View metadata, citation and similar papers at core.ac.uk
brought to you by CORE

Acta Polytechnica **53**(Supplement):803–806, 2013
doi:10.14311/AP.2013.53.0803
© Czech Technical University in Prague, 2013
available online at http://ojs.cvut.cz/ojs/index.php/ap

THE ASTRO-H MISSION

Yoshitomo Maeda[a,*], Tadayuki Takahashi[a], Kazuhisa Mitsuda[a], Richard Kelley[b], on behalf of the ASTRO-H Team

[a] *Institute of Space and Astronautical Science (ISAS), JAXA, Kanagawa, 252-5210, Japan*
[b] *NASA/Goddard Space Flight Center, Greenbert, MD 20771, USA*
[*] corresponding author: ymaeda@astro.isas.jaxa.jp

Abstract. A review of the Astro-H mission is presented here on behalf of the Astro-H collaboration. The joint JAXA/NASA ASTRO-H mission is the sixth in a series of highly successful X-ray missions initiated by the Institute of Space and Astronautical Science (ISAS). One of the main uniquenesses of the ASTRO-H satellite is the high sensitivity and imaging capability of the wide energy band from 0.3 keV to 600 keV. The coverage is achieved by combining the four instruments of the SXS, SXI, HXI, and SGD. The other main uniqueness is a spectroscopic capability not only for a point-like source but also for an extended source with high spectral resolution of $\Delta E \sim 4 \div 7$ eV of SXS. Using the unique powers of these instruments, ASTRO-H will address unresolved issues in high-energy astrophysics.

Keywords: X-ray, hard X-ray, gamma-ray, X-ray astronomy, gamma-ray astronomy, micro-calorimeter.

1. Introduction and current status

ASTRO-H (formerly known as "NeXT") is a facility-class mission to be launched on JAXA H-IIA into low Earth orbit in 2014 [1–3]. NASA has selected US participation in ASTRO-H as a Mission of Opportunity. Up to now, more than 160 scientists from Japan/US/Europe/Canada have contributed to the ASTRO-H mission.

ASTRO-H will be launched into a circular orbit with altitude $500 \div 600$ km, and inclination 31 degrees or less. The total mass at launch will be as heavy as 2700 kg while the length is about 14 m in orbit. ASTRO-H is a pointing observation-type satellite; each target is pointed until the integrated observing time is accumulated, and then slews to the next target. All instruments introduced in the later section are co-aligned and will operate simultaneously.

ASTRO-H has just completed the first half of the critical design review (CDR-1) which is required before making the system tests using the Thermal Test Model (TTM) or The Mechanical Test Model (MTM) and producing a part of the flight modules. In this paper, we will summarize the mission concept and the current baseline configuration of instruments of ASTRO-H. A comprehensive introduction and most recent reviews of the ASTRO-H mission will be presented at the SPIE meeting in July, 2012 [3].

2. Spacecraft and instruments

ASTRO-H will carry three focusing optics-type telescopes (SXS, SXI, HXI) and one Compton telescope (SGD). The conceptual design of each instrument is shown in Fig. 1, and the requirements and specifications of the instruments based on the base-line design are summarized in Tab. 1.

The Soft X-ray Spectrometer (SXS) achieves high resolution spectroscopy with imaging [4, 5]. SXS has the X-ray Calorimeter Spectrometer (XCS) focused by the Soft X-ray Telescope (SXT-S) [6, 7]. The energy resolution of the XCS is as good as ≤ 7 eV in the $0.3 \div 12$ keV band pass with an effective area at 6 keV of $\sim 210\,\mathrm{cm}^2$. The detector array corresponds to a field of view of 3.04 arcmin on a side.

A filter wheel (FW) assembly, which includes a wheel with selectable filters and a set of modulated X-ray sources will be installed between the SXT-S and XCS. The FW is able to rotate a suitable filter into the beam to optimize the count rate [9]. An high count rate degrades the energy resolution power. In addition to the filters, a set of on-off-switchable X-ray calibration sources, using light sensitive photo-cathode, will be implemented. These calibration sources will allow proper gain and linearity calibration of the detector in flight.

