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Recent results from the HETE mission

G. Pizzichini , F. Gianotti , E. Morelli
and the HETE Team

Istituto IASF/CNR, Sezione di Bologna, via Gobetti 101, 40129 Bologna, Italy
e-mail: `pizzichini@bo.iasf.cnr.it`

Abstract. HETE is an experiment entirely dedicated to the detection and study of Gamma-Ray Bursts. It is in fact the first spacecraft built and launched solely for that purpose. HETE is a small mission, but because of its dedicated nature it reaches a sensitivity for the detection of the events comparable to that of much larger spacecraft. HETE provides light curves and spectral information for all the events which it detects. For approximately 25 bursts/year it determines also location error boxes. HETE was purposely designed in order to disseminate precise burst coordinates as soon and as freely as possible, in order to allow fast X-ray, optical, IR and radio follow-up. We give here a brief resume of recent results.

Key words. Gamma-Ray Bursts – Gamma-Ray Astronomy –

1. Introduction

Early observations of Gamma-Ray Bursts (hereinafter GRBs) (Terrell et al. 1982) already showed that at least some events had detectable emission in X-rays. The HETE mission (Ricker et al. 2002) was designed in order to detect GRBs both in gamma and in X-rays, giving time and spectral information, and to take advantage of the possibility to localize X-rays much more precisely than gamma-rays. It was also evident (Terrell et al. 1982; Yoshida et al. 1989) that the X-ray emission could last considerably longer than the "classical" GRB. For these reasons the first HETE spacecraft, which was unfortunately lost in November 1996 due to malfunctioning of the launch rocket, carried both a gamma-ray detector, FREGATE, and two position sensitive X-ray detectors, WXM and SXC. The first HETE already had the possibility to derive the GRB location directly on-board and was meant to be continuosly in contact with a chain of Secondary Ground Stations (SGS), in order to disseminate the burst coordinates as soon as possible. The detectors were planned to be pointed in the antisolar direction, in order to allow optical searches and follow-ups immediately after the localization of the GRB. Other GRB monitors, for example INTEGRAL, point at 90 degrees from the Sun, thus the sky areas monitored by them and by HETE are complementary.

HETE was rebuilt and launched again on October 9, 2000. In the meantime the importance of making available fast and precise GRB error boxes had been demon-

Send offprint requests to: G. Pizzichini
Correspondence to: via Gobetti 101, 40129 Bologna

