Abstract We describe briefly the ongoing and future X-ray missions in Japan. In addition to the observatory class missions, we plan to advance the small satellite program and participation to the international missions.

Key words: Instruments: detectors — Telescopes — X-rays: general

1 On Going Mission: Suzaku

ISAS successfully launched the X-ray astronomy satellite Suzaku (formally Astro-EII) on July 10th, 2005, with the M-V-6 rocket ([3]). Suzaku is the fifth in the series of Japanese X-ray astronomy satellites, following Hakuto (1979), Tenma (1983), Ginga (1987) and ASCA (1993). The mission is based on the collaboration between Japanese universities and institutions and the NASA Goddard Spade Flight Center. Suzaku is designed for observations of hot plasmas and energetic phenomena in the Universe. It equipped with X-ray telescopes and 3 kinds of detectors to perform broad-band and high-resolution X-ray spectroscopy. Unfortunately, the micro-calorimeter, which operated at a temperature as low as 60 mK to achieve an energy resolution twenty times better than that of a CCD camera, stopped functioning about a month after the launch due to the loss of liquid He. However, we could confirm its high energy resolution in space using the internal calibration source ([2]). The remaining instruments are working well and have demonstrated the high-sensitivity, broad band X-ray spectroscopy. Observation programs of the first eight months were determined by the international science working group (SWG). After the SWG period, observation programs were planned based on the peer review of proposals submitted from all over the world. Suzaku provides capabilities complementary to those of other large X-ray observatories Chandra (NASA) and XMM-Newton (ESA), and is a great asset for X-ray astronomers world-wide. Initial results from Suzaku, together with the description of the satellite and the instruments, are found in the special issue (vol. 59, SP1) of Publications of the Astronomical Society of Japan.

2 Future Programs

2.1 Monitor of All-sky X-ray Image: MAXI

MAXI is an all sky X-ray monitor to be mounted on the Japanese Experimental Module in the International Space Station (ISS). It is currently scheduled to be launched in 2008. MAXI scans almost whole the sky every 96 minutes, in the course of the orbital motion of the ISS. MAXI is designed to have a significantly higher sensitivity than the previous X-ray all-sky monitors ([10]). It can detect X-ray sources as faint as 1 mCrab in a week of observation. Therefore, MAXI is expected to create a novel catalogue of not only the stable X-ray sources but also the highly variable ones in the sky, especially active galactic nuclei for the first time.
If MAXI detects X-ray transients, alerts will be quickly circulated in the community through Internet.

2.2 NEXT: New Exploration X-ray Telescope

The New Exploration X-ray Telescope (hereafter abbreviated as NEXT) will be the sixth Japanese X-ray astronomy observatory following Suzaku ([8]). It combines wide-band imaging spectroscopy (3-80 keV) provided by focusing hard X-ray mirrors and pixel detectors, high energy-resolution spectroscopy (0.3-10 keV) with the micro-calorimeter, wide-field coverage with a CCD camera and soft γ-ray sensitivity provided by a Compton camera. NEXT aims at comprehensive understanding of high-energy non-thermal phenomena such as cluster mergers, particle acceleration in a shock, and relativistic effects near the black holes.

In Fig. 1 a schematic view of the configuration of the NEXT instruments is shown. One of the two main instruments is the system composed of the Soft X-ray Telescope for Spectrometer (SXT-S) and the Soft X-ray Spectrometer (SXS). This system adopt the basic design of the Suzaku XRS, utilizing the pixelized mercury telluride as the detector. The SXS will carry out a fine spectroscopy with an energy resolution of $E/\Delta E \approx 1000$ at 6 keV, which is more than 20 times better than a CCD camera. Fig. 2 shows a comparison of iron line spectra between a CCD camera and the SXS. Cryogenics of SXS will be much improved compared to that of XRS to extend the life of the system, including a two-stage Stirling cycle cooler, and a $^3$He Joule-Thomson cooler. The SXS will be developed in collaboration with NASA/GSFC and the Wisconsin University.

The other main instrument is composed of the Hard X-ray Telescope (HXT) and the Hard X-ray Imager (HXI). The HXT utilize the so-called super mirror technology developed by the Nagoya University, whose capability was already demonstrated in the balloon-borne experiments several times since 2001 ([4]). It adopts the same Wolter I type optics as the SXTs,
but a Pt/C multilayer is coated on the mirror surface. This enables reflection of hard X-rays according to the Bragg reflection in addition to the total reflection below $\sim 10$ keV. This is referred to as ‘super mirror’ technology, and enables the HXT to focus X-rays up to 80 keV for the first time. The sensitivity in 10–80 keV band can be increased roughly by two orders of magnitude with the HXT, as demonstrated in Fig. 3. The HXI is composed of Si micro-strip and CdTe semiconductors deeply embedded into the well made from BGO crystal that works as an active shield, as was the case for the Suzaku HXD.

