EXPLORING THE MARTIAN SUBSURFACE WITH MA_MISS ON EXOMARS 2022. M.C. De Sanctis[1], F. Altieri[1], E. Ammannito[2], S. De Angelis[1], B. Ehlmann[3], M. Ferrari[1], A. Frigeri[1], S. Fonte[1], M. Formisano[1], A. Apuzzo[1], J. Brossier[1],N.Costa[1], L. Rossi[1], G. Vizzini [1] M. Giardino[2], R. Mugnuolo[2], S. Pirrotta[2], J-P. Bibring[4], T. Di Iorio[5], F. Capaccioni[1], M.T. Capria[1], V. Ciarletti[6], Cousin, C.[7] ; Ercoli Finzi, A.[8], C. Federico[1], G. Magni[1], O. Korablev[9], M. Lavagna[8], S. Mantsevich[9], G. Piccioni[1], Stephan, K.[10], F. Westall[11]
[1]Institute for Space Astrophysics and Planetology, IAPS-INAF, Rome, Italy,(mariacristina.desanctis@inaf.it) [2]Italian Space Agency, ASI, Italy; [3]Calthec, USA;[4]IAS, Orsay, France;[5]ENEA, Rome, Italy;[6] LATMOS, France; [7] University of St Andrews, UK.; [8] POLI-MI, Italy, [9] IKI, Moscow, Rus., [10] DLR, Berlin, Germany; [11] CNRS Orleans, France.

Introduction: Mars is a primary destination to search for signs of life in our Solar System and the search for life is the aim of ExoMars 2022. ExoMars 2022 mission is composed by a lander and a rover. The rover includes a drill to collect samples and has a complex payload able to conduct detailed investigations of composition, search for organics, and to recognize indicators of past or extant life [1].The drill is a critical element of the mission which will explore and collect samples down to 2 m of depth. Access to the Martian subsurface, below the most altered layers, is needed to understand the nature, timing and duration of alteration and sedimentation processes on Mars, as well as habitability conditions. An essential part of the payload is Ma_MISS (Mars Multispectral Imager for Subsurface Studies) experiment hosted by the drill system [2]. Ma_MISS is a Visible and Near Infrared (VNIR) miniaturized spectrometer with an optical head inside the drill tip capable of observing the borehole from where samples are collected.

Ma_MISS instrument: Ma_MISS is a modular instrument and it consists of two main parts: i) the spectrometer and the proximity electronics located outside of the drilling tool and ii) the Optical Head and fibers located inside the drill itself [2]. The Drill consists of a main rod, which hosts the drill tip, plus three additional rods (each 50 cm long), which allow it to reach a maximum depth of 2 m. The drill tip has the Ma_MISS Optical Head and a sapphire window to observe the borehole wall. All the rods are equipped with optical fibers, able to transmit light and signal. Ma_MISS is equipped with a light source of 5W to illuminate the borehole. The illumination spot on the target is about 1 mm in diameter at a focal distance of about 0.6 mm. The reflected light is collected through a 120 µm spot (defining the spatial resolution). The spectrometer observes a single point target on the borehole wall subsurface and using the drill movements, can build up spectral images of the target. By combining a number of column and ring observations, Ma_MISS allows the reconstruction of a fairly complete image of the borehole wall [3].

Natural rocks observed during Ma_MISS calibration campaign: During the Ma_MISS calibration campaign, laboratory measurements were performed on different minerals and rocks that can be considered as Mars analogs with the aim of characterize the scientific performance of the Ma_MISS flight spectrometer. Moreover, we also checked the Ma_MISS capability to recognize spectral features when the Drill rods are mounted. During the characterization phase we selected three natural samples: 1) a slab of Dunite rock, 2) a slab of Montiferru lava and 3) a slab of gypsum.

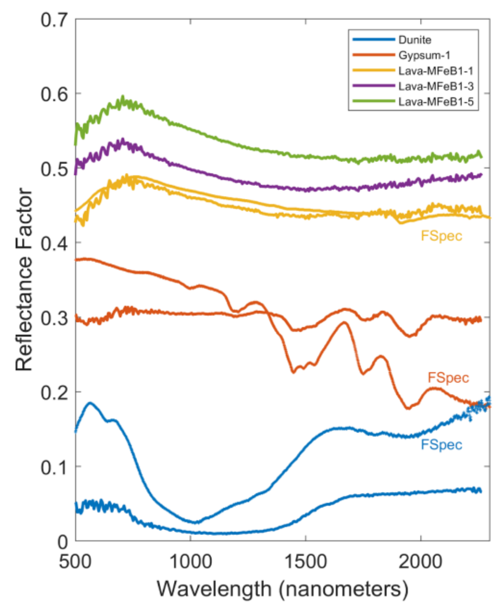

Fig.1 Rock/mineral slabs spectra acquired with Ma_MISS Flight Model during the on-ground calibration campaign; data are compared with spectra acquired on the same samples at IAPS-INAF Laboratory (labeled FSpec).

