Suzaku Joins the Third Interplanetary Network
A Cycle 1 Guest Investigator Project

K. Hurley, University of California Space Sciences Laboratory, Berkeley, CA
K. Yamaoka, Aoyama Gakuin University, Tokyo, Japan
Y. Fukazawa, M. Ohno, Hiroshima University, Hiroshima, Japan
T. Takahashi, ISAS/JAXA, Tokyo, Japan
Y. Terada, RIKEN, Saitama, Japan
M. Tashiro, Saitama University, Saitama, Japan

ABSTRACT

The BGO anticoincidence shield of the Suzaku Hard X-Ray Detector Wideband All-Sky Monitor (HXD WAM) presents a geometrical area of 800 cm$^2$, and operates in the 50 -5000 keV energy range. It has been designed to act as a gamma-ray burst detector, providing light curves with up to 15.625 millisecond time resolution and energy spectra with up to 55 channels. It was incorporated into the six-spacecraft interplanetary network shortly after launch. It now detects about one confirmed gamma-ray or soft gamma repeater burst every 2 days, and has detected almost 200 events in 14 months of operation. It also detects numerous other weak bursts which are below the threshold of the other IPN instruments and are therefore unconfirmed, but are almost certainly of cosmic origin. We describe the operation of the HXD-WAM and some of its unique features, and explain how the data are being utilized by the scientific community.

INTRODUCTION

We are using the data from the Suzaku Hard X-Ray Detector Wideband All-Sky Monitor (HXD WAM), in conjunction with the data from other instruments in the Interplanetary Network (IPN), to derive the positions of gamma-ray bursts by triangulation. The GRB data which we use are recorded automatically, regardless of Suzaku’s pointing direction. The IPN has the advantage of possessing an isotropic response, with little or none of the sky blocked, when the integrated response of all the instruments in the network is considered, and a limiting accuracy of <1’. Indeed, the IPN is the only all-sky, full time GRB monitor. Thus its current event detection rate is ~200/year above a threshold of ~10$^{-7}$ erg cm$^{-2}$, considering only those bursts detected by two or more spacecraft. This makes it possible to study a wide variety of events which narrow field-of-view GRB instruments like the Swift BAT and INTEGRAL-IBIS will seldom detect. These include very intense bursts, very long bursts (Figure 1), repeating sources (gravitationally lensed GRBs and bursting pulsars like GRO1744-28 are two examples), soft gamma repeater activity, and possibly other as-yet undiscovered phenomena. The IPN detection rate of short-duration GRBs is also much greater than those of narrow-field instruments (e.g. Ohno et al. 2007).

THE Suzaku HXD WAM

The HXD WAM is described in Takahashi et al. 2006. We use the data from the 20 BGO anticoincidence shields for the purposes of IPN triangulation. These shields present a geometrical area of 800 cm$^2$ at normal incidence to a side, and the wedge-shaped units
which comprise the shield have an average thickness of 2.6 cm. Each unit is read out by a PMT, and the energy range is 50 – 5000 keV. The shield electronics comprises a GRB trigger, and triggered data include both 15.625 or 31.25 ms resolution time histories in 4 energy channels, and 55 channel energy spectra with 1 s resolution. The HXD also detects bursts in the untriggered data with 1 s time resolution. By comparing the responses of the units which comprise the shield, a coarse GRB localization may be obtained. 198 confirmed and 150 unconfirmed GRBs have been detected in both modes between August 2005 and October 2006 (Table 1). “Confirmed” means that the event was observed by at least one other spacecraft in the IPN, and can therefore be localized to some extent. Thus the Suzaku/IPN rate is ~1 burst/2 days. The limiting 50-5000 keV burst sensitivity of the HXD is ~5x10^{-7} erg cm^{-2}. Examples are shown in Figures 1 (an untriggered burst) and 2 (a triggered event). Much of the data may be found on the Suzaku website: www.astro.isas.jaxa.jp/suzaku/HXD-WAM/WAM-GRB/.

<table>
<thead>
<tr>
<th></th>
<th>Triggered bursts</th>
<th>Untriggered bursts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirmed</td>
<td>111</td>
<td>87</td>
</tr>
<tr>
<td>Unconfirmed</td>
<td>59</td>
<td>91</td>
</tr>
</tbody>
</table>


**CURRENT STATUS OF THE 3RD INTERPLANETARY NETWORK (IPN)**

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-2, Mars Odyssey, RHESSI, MESSENGER, and Suzaku. The Ulysses mission has been approved through 2008. Power-sharing is in effect on the spacecraft, which means that all the experiments cannot be powered on at once. The Wind mission (with the KONUS experiment), RHESSI, and Swift have similarly been approved through 2008. HETE-2 is no longer supported by NASA, and is returning data only sporadically; Suzaku is an excellent replacement for it, as far as the IPN is concerned. Mars Odyssey has been approved through March 2008. ESA intends to keep INTEGRAL operating through 2010. The Neutron Spectrometer aboard MESSENGER, which acts as a GRB detector, was turned on in January 2007. Table 2 compares the properties of the current IPN detectors and missions. Future additions to the IPN will include the AGILE and GLAST. Localization data and other information may be found on the IPN website: ssl.berkeley.edu/ipn3/index.html.

