Laboratory and observational studies of C_{60} and C_{60}^{+}

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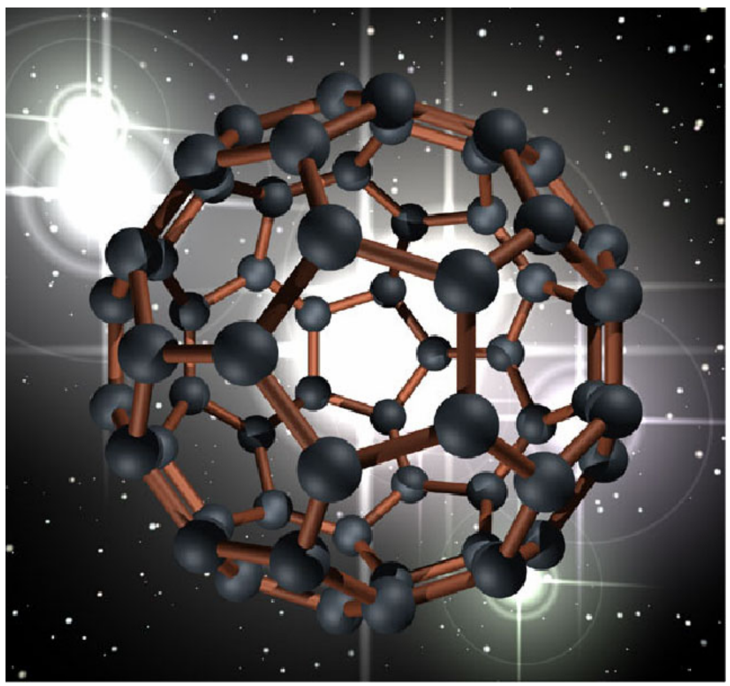


Outline

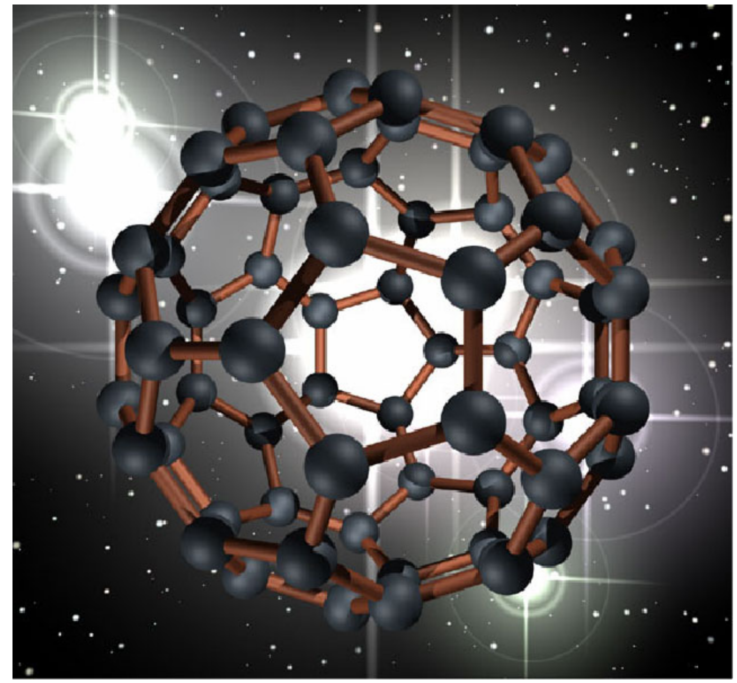
I. Motivations for studying C_{60} and C_{60}^{+}

II. Spectral studies of C_{60}

III. Observational studies of C_{60} with TEXES at IRTF

IV. Spectral studies of C_{60}^{+}

Motivations for Studying C_{60} and C_{60}^+

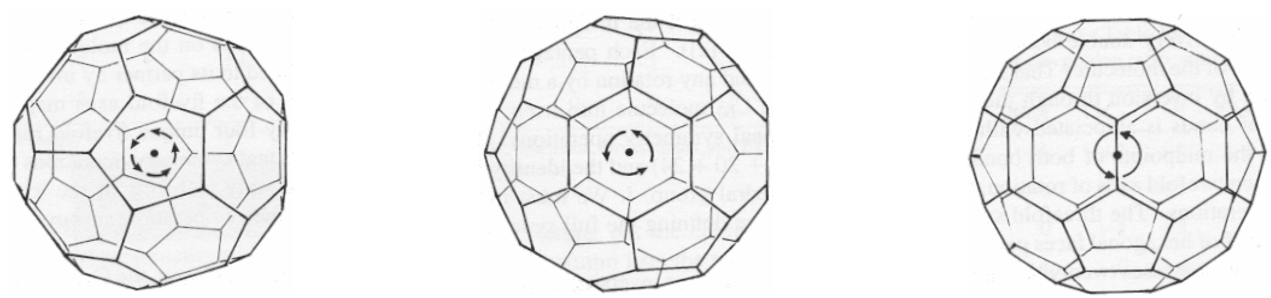


- C_{60} was discovered during experiments designed to simulate outflows of carbon stars.
- C_{60} should be stable in the ISM (~ 44 eV required to break cage).
- C_{60} has been found in sediments related to meteorite impacts.
- C_{60} has been found in LDEF craters.
- C_{60} should be ionized by stellar radiation and "C_{60}^+ should be ubiquitously distributed in space."