In addition to these two main instruments, the mission payload include the Soft X-ray Telescope for Imaging (SXT-I) and the Soft X-ray Imager (SXI), which adopt a total reflection Wolter I type telescope and a CCD camera, respectively. The depletion layer of the CCD is much thicker than that of Suzaku. The imaging capability of the SXT-I will also be significantly improved from Suzaku. A Soft Gamma-ray Detector (SGD), sensitive to 10–300 keV, will be a well-type, actively shielded detector like the HXD aboard Suzaku. If only the signals due to photo-electric absorption are used, it works just as HXD. However, it can also work as a Compton camera, in which the incident direction of the $\gamma$-ray photon is determined by solving the Compton kinematics. This Compton mode is useful to reduce the background.

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**Figure 2:** Comparison of the iron band energy spectra from a thermal plasma observed with a CCD camera and the SXS.

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**Figure 3:** (Left): Sensitivity of the HXT and HXI system. (Right): its effective area.
event largely. The mission is in the phase-A development and recognized as a pre-project in JAXA as of January 2008. We expect to launch NEXT in 2013 with the HIIA rocket. It will be more than 10 years in 2013 since the major Europe and US missions XMM-Newton and Chandra were launched, but more than five years would be required before the advent of the next large X-ray missions such as XEUS and Constellation-X. It is thus widely expected that NEXT will fill this vacuum between large X-ray observatories.

2.3 XEUS: X-ray Evolving Universe Spectroscopy

X-ray Evolving Universe Spectroscopy (hereafter XEUS; [6]) is a large X-ray astronomy mission proposed by the European X-ray community as the next generation X-ray observatory following XMM-Newton to the program “Cosmic Vision 2015–2025” announced by ESA in 2007 March. The mission aims at understanding fundamental physical questions, such as the nature of the fundamental physical laws in the universe, how the universe originated, and what it is made of, by means of a huge effective area of several m$^2$ and an excellent spatial resolution better than $\sim 5''$. Major participation of Japan to this mission is being studied now.

2.4 Smaller missions under study

2.4.1 SRG: Spectrum Röntgen Gamma

Spectrum Röntgen Gamma (hereafter SRG; [7]) is a Russian mission currently planned to be launched around the end of 2011 either from Kourou or Baikonur with Soyuz-2 and to be placed in an orbit with an altitude of 600 km and an inclination either of $< 4^\circ$ or $29^\circ$. The main instrument of SRG is eROSITA, supplied by Germany, which is comprised of seven modules of the X-ray telescope and the CCD camera to carry out an all-sky survey in the 2–10 keV band. JAXA, collaborating with other institutes, will provide a calorimeter system (SXC) similar to the NEXT SXS and will be responsible for the whole cryogenic system, an instrument digital electronics, and a power-supply unit. The main science of the SRG SXC, dynamics of the intergalactic medium in nearby clusters of galaxies.

2.4.2 DIOS: Diffuse Intergalactic Oxygen Surveyor

Diffuse Intergalactic Oxygen Surveyor (DIOS) is proposed to ISAS/JAXA as one of the small satellite missions (Ohashi et al. 2006). The main objective is to detect and to make 3-D map of Warm-Hot Intergalactic Medium (WHIM). The technology is similar to the XRS onboard Suzaku, NEXT and SRG.

2.4.3 FFAST: Formation Flying All-Sky monitoring Telescope

Formation Flying All-Sky monitoring Telescope (hereafter FFAST) is a unique all-sky survey mission that covers the energy band up to $\sim 80$ keV ([9]). It comprises a Wolter I type X-ray telescope with a reflector surface coated by Pt/C multilayer. In order to reflect and focus X-rays up to 80 keV, a long focal length is required. Hence, the mission consists of two satellites, i.e. a telescope satellite and a detector satellite, both flying in formation with a
constant separation of 20 m, which corresponds to the focal length of the telescope. \textit{FFAST} adopts a Scintillator-Deposited CCD (SD-CCD) camera developed by Osaka University as a focal plane detector.

\subsection*{2.4.4 Polaris: Polarimetry Satellite}

Polaris, led by the Osaka University, is designed for observing X-ray polarization in a wide energy band of 0.25–80 keV combining the multilayer super mirror technology and a Compton-scattering polarimeter ([1]). The mission aims to measure the X-ray polarization other than the Crab nebula for the first time. Expected targets include rotation-powered pulsars, X-ray binaries, active galactic nuclei, and the $\gamma$-ray bursts. Performance of the Compton-scattering polarimeter has been tested by the balloon experiments lead by the Yamagata University.

\section*{References}