Mars Organic Molecule Analyzer (MOMA) onboard ExoMars 2018. H. Steininger[1], E. Steinmetz[1], D. K. Martin[2], B. Lustrement[3], C. Kolleck, [4] F. Goesmann[1],W. B. Brinckerhoff[2], P. R. Mahaffy[2], F. Raulin[5], R. J. Cotter[6], C. Szopa[3] and the MOMA team, [1] (Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Strasse 2, 37191 Katlenburg-Lindau, Germany, steininger@mps.mpg.de), [2] (NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA), [3] (UPMC Univ. Paris 06, Université Versailles St-Quentin, CNRS/INSU, LATMOS-IPSL, 75005 Paris cedex, France), [4] (Laser Zentrum Hannover e.V., 30419 Hannover, Germany), [5](LISA, Universités Paris Est-Créteil, Paris 7, Denis Diderot et CNRS, CMC, 94010 Créteil cedex, France). [6](Howard Hughes Medical Institute, The Johns Hopkins University School of Medicine, Baltimore, Maryland 21205, USA)

Introduction: The Mars Organic Molecule Analyzer (MOMA) is a combined pyrolysis gas chromatograph mass spectrometer (GC-MS) and laser desorption mass spectrometer (LD-MS). It will be the key instrument of the ESA Roscosmos ExoMars 2018 mission to search for extinct and extant life. Additionally the instrument should detect the organic background for example delivered by meteorites to Mars.

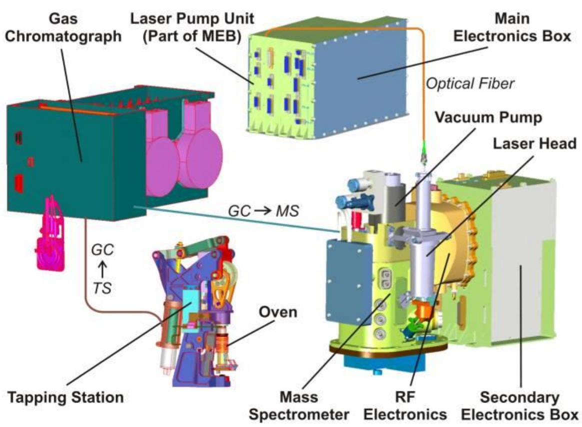

Fig. 1. Overview of MOMA instrument modules (not to scale).

Science scope: The long standing question of life on Mars was targeted by several missions but up to now no conclusive evidence for life was found. Moreover organic molecules were absent or nearly absent in all in situ measured samples. The absolute lack of organic material is astonishing as the annual meteoritic influx is estimated to ~2 10^6 kg (equivalent to ~2 10^5 kg organic carbon [1].

LD-MS and GC-MS target different sections of the organic molecule inventory. The LD-MS is capable to volatilize and ionize large refractory molecules. It is nearly impossible to imagine a non-biological synthesis of large molecules with a specific (non statistical) mass distribution. Therefore this would indicate extant life or recent life because large molecules tend to deteriorate over time. GC-MS is capable to separate and identify smaller molecules. The separation is especially important to find patterns in the distribution of the molecules (patterns in molecule distribution). An example for such patterns is the distribution like here on earth where most of the fatty acids encountered are even-numbered because they are synthesized by C2 units. This is a good indicator for an active biochemistry.

In addition to the focus on organic molecules the LD-MS is capable also to detect atoms and clusters from inorganic rock matrix.

Simple thermal analysis is possible during the heating of the sample in the oven. The temperature will be monitored making it possible to observe exothermic or endothermic reactions in the sample.

Mission: In the beginning ExoMars was planned as a technical demonstration mission as the first in a long series ending with the manned European mission to Mars. The incorporation of scientific payload and several changes in mission design culminated in the combination of the NASA caching rover MAX-C with the Exomars rover yielding a Mars Science Laboratory size rover. At this point in 2011 mass and power allocated to the science instruments was at a maximum. Since NASA has left the ExoMars project the much smaller previous design will be used in a joint ESA/Roscosmos mission.

Goal of the mission is the search for extinct and extant life. A drill will be capable to acquire samples from a depth of up to 2 meters below the surface where the survival rate of organic molecules might be higher [2]. The other instruments in the analytical drawer are the Raman spectrometer and the MicOmega (visible and infrared microscope). The combination of the results of all three instrumens provides an overview of organic and inorganic environment of the acquired sample.

Instrument: MOMA is focusing on the detection and identification of organic compounds. Mass spectroscopy is an ideal method to identify organic compounds by their fragmentation pattern. Fragmentation is induced by electron impact or collision yielding smaller fragments from which the structure of the complete molecule can be deduced.

