

HETE-II and the Interplanetary Network

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Abstract.

The FREGATE experiment aboard HETE-II has been successfully integrated into the Third Interplanetary Network (IPN) of gamma-ray burst detectors. We show how HETE's timing has been verified in flight, and discuss what HETE can do for the IPN and vice-versa.

INTRODUCTION

The FREGATE experiment aboard HETE-II is an excellent complement to the detectors in the IPN. It has good sensitivity to bursts, thanks to its large surface area and its steady background in equatorial orbit. Its time resolution in both triggered and untriggered modes is sufficiently high for cross-correlating precisely with other spacecraft. And finally, its energy range is well matched to those of other instruments in the network. However, before any experiment can be added to the network, its timing must be verified in flight. In this paper, we will first explain the procedure we have used to demonstrate that the HETE timing is accurate. Then we will show how the IPN can be used to improve the location accuracy of HETE bursts, and how the FREGATE data are useful to the IPN.

TIMING

In principle, we expect the timing of the HETE spacecraft to be good, both because it is in low Earth orbit, and because it is derived from an onboard GPS receiver. While there are several ways to confirm the timing of any spacecraft in flight, the best is to triangulate burst sources with known positions, either soft gamma repeaters, or gamma-ray bursts for which optical or radio counterparts are found. In its first year of operation, FREGATE detected numerous bursts from SGR1806-20 and 1900+14; seven of them were observed in conjunction with other spacecraft in the IPN. The positions of both SGRs are known to arcsecond or sub-arcsecond ac-

curacy, and therefore serve as timing calibration sources.

In figures 1 and 2 we show HETE/Ulysses annuli for bursts from each SGR. From these triangulations we conclude that HETE timing errors are indeed negligible, and moreover, that HETE is a sensitive SGR detector when it is pointed towards the Galactic plane. Since this occurs for several months around December and June, it is clear that HETE will serve as a monitor of the known SGRs, and may also detect new ones when they become active.

WHAT HETE BRINGS TO THE IPN

At present, the IPN consists of Ulysses, in heliocentric orbit, Mars Odyssey, now in orbit around Mars, and several missions close to Earth [1]. Prior to the launch of HETE, the two principal GRB detectors close to Earth were the BeppoSAX Gamma-Ray Burst Monitor (GRBM) and the Konus experiment aboard the Wind spacecraft. BeppoSAX has a high duty cycle, but as it is in low-Earth orbit, it misses roughly half of all GRBs due to Earth occultation. The GRBM has a coarse location capability ($10\text{-}20^\circ$). The mission will end some time in 2002. Wind is nominally at the L_1 Lagrange point, so no bursts are missed due to occultation, but the duty cycle is not as high as that of BeppoSAX, and this causes some events to be missed. Because of the placement of the two Konus detectors aboard the spacecraft, the experiment can be used to determine the ecliptic latitude of a burst to an accuracy of about 10° in many, but not all, cases. The Wind mission is now expected to be supported at least through 2002, at which time the launch of

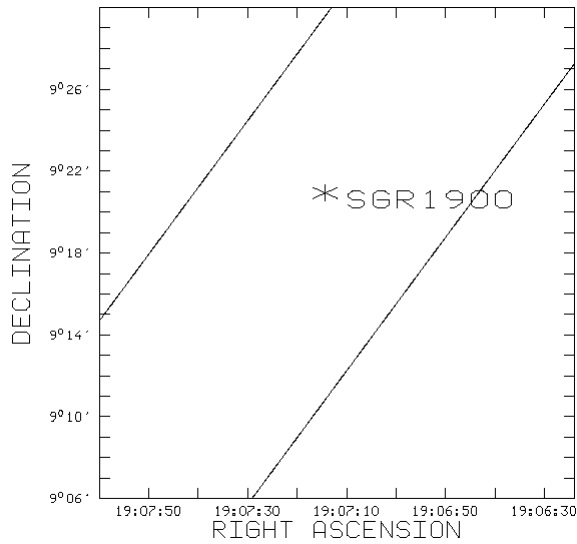


FIGURE 1. The FREGATE/Ulysses location annulus for a burst from SGR1900+14 on June 29 2001. The annulus width is 11'. The displacement between the known position of the SGR and the center line of the annulus is 31", which corresponds to a timing error of 93 ms. As this is much less than the 1 sigma statistical uncertainty in the cross-correlation, it indicates that the HETE timing errors are negligible.

