Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008

Vol. 3 (OG part 2), pages 1155–1158

Gamma-Ray Burst observation with GLAST

F. PIRON[1], ON BEHALF OF THE GLAST LAT COLLABORATION
[1]*LPTA, Université Montpellier 2, CNRS/IN2P3, Montpellier, France*
piron@lpta.in2p3.fr

Abstract: The GLAST Large Area Telescope (LAT) is the next generation satellite experiment for high-energy gamma-ray astronomy. It is a pair conversion telescope built with a plastic anticoincidence shield, a segmented CsI electromagnetic calorimeter, and the largest silicon strip tracker ever built. It will cover the energy range from 20 MeV to more than 300 GeV, shedding light on many issues left open by its predecessor EGRET. One of the most exciting science topics is the detection and observation of gamma-ray bursts (GRBs). Here we present the work done so far by the GRB LAT science group in studying the performance of the LAT detector to observe GRBs. We report on the simulation framework developed by the group and on the science tools dedicated to GRB data analysis. We present the LAT sensitivity to GRBs obtained with such simulations, as well as the general scheme of GRB detection that will be adopted on orbit.

Introduction

GLAST [1] [2] is an international mission that will study the gamma-ray Universe. The heart of GLAST is the Large Area Telescope (LAT) [3], a pair production telescope sensitive to gamma rays in the energy range from 20 MeV to 300 GeV and above. The LAT is an array of 4×4 identical towers, each made by a tracker of silicon strip planes with slabs of tungsten converter, followed by a hodoscopic calorimeter. The array of towers is surrounded by an anticoincidence detector which identifies charged cosmic rays. The LAT energy range, effective area, field-of-view (FoV) and angular resolution [4] are vastly improved in comparison with those of its highly-successful predecessor EGRET (1991–2000), so that the LAT will provide a factor 30 or more advance in sensitivity. This improvement should enable the detection of several thousands of new high-energy sources and allow the study of GRBs.

The second detector onboard the GLAST satellite is the GLAST Burst Monitor (GBM) [5], which consists of twelve NaI detectors (10 keV to 1 MeV) and two BGO detectors (150 keV to 30 MeV). It covers the entire visible sky not occulted by the Earth, and it is designed to tie the unknown high-energy emission observed by the LAT to the better known region between 10 keV and 30 MeV, where most of the GRB emission takes place. GBM and LAT data will be jointly fitted providing spectral information over more than seven energy decades.

Gamma-Ray Bursts and GLAST

GRBs are still a puzzling topic and few observations are nowadays available above 100 MeV. EGRET sensitivity to GRBs was limited by its low effective area above 1 GeV and its large deadtime. It detected only a few high-energy bursts [6], and did not detect the high-energy cutoff that must exist for some hard spectra to keep the energy flux finite. Surprisingly, GeV emission was found to last up to 90 minutes after the burst in GRB940217 [7], and an extra spectral component was observed at 100 MeV in GRB941017 [8].

GLAST will make a real breakthrough in the observation of GRBs. In the first year it will operate in scanning mode most of the time, providing uniform full sky coverage every three hours. Starting from the second year of operations, and depending on the Guest Investigator program, GLAST may also be used in pointing mode. In case of intense burst, it will also be able to repoint in order to maintain the celestial source in the LAT FoV during the prompt emission phase or to search for delayed emission.

The GBM and LAT will independently trigger on GRBs: the first on a rapid increase of the count rate, and the second considering spatial and temporal clustering of counts. The GBM threshold flux in the 50–300 keV range, along the LAT axis, is 0.8 s^{-1} cm^{-2}. Assuming a BATSE-like population of bursts, this implies that the GBM will detect 200 bursts per year, of which more than 60 will fall in the 2.4 sr FoV of the LAT, allowing joint observations. In case of a GRB trigger, an alert message will be sent to ground in near real-time via TDRSS (a communication satellite system). This will provide basic information for follow-up observations. The initial on-board GBM localization error will be less than 15° (within 2 s). Updates will come later, reducing this error box down to 3° for a bright burst. The LAT detector can provide better accuracy, of the order of 10 arcmin or less, depending on the burst intensity. A full downlink of all the data will be performed via TDRSS $\sim$6 times a day and the scientific data, after a first analysis done by the LAT collaboration, will be delivered to the user community (LAT event data will be public after the first year of scientific operations). GLAST will also cooperate with other space telescopes (like Swift [9]) in studying bursts. As an example, simple computations show that 20 Swift-detected GRBs per year will also be in the LAT FoV.

LAT sensitivity to GRBs

To study the performance of the LAT in observing GRBs, we have set up a full simulation chain that starts from a detailed description of the sky, and adopts either a full Monte Carlo simulation of the instrument (by propagating every single particle through the different materials of the detector), or a fast science simulator which uses a parameterized description of the instrument for processing the incoming fluxes. Since the LAT sensitivity to GRBs strongly depends on their high-energy emission where little is known, we have developed different models, two of which are described in the following.