Heritage. Some parts of the instrument have a history on other missions. The oven and tapping station to contact and close the oven is a size increased improved version which is part of the Cometary Sampling and Composition (COSAC) experiment onboard of the Rosetta mission. In the GC valves to switch the helium gas are similar to the ones used in COSAC [3], while the GC-column assembly is very similar to the one used in SAM onboard MSL. The Data Processing Unit (DPU) is derived from the electronics used for Sample Analysis on Mars (SAM) onboard MSL [4].

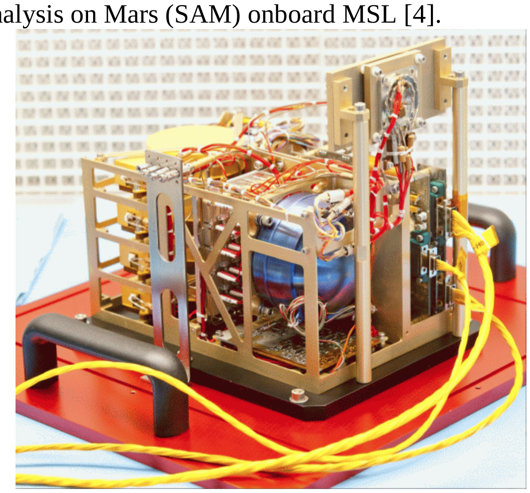

Fig. 2. Prototype of the MOMA GC.

Gas-chromatograph. The gas chromatograph [Fig. 2] is provided by two French institutes LATMOS and LISA. The development of the instrument is based on the SAM GC. Some parts like the GC-column packages are very similar, while the Helium handling system is dominated by electrostatically switched micro valves similar to those used in COSAC.

Three of the four GC-colums will cover the range from very volatile organic compounds to more refractory ones. One column will use chiral column material to enable the GC to separate enantiomeres. The GC will be able to detect organic molecules with thermal conductivity detectors (TCD) independent of the operations of the MS. The helium pressure tank stores the helium used as mobile phase for the gas chromatography. To improve the resolution the volatile compounds from the oven are trapped in cold traps and then injected by rapid heating of the traps. The GC contains electronics to measure and regulate all internal parameters. For example the heaters for the columns, the TCD and the capillaries.

Mass spectrometer. The mass spectrometer together with the data processing unit is provided by the Goddard Space Flight Center. The linear ion trap (LIT) [Fig. 3] is capable of working at a relatively high pressure compared to time of flight and sector field mass spectrometers. This is a benefit because it reduces the need for large vacuum pumps. The Creare pump used is a smaller version of the ones used in the SAM instrument. The mass spectrometer will be sensitive to masses in the range of 44 to 1000 amu. The lower mass cut off is due to the carbon dioxide (mass 44) and the restrictions of an ion trap MS. The achievable mass resolution below *m/z* 500 will be 1 Da and and 2 Da between *m/z* 500-1000 (full width half maximum peak widths).

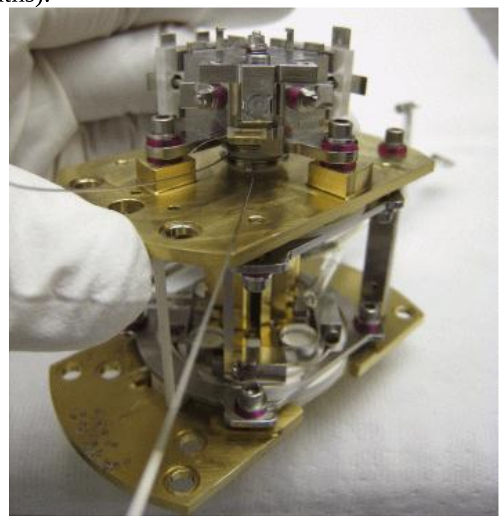

Fig. 3. MOMA LIT-MS with SAM heritage EI source assembly.

The mass spectrometer either works as a detector for the gas from the GC or as detector for the Laser desorption. To avoid saturation in GC mode part of the gas is vented in a split. The gas is introduced into the MS and then ionized by an electron beam. In LD mode the crushed rock sample is presented to the MS on the refillable sample container directly below the aperture valve. The laser hits the sample at a rate of up to 100 Hz in burst mode and the valve opens. The pressure gradient and the ion optics guides the ions into the MS and the aperture valve closes again. During pump down the ions are stored in the trap and after reaching an acceptable vacuum the mass spectrum is recorded.

Laser. The laser desorption works best at short wavelength. Therefore a UV-laser is used in the instrument. The laser has two parts: the laser electronics and the pump unit [Fig. 4]. An 808 nm diode laser module provided by Jenoptic is the heart of the pump unit. The necessary electronics and capacitor banks are built at the Max-Plank-Institut für Sonnensystemforschung (MPI). The pump unit is connected to the laser head by a glass fiber. The laser head which is provided by the Laser Zentrum Hannover (LZH) houses the neodymium-YAG laser medium, two subsequent doubling crystals and the focusing lenses for the beam. The doubling from 1064 nm to 532 nm and another doubling to 266 nm leads to 75% loss of initial beam energy. The resulting 1 ns laserpulse of 250 µJ is focused on a spot of 400 µm.. With a repetition rate of 10Hz and a burst mode of 100 Hz the laser is capable to generate the necessary amount of ions[5].

