Laboratory studies of the cosmic origins of organic chemistry

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Laboratory studies of the cosmic origins of organic chemistry

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Synopsis We are constructing a novel merged-beams apparatus to study the cosmic origins of organic chemistry. With this, we plan to measure reaction rate coefficients of atomic C with molecular ions. Such chemical data is important for astrochemical models and observations of cosmic objects.

The cosmic pathway towards life is thought to begin in molecular clouds when atomic carbon is "fixed" into molecules, initiating organic chemistry and the synthesis of complex organic species. Much of our knowledge of this process is through spectroscopic observations and sophisticated astrochemical models to interpret the collected spectra [1]. However, our understanding of the molecular universe is limited, to a large degree, by uncertainties in the underlying chemical data in these models.

Our current understanding of interactions between neutral atomic C and molecular ions is extremely poor. Experimentally, this is due to the difficulty in producing a sufficiently intense and well characterized beam of neutral carbon atoms [2]. Theoretically, this is because fully quantum mechanical calculations with four or more atoms are computationally prohibitive.

We are currently constructing a new and unique laboratory instrument to study reactions of neutral atomic C with molecular ions. A schematic is shown in Fig. 1. Our initial studies will focus on the reaction

$$C + H_3^+ \rightarrow CH^+ + H_2. \qquad (1)$$

As H_3^+ is ubiquitous in both diffuse and dense molecular clouds [3], reaction 1 is one of the first steps towards organic chemistry within such clouds [4].

We generate a C^- beam using a cesium ion sputter source and accelerate it to 30 keV. A well defined, colliminated beam is created using a series of apertures and electrostatic optics. The C^- beam is crossed with an 808 nm (1.53 eV) laser beam to photodetach and neutralize ∼ 10% of the C^- beam. Electrostatically removing the remaining C^- will yield a pure, well defined ground term C beam.

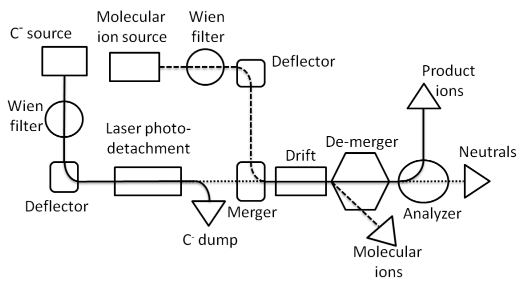

Figure 1. Simplified schematic overview of the experimental apparatus.

A velocity matched H_3^+ ion beam at ∼ 7.5 keV will be generated using a duoplasmatron source and merged to co-propagate with the C beam. Both beams will be traveling at keV lab energies, allowing for ease of handling and easy beam profile measurements. As the beams are co-propagating, this will enable studies of reactions for center-of-mass energies from tens of meV (∼ 100 K) to eVs in energy. Reaction channels will be studied using an energy analyzer to separate and detect the charged end products. Measuring all the relevant currents, beam shapes, energies, signal counts and background rates will allow an absolute reaction cross-section to be determined.

References

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