Phenomenological model

In the phenomenological description of GRBs, the emission at LAT energies is obtained by extrapolating the spectrum from the BATSE region (see, e.g., Fig. 1). For each simulated burst the duration is drawn from the observed T90 distribution and its flux is sampled from the BATSE peak flux distribution in the 50–300 keV energy range. Each burst has a spectrum described by the Band function [10], where the peak energy $E_{\rm p}$ and the low and high-energy spectral indices α and β are sampled from the observed distributions [11]. The light curve of the GRBs are obtained by adding many pulses (until the duration of the burst is in agreement with the sampled T90 parameter). Each pulse is described by a universal family of functions, and we extrapolated the so called “pulse paradigm” [12][13], for which the width of the pulses scales with the energy of the light curve as $E^{-0.4}$. Short and long bursts are treated separately so that the observed hardness-duration correlation is reproduced.

In order to compute the sensitivity of the LAT detector to GRBs, we simulated one year of observation in scanning mode, assuming a burst rate of 650 per year (full sky). The orbit of the GLAST satellite, the passages through the South Atlantic Anomaly and the Earth occultations were considered. The observed energy, direction and detection probability were computed for each simulated burst photon, by taking into account the instrument response functions. These quantities were used to estimate the number of photons that would be detected by the LAT detector. At high energies ($>$10 GeV), it is also important to consider the attenuation of the flux due to the interaction of burst photons with the optical-UV photons of the extragalactic background light (EBL). We included this effect in the simulation, adopting the EBL model proposed by [14] and assuming the long burst redshift distribution from [15] and the short burst distribution from [16].

Fig. 2 shows the number of expected bursts per year as a function of the number of photons per burst detected by the LAT. Different lines refer to different energy thresholds. The EBL attenuation affects only the high-energy curve, as expected from the theory, leaving almost unchanged the sen-

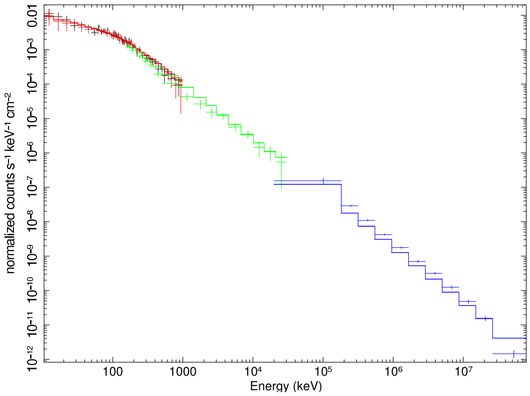

Figure 1: Data (points with error bars) and folded model (lines) for a simulated GRB described by a single Band function. Shown in red and black are the GBM/NaI detectors, in green the GBM/BGO detector and in blue the LAT.

sitivities for thresholds less than 10 GeV. In this calculation, the LAT will independently detect 50–70 bursts per year, depending on the sensitivity of the detection algorithm. A few bursts per month will give more than a hundred counts in the LAT detector: these are the bursts for which a detailed spectral or even time resolved spectral analysis will be possible. Finally, a few bursts per year will show high-energy prompt emission with photons above 50 GeV.

Physical model

We have also developed a physical model based on the internal shock scenario [17]. In this framework GRB spectra are obtained by synchrotron radiation of shock accelerated particles in relativistically expanding emitting shells. Additional high-energy radiation can be also emitted by inverse Compton scattering (self synchrotron Compton), with a flux and a maximal energy limited by internal absorption due to pair attenuation [18]. For these models, the synthetic spectrum is stored as a two dimensional histogram of count rate as a function of time and energy, and is used to sample photons that are then sent to the simulator of the LAT instrument. As for the phenomenological model, the output files have the same data-structure of the "real" level 1 data which will be available to the community when GLAST will be on-orbit. Output data files are also produced for the GBM instrument and can be used for joint analysis (see, e.g., Fig. 3 and [19]). The sensitivity of the LAT to these models was evaluated as a function of the ratio of inverse Compton to synchrotron power outputs (Fig. 4). The LAT will be able to detect prompt emission from tens of GRB per year, and some of these detected bursts will have enough photons to be suitable for spectral analysis.

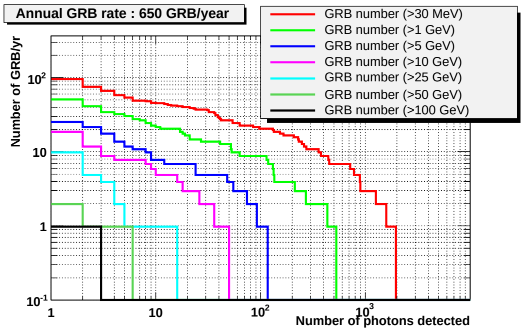

Figure 2: Model-dependent LAT sensitivity to GRBs. The GRB spectrum is extrapolated from BATSE to LAT energies. The burst rate in the 4π sphere is assumed to be 650 GRB/yr, in agreement with BATSE statistics. The effect of the EBL absorption is included. Different curves refer to different energy thresholds.