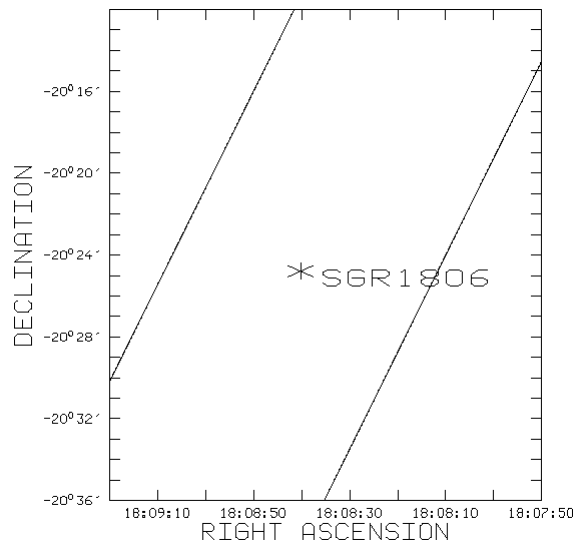


FIGURE 2. The FREGATE/Ulysses location annulus for a burst from SGR1806-20 on June 23 2001. The annulus width is 12'. The displacement between the known position of the SGR and the center line of the annulus is 1", which corresponds to a negligible timing error of 3 ms.

INTEGRAL should provide a replacement or near-Earth vertex for the IPN.

HETE complements these missions in three ways, as far as the IPN is concerned. First, it fills in the gaps by providing data on bursts missed by the other spacecraft. To date, about one burst per month has been detected by FREGATE and verified by Ulysses or Mars Odyssey, but has not been detected by Konus or by the GRBM. Second, it provides burst data in near-real time. The GRBM data are delayed by up to several hours, and the Konus data by half a day or more. Thus even when these experiments detect a burst, valuable time can be gained by receiving the HETE data and alerting the Ulysses and Mars Odyssey teams at JPL to expedite processing of the data in the small time window where the burst should occur. Finally, FREGATE data can be used to resolve the ambiguity in a 3 or 4 spacecraft localization. In the case where Ulysses, Mars Odyssey, and FREGATE observe a burst, FREGATE's coarse localization capability can serve to indicate which of two alternate triangulation positions is the correct one. In the case where Ulysses, Mars Odyssey, FREGATE, and Konus observe a burst, the separation between FREGATE and Konus will often be just enough to generate a third, independent annulus of location which again resolves the ambiguity. It should also be noted that the time resolution of FREGATE in the untriggered mode is 0.164 s, which is a factor of about 5 to 20 better than the untriggered modes of the GRBM and Konus, which results in more accurate cross-correlations.

WHAT THE IPN DOES FOR HETE

The IPN can assist the HETE mission in four ways. First, it can confirm candidate GRBs and SGR bursts. Typically, these are events which are observed only by FREGATE. 24 such bursts have been confirmed to date, or a rate of about two per month.

Second, it can refine WXM error circles. Figure 3 shows one example, GRB010613. This is an extreme case, in that both the WXM error circle and the IPN annulus are rather large. However, there are numerous examples of smaller BeppoSAX WFC error circles which were refined by the IPN [2], and we expect most HETE-IPN bursts to be similar to them.

