INTEGRAL JOINS THE 3RD INTERPLANETARY NETWORK

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ABSTRACT

The BGO anticoincidence shield of the SPI detectors has a maximum effective area of over 5000 cm^2, and operates in the energy range >75 keV. It was incorporated into the 6- spacecraft interplanetary network shortly after launch. It detects about one confirmed burst every three days, and has detected over 125 cosmic and soft gamma repeater bursts since it started operation. It also detects numerous other bursts which are below the thresholds of the other IPN instruments and are therefore unconfirmed, but which are almost certainly cosmic. We describe the operation of the SPI-ACS and some of its unique features, and explain how the data on bursts are being utilized by the scientific community.

Key words: gamma rays; gamma-ray bursts; soft gamma repeaters.

1. INTRODUCTION

Despite the great progress which has been made in understanding the nature of cosmic gamma-ray bursts (GRBs), a number of fundamental questions remain, among them:

- What is the nature of the short GRBs?
- Are all long-duration GRBs associated with Type Ic supernovae or hypernovae?
- What is the nature of the "dark" or radio-quiet bursts, which display no long wavelength afterglows?
- Can examples be found of bursts which are outside of their host galaxies, as might be expected in some cases in the merging neutron star model?
- How many GRBs display strong linear polarization in their prompt gamma-ray emission?

The detection, localization, and multiwavelength follow-up observations of many more bursts will be required to answer these and other questions. Thus INTEGRAL's capability to detect and localize bursts with the spectrometer anticoincidence shield (ACS) in the 3rd Interplanetary Network (IPN) of gamma-ray burst detectors is an important one, which complements IBIS's independent GRB localization capabilities.

2. THE ANTI-COINCIDENCE SUBYSTEM OF THE INTEGRAL SPECTROMETER SPI

INTEGRAL's SPI germanium detectors are shielded on the side and bottom by a large anticoincidence shield, consisting of 91 BGO crystals whose thicknesses are 1.6 – 5 cm and whose maximum effective area is $\sim$ 5250 cm^2 at 100 keV (von Kienlin et al. 2003). At the urging of numerous people (e.g. Hurley 1997) it was decided to enable this system to provide data on cosmic gamma-ray bursts. Thus 50 ms count rates for a single energy channel >75 keV are transmitted to the ISDC, where ground-based trigger software searches for statistically significant increases, filters out false events, and identifies bursts. Burst data, including a light curve and spacecraft ephemeris, are placed on a public website, and a burst alert is sent out to subscribers in near-real-time. Figure 1 shows the SPI and the ACS. As an example, figure 2 shows the time history of GRB021206 as observed by the ACS.

3. THE 3RD INTERPLANETARY NETWORK

Interplanetary networks of gamma-ray burst detectors have been in operation since the late 1970's. They localize GRBs by timing their arrival at various spacecraft. The current IPN began in late 1990, with the launch of the Ulysses spacecraft. Today, it comprises Ulysses, INTEGRAL, Konus-Wind, HETE-II, Mars Odyssey, and RHESSI. Despite the great diversity of detector shapes, sizes, time and energy resolutions, and experiment configurations (table 1), these

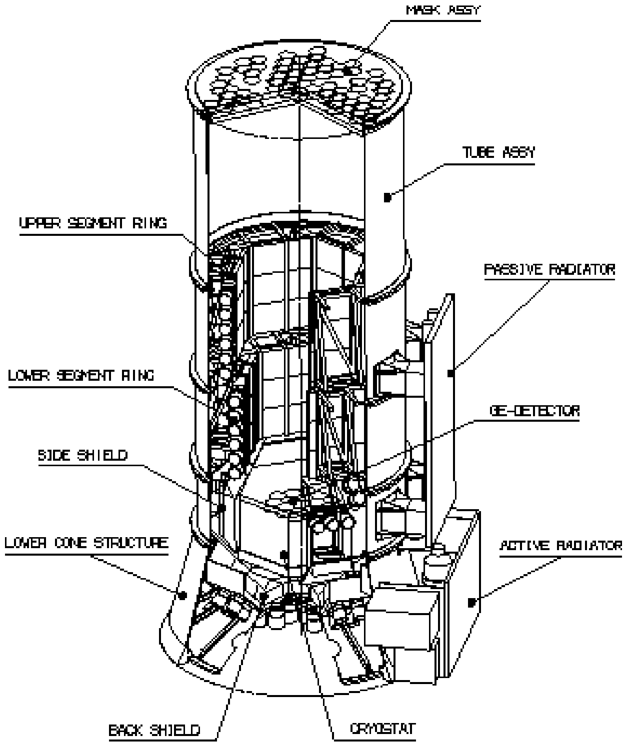

Figure 1. The SPI and ACS subsystems. More details may be found in Lichti et al. (2000).

