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The MA_MISS experiment on board the ExoMars Rover

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Abstract

MA_MISS (MArs Multispectral Imager for Subsurface Studies) is the Visible and Near Infrared (VNIR) miniaturized spectrometer 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 (≤2 m). The spectral sampling is 20 nm while the spatial resolution is 120 µm. Using the drill's movement the instrument slit can scan a ring and build up hyperspectral images of the borehole. MA_MISS findings will help to refine criteria for deciding from where to collect samples.

1. Introduction

Recent 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 bio-signatures 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 needed to search for possible indicators of past life. MA_MISS instrument [1] is a miniaturized imaging spectrometer designed to provide imaging and spectra in the VNIR wavelength region. By operating during pauses in drilling activity, it will produce hyperspectral images of the drill's 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.

2. MA_MISS scientific objectives

MA_MISS will accomplish 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 bands can be used to identify different 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 in the subsurface layers can be detected thanks to minima positions at 1.5 and 2 µm and band shapes analysis.

3) characterize important optical and physical properties of materials: The study of spectral parameters, such as continuum reflectance level and slope can help to determine important physical parameters like the different grain sizes in materials that can help us to 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 mineralogical, textural, and geochemical signatures preserved in the sedimentary rock record in stratigraphic sections. These insights could also have been preserved in Martian subsurface. Having access to the Martian subsurface will be fundamental to constrain the nature of processes at the ExoMars rover locations.

3. Instrument Description

The Ma_MISS instrument main requirement is miniaturization because it is embedded within drill. The spectrometer is placed in a box on the side wall of the drill box. The spectral range is 0.4–2.2 μm, with a spectral resolution of 20 nm and SNR~100. The light from a 5W lamp is collected and carried, through an optical fiber bundle, to the miniaturized Optical Head (OH), hosted within the drill tip. A Sapphire Window (SW) with high hardness and transparency on the drill tip protects the MA_MISS OH allowing to observe the borehole wall. Different depths can be reached by the use of 3 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 Drill, 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.

4. MA_MISS breadboard analysis

Spectroscopic campaigns have been performed to characterize the spectral performances of the laboratory model of the Ma_MISS instrument (breadboard, BB). Measurements have been carried out on both particulate samples and slab rocks [7]. Spectra of a slab rock are shown in fig.1. In box I spectra acquired on a lava sample with a FieldSpec Pro+QTH lamp (6 mm spatial resolution), in 4 areas (A,B,C,D), are shown. Spectra are very similar, at this scale the sample is homogeneous. In box II spectra acquired with Ma_MISS BB (120 μm) in different positions, in each area (A-D), are shown. At sub-mm scale the rock surface appears heterogeneous and a variety of mineralogical phases occur. 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 rover's analytical laboratory.

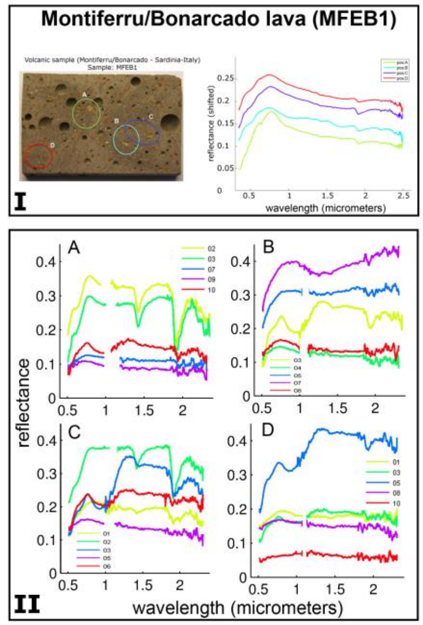

Figure 1: Box I: spectra acquired on a lava sample, with FieldSpec Pro + QTH lamp (6 mm spatial resolution), in 4 areas. Box II: spectra acquired with Ma_MISS BB (120 μm) in each area.

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