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# Search for extended emission in Fermi/GBM GRBs

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Gamma-Ray Bursts (GRBs) are characterised at high energies in their prompt emission by impulsive peaks with sharp rises, often highly structured, and easily distinguishable against instrumental backgrounds. The longer lived afterglow radiation seen at lower energies is much smoother and would be difficult to detect in a background-limited instrument such as the Gamma-ray Burst Monitor (GBM) on board *Fermi*. Observations above 100 MeV of this type of long lived emission from bright GBM detected GRBs by the *Fermi* Large Area Telescope (LAT) suggest the possibility of extended lower-energy gamma-ray emission. In order to search for such emission in GBM GRBs we have developed a new background estimation tool. We report the results of this search on $\sim$ 580 long GRBs from the first 3 years of operation.

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## 1. Introduction

Capable of making observations across an unprecedented 8 decades of energy (10 keV - 300 GeV), the *Fermi* Gamma-Ray Space Telescope has ushered in a new era in gamma-ray astrophysics. This broad energy bandwidth is afforded by its two constituent instruments, the Large Area Telescope (LAT), a pair-production telescope with an effective energy bandwidth of 20 MeV - 300 GeV [1] and the supporting instrument, the Gamma-ray Burst Monitor (GBM), which consists of 14 individual scintillation detectors with an effective energy range of 10 keV - 40 MeV [2]. 12 of the detectors on GBM are sodium iodide (NaI) which cover the energy range 10 - 1000 keV. The remaining 2 are bismuth germanate (BGO) which cover 200 keV - 40 MeV. The 12 NaI detectors are positioned in clusters of three around the spacecraft such that any event which is above the horizon of the Earth's limb will illuminate at least one cluster. The two BGO detectors are positioned at opposite sides of the spacecraft, aligned perpendicular to the LAT boresight.

The primary observation mode of *Fermi* is sky survey mode, which optimises the sky coverage of the LAT whilst maintaining near uniform exposure. In this mode the satellite rocks about the zenith such that the entire sky is observed for $\sim$30 minutes every 2 orbits ($\sim$ 3 hours). The variation in pointing complicates the background in GBM, already highly variable due to the changing geomagnetic conditions.

## 2. Motivation and Technique

The sensitivity of the LAT has led to the discovery of long lived emission in the MeV-GeV energy range on kilo-second timescales. Extended emission from GRBs above 100 MeV had previously been hinted at by observations made by the EGRET instrument on board the Compton Gamma Ray Observatory [3]. This emission has been observed in several GRBs by the LAT and can be explained as synchrotron emission from the external forward shock [4, 5]. These observations on timescales which have been conventionally associated with lower energy (sub-MeV) afterglow emission have raised the question of whether such emission would be visible in GBM.

**Table 1:** Energy ranges used and the rationale for their selection.

| Energy Range (keV) | Rationale |
|---|---|
| 10 - 1,000 | Full effective energy range of NaI detectors |
| 25 - 1,000 | Excludes the lowest energy channels of the NaI detectors which frequently exhibit large fluctuations. |
| 50 - 300 | Most sensitive range of the NaI detectors |

The conventional method for determining the background of GBM is to interpolate time intervals before and after the event of interest as a polynomial (usually of order 0-4). This is particularly well suited to the study of GRBs, the prompt emission of which is characterised by impulsive peaks with sharp rises, often highly structured, and easily distinguishable against instrumental backgrounds. The timescales on which the prompt emission occurs is usually short enough that

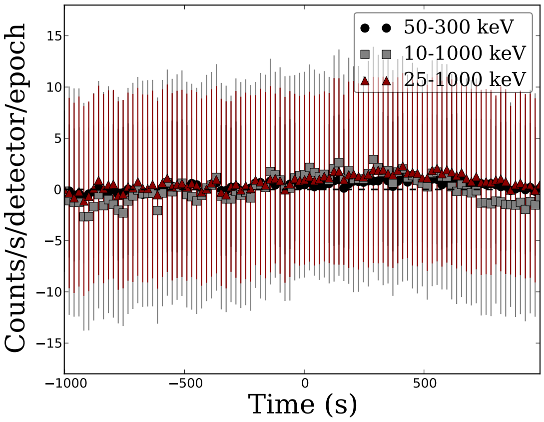

**Figure 1:** Average lightcurves in each energy band for blank field regions for NaI detectors in ∼20 s bins. For each energy band, the data is best described by a $0^{\text{th}}$ order polynomial of intercept zero.

this method is sufficient, however for events with long durations or less impulsive time profiles, a more rigorous background determination is required.

