In-flight performance of the Soft Gamma-ray Detector (SGD) onboard Hitomi

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Abstract

The Soft Gamma-ray Detector (SGD) is one of observational instruments onboard the Hitomi (ASTRO-H), and will provide better sensitivity in 60–600 keV than the past observatories. The SGD utilizes similar technologies to the Hard X-ray Imager (HXI) onboard the ASTRO-H. The SGD achieves low background by constraining gamma-ray events within a narrow field-of-view by Compton kinematics, in addition to the BGO active shield. SGD was successfully turned on and observed the Crab nebula. All the instrumental components, including 6 Compton cameras and 50 BGO active shields, were worked well without significant problems. Noise performance was <2 keV (FWHM) at 100 keV, as well as expected, and the pulse profle from the Crab netron star was obtained. Polarization studies of the Crab nebula is going on. In this paper, we will report the in-flight operation, calibration, and performance of SGD.

Key words: Gamma-rays Instruments — Gamma-rays: Soft Gamma-ray Compton Camera

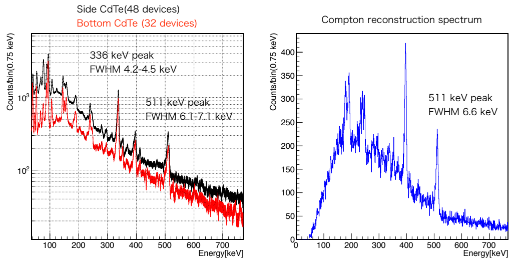

Fig. 1. SGD1 CC1 spectra in orbit. The left panel shows the spectra of the CdTe detectors. The sum spectrum of 48 side CdTe detectors and that of 32 bottom CdTe detectors are shown in black and red, respectively. The right panel shows the spectrum of Compton-reconstructed events. Gamma-ray emission lines from activated materials can be seen.

A Compton camera of SGD consists of a stack of 32 layers of 0.6 mm thick Si pixel sensors followed by 8 layers of 0.75 mm thick CdTe pixel, surround by 2 layers of 0.75 mm thick CdTe pixel sensors on the four sides. Signal processing chain of the Compton camera consists of 208 Front-End Cards (FECs) followed by four ASIC Driver Boards (ADBs) and an ASIC Control Board (ACB). These components are packed in a $12\times12\times12$ cm^3 aluminum enclosure. Such a high-density stacking of Si and CdTe sensors is critical to obtain a high efficiency of Compton reconstruction of 10–15% around 100 keV. Detailed design of Compton camera of SGD is described in Watanabe et al. (2014).

The start-up operation of SGD-S began from March 15, 2016. From March 21, SGD1-S had been operated in the nominal observation mode, and SGD2-S was put into the nominal observation on March 24 2016, just before the maneuver to the Crab nebula. The exposure of the Crab observation was about 5 ks. The data before the maneuver to the Crab nebula is useful for the background studies of SGD.

In orbit, we confirmed the performance by using gamma-ray emission lines from activated materials. Figure 1 shows the single-hit spectra of CdTe sensors and the spectrum of Compton reconstructed events in orbit. Good energy resolutions consistent with the expectation from the on-ground performance were also verified as there was no degradation from the performance obtained in the component level tests.

In order to confirm the alignment with the optical axis of the satellite, we compared the observed rate for the Crab nebula with the Monte Carlo simulation result assuming the nominal Crab flux. The count rates of 35–60 keV, where the effects of threshold dispersions are insignificant, were obtained within less than 5 percents, which means that the misalignments among six fine collimators was less than 1.5 arcmin. The count rate predicted by simulation was consistent with the observed value, implying that the effects of the fine collimator misalignment and distortion are negligible.

In order to confirm the time assignment, pulse analyses of the Crab pulsar were performed. In order to obtain large number of events, photo-absorption signals in the top 4 Si layers are used in this analysis. The tool for ASTRO-H time assignments is applied to the SGD Crab data, and, barycentric correction is also applied. The pulse period of 33.720462 ms was successfully detected, as shown in Figure 2 left.

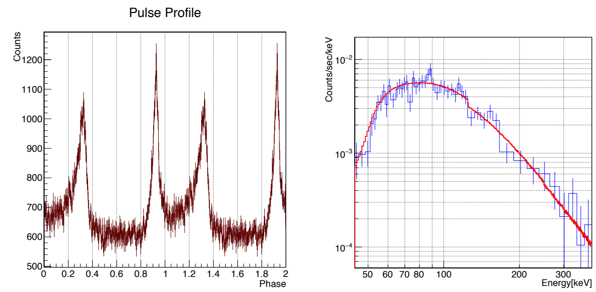

Fig. 2. (left) Obtained pulse profile of top 4 layers Si detector events. All events of six Compton cameras are summed. The pulse period is 33.720462 ms. (right) Compton event reconstructed spectrum during the Crab observation. The background is subtracted. The events from four Compton cameras (SGD1CC1,CC2,CC3 and SGD2CC1) are summed. A result of the Monte Carlo simulation is shown in the red.

In SGD, we can reject backgrounds which are unlikely to be celestial gamma rays by requiring the consistency of the Compton scattering angles, one derived from the Compton kinematics, and the other derived from the geometrical information. The resulting spectrum in four operational Compton cameras (three in SGD1 and one in SGD2) after the background subtraction during the Crab observation is shown in Figure 2 right. The preliminary result of the Monte Carlo simulation after the same event reconstruction as the observation data is also shown in the red spectrum. In the simulation of the Crab nebula observation, we assumed a power-law spectrum with a photon index of 2.1. The 40–1000 keV flux was 2.0×10^{-8} erg/cm^2/s. During the Crab observation, we have obtained about 3500 Compton-reconstructed events in the range of 50–300 keV, which can also be used for the polarization measurement, and the careful analysis for the polarization measurement is in progress.

The Detail of in-flight performance of SGD is summarized in Watanabe et al. (2016), and also the performance of BGO Anti-coincidence detectors are reported in Ohno et al. (2017) in this proceeding.

Watanabe et al. 2014, NIM-A 765, 192
Watanabe et al. 2016, Proc. SPIE 9905, 13