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New background-filtering algorithm based on the motion of the Fermi Gamma-ray Space Telescope

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Abstract. The Fermi Gamma-ray Space Telescope is programmed to have a proper motion during its flight: if a gamma-ray burst occures, the satellite changes its orientation toward the burst. This rapid rotation has a contribution to the measured data, therefore, the background of a lightcurve varies in time. In order to get the statistical parameters of a burst, we need to separate the data from the background. In this paper, we present a new background-filtering method based on the motion and orientation of the satellite, considering the celestial position of the burst, the Sun and the Earth as well. We show that our method is effective to compute the statistical parameters and it is appropriate for the Fermi's data set.

Key words. Gamma-ray Burst – Fermi – background

1. Introduction

NASA's Fermi Gamma-ray Space Telescope is designed to measure the position of a burst in seconds and change the detectors' orientation so that the orientation of the effective area of the main detector (LAT) and the celestial position of the burst have the smallest angle (Meegan et al. 2009). The problem is that the secondary detector (GBM) measures a quickly varying backgroung superponed on the substantial data because of the rapid motion of the satellite. Though, the work with the GBM data must be anticipated by the removing of the backgorund, the ordinary used methods, like fitting the background with a polynomial function of time, are too simple and poorly effective in the case of Fermi.

We construct a model that involves real motion and orientation of the satellite during its flight and the position and contribution of the main gamma-ray sources to the background.

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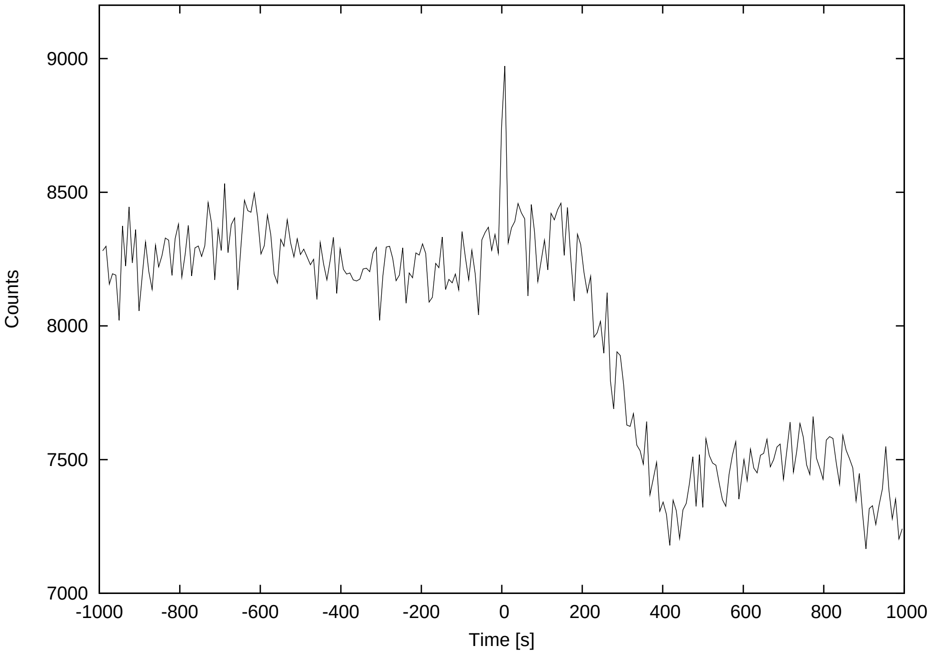

Fig. 1. Lightcurve of the Fermi-burst 091030613 measured by the 3rd GBM detector. The burst is at 0 s but the varying of the background is comparable with its height and cannot be modelled by a simple second or third order polynomial function of time.

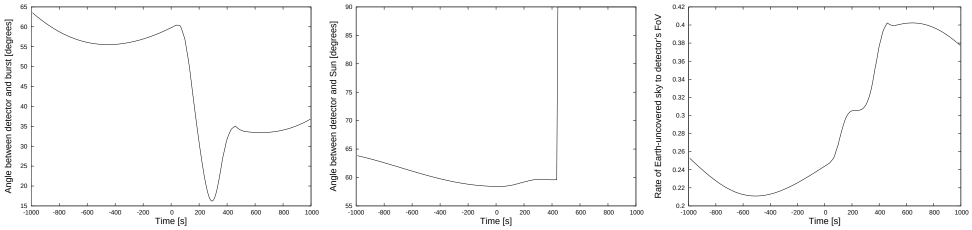

Fig. 2. From left to right: The celestial distance of the 3rd GBM detector and the position of Fermi-burst 091030613; the same with the Sun; and the rate of the Earth-uncovered sky to the 3rd GBM detector's field of view, both in the function of time. It is worth comparing to Fig. 1. (If the Sun is behind the detector's field of view or is hidden by the Earth limb, the celestial distance is automatically set to 90°.)

2. Lightcurve and reason of the background

After some basic data transformation, we can plot a GBM-lightcurve as shown in Fig. 1, which is a typical one.

