Research Group

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Star Formation

Figure Credit: Bill Saxton, NRAO/AUI/NSF
Tracing Stellar Evolution Using Chemistry

Figure Credit: Qi et al. (2013)
Protoplanetary Disk

Figure Credit: Ceccarelli et al. (2014)
Formation of Ions

1) $N_2 + H_3^+ \rightarrow N_2H^+ + H_2$
2) $N_2 + H_2D^+ \rightarrow N_2H^+ + HD$
3) $N_2 + D_2H^+ \rightarrow N_2H^+ + D_2$
4) $N_2 + D_3^+ \rightarrow N_2D^+ + D_2$
5) $N_2 + D_2H^+ \rightarrow N_2D^+ + HD$
6) $N_2 + H_2D^+ \rightarrow N_2D^+ + H_2$

Public rate coefficients scatter by a factor of 2
Dual-source ion-neutral merged-fast-beam apparatus
Dual-source ion-neutral merged-fast-beam apparatus

\[
\text{N}_2^+ \rightarrow \text{N}_2, \quad \text{H}_3^+, \quad \text{Detector}, \quad \text{Chemistry}, \quad \text{N}_2\text{H}^+ \text{ or } \text{N}_2\text{D}^+
\]
My Role

Lab Safety

Experiment
- Collect data
- Analyze data
- Recoat filament

Hardware
- Inventory vacuum pumps
- Set up vacuum system
- Detect leak

Lab Safety
- Trace exhaust lines
- Report protocols for CO
<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>Operating Hours</th>
<th>Current (A)</th>
<th>Pressure (torr)</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral Source</td>
<td>HiPace 300</td>
<td>45135</td>
<td>0.62 +/- 0.03</td>
<td>2.00E-06</td>
<td>Hudson Line</td>
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<td>4497</td>
<td>0.37 +/- 0.04</td>
<td>2.00E-08</td>
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<tr>
<td>3</td>
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<td>3.00E-08</td>
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<tr>
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<td>Dump</td>
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<td>2785</td>
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<td>7.00E-08</td>
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<tr>
<td>Merger/5</td>
<td>TC 110</td>
<td>397</td>
<td>0.40 +/- 0.05</td>
<td>5.00E-09</td>
<td>Interaction/Detection</td>
</tr>
<tr>
<td>Interaction/6</td>
<td>HiPace 300</td>
<td>2797</td>
<td>0.40 +/- 0.04</td>
<td>1.00E-08</td>
<td></td>
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<tr>
<td>Final Analyzer/7</td>
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<td>51555</td>
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<td>1.00E-08</td>
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<tr>
<td>Ion Source</td>
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<td>7.00E-07</td>
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<tr>
<td>B</td>
<td>HiPace 300</td>
<td>32768</td>
<td>0.18 +/- 0.03</td>
<td>2.00E-08</td>
<td></td>
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<tr>
<td>C</td>
<td>HiPace 300</td>
<td>2796</td>
<td>0.40 +/- 0.05</td>
<td>1.50E-08</td>
<td></td>
</tr>
</tbody>
</table>
Stand

Face On View
Stand

Channeltron

5E-08 torr
Extension
\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Diagram of ion species: $N_2^+$, $N_2H^+$, $N_2D^+$.}
\label{fig:ionspecies}
\end{figure}

<table>
<thead>
<tr>
<th>Ion</th>
<th>m, amu</th>
<th>$E_{K'}$, keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_2^+$</td>
<td>28.0129</td>
<td>20</td>
</tr>
<tr>
<td>$N_2H^+$</td>
<td>29.0213</td>
<td>20.71</td>
</tr>
<tr>
<td>$N_2D^+$</td>
<td>30.0270</td>
<td>21.43</td>
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</tbody>
</table>

Figure Credit: Dmitry Ivanov
Leak Detection

- Check connections
- Pump out system & sections
  - Compare pressures
- Supply gas to system/sections
  - Check pressures over time
- Use leak detector liquid
Tracing Exhaust Lines

