ASSESSMENT OF THE PERFORMANCE OF FLIGTH MODEL OF THE MARS ORGANIC MOLECULE ANLAYZER (MOMA)

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Introduction: The Mars Organic Molecule Analyzer (MOMA) is one among the nine science instruments onboard the Rosalind Franklin rover of the joint ESA/Roscosmos Exomars 2020 mission. MOMA is an unique chemical laboratory fully devoted to the search for organic molecules in the soil samples collected by the rover drill from the top surface down to 2 m deep. Thus, MOMA will analyze samples that have been exposed to the radiation and chemical conditions at the surface of Mars, as the gas chromatography-mass spectrometry (GCMS) experiment [1] onboard the Viking landing probes and the SAM experiment [2] onboard the Curiosity rover have done before, but also samples that have potentially been protected from these harsh surface conditions. This possibility will therefore increase the potential to detect ancient organic materials, including key organic molecules for prebiotic chemistry or even life, such as amino acids.

To achieve its goal, MOMA is composed of four main subsystems:

- a pulsed UV laser (λ=266 nm, 1 ns duration) for performing Laser Desorption/Ionization (LDI) of molecules from the solid samples collected by the rover. This sampling method is known as a soft ionization process producing large, intact ions from the sample.
- a set of ovens able to conduct sample pyrolysis up to 850°C, or chemical extraction (i.e. derivatization and thermochemolysis) of the sample to enhance the analysis of key organic species indicating biotic or prebiotic chemistry, such as amino acids.
- a gas chromatograph (GC) devoted to separate the many volatile species that may be released by heating or chemical extraction of the solid samples in the ovens. To produce the separation, the GC is composed of 4 analytical channels, each one targeted for separating a specific class of organic compounds. One of them will perform enantiomeric separation in order to assess the enantiomeric excess of key organic molecules, a feature that is important for identifying the existence of prebiotic chemistry.
- an ion trap mass spectrometer (MS) that will characterize the ions produced from LDI, or from ionization by electronic impact (EI) of the molecules eluting from the GC. The design of this new mass spectrometer allows for both LDMS and GCMS analyses and its performances can be tailored to the analytical mode. The MS is able to characterize ions in the 50-500 m/z range in the GCMS mode, and the 100-1000 m/z range in the LDMS mode, thereby focusing on the expected mass ranges produced by each ionization technique.

The construction of different components of the MOMA flight model were completed in 2018 and were subjected to two series of thermal vacuum tests (TVAC) devoted to confirming their capability to work together under the constrained environmental conditions in the rover. A first series was performed at NASA Goddard Space Flight Center (USA) which included the MOMA flight suite on its own, and a final campaign was completed at Thales Alenia Space-I (TAS-I, Ita.) where the instrument was integrated in the ALD (Analytical Laboratory Drawer) with the two other instruments on the rover that will analyze the collected samples as well as the sampling handling equipment. Despite limitations in the acceptable analytical tests that could be performed on the flight instrumentation, due to safety and planetary protection constraints, these tests gave the opportunity to assess the performance of the MOMA flight model. This contribution presents these tests and their results, as well as some comparisons with experiments performed in the laboratory with a commercial GCMS instrument.

Experiments:

Thermal vacuum experiments were performed with the flight instrumentation including the laser, the GC, the MS and tapping station with an oven. Both at NASA/GSFC and TAS-I (Fig. 1), these instruments were assembled and placed in a chamber capable ofcontrol overof the temperature and the pressure of the instrument environment. These parameters were controlled to simulate their day-night and seasonal cycles at the Mars surface compatible with the Oxia Planum landing site of the rover. During the thermal vacuum cycles, both LDI-MS and GCMS modes were tested in conditions mimicking those to be experienced by the flight model on Mars. To prevent any contamination of the flight model with organic molecules from the laboratory, it was not possible to inject any chemical standard for the test performed at TAS-I. However, chemical tracers present in the experiment allowed the acquisition of a signal which can be used to assess the analytical performances of the instrument. At NASA/GSFC; it was possible to inject a mixture of light hydrocarbons into the GC as well as analyze very low levels of refractory materials via LDI. The small hydrocarbons are very volatile molecules which were easy to clean from the instrument prior to its delivery to TAS-I and its integration into the ALD.

