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A Laboratory plasma experiment for application to X-ray astronomy using a compact electron beam ion trap (EBIT)

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X-ray observations of astronomical objects play a critical role in understanding the structure formation and chemical evolution of the Universe. The X-ray astronomy satellite XRISM, launched in September 2023, is equipped with a microcalorimeter, which provides high-resolution X-ray spectroscopy in the soft X-ray bandpass up to 12 keV with an energy resolution of $E/\Delta E \approx 1300$ at 6 keV. This spectral resolution allows precise diagnostics of astrophysical plasmas, including measurements of velocity structures and elemental abundances of objects. However, more accurate atomic data are needed to analyze the high-resolution X-ray spectra.

In collaboration with the Japan Aerospace and Exploration Agency and the Max Planck Institute for Nuclear Physics, we have introduced an electron-beam ion trap (EBIT) to the Japanese astronomical community. The EBIT produces highly charged ions in arbitrary charge states using a monochromatic electron beam (Figure 1), providing an experimental benchmark for atomic data. In this presentation, we will review the results and future works of our EBIT experiment. In June 2024, we performed high-resolution photoexcitation spectroscopy of highly charged ions at the synchrotron radiation facility SPring-8. As a result, we successfully measured the resonance transition of the L-shell of Ne-like Fe. The L-shell lines of Ne-like Fe are a prominent spectral feature in the 700-1000 keV range of X-ray spectra of the astronomical objects including supernova remnants and galaxy clusters. These lines are used to diagnose electron temperature, abundance of Fe, and velocity turbulence through X-ray opacity, but theoretical predictions of these line ratios often differ from those obtained from astronomical observations. Our results are useful for constraining the centroid energies and oscillator strengths of these lines.

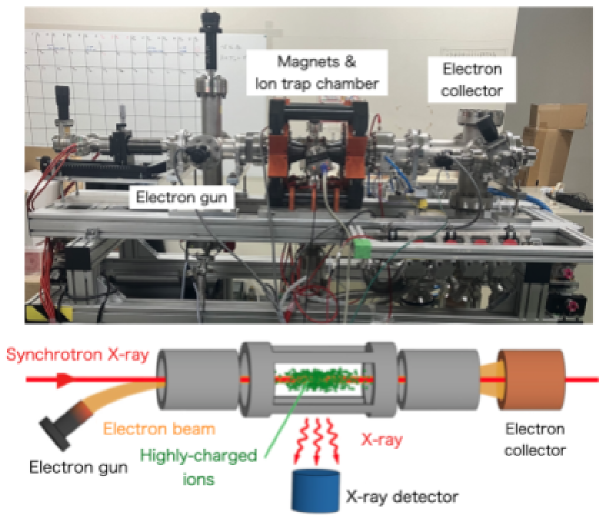

FIgure 1: Photograph and schematic view of the EBIT [2, 3].

Meanwhile, XRISM has observed various high-energy astrophysical phenomena, including supernova remnants, active galactic nuclei, and X-ray binaries, producing pioneering results. These observations have also highlighted the urgent need for new atomic data. For example, the wavelengths and transition rates of inner-shell transitions such as 1s – 3p transitions of Li-like ions are needed to analyze observational data from X-ray binaries and supernova remnants. We will also present the current status of updating the EBIT to measure these atomic data.

References

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