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Statistics of HETE-2 gamma ray bursts

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Abstract. Between the years 2000 and 2006 HETE-2 detected several hundreds GRBs and localized 84 of them, with a precision even as low as few arcminutes and a delay even of only one minute. The low energy threshold of the instruments made HETE-2 particularly apt for detecting X-Ray Flashes and X-Ray Rich GRBs and for the study of the low part of the energy spectrum in general. We shall report on some preliminary statistical studies of the HETE-2 events.

Key words. experiment: HETE-2 – gamma-ray bursts – X-ray flashes

1. Introduction

HETE-2 (Ricker et al. 2003) was an international satellite mission devoted to the detection and localization of gamma-ray bursts by using 3 wide-field instruments with a total spectral coverage from 2 to 400 keV. The trigger was performed by the gamma-ray detector FREGATE (Atteia et al. 2003) with the largest FoV ($\tilde{3}$ srad) and the highest sensitivity (3×10^{-8} erg cm$^{-2}s^{-1}$) but no imaging capability. The burst position was obtained by the lower-energy coded-mask detectors Wide-field X-ray Monitor (WXM, Nakagawa et al. 2005), with a precision of $5\sim 10'$, and, when possible, by the Soft X-ray Camera (SXC) with smaller detection area and FoV but finer localization. The experiment was dedicated to the detection of GRBs, XRFs and SGRs. It also detected a large number of X-ray bursts (Nakagawa et al. 2004). With a total mass of only 123 kg the re-pointing capability was limited. Therefore for most of the time no observation plan was adopted and the satellite pointing was in the anti-solar direction, which maximized the possibility of optical followup.

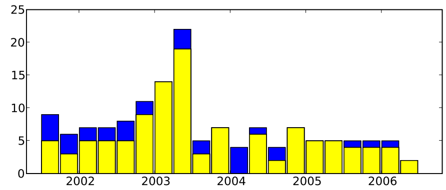

Fig. 1. Number of bursts detected (in bins of three month) by HETE-2. Light part of the bars shows the number of localized bursts.

Prompt alerts (mostly GRBs) were possible thanks to a network of 3 primary and 11 secondary ground stations distributed along the earth's equator: in total 1292 GCN alerts[1] were issued concerning 176 events, out of which 145 were localized (including non-GRB sources). Another advantage of the equatorial orbit of HETE-2 (hence on simply HETE) was its quite

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[1] Available at http://gcn.gsfc.nasa.gov/.

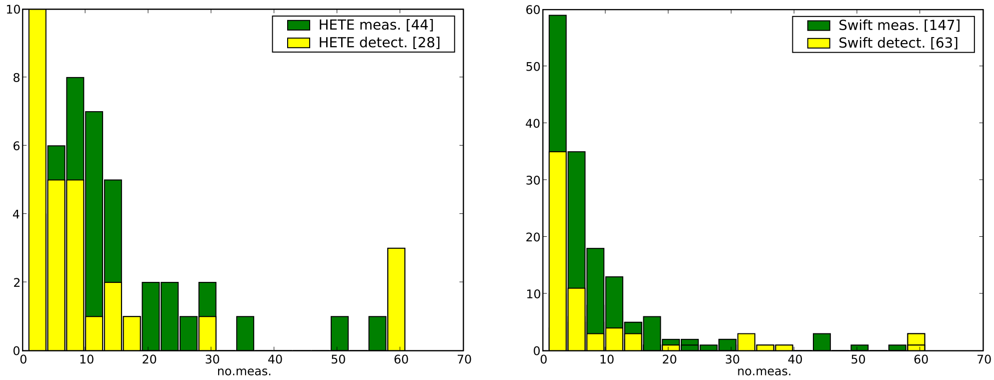

Fig. 2. Statistics of optical afterglows: number of measurements – including upper limits (dark) – and positive detections only (light) per burst for triggers by HETE-2 and Swift (as counted until end 2007). The average number of measured optical afterglow values per GRB is 8.4 (4.7 detections) for HETE bursts, 5.2 (2.1 det.) for Swift bursts.

low particle background; variations of the detector countrate were also related to the occultation of bright sources within the field-of-view. Fig. 1 gives the evolution of number of GRBs detected during HETE lifetime.