The X-ray sensitive silicon charge-coupled devices (CCDs) of the Soft X-ray imaging system (SXI) provide a low background and high energy resolution tool. SXI will consist of a telescope (SXT-I) and the focal plane detector "Soft X-ray Imager" [11, 12]. The design of SXT-I is the same as that of SXT-S [6, 7]. SXI will use next generation Hamamatsu CCD chips with a thick depletion layer of 200 µm, low noise, and almost no cosmetic defects. SXI features a large FOV and covers a $38 \times 38\,\mathrm{arcmin}^2$ region on the sky, complementing the smaller FOV of the SXS calorimeter. The effective area is larger than one unit of the Suzaku XIS.

The hard X-ray imaging system (HXI) consists of the Hard X-ray Telescope (HXT) and its Hard X-ray Imager focal plane detector and enables imaging spectroscopy in the $5 \div 80$ keV band. The HXT has

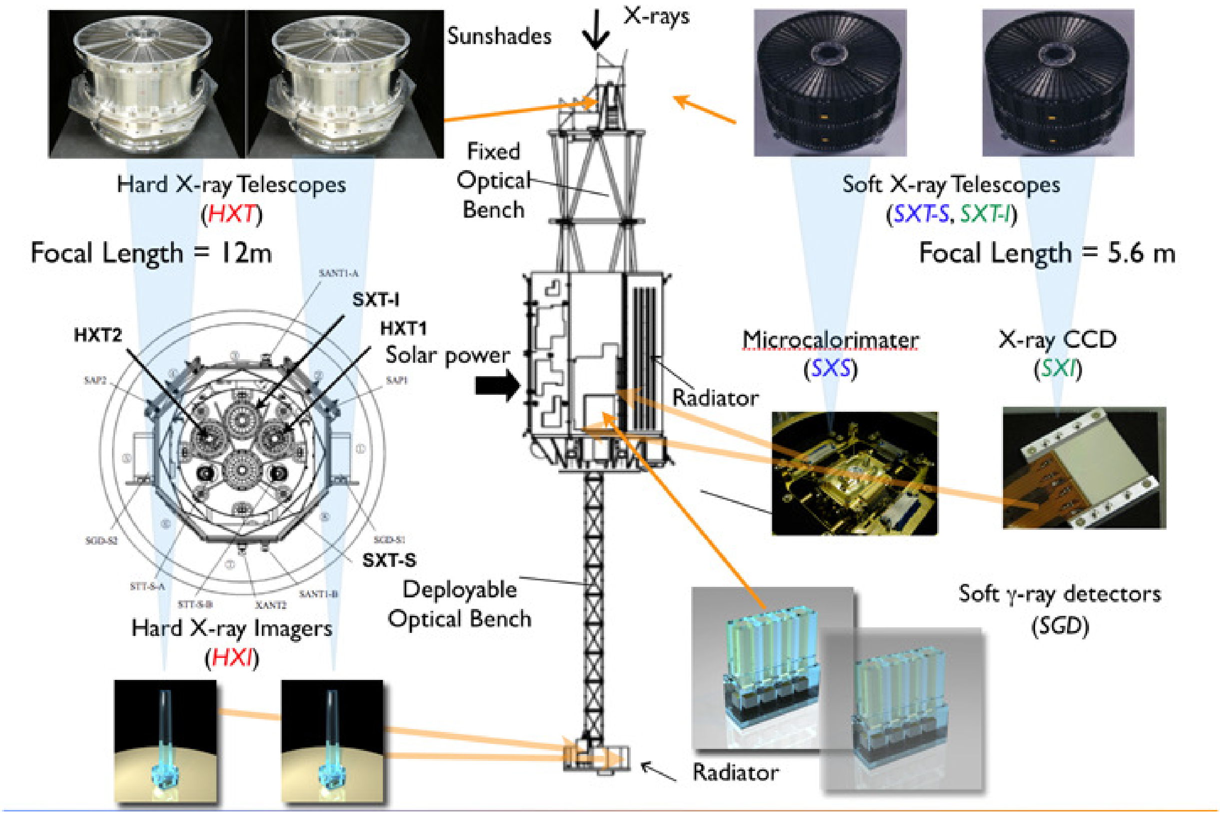

FIGURE 1. Configuration of the ASTRO-H satellite. [3].

