

# A dual source ion trap mass spectrometer for the Mars Organic Molecule Analyzer on ExoMars 2018

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## Abstract

We present details on the objectives, requirements, design, and operational approach of the core mass spectrometer of the Mars Organic Molecule Analyzer (MOMA) investigation on the 2018 ExoMars mission. The MOMA mass spectrometer enables the investigation to fulfill its objective of analyzing the chemical composition of organic compounds in solid samples obtained from the near surface of Mars. Two methods of ionization are realized, associated with different modes of MOMA operation, in a single compact ion trap mass spectrometer. The stringent mass and power constraints of the mission have led to features such as low voltage and low frequency RF operation [1] and pulse counting detection.

## 1. Introduction

The 2018 ExoMars rover mission seeks the signs of past or present life in the near-surface environment of Mars. As a joint ESA-NASA mission, the rover will obtain samples from as deep as two meters beneath the surface and deliver them to an onboard analytical laboratory for detailed examination. As currently conceived some of the samples acquired by the rover are to be cached for eventual return to Earth by subsequent missions as part of the Mars Sample Return (MSR) campaign. The Mars Organic Molecule Analyzer (MOMA) investigation forms a core part of the sample analysis capability of ExoMars. Its top objective is to support the main goal of the mission, to seek the signs of past or present life on Mars, through detailed chemical analysis of the acquired samples. MOMA has a particular focus on the characterization of any organic compounds that may be present in the samples. MOMA may also play a key role in supporting the caching and sample return objectives of the mission; the details of this

role are yet to be determined during the ongoing redefinition phase of the mission.

## 2. MOMA mass spectrometer

The overall MOMA investigation, including the mass spectrometer, a gas chromatograph (GC), pyrolysis and chemical derivatization facilities, and a laser subsystem, is described in this volume by Goetz et al. The main requirement of the mass spectrometer is to support the analysis of molecules from both GC and laser sources. In “GC mode” heat-evolved neutral gas passed through the GC is admitted to an external electron impact (EI) ionization source. In “laser mode” a pulsed laser desorbs and ionizes molecules directly from powdered samples presented to the inlet of the mass spectrometer at Mars ambient pressure (5-7 torr). In this case ions transfer into the mass spectrometer via a low-conductance leak that also serves as an ion optical lens. Such a dual source capability is achieved by using an ion trap mass spectrometer (ITMS), which operates at the higher (mtorr) pressures amenable to the MOMA design. The required vacuum conditions in the ion trap are achieved with a miniature turbomolecular drag pump, smaller than the Wide Range Pump on the MSL Sample Analysis at Mars (SAM) investigation, and a set of microvalves. Aspects of the ITMS design including the linear ion trap electrode configuration and pulse counting ion detection are given here.

### 2.1 Linear ion trap configuration

A linear ion trap (LIT), or two-dimensional (2D) configuration for the mass spectrometer electrodes has been selected for its particular advantages for the MOMA application. The conceptual design of the LIT is shown in Figure 1. A set of four high-precision hyperbolic rods is held in a brace forming an internal volume with characteristic radius  $r = 3$

mm (smaller than the comparable Thermo LTQ design with  $r = 4$  mm [2]) and approximately 3 cm long. Ions are injected from either end via the two ion sources (laser and EI) which interface to the volume via end plate electrodes (not shown). The trapping and ejection parameters of this LIT are given in Table 1. An analytical scan includes ionization and transfer into the trap, trapping and cooling, and ejection to a detector. During trapping ions oscillate in the fixed RF field of the rods, between end plates held at a positive DC bias relative to the rods. During ejection ions are excited by an auxiliary waveform applied to one pair of opposing rods containing narrow slits that permit ejection to a dynode and channel electron multiplier detector (not shown).

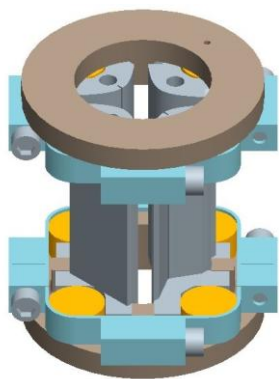


Figure 1: The MOMA linear ion trap is defined by a set of four hyperbolic rod electrodes, two of which contain a narrow slit to permit ejection of ions. The assembly shown is approximately 4 cm long.

In addition to permitting dual ion sources, the LIT configuration supports a larger capacity for ions, and thus may be reduced in diameter somewhat to achieve a high mass range (here 2 kDa) at lower voltages, than a comparable quadrupolar (3D) ion trap. The LIT also permits use of two detectors which can be operated simultaneously to increase sensitivity.

Table 1: MOMA LIT electrical parameters

| Parameter   | Definition           | Value      |
|-------------|----------------------|------------|
| $r$         | internal radius      | 3 mm       |
| $V_{pp}$    | main RF voltage      | 1.2 kV     |
| $f$         | main RF frequency    | 700 kHz    |
| $V_{AUX}$   | aux. RF voltage (pp) | 10 V       |
| $f_{AUX}$   | aux. RF frequency    | 50-350 kHz |
| $V_{DC}$    | DC end plate bias    | 0-100 V    |
| $q_{eject}$ | trap ejection point  | 0.64       |

## 2.2 Pulse Counting Detection

The use of digital or pulse-counting detection, versus analog or current detection, in the MOMA LIT offers additional advantages [3]. While not typically employed in ITMS, the rapid conversion of detector pulses into the digital domain reduces risks associated with the extreme thermal, radiation, and electromagnetic interference environment of the instrument. An early 3D MOMA ion trap prototype was tested in pulse counting mode with EI analysis of perfluorotributylamine (PFTBA). Amplified pulses were recorded during the ejection scan using an FPGA with high bandwidth (>250 MHz). Spectra obtained revealed a lower detector input noise level, improved mass resolution, and increased amplitude linearity at low ion loading compared with current mode spectra. The digital mode additionally offers the important ability to diagnose any detector degradation over the duration of the mission, via analysis of pulse height distributions and calibration spectra, permitting the gain to be adjusted as needed.

## 6. Summary and Conclusions

The MOMA mass spectrometer requirements are met with a linear ion trap design that supports introduction and analysis of ions from laser desorption/ionization and GC/EI modes. The radial ejection of ions to a dynode and electron multiplier and detection by pulse-counting electronics permits MOMA to achieve high analytical performance in a very compact and low-power instrument.

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## References

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