(Kroto *Science* **242**, 1988)

About C_{60}

- 3(60)-6 = 174 vibrational degrees of freedom
- Icosahedral (I_h) Symmetry: 6 five-fold axes, 10 three-fold axes, 15 two-fold axes

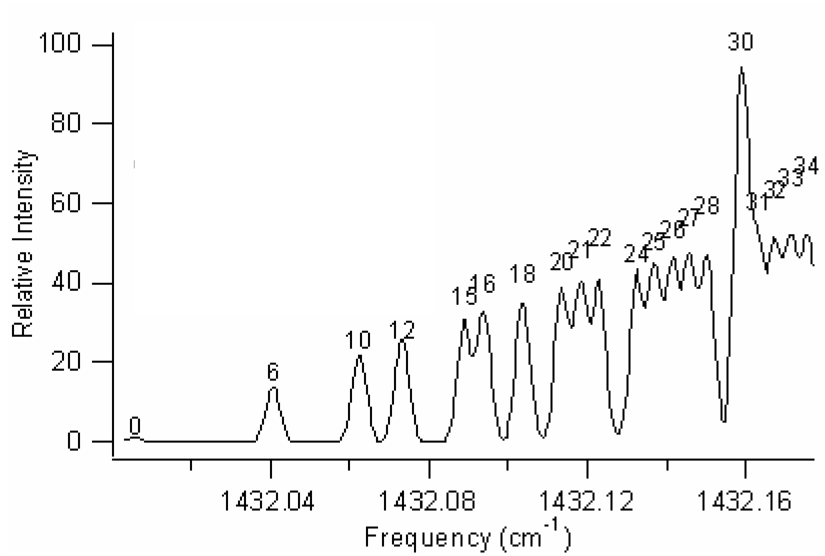


- Sixty quantum-mechanically indistinguishable (spin 0) bosons
- Symmetry restrictions on total wavefunction

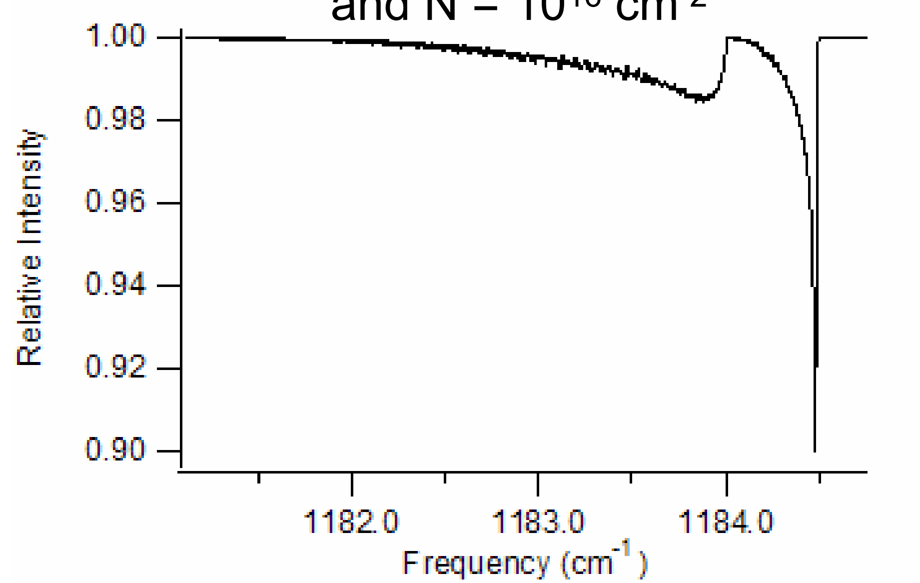
IR Spectroscopy of C_{60}

- 4 F_{1u} IR active modes [1432, 1183, 577, 528 cm^{-1}]
- Gas phase IR spectrum observed at 1065 K; no rotational structure resolved (Frum et al. *Chem. Phys. Lett.* **176**, 1991)

