GLAST's GBM Burst Trigger

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Summary

The GLAST Burst Monitor (GBM) will detect and localize bursts for the mission, and provide the spectral and temporal context in the traditional 10 keV to 25 MeV band for the high energy observations by the Large Area Telescope. The GBM will use traditional rate triggers in three energy bands, including the BATSE 50-300 keV band, and on a variety of timescales between 16 ms and 16 s.

The Mission

The **G**amma-ray **L**arge **A**rea **S**pace **T**elescope (GLAST) is the next NASA general gamma-ray astrophysics mission, which is scheduled to be launched into low Earth orbit in September, 2006, for 5-10 years of operation. It will consist of two instruments: the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). A product of a NASA/DOE/international collaboration, the LAT will be a pair conversion telescope covering the <20 MeV to >300 GeV energy band. The LAT will be ~30 times more sensitive than EGRET, while the GBM is a less sensitive descendant of BATSE.

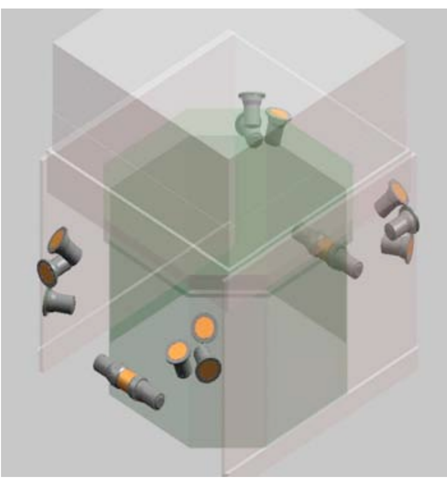
The GBM will detect and localize bursts, and extend GLAST's burst spectral sensitivity to the <10 keV to >25 MeV band. Consisting of 12 NaI(*Tl*) (10-1000 keV) and 2 BGO (0.15-25 MeV) detectors, the GBM will monitor >8 sr of the sky, including the LAT's field-of-view (FOV). Bursts will be localized to <15º (1σ) by comparing the rates in different detectors. The figure below shows the planned placement of the GBM's detectors on the GLAST spacecraft.

During most of the mission GLAST will survey the sky by rocking ~30° above and below the orbital plane around the zenith direction once per orbit. The first year will be devoted to a sky survey while the instrument teams calibrate their instruments. During subsequent years guest investigators may propose pointed observations, but continued survey mode is anticipated because it will usually be most efficient.

Both the GBM and the LAT will have burst triggers. When either instrument triggers, a notice with a preliminary localization will be sent to the ground through TDRSS and then disseminated by GCN within 7s. Additional data will be sent down through TDRSS for an improved localization at the Mission Operations Center. Both Instrument Operations Centers will calculate "final" positions from the full downlinked data. All positions will be disseminated as GCN Notices, and additional information (e.g., fluences) will be sent as GCN Circulars.

Using its own and the GBM's observations, the LAT will determine whether the burst was intense enough for followup pointed observation of the burst location for 5 hours (interrupted by Earth occultations). The threshold will be higher for GBM-detected bursts outside the LAT's FOV.

Here we discuss the plans for the GBM's triggers, and the resulting sensitivity.



The GBM's Trigger

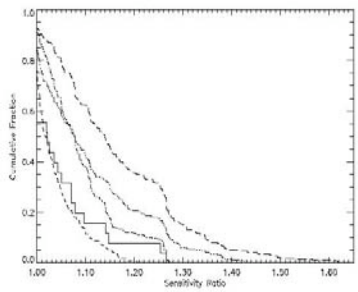
The GBM's NaI and GBM detectors will provide the number of counts detected in 8 energy bands every 16 ms. Rate triggers will test whether the increase in the number of counts in an energy band ΔE and time bin Δt is statistically significant. We are performing trade studies to optimize the sensitivity of these triggers. The issues are:

- Choice of ΔE?
- Which Δt should be used?
- How should the time bins be spaced?
- How should the background be calculated (e.g., fit a polynomial in time?)?
- Can the BGO detectors be used for the trigger?
- What trigger significance should be used?
- Should more than 2 detectors be required to trigger?

Here we present the results of some of our studies addressing these issues.

Time Bins

We consider two Δt hierarchies—Δt spaced by factors of ×2 (e.g., 16 ms, 32 ms, 64 ms…) or ×4 (e.g., 16 ms, 64 ms, 256 ms…)—and three time bin registrations—non-overlapping bins (e.g., separated by 1024 ms for Δt=1024 ms bins), half-step bins (e.g., separated by 512 ms for Δt=1024 ms bins), and all possible bins (e.g., every 16 ms). Varying Δt can optimize the signal-to-noise ratio, while more time registrations permit the bin to be centered over the peak flux, maximizing the signal-to-noise ratio. To test these 6 triggers we applied them to the 64 ms lightcurves of the 25 brightest BATSE bursts; for each lightcurve we chose 10 starting times at random. Note that the GBM lightcurves will have 16 ms resolution. The plot below shows the cumulative distribution of the sensitivities of the 5 less triggers relative to the most sensitive (all possible time bins, Δt spaced by ×2). The curves are: solid—all bins, ×4 Δt; dashed—half steps, ×2 Δt; dot-dashed–half steps, ×4 Δt; dots-dashed—non-overlapping bins, ×2 Δt; and long dashed—non-overlapping bins, ×2 Δt.



The most sensitive trigger would have Δt spaced by ×2 and every possible time bin. The next most sensitive trigger would have Δt spaced by ×2 and bins every half step. These triggers would test different numbers of bins. The following table shows the number of bins tested in 16.384 s.