Third, it can transform "one dimensional" WXM error boxes which are too large to search for counterparts into small error boxes which are suitable for optical and radio follow-up observations. A "one-dimensional" WXM error box is one which results when a burst is detected and localized in only one of the two crossed WXM detectors, leading to a long, narrow error box. Figure 4 shows an example, GRB010921. Figure 5 shows an enlargement of the region where the IPN annulus intersects the WXM

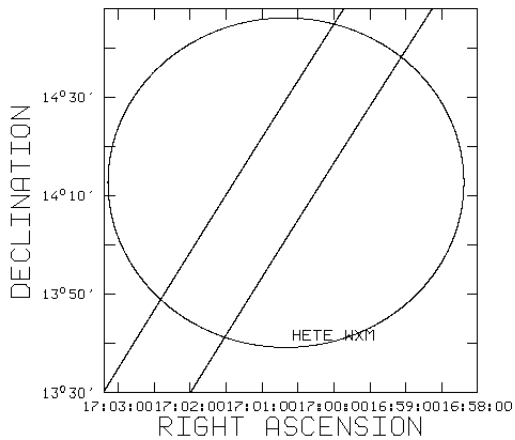


FIGURE 3. The 72' diameter WXM error circle for GRB010613, and the 15' wide FREGATE/Ulysses location annulus for it. The intersection of the annulus and the error circle forms an error box whose area is approximately 1000 square arcminutes, or about a factor of four smaller than the error circle alone. A similar annulus could also have been generated using the Konus-Wind data, had FREGATE not detected this burst for any reason.

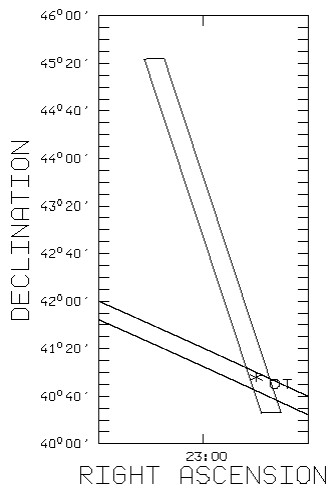


FIGURE 4. The 5.2° by 17' one-dimensional WXM error box for GRB010921, and the 14' wide FREGATE/Ulysses location annulus for it. The position of the optical transient is marked with an asterisk. A similar annulus could also have been generated using the Konus-Wind data, had FREGATE not detected this burst for any reason.

error box. This burst and its counterpart are described in detail elsewhere [3, 4, 5].

Finally, the IPN can, in principle, transform one dimensional SXC error boxes into small error boxes in the same way that it transforms WXM error boxes. However, this has not yet been done for any burst, since none has

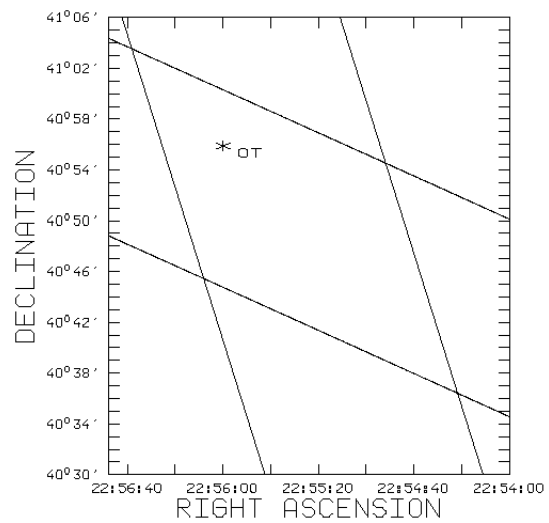


FIGURE 5. Expanded view of the 310 square arcminute IPN/WXM error box for GRB010921, and the position of the optical transient.

been localized by the SXC in this way.

CONCLUSIONS

We have successfully integrated the HETE spacecraft into the third interplanetary network of gamma-ray burst detectors, and have demonstrated the value of HETE to the IPN and vice-versa. We are now looking forward to several more years of operations.

ACKNOWLEDGMENTS

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