Parameter	Hard X-ray Imager (HXI)	Soft X-ray Spectrometer (SXS)	Soft X-ray Imager (SXI)	Soft γ-ray Detector (SGD)
Detector technology	Si/CdTe cross-strips	micro calorimeter	X-ray CCD	Si/CdTe Compton Camera
Focal length	12 m	5.6 m	5.6 m	–
Effective area	300 cm^2@30 keV	210 cm^2@6 keV 160 cm^2@1 keV	360 cm^2@6 keV	> 20 cm^2@100 keV Compton Mode
Energy range	5 ÷ 80 keV	0.3 ÷ 12 keV	0.5 ÷ 12 keV	40 ÷ 600 keV
Energy resolution (FWHM)	2 keV (@60 keV)	< 7 eV (@6 keV)	< 200 eV (@6 keV)	< 4 keV (@60 keV)
Angular resolution	< 1.7 arcmin	< 1.3 arcmin	< 1.3 arcmin	–
Effective Field of View	∼ 9 × 9 arcmin^2	∼ 3 × 3 arcmin^2	∼ 38 × 38 arcmin^2	0.6 × 0.6 deg^2 (< 150 keV)
Time resolution	25.6 µs	5 µs	4 s/0.1 s	25.6 µs
Operating temperature	−20 °C	50 mK	−120 °C	−20 °C

TABLE 1. Summary of the four instruments of ASTRO-H [3].

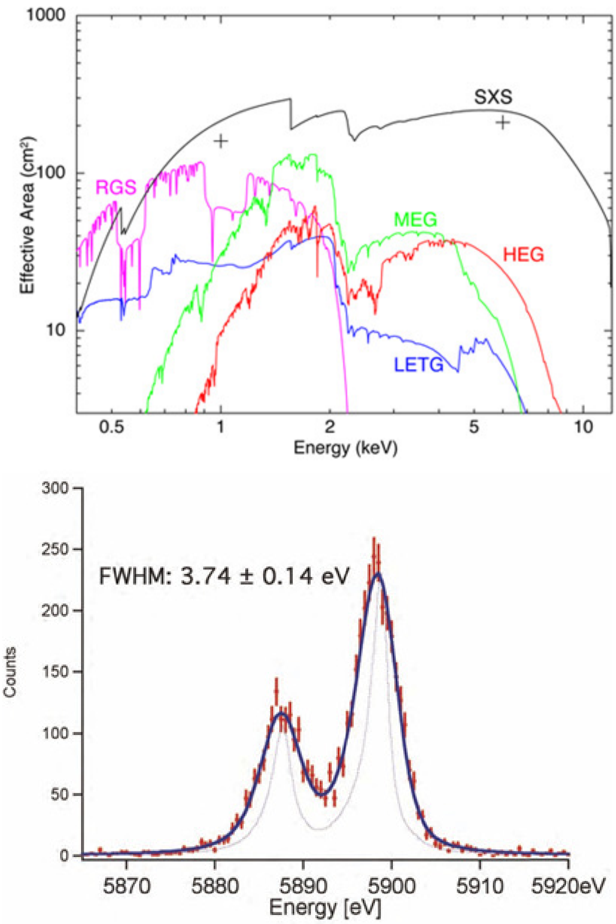

FIGURE 2. (top) The effective area of SXS. (below) The energy resolution obtained from Mn Kα_1 using a detector from the XRS program but with a new sample of absorber material (HgTe) that has lower specific heat, leading to an energy resolution of 3.7 eV (FWHM). SXS could have energy resolution approaching this value [8].

conical-foil mirrors with depth-graded multilayer reflecting surfaces that provide a $5 \div 80$ keV energy range [13, 14]. The focal plane imager consists of four-layers of 0.5 mm thick Double-sided Silicon Strip Detectors (DSSD) and one layer of 0.75 mm thick CdTe double sided cross-strip detector [15, 16].

