Analysis of rocks particulates by VNIR spectroscopy with Ma_Miss instrument breadboard.
S.De Angelis[1], M.C.De Sanctis[1], E.Ammannito[1], F.Altieri[1], C.Carli[1], A.Frigeri[1], A.Boccaccini[1], M.Giardino[1], [1]Space Astrophysics and Planetology Institute - INAF-IAPS, via Fosso del Cavaliere, 100 – 00133, 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 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 six particulate rock samples (two carbonates and four volcanic rocks) in nine different grain size intervals in the range <0.020–0.80 mm; all the samples have been previously characterized with the setup in use at S.LAB at IAPS-INAF, a spectro-goniometer, consisting of the FieldSpec coupled with a goniometer.

Instrument description. *Ma_Miss***:** the Mars Multispectral Imager for Subsurface Studies is a miniaturized Visible and Near-Infrared spectrometer [2], which will be completely integrated within the Drilling System of the ExoMars Pasteur Rover. It will acquire VNIR spectra from the borehole wall excavated by the drill in the Martian subsurface, at different depths down to 2 m. The spectral range is 0.4 – 2.2 μm, the spatial resolution is 120 μm, the spectral resolution is 20 nm. A 5 W lamp supplies the illumination; an optical fibres bundle carries the light from the lamp to the Optical Head, which has the double task of focusing the light on the observed target and of collecting the scattered light from the target. The illumination spot on the target is 1 mm in diameter, while the light is 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 has 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 of the instrument includes all the subsystems [fig.1]: 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°.

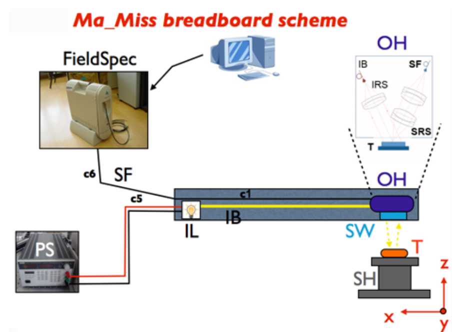

Fig.1: schematic picture of the Ma_Miss breadboard.

*S.LAB setup***:** all the analysed samples have been also characterized with the FieldSpec Pro in the spectro-goniometer configuration [3]. 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° and e=0° (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. Six rock samples have been analysed: a carbonate rock (red micritic limestone, Umbrian Apennines, Italy), a calcite sample (Lazio-Abruzzi Apennines), and four volcanic rocks: San Bartolo Lava (Stromboli, Aeolian Islands, Italy; basaltic andesite), a sample from Vulcanello (Vulcano, Aeolian Islands; vesiculed scoria, mugearite), a sample from ''La Sommata'' (Vulcano, Aeolian Islands; basalt) and a lava from Iceland (tholeiitic basalt). All six samples have been grinded in powders starting from representative rock portions; they've been separated in nine different grain sizes in the range d<0.02-0.80 mm.

Analytical approach. In this work we focused our attention on the continuum slope and the reflectance values of the spectra acquired with the Ma_Miss breadboard setup, and we compared them with the laboratory set-up data. *Continuum slope*: here we calculated the slope in three different ranges: a VIS-slope, in the range 0.5-0.8 μm, a NIR-slope, in the range

1.2-1.8 μm, and a VNIR-slope in the range 0.6 – 2.0 μm. *The reflectance value*: we evaluated in two distinct regions of the analysed spectra, at 0.8 μm and at 1.62 μm. In our work, the reflectance at 0.8 μm is coincident with the peak in the visible in almost all the spectra, while the reflectance at 1.62 μm is out from absorption bands. The analysis of the spectral parameters has been carried on with data from Spectro-goniometer and from Ma_Miss measurements. **Results and discussion**. The VIS-slope has been computed for each sample and for all the nine grain size intervals, and then plotted in function of the grain size. The classical correlation between the continuum slope and grain size has been observed with both setups: the slope clearly decreases with increasing grain size [1][7][8]. The only unexpected trend is the increasing of VIS-slope with increasing grain size for calcite sample, obtained with S.LAB set-up. The slope in the NIR region has also been plotted as a function of the size intervals. Although there is not a strictly monotone correlation, nevertheless we observe a trend: the slope definitely decreases with the grain size increase. Finally an analogous negative trend is observed if we plot the VNIR-slope versus the grain size. The reflectance at 0.8 μm (fig.2 top) and 1.62 μm has then been plotted in function of the grain size intervals; a definite trend of decreasing reflectance towards larger particles results for both carbonates and volcanic rocks; moreover the two types of rocks clearly cluster in two non-overlapping regions in the plot: the volcanic rocks occupy a lower reflectance area and the carbonates a higher reflectance area.

The plot in fig.2 (bottom) shows the correlations between the VNIR-slope and the reflectance at 1.62 μm; each sample shows a clear trend of increasing slope with reflectance.

Then we compared *the spectral parameters determined with the two experimental setups*. The spectral parameters derived from Ma_Miss breadboard measurements (fig.2) show a general behaviour that is consistent with the trends observed from S.LAB measurements (not shown here). The reflectance values derived with the two setups are very similar. The trends relative to the slopes are more irregular, even if there is a general decreasing with increasing of the grain size, as expected. The differences observed in the continuum slopes as seen by the two instruments can be justified taking into account the different spatial resolutions, viewing geometries [1][5][6], the angular diameter of the source as seen by the target, and the ratio between the instrument spatial spot and the grain size. The phase angle is 30° in the case of the spectro-goniometer setup, while in the case of Ma_Miss layout the phase angle is 0°; in this geometrical condition the opposition effect [4][5] becomes relevant. Regarding the source