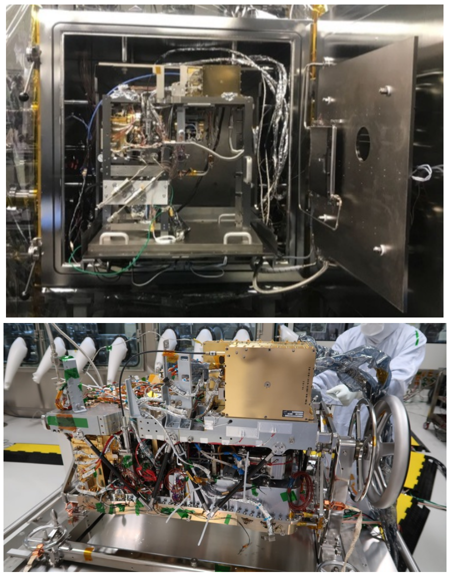

Figure 1 : MOMA flight model in the thermal chamber at NASA/GSFC (upper picture) and integrated in its final configuration with the rest of the ALD at TAS-I (lower picture)

In parallel to the tests of the FM, experiments were carried out in the laboratory with chromatographic columns identical to those integrated in the MOMA GC. Analyses were performed under the operating conditions of the flight model, using chemical standards representative of the hydrocarbons mixture used at NASA/GSFC. These results were compared to those obtained with the flight model, allowing a comparison of the performance of MOMA with an optimized laboratory instrument.

Results : Fig. 2 shows the chromatographic performances of column MXT5 in the FM. When compared to data obtained in the laboratory for the column only, we observe that retention times are quite similar despite slight discrepancies in the control of the temperature and gas flow rate through the column between the two instrumental set ups. We also observe that peaks are slightly broader in the FM chromatogram, likely due to the thermal desorption mode used for the injection in the FM compared to a syringe injection used in the laboratory. However, the peak width measured in the FM chromatogram are sufficiently low to have a separation power compatible with the separation of the wide range of compounds to be separated with MOMA GC. The mass spectra obtained for each chromatographic peak are shown to be accurate as their comparison with the reference mass spectra database from NIST allows to identify each peak without ambiguity.

Figure 3 shows one aspect of the LDMS performance that was measured and verified during the GSFC TVAC test campaign. MS detection and MS/MS analysis of Rhodamine 6G at a loading level 20X lower than the detection limit requirement for MOMA, demonstrates the potential power of this instrument operation mode. Other requirements such as mass range, resolution, accuracy and stability were also verified during the TVAC campaigns.

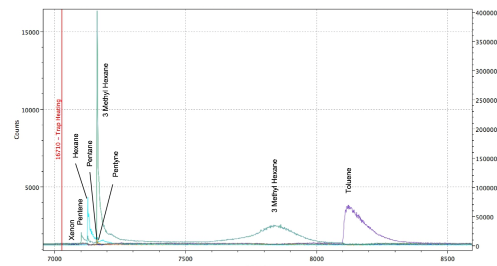

Figure 2 : chromatogram obtained with the MXT5 column of the flight model tested at NASA/GSFC for the analysis of a mixture of hydrocarbons.

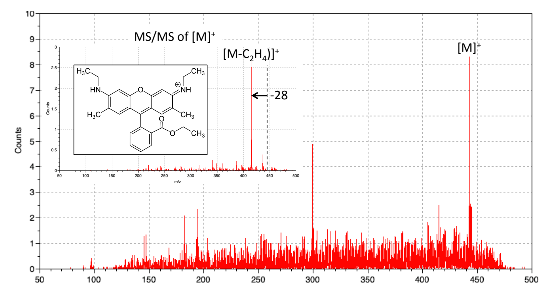

Figure 3 : MS detection and (inset) MS/MS analysis of Rhodamine 6G at 50 fmol/mm^2 with LDI-MS.

Conclusions: Through tests performed under environmental conditions representative of Mars surface conditions, the MOMA flight model integrated in the ALD is shown to meet the analytical requirements defined for the detection and identification of a wide range of organic molecules within samples collected on Mars. The next analysis will be performed on Mars shortly after the landing of the rover, to confirm the health of the instrument. Then the first sample collected will be analyzed in spring 2021.

References: [1] Biemann K. et al (1977) *JGR, 82,* 4641. [2] Freissinet C. et al. (2015) *JGR, 120.* [3] Goesmann F. et al. (2017) *Astrobiology 17.*