

Overview of the MOMA Mass Spectrometer and Examination of Some Mineral Matrices as Learning Curve for MOMA Return Data



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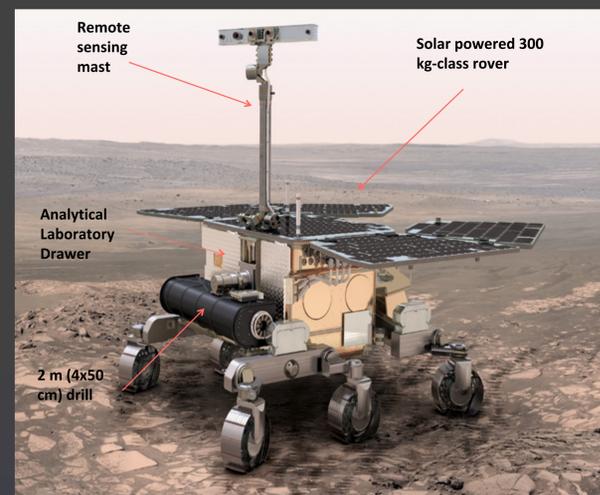
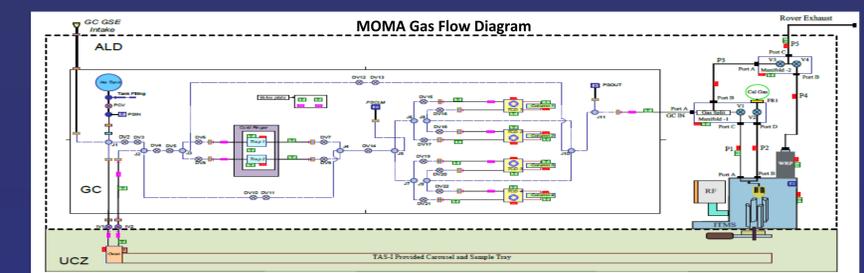
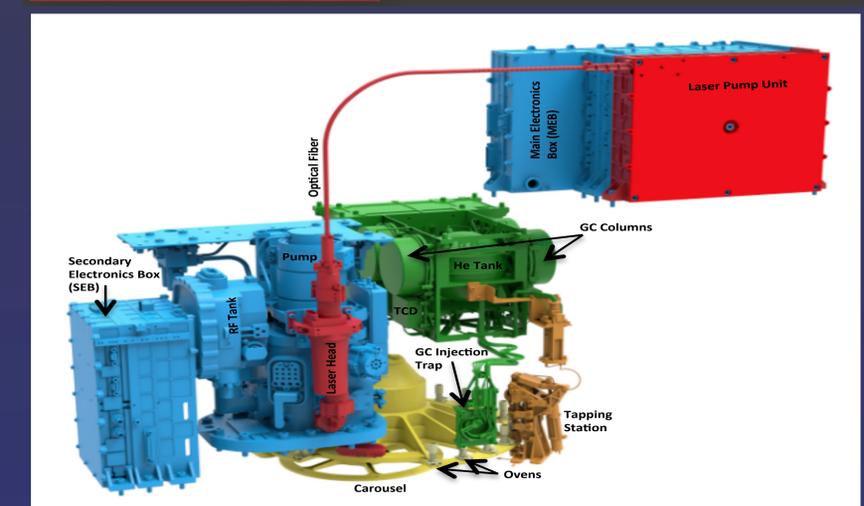
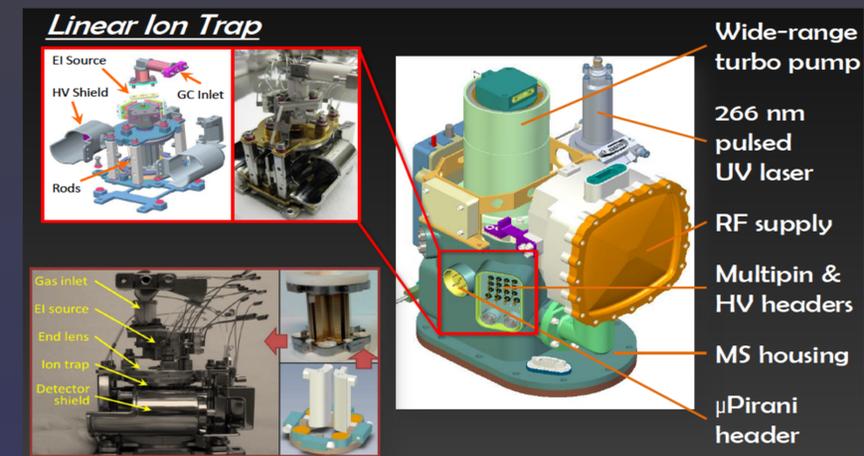
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ExoMars Mission Rosalind Franklin Rover

The ExoMars mission goals of the instrument suite are to find signs of past and present life on Mars through chemical investigations on surface and below surface up to 2 m deep. The Mars Organic Molecule Analyzer (MOMA) instrument, a linear ion trap (LIT) mass spectrometer for chemical analysis was built and evaluated at Goddard Space Flight Center in Maryland and is implemented into the European Rosalind Franklin rover in Italy.

