MARS ORGANIC MOLECULE ANALYZER (MOMA): UPDATES AND ANALOG SAMPLE STUDIES FOR THE EXOMARS ROVER MISSION Xiang Li[1,6], Friso van Amerom[2], Walter Goetz[3], Desmond Kaplan[4], Ryan Danell[5], Andrej Grubisic[6], Stephanie Getty[6], Marco Castillo[7], Ricardo Arevalo[8] and William Brinckerhoff[6], [1]*University of Maryland, Baltimore County, Baltimore, MD 21250. (xiang.li@nasa.gov);* [2]*Mini-Mass Consulting, Inc.;* [3]*Max Planck Institute for Solar System Research;* [4]*KapScience;* [5]*Danell Consulting, Inc.;* [6]*NASA/Goddard Space Flight Center;* [7]*ATA Aerospace;* [8]*University of Maryland, College Park.*

Introduction: The Mars Organic Molecule Analyzer (MOMA), a linear ion trap (LIT)-based mass spectrometer (MS) investigation onboard the 2020 ExoMars rover mission, directly addresses the scientific objective to search for signs of past or present life on Mars [1,2]. A wide range of organic compounds from drilled samples acquired from up to 2 m below the martian surface will be analyzed through both pyrolysis-gas chromatography mass spectrometry (pyr/GC–MS) and laser desorption/ionization mass spectrometry (LDI-MS) modes. MOMA will represent the first implementation of LDI on another planet. LDI employs intense ultraviolet (UV) laser pulses to desorb molecules from geological fines, breaking chemical bonds and inducing prompt ionization of organics embedded in a mineral matrix for MS analysis. LDI-MS is capable of detecting both nonvolatile organic compounds and inorganic species indicative of host mineralogy. During Mars operations, an LDI survey mode provides broad molecular composition to guide selection of focused follow-on experiments, for detailed study of observed molecular features. Advanced LDI modes employ Stored Waveform Inverse Fourier Transform (SWIFT) for selected ion isolation and amplification and tandem mass spectrometry (MS/MS) for structural analysis which can support interpretation of the origin and processing of organics. We report here an updated status of the MOMA instrument, as well as analog sample studies we have performed in LDI-MS mode aimed at providing guidance for *in situ* surface operations and data interpretation on ExoMars.

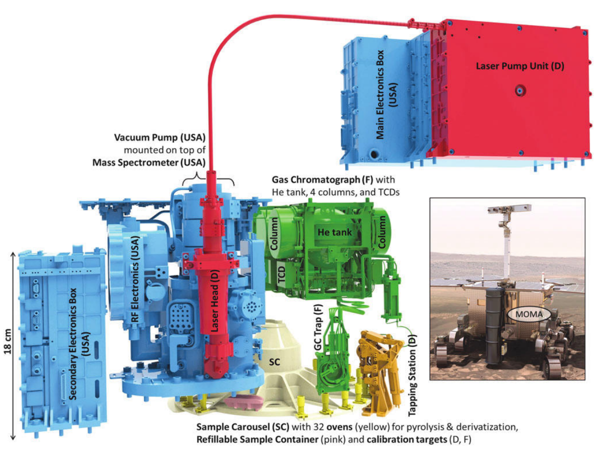

Figure 1. *MOMA flight instrument configuration.*

MOMA status: The configuration of the MOMA flight model (FM) is shown in Figure 1. The FM was delivered to the European Space Agency in mid-2018 for integration and testing, meeting all critical requirements during the Analytical Laboratory Drawer (ALD) thermal vacuum tests ahead of launch in July, 2020. The MOMA Testbed that will serve as the "clean" flight reference model is being integrated at NASA GSFC, and the MOMA engineering test unit (ETU) at GSFC has been refurbished to match flight characteristics for analog sample studies and continued support of operational strategy development.

Analog sample study: Various types of minerals, organic standards, spiked samples, and more complex natural analog samples have been tested on the MOMA ETU. The studied samples are typically crushed to match ExoMars rover sampling. For comparison purposes, drop-cast standard samples as well as some thin section mineral samples have also been studied. Furthermore, analog samples collected from field sites at different depths under the surface have been characterized to mimic the analysis of drilled samples on Mars.

