The MA_MISS Experiment on board the ExoMars 2020 Rover

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Introduction: Results from the MEX and MRO orbiters and from the MER and MSL rovers have clearly shown that water played a crucial role in the past history of Mars, providing favorable conditions for life. Due to the very tenuous Martian atmosphere, potential chemical biosignatures at or in the vicinity of the Martian surface could have been degraded or destroyed by i) ultraviolet (UV) radiation ii) UV-induced photochemistry producing reactive oxidant species, and iii) ionizing radiation. Long-term effects of radiation decrease with depth. Organic molecules and potential biomarkers could be better preserved in the subsurface. Subsurface investigations are thus mandatory to search for possible indicators of past life. MA_MISS (MArs Multispectral Imager for Subsurface Studies) is the Visible and Near Infrared (VNIR) miniaturized spectrometer [1] hosted by the drill system of the ExoMars 2020 rover. It will perform spectral reflectance investigations in the 0.4–2.2 µm range to characterize the mineralogy of the excavated borehole wall at different depths (0 - 2 m). The spectral sampling is about 20 nm while the spatial resolution over the target is 120 µm. Making use of the drill's movement the instrument slit can scan a ring and build up hyperspectral images of the borehole. MA_MISS is the only instrument in the rover's Pasteur payload able to analyze subsurface material in its natural condition (in situ), prior to extracting samples for further analysis. MA_MISS findings will help to refine criteria for deciding form where to collect samples.

Scientific Objectives: MA_MISS has been designed to pursued the following scientific objectives:

1) *determine the composition of subsurface materials*: MA_MISS spectral range and high spatial resolution will allow identifying differences in lithologies, and distinguishing between volcanic and sedimentary rocks. Analysis of absorption band positions and shapes can be used to identify different types of mineralogical phases. Crystal field absorptions due to Fe^{2+}-Fe^{3+} (near 1 and 2 µm) and other transition elements in association with iron-bearing minerals can be used to identify many types of silicates, oxides, etc. [2]. The occurrence of OH^-/H_2O vibrational bands near 1.0, 1.4, and 1.9 µm (overtones and combinations) is indicative of the hydration state of materials [3]. Carbonates also display overtones and combinations of vibrational features that are in principle observable in the 1.75–2.20 µm range [3].

2) *map the distribution of subsurface water and volatiles*: Currently ice deposits in the Martian shallow subsurface have been inferred from remote-sensing detection of hydrogen based on neutron and gamma ray spectroscopy [4] and from permafrost evidences [5]. Detections of low latitude H_2O frost on pole facing slopes are also consistent with a subsurface ice layer at those latitudes [6]. Although no morphologic or spectroscopic evidence of H_2O or CO_2 ices have been observed at the ExoMars potential landing sites, ice inclusions cannot be ruled out. Both H_2O and CO_2 ices show diagnostic features in the Ma_MISS spectral range. Ice deposits or inclusions in the subsurface layers can be performed thanks to minima positions at 1.5 and 2 µm and band shapes analysis.

3) characterize important optical and physical properties of materials (e.g. grain size): The study of spectral parameters, such as continuum reflectance level and slope can help to determine important physical parameters like the different dimensions of grains in materials that can help us to better assess the type and state of sediments in the subsurface.

4) *produce a model stratigraphic column to obtain clues about subsurface geological processes:* Mars surface is rich in sedimentary outcrops that exhibit stratigraphic features at a range of spatial scales. On Earth, our understanding of the evolution of ancient climate and life development derives from the study of mineralogic, textural, and geochemical signatures preserved in the sedimentary rock record in stratigraphic sections. These insights could also have been preserved in Martian subsurface stratigraphy. Having access to the Martian subsurface record will be fundamental to constrain the nature, timing and duration of alteration and sedimentation processes at the ExoMars rover locations.

Instrument Description: The Ma_MISS instrument main requirement is miniaturization because it is embedded within drill parts. The spectrometer is accommodated in a box on the external wall of the drill box. The spectral range is 0.4–2.2 μm, with a spectral resolution of 20 nm and an expected signal to noise ratio of about 100. The light from an integrated 5W lamp is collected and carried to the miniaturized Optical Head (OH) using an optical fiber bundle. The OH is within the drill tip. An anti-reflective coated Sapphire Window (SW) with high hardness and transparency on the drill tip tool protects the MA_MISS OH permitting the observation of the borehole wall. Different depths can be reached by the use of three extension rods, 50 cm long, each containing optical fibers and a collimator. The first extension rod is connected to the non-rotating part of the Drilling System, hosted on the rover, through a Fiber Optical Rotating Joint (FORJ), that allows the continuity of the signal link between the rotating part of the drill and the spectrometer subsystem. Currently the spectrometer is under construction and the calibration set up is finalized.

MA_MISS Breadboard Measurements In order to characterize the spectral performances of the laboratory model of the Ma_MISS instrument (breadboard), a series of spectroscopic campaigns have been performed. Measurements have been carried out on both particulate samples and on slab rocks [7]. Breadboard data analysis confirms that MA_MISS spectral range, resolution, and imaging capabilities are suitable to characterize the subsurface environment and the samples that will be delivered to the rover's analytical laboratory.

References:

[1] De Sacntis et al., Ma_MISS on ExoMars: mineralogical characterization of the Martian subsurface, **Astrobiology**, 17, 6-7, 612-620, 2017
[2] Burns, Mineralogical Applications of Crystal Field Theory, **Cambridge University Press**, 551 pp.
[3] High Spectral Resolution Reflectance Spectroscopy of Minerals, **JGR**, VOL. 95, NO. B8, Pages 12,653-12,680, 1990
[4] Boynton et al., Distribution of Hydrogen in the Near Surface of Mars: Evidence for Subsurface Ice Deposits, **Scienc**e, 297, 81; 2002
[5] Baker, Water and the Martian landscape, **Nature**, vol 412, 12, 2001) 2001
[6] Carrozzo et al., Mapping of water frost and ice at low latitudes on Mars, **Icarus**, 203, 2, 406-420, 2009
[7] De Angelis et al., Application of spectral linear mixing to rock slabs analyses at various scales using Ma_MISS Bread Board instrument, **P&SS**, 144, 1-15, 2017.

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