<table>
<thead>
<tr>
<th>Mission/Experiment</th>
<th>Maximum area, cm²</th>
<th>Sensor</th>
<th>Best time resolution, s.</th>
<th>Energy range, keV</th>
<th>Orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suzaku HXD/WAM</td>
<td>800</td>
<td>BGO</td>
<td>.015625</td>
<td>50-5000</td>
<td>LEO</td>
</tr>
<tr>
<td>RHESSI</td>
<td>350</td>
<td>Ge</td>
<td>Time-tagged</td>
<td>30-150</td>
<td>LEO</td>
</tr>
<tr>
<td>INTEGRAL SPI-ACS</td>
<td>5250</td>
<td>BGO</td>
<td>.050</td>
<td>&gt;80</td>
<td>Eccentric</td>
</tr>
<tr>
<td>Konus (2 det.)</td>
<td>130 each</td>
<td>NaI</td>
<td>.002</td>
<td>15-10000</td>
<td>Distant prograde</td>
</tr>
<tr>
<td>MO (2 expts.)</td>
<td>35 each</td>
<td>Ge/CsI</td>
<td>.032</td>
<td>30-10000</td>
<td>Mars</td>
</tr>
<tr>
<td>Ulysses</td>
<td>20 (isotropic)</td>
<td>CsI</td>
<td>.008</td>
<td>25-150</td>
<td>Heliocentric</td>
</tr>
<tr>
<td>MESSENGER</td>
<td>100</td>
<td>BC454</td>
<td>1</td>
<td>40-160</td>
<td>Mercury</td>
</tr>
</tbody>
</table>

Table 2. Some properties of the current IPN instruments.

**BRINGING THE HXD-WAM INTO THE IPN**

Over the past year, we have begun to incorporate the HXD-WAM into the IPN. When an HXD-WAM trigger occurs, the data are automatically sent to UC Berkeley, where searches are automatically initiated in the data of the other IPN spacecraft. (Information on untriggered HXD-WAM bursts is sent manually, and searches for them are done manually.) The IPN software for cross-correlating time histories and producing localizations has been modified to accept the WAM data. Whenever a burst is localized to a sufficiently small error box, the information is communicated to the Suzaku team, so that spectral analysis can be done. When an interesting, time-critical GRB is localized, GCN messages are sent out, and ToO requests are initiated if it is warranted.

As an end-to-end test of the spacecraft timing, ephemeris, and correct integration of the data into the IPN, we have triangulated events whose positions were precisely known by other means, such as SGR bursts and GRBs with counterparts. The SGRs confirmed the Suzaku timing to ~2 ms, and the GRBs to values of several 10’s of ms in the best cases; the Suzaku data are therefore consistent with having no significant timing errors.
SOME RESULTS TO DATE

GCN circulars 4762, 4856, 4989, 5005, 5067, 5416, 5684, and 5702 were issued for 8 interesting Suzaku-IPN events whose localizations were determined rapidly and accurately enough for quick follow-up searches (GRB 060213, 060303, 060418, 060425, 060429, 060806, 060928, and 061006). We called a Swift ToO for GRB060928 (figure 2), and its X-ray counterpart was identified (GCN 5686, 5721); the Suzaku spectrum was circulated in GCN 5688 (a total of 15 bursts have been used for Suzaku spectral analysis, and the results have been announced in GCN Circulars 4297, 4299, 4393, 4571, 4573, 5083, 5462, 5477, 5487, 5543, 5688, 5717, and 5724). Another Swift ToO was called for SGR1806-20, when it emitted a long, exceptionally bright event, which we announced in GCN 5416. Other bursts, with only coarse and/or delayed localizations, have found a wide variety of uses. For example, they are being used by the AMANDA group at UC Irvine, the ANITA group at UCLA, and the RICE group at the University of Canterbury (NZ) to search for neutrino emission associated with GRBs. They are also being used by the Milagro group at LANL to search for very high energy photons in conjunction with GRBs, and by Elena Pian and collaborators to set limits on gamma-ray burst emission from type Ic supernovae. The LIGO group has used them to search for coincident gravitational radiation, and numerous requests for data are received from people searching for orphan afterglows. Observations of SGR bursts are also of great interest to many groups for triggering multi-wavelength ToO observations.

SUMMARY

Maintaining Suzaku in the IPN is useful to the Suzaku project in several ways. First, IPN localizations make it possible to deconvolve the energy spectra of HXD bursts. Second, they can be used to improve the independent localization capability of the HXD. Finally, if the spacecraft timing should ever be considered uncertain, IPN bursts can be used to study the problem. HXD data are useful to the IPN for several reasons. For >30% of the IPN bursts that Suzaku has observed, it is the only near-Earth spacecraft to have observed them. (This is about the number expected, given Earth-blocking and duty cycle considerations.) Thus it provides a unique vertex in the IPN which is crucial for triangulation. Also, for the remaining bursts, Suzaku often provided a time history with the best signal-to-noise ratio, because of its large collecting area. Finally, the HXD’s coarse location capability often resolves the ambiguity in 3-spacecraft triangulations, which produce two alternate error boxes. The public IPN data, in turn, are useful to many groups studying GRBs in diverse ways, including their non-electromagnetic signatures.

REFERENCES

Ohno, M., et al., PASJ, accepted, 2007
Takahashi, T., et al., PASJ 58, in press, 2006

ACKNOWLEDGMENT

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