CO exhausting line

Pump 1

Pump 2

Pump B

Pump A

Pump 3

Tracing Exhaust Lines
Tracing Exhaust Lines
CO Safety

- Met with Columbia’s Environmental Health & Safety on 06/27/2023

- Requirements:
  - Detector
  - Gas Cabinet
  - Steel Lines
  - Flash Arrestors
  - Signs
  - Training
Experimental Steps

1) Cool System
2) Heat Filament
3) Refresh Gas
4) Enable & Optimize Ion Optics
5) Check Beam Profiles
6) Record Measurements
Recoating the Filaments

Before
(360 hours)

After

Ba-Sr-Ca
Beam Profiles

Ω_BPM3 = 3.576 cm⁻²
Ω_BPM4 = 2.691 cm⁻²
<Ω> = 3.218 cm⁻²
θ_bulk = 0.498 mrad
230613155305.csv 230613155348.csv

Figure Credit: Dmitry Ivanov
Equation/Measurements

\[
\langle \sigma v_r \rangle = \frac{S e^2}{T_a T_g \eta I_n I_i} \frac{v_n v_i}{L \langle \Omega(z) \rangle}
\]

ICS * Relative Velocity
Avg. over Energy Spread

Signal Counts
→ 24 keV

Electron Charge
Squared

Transmissions &
Detection Efficiency

Currents/
Intensities
(100s nA)

Interaction
Length
1.2 m

Avg. Overlap
Factor (cm^-2)
along propagation
axis z

Ion Beam: 5 keV
Neutral Beam: 23 keV

Equation Credit: O’Connor et al. 2015a
How to Measure a Neutral Signal

1) Fast neutral beam
2) Hits target to produce electrons
3) Electrons are collected & measured
   a) Current signal (in nA)
4) Convert electron signal into a neutral current signal
Final Results

Figure Credit: Dmitry Ivanov
Thank You

Any questions?

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Dual-source ion-neutral merged-fast-beam apparatus
Relative Energy Equation

\[ E_r = \mu \left( \frac{E_D}{m_D} + \frac{E_i}{m_i} - 2 \sqrt{\frac{E_D E_i}{m_D m_i \cos \theta}} \right) \]
# Floating Cell Voltage Equation:

def Uf(En,Ei,mn,mi): # defining function (Uf) and parameters: energy of neutrals (En); energy of ions (Ei); mass of neutral (mn); mass of ion (mi)
    Uf = Ei*(mn/mi)-En # derived from KE = 1/2 m v^2
    return Uf # in keV

# Print Uf Value: (Note: for En = 21 keV just subtract 1 eV)

En = 20 # energy of neutrals in keV
Ei = 4.9 # energy of ions in keV
mn = 28.0134 # mass of neutral in any units
mi = 6.042305334 # mass of ion in same units as mn
z = Uf(En,Ei,mn,mi)
print(z)

2.7174319114987107

# Energy of Daughter Product Equation:

def E(En,Ei,Uf): # defining function (E) and parameters: energy of neutral (En); energy of ion (Ei); floating cell voltage (Uf)
    E = En + Uf + Ei/3
    return E # in keV

# Print E value: (Note: same E value for 20 keV and 21 keV)

En = 20 # energy of neutral in keV
Ei = 4.9 # energy of ion in keV
Uf = z # floating cell voltage in keV
print(E(En,Ei,Uf))

24.350765244832044
Neutral Signal Conversion

\[ I_n = \frac{I_{ND}}{\gamma T_n} \]
Gamma Factor

\[ \gamma = \frac{I(N_2)_{\text{fin}}}{I(N_2^+)_{\text{up}} - I(N_2^+)_{\text{gas}}_{\text{up}}} \cdot \frac{I(N_2^+)_{\text{up}}}{I(N_2^+)_{\text{fin}}} \]

1.81 +/- 0.01
Transmissions

\[ T_n = \frac{I(N_2^+)_{\text{fin}}}{I(N_2^+)_{\text{int}}} \]
\[ T_i = \frac{I(D_3^+)_{\text{chicane}}}{I(D_3^+)_{\text{FCC}}} \]

1.00 Neutral

0.93 Ion
Preliminary Results

\[ \text{N}_2 + \text{D}_3^+ \rightarrow \text{N}_2\text{D}^+ + \text{D}_2 \text{ analyzed on 06/13/23} \]