The Soft Gamma-ray Detector (SGD) is a Compton telescope which is sensitive to a broad band of $40 \div 600$ keV [17, 18]. The sensitivity at 300 keV is 10 times better than the Suzaku HXD. It outperforms previous soft γ-ray instruments in background rejection capability by adopting a new concept of narrow-FOV Compton telescope. The SGD can be functioned in two ways. One is the "photo absorption" mode in which the larger effective area is achieved but the imaging is not functional. The other is the Compton mode in which the SGD is capable of measuring polarization as well as image.

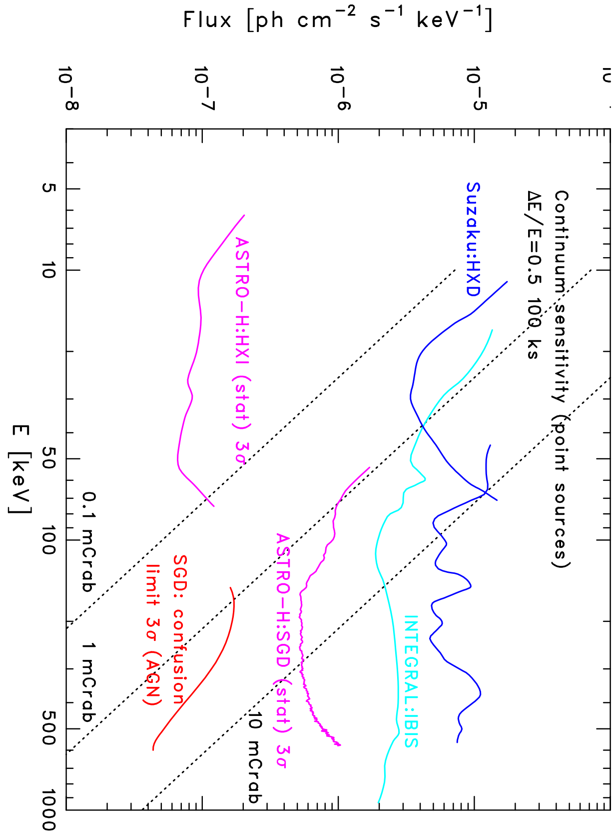

FIGURE 3. Detection limits of the SXT-I/SXI, HXT/HXI and SGD for point sources as functions of X-ray energy, where spectral binning with $\Delta E/E = 0.5$ and 1000 ks exposure are assumed. [3].

3. Expected Scientific Performance

In contrast to the high-resolution gratings of Chandra/HEG and XMM-Newton/RGS, at $E > 2$ keV, SXS is the more sensitive and has higher resolution (Fig. 2). It is notable that in the Fe K band SXS has 10 times the collecting area and much better energy resolution than Chandra/HEG. The SXS band covers the critical inner-shell emission and absorption lines of Fe I–XXVI between 6.4 and 9.1 keV often seen in the spectra from AGN or Galactic BH candidates.

SXS uniquely performs high-resolution spectroscopy of extended sources such as cluster of galaxies and supernova remnants because it is non-dispersive. For sources with angular extent larger than 10 arcsec, the Chandra MEG energy resolution is degraded down to the level of CCD. The energy resolution of the XMM-Newton RGS is similarly degraded for sources with angular extent ≥ 2 arcmin. SXS makes possible high-resolution spectroscopy of sources inaccessible to current grating instruments.