Simulated Laboratory Spectrum at 10 K

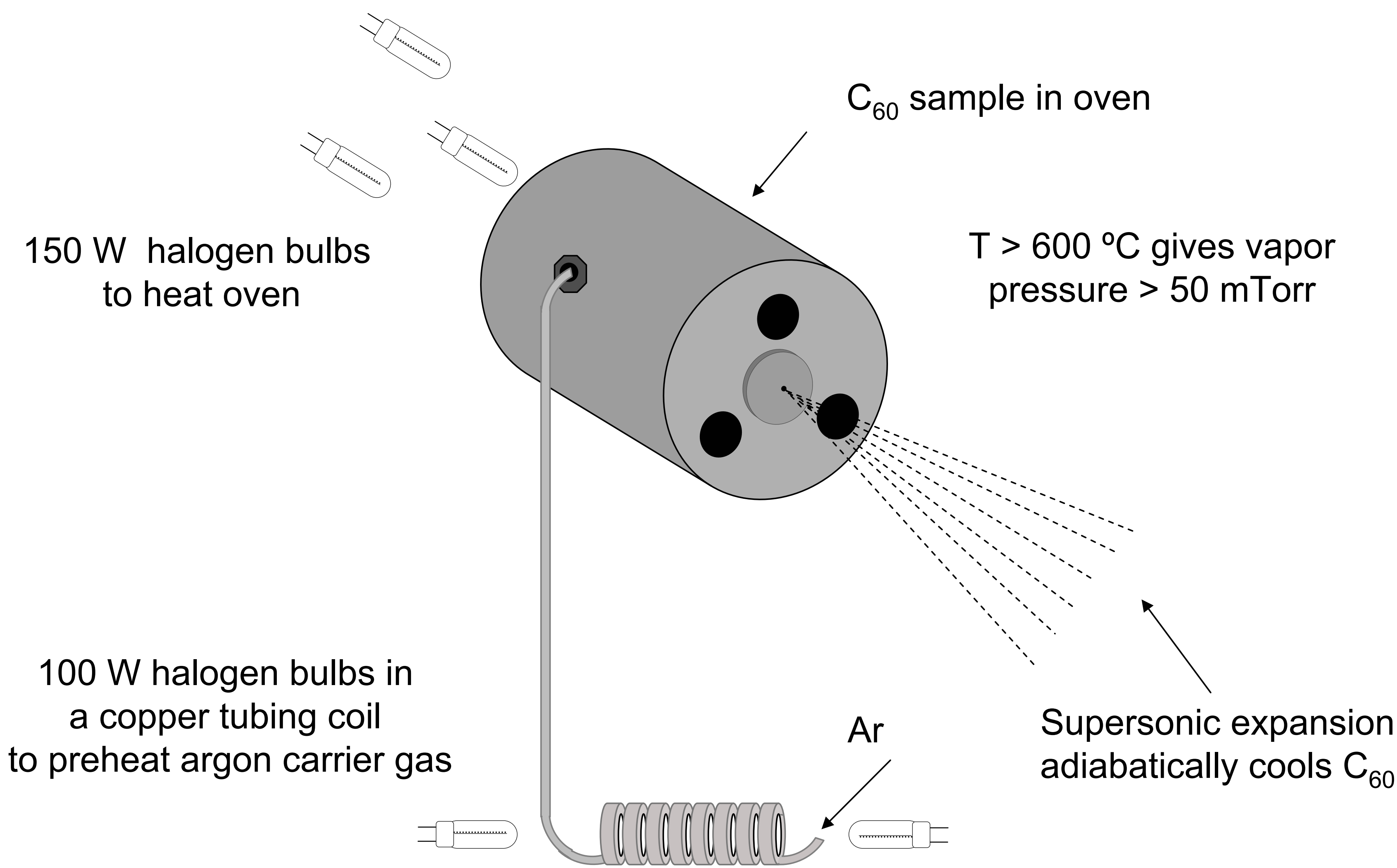


Simulated Interstellar Spectrum at 30 K and N = 10^{16} cm^{-2}



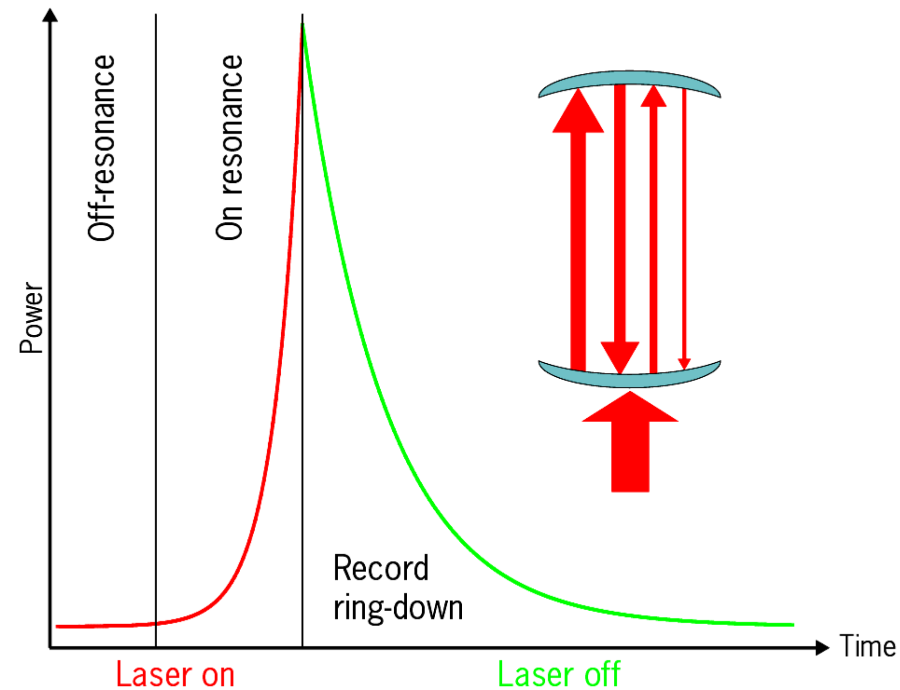
A rotationally cold spectrum is required for comparison to interstellar spectra.