MOMA-MS Instrument

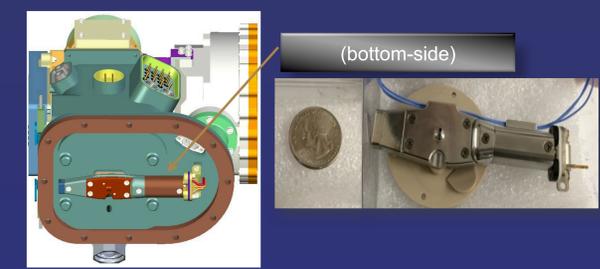
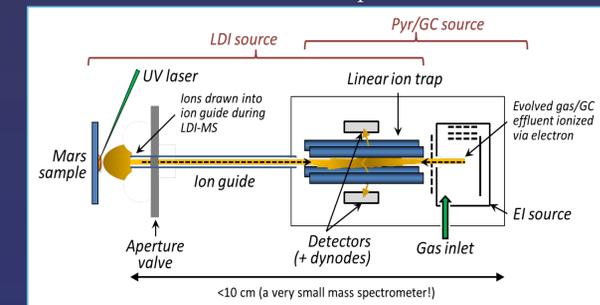
MOMA-MS is a dual-source linear ion trap mass spectrometer (ITMS) subsystem of MOMA. The linear ion trap consists of four hyperbolic rods. Externally-generated ions (see below) are injected into the trap through endplate electrodes. Ions are scanned out through narrow slits in two of the rods, to a detector (2 for redundancy) each comprising a conversion dynode and a channel electron multiplier. The MS is supported with a wide-range hybrid turbodrag pump that operates at 7 Torr CO₂ back pressure, a 266 nm pulsed Nd:YAG laser, redundant W:Re filaments for electron ionization (EI) of GC effluent, RF electronics (1.2 kV, 1 MHz), high speed pulse-counting detector electronics, and the MOMA Main and Secondary electronics boxes.



For lower mass range an electron ionization (EI) source is implemented (m/z 45-550). A laser desorption ionization (LDI) source is implemented for higher mass range (m/z 150-1000). Weight is approximately 9.3 kg and power consumption is 70 Watts peak.

Implementation of GCMS and LDMS Modes in MOMA

In GCMS mode, samples loaded into MOMA ovens, sealed with a tapping station and pyrolyzed to ~850 C. Analyte gases, entrained in He, flow through the GC system to the MS. The GC includes two cooled hydrocarbon traps (Tenax and Carbosieve) that are opened after major water evolution (above 100 C) but before organic thermodesorption (from ~300 C up to > 500 C). Trapped organics are then injected onto one of four columns (1 chiral column) and eluted over a temperature ramp to the MS EI source via a Mars vented split manifold. In LDMS mode, molecules are desorbed and ionized directly from crushed, powder samples with a pulsed UV laser (266 nm, 1 ns duration) at Mars ambient pressures (i.e., 5-8 Torr, primarily CO₂). Parent molecular cations, and their fragments, are injected into the MS through an ion inlet system that uses an aperture valve that closes after ions are trapped, permitting the ion trap pressure to reduce to <10⁻³ Torr so that the detectors can be operated.



Mineral Matrix Investigation

Minerals are being investigated on the engineering test unit (ETU) with full flight capability to learn about mineral mass spectra, Laser desorption ionization parameters and prepare for flight instrument operations on Mars.

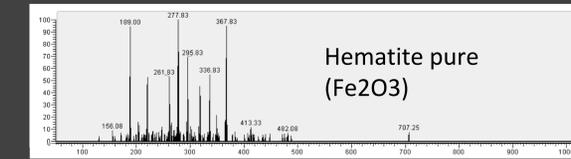


Figure 1. Hematite was investigated on the ETU and LTQ velos. Spectra were compared. Comparison showed depending on the water content in ultra clean zone, ion trap housing and mineral spectra can differ significantly.