? t spacing	Bin registration	Number of bins tested
? 2	All bins	11264
? 4	All bins	6144
? 2	Half-step	3070
? 4	Half-step	1706
? 2	Non-overlapping	2047
? 4	Non-overlapping	1365

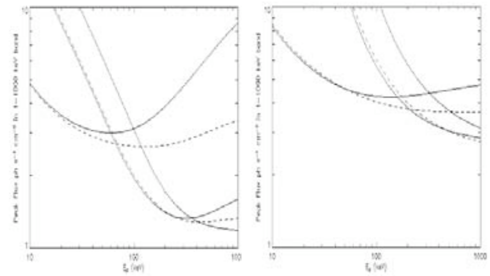
Besides the increased computational burden, the risk of a false trigger increases as the number of bins tested increases, but the false trigger probability is not proportional to the number of bins because the bins are not independent. Our simulations indicate this is a <5% effect—the trigger threshold should be raised by a few percent for the same false trigger rate for triggers with many more bins tested relative to triggers with fewer bins tested.

Choice of ΔE

Triggering on the counts accumulated in different ΔE can tailor the detector sensitivity to hard or soft bursts. The GBM will be able to trigger on more than one ΔE, and therefore we would like the set that will maximize the sensitivity for both hard and soft bursts, although hard bursts are a priority since their spectra are more likely to extend into the LAT's energy band. For the study of detector sensitivity to different types of bursts and for comparisons between detectors, the F_T-E_p plane is useful, where F_T is the peak photon flux in a fiducial energy band (here 1-1000 keV) and E_p is the energy of the peak of $E^2N(E)\propto \nu f_\nu$ (see the poster "Burst Populations and Detector Sensitivity" by D. Band). For a given set of spectral indices the detector sensitivity (the threshold value of F_T at a give E_p) is a curve in this plane.

To calculate these sensitivity curves we need both the number of counts a detector will detect in the nominal ΔE band for a given burst spectrum and the number of background counts in this ΔE. R. Kippen has developed a code that calculates these numbers for each GBM detector for a burst in any direction relative to the spacecraft. The code uses response matrices for the flux directly incident on the detectors (without scattering off the spacecraft or the Earth, but with obscuration by other parts of the observatory), and a model of the background on orbit. We used this code to calculate the sensitivity along the normal to the LAT for Δt=1.024 s assuming at least two detectors trigger at $\sigma_0 \geq 5.5$.

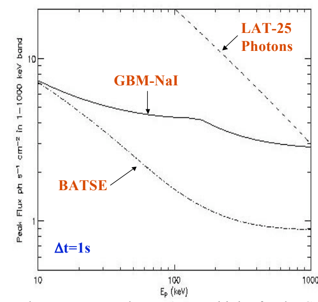
We calculated these sensitivity curves for a variety of ΔE. To compare the GBM and BATSE burst distributions we want to include ΔE=50-300 keV which was BATSE's primary trigger band. The extremes of our sets of spectral indices were α=0, β=-2 and α=-1, β=-25. The first set is similar to the spectra sometimes observed early in a burst; its high energy tail might be detected by the LAT. The second set is a spectrum with no high energy tail.



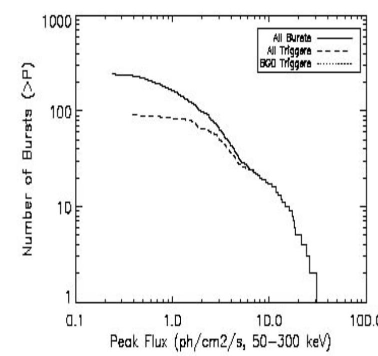
These plots show the sensitivity for two sets of ΔE. The left hand plot is for α=0, β=-2 and the right hand plot for α=-1, β=-25. The solid curves are for (left to right) ΔE=5-100, 50-300 and 100-1000 keV and the dashed for ΔE=5-1000 and 50-1000 keV.

As can be seen, ΔE with a low energy cutoff of ~50 keV is optimal for high energy sensitivity because it does not include the large low energy background. Conversely, ΔE should extend to the highest energy possible because of the low high energy background.

Preliminary results show that the BGO detectors will not assist in burst detection.



The figure above compares the Δt=1 s sensitivity for the GBM (solid) and BATSE (dot-dashed) with the intensity of the spectrum (dashed) that when extrapolated to the LAT energy band will result in 25 detected photons per second. The burst is on the LAT normal, α=-1, β=-2, and ΔE=5-100 and 50-300 keV for the GBM. Thus under the specified conditions the GBM would trigger on a burst that would produce 25 LAT photons in 1 s for E_p<1000 keV.



Putting It All Together

The figure above shows a simulation where an isotropic (with respect to the spacecraft) burst distribution is detected by the GBM with three ΔE ranges and Δt spaced by ×4. The burst lightcurves and spectra were created by drawing from empirical pulse and spectrum distributions. The solid curve is the input intensity distribution and the dashed is the detected distribution (note that the BGO detectors did not assist in the detections).

Conclusions

The Δt calculations suggest that spacing Δt by factors of 2 (i.e., 16 ms, 32 ms, 64 ms…) and staggering the bins by half a timestep (e.g., the 1024 ms bins are accumulated every 512 ms) would be particularly efficient given the number of time bins that would be tested. Choosing two triggers with ΔE starting at 5 keV and 50 keV would provide good high and low energy sensitivity. Using ΔE=50-300 keV would reproduce the BATSE trigger, but would reduce the E_p>500 keV sensitivity for the hardest bursts (which are more likely to have LAT flux); this can be mitigated by adding ΔE=100-1000 keV.

Ultimately the trigger design will be constrained by the computational capabilities of the GBM's processor.