Gas Phase Spectral Studies of C_{60}



CW Cavity Ringdown Spectroscopy

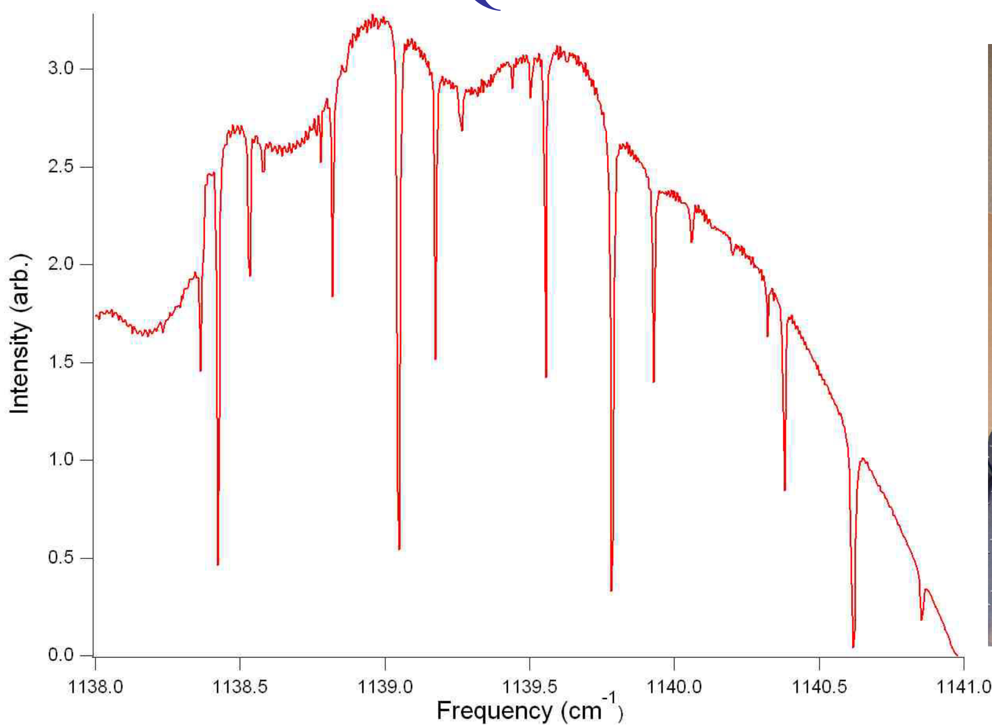
- A high finesse cavity is placed around the supersonic expansion.
- Radiation is coupled into the cavity, which is cycled in and out of resonance.

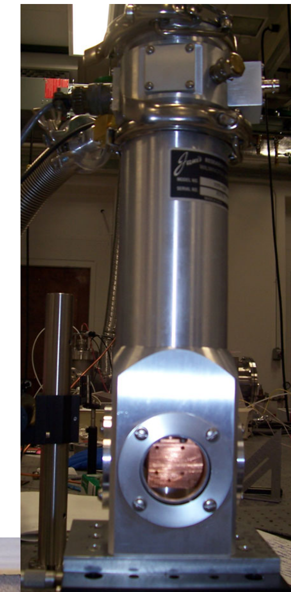


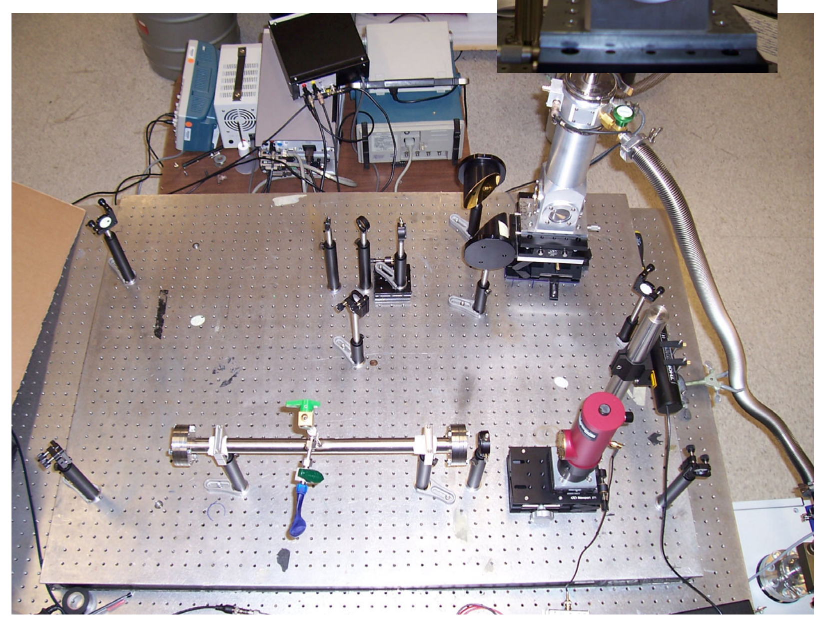
- When the cavity is on resonance the radiation is switched off.
- The exponential decay rate is a direct measurement of absorption.

Current State of the C_{60} Experiment

- Sustained flow of gas phase C_{60} achieved
- Optics for CW cavity ringdown at 1183 cm^{-1} currently being assembled
- Direct absorption N_2O spectrum obtained with a test QCL

