THE SYNERGY BETWEEN THE LAT AND GBM IN GLAST'S STUDY OF GAMMA-RAY BURSTS

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Abstract. Using semi-analytic calculations I characterize the gamma-ray bursts to which GLAST's LAT and GBM detectors will be sensitive. The thresholds of both instruments are at approximately the same $\nu f_\nu \propto E^2N(E)$ values, i.e., the thresholds can be connected by an E^{-2} spectrum. Therefore simultaneous detections by both instruments will be biased towards spectral components flatter than E^{-2}.

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GLAST is expected to discover new gamma-ray burst temporal and spectral components that were only hinted at by the observations of the *Compton Gamma-Ray Observatory*'s EGRET and BATSE detectors. GLAST's burst studies will be enhanced by the synergy between the Large Area Telescope (LAT; <20 MeV to >300 GeV) and the GLAST Burst Monitor (GBM; 8 keV to 30 MeV). Between these two detectors GLAST may observe burst spectra covering 7 energy decades; the GBM's field-of-view (FOV) covers the LAT's large FOV totally. Here I use semi-analytic calculations to characterize the bursts to which each detector will be sensitive.

EGRET indicated that some bursts' $\sim$1 GeV emission was not merely an extrapolation of the 'prompt' $\sim$100 keV emission observed by detectors such as BATSE and *Swift*.[6] However, before GLAST's launch we have little detailed guidance as to what to expect, and therefore my calculations use extrapolations from the $\sim$ 100 keV observations; at a minimum, these calculations indicate the constraints that can be placed on the correlations between the LAT and GBM energy bands. Thus, in my analysis I assume a single spectral component in both the GBM and LAT bands which is described by the 'Band Function,[4]' a smoothly broken power law: a low energy power law, E^α (typically $\alpha \sim$-1); a high energy power law, E^β (typically $\beta <$ -2); a break between these two power laws characterized by E_p, the energy of peak of $E^2N(E) \propto \nu f_\nu$; and the normalization, F_T, the 1–1000 keV flux. The expectations (e.g., spectrum and burst rate) for the GBM are based on BATSE,[1] which had an energy band similar to the GBM's NaI detectors.

The GBM will detect bursts with a rate trigger, which searches the detector rates for a statistically significant increase. The rates from the different NaI detectors are binned continuously in energy range ΔE and accumulation time Δt bins. A count rate increase of $> 4.5\sigma$ in the bins from 2 NaI detectors will be required for a trigger. For a given set of spectral parameters α, β, and E_p, the peak value of F_T (when integrated over Δt) will determine whether the burst is detected. Therefore the GBM's sensitivity is the threshold value of F_T for a given set of spectral parameters. The lower set of curves on Figure 1 shows the threshold F_T over Δt=1 s as a function of E_p, holding α=-1 fixed for β=-2 (solid curve), -2.5 (dashed curve), and -3 (dot-dashed curve). Note that F_T at a given E_p is *not* the detector sensitivity at a photon energy equal to E_p. The E_p and peak F_T for a sample of BATSE bursts are shown by the dots;[7] a large fraction of this sample is below the GBM trigger threshold for Δt=1 s (see [2]).

In my GBM calculations I use a preliminary 'direct' response function, i.e., with no scattering off the spacecraft or Earth's atmosphere. The background is modeled on the BATSE backgrounds. Different ΔE are used to maximize the GBM's sensitivity to bursts with low and high E_p. The most effective ΔE for a given burst depends on the spectral shape of the burst and the background.

For comparison, I show on Figure 1 (upper set of curves) the values of F_T and E_p for spectra that, when extrapolated to the LAT energy band, would result in 5 LAT counts in Δt=1 s (i.e., 5 photons would be detected). Given the low LAT background, a statistically significant detection in 1 s will require of order 5 counts. Again, α=-1, and β=-2 (solid curve), -2.5 (dashed curve), and -3 (dot-dashed curve). For this analysis I use a more inclusive set of cuts that increases the effective area at the expense of greater background (the 'DC2' analysis classes A and B).

This analysis assumed that Δt=1 s. However, gamma-ray burst durations are both shorter and longer than 1 s. The GBM trigger will use a set of Δt that will increase the sensitivity to both long and short bursts (see [1, 2, 3] for the

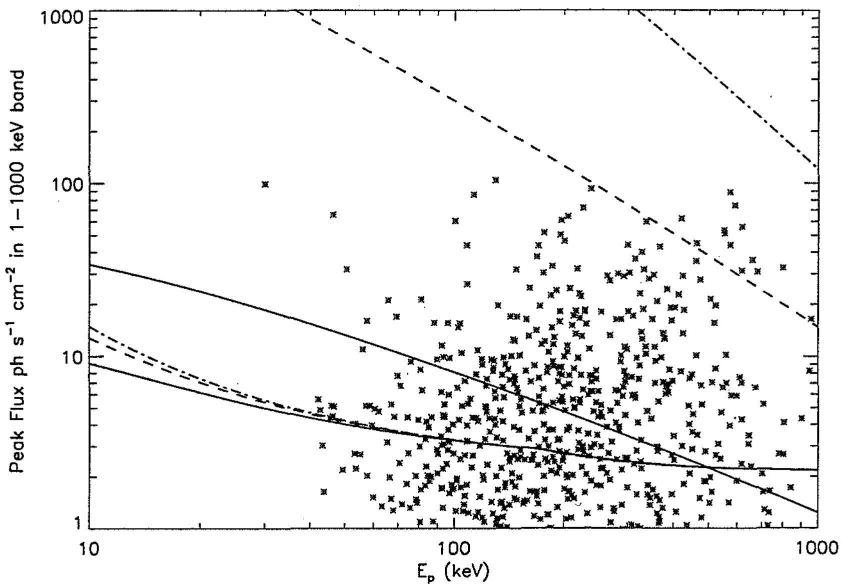

FIGURE 1. Comparison of LAT (upper set of curves) and GBM (lower set of curves) sensitivities as a function of E_p for Δt=1 s. For each set of curves the low energy spectral index α=-1 and the high energy spectral index β =-2 (solid curves), -2.5 (dashed curves) and -3 (dot-dashed curves). The dots result from fits to a set of BATSE bursts. See the text for further details.

dependence on Δt). Similarly, the LAT count data can be searched for burst emission on different timescales; statistical significance will depend on both timescale and photon energy.

Nonetheless, Figure 1 shows that the GBM and LAT are well matched for bursts with β=-2, i.e., constant $\nu f_\nu \propto E^2N(E)$. LAT bursts with β <-2.5 will be brighter in the GBM band than most of the bursts that BATSE observed, and therefore rare. Thus there will be a bias towards LAT bursts with β =-2. These conclusions assume that the GBM and LAT observe the same spectral component. Additional spectral and temporal components are expected,[6, 5] and thus LAT emission may be detected even when $\beta < -2.5$ for the GBM spectra. Conversely, in general the non-detection of LAT counts will be relevant when $\beta > -2.5$ for the GBM spectra. Thus this type of analysis can be used to understand the burst populations GLAST's detectors detect, and do not detect.

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