Figure 3 shows the broad-band sensitivity achieved by combing the two instruments, HXI and SGD for point sources. The sensitivity at 30 and 300 keV is two orders and one order of magnitude better than the Suzaku HXD. A cloud of cool gas has been spotted approaching the supermassive black hole SgrA* which lies at the center of our Milky Way galaxy [19]. In 2013, one year before the ASTRO-H launch, the cloud may reach the event horizon, starting a bright X-ray flaring activity [20] that will shed new light on the black hole's feeding behavior. With its broad band capability, ASTRO-H will catch the flare with a flux brighter than $10^{35\div36}\,\mathrm{erg\,s^{-1}}$ that will shed new light on the black hole's feeding behavior.

Acknowledgements

The authors are deeply grateful for on-going contributions provided by other members in the ASTRO-H team in Japan, the US, Europe and Canada.

References

[1] NeXT Satellite Proposal,the NeXT working group, submitted to ISAS/JAXA (2003)

[2] T. Takahashi, K. Mitsuda, R.L. Kelley et al., "The ASTRO-H Mission", Proc. SPIE, **7732**, pp. 77320Z-77320Z-18 (2010)

[3] T. Takahashi, et al., "The ASTRO-H Mission", SPIE, **8443**, submitted (2012)

[4] K. Mitsuda et al. "The high-resolution X-ray microcalorimeter spectrometer system for the SXS on ASTRO-H", Proc. SPIE **7732**, pp. 773211-773211-10 (2010)

[5] R.L. Kelley et al., "The high resolution microcalorimeter soft X-ray spectrometer for the Astro-H Mission", Proc. SPIE, **8443**, submitted (2012)

[6] P. Serlemitsos et al., "Foil X-ray mirrors for astronomical observations: still an evolving technology", Proc. SPIE **7732**, pp. 77320A-77320A-6 (2010)

[7] T. Okajima et al. "The first measurement of the ASTRO-H soft X-ray telescope performance", Proc. SPIE, **8443**, submitted (2012)

[8] F. S. Porter and et al., "The Astro-H Soft X-ray Spectrometer (SXS)", AIP Conference proceedings **1185**, pp.91-94 (2009)

[9] C.P. de Vries et al., "Filters and calibration sources for the Soft X-ray Spectrometer (SXS) instrument on ASTRO-H", SPIE **7732**, pp. 773213-773213-9 (2010)

[10] C. P. de Vries et al., "Calibration sources for the soft X-ray spectrometer instrument on ASTRO-H", Proc. SPIE, **8443**, submitted (2012)

[11] H. Tsunemi et al., "The SXI: CCD camera onboard ASTRO-H", Proc. SPIE **7732**, pp. 773210-773210-11 (2010)

[12] H. Tsunemi et al., "Soft X-ray imager (SXI) onboard ASTRO-H", Proc. SPIE, **8443**, submitted (2012)

[13] H. Kunieda, et al., "Hard X-ray Telescope to be onboard ASTRO-H", Proc. SPIE **7732**, pp. 773214-773214-12 (2010)

[14] H. Awaki et al., "Current status of ASTRO-H hard X-ray telescopes (HXTs)", Proc. SPIE, **8443**, submitted (2012)

[15] M. Kokubun et al., "Hard X-ray imager for the ASTRO-H Mission", Proc. SPIE **7732**, pp. 773215-773215-13 (2010)

[16] M. Kokubun et al., "Hard X-ray imager (HXI) for the ASTRO-H Mission", Proc. SPIE, **8443**, submitted (2012)

[17] H. Tajima. et al.,"Soft Gamma-ray Detector for the ASTRO-H Mission", Proc. SPIE **7732**, pp. 773216-773216-17 (2010)

[18] S. Watanabe et al., "Soft gamma-ray detector for the ASTRO-H Mission", Proc. SPIE, **8443**, submitted (2012)

[19] S. Gillessen, et al. "A gas cloud on its way towards the supermassive black hole at the Galactic Centre", Nature 481, 51–54 (2012)

[20] F. K. Baganoff, et al. "Rapid X-ray flaring from the direction of the supermassive black hole at the Galactic Centre" Nature 413, 45–48 (2001)