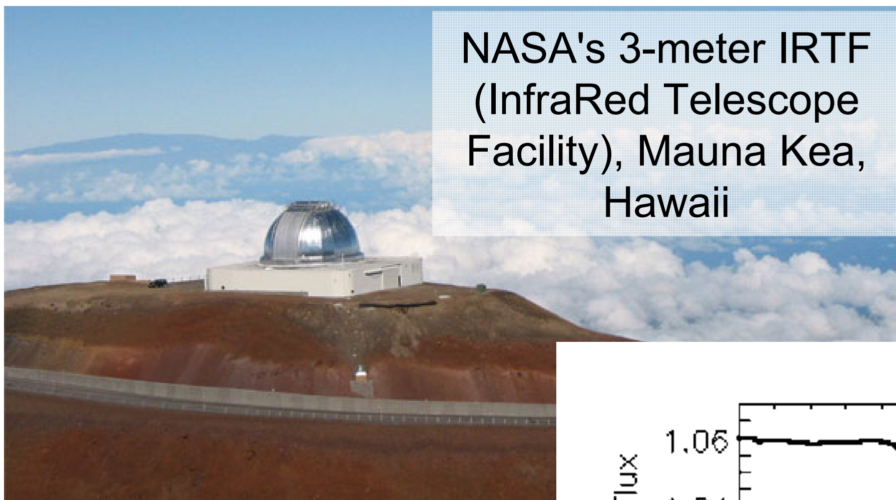


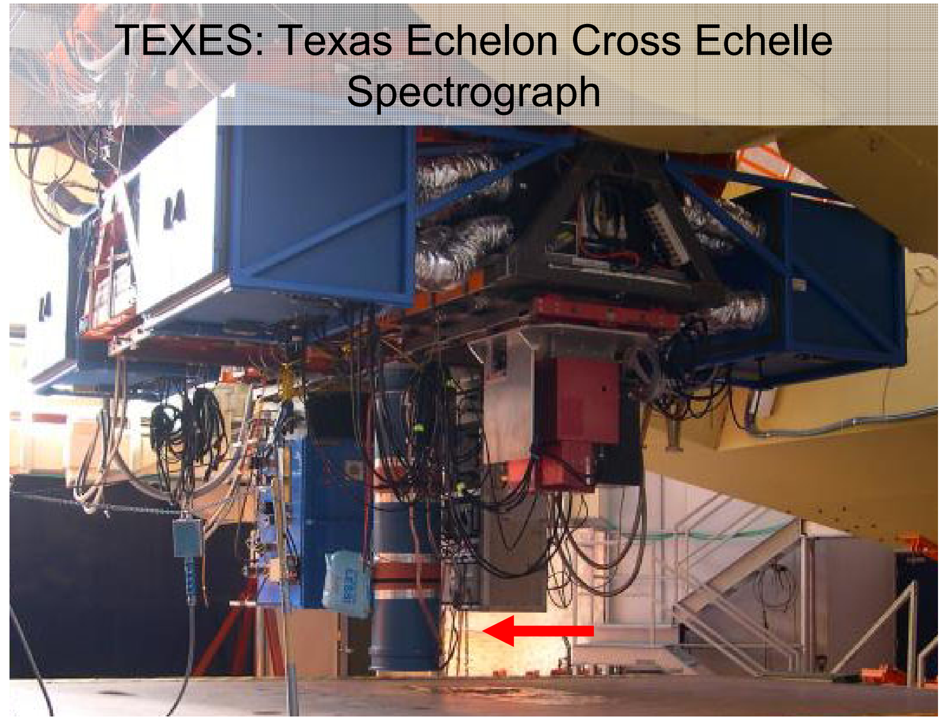


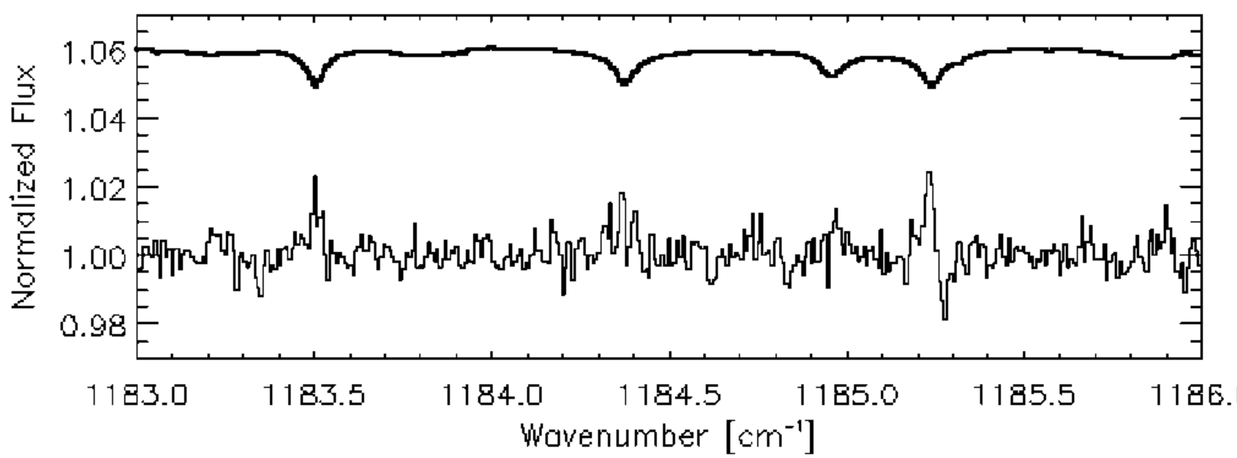


Astronomical Spectroscopy of C_{60}

- Data obtained June 2003
- Upper limit ~ 3×10^{15} cm^{-2}
- Need laboratory spectrum!

