Advancing Chemical Understanding through Astronomical Observations

SCRIBES: Sensitive, Cooled, Resolved, Ion BEam Spectroscopy

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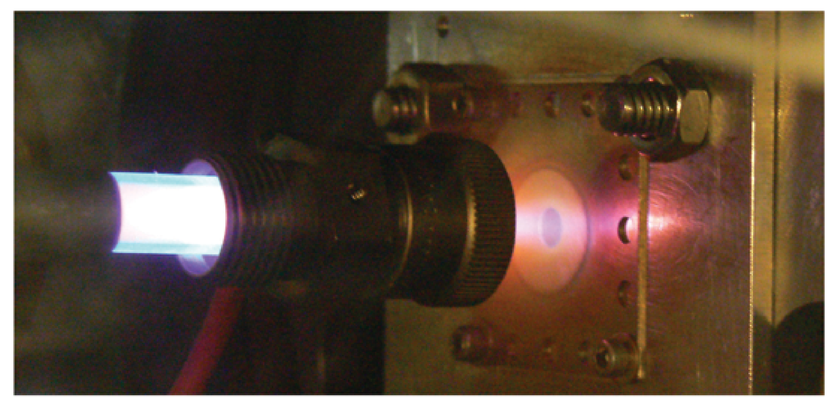
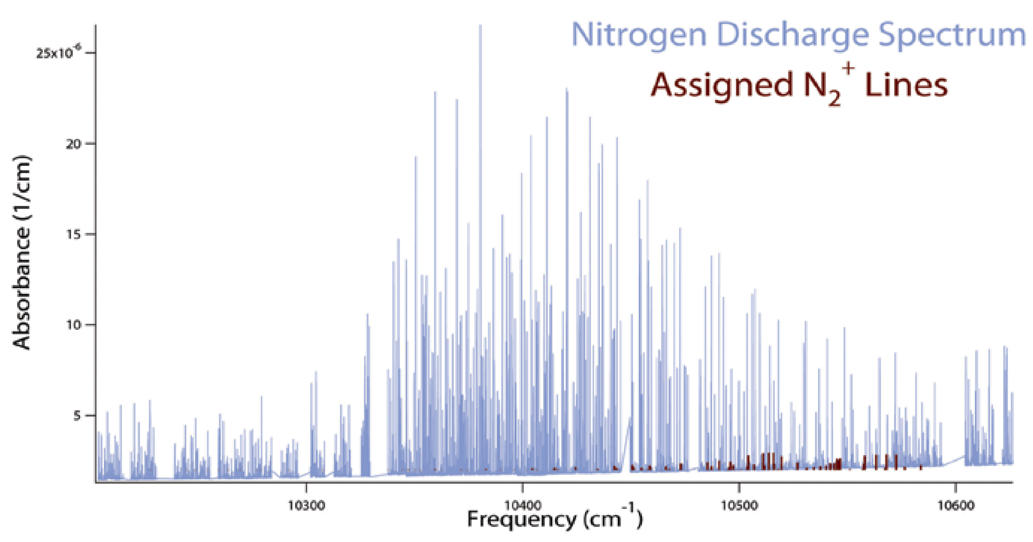
Ion Beam

In a typical plasma, the ion density is ~10^{-6} relative to the neutral density. Ion/neutral discrimination techniques prevent neutral features from dominating spectra, as can be seen below in the spectrum of a N_2 discharge.





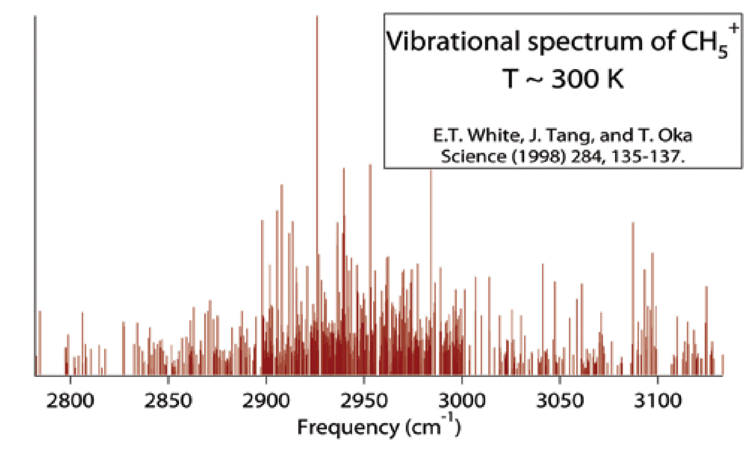
The ion beam in SCRIBES spatially separates ions from neutrals, allowing spectroscopy to be performed only on ionic species.

