INTEGRAL IN THE THIRD INTERPLANETARY NETWORK FOR GAMMA-RAY BURSTS

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ABSTRACT

The Third Interplanetary Network, currently consisting of Ulysses, NEAR, Konus-Wind, and BeppoSAX, produces about one small gamma-ray burst error box per week. In 2002, INTEGRAL will join this network, providing burst data with the SPI anticoincidence shield. We discuss the configuration of the network in the years 2002 - 2004, as well as the rate and the sizes of the error boxes which the network is expected to produce. We compare these properties to those of other missions expected to be in operation at that time.

Key words: γ-ray bursts.

1. INTRODUCTION

Interplanetary networks (IPNs) of gamma-ray burst (GRB) detectors have been in operation since 1977, producing small error boxes suitable for counterpart searches. Even with the spectacular success of the BeppoSAX Wide Field Camera and Narrow Field Instruments in localizing bursts, the IPN remains a valuable tool in GRB research today for several reasons, among them 1) the ability to detect bursts over the entire sky at a rate which is higher than that of most other experiments with limited fields of view, 2) the possibility of obtaining very small error boxes, down to 10 square acminutes, and 3) the fact that IPN error boxes can be combined with localizations from other experiments (e.g., the BeppoSAX WFC) to reduce their sizes.

In its current form, the third Interplanetary Network consists of the Ulysses spacecraft, in heliocentric orbit, the Near Earth Asteroid Rendezvous (NEAR) mission, in orbit about the asteroid Eros, the Konus experiment aboard the Wind mission, located at the L_1 Lagrange point, and the BeppoSAX Gamma-Ray Burst Monitor, in low Earth orbit. This network is currently producing about one rapidly determined (10 - 50 hours), precise (10 - 300 square arcmintes) GRB error box per week. Optical and radio searches of these locations have now revealed 9 counterparts, and redshifts have been measured for five, increasing the size of the counterpart database by $\sim 50\%$. By the time INTEGRAL launches in 2002, the network will have a somewhat different configuration. (In the four years or so since the addition of a GRB capability to the INTEGRAL SPI anticoincidence has been discussed, the network has undergone several changes; see Hurley 1997 and Hurley 1999). NEAR will have completed its mission, and it will be replaced by Mars Odyssey 2001 (MO), which will be launched in April 2001 and arrive at Mars in October 2001. A mission extension seems likely for Wind, and is possible for BeppoSAX. Also, HETE-II will have been launched into low Earth orbit. The positions of the main components of the network in April 2002 are shown in figures 1 and 2.

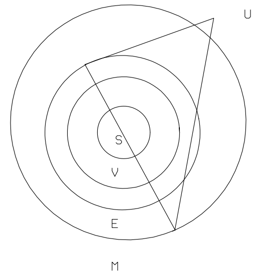

Figure 1. The configuration of the IPN in April 2002. The Sun and the orbits of Venus, Earth, and Mars are shown. A line connects the Earth-orbiting, Mars-orbiting, and Ulysses spacecraft. The Earth-Ulysses distance is 3.2 AU. The view is from the north ecliptic pole.

The network operates by cross-correlating the time histories of the bursts detected by these spacecraft to obtain an accurate time delay between them. Each pair of spacecraft then results in an annulus of possible locations. Three widely separated spacecraft yield two annuli, which intersect at two points. In general, if all the detectors are omnidirectional, a fourth spacecraft is required to resolve the ambiguity. However, both Konus and the BeppoSAX GRBM have modest directional capabilities, and these are often used to reject one intersection. Even when this is not possible, the separation between Konus and SAX, which is only ~ 1 light-second, is sufficient to

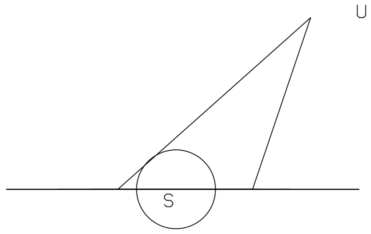

Figure 2. Same as figure 1, except that the view is from within the ecliptic plane.

break the ambiguity.