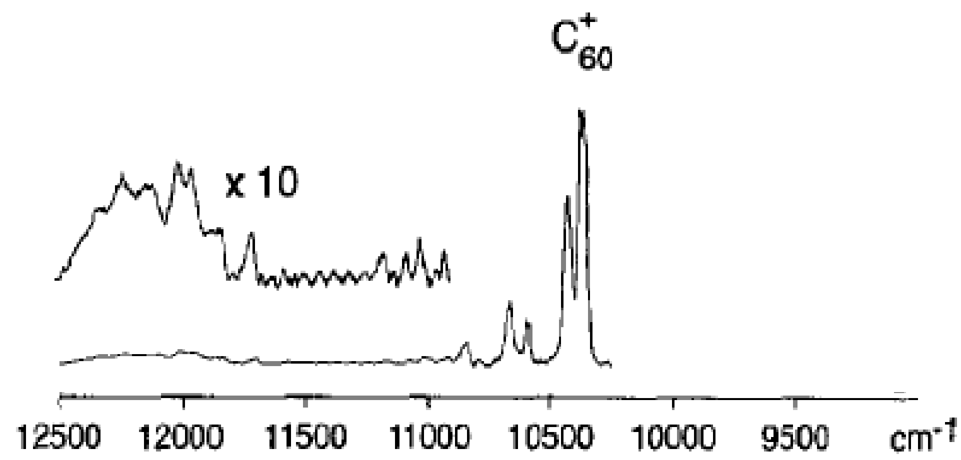






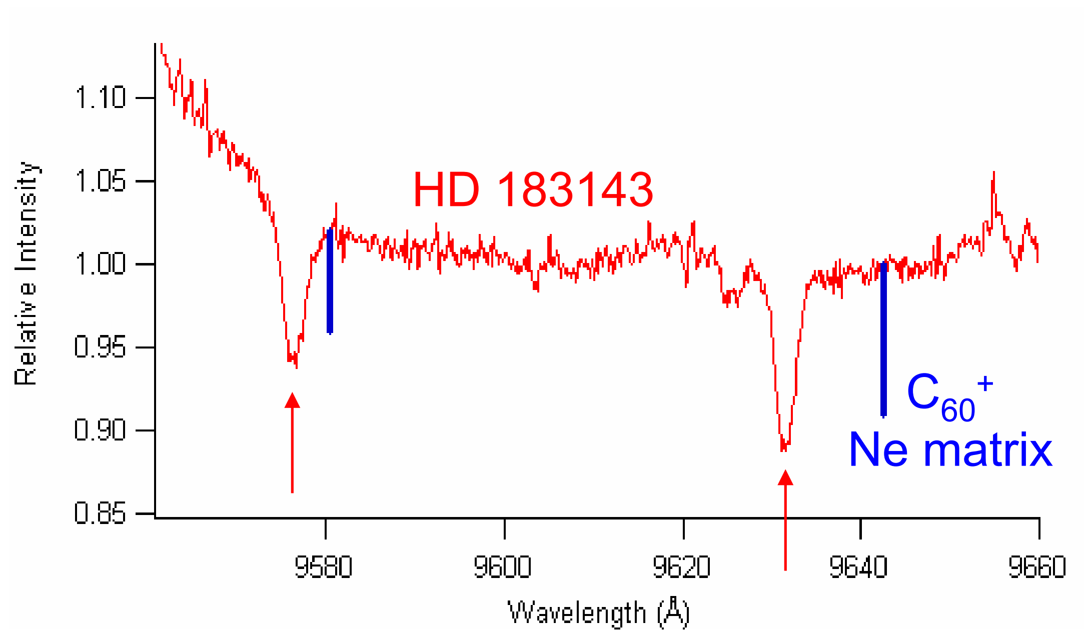
Spectroscopy of C_{60}^{+}

The electronic and infrared spectra of C_{60}^{+} were observed in neon and argon matrices.



(Fulara, Jakobi and Maier *Chem. Phys. Lett.* **211**, 1993)

This was used as a basis for observational searches and two DIBs were attributed to C_{60}^{+}.



(Foing and Ehrenfreund *Nature* **369**, 1994; *A&A* **319**, 1997)

Is C_{60}^{+} Really a DIB Carrier?

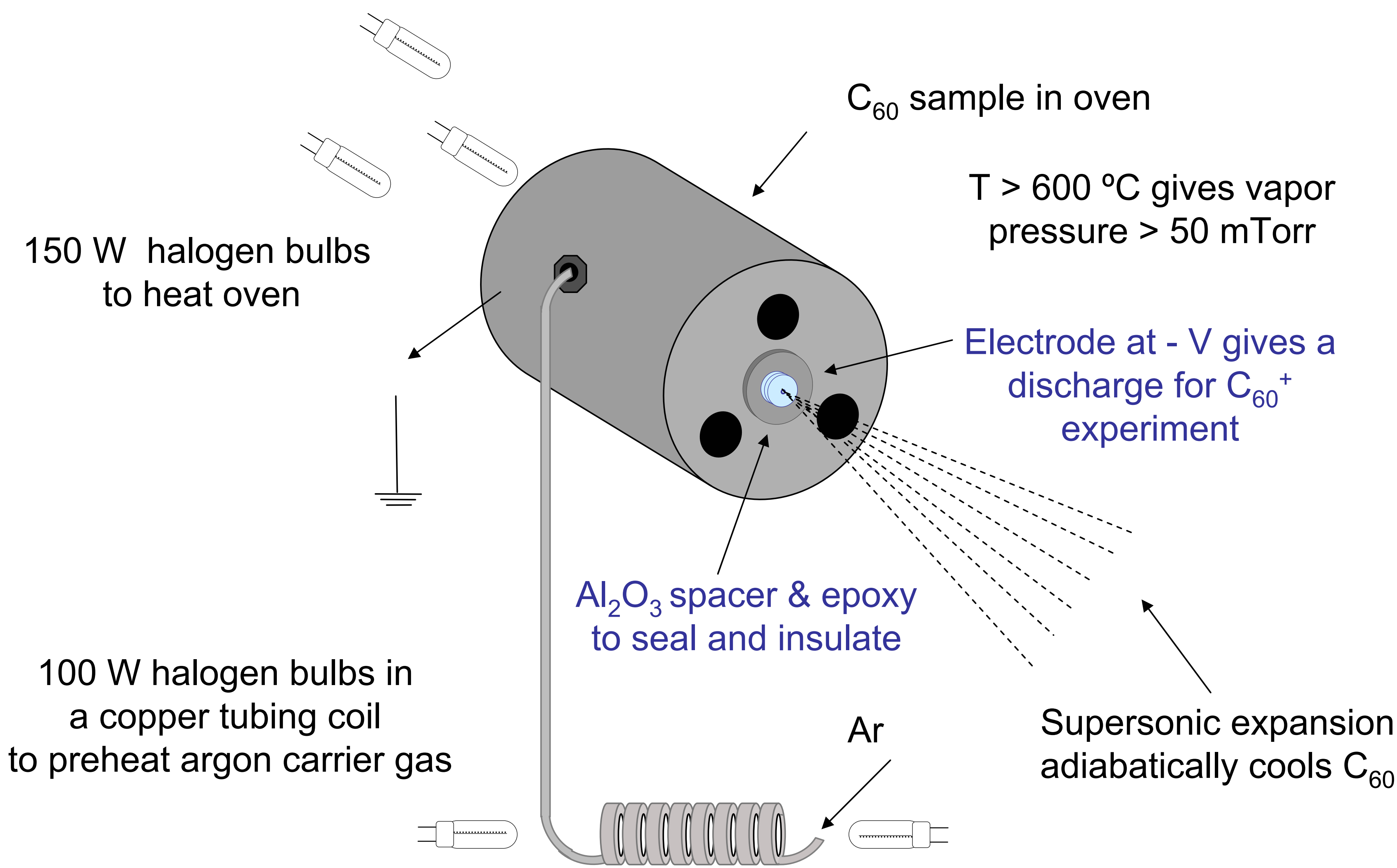
Criteria for these two DIBs to be C_{60}^{+}:

1. The same FWHM ✓
2. Matching relative intensities to lab spectra ?
3. Gas-matrix shifts consistent with experimental information ?

A gas phase C_{60}^{+} spectrum is required to answer this question definitively.

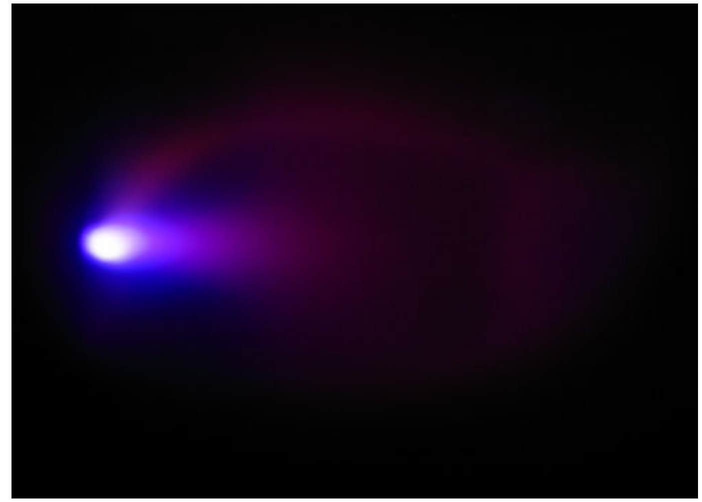
"The case for C_{60}^{+} is better than for many other [DIB] candidates and now rests in the court of laboratory spectroscopists." (Jenniskens et al. *A&A* **327**, 1997.)

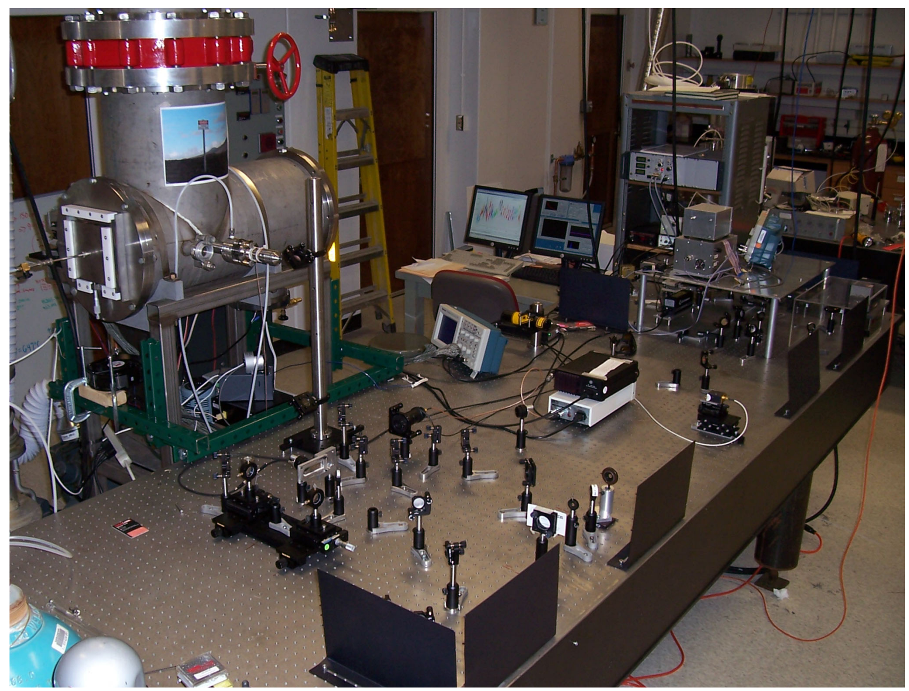
Gas Phase Spectral Studies of C_{60}^{+}



