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 \( v_f = E^2 N(E) \) 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, \( E_\alpha \) (typically \( \alpha \sim -1 \)); a high energy power law, \( E_\beta \) (typically \( \beta < -2 \)); a break between these two power laws characterized by \( E_p \), the energy of peak of \( E^2 N(E) = v_f \), and the normalization, \( F_r \), the 1–1000 eV 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 \( \Delta E \) and accumulation time \( \Delta t \) 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 \( \alpha, \beta, \) and \( E_p \), the peak value of \( F_r \) (when integrated over \( \Delta t \)) will determine whether the burst is detected. Therefore the GBM's sensitivity is the threshold value of \( F_r \) for a given set of spectral parameters. The lower set of curves on Figure 1 shows the threshold \( F_r \) over \( \Delta t = 1 \) s as a function of \( E_p \), holding \( \alpha = 1 \) fixed for \( \beta = -2 \) (solid curve), -2.5 (dashed curve), and -3 (dot-dashed curve). Note that \( F_r \) at a given \( E_p \) is not the detector sensitivity at a photon energy equal to \( E_p \). The \( E_p \) and peak \( F_r \) for a sample of BATSE bursts are shown by the dots.[7]

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 \( \Delta E \) are used to maximize the GBM's sensitivity to bursts with low and high \( E_p \). The most effective \( \Delta E \) 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 \( F_r \) and \( E_p \) for spectra that, when extrapolated to the LAT energy band, would result in 5 LAT counts in \( \Delta t = 1 \) 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, \( \alpha = -1 \), and \( \beta = -2 \) (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 \( \Delta t = 1 \) s. However, gamma-ray burst durations are both shorter and longer than 1 s. The GBM trigger will use a set of \( \Delta t \) 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 $\Delta t=1$ s. For each set of curves the low energy spectral index $\alpha=-1$ and the high energy spectral index $\beta=-2$ (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 $\Delta t$). 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 $\beta=-2$, i.e., constant $v f_v \propto E^2 N(E)$. LAT bursts with $\beta < -2.5$ 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 $\beta = -2$. 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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REFERENCES