Laboratory measurements compellingly supports a charge-exchange mechanism for the "Dark matter" $\sim$ 3.5 keV X-ray line

Chintan Shah*, Stepan Dobrodey*, Sven Bernitt*,†, René Steinbrügge*, Liyi Gu‡, Jelle Kaastra‡,♮, and José R. Crespo López-Urrutia*

*Max–Planck–Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
†Friedrich-Schiller-Universität Jena, Fürstengraben 1, 07743 Jena, Germany
‡SRON Netherlands Institute for Space Research, Utrecht, The Netherlands
♮ Leiden Observatory, Leiden University, 2300 RA Leiden, The Netherlands

Synopsis The reported observations of an unidentified X-ray line feature at $\sim$ 3.5 keV from galaxy clusters have driven a lively discussion about its possible dark matter origin. Motivated by this, we have investigated the X-ray spectra of highly ionized bare sulfur ions following charge exchange with residual gas in the electron beam ion trap, as a source or a contributor to this X-ray line. The X-ray feature at about 3.5 keV shows up in the experiment, which could explain the the astrophysical observations and confirm the predictions of Gu *et al.*

A mysterious X-ray signal at 3.5 keV from nearby galaxies and galaxy clusters [1] recently sparked an incredible interest in the scientific community and given rise to a tide of publications attempting to explain the possible cause for this line. The origin of this line has been hypothesized as the result of decaying sterile neutrinos–potential dark matter particle candidate, presumably on the fact that this X-ray line is not available in the standard spectral databases and models for thermal plasmas. Cautiously, Gu *et al.* [2] have pointed out to an alternative explanation for this phenomenon: charge exchange between bare ions of sulfur and atomic hydrogen. Their model shows that X-rays should emitted at 3.5 keV by a set of S^{15+} transitions from $n \geq 9$ to the ground states, where n is the principle quantum number.

With this motivation, we tested the hypothesis of Gu in the laboratory by measuring K-shell X-ray spectra of highly ionized bare sulfur ions following charge exchange with gaseous molecules in an electron beam ion trap. We produced bare S^{16+} and H-like S^{15+} ions and let them capture electrons in collision with those molecules with the electron beam turned off while recording X-ray spectra. The 3.5 keV transition clearly shows up in the charge-exchange induced spectrum under broad range of conditions. The inferred X-ray energy, 3.47 $\pm$ 0.06 keV, is in full accord agreement with both the astrophysical observations and theoretical calculations, and confirms the novel scenario proposed by Gu [2, 3]. Taking the experimental uncertainties and inaccuracies of the astrophysical measurements into account, we conclude that the charge exchange between bare sulfur and hydrogen atoms can outstandingly explain the mysterious signal at around 3.5 keV [3].

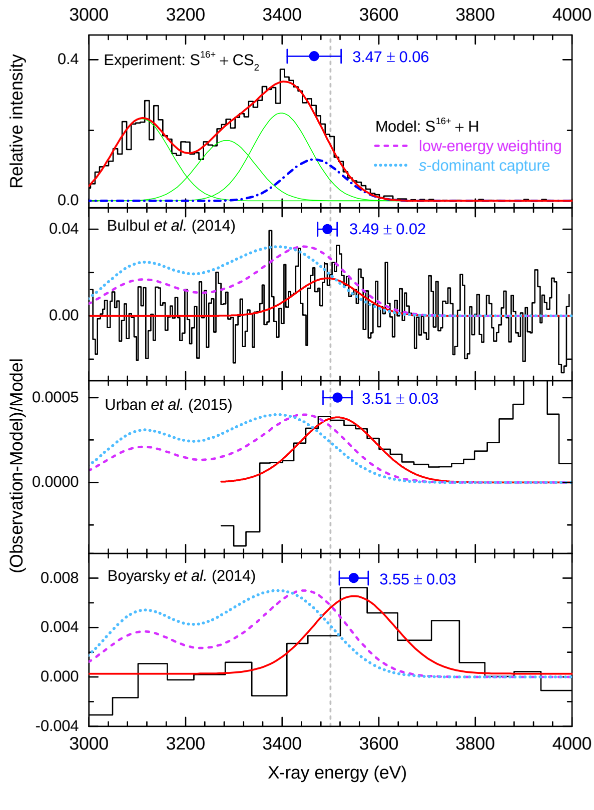

Figure 1. Charge-exchange-induced X-ray spectrum in comparison with recently reported astrophysical observations. The experimental data and observations are compared with the charge exchange model of Gu.

References

[1] E. Bulbul *et al.* 2014 *Astrophys. J* **13** 789

[2] L. Gu *et al.* 2015 *A & A* **L11** 584

[3] C. Shah *et al.* 2016 *Astrophys. J* **833** 52