Background fitting of Fermi gamma-ray burst 091030613

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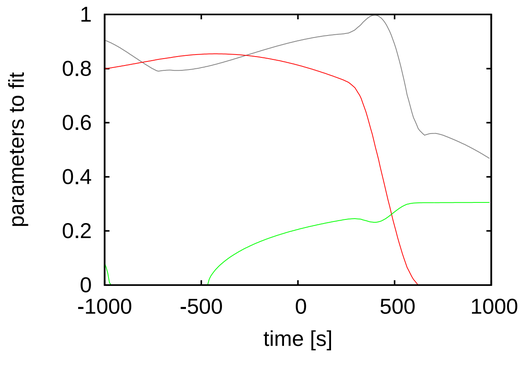
Abstract

Fermi Gamma-ray Burst Monitor (GBM) detects gamma-rays in the energy range 8 keV – 40 MeV. Background fitting of the Fermi data is not trivial in some cases, especially when an Autonomous Repoint Request (ARR) is received. One good example is the burst 091030613 measured by the GBM, which cannot be fitted properly by a third-order polynomial of time [3]. We present the background fitting of this burst for energy channels given in the CTIME data file. Our method is based on the motion of the satellite: we define three underlying parameters which depend on the actual position and orientation of the satellite and use them to fit the background. The main steps and results of this process are shown on the poster for the triggered NaI detector '3'.

Underlying variables



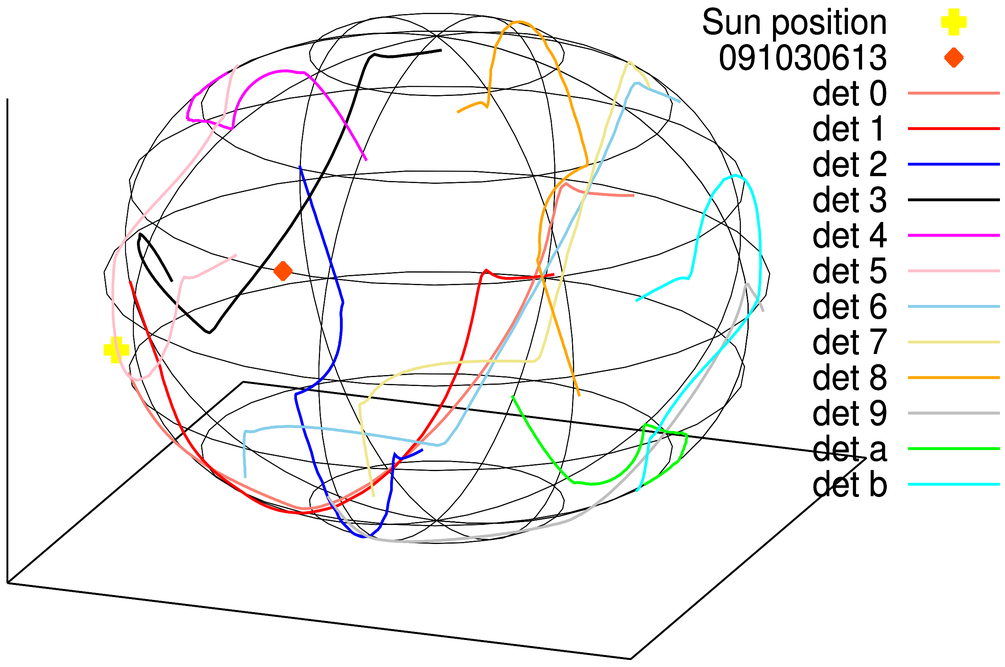
We use three underlying parameters:

- cosine of the Celestial Distance of the Burst's position and the Detector's normal vector (grey)
- cosine of the Celestial Distance of the Burst and the Sun (as most significant source of gamma background, red)
- the ratio of the Earth-uncovered Sky to the Detector Total Field of View (green)

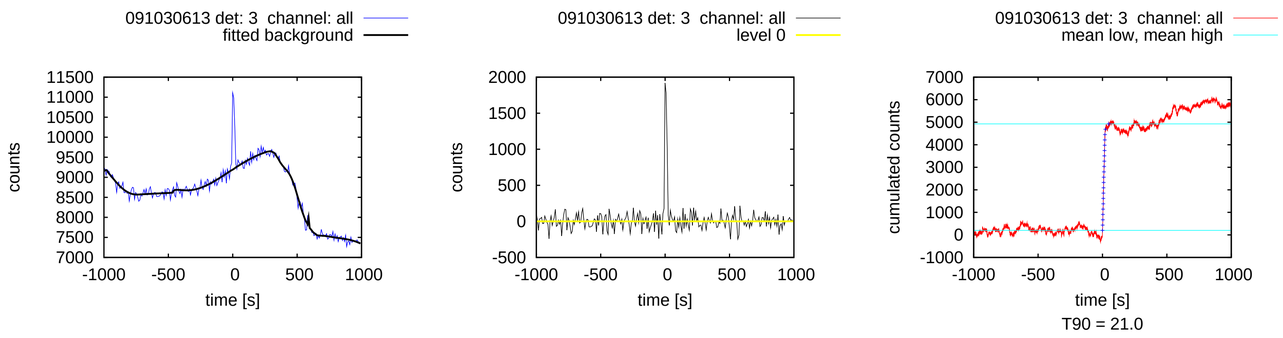
Directions of the 12 NaI detectors' normal vector on the sky (in the second equatorial system), during the pre- and post-1000 seconds around the burst 091030613.

