Probing Cosmic Rays utilizing Atomic-Collision Data

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Synopsis Cosmic Rays (CRs) are high-energy particles in space and play an essential role for the structure and evolution of our galaxy. While previous X-ray/GeV–TeV gamma-ray observations revealed the presence of GeV–TeV electrons and protons at acceleration sites far from the solar system, heavy ions are unexplored by any means. Recently, we found a strong FeI Kα line emission from interacting cold gases near supernova remnants. The FeI Kα emission can be attributed to K-shell ionization of Fe atoms by CRs. In this case, the observed spectrum has a complex structure due to multiple ionization effects by heavy ions of CRs. We calculated the line structure by using satellite-structure scalings and ECPSSR cross sections. We aim to explore for heavy ions of CRs through a detection of the structure with *the X-Ray Imaging and Spectroscopy Mission* scheduled to be launched in 2022. Here we present the detail of the calculation of the line structure and the exploration of CRs.

Cosmic Rays (CRs) are high-energy particles in space. CRs are one of the major energy component in our galaxy, and hence play an important role for the structure and evolution of our galaxy. Direct measurements of CRs arriving at the solar system revealed the presence of high-energy electron, proton and heavy ions. X-ray/GeV–TeV gamma-ray data revealed the presence of GeV–TeV electrons and protons at acceleration sites far from the solar system [1, 2]. However, any property of heavy ions in CRs at the acceleration sites is still unknown since they are unexplored by any means. We detected a strong line emission of neutral Fe (FeI Kα at 6.4 keV) from interacting cold gases near supernova remnants (SNRs) (e.g., [3]). Given that SNRs are considered to be the major CR sources, the Fe Kα emission would be attributed to K-shell ionization of Fe atoms by accelerated particles.

X-Ray Imaging and Spectroscopy Mission (*XRISM*) is planned to be launched in 2022, which enables an X-ray spectroscopy with an energy resolutions of ~ 5 keV in FWHM at 6 keV. That high resolution spectroscopy provides us with a new unique tool for exploring CRs. When CRs ionize Fe atoms, the observed spectrum consists of many lines (e.g., KαL1, KαL2...) brought by multiple ionization effects (MIEs) in addition to Kα1 and Kα2 lines. In particular, the heavier the projectile ion is, the more significant the MIE satellite lines become. Assuming the same energy spectrum and heavy-ion-composition of CRs as arriving in the solar system, we simulated the Fe Kα line structure expecting with *XRISM* (Fig. 1). We calculated the intensity and center energy of the lines via satellite-structure scalings [4] and ECPSSR cross sections [5]. Here we present details of the calculations as well as about the exploration of CRs.

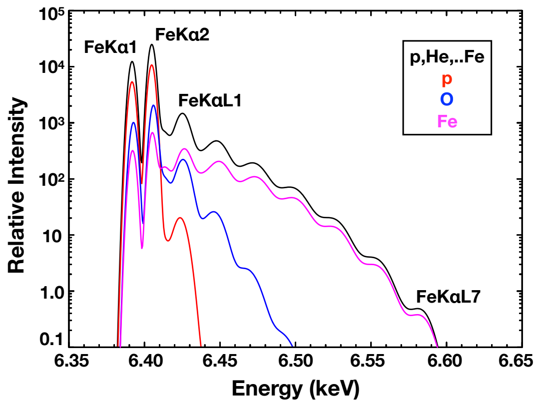

Figure 1. Simulated FeKα line structure in CR-Fe collisions. The black line denotes total contribution of all ions between p and Fe in CRs The red, blue and magenta lines show the contribution of p, O and Fe projectile ions, respectively.

References

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