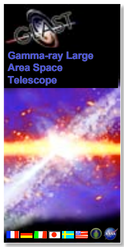
# GLAST'S SENSITIVITY TO GAMMA-RAY BURSTS

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## Abstract

The Gamma-ray Large Area Space Telescope (GLAST) will advance the study of gamma-ray bursts. The spectral coverage of more than 7 energy decades and large fields-of-view of the Large Area Telescope (LAT; <20 MeV to >300 GeV) and the GLAST Burst Monitor (GBM; 8 keV to 30 GeV) will result in unprecedented spectral and temporal coverage of a large number of bursts. Semi-analytic calculations characterize the burst populations to which each instrument will be sensitive.


## The Mission

The **G**amma-ray **L**arge **A**rea **S**pace **T**elescope (GLAST) is the next US general gamma-ray astrophysics mission, which is scheduled to be launched into low Earth orbit in Fall, 2007, for 5-10 years of operation. It will consist of two instruments: the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). For more information at this meeting:

- Posters 1.15, 1.40, 7.18, 7.29, 7.41, 7.56, 13.3, 13.27, 18.01-18.11, 18.56, 18.62
- GLAST special session (#20, 10/7 at 11:15 am)
- GLAST booth

## The LAT

A product of a NASA/DOE/international collaboration, the Large Area Telescope (LAT) builds on the success of *CGRO*'s EGRET. The LAT is a pair conversion telescope: gamma rays (and particles) will pair-produce in tungsten foils; silicon strip detectors will track the resulting pairs; the resulting particle shower will deposit energy in the silicon strip detectors and a CsI calorimeter; and an anticoincidence detector will veto charged particles. The anticoincidence detector will be segmented to eliminate the self-vetoing that plagued EGRET. The outside dimension of the LAT is 1.8 m×1.8 m×1m, and weighs ~3000 kg.

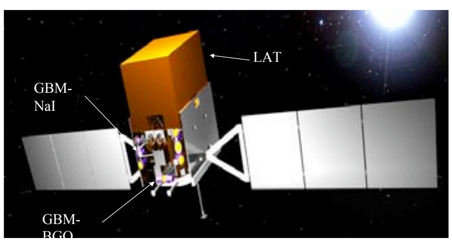
The astrophysical photons will be only a small fraction of the total number of events detected by the LAT, most of which will result from charged particles. Therefore, filtering of the events on board will reduce the ~2.5 kHz event rate to ~400 Hz that will be telemetered to the ground; ground processing will result in a ~2-5 Hz photon rate.

The salient detector characteristics are:

- Energy Range—<20 MeV to >300 GeV
- Effective area—>8000 cm$^2$
- Angular resolution—<3.5º at 100 MeV, <0.15º at 10 GeV
- Field of view—>2sr, effective area half maximum at 55°
- Deadtime— ~20 μs per event
- Time resolution— ~2 μs

## The GBM

A descendant of BATSE, the GBM will detect gamma-ray bursts and extend GLAST's burst spectral sensitivity to the ~8 keV to ~30 MeV band. Consisting of 12 NaI(*Tl*) (~8-1000 keV) and 2 BGO (~0.15-30 MeV) detectors, the GBM will monitor ~9 sr of the sky, including the LAT's field-of-view. Bursts will be localized to 9° (1σ, brightest 40% of the bursts) by comparing the rates in different detectors. The GBM will trigger if the rates in two or more NaI detectors increase by 4.5σ. The trigger will use a variety of energy bands and time windows.




## Observing Plan

After a 60 day checkout phase, GLAST will undertake a 1 year sky survey while the LAT team calibrates the instrument. In survey mode GLAST will rock ~30° from side to side of the zenith direction once per orbit. The observing plan for subsequent years will be driven by guest investigation proposals. While pointed observations will be feasible, continued survey mode operation will usually be most efficient, and will predominate. Pointing towards the earth will be avoided because of the large flux of albedo gamma rays from the earth's limb. All operational modes may be interrupted for targets of opportunity. GLAST will autonomously point for ~5 hours at the location of strong bursts detected on board.

## Response to Bursts

Both the GBM and the LAT will have burst triggers. The GBM will notify the LAT when it triggers. When either instrument triggers, a notice with a preliminary localization will be sent immediately to the ground through TDRSS and will then be disseminated by GCN within 7s. Additional data will be sent down through TDRSS for an improved automated localization on the ground. Both Instrument Operations Centers will calculate "final" positions from the full downlinked data. All positions will be disseminated by GCN.

If the burst is sufficiently intense, the spacecraft will autonomously repoint towards the burst location for ~5 hours (interrupted by earth occultations).

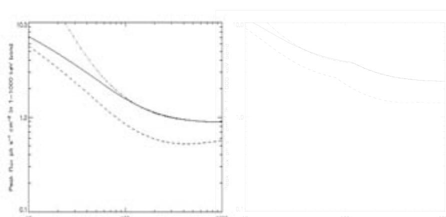
## Emission in GBM and LAT Energy Bands

Burst emission in the LAT energy band may be: 1) a continuation of the low energy spectra; 2) an additional spectral component during the ~100 keV emission; and 3) an afterglow. The EGRET observations indicate all three occur! However, I predict LAT fluxes only under the assumption that the GBM spectrum can be extrapolated to the LAT energy band.