Since the varying of the background is caused by the rapid motion of the satellite, we need a specific model involving the position and orientation of the Fermi in each second. We made such a model considering the detector's orientation and the celestial position of the burst, the Sun and the Earth limb. The effect of every other gamma-source is included into

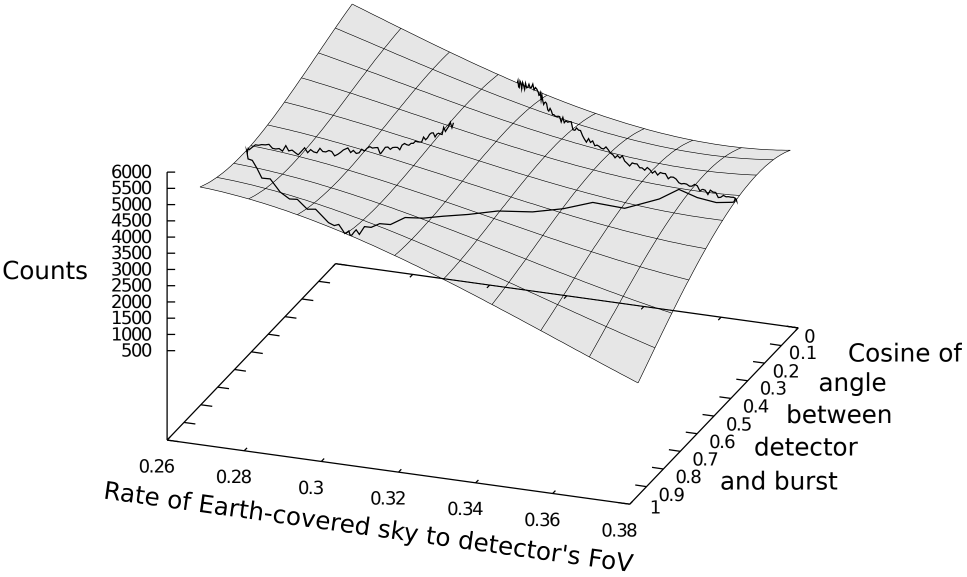

Fig. 3. In this intriguing picture, one can see a 2-dimensional hypersurface fitting to the Fermi-lightcurve 091207333. The fitted parameters are along the horizontal axes, while vertical axis represents the counts of the lightcurve, which is shown by the black curve on the fitted grey plane. In our method, we fitted 3-dimensional hypersurfaces with the contribution of the Sun as well, but the principle is the same.

an isotropic constant gamma-ray background in this approximation.

Comparing Fig. 1 to Fig. 2, we can realise the connection between them: where the angles and the Earth limb's uncovering are varying, the background of the lightcurve is varying, too.

3. Fitting the background

Since we have 3 parameters changing in time the same way like the background of the lightcurve, we fitted a 3-dimensional hypersurface of degree 3 to the lightcurve's background, in order to separate the background from the burst's real data. Fitting was done by Octave (Long 2005), with the tool of Singular Value Decomposition (Kendall and Stuart 1973).

4. Results

After subtracting the hypersurface from the lightcurve, we get the background-free lightcurve shown in Fig. 4.

Comparing Fig. 1 to Fig. 4, we can make a statement that our background filtering was successful since the resulted lightcurve is perfectly background-free.

5. Conclusion

The Fermi satellite has a particular motion during its flight in order to catch the gamma-ray bursts mostly well. The side-effect of this favourable feature is that the lightcurves of the GBM detectors are stressed by rapidly and extremely varying background. Before processing these data, they need to be separated from the background. We developed a method that takes orientation of the detectors into account in every second. In addition the Sun's and the Earth disc's contribution to the background are considered. Of course, the method may be fur-

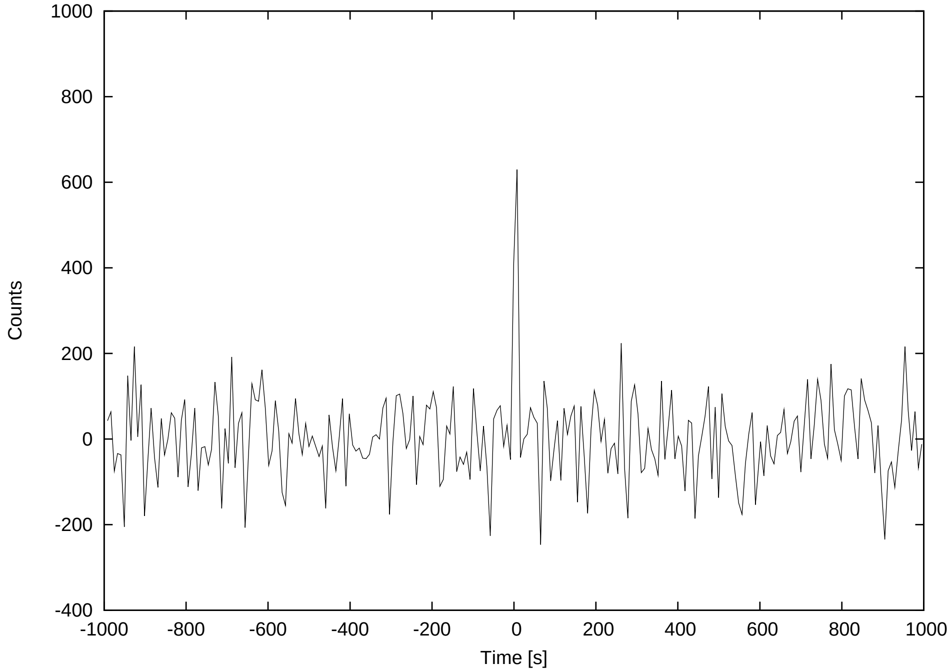

Fig. 4. After the background fitting: lightcurve of the Fermi-burst 091030613 measured by the 3rd GBM detector.

ther improved with the contribution of other gamma-sources from the cosmos and the spectral feature of the data set, but the results published in this paper seem to be sufficiently satisfying.

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