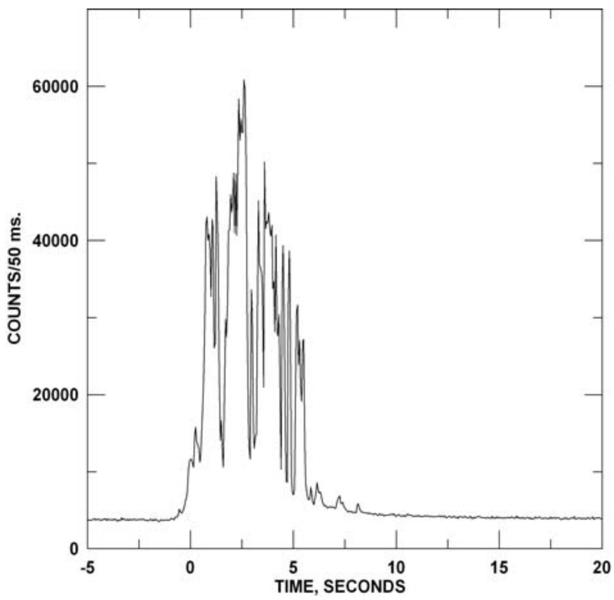

Figure 2. SPI-ACS time history of the intense GRB021206, in the >75 keV energy range. This is the burst for which the RHESSI spacecraft detected polarization. Its IPN localization is shown in figure 3.

missions have all been successfully integrated into the IPN, and $\sim$ 800 localizations have been published in seven catalogs in the Astrophysical Journal to date (Hurley et al. 1999a,b, 2000a,b,c; Laros et al. 1997, 1998). Localization data for these and other bursts may also be found on the IPN website (ssl.berkeley.edu/ipn3/index.html).

One advantage which the INTEGRAL SPI–ACS data bring to the IPN is their ability to resolve alternate error boxes. When an IPN has just three widely separated spacecraft, it produces two annuli which intersect at two locations. If none of the instruments has sufficient directional capability, it is impossible to choose the correct location. This is also true even when an IPN has more than three spacecraft, if some of them are very close to one another (e.g., in near-Earth orbit). In effect, such spacecraft count as a single point in the network because they are separated by distances which, expressed in light-seconds, are smaller than the uncertainties in cross-correlating their time histories. INTEGRAL's eccentric orbit, however, means that it is not redundant with respect to the near-Earth missions; a burst observed by Ulysses, Mars Odyssey, INTEGRAL, and any other Earth orbiting spacecraft can be triangulated to a single error box, without using the directional capability of any instrument.

HETE, and soon, Swift, can localize GRBs almost in real-time, whereas the IPN delays are of the order of 10 hours. Is the IPN still useful under these conditions? The answer is yes, for several reasons. First, HETE and Swift view only about 1/10th of the sky, while the IPN is isotropic. Thus the detection rate for bursts above the IPN threshold is roughly 10 times that of HETE and Swift. These bursts tend to be the brighter ones, and it is often possible to do special analyses of their properties. A good example is GRB021206 (figures 2 & 3), for which RHESSI discovered 80% linear polarization in gamma rays (Coburn & Boggs 2003), and which has been used to set limits on quantum gravity (Boggs et al. 2004). Because the arrival direction of this burst was only 18° from the Sun, it was not detected by HETE, and probably would not have been detected by Swift for the same reason. Second, the IPN can monitor the entire sky for repeating sources, such as the Soft Gamma Repeaters, the bursting pulsar, and similar phenomena. Third, sensitive searches are now underway for neutrino, gravitational radiation, and very high energy gamma-ray emission by experiments such as AMANDA (Ahrens et al. 2003), LIGO (Katsavounidis 2003), and Milagro (Noyes 2003). These experiments do not require rapid notification of bursts, or even, in many cases, small error boxes, but they do rely in some cases on the co-addition of the responses to many GRBs to achieve their sensitivities; also, to first order, one might expect that detections will come from studying the more intense events. Thus the IPN data are ideally suited to these efforts.

Table 1. Comparison of experiments in the Interplanetary Network.

Mission or Experiment	Maximum Sensor Area, cm^2	Sensor	Best Time Resolution, s.	Energy Range keV	Orbit
INTEGRAL/SPI-ACS	5250	BGO	.050	>75	Eccentric
RHESSI	350	Ge	Time-tagged	30-150	LEO
HETE-II	160	NaI	Time-tagged	5-400	LEO
Konus (2 det.)	130 each	NaI	.002	15-10000	Distant prograde
Odyssey (2 expts.)	35 each	Ge/CsI	.032	30-10000	Mars
Ulysses	20 (isotropic)	CsI	.008	25-150	Heliocentric

