MAss Spectrometer for Planetary EXploration (MASPEX)

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TOF Concept

- A packet of ions is accelerated to a defined kinetic energy and the time required to move through a fixed distance is measured.
- As $KE = \frac{mv^2}{2}$ then lighter ions travel faster than heavier ones $\rightarrow$ mass separation.
- The greater the distance between source and detector the smaller the mass difference that can be seen (resolution).

SwRI proprietary information
## MASPEX performance comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>MASPEX</th>
<th>Cassini INMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage source increases duty cycle to ~100%, provides ~200,000 ions per extraction</td>
<td>Sensitivity ($N_2$)</td>
<td>0.02</td>
</tr>
<tr>
<td>Multi-bounce geometry enables variable path length increasing resolution</td>
<td>Resolution $m/\Delta m$</td>
<td>12,300</td>
</tr>
<tr>
<td>Maximum mass limited by flight time not by field strength or frequency</td>
<td>Mass range</td>
<td>1.1000</td>
</tr>
<tr>
<td>2000 source extractions per second, each producing a spectrum, provides increased spatial resolution and sensitivity</td>
<td>Single spectrum acquisition time</td>
<td>0.5</td>
</tr>
<tr>
<td>Dual stage detector provides wide dynamic range</td>
<td>Dynamic range</td>
<td>$10^9$</td>
</tr>
</tbody>
</table>
Resolution: Multi-Bounce Time-of-Flight

16" 

Ion source  

Detector  

3rd Generation Prototype 

Mass Resolution = 10,800 in 12 bounces 

Xenon 

2-Bounce 

6-Bounce 

12-Bounce 

TOF (ns)
MASPEX Performance

- Extended mass range for heavy organic molecules (>1000 u)
- Enhanced mass resolution for critical isotopes (>10,000 m/Δm)
- Enhanced dynamic range for high S/N (10^9 in a 1s period)
- Improved sensitivity for rare noble gases (>1ppt with cryotrap)
- High throughput (2000 spectra/s)
Isotopic determination in complex volatile mixtures

- High mass resolution mass spectrometry is essential for H, C, N, and O isotope determination in complex mixtures containing water, ammonia, methane, and organic volatiles.

- Shown here is the determination of the H/D ratio in water requiring a resolution of 12,300, which takes 30 bounces on the MBTOF.
High Sensitivity: Cryo-trapping

- Argon over 5 sample sizes and a blank.
  - The sample is held on the adsorber to ~450 seconds.
  - During this period the ion pump is opened and a dip in the line would indicate that some of the sample remains unadsorbed.
  - The noisy trace seen here is because the RGA is at the limit of its sensitivity.
  - The ion pump is then closed and the adsorber allowed to warm to room temperature, during which period the trapped sample is evolved.
  - After deducting the blank contribution the samples fit the calibration curve with an $R^2$ value of 0.99985 and indicate that the adsorber is quantitative.
Versatility

- Open source
  - Ions
  - Reactive neutrals

- Closed source
  - Ambient gas
  - Cryotrapped gas
    - Increased sensitivity
    - Purification (NEG)

- MBTOF
  - Extraction rate
    - power / integration time
  - Resolution
    - selectivity / mass range
  - Integration time
    - data rate / dynamic signals
Formation: Hydrogen and oxygen isotopes in water

- D/H in the solar system taken from Alexander et al. [2012].
- Tagish Lake is best chondritic match to P and D type asteroids that formed the Galilean and Saturnian satellites and also likely represents the rocky fraction of cometary materials.
- Oxygen isotopes in the solar system from McKeegan et al. [2009].
- Measurements of oxygen isotopes of water are virtually non-existent in the outer solar system – the gray area delineates out our present ambiguity.
Astrobiological Studies

Mars Analytical Chemistry Experiment (MACE)

Picasso:
Pyrolysis Inlet Chromatographic Analytical Spectrometer for Surface Organics
- Structural, elemental, and isotopic analysis of carbon compounds
- Enriched gas analysis of N, O, H, and Hetero-species from salts, minerals, and rocks

MACE uses proven analytical techniques to:
- Thoroughly assess the habitability of the MSL landing site
- Greatly improve our understanding of the Mars-Microwave glacial cycle

Paloma:
Payload for Local Observation of Mars Atmosphere
- Analysis of trace gases and their isotopes
- High-resolution analysis of atmospheric H2O, CO2, N2, and other trace constituents

JPL
Studies of Interior Processes

Enceladus Cryo-Geyser

Cassini INMS Neutral Mass Spectrum

Tidal heating of the icy interior

Composition like a comet?
Atmospheric Chemistry and Structure

Meeting the Science Requirements

**STEP 1:** Atmosphere model produced as the basis for estimating the MASPEX measurement requirements.

**STEP 2:** Simulated MASPEX spectrum generated using lab line shapes from our mass spectrometer combined with NIST fragmentation and ionization data, and solar isotopic abundance information.

**STEP 3:** Spreadsheet program developed to determine mass resolution and measurement time needed to satisfy the RFI requirements and thus generate a realistic operational scenario.
Summary

- MASPEX has a long history of development from internal and, more recently, external sources.

- NASA’s funding of the PriME Technology Development and ICEE program demonstrate NASA’s confidence to the development of MASPEX.