Current Status of the Suzaku Wide-band All-sky Monitor (WAM)

Kazutaka Yamaoka[*], Satoshi Sugita[*,†], Makoto Tashiro[**], Yukikatsu Terada[**], Yuji Urata[**,‡], Akira Endo[**], Kaori Onda[**], Kouichi Morigami[**], Natsuki Kodaka[**], Takako Sugasawara[**], Wataru Iwakiri[**], Yasushi Fukazawa[§], Takeshi Uehara[§], Chie Kira[§], Yoshitaka Hanabata[§], Makoto Yamauchi[¶], Eri Sonoda[¶], Hiroki Tanaka[¶], Ryuji Hara[¶], Norisuke Ohmori[¶], Hidenori Hayashi[¶], Kenta Kono[¶], Soojing Hong[‖], Kazuo Makishima[††,†], Kazuhiro Nakazawa[††], Teruaki Enoto[††], Hiroyasu Tajima[‡‡], Tadayuki Takahashi[§§], Motohide Kokubun[§§], Masanori Ohno[§§], Yujin E. Nakagawa[†], Tohru Tamagawa[†], Toshio Murakami[¶¶] and Kevin Hurley[***]

[*]*Department of Physics and Mathematics, Aoyama Gakuin University, Kanagawa, Japan*
[†]*Institute of Physical and Chemical Research (RIKEN), Saitama, Japan*
[**]*Department of Physics, Saitama University, Saitama, Japan*
[‡]*Academia Sinica Institute of Astronomy and Astrophysics, Taiwan, Rebuplic of China*
[§]*Department of Physics, Hiroshima University, Hiroshima, Japan*
[¶]*Department of Applied Physics, University of Miyazaki, Miyazaki, Japan*
[‖]*College of Science and Technology, Nihon University, Chiba, Japan*
[††]*Department of Physics, University of Tokyo, Tokyo, Japan*
[‡‡]*Stanford Linear Accelerator Center (SLAC), CA, USA*
[§§]*Institute of Space and Astronautical Science (ISAS/JAXA), Kanagawa, Japan*
[¶¶]*Department of Physics, Kanazawa University, Kanazawa, Japan*
[***]*University of California, Berkeley, Space Sciences Laboratory, CA, USA*

Abstract. The Suzaku Wide-band All-sky Monitor (WAM) consists of 20 BGO anti-coincidence scintillators for the Hard X-ray Detector (HXD). The WAM has a wide field of view (FOV), about half of the whole sky, a large collecting area, 800 cm^2, and broad-band energy coverage from 50 to 5000 keV. Thus it has been designed to work as a gamma-ray burst detector. For the three years since Suzaku launch in July 2005, the WAM has been working very well. About 500 GRBs have been detected through the end of 2008, corresponding to a detection rate of ~140 GRBs per year. The current status of the WAM is presented in this paper.

Keywords: X- and γ-ray telescopes and instrumentation, γ-ray sources; γ-ray bursts, Suzaku
PACS: 95.55.Ka,98.70.Rz

THE SUZAKU WIDE-BAND ALL-SKY MONITOR

The WAM is composed of four identical, lateral BGO shields around the Suzaku Hard X-ray Detector (HXD; Takahashi et al. 2007 and Kokubun et al. 2007; left panel of Figure 1). The primary purpose of the WAM is to reduce the particle background of the HXD Si PIN diodes and GSO, but the WAM is also a sensitive gamma-ray burst monitor owing to its large field of view (about 2 π sr.), broadband energy coverage (50–5000 keV), and large geometrical area (800 cm^2 per shield element). A unique feature of the WAM is its large effective area around 1 MeV, 400 cm^2, which far exceeds that of any other past GRB detector (right panel of Figure 1). For GRB observations, the WAM has an on-board trigger system and can obtain high time resolution light curves around the GRB trigger time if triggered by a GRB (BST data: 1/64 sec time resolution and 4 energy bands). It also has real-time data for monitoring weak GRBs and transient sources (TRN data: 1 sec and 55 energy channels). Both types of WAM data are transferred to the ground station 3–5 times per day in Japan, so no rapid responses to GRBs like Swift are expected. A detailed description of the WAM instrument is presented in Yamaoka et al. (2009).