Sun's position: α_S=210.12°, δ_S=-13.00°

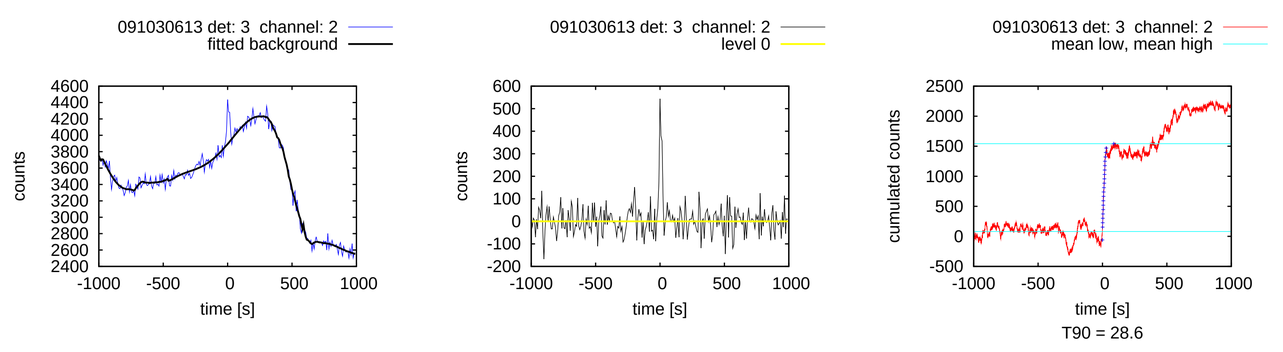
Burst position: α_b=260.72°, δ_b=22.67°



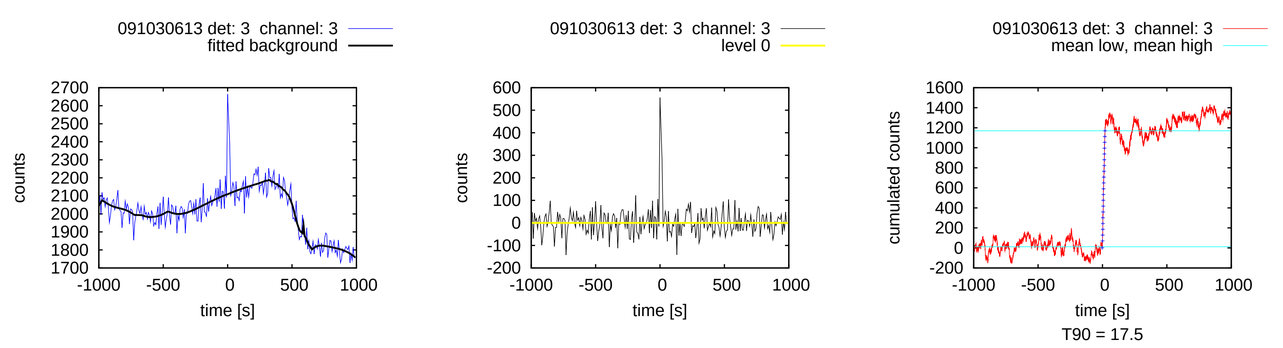
Sum of channels (11.50–982.23 keV)



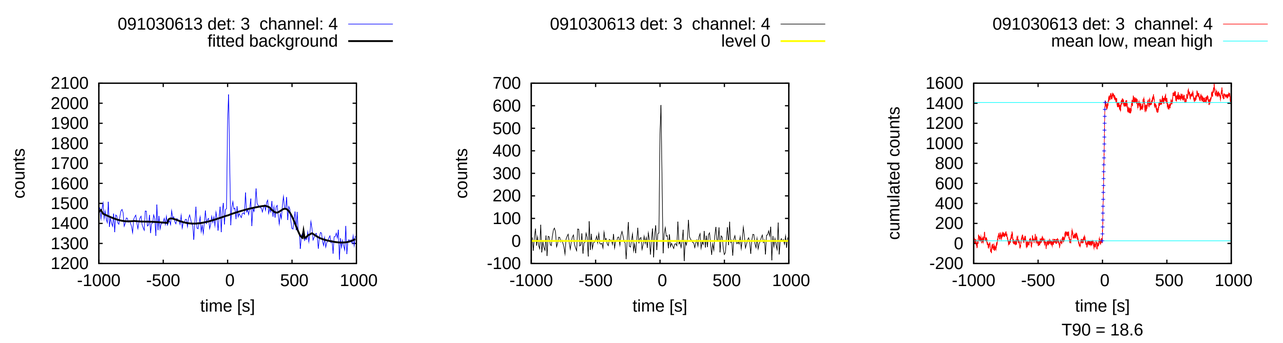
Channel *2* (11.50–26.63 keV)