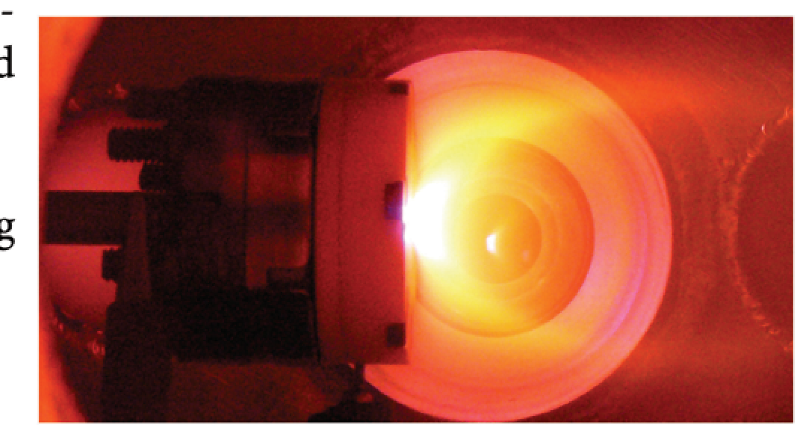
In a fast ion beam, an effect called "kinematic compression" allows transitions to be measured with sub-Doppler linewidths. This enables us to determine transition frequencies with high precision.

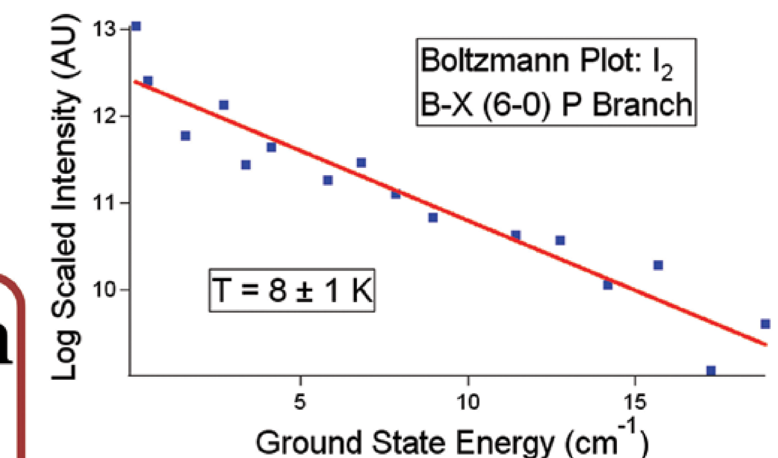
Supersonic Expansion Discharge Source

The continuous supersonic expansion discharge source produces rotationally-cold molecular ions via collisional cooling.

Its operational lifetime exceeds 120 running hours.





