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Gamma-ray bursts observed by HETE-2

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Abstract. HETE-2 satellite dedicated to observations of Gamma-ray Bursts (GRB) has recorded between years 2001 and 2006 hundreds of events and localized 84 with a precision of several arc-minutes and a delay better than 1 minute. Low threshold of HETE-2 instruments made HETE-2 especially adapted for detection of bursts of X-ray rich (XRR) type and X-ray flashes (XRF) as well as for study of "soft" part of their spectra in general. We have contributed to the final version of the catalogue and contibuted by following statistical studies of the events.

1. Introduction

High Energy Transient Explorer (HETE) II was an "university class" mission whose active lifetime spanned between 2001 and 2006, covering period between major GRB-devoted experiments, BATSE and Swift. Devoted to the monitoring of (a large part of) the sky and without a fast-repointing capability, it was equipped only with wide-field instruments, 2 of them (based on coded-mask technique) allowing position reconstruction of a transient source. The localization precision varied with position within the field-of-view, for on-axis bright events being 19 arcmin for Wide X-ray Monitor (WXM, Nakagawa et al. (2005)) and 0.7 arcmin for a smaller Soft X-ray Camera (SXC). The most sensitive device, FREGATE (French Gamma-ray Telescope, Atteia et al. (2003)), integrated signal from its large 3 sterad field of view (not being able to distinguish between photons arriving from different directions), the feature that resulted in a rather high (and, more importantly, variable) background that complicated reconstruction of the lightcurve parameters. This detector was the principal source of the trigger for HETE (in a few percent of cases the trigger comes from WXM). On-board localization from WXM was sent through a network of ground stations distributed along the satellite's equatorial orbit. Refined positions from off-board calculation followed as update alerts sent into a Gamma-Ray Burst Coordination Network (see `http://gcn.gsfc.nasa.gov/`). Out of 173 bursts two thirds were localized within 1 hour, an important achievement especially in the pre-Swift era, that gained HETE-II good response from the community of optical observers. About 9 percent of the localizations came from the Inter-Planetary Network triangulation.

First GRB localized by HETE was GRB021211 – at coordinates sent only 33 sec. after trigger was found an optical transient (OT) 53 minutes later. One of the historical records of HETE was GRB050709, when the optical counterpart of a short burst[1] was

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[1] GRB with T90 duration less than 2 sec

detected for the first time. HETE fast localization capacity also allowed capturing optical transients that fell rapidly below observation limits and to clarify the fact that many GRBs considered to be optically dark were in fact only optically dim events. HETE pointing direction was almost exclusively anti-solar (constrained naturaly by a fixed position of its solar panels) which helped ground observers by maximizing the probability the OT will occur in night time.

In comparision with BATSE GRB set the trigger of HETE seems to favorize softer events. In the catalogue of HETE bursts appears well populated categories of X-ray flashes (XRF) and X-ray rich bursts (XRR) using the definition from Sakamoto et al. (2005) based on the hardness ratio. However, the distribution of parameters calculated for bursts in these categories join smoothly to those of normal GRBs; these softer events are continuous extension of the older BATSE set.

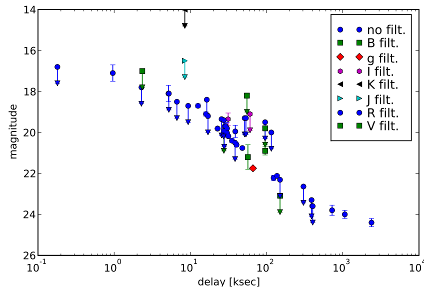

Fig. 1. One of the richer sets of observations of the optical transient comming after HETE GRB 041006. The decrease of the brightness is exponential with typical achromatic breaks (change of slope at the same time for different colours).

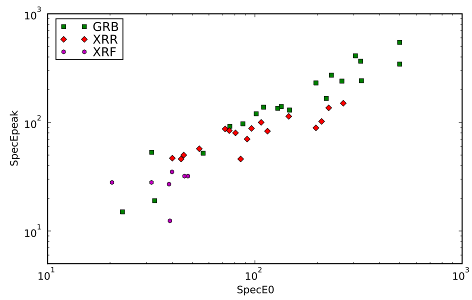

Fig. 2. Correlation of two parameters – total energy and position of peak energy (in keV) in observer's frame – obtained from spectral fitting of a subset of bursts. We are labeling different classes of bursts: 7 XRFs by circles, 18 XRRs by diamonds and 20 "normal" GRBs by squares.