CP1133, *Gamma Ray Bursts, 6th Huntsville Symposium*
edited by C. Meegan, N. Gehrels, and C. Kouveliotou

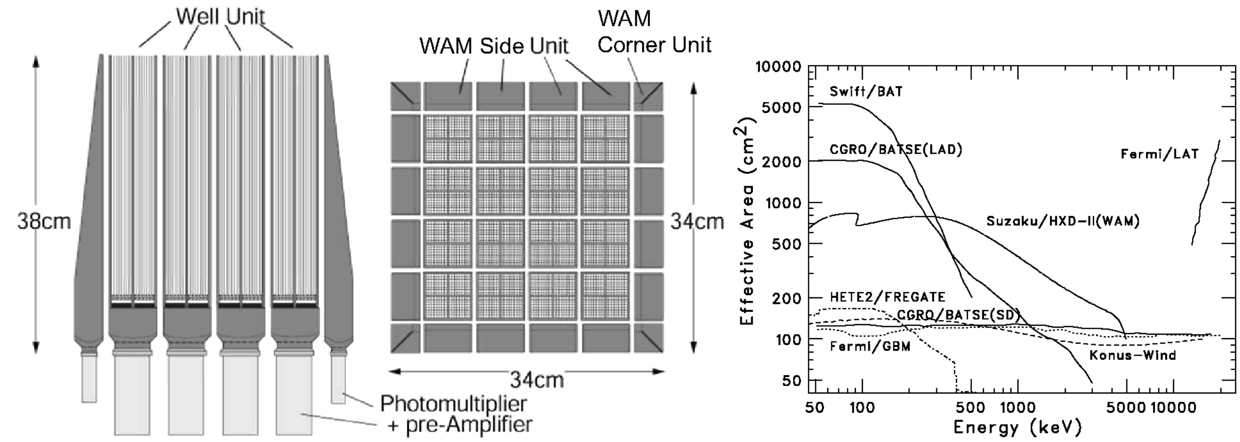

FIGURE 1. Left panel: Schematic view of the Suzaku Hard X-ray Detector. The WAM is the surrounding anti-coincidence shield. Right panel: The WAM on-axis effective area in comparison with other GRB detectors.

CURRENT STATUS

Suzaku was launched on July 10, 2005 and placed into a circular orbit around the Earth (550 km altitude, 31 degrees inclination). The WAM was activated on August 17, 2005. Since then, the WAM sensors and electronics have been working well for about three years. The GRB trigger level is currently set at 5.7 σ above background fluctuations during 1 or 1/4 sec in the 110–240 keV range. The current trigger level results in about one trigger per day, or in total 1132 events, including false events.

Table 1 give a summary of all the WAM events (also available at the WAM web site http://www.astro.isas.jaxa.jp/Suzaku-WAM/WAM-GRB/), and simultaneous detection information for GRBs through December 2008. Each event has been classified using multiple criteria: the shapes and durations of the light curves, the spacecraft Earth coordinates, the hardness ratio, GOES solar flare information, and GRB information provided by the Interplanetary Network (IPN; IPN web site: http://ssl.berkeley.edu/ipn3/index.html). 484 GRBs were confirmed by other satellites and a further 317 possible cosmic events were detected. This means that the WAM is detecting more than 140 GRBs per year, which is comparable to Swift and Fermi-GBM. The detection level is estimated to be about 0.7 photons cm^{-2} s^{-1} in the 50–300 keV range for 1-sec integration.

TABLE 1. Summary of classified events (2005 Aug.1 – 2008 Dec. 30)

Classification	Number*	Notes
Confirmed GRBs	484(299)	Swift-BAT(90 within FOV, 89 outside of FOV) Fermi-GBM(31),INTEGRAL-IBIS(7)
Possible GRBs	317(145)	Some false events may be included.
SGRs	79 (5)	SGR 1806–20, 1900+14, and 0501+4516
Solar flares	172 (28)	GOES class B–X

* Values in parentheses indicate triggered events.

The left panel of Figure 2 shows the T90 duration distribution for confirmed and possible GRBs compared with the CGRO/BATSE sample (Paciesas et al. 1999). Confirmed WAM GRBs show a bimodal distribution peaked at 0.2 sec and 20 sec which is similar to BATSE, while possible GRB events are clustered around much shorter durations. Possible events might be confused with phenomena such as terrestrial gamma-ray flashes and particle events. Examples of some GRB light curves with 1/64 sec time resolution are shown in the right panel of Figure 2. Thanks to WAM's large effective area, high quality light curves and spectra can be obtained for bright bursts. The light curves are automatically sent to the IPN team and used for localization. Light curves for confirmed GRBs with 1/64 sec and 1 sec time resolutions are publicly available at the WAM web site.

