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A search for long-lived emission from well-localised Fermi GBM GRBs using the Earth Occultation Technique

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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) onboard *Fermi*. Observations above 100 MeV of this type of smooth, 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 which cannot be seen with GBM using typical GRB analysis methods. We use the Earth Occultation Technique (EOT) to search for long-lived signals in GBM from well-localised GRBs, with special emphasis on those bursts for which extended emission was detected above 100 MeV by the *Fermi* LAT.

We present here an overview of the methods employed in this study as well as some preliminary results and future goals.

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1. Introduction

Launched into a low earth orbit (attitude 565km, i=28.5°) in June 2008, the *Fermi* Gamma-Ray Space Telescope consists of two instruments, the primary of which is the Large Area Telescope (LAT) which uses a pair-production system of detection [1]. The secondary instrument on *Fermi*, GBM, consists of 12 sodium iodide (NaI) and 2 bismuth germanate (BGO) scintillation detectors [2]. The 12 NaI detectors are positioned in clusters of 3 at the corners of the LAT. This gives GBM a field of view (FOV) which encompasses the entire unocculted sky. Locations of GRBs are determined via the relative counts in each detector with a statistical error of 1° for the brightest bursts and an additional systematic error of $\sigma_{sys} = 3.8^\circ \pm 0.5^\circ$ [3]. The combination of NaI and BGO detectors gives GBM an energy range of 8 keV-40 MeV which overlaps with the lower end of the LAT's range (20 MeV-300 GeV).

The most luminous explosions in the universe, GRBs have been studied since their discovery in the late 1960s [4]. The first afterglow emission was detected in X-ray [5] and optical [6] in 1997. GRB afterglows in the energy range 1-10 keV have been extensively studied with the *Swift*/XRT [7]. However, observations of long-lived high-energy emission from GRBs by the LAT (>100 MeV) on timescales of ks [8] imply the possibility that there exists an extended higher-energy (>10 keV) emission element that may be detected by GBM. The fact that GBM observes the entire sky means that a smooth structureless feature will be hard to pick out over the background variations; therefore in order to observe it, a novel method must be employed. Using the EOT a search was undertaken for evidence of extended emission in the continuous GBM data.

2. Earth Occultation Technique (EOT)

The EOT uses the change in the count rate observed in the NaI detectors when a particular source enters or exits Earth occultation to determine the flux contribution from that source. This technique was also applied to the Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory (CGRO) [9]. Currently, continuous GBM CTIME data is used; this has 8 energy channels over a range from ∼10 keV-1 MeV and 0.256 s time binning.

For each source of interest the time at which it is occulted is calculated. NaI detectors with angles less than 60° to the source are selected. As the source enters or exits occultation the change in counts will produce a step in the data for the selected detectors. The source of interest and any other sources which are occulted in the same window are fit with a quadratic background and source model. The detector responses are then used to determine the flux. The EOT has successfully been verified on X-ray sources such as the Crab [10].

To date, GBM has detected and localised over 500 GRBs. Due to the relatively poor accuracy of these locations they are not suitable for use with the EOT. Fortunately, a subset of some 100 have been coincidentally observed by complimentary instruments such as Swift, AGILE and the LAT, which can provide a sufficiently accurate location such that the EOT may be employed. Additionally, bursts which have been localised by the Interplanetary Network (IPN) [11] generally have sufficiently good localisations that they are considered for use in this study.

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3. Preliminary Results

It was found that 102 GRBs had a localisation accurate enough to be considered for use. Of these, 14 did not occult in the neighbourhood of the trigger ($\sim$ 24 hours) and were discarded. The remaining 88 were processed using the EOT method. Of particular interest to this study were 7 LAT GRBs with evidence of long-lived emission; 080916C [12], 090323 [13], 090328 [13], 090510 [14], 090626 [15], 090902B [16] and 090926 [17]. Of these, all but 080916C were occulted in the vicinity of the trigger. Figure 1 shows the lightcurve for 090510, which was also observed by Swift [18]. The number of times a source is occulted daily depends on its coordinates. Typically it was found that the GRBs in this study were occulted 10-20 times daily (taking the rise and set as two separate occultations).

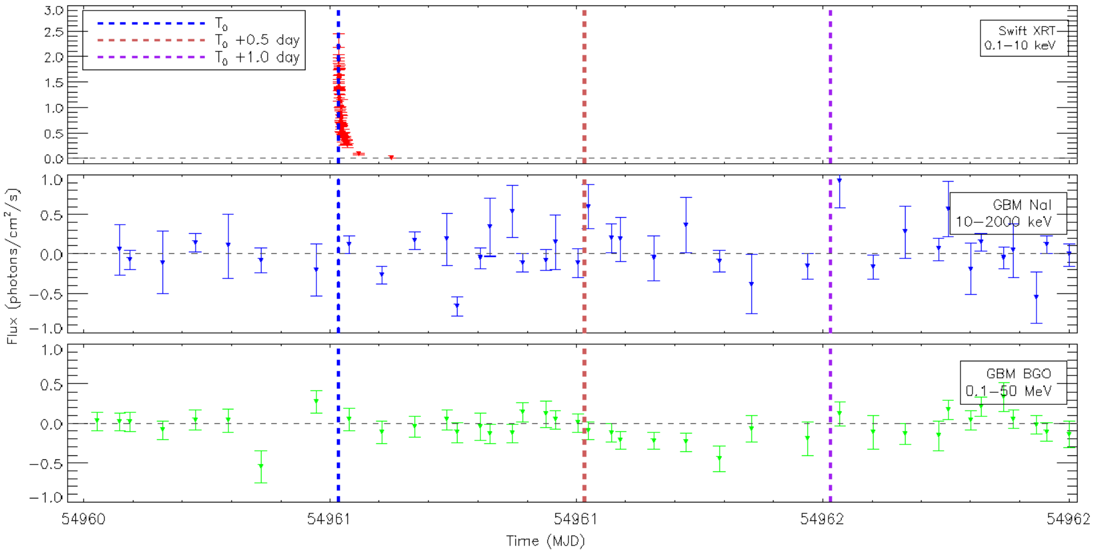

Figure 1: Swift XRT [19], GBM NaI and BGO lightcurves for GRB090510. No clear excess is visible in the GBM data.

In a preliminary analysis, no obvious excess was noted in these 88 GRBs in the summed-energy day-scale EOT lightcurve, but further investigation on different time-scales and energy bands is in progress.

4. Future Work

Upper limits will be calculated for the possible long-lived GBM emission in coincidence with extended emission seen in the LAT. A catalogue of locations from the IPN is expected to be published soon [20]. IPN bursts tend to be bright, increasing the possibility of being able to observe the counterpart to the long-lived emission seen by the LAT. This will also serve to extend the size of our sample.

X-ray flares in the afterglows of GRBs [21] have been observed by Swift XRT. In our preliminary analysis we have not observed coincident flaring with GBM, however in the future we hope to undertake a more rigorous study.

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