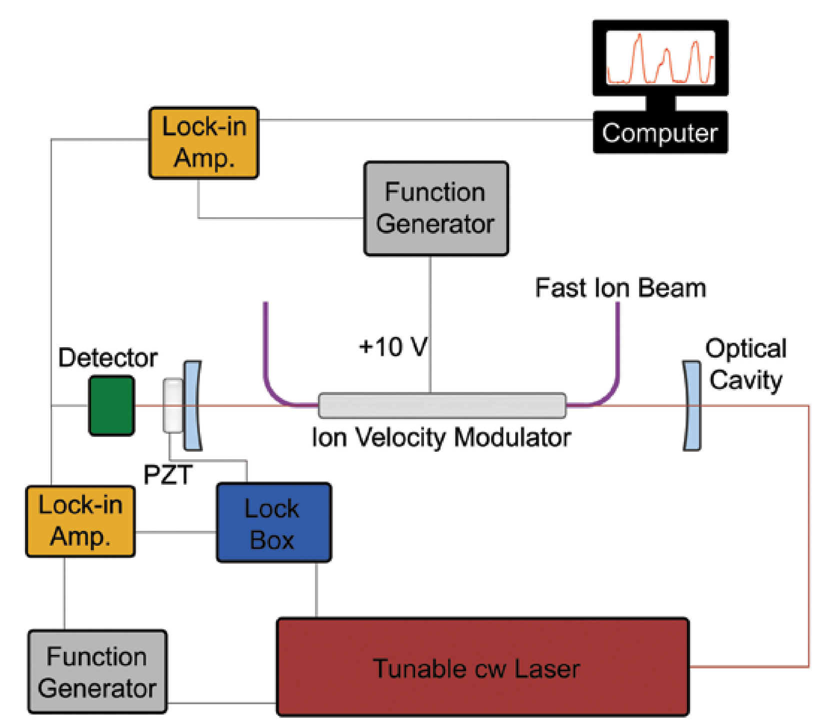


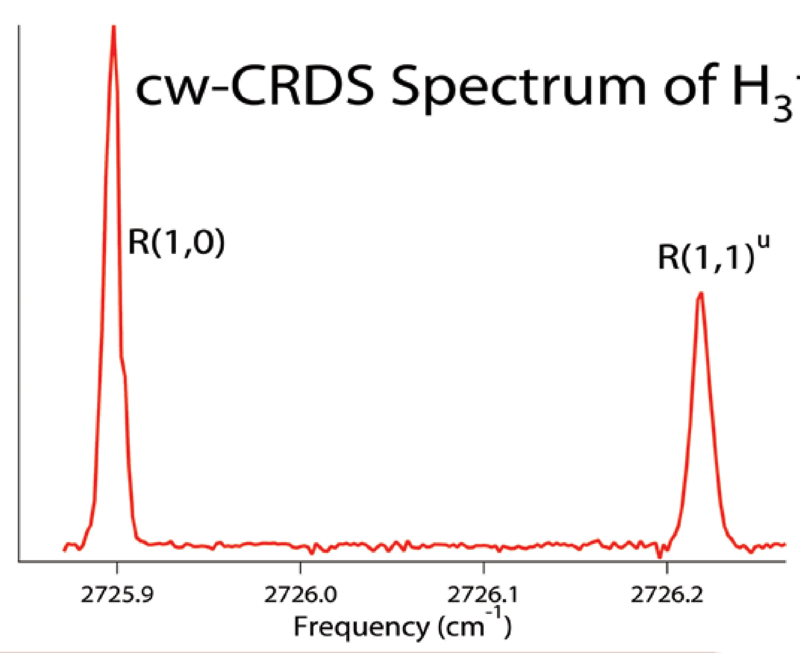
Laser Spectroscopy

The laser spectrometer equipped with SCRIBES can operate in continuous-wave cavity ringdown mode, or it can be used for cavity-enhanced beam velocity modulation spectroscopy.