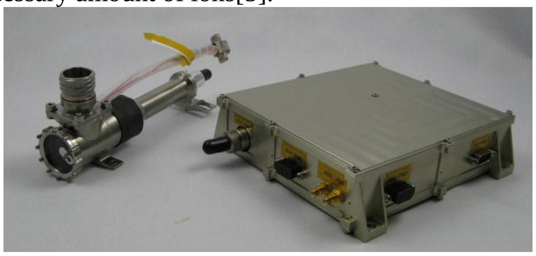

Fig. 4. MOMA laserhead (left) and laser electronics and pump module (right).

Oven and tapping station. The oven and tapping station [Fig. 5] are used to handle the sample delivered by the Sample Preparation and Distribution System (SPDS). The tapping station is used to encapsulate the sample and provide pneumatic connection for the helium to get into the oven and conduct volatilized compounds into the GC. The electrical contacts for the heaters and the temperature sensor are also provided by the tapping station. Two kinds of ovens are planned to be used. The first is a pyrolysis oven capable to reach a temperature of 1000°C. This temperature is needed to volatilize the refractory organics[6]. The second oven type has small sealed capsules filled with a chemical substance which reacts with active sites of potential organic molecules present and improves their volatilization. Derivatisation is an established method in mass spectroscopy and it is part of the COSAC experiment and SAM. For the derivatization ovens the temperature range will be lower.

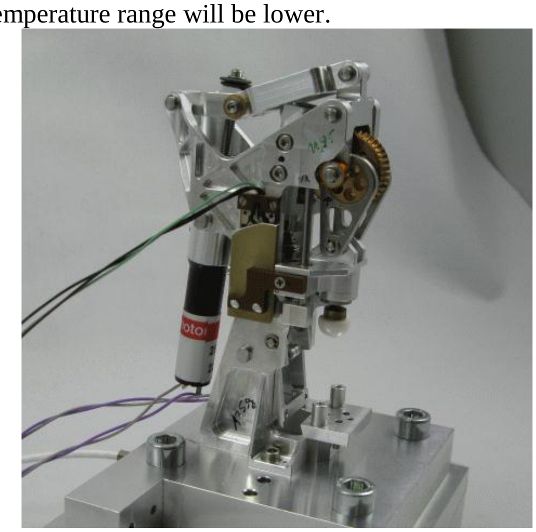

Fig.5.Tapping station prototype on pressure test stand.

Operational modes: Several types of measurements can be done with the instrument. As helium and ovens are limited in amount the LDI method which uses no consumables will do the first measurements to establish an insight into the amount of organic material present in the sample. There is a fast survey mode which uses only limited amount of time and a detailed mode in which several spots on the sample are tested with varying parameters on laser energy and MS parameters.

If a sample looks promising GC-MS will be used as well. Either an derivatization oven or a pyrolysis oven will be used depending on the results of the LD-MS and the other ExoMars instruments. The SPDS is able to distribute a second aliquot of the sample to the refillable sample container or one of the ovens enabling the instrument to use all methods on one sample.

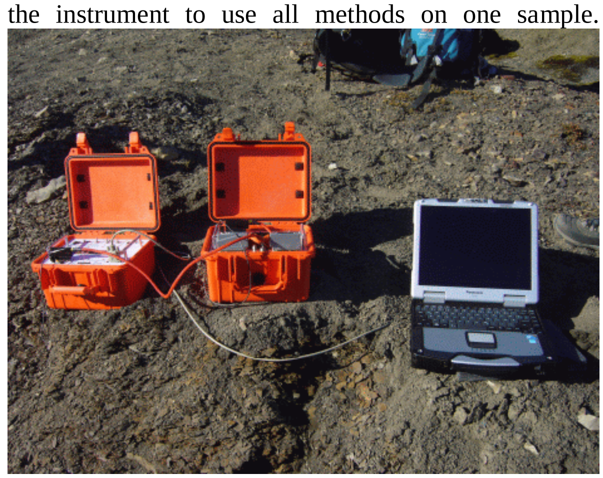

Fig. 6. MOMA GC breadboard during AMASE fieldtrip.

AMASE 10 and 11. The GC was tested twice during the Arctic Mars Analogue Sample Expedition in 2010 and 2011 [Fig. 6]. The performance and the stability of the instrument were above expectations and provided GC plots of pyrolysis products from rock samples[7].

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