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Analysis of rocks slabs by VNIR spectroscopy and linear mixing with Ma_Miss instrument breadboard. S.De Angelis¹, M.C.De Sanctis¹, P.Manzari¹, E.Ammannito^{1,2}, T.Di Iorio³, F.Altieri¹, C.Carli¹, ¹Space Astrophysics and Planetology Institute - INAF-IAPS, via Fosso del Cavaliere, 100 – 00133, Rome (Italy), ²University of California Los Angeles – IGPP (CA-USA), ³ENEA, UTMEA-TER, Rome (Italy) (simone.deangelis@iaps.inaf.it)

Introduction. The Ma_Miss miniaturized spectrometer will observe the Martian subsoil in the VNIR spectral range 0.4 – 2.2 μm , with high spatial resolution, 120 μm . It will be integrated in the Drill of the Pasteur Rover of the ExoMars 2018 mission, and will acquire spectra of the borehole wall performed by the Drill in the subsurface, at depths down to 2 meters. The goal of Ma_Miss is the study of the Martian subsurface. The scientific objectives are (1) the determination of the subsurface mineralogical composition of the subsurface materials, by means of Visible and Near Infrared reflectance spectroscopy; (2) the determination of physical properties of materials; (3) the reconstruction of a stratigraphic column, thus getting clues about subsurface geological processes. The search of present or past life and the investigation about the conditions favourable to the development of life is the main objective of Exomars mission. So the characterization of the possible past water/geochemical environment is the primary goal: thus objectives will be the search for hydrated silicates as well as carbonate or sulphate layers. In this work reflectance spectra have been acquired on a set of five rock samples in slab form (two carbonates and three volcanic rocks); all the samples have been previously characterized with the setup in use at S.LAB. at IAPS-INAF, a spectro-goniometer (SPG), consisting of the FieldSpec Pro [®] coupled with a goniometer. Spectra acquired with Ma_Miss breadboard (at higher spatial resolution) have been combined applying two methods (linear mixing and arithmetic average) and then compared with spectra acquired with the SPG, at lower spatial resolution.

Instrument description. *Ma_Miss*: the Mars Multispectral Imager for Subsurface Studies is a miniaturized Visible and Near-Infrared spectrometer [2,3]: it will be hosted within the Drill of the ExoMars-2018 Pasteur Rover. The integrated light source is a 5 W lamp; a bundle of optical fibres carries the light from the lamp to the Optical Head, which is used (i) to focus the light on the observed target and (ii) to collect the scattered light from the target. The illumination spot on the target is 1 mm in diameter; the light is then recollected from a 120- μm spot (spatial resolution). A single optical fibre carries the collected light from the Optical Head to the spectrometer. The interface between the Optical Head and the subsurface wall is the Sapphire Window, which is characterized by high hardness and transparency. The light is focused on the wall at a distance of less than 1 mm outside the Sapphire Window. The Optical Head is integrated in the Drill Tip; different depths can be reached by the use of three extension rods, each 50 cm long, containing optical fibres. The instrument will acquire spectra during a vertical

translation, at different depths, and during a rotation at a fixed depth. The laboratory model, breadboard (BB), of the instrument includes all the subsystems [3]: the lamp and the illumination bundle; the Optical Head, the Sapphire Window, the Signal Fibre, that carries the collected light from the Optical Head to a spectrometer. At the moment, the breadboard only contains the optical critical subsystems, and it has been coupled with a laboratory spectrometer, the FieldSpec Pro with the spectral range 0.35–2.5 μm . LabSphere Spectralon reflectance standards, with reflectance in the range 2–99%, are used as reference. The phase angle is close to 0°.

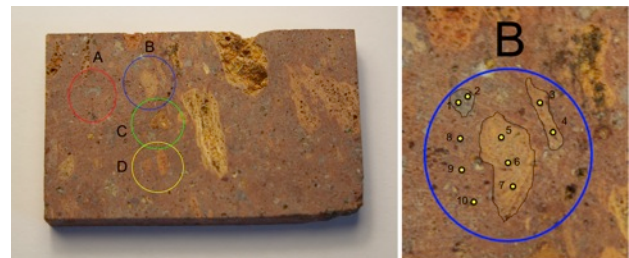


Fig.1: left: the sample analysed, with 4 areas measured with SPG setup. Right: inside the B area, the positions of spectra acquired with Ma_Miss BB are evidenced.

S.LAB setup (SPG): all the analysed samples have been also characterized with the FieldSpec Pro in the spectrogoniometer configuration [4]. The FieldSpec is coupled to a goniometer: the illumination angle (i) and the emission angle (e) can be set at different values: in this case we used $i=30^\circ$ and $e=0^\circ$ (phase angle = 30°). The light source is an 84W QTH lamp; the spatial resolution on the target is about 6 mm in diameter.

Sample description and preparation. Five rock samples have been analysed: two carbonate rocks (two limestones, Central Apennines, Italy (CAL1, GPR18)), and three volcanic rocks: San Bartolo Lava (Stromboli, Aeolian Islands, Italy, STR72), and two samples from Sardinia (Montiferru, MFEB1 and Fordongianus, FOR5). All five samples have been analysed in slab form.