Connaughton (2002) [6] employed a method of background estimation to create background subtracted signals from hundreds of BATSE GRBs. By summing these, extended emission up to hundreds of seconds after the bursts was found. Motivated by this, we have implemented a simple method which uses the rates from adjacent days, when the satellite has the same geographical footprint, to estimate the background at the time of interest. The orbit of *Fermi* is such that it will be at approximately the same geographical coordinates every 15 orbits (∼24 hrs). However, due to the rocking angle of the spacecraft in sky survey mode, the pointing of the individual GBM detectors is only the same every second orbit. We therefore use the rates from ±30 orbits.

## 3. Validation of Method

In order to search for systematic offsets, 120 blank fields of duration 2 ks were selected from the first three years of operation (excluding regions of high solar and Soft-Gamma Repeater (SGR) activity). For each region, lightcurves of the `on` region (defined as the source) and the estimated `off` region (defined as the background) in three representative energy bands for the NaI were generated using the rates from ±30 orbits. Details of these energy bands and the rationale for their selection can be seen in Table 1. The data used were continuous CSPEC, which consist of 128 pseudo-logarithmic spectral bins and 4.096 s timing resolution. Regions where there was clear evidence of an interfering source or a systematic offset between the `on` and the `off` were flagged as bad and discarded. For each energy band, an average residual lightcurve (`on` − `off`) was found by averaging all regions; the results are shown in Fig. 1. For each energy band, the average lightcurve is best fit with a $0^{\text{th}}$ order polynomial which is consistent with a straight line of intercept zero.

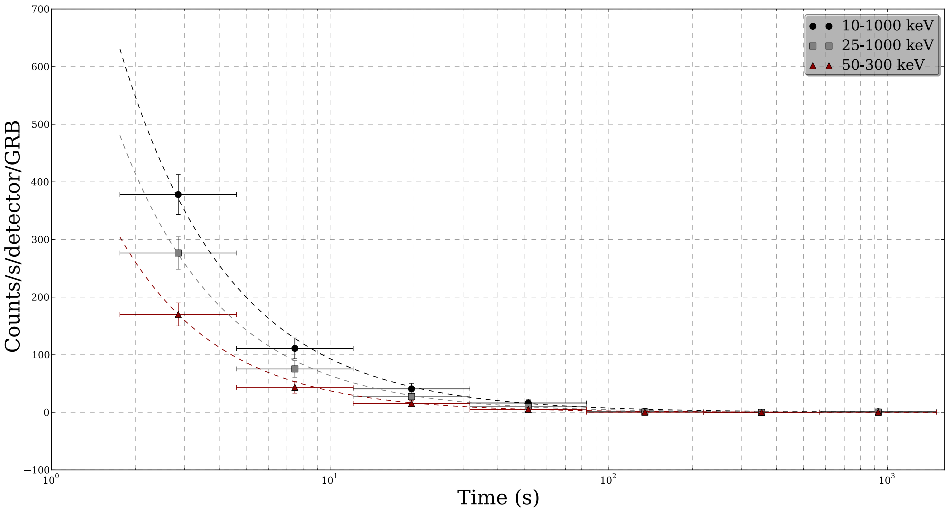

**Figure 2:** Average residual lightcurves in each energy band for 348 long GRBs. The data in each energy band are well described by power laws (overplotted).

## 4. Results

Over the first three years of operations[1] GBM has triggered on ~580 long GRBs. For each GRB, background subtracted lightcurves in each of the three energy bands were found by first creating good time intervals[2] (GTIs) for the NaI detectors. As in § 3 the data used was continuous CSPEC. These intervals were examined and regions with systematic offsets or interfering sources were flagged as bad and discarded, leaving 348 GRBs. An average lightcurve of `on` and `off` was then found for each burst by averaging the individual detectors. In each energy band, the individual GRB lightcurves were aligned coarsely by the 1.024 s peak flux interval start time. The average residual lightcurve was then found in each energy band and is shown in Fig. 2. The residual lightcurves in each energy band were found to be well described by power laws with indices of $-1.2 \pm 0.04$, $-1.1 \pm 0.02$ and $-1.2 \pm 0.03$, for 10 - 1000 keV, 25 - 1000 keV and 50 - 300 keV respectively. Excluding the $T_{90}$ period from the analysis yields values of $-1.2 \pm 0.58$, $-0.9 \pm 0.17$ and $-1.2 \pm 0.45$ respectively, consistent with Connaughton (2002) [6] who performed a similar analysis.

## 5. Conclusion

Attempting to study long lived emission in a background limited instrument like GBM presents many challenges. We have shown that by averaging the contribution from hundreds of long GRBs, extended emission out to hundreds of seconds can be seen. This is consistent with the results of Connaughton (2002) [6].

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[1] Taken as August 2008 - August 2011

[2] Intervals where the angle between the source and detector normal angle is $< 60^\circ$.

While these initial results are promising, this work is far from complete. Future work will involve the inclusion of short GRBs in the study and the incorporation of data from the BGO. A more quantitative study of the significance of the observed extended emission will also be performed.

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