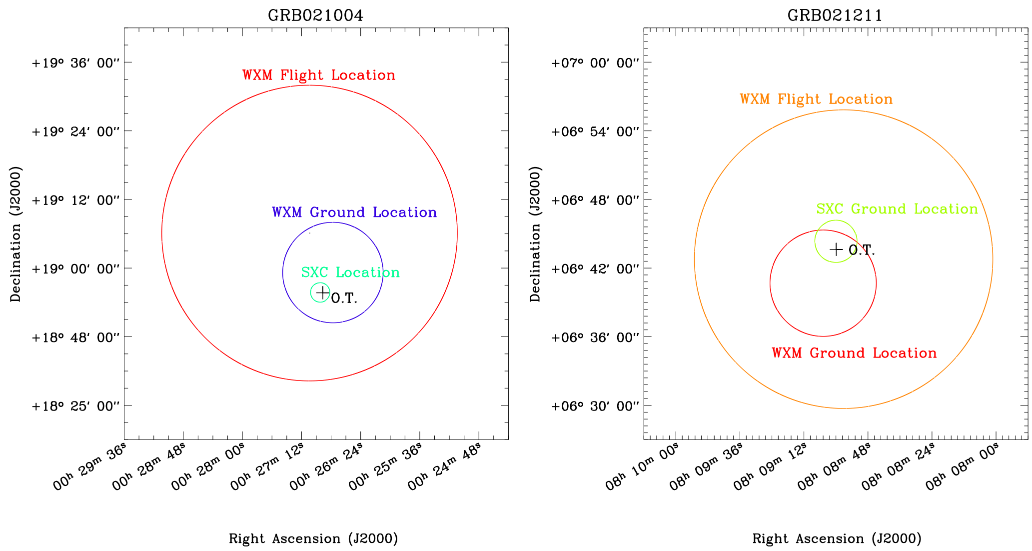

Fig. 1. Left panel: HETE localization history of GRB021004 (Shirasaki et al. 2002; Doty et al. 2002). Starting from the trigger time: the WXM in-flight error circle, released after 49 seconds, had a 30 arcsec. radius. The WXM ground analysis, released at t=74 minutes, had a 10 arcmin., 90% confidence radius. The first SXC localization was released at t=154 minutes, the revised one at t=6.5 hours. The final 90% radius was 62 arcsec. It was consistent with the OT reported by Fox (2002) at t=3.1 hours. Right panel: the same for GRB021211 (Crew et al. 2002). WXM flight location, released at t= 2 seconds, error radius=14 arcmin.; WXM and SXC ground analysis, at=131 seconds, 90% confidence error radius=5 arcmin. and 2 arcmin. respectively, consistent with the OT reported by Fox & Price (2002) at t=53 minutes.

strated by the discovery of GRB optical and radio afterglows (van Paradijs et al. 1997; Frail et al. 1997).

The energy range of the HETE instruments is also important: most GRB detectors in the past were not sensitive under 30 KeVs, while the HETE energy range is from 6 to 400 keV for the FREnch GAmma TElescope (FREGATE), which is the GRB trigger instrument, 2 to 25 keV for the Wide Field X-ray Monitor (WXM) and 0.5 to 14 keV for the Soft X-ray Camera (SXC). Thus HETE is more likely to detect also X Ray Flashes (XRF), which have softer spectra, besides "canonical" GRBs. For the same reason, SGR bursts and X-ray bursts can also be observed when the galactic plane is in the FOV, although they might reduce the available time for GRB detection. HETE mission is in the equatorial orbit, with an inclination of only 2 degrees, which gives a low background to the gamma and X-ray instruments. The web page: http://space.mit.edu/HETE/ provides a detailed description of the HETE mission.

2. Recent HETE detections

For lack of space here we limit ourselves to show how prompt the HETE localizations of GRBs can be. For the same reason we show only four examples of such prompt localizations in the last few months.

GRB021004 and GRB021211 (Fig. 1): in both cases it is evident that the flight localization was precise enough to start optical observations as early as 65 seconds and 9 minutes later, but in both cases the OTs