## The Trigger Sensitivity of the GBM

To compare detectors with different energy sensitivities for bursts with different spectral characteristics, the detection thresholds in the plane of 1-1000 keV peak flux vs. $E_p$ (energy of the peak of the $\nu f_\nu$ curve) should be considered. The plots below compare the thresholds for BATSE and the GBM NaI detectors assuming a time window of $\Delta t$=1s. There is a weaker dependence on the low and high energy spectral indices (assuming the standard smoothly broken power law functional form): solid line—α=-1, β=-2; dashed line—α=-0.5, β=-2; dot-dashed line—α=-1, β=-3. **Note: these plots do NOT show the threshold flux per keV at a single photon energy; instead, they show the threshold 1-1000 keV flux for a burst with a given α and β at the indicated $E_p$.**

These plots use a preliminary model of the 'direct' component of the GBM response. The total response includes scattering off the spacecraft and the Earth's atmosphere, which will often increase the count rate.



BATSE: $\Delta t$=1s, σ=5.5 GBM, NaI(*Tl*): $\Delta t$=1s, σ=4.5

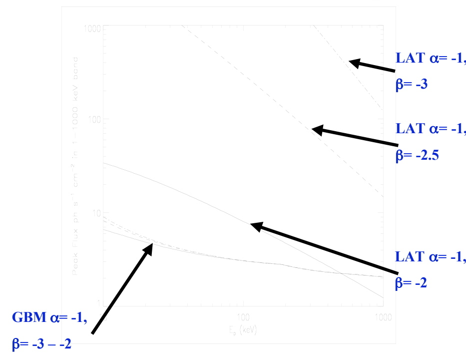
## LAT Burst Sensitivity

Different trigger algorithms are under consideration for use onboard and on the ground. These algorithms look for a spatial and temporal clustering of counts that is statistically significant. The actual sensitivity depends on the details of the algorithm, but the optimal sensitivity can be estimated semi-analytically. **A gamma-ray burst can be detected when the number of burst counts detected by the LAT is significantly greater than the number of non-burst counts in a region of order the PSF of the median photon energy when accumulated over Δt.**

- Poisson statistics are necessary because the numbers are small
- The detection sensitivity decreases as the background of non-burst counts increases
  - o The background on the ground will be smaller than onboard (a consequence of the available computer power), and therefore the ground sensitivity will be greater than the onboard sensitivity
  - o When astrophysical photons dominate the background, the burst sensitivity decreases near the Galactic Plane.
- More burst counts are necessary to detect longer duration bursts ($\Delta t$, and therefore the background, increases)
- Typical (preliminary) threshold fluxes:
  - o On axis, $\Delta t$=1 s, $E^{-2}$ spectrum: F(>100 MeV)~$8\times10^{-4}$ ph s$^{-1}$ cm$^{-2}$
  - o On axis, $\Delta t$=100 s, $E^{-2}$ spectrum: F(>100 MeV)~$3\times10^{-5}$ ph s$^{-1}$ cm$^{-2}$
- If the burst spectrum observed by the LAT is the power law extrapolation of the 'Band' spectrum observed by the GBM, then the LAT and GBM thresholds can be compared.


## Acknowledgements

I thank the members of the LAT and GBM instrument teams for their calculations of the responses for both instruments. I also thank the members of the Gamma-Ray Burst Science Group for discussions and comments on this work.


## Comparison of LAT and GBM Sensitivity

If we assume that the same 'Band' spectrum extends from <10 keV to >300 GeV then the threshold intensity of the GBM and the LAT can be compared as a function of the parameters α (low energy spectral index, $E^\alpha$), β (high energy spectral index, $E^\beta$) and $E_p$ (peak energy) that determine the shape of the spectrum. I parameterize the intensity as $F_T$, the 1-1000 keV photon flux. Since a spectrum is assumed, it does not matter that a detector does not observe photons in the 1-1000 keV band. The above plot shows the threshold $F_T$ for the LAT (upper three curves) and the GBM (lower three curves) for α=-1 and β between -2 and -3. **Note: this plot shows the threshold $F_T$ (1-1000 keV flux) for a burst with a given α, β and $E_p$, NOT the threshold flux per keV at a single photon energy.** An accumulation time of $\Delta t$=1s is assumed, for which a LAT detection requires 5 counts. As $\Delta t$ increases, all the curves shift downwards. Conclusions:

- In almost all cases the GBM will detect the bursts the LAT will detect.
- Bursts the LAT detects with β steeper than -2 will be very bright in the GBM band. This introduces a bias towards β~-2 and high $E_p$.

These conclusions assume there are no additional >100 MeV spectral or temporal components.

## Spectral Coverage

Between the GBM and the LAT, GLAST will cover 7.5 energy decades! The plot below shows the count spectrum (E dC/dE) that will be detected by one of the GBM's 12 NaI detectors (solid curve), one of the GBM's 2 BGO detectors (dashed curve) and the LAT (dot-dashed curve) for α= -1, β= -2 and $E_p$=250 keV; more than one GBM detector will observe a burst. The two dotted curves show a model of the background for the NaI (lower curve) and BGO (upper curve) detectors. The spectrum is shown for a fairly bright burst—an order of magnitude brighter than BATSE's threshold and a factor of ~3 brighter than the GBM's. The LAT spectrum is calculated using the current effective area function, which is preliminary; in particular, future calculations are anticipated to result in a larger low energy LAT effective area.