

**SPECTRAL DIAGNOSTICS OF GALACTIC
AND
STELLAR X-RAY EMISSION FROM CHARGE EXCHANGE RECOMBINATION**

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Annual Report

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The proposed research uses the electron beam ion trap at the Lawrence Livermore National Laboratory to study X-ray emission from charge-exchange recombination of highly charged ions with neutral gases. The resulting data fill a void in existing experimental and theoretical understanding of this atomic physics process, and are needed to explain all or part of the observed X-ray emission from the soft X-ray background, stellar winds, the Galactic Center, supernova ejecta, and photoionized nebulae.

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Progress During Year 1:
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We have successfully carried out the proposed tasks for the first year. In Year 1 our investigation concentrated on surveying the X-ray emission from H-like and He-like Ne, Ar, and Fe ions after undergoing charge-exchange reactions. Detailed analyses have been carried out, and a paper on our measurements of the X-rays emitted by H-like Fe²⁵⁺ and He-like Fe²⁴⁺ is now in preparation for publication in the Astrophysical Journal. The measurements have been performed in an energy range (2-30 eV/amu) that matches the ion energies (50 to 1000 eV, depending on the ion species) in collisional and photoionized X-ray emitting plasmas. Another Astro-physical Journal paper describing the measurement of Proxima Centauri's stellar mass loss rate based on the level of charge-exchange emission observed by the Chandra X-ray Observatory has recently been submitted.

Installation of the Goddard X-ray microcalorimeter array (XRS) from the Astro-E mission on our electron beam ion trap proceeded faster than expected during Year 1. The system is now ready to study X rays produced in charge-exchange reactions with high resolution, i.e., a resolution of 10 eV. This resolution is 15 to 20 times better than the resolution of our survey investigations and is a major enhancement of our laboratory astrophysics capabilities. We found that the saturation of the counting apparatus, which we described in our proposal as a potential concern, does not occur or is not a problem for studying charge exchange. With the XRS operational we are now well prepared for carrying out the tasks we proposed for Year 2.

Moreover, an additional very-high-resolution spectrometer was built in Year 1 that allows us to measure the temperature of the trapped ions undergoing charge-exchange processes. With this new capability we will be able to resolve and measure the widths of key spectral lines and thus determine ion-neutral interaction energies during Year 2 investigations.

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Statement of Work for Year 2
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During Year 2 we will use the Goddard XRS microcalorimeter to study emission from H-like and He-like Ne, Ar, and Fe with high resolution. The measurements will be carried out as a function of collision energy, i.e., as a function of ion temperature in our electron beam ion trap. Several kinds of neutral gas will be used (H₂, He, and Ne) in order to study the effects of the neutral gas chemistry on the X-ray emission.

During Year 2 we will also start with the installation of an atomic hydrogen beam on our source. Funds for the atomic hydrogen beam have recently been obtained from additional sources, leveraging the present project funds.

We expect to write up several of our results for publication in Year 2.