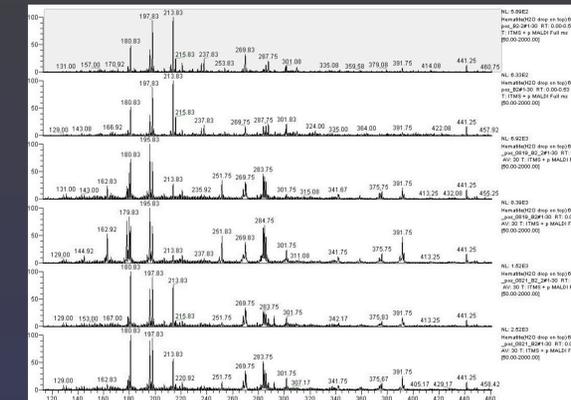


Figure 2. Tests were performed where Hematite was doped with water in the LTQ. The spectrum showed much more similarity with the ETU than the 'dry' hematite. After measurements the sample was left and for several days the sample was interrogated. The water attachment did not indicate reversal under vacuum conditions.

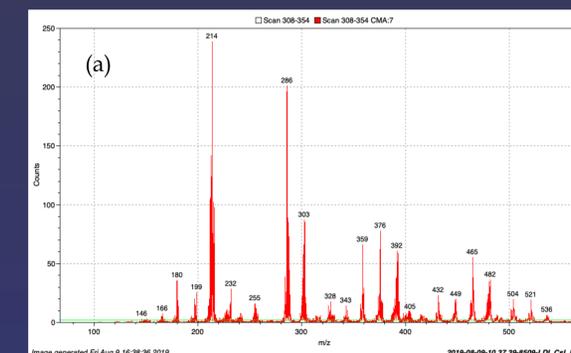


Figure 3a Pure hematite mass spectrum obtained from the ETU. The mass spectrum is more similar to the 'wet' hematite in the LTQ than the dry hematite mass spectrum obtained from the LTQ. b. A zoom of the ETU spectrum. The encircled region of m/z 214 shows many peaks hinting combinations of different numbers of hydrogen in this complex besides the isotopes of Fe.

Conclusions

Harsh environment field portable mass spectrometers are sensitive to their environment causing instrumental drifts. These drifts need to be accounted for to understand unknown complex spectra. This requires compensation of this drift to obtain high accuracy. The understanding of the complexity of the matrix behavior is undeniably important during the advent of finding organic compounds in such matrix. Studying their behavior will aid in the unraveling the many mass peaks found in such spectra. High resolution mass spectrometry can also aid in this process. The Mars environment will add to the difficulty because it is hard to predict how much water the minerals will contain complicating the establishment of a database for minerals to be used for identification. More recently, deep learning is being applied to ETU recorded data to aid this process.

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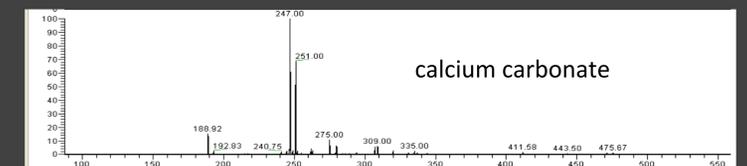
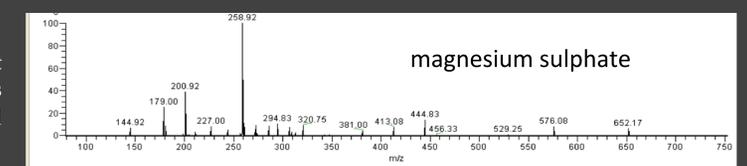


Figure 4. Mass spectra obtained in the LTQ. Some matrices have much less interaction with the laser light and give less intense spectra. This not necessarily means less complex spectra as for calcium carbonate can form identical water clusters. On ETU the Calcium Carbonate indicated also more water complexes.

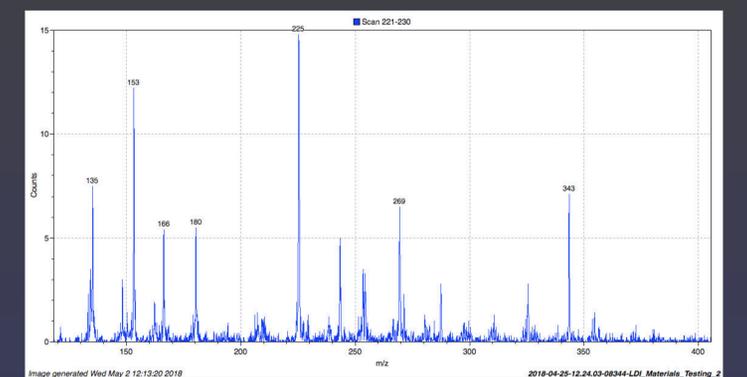


Figure 5. Mass spectrum of calcium carbonate recorded on ETU shows complexity. Examination of the mass differences reveals water attachments.