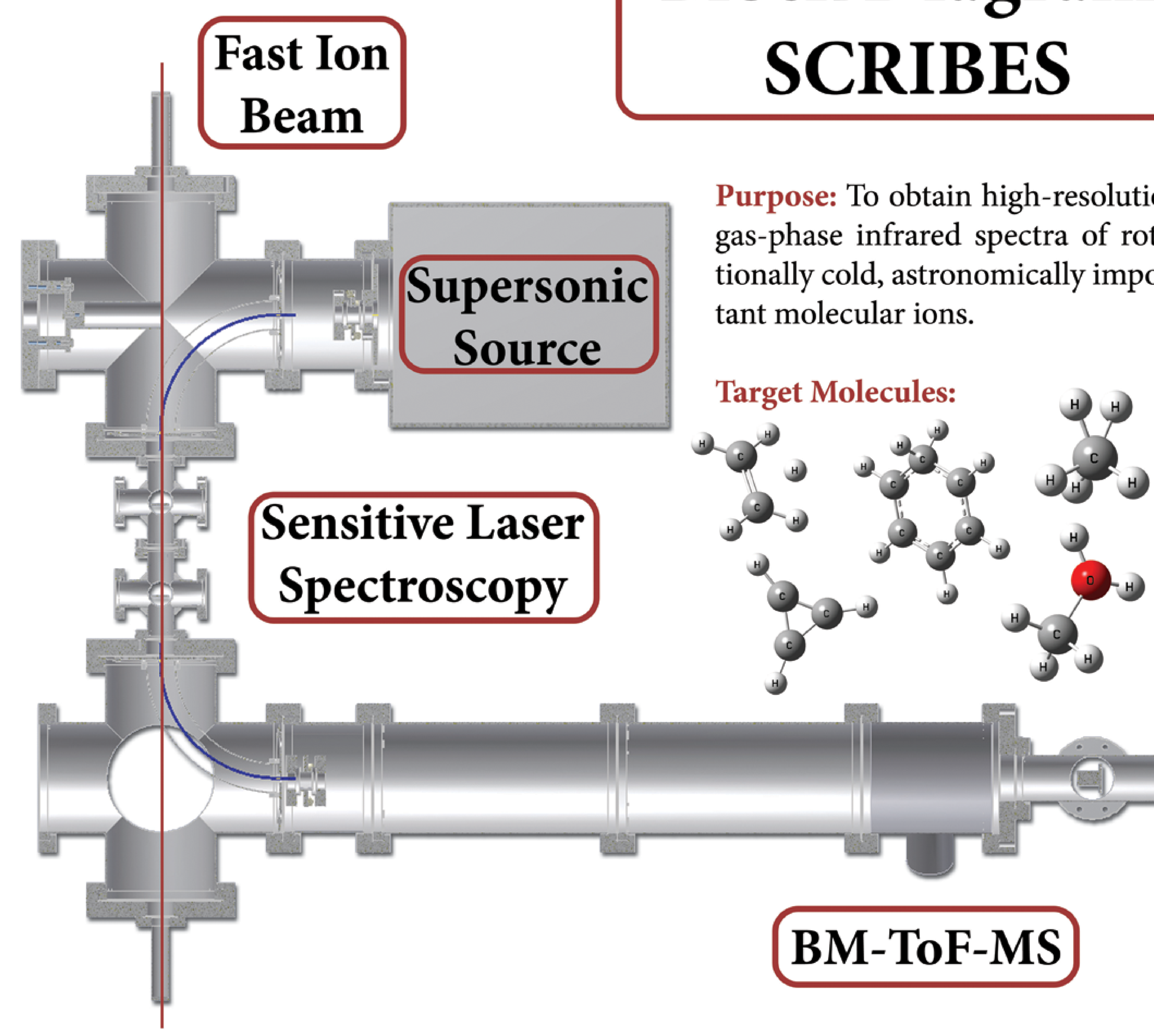
A homebuilt cw-difference frequency generation laser provides coverage of the 2.8-4.8 micron spectral region. Most carbon-based molecular ions have a vibrational transition in this range.

Using sensitive, high-resolution spectroscopic techniques, we can enable astronomical searches for important molecular ions.