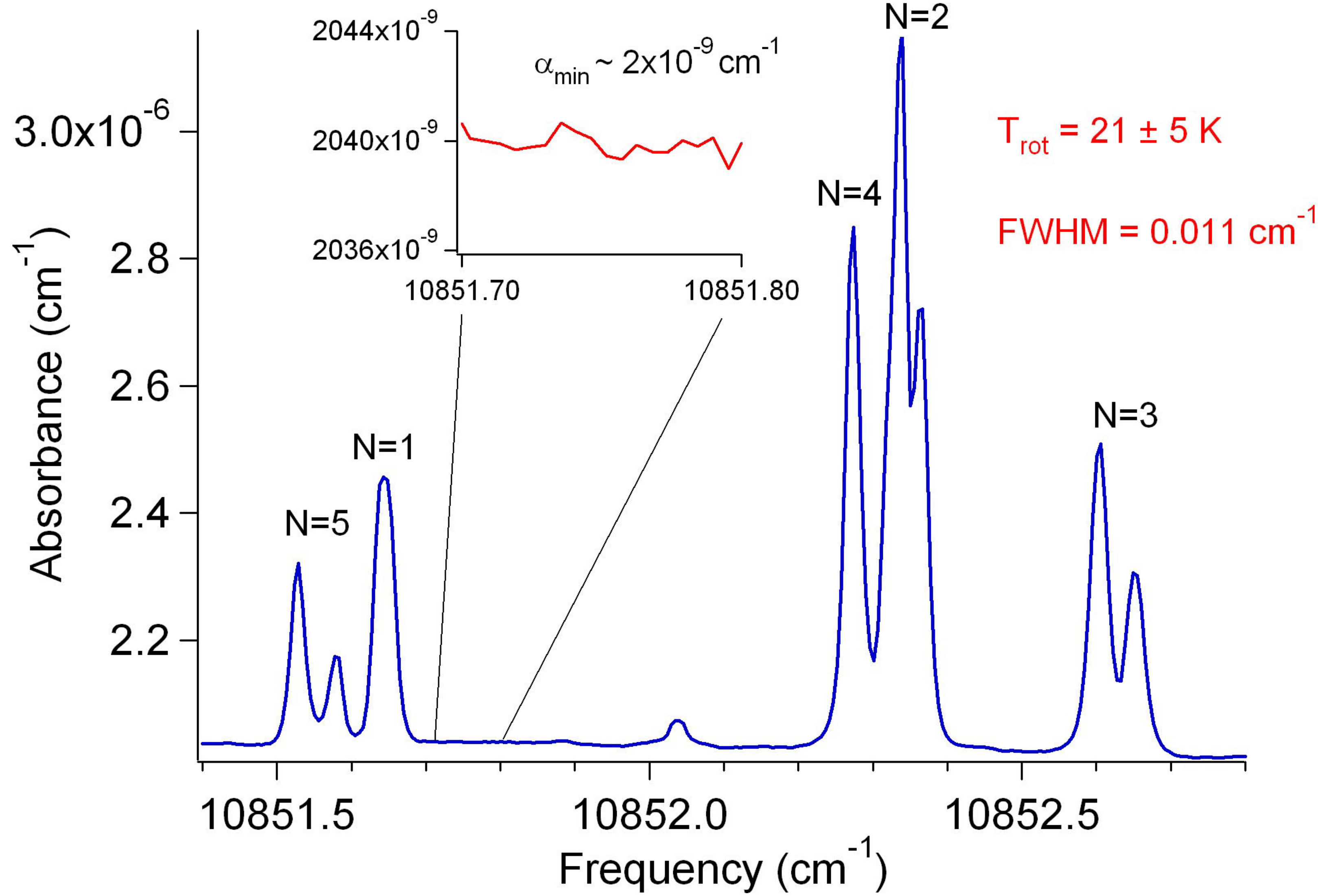
Current State of the C_{60}^+ Experiment

- CW cavity ringdown achieved at 950 nm
- Discharge source built from high temperature materials and tested with N_2/Ar and C_{60}/Ar
- Cold N_2^+ spectrum observed with N_2/Ar discharge while heating gas and oven to > 600ºC
- The search for the C_{60}^+ spectrum is underway

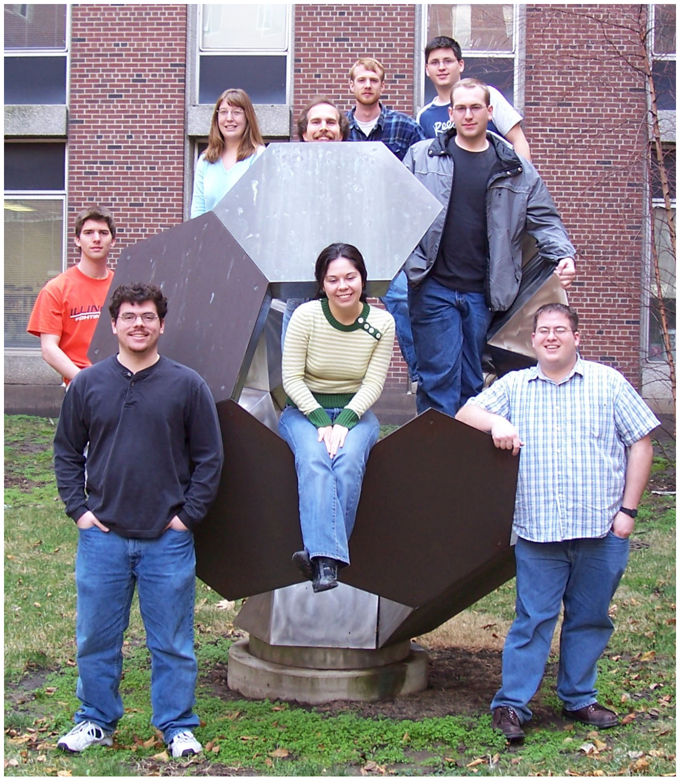




Cold N_2^+ Ions at High Resolution and Sensitivity



Acknowledgements



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