COLTRIMS Measurements of Charge Exchange with Highly Charged Ions and Simple Molecules

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Projected Timeline

- Aug/Sep 2020: Finish Machining + Assembly of Deflection Schemes
- Fall 2020: Electronics + Detector testing; HCl beam extraction testing
- Spring 2021: Relocate + Setup COLTRIMS apparatus at CUBEB
- Summer 2021: Onward: CX Measurements with H2/He targets.
- Future (time permitting) CX measurements of CO/CO2 targets.

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References


Impact on Xray Observations

Our measurements will address standing issues with interpretations of CX emission spectra. By tuning the beam energy with CUBEB, we can measure energy-dependent CX cross sections for both single- and multi-electron capture. The COLTRIMS apparatus is operable with any gas target and will be used to measure cross sections for common neutrals. The observed spectra and measured cross sections will enable direct benchmarking of theoretical models of CX emission for both simple molecules (H2, HF, CO, CO2) and multi-electron targets (H2, He, CO, etc). These results can help reduce uncertainties in currently available xray observations (CHANDRA, XMM), as well as provide highly accurate atomic data for future high-resolution xray emissions such as the upcoming Arcus telescope.

Experimental Program

We will measure xray spectra and relative CX cross sections for the following systems with collision velocities spanning a range typical of the solar wind (200 – 300 km/s):

- Fe+ and Ne+ represented by common astrophysically relevant neutrals (H, H2, He, CO, CO2, etc.). Several theoretical treatments are available for calculating cross sections of this process and producing the subsequent xray cascade spectra: e.g. Multi-channel Landau-Zener or Atomic Orbital Close Coupling [1]. These cross sections and other tools are available in the KRONOS database hosted by UGA. Following CX with a bare ion, the populated f-states are degenerate, and though they have no spin, they will be populated by the ion. Some of these highly energetic states will decay to lower energy states and can be used to measure cross sections.

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Solar Wind Charge Exchange

\( Aq^+ + B \rightarrow A^q(1) + B^+ \rightarrow A^q(1) + B^+ + \gamma \)

Where \( A \) is a highly charged ion (HCl) of C, N, O, Ne, Mg, Si, P, S, Ar, Kr, Xe, and \( B \) represents common, astrophysically relevant neutrals (H, H2, He, CO, CO2, etc.). Several theoretical treatments are available for calculating cross sections of this process and producing the subsequent xray cascade spectra: e.g. Multi-channel Landau-Zener or Atomic Orbital Close Coupling [1]. These cross sections and other tools are available in the KRONOS database hosted by UGA. Following CX with a bare ion, the populated f-states are degenerate, and though they have no spin, they will be populated by the ion. Some of these highly energetic states will decay to lower energy states and can be used to measure cross sections.

Cold Target Recoil Ion Momentum Spectroscopy (COLTRIMS)

COLTRIMS is a technique for studying collisions and fully resolving the collision dynamics by capturing all collision products. We cross a cold, neutral gas jet with a highly charged ion beam, and extract the momentum transfer from measured times-of-flight and spatially-resolved detections of both the HCl charge state(s) and the slow ions produced by CX. Our team incorporates an xray microcalorimeter to measure the xray spectra from which the fragment mass spectra can be extracted. Given the timing resolution of our apparatus, we will resolve both single- and multi-electron capture events.

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