9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

X-Ray Imaging and Spectroscopy Mission (XRISM): High-Resolution Spectroscopy of Astrophysical Plasmas

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Plasmas are ubiquitous in the universe; it is widely known that more than 90% of cosmic baryons are in the form of hot plasma that emits X-rays. Therefore, X-ray observations of astrophysical plasmas are crucial to understanding the evolution of the universe as well as the nature of individual objects with a wide range of spatial scale, from the solar corona to the intergalactic medium.

The X-Ray Imaging and Spectroscopic Mission (XRISM) is a space X-ray observatory, developed by JAXA and NASA with ESA's participation, and launched in September 2023[1]. Its main instrument, *Resolve*, is an X-ray microcalorimeter that has enabled 'non-dispersive' high-resolution spectroscopy of astrophysical plasmas with the unprecedented energy resolution of ~4.5 eV (FHWM) in the 2-10 keV band. The science objectives of XRISM are to reveal (1) formation history of the large-scale structure in the universe, (2) history of baryonic circulation (i.e., cosmic chemical evolution), and (3) mechanism of energy transportation and circulation in the universe, and to open (4) new science with unprecedented high-resolution X-ray spectroscopy. In this talk, I will review some initial science results from XRISM and discuss how the high-resolution spectroscopy plays an essential role in addressing these objectives.

Observations of galaxy clusters have successfully resolved fine structures of He-like Fe emission lines (Figure 1)[3], enabling velocity measurement of the intergalactic medium with an accuracy of ~10 km s^{-1}. This helps us reveal evidence of gas motion due to past cluster mergers, the key to understanding the formation history of the large-scale structure in the universe. Observations of supernova remnants have detected various heavy elements synthesized in their progenitors, including Si, P, S, Cl, Ar, K, Ca, Ti, Cr, Mn, Fe, and Ni[4]. The abundances of these elements provide us crucial information about the cosmic chemical evolution. Observations of active galactic nuclei have detected robust evidence of the so-called ultra-fast outflow from supermassive black holes[5], the key to understanding the galaxy-scale energy transportation.

The high-resolution X-ray spectra of astrophysical plasmas also contribute to advancing our understanding of fundamental atomic physics. For instance, the *Resolve* has detected a number of emission and absorption lines of Fe ions in different charge states from the X-ray binary Cygnus X-3 (Figure 2)[6], allowing us to investigate the complex atomic structure of multiple-electron atoms in detail. I will also discuss potential future collaboration between plasma/atomic physicists and astrophysicists in this context.

References
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[6] XRISM Collaboration, ApJL, 977, L34 (2024)

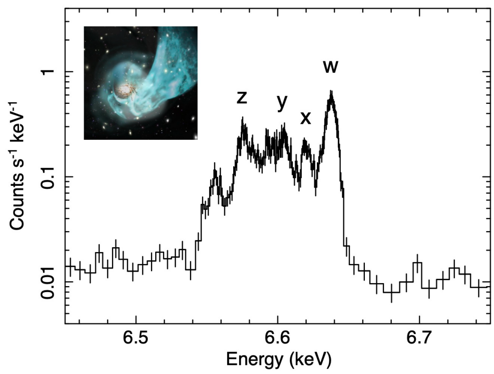

Figure 1. XRISM/*Resolve* spectrum of the Centaurus Cluster around the He-like Fe emission: w, x, y, and z denote the resonance transition from the excited state of 1s2p $^1P_1$, intercombination transitions from 1s2p $^3P_2$ and 1s2p $^3P_1$, and forbidden transition from 1s2s $^3S_1$ to the ground state, respectively. The cosmological redshift of this cluster z = 0.0114. (Figure credit: JAXA)

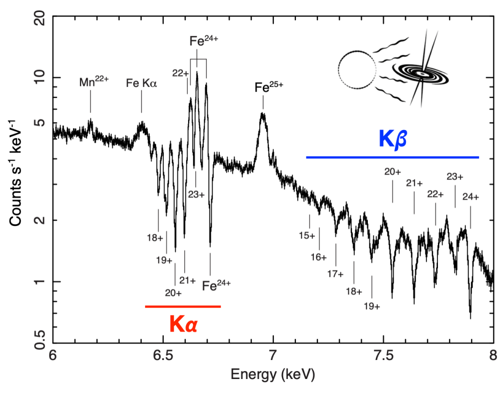

Figure 2. XRISM/*Resolve* spectrum of the X-ray binary Cygnus X-3 in the 6-8 keV band. (Figure credit: JAXA)