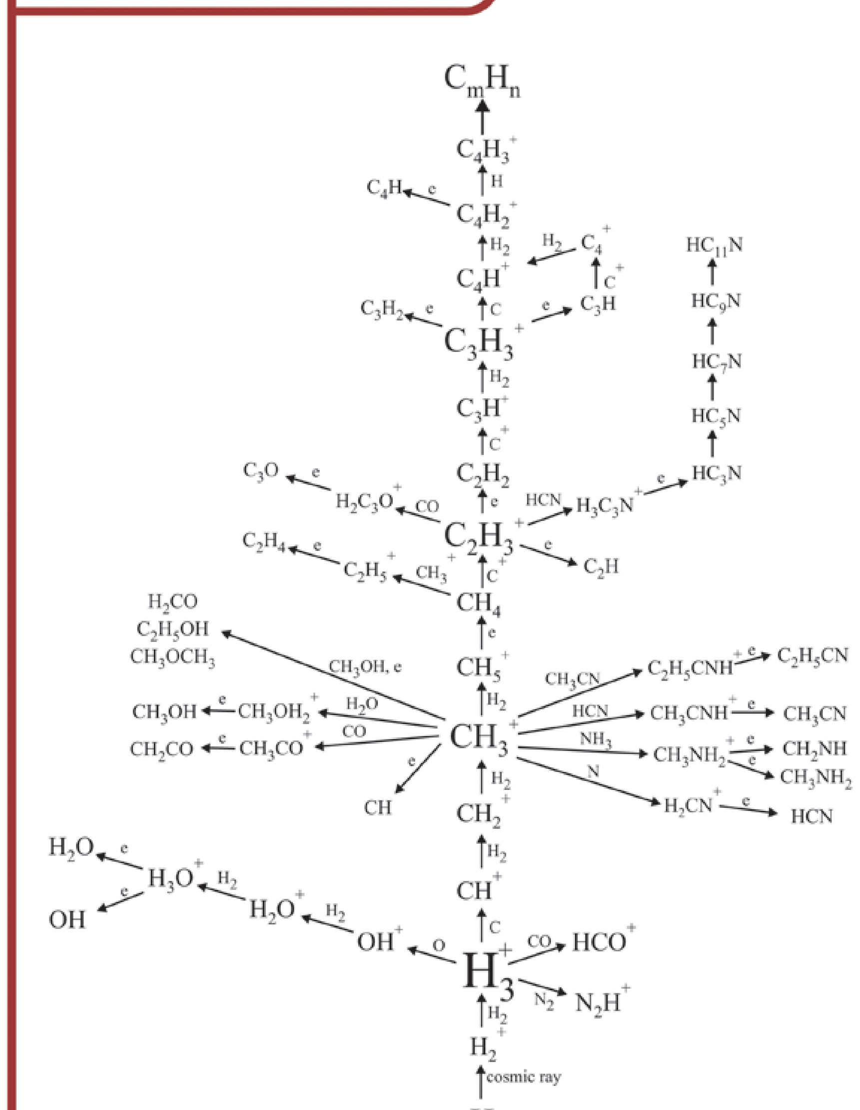
Block Diagram: SCRIBES



Purpose: To obtain high-resolution gas-phase infrared spectra of rotationally cold, astronomically important molecular ions.

Target Molecules:

Motivation



Why Molecular Ions?

As illustrated in the reaction chart to the left, molecular ions are responsible for driving the chemistry resulting in the formation of complex organic/prebiotic molecules. Detecting these ions in the ISM will lead to a better understanding of chemical evolution in space.

Why High-Resolution Spectroscopy?

High-resolution spectra serve as molecular fingerprints, enabling astronomical searches for these species in the ISM, planetary atmospheres, and circumstellar environments.

Why Infrared Spectroscopy?

Infrared frequencies can be used to search for molecules without a permanent dipole (precluding microwave spectroscopy/radio astronomy), and can also be used to derive pure rotational transition frequencies of species which do contain a permanent dipole.

The Combined Array for Millimeter-wave Astronomy (CARMA)

THz Frequencies

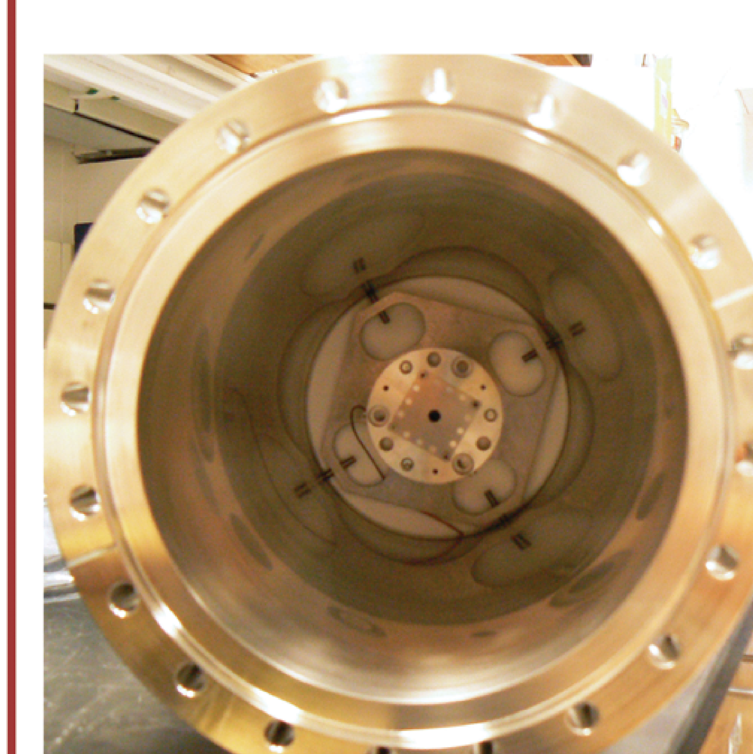
Using our optical frequency comb (pictured below), we can measure the frequencies of our cw lasers with sub-MHz precision and accuracy.

The versatility of SCRIBES enables us to use either the supersonic expansion source or the uncooled cold cathode source. By observing a wide range of rovibrational transitions with our accurately-measured lasers, we can derive THz frequencies via a combination differences analysis.

BM-ToF-MS

The beam-modulated time-of-flight mass spectrometer attached to SCRIBES provides mass identification of species present within the ion beam.

Another function of the mass spectrometer is to measure the energy spread of the beam, which is a helpful diagnostic for assessing the performance of the ion optics.



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