2. ADDING INTEGRAL TO THE IPN

The INTEGRAL SPI BGO anticoincidence shield has an effective area of $\sim 3000\,\mathrm{cm}^2$, and operates in the energy range ~100 keV and above. It will transmit count rates with a time resolution of 50 ms (Lichti et al. 2000). In many respects, it is similar to the NEAR anticoincidence shield which has served quite successfully as a GRB detector in the current IPN. The NEAR shield is smaller ($\sim 125\,\mathrm{cm}^2$ effective area), but also made of BGO, and operates at a lower threshold of ~100 keV; its time resolution is 1 s. Thus the performance of the INTEGRAL shield is expected to be considerably better: it should detect bursts at a much higher rate (~ several hundred per year, the majority of which will not be detected within the SPI, IBIS, JEM-X, or OM fields of view) and with much better time history statistics. Its superior time resolution will make it possible to localize bursts more accurately because the cross-correlations will be more precise. In addition, the SPI anticoincidence shield will have a modest directional capability. Thus, even when only Ulysses, MO, and INTEGRAL detect a burst, it is likely that a single error box can be obtained.

For comparison, we give the approximate effective areas of the other experiments in the network: Ulysses, 20 cm^2; Konus, 130 cm^2; MO, two ~ 35 cm^2 detectors; HETE-II, 120 cm^2; BeppoSAX, 420 cm^2.

3. ANTICIPATED PERFORMANCE

In the current IPN, when all the different instruments and operating modes are counted, there are over 100 distinct ways to observe and triangulate gamma-ray bursts. This will be true when INTEGRAL is in the IPN, too. For illustration, we have simulated a single case, a GRB detected by Ulysses, MO, and INTEGRAL in April 2002. The result is shown in figure 3. The two IPN annuli intersect to form an 8 square arcminute error box. An IBIS 1.5 arcminute radius error circle is superposed for comparison. From this, it can be seen that even if, say, MO had not detected this burst, the Ulysses/INTEGRAL annulus would still reduce the size of the IBIS error circle. Indeed, IPN annuli have been very useful in reducing the sizes of BeppoSAX Wide Field Camera error circles (Hurley et al. 2000).

The burst detection rate can be estimated from the performance of the current IPN. Even though the SPI shield will be more sensitive than the detectors which are currently in the IPN, it is always the *least* sensitive instrument which determines the detection rate of 3-spacecraft bursts. This will probably be Ulysses in 2002, so the rate is likely to remain in the one per week range.

4. COMPARISON WITH OTHER EXPERIMENTS

IBIS on INTEGRAL will detect 1-2 bursts/month in its field of view, and localize them rapidly to several arcminute accuracy (Mereghetti et al. 1999; Ubertini et al. 1999). HETE-II will also be in operation at this time, detecting about one burst per week rapidly, and localizing them to 10 arcsecond – 10 arcminute accuracy. The IPN detection rate is therefore comparable to the rates of these two missions, and the three sets of bursts will not entirely overlap. The accuracies of the IPN error boxes will be in the arcminute and above range.

The IPN localizations will be determined with a delay of a day or so, while INTEGRAL and HETE-II will broadcast their positions within seconds. However, this delay has not significantly hindered the search for counterparts. Indeed four counterparts to IPN bursts were discovered when the delay was in the 30 – 50 hour range. This sometimes occurs because the radio afterglow emission peaks several days after the burst. The detection of the radio counterpart leads to an extremely precise position which optical observers can search to very faint magnitudes.

5. CONCLUSION

The addition of INTEGRAL to the IPN is expected to play an important role in maintaining the vitality and viability of the network. Over INTEGRAL's nominal 2 year lifetime, some 100 bursts should be detected and localized by the IPN, leading to numerous counterpart identifications.

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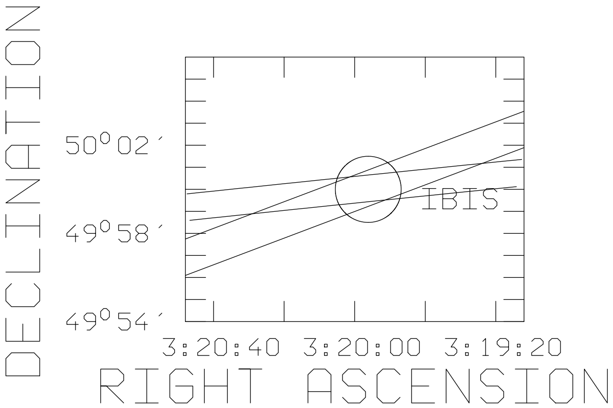

Figure 3. Simulated triangulation of a GRB on April 20 2002. Ulysses/MSO and Ulysses/INTEGRAL annuli are shown. They intersect to form an 8 square arcminute error box. For comparison, a 1.5 arcminute radius IBIS error circle is shown.

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