Experimental and Analytical approach. For each slab, several different spots have been analysed with the SPG setup, which has a spatial resolution of 6 mm (fig.1, left, and fig.2). Then the Ma_Miss BB has been used. Thanks to its higher resolution (120 μm), in each of the SPG spots, ten spectra have been acquired (fig.1, right). Thus for each area the ten spectra acquired with the BB setup have been combined in order to be compared with the spectra acquired with the SPG setup of the same region. Two methods have been used to combine the Ma_Miss BB spectra: (i) an arithmetic average among the ten spectra obtained inside each area; thus for each SPG area,

the average spectrum obtained from BB measurements is given by:

$$S_{AVG} = \frac{1}{N} \sum_{i=1}^{10} S_i$$

(ii) linear mixing has been applied, after choosing three endmember spectra S_1 , S_2 and S_3 :

$$S_{mix} = c_1 \times S_1 + c_2 \times S_2 + c_3 \times S_3$$

with the condition that $c_1 + c_2 + c_3 = 1$. These three parameters are chosen in order to minimize the residue between S_{mix} and the spectrum obtained with SPG setup, for the corresponding area.

Results and discussion. In fig.2 the spectra acquired with SPG setup in 4 different areas of the volcanic sample FOR5 (from Sardinia) are presented, as an example. They are all characterized basically by Fe^{2+} - Fe^{3+} absorption at $0.9 \mu m$ (oxidation/weathering) and by the H_2O absorption at $1.9 \mu m$ [1].

In fig.3 the three endmembers spectra chosen from Ma_Miss BB measurements, corresponding to blue spectrum in fig.2, are showed. The spectral and mineralogical diversity, that can be measured with Ma_Miss instrument, is here evident.

We consider as endmembers S_1 , S_2 and S_3 , the spectra s-04, s-06 and s-10 of fig.3.

In fig.4 the spectrum S_{mix} relative to position B is presented. The green spectrum has been acquired with SPG setup. The blue spectrum is S_{mix} , obtained combining the three endmembers of fig.3. The residue between the two spectra is $R=2 \times 10^{-4}$; the parameters are $c_1=0.1$, $c_2=0.1$ and $c_3=0.8$. Thus the application of this method suggests us, for example, that about 80% of the analysed surface is given by the green component of fig.3.

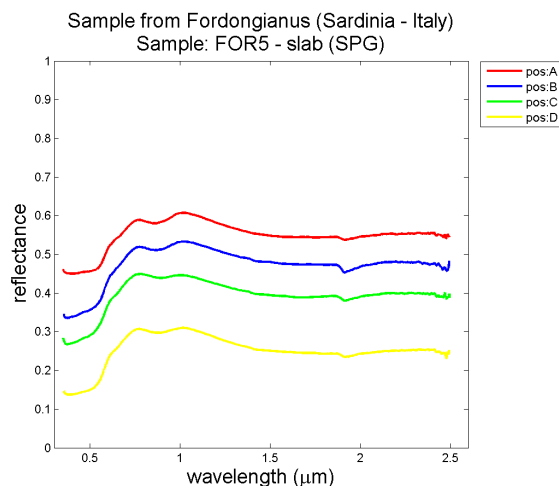


Fig.2: sample from Fordongianus (Sardinia): spectra acquired with SPG setup in 4 different positions.

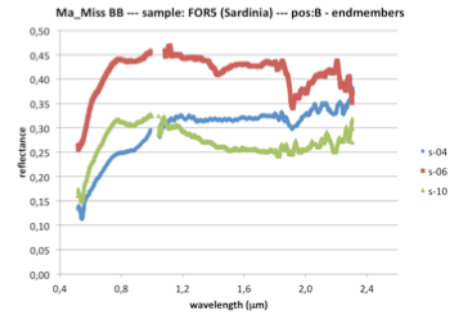


Fig.3: Ma_Miss BB endmembers spectra, relative to sample FOR5, position B.

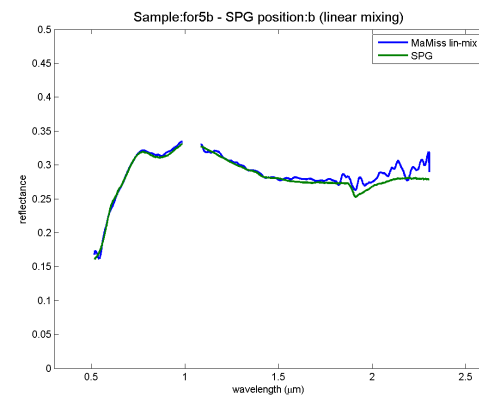


Fig.4: sample from Fordongianus (Sardinia), position B. The green spectrum has been acquired with SPG setup. The blue spectrum has been obtained applying linear mixing to three endmember spectra obtained with Ma_Miss BB setup.

Conclusions. Five samples (two carbonates and three volcanic rocks, all in form of slab) have been analysed with the Ma_Miss breadboard (BB) and a second laboratory setup (SPG). Higher spatial resolution spectra obtained with Ma_Miss BB ($120 \mu m$) have been combined using spectral linear mixing and then compared with lower resolution SPG spectra ($6 mm$) obtained in same areas. Ma_Miss instrument proves to have great capabilities to analyse rock surfaces, and to be useful in order to reveal the spectral and mineralogical heterogeneity of samples.

References. [1] Clark, R.N., Chapter 1, Volume 3, in Remote Sensing for the Earth Sciences, (Rencz, ed.) John Wiley & Sons, New York, 1999. [2] Coradini A., et al, Adv. Space Res., Vol.28, No.8, 2001. [3] De Angelis S., et al, Planetary and Space Science, 101, 89–107, 2014. [4] Coradini, A. et al, Asteroid, Comets, Meteors – IAU Symposium 229, Rio de Janeiro, 2005.

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