **Monte Carlo Simulator**
  - ➢**models other than fireball can be implemented (e.g. hybrid thermal + power law model** *Felix Ryde & Milan Battelino 2005 NCimC, 28, 335R* **)**
  - ➢**LAT photons are extracted from the predicted flux and processed by the GLAST/LAT Software (full Monte Carlo or parameterized fast simulation)**
  - ➢**GBM photons are extracted from flux provided by the GBM simulations into the LAT Monte Carlo simulator** ***(See Poster 18.10 Connaughton et al for more details on the GBM)***

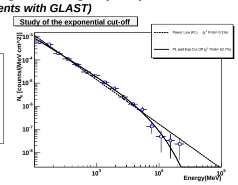




Comparison between the simulated and the BATSE catalog. Generated 650 bursts per year per 4 π . Duration, fluence, peak energy and spectral indexes were sampled from the observed distributions. Simulation corresponds to one year of data taking and orbital motion of the satellite is considered (bursts inclination).

- **High Energy Cut-off**
  - ➢**GLAST/LAT will study the high energy spectrum of GRBs, measure the cut-offs up to energies above 10 GeV for single bursts.**
  - ➢ **Information on the Lorentz Factor of the expanding shells (synchrotron emission from accelerated electrons)**
  - ➢**Cosmological cut-off: Redshift-dependent absorption of E > 10 GeV gammas due to pair-production interaction with ambient photons from the Extragalactic Background Light (EBL).** ***(See Poster 7.41 Reyes for more details on the EBL measurements with GLAST)***

Generated cutoff = 4.5 GeV
Reconstructed cut off
5.5±1.5 GeV
Γ=220±60



- **Emission Models**
  - ➢**GLAST/LAT detector will detect the high energy component and localize the SSC peak of the νFν spectrum**
  - ➢**The Inverse Compton component should be present in the LAT range and is important for understanding the Energy reservoir**