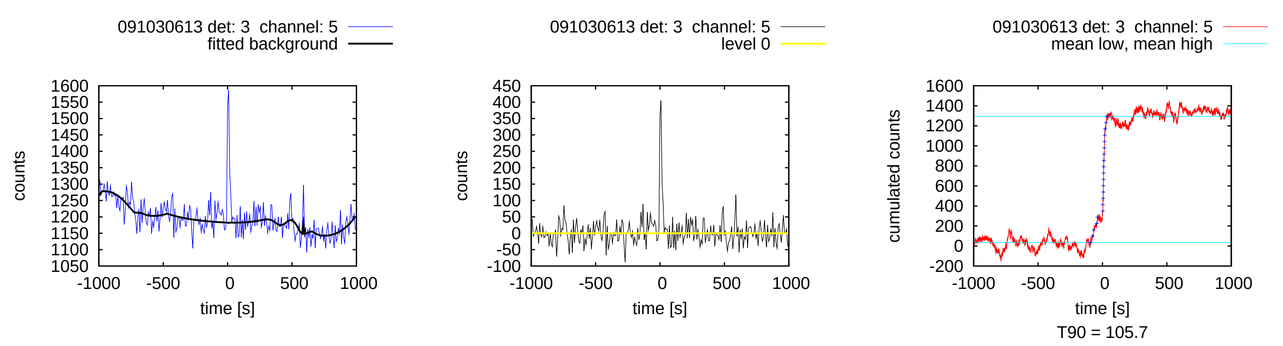
Channel *3* (26.63–50.43 keV)



Channel *4* (50.43–102.38 keV)



Channel *5* (102.39–295.74 keV)



Summary of the method

One only can perform a multitude of analyses of the Fermi data, if there is a satisfying background subtraction [1]. Since in the case of burst 091030613, fitting with a low-order polynomial function of time does not yield a satisfying result [3], we were looking for other variables, which can better describe the varying background.

Using the LAT Spacecraft position files [5], we plotted the actual orientation of the 12 NaI detectors during the burst. One can see how the detectors are 'jumping' all over the sky: this is caused by the fast rotation of the satellite. Considering this behaviour, it is not surprising that the backgrounds of the lightcurves are very complicated to fit.

If one takes a look to the unfiltered lightcurves shown in blue lines in the left column, one can see the burst at T=0 and the varying background. In order to fit and subtract this, we defined three underlying variables (see above) based on the actual position and rotation of the Fermi. Using these, we fitted a 3rd order hypersurface (black line on left hand side) and subtracted from the data (lightcurves in the middle). The following formula was used:

$$surface(x,y,z) = A\cdot x^3 + B\cdot x^2 + C\cdot x + D\cdot y^3 + E\cdot y^2 + F\cdot y + G\cdot z^2 + H\cdot z^2 + I\cdot z + J\cdot x^2\cdot y + K\cdot x\cdot y^2 + L\cdot x^2\cdot z + M\cdot x\cdot z^2 + N\cdot y^2\cdot z + O\cdot y\cdot z^2 + P\cdot x\cdot y\cdot z + Q\cdot x\cdot y + R\cdot x\cdot z + S\cdot y\cdot z + T$$

where x, y and z are the three underlying variables described above, and the capital letters are fitted parameters. Fitting was done by the method of least squares, using `Octave`'s pseudoinvert function [6].

At the right hand side, we plotted cumulated lightcurves and used them to measure duration of the burst (T_{90} written at the bottom of the pictures). Fermi GBM Catalogue reports $T_{90}^{Cat.}$=19.2±0.9 s [4].

Discussion of the results

First of all, we emphasise that we created a Fermi-specific method based on the motion of the satellite, which gave a good model for the background.

Detector '3' and '8' gave trigger sign. We analysed the lightcurves of detector '3'. (On the picture of the sky above, path of detector '3' is shown with black line.) CTIME files contain 8 channels between 4 keV–2000 keV but data of lowest and highest channels contain too much noise. Sum of channels *2*-*7*, and channels *2*, *3*, *4*, and *5* were plotted.

Sum of the channels give us a T_{90}^{Sum}=21.0 s, which we can take as our final result for the duration of this burst. However, there is no phisical evidence that a GRB has the same duration in every energy range, as the lightcurves of the different channels suggest (T_{90}^{3}=17.5 s and T_{90}^{4}=18.6 s). Furthermore, channels *2* and *5* show some strong deviation from the T_{90}^{Sum}, probably because of a higher level of noise.

Channel *4* contains the highest rate of counts, and here our result (T_{90}^{4}=18.6) is consistent with the Fermi GBM Catalogue within the error limits.

References

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