A brief history of the High-Energy Astrophysics Laboratory

T. Tamagawa, *1 on behalf of the laboratory members

1 Overview

The High-Energy Astrophysics Laboratory started in April 2010. The goals of our research activities are 1) to reveal the mechanism of nucleosynthesis and the evolution of elements in our universe, 2) to study the particle acceleration mechanisms by shockwaves or electrical potential, and 3) to observe/discover exotic physical phenomena in extremely strong magnetic and/or gravitational fields. We have observed supernova remnants (SNRs), strongly magnetized neutron stars, pulsars, black holes, galaxies, and planets of the solar system with UV, X-ray, and gamma-ray astronomical satellites and/or ground-based telescopes.

At the beginning of the laboratory in 2010, we set a goal for the first five years to complete the construction of two X-ray satellite missions, ASTRO-H (spectroscopy) and PRAXyS (polarimetry). X-rays carry four independent physical quantities: position, timing, energy, and polarization. X-ray astrophysics has been advanced by observing those quantities of X-rays from high-energy astrophysical objects. However, there is significant room to improve the observational sensitivities in X-ray spectroscopy and polarimetry with current techniques. This is why we are concentrating on those two quantities to open a new window in astrophysics.

In general, the construction of satellite missions is not an easy task. Five post-doctoral fellows (A. Hayato, T. Kitaguchi, T. Enoto, W. Iwakiri, and T. Nakano) have contributed to the PRAXyS project, and five other post-doctoral fellows (T. Yuasa, H. Noda, K. Ishikawa, G. Sato, and T. Enoto) have contributed to the construction, integration, and testing of ASTRO-H.

In parallel with the contribution to those missions, we have analyzed the data of high-energy stellar objects observed by currently working satellites such as Suzaku (5th Japanese satellite launched in 2005), XMM-Newton (Europe), and Chandra (US). Some of the research highlights are the first detection of Cr and Mn in a Type-Ia SNR, the first measurement of the expansion velocity of ejecta in Tycho's SNR,[1] and discovery of charge-exchange emission in SNRs.[2]

2 PRAXyS and ASTRO-H missions

The polarimeter for Astrophysical X-ray Sources (PRAXyS) is one of NASA's small explorer missions and is led by the Goddard Space Flight Center (NASA/GSFC). RIKEN is a key institute of the project, providing a core device, "Gas Electron Multiplier (GEM) foil," of the X-ray polarimeter. In 2009 the project was selected by NASA for launch in 2014. However, it was cancelled in May 2012 owing to unexpected cost overrun by NASA. The joint group of NASA and RIKEN re-submitted the project proposal to NASA, which was fortunately selected for Phase-A (conceptual design) study in July 2015. We have led the Phase A study with NASA/GSFC, and our results are summarized in Iwakiri et al. (2016).[3]

The 6th Japanese X-ray astronomical satellite ASTRO-H (named "Hitomi" after the launch), which was launched on February 17, 2016 from JAXA's Tanegashima Space Center (TNSC) by the H-IIA launch vehicle F-30. The Hitomi satellite is constructed by all the Japanese institutes related to the X-ray astrophysics including RIKEN in collaboration with US and Europe. The total mass of the satellite is 2.7 ton, and the length is 14 m after deploying the optical boom. Hitomi carries four X-ray and gamma-ray detectors covering the 0.3–600 keV energy range. Our laboratory, in collaboration with JAXA, Tokyo Metropolitan University, Kanazawa University, Saitama University, NASA/GSFC etc., contributed to the soft X-ray spectrometer (SXS), which achieved unprecedented energy resolution ($\sim$5 eV) in the 0.3–12 keV energy band with a low-temperature micro calorimeter. Soon after the launch, SXS achieved the operation temperature and observed the Perseus galaxy cluster and some other celestial objects for verifying the detector system. Although the Hitomi satellite was lost in March 2016 owing to a tragic accident, the data obtained in the verification phase were analyzed and published in Nature.[4] This analysis demonstrated the excellent capability of the microcalorimeter in spectroscopy. A recovery mission is planned for launch in 2021.

3 Other missions

Besides the missions described above, we are partially contributing to the following missions:

- Hisaki: The Japanese small satellite dedicated for planetary science, observing EUV photons. (Contributor: T. Kimura.) The transient brightening of Jupitar's aurora coincident with the arrival of the solar wind was discovered and published by Kimura.[5]
- NuSTAR: NASA's small explorer mission for hard X-ray imaging in the 5–80 keV band. The world's first project with imaging capability in the hard X-ray band opened a new field in observation:

*1 Associate Chief Scientist/Chief Scientist of High Energy Astrophysics Laboratory (2010–present) nuclear astrophysics. A major achievement is the mapping of radioactive ^{44}Ti in Cassiopeia A SNR.[6] (Contributor: T. Kitaguchi)

- NICER and MAXI: Both are X-ray observatories onboard the International Space Station (ISS). NICER is a mission of NASA/GSFC for exploring the interior of neutron stars, which was launch in June 2017. MAXI is the RIKEN-led all sky X-ray monitor mission. It is expected that alerts of transient phenomena such as outbursts of neutron star or black hole binaries detected by MAXI will trigger deeper observations by NICER. Those observations probably permit the detection of elements produced in the nuclear burning on the neutron star surface etc. (Contributors: T. Enoto, W. Iwakiri, and T. Tamagawa)
- Large Synoptic Survey Telescope (LSST): All sky survey telescope in the optical band being constructed by a US community. The telescope surveys all sky of the southern hemisphere with $\sim$24 mag sensitivity every three days. It is under construction and the expected first light is in 2019. This telescope has good synergy with all sky X-ray monitor missions such as MAXI in astrophysics. (Contributors: Y. Okura, T. Tamagawa through RIKEN Brookhaven Research Center) A major contribution to LSST is the evaluation of CCD systematics.[7]
- Future X-ray spectrometry missions, DIOS and Athena: DIOS is a Japanese small satellite that will explore the missing baryon in the universe in the 2020s, and Athena is the ESA's large class mission for observing the evolution of galaxies/clusters in the late 2020s. (Contributors: H. Noda, T. Tamagawa)

References

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