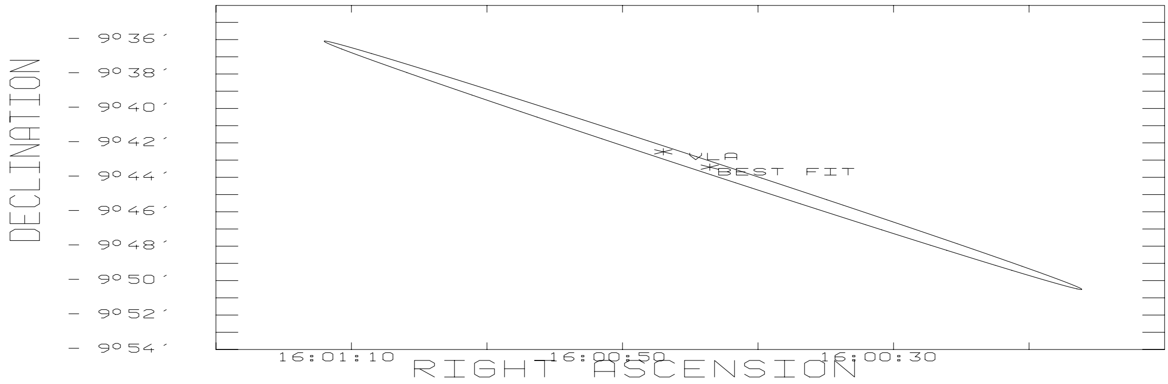

Figure 3. IPN localiztion of GRB021206. The area of the error ellipse is ∼ 9 square arcminutes (Hurley et al. 2003). The asterisk labelled "Best Fit" is the center of the ellipse, and the asterisk labelled "VLA" indicates the position of the fading radio counterpart (Frail et al. 2003). The SPI-ACS data played a key role in obtaining this localization.

4. BRINGING THE SPI-ACS INTO THE IPN

Over the past year, we have assisted the ISDC in fine-tuning the trigger algorithm to maximize the number of true bursts while minimizing the number of false alerts. This involved examining many triggers for evidence of confirming data from other IPN spacecraft, and setting not only the trigger threshold, but also the acceptable portions of the INTEGRAL orbit (to avoid particle triggers). The present SPI-ACS burst alert rate is 1/1.3 days. Many of these are valid cosmic events, even though they cannot all be verified by the less sensitive IPN experiments. Second, we have developed software to use the SPI-ACS burst alerts to automate the retrieval of GRB data from the public website; once the data are retrieved, automatic searches for the burst in the data of the other IPN experiments are conducted. Third, using the known positions of both GRB sources and soft gamma repeaters observed by the ACS, we have verified that the INTEGRAL timing is good to ∼ 100 milliseconds, which is quite adequate for almost all IPN applications; we are currently attempting to refine this. Fourth, we have instituted a procedure where localization data on almost every burst is sent out via the GRB Coordinates Network. (Previously, only small, rapidly-determined error boxes were circulated, for the benefit of optical and radio astronomers.) This was done to accommodate the new requirements of experimenters searching for neutrino, gravitational radiation, and VHE gamma-ray emission in conjunction with GRBs. To date, over 100 GCNs involving SPI-ACS data have been sent out, or 1/3.7 days. Finally, we confirmed or refined IBIS-only localizations of GRBs by providing IPN annuli for four bursts (GRB021219, 030131, 030320, and 030501) and an IPN error box for a fifth (GRB021125 - figure 3). A statistical analysis of the SPI-ACS burst sample is presented elsewhere (Rau et al. 2004).

5. FUTURE WORK

We will continue to issue GCN reports for all GRBs and SGRs which have localizations, in order to support ground- and space-based experiments studying multi-wavelength, neutrino, and gravitational radiation emission from these sources. Our effort will also support INTEGRAL-IBIS, HETE, and Swift burst localizations in some cases by reducing the areas of their error circles, as it has done in the past. It should also be possible to trigger Swift pointed observations of interesting GRBs.

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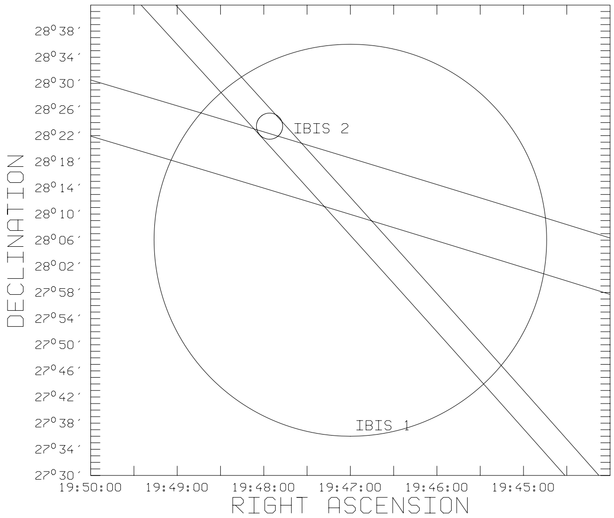

Figure 4. Initial and final IBIS error circles for GRB021125 (Bazzano & Paizis 2002, Gros & Produit 2002). The two annuli cross to produce the IPN error box (Hurley et al. 2002).

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