2. Catalogue

We have based our work on a set of 284 HETE records (some were later proven to be false events, caused for example by an emmersion or immersion of a bright source behind the Earth's limb). Some of them were also due to recurrent sources such as X-ray Bursts and Soft Gamma-ray Repeaters. Out of the total of 250 confirmed GRBs we have obtained lightcurves from FREGATE for 184 of them, and localized position from WXM for cca. 150 bursts (the instrument has masks coded separately in the X and Y direction; sometimes only one of the coordinates was reconstructed successfuly).

The analysis was independently performed by three groups (in France, USA and Japan) of the collaboration[2]. The results were summarized in up to 160 numbers per burst, that form the core of the HETE catalogue (currently available for internal use of HETE team). First version was published in Vanderspek et al. (2004), the presentation of its complete version is still in preparation. Meanwhile we have worked on an user-friendly web interface to the dataset that will allow plotting different correlations (see fig. 2) of the values therein, or showing densities of bursts in different parts of the parameter plane (see fig. 3). Moreower we can display lightcurves of the prompt emission where available (with optional visualisation of results of our further analysis, as described below).

Divided into three burst categories defined above, number of XRFs in the dataset is 28, 34 XRRs and the rest is 194 "normal" GRBs.

The catalogue content was supplemented with data from optical observations of afterglows. The magnitudes in different optical fil-

[2] For detailed list see `http://space.mit.edu/HETE/institutions.html`.

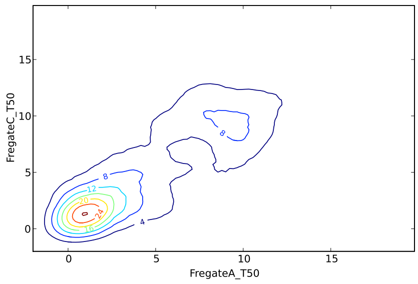

Fig. 3. Concentration of bursts in a plane defined by 2 estimated values of T50 (middle time interval covering 50% of fluence.) in 2 FREGATE spectral bands (A: 7−40, C: 30−400 keV). Time is in seconds.

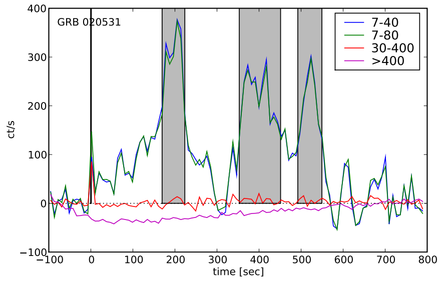

Fig. 4. Sample lightcurve from FREGATE for GRB 020531 with subtracted background and demarked peak intervals.

ters (or at least their upper limits) were collected from GCN notices and the literature by GRBlog web service (`http://grblog.org/`) – we included this data in our database. Fig. 1 shows an example of afterglow observations of GRB 041006.

3. Prompt emission

Data recorded by FREGATE are binned in 4 standard channels: 7−40, 7−80, 30−400 and >400 keV. This wide spectral coverage (much better than e.g. for BAT instrument of Swift) is further extended by WXM data measuring X-ray flux between 2 and 25 keV (which overlaps with the effective detection range for SXC 2−10 keV). The lightcurve in FREGATE bands seems to be more structured than the soft X-ray counterpart – we focused on the former data in the search of separated peaks in the lightcurves of the prompt emission.

Another reason for this investigation was the fact that standard parameters used to characterize the prompt emission were sensitive to errors in the estimation of background level. It often varied non-linearly on the timescale of hundreds of seconds while estimations of the fluence or of the length of the burst like T90 (an interval between registering 5 and 95 of the total fluence in the given energy band) vary significantly with the choice of the background profile. Localization of separated peaks in the lightcurve allows identification of the precursors, different phases of the prompt emission and to determine more properly intervals where background level can be estimated. An example of one lightcurve with selected peak intervals is given in fig. 4.

In more detailed studies of peak positions presented in Munz et al. (2008) we found a hint of an increase of a time lag between two FREGATE spectral bands during burst prompt emission. No regularity was found for the change of hardness ratio for earlier and later peaks in the lightcurve.

4. Conclusion

The original HETE-2 catalog is a set of 256 records, 188 triggered and 68 untriggered ones, all detected by the same instruments. It provides a valuable data set for statistical studies, in particular because of the low energy threshold.

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