The spectra collected on the three points on the slab of Montiferru ignimbrite (purple, green and yellow spectra in fig.DATA) are quite similar to each other. The weak absorption feature at 1.9 µm is due to the presence of some hydrated phase in the sample. The spectrum obtained on the gypsum slab shows all its typical absorption features related to water molecules vibrations. The blue spectrum acquired on the dunite sample shows the wide absorption band (from 0.6 to 1.6 μm) near 1 μm typical of olivine.

The data acquired with the Ma_MISS FM on different natural samples confirms the ability of the instrument in the identification of the spectral features characterizing such samples.

What mineralogy is expected in the subsurface? Ma_MISS will investigate deeper into the subsurface than prior rover missions. The two Viking landers and Phoenix landers scooped materials from the upper few centimeters of regolith for compositional analysis. The Mars Exploration Rovers (MER) used their wheels to excavated trenches up to 11 cm deep[4] and collected chemical and mineralogical compositional profiles with the alpha-particle x-ray spectrometer and Mossbauer instruments. The MER rovers also had a rock abrasion tool (RAT) [5] that ground up to 9 mm deep and revealed coatings enriched in S, Cl, Zn and Ni and iron oxides on outer rock surfaces. The data collected by the MER on select soils excavated from the subsurface show that those soils had high ferric sulfate contents or silica contents, likely signaling an influence from volcanic or hydrothermal processes [6,7].

Mars Science Laboratory (MSL) drilled ~5cm into multiple rocks, collecting powdered materials for analysis below any coatings. MSL rover successfully drilled twelve full depth drill holes into the Martian surface and analyzed the sampled material using onboard instruments, giving us new insights into the potential habitability and geologic diversity of ancient Mars. The samples acquired by MSL demonstrate differences between the surface and the subsurface, as shown in the colors of the excavated fines, mainly linked with the oxidation state of the materials. Drilled powered samples exhibit a range of grey and reddish colors that reflect mineralogical changes from alteration and fluid: rock interactions [8]. Most interesting is the fact that well preserved organic material was discovered at Pahrump Hills (Confidence Hills and Mojave 2), even with the very harsh surface conditions, suggesting even better preservation may be possible farther beneath the Martian surface [9].

Differently from the previous missions, the drill and Ma_MISS measurements will be the deepest compositional measurements made on Mars up to 2m depth. Over the 2m ExoMars is expected to drill, Ma_MISS is equipped to be able to detect compositional gradients with depth. Changes in type and abundance of minerals, weathering fronts or rinds, and diagenetic veins or nodules will be mapped as a function of depth. The spectral range of Ma_MISS (0.5-2.3 micron) is optimal to detect changes in the occurrence and crystal chemistry of olivines and pyroxenes as well as Fe(II)/Fe(III) in silicates, oxides, and salts. In particular, there may be changes in these redox sensitive minerals with depth that record different environments.

Furthermore, changes in the hydration state of materials has also been observed with depth on Mars with uppermost surfaces more desiccated than interiors. Thus, Ma_MISS observations are the best measurements to characterize the materials via 1.4, 1.9, and 2.2 μm absorptions. Though water ice is not predicted at the near surface at these latitudes, water ice is also detectable by Ma_MISS from its 0.94, 1.5, and 2.0 μm absorptions. Experiments done with the Ma_MISS breadboard demonstrated that at sufficient concentrations, organic molecules will also be detectable [10].

Conclusion: Ma_MISS will reconstruct the 3-D images of the borehole excavated by the ExoMars drill and will acquire spectra of the subsurface layers from which the sample will be collected. The calibration and tests performed with the flight model demonstrate the ability of the instrument in detecting most of the spectral signatures expected in Martian subsurface, including those due to the presence of possible salts and organics.

Acknowledgments: Ma_MISS instrument is fully funded and supported by ASI (Italian Space Agency (grant ASI-INAF n. 2017-48-H.0).

References: [1] Vago, J. L. et al. (2017), Astrobiology, 17(6–7), doi: 10.1089/ast.2016.1533; [2] De Sanctis, M. C. et al. (2017) Astrobiology, 17(6–7), doi: 10.1089/ast.2016.1541; [3] Ferrari, M. et al., this conference. [4] Sullivan, R., et al.. (2011), J. Geophys. Res., 116, E02006, doi:10.1029/2010JE003625; [5] Gorevan et al., (2003), J. Geophys. Res., 108, 8068, doi:10.1029/2003JE002061, E12; [6] Gellert, R and Yen, A.S, (2019) Remote Compositional Analysis, 10.1017/9781316888872, (555-572); [7] Morris et al., (2019), Remote Compositional Analysis, 10.1017/9781316888872, (538-554); [8] Abbey et al., (2020), Icarus, /doi.org/10.1016/j.icarus.2020.113885 [9] Eigenbrode et al., (2018), Science, doi/10.1126/science.aas9185, [10] Ferrari et al., EPSC2020-348, https://doi.org/10.5194/epsc2020-348