Conclusion

GLAST is now fully integrated and the launch is scheduled in late 2007. It has the unique capabilities in observing GRBs from tens of keV up to hundreds of GeV, providing a broad spectral coverage and connecting the known part of the GRB spectra to the previously unobserved high-energy region. The phenomenological and physical approaches for GRB high-energy modelling, which were used to estimate the LAT sensitivity, show that a few to tens of well detected bursts are expected per year in the LAT energy range, where many features can increase our understanding of the phenomena. In GRBs, magnetic fields are supposed to be very intense, and relativistic accelerated particles loose energy via synchrotron radia-

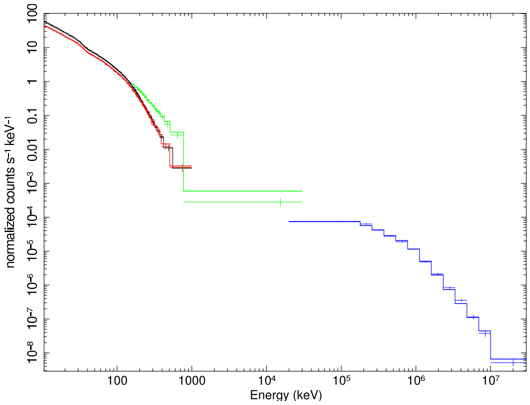

Figure 3: Data (points with error bars) and folded model (lines) for a simulated GRB with inverse Compton component. Shown in red and black are the GBM/NaI detectors, in green the GBM/BGO detector and in blue the LAT.

tion. Due to the intense cooling, the high-energy cut-off of the synchrotron spectrum is in the GeV energy range. In addition, if inverse Compton emission takes place, then GLAST will the first the mission able to study it in detail.

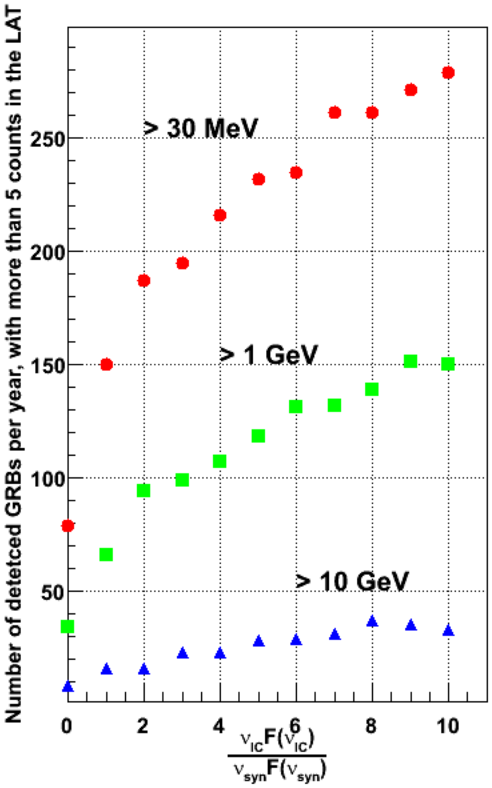

Figure 4: LAT sensitivity to GRBs for a self synchrotron Compton model as a function of the ratio of inverse Compton to synchroton power outputs. Different curves refer to different energy thresholds.

References

[1] J. E. McEnery, The GLAST mission, in: these proceedings.
[2] G. web site, http://glast.gsfc.nasa.gov.
[3] J. Cohen-Tanugi, GLAST Large Area Telescope: Design and Science Prospects, in: these proceedings.
[4] L. web site, http://www-glast.stanford.edu.
[5] C. A. Meegan et al., The GLAST Burst Monitor, in: Proc. of the first GLAST Symposium (2007).
[6] B. L. Dingus et al., Astrophys. and Space Sci. 231, 187 (1995).
[7] K. Hurley et al., Nature 372, 653 (1994).
[8] M. M. Gonzalez et al., Nature 424, 749 (2003).
[9] N. Gehrels et al., ApJ 611, 1005 (2004).
[10] D. Band et al., ApJ 413, 281 (1993).
[11] R. D. Preece et al., ApJSS 126, 19 (2000).
[12] J. P. Norris et al., ApJ 459, 393 (1996).
[13] E. E. Fenimore et al., ApJ 448, L101, (1995).
[14] T. M. Kneiske et al., Astron. and Astrophys. 413, 807 (2004).
[15] C. Porciani, P. Madau, ApJ 548, 522 (2001).
[16] D. Guetta, T. Piran, Astron. and Astrophys. 435, 421 (2005).
[17] T. Piran, Phys. Rep. 314, 57 (1999).
[18] J. Cohen-Tanugi, J. Granot, E. do Couto e Silva, Opacity Build-up in Impulsive Relativistic Sources, in: these proceedings.
[19] N. Komin, F. Piron, The potential of GLAST in observing features in the high-energy spectra of GRBs, in: these proceedings.