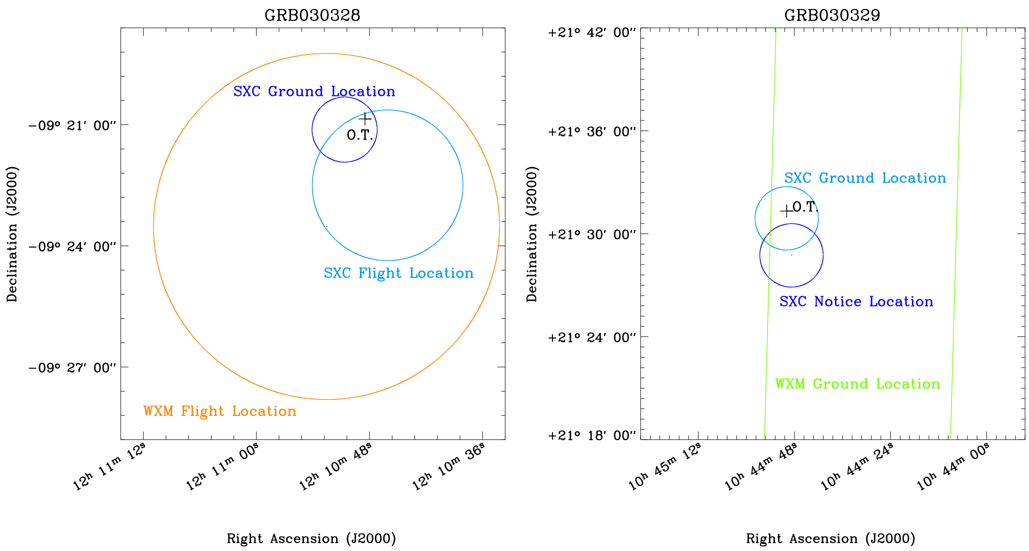

Fig. 2. Left panel: HETE localization history of GRB030328 (Villasenor et al. 2003). SXC flight location, 90% confidence radius=2 arcmin reported at t=53 minutes after trigger; WXM and SXC ground localizations, at t = 121 minutes, 90% confidence radius 4.6 arcmin and 52 arcsec. respectively, all of them consistent with the OT reported by Peterson & Price (2003a); Price & Peterson (2003) at t=152 minutes. Right panel: the same for GRB030329. Ground only localizations, because the burst was at the edge of the SXC and WXM fields of view (Vanderspek et al. 2003). First SXC localization at t=73 minutes, WXM and second SXC localizations, corrected for systematic errors, at t=8 hours. The WXM and 2 arcmin radius 90% confidence second SXC error box are consistent with the OT reported by Peterson & Price (2003b) at t=110 minutes near the edge of the first SXC error circle.

were reported as soon as the better precision of the ground localizations had considerably reduced the error box size.

Observations of early optical afterglows are important not only for practical purposes: they may constrain the initial Lorentz factor of the GRB fireball and provide evidence for the central engine (Zhang, Kobayashi & Meszaros 2003). For GRB021004, the prompt OT detection allowed observations of early rebrightening, which can be interpreted as reverse shock emission (Kobayashi & Zhang 2003). The OT of GRB021211 shows that some optical afterglows can be four magnitudes weaker than other ones having the same temporal decay (Li et al. 2003). Thus many "optically dark" GRBs might simply have been localized too late for detection of the OT, confirming the importance of fast and precise localizations.

GRB030328 and GRB030329 (Fig. 2): these events prove that, even when HETE does not succeed in directly releasing the in-flight location, the follow up can be almost as prompt, thanks to the continuos monitorage by the operations team. When the on-board software incorrectly invalidated the trigger for GRB030328, the team released the in-flight SXC localization after 53 minutes. Possibly because of the detection of GRB030329 on the following day, this event, with measured redshift and possible initial rebrightening (Martini, Garnavich & Stanek 2003; Rol, Vreeswijk & Jaunsen 2003; Fugazza et al. 2003) is not yet the subject of theoretical interpretations.

GRB030329: this very intense burst has instead already been the subject of several papers. For a complete bibliography see www.bo.iasf.cnr.it /p̃izzichini/b030329.tex The main reason for that is probably the discovery in the afterglow of a SN spectrum of type Ic (Matheson et al. 2003) much better observed than in SN1998bw, but our purpose here is to report on how HETE detected it and released its location. The burst triggered all three HETE instruments, but it was at the edge of the FOV both for the SXC and the WXM, thus systematic errors, which would otherwise be negligible, needed to be considered and only the ground localization was produced. Even so, the first SXC localization was released after only 73 minutes. Optical observations started at t=105 seconds (Torii 2003; Uemura et al. 2003) , thus allowing detection of very early structures in the light curve.

Until now HETE has localized, in as little as 2 seconds for the first error box, 44 GRBs , which led to detection of 21 afterglows and 11 redshifts. For the first time, the OT and X-ray afterglow of an XRF (030723) (Prigozhin et al. 2003; Butler et al. 2003; Fox et al. 2003) have been detected, but other events, e.g. GRB030216, show very interesting features. For a complete list see /Bursts in the above mentioned HETE web page, where also SGR events and X-ray bursts, by now respectively more than 50 and 800 , are listed.

3. Conclusions

The HETE mission has proven to be very effective in pursuing its original purpose, detection and fast localization of GRBs, observation of their light curves and spectra and detection of other fast transient phenomena. We expect it to continue doing so successfully in the future.

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