The WAM energy response, required for spectral analysis, depends on the GRB incidence angle. When a GRB location is determined by another instrument, e.g. Swift/BAT, INTEGRAL/IBIS, or the IPN, a GCN circular giving the IPN localization and/or thex WAM spectral information is released (81 circulars so far). The WAM energy response

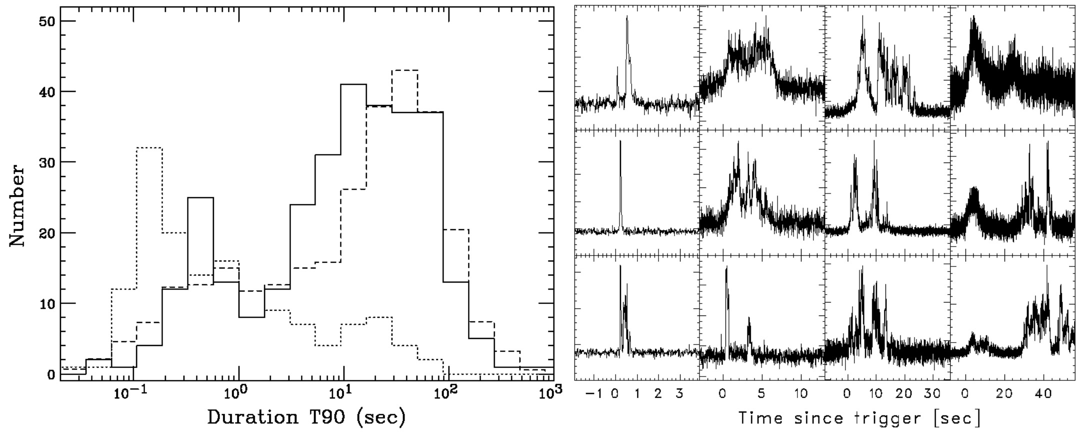

FIGURE 2. Left panel: T90 duration distribution for the WAM GRB sample (Confirmed events are shown by a solid line, possible events by a dotted line, and the BATSE sample by a dashed line). Right panel: An example of the WAM GRB light curves with 1/64 sec time resolution.

is calculated using GEANT4 Monte-Calro simulations which include the modeled geometry of the Suzaku satellite. The accuracy of the geometry was verified with pre-flight calibrations, and further modifications to the geometry have been done in orbit. The in-orbit calibration was done using GRBs which were simultaneously detected by Swift/BAT and/or Konus-Wind, the Crab Nebula, and solar flares. The flux uncertainty is estimated to be 20–30 % for most directions. GRB spectral analyses with WAM alone, and with a combination of Swift-BAT and WAM, are presented in Ohno et al. (2009) and Krimm et al. (2009).

The absolute timing accuracy has been verified to several milliseconds by cross-correlating WAM light curves with those of various satellites for soft gamma-ray repeaters and GRBs with accurately known position information. After this verification, the WAM has played an important role as one of the IPN instruments in near-Earth orbit thanks to its large detection rate. The rapid and precise localizations of some events has led to the discovery of X-ray and optical afterglows for events such as the bright GRB 070125, and has helped verify events which Swift detected during slew GRB. IPN_RAW Notices with detection information are now available at http://gcn.gsfc.nasa.gov/ipn/gcn_ipn_raw.html and are useful for wide field instruments operating in the optical and high energy gamma-ray ranges, as well as in non-electromagnetic regimes. The GRB localization by the WAM alone, which is done with a technique similar to that used by BATSE, is still under development, although we have verified so far that it can constrain a position to about 5 degrees in the azimuthal direction.

The WAM software is available in the HEADAS standard package, so one can produce light curves and energy spectra over arbitrary time intervals. However, the WAM energy response generator will not be made generally available because of its complex structure; however, we will make the responses publicly available for individual bursts in the near future. If you have any requests or questions about the WAM data, please let the Suzaku-WAM team know through the e-mail address suzaku-wam@astro.isas.jaxa.jp. Any collaborations with our team will be welcome.

ACKNOWLEDGMENTS

This research has been supported in part by a Grant-in-Aid for Scientific Research (19047001 KY) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

REFERENCES

1. T. Takahashi et Cal., *PASJ*, **59**, S35 (2007)
2. M. Kokubun et Cal., *PASJ*, **59**, S53 (2007)
3. K. Yamaoka et Cal., *PASJ*, to appeared in the third Suzaku special issue, (2009)
4. W.S. Spaces et al., *Pays*, **122**, 465 (1999)
5. M. Ohno et al., these proceedings (2009)
6. H. A. Krimm et al., these proceedings (2009)