During sample analysis, operational procedures are tuned to achieve the best results. For example, automatic gain control (AGC) is used to guide the laser energy ramping and control the number of ions that are allowed to enter the MS for optimized mass resolution. SWIFT is used to enhance the detection

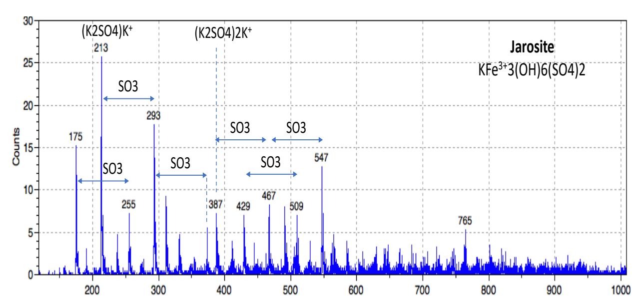

Figure 2. *Mass spectrum of jarosite, a K-bearing sulfate mineral observed on Mars spectroscopically, collected by LDI-MS on MOMA ETU.*

sensitivity and mass resolution for narrower mass range when there are too many competing mass spectral signals. MS/MS is used to isolate and identify specific peaks when particular masses of interest emerge.

Minerals and organics: At the start of the analog sample study, pure minerals and standard organic compounds have been tested. Unlike some other techniques (e.g., GCMS), there are no publicly available comprehensive spectral databases for the MOMA LDI-MS mode of operation. As such, we are building up a MOMA mass spectral library as a reference for future Mars sample characterization. An example mass spectrum of jarosite with peak assignments is shown in Figure 2. Individual minerals and amorphous phases manually spiked with organic reference materials have also been tested to understand organic-mineral interactions and instrument detection sensitivity.

Terrestrial organic rich analog samples: Yellowstone hot spring samples have been used as an example complex "real-world" analog. The LDI-MS results demonstrate that various lipids in the samples can be detected and identified successfully. The use of SWIFT is especially important in enhancing the detection sensitivity for such complex organic compositions.

Terrestrial analog samples from different depths: Hematite samples and Atacama desert samples, collected from a range of depths within the ExoMars 2 m range, have been characterized on the ETU. As shown in Figure 3, clear and characteristic compositional variations have been observed among the samples from different layers, indicating distinct organic populations consistent with depositional and preservational influences. These results provide confidence that MOMA should distinguish any broad compositional differences among the samples collected by the ExoMars drill over its Vertical Survey range.

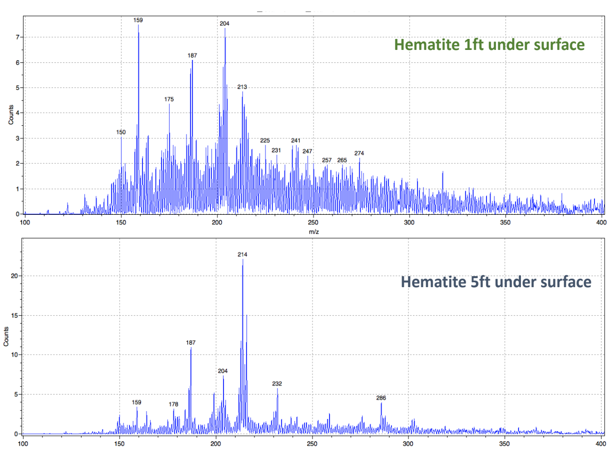

Figure 3. *Mass spectra of Hematite-rich soil from different depths (sample collected at Sri Lanka, provided by Dr. Sudeera Wickramarathna from Mississippi State University) collected by LDI-MS on MOMA ETU.*

Conclusion: The MOMA LDI-MS mode of operation, combined with SWIFT and MS/MS techniques, enable compositional and structural information to be derived from Martian samples *in situ*. As such, the instrument provides a great opportunity to probe the full organic inventory of Mars surface and subsurface samples. Analog sample studies are a critical part for a successful scientific investigation on ExoMars mission. We have demonstrated that MOMA LDI-MS provides powerful capabilities to characterize organics and mineralogical matrices. This work is continuing, targeting analyses of even broader types of minerals and organics, particularly phases related to the minerology at the recently determined ExoMars landing site in Oxia Planum.

References: [1] W. Goetz et al. (2016) *Int. J Astrobio. 15*, 239-250. [2] X. Li et. al.(2017) *IJMS, 422*, 177-187.

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