As demonstrated in fig. 2, the HETE sample of bursts can boast of a significantly better followup than a wider sample of 224 bursts detected by Swift satellite until the end of 2007. This is partly due to the optical-friendly pointing strategy of HETE, partly to the much lower cadence of GRB detection that left considerably longer time to ground-based observers to focus on a given event. The record burst in this respect is the famous GRB 030329 with 690 measurements (counting basically those from GCNs) that definitely confirmed the connection of GRBs and supernovae (first suggested by GRB 980425 and SN 1998bw). An important point is also the fast localization capacity of HETE and rapid distribution of position alerts, as can be deduced from fig. 3.

2. The catalog

Starting point for our work is the preliminary version of a catalog (Vanderspek et al. 2004, 2008) tabulating values obtained with standard analysis procedures performed on-board or during off-line reconstruction by hardware and software teams.[2] It consists of up to 160 parameters per burst; we are trying to look for possible outliers in the parameter space to pick-out peculiar events.

Most detailed primary information comes from FREGATE (and sometimes WXM) light-curves available in ASCII format on internal HETE repository giving evolution during a few hundred seconds before and after the trigger. A longer period of gamma-ray time histories can be obtained (with low sampling rate) from house-keeping data available as FITS files in NASA legacy archive.

We also tried to collect all available secondary data for each of HETE bursts, especially the GCNs and publications of optical followup, which data are essential for extraction of physical parameters. In the original catalog 20 GRBs have measured redshift and 70 estimated pseudoredshift (Pélangeon et al. 2006). In 2/3 of cases the difference of pseudo-Z and the measured one is smaller than 0.6.

2.1. Light-curves

We give here an example of the problems arising from our analysis of the prompt emission.

[2] Find team listing at `http://space.mit.edu/HETE/institutions.html`.

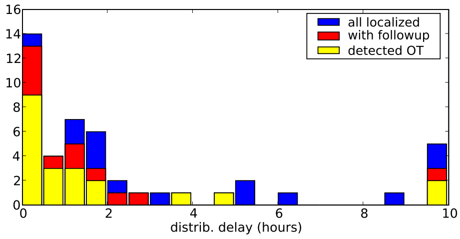

Fig. 3. Delay of distribution of first positional information of HETE bursts, lighter bars showing fraction of those that were followed optically and those with detected optical afterglow.

Usual analysis bands of FREGATE data are 7−40 (marked A), 7−80 (B), 30−400 (C) and above 400 keV. The sampling time is of the order of 0.1 s, usually a re-binning by a factor of 10 or so is necessary before reaching S/N sufficient for bin-to-bin analysis.

The basic task of verification of catalog values of the principal parameters, such as fluence or T90 in these bands proved to be much complicated by the very variable nature of the background, since even a small shift in its level brings about a big error in signal counts and in consequence in burst boundary estimates. The linear interpolation of trends estimated on both sides often was not sufficient and a higher order polynomial was fitted using also some values in between. In fact quite often one observes series of peaks separated by an interval of low or no activity (as on fig. 4). This behavior is hardly sufficiently described by T90/T50 parameters – instead we identify these (multi-)peak regions in the lightcurve and extract their (binning independent) parameters. Since this identification is done in all bands independently, we proceed with cross-matching of these "peaks" in different energy regions (although the standard working bands of FREGATE are overlapping). This finally allows us to estimate the time lags or hardness ratios and their changes during the prompt phase. Important point is that only the peak boundaries are stored and an update of, e.g., the background subtraction allows to correct the peak parameters immediately.

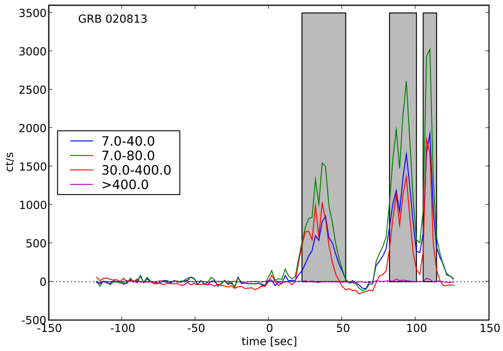

Fig. 4. Example of a (rebinned) lightcurve in FREGATE bands of GRB 020813. The measurement was interrupted soon after the burst (which triggered some 30 sec before the main components); in this case the background estimation can be based on pre-burst values only and its slope is evidently not yet correct.

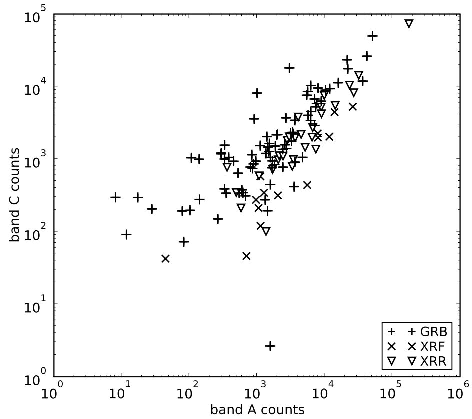

Fig. 5. Relation between the counts recorded in spectral bands A (7−40 keV) and C (40−300 keV) of FREGATE for 3 classes of burst events in HETE catalog.

3. Correlations

The catalog shall provide an easy way to correlate different burst parameters and derived quantities stored in the catalog. They can be plotted as simple scatter plots or a contours of *kernel density estimators*. Fig. 5 shows one example of the former, in which the comparison

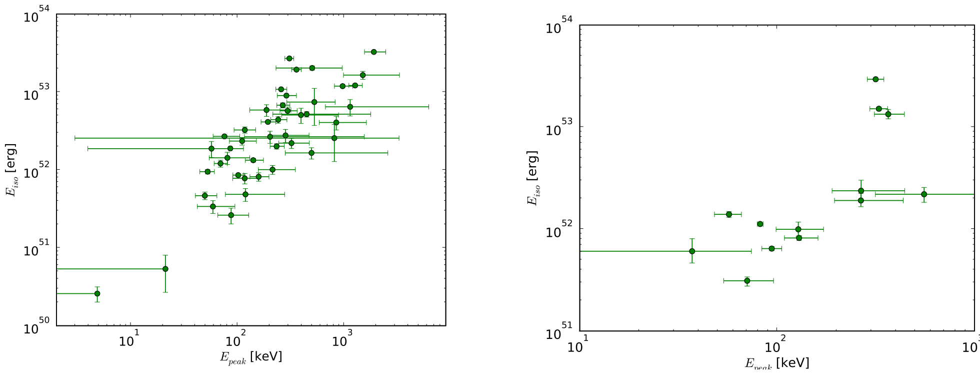

Fig. 6. Correlation of redshift corrected peak energy (in keV) and E_{iso} (using H=75, Ω_M=0.3, in ergs); left – using pseudoredshift for 44 bursts from HETE catalog, right – using measured redshift for 13 bursts.

of counts in lower and higher spectral bands of HETE corresponds to the classification of bursts as GRBs, X-ray flashes (XRFs) and X-Ray Rich bursts (XRRs).

Concerning the prompt emission, in 69 cases the FREGATE spectrum is fitted with one of 3 basic models (power-law with and without exponential cut-off and Band function Barraud et al. 2003; Sakamoto et al. 2005). Based on these fits, and the position of the source within the FoV, one can convert instrumental fluxes into the physical ones. The case of WXM is much more complicated and the absolute calibration requires basically to construct a special response matrix for each burst individually.

By using the spectral and redshift information the classical Amati relation (Amati et al. 2002) was extended towards lower energies thanks to the wide energy coverage of HETE instruments (fig. 6).

4. Conclusions

HETE bursts represent a unique sample of GRBs and XRFs with wide spectral coverage of prompt emission and a rich set of optical followup. We are currently in a process of verification of the information obtained for each of the detected bursts and development of an easily accessible interface to the whole catalog. The availability of a large number of parameters estimated from the prompt GRB measurements and of the information derived from published follow-ups shall certainly help in understanding the nature of the phenomenon and in distinguishing various classes or subclasses of events.

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