The GLAST Burst Monitor (GBM)

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Abstract. The selection of the GLAST burst monitor (GBM) by NASA will allow the investigation of the relation between the keV and the MeV-GeV emission from γ-ray bursts. The GBM consists of 12 NaI and 2 BGO crystals allowing a continuous measurement of the energy spectra of γ-ray bursts from ~ 5 keV to ~ 30 MeV. One feature of the GBM is its high time resolution for time-resolved γ-ray spectroscopy. Moreover the arrangement of the NaI-crystals allows a rapid on-board location ($< 15°$) of a γ-ray burst within a FoV of ~ 8.6 sr. This position will be communicated to the main instrument of GLAST making follow-up observations at high energies possible.

1 Introduction

It was in 1994 that EGRET observed a γ-ray burst which showed a γ-ray emission above 50 MeV up to $\sim$1.5 hours after the start of the burst. The γ-quantum with the highest energy was observed after $\sim$1.3 hours with an energy of 18 GeV [4]. This was an unexpected and very surprising result and as of yet the relation between this high-energy and the low-energy emission is not understood. It is a goal of the GLAST mission to investigate this relation and to unravel the underlying physical processes.

2 Characteristics of energy spectra of γ-ray bursts

A typical spectrum of a γ-ray burst is characterized by a broken power law (see Figure 1). Below a certain break energy E_{p} the spectrum can be described by a power law E^{α} with an exponential decline, whereas above this energy it is a pure power law E^{β} indicating a non-thermal origin of this part of the spectrum. The break-energy E_{p} at which the luminosity reaches a maximum has a log-normal distribution around an energy of 250 keV [5]. In order to determine E_{p} well enough one needs a long lever arm on both sides of this energy, accentuating the importance of low- and high-energy measurements.

The spectral index α of the low-energy emission is distributed around a value of -1 spanning the range from -2 to 0. This distribution strongly constrains popular burst-emission models like the synchrotron emission from shocked electrons ([7] and [6]) or the blast-wave model [2] strongly. The distribution of the spectral index β of the high-energy emission reaches a maximum around -2.3. It extends
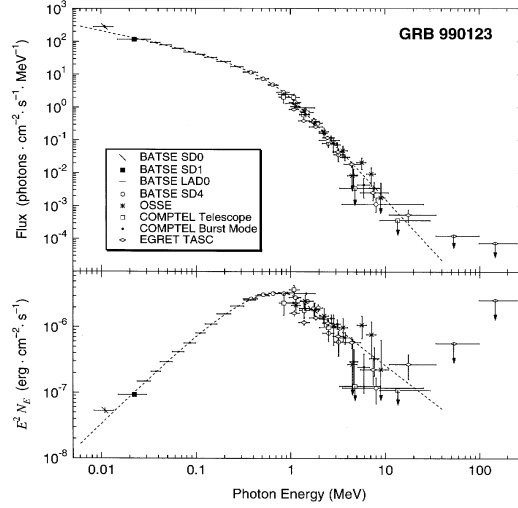
Fig. 1. The energy spectrum of GRB990123

from -3.5 to -1.4 [5]. The spectra with β-values >-2 are of special interest because in this case the spectrum would diverge for E $\rightarrow \infty$. Therefore a cut off at high energies must exist. An interersting question which will be answered by GLAST is, at which energy this cutoff occurs.

3   The GLAST mission

GLAST will continue the successful measurements of EGRET in a wider energy range, with a higher sensitivity and with a better location accuracy. Its main instrument, the Large-Area Telescope (LAT), will use the same physical processes as EGRET for the detection of γ-rays, but using an advanced technical concept. It will consist of an array of towers of pair-conversion chamber stacks made from Silicon-strip detectors.

The LAT measures γ-rays in the energy range $\sim$15 MeV to $\sim$500 GeV, reaching a point-source sensitivity of better than $4 \cdot 10^{-9}$ photons/(cm^2 s) above 100 MeV for an observation time of one year. It will therefore be more than 30 times more sensitive than EGRET. Within its large FoV of <3 sr it will locate point sources from 5' down to 30". With its fairly good energy resolution of $\sim$10% it will measure the energy spectra of sources with a high accuracy. The LAT is devoted to the study of particle acceleration in the universe as it takes place in the nuclei of active galaxies, at or near pulsars, in supernova remnants and in interactions of the cosmic rays with the interstellar matter. In addition, it will detect $\sim$50–150 γ-ray bursts per year. For a description of GLAST see [3].

From the latter measurements it is hoped to solve the afore-mentioned problem of the high-energy burst emission. However, the LAT suffers from some

deficiencies because high-energy measurements alone do not allow a unique classification of γ-ray bursts, because the break energy E_{p} of a burst lies below GLAST's energy threshold of $\sim$15 MeV. Therefore without low-energy measurements a classification of the bursts is difficult, since most bursts were measured by BATSE at these energies and the connection to the BATSE data archive cannot be established. Another deficiency is that the trigger conditions of the LAT for weak bursts are unfavourable because of the rather high background rate. In order to overcome these deficiencies a secondary instrument was proposed, the GBM. It will extend the energy range of GLAST towards lower energies and it will have a much larger FoV than the LAT. Therefore it will detect more bursts than this instrument. The GBM will communicate the positions of these bursts to the LAT which then will, after reorientation if needed, search for high-energy γ-rays. Moreover, for weak bursts the LAT will use GBM-provided information to reduce background by eliminating events with directions far frm the GBM burst location.

4   Description of the GBM and its performance

The goals of the GBM described above can be achieved by an arrangement of 12 thin NaI discs which are oriented such that from the relative count rates the direction to the burst can be derived (KONUS/BATSE principle). They will in addition measure the burst spectra in the energy range 5 keV - 1 MeV.

In order to obtain spectral overlap with the LAT, two cylindrical BGO crystals will be mounted to the GLAST spacecraft which are sensitive to γ-rays in the energy range from 150 keV - 30 MeV. A more detailed description of the GBM can be found in [8]. Within the large FoV of $\sim$8.6 sr $\sim$215 bursts/year will be detected by the GBM. Most of them will be located on board in real time with an accuracy $<$ 15°. On ground much better locations ($\sim$3°) can be derived. The 50–300 keV sensitivity for nominal on-board triggers will be $\sim$0.6 photons/(cm^2 s), whereas an ultimate 5σ sensitivity of $\sim$0.35 photons/(cm^2 s) can be achieved on ground.

5   Scientific goals and expected results

With the GBM continuous measurements of energy spectra from $\sim$5 keV to $\sim$30 MeV will be performed. Apart from spectra also the light curves of bursts will be recorded with a time resolution in the μs-range. The GBM will serve as a sensitive burst trigger for the LAT and will communicate very rapidly ($<$5 s) the burst location to it. This trigger will initialize data-reduction modes in the LAT which will then observe the burst and localize it with a much better accuracy ($<$3'). This precise location will be communicated within less than 10 s to ground in order to allow a search for objects at other wavelengths. The burst data collected by the GBM will preserve the continuity to the BATSE data and enlarge this important archive. Moreover the GBM will be part of the IPN as a near-earth burst detector.
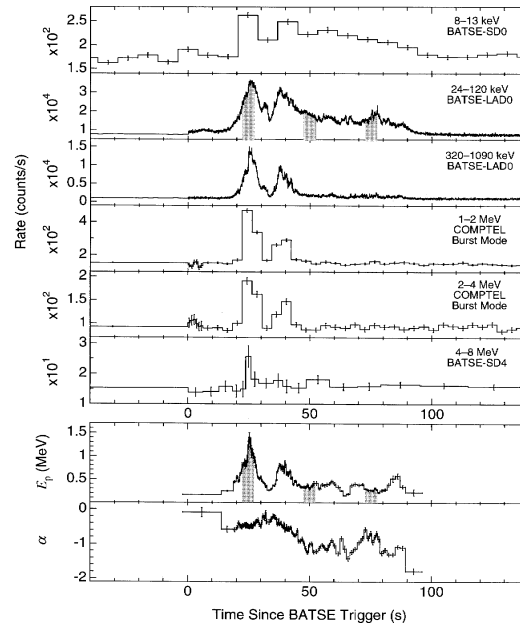
Fig. 2. The energy-resolved light curves of GRB990123 and the evolution of E_p and α

With the GBM the relation between the keV-MeV-GeV emission can be investigated in great detail. Time-resolved energy spectra will be measured allowing time-resolved spectroscopy (see Figure 2 of [1]). This permits the investigation of the hard-to-soft evolution of the power-law index α and the hardness-intensity correlation and tackles the problem of the narrowing of the peaks with energy. It may also give an answer to the question why the low-energy emission lasts longer than the high-energy one. Together with the LAT it will be possible to investigate these correlations to high energies with the aim to measure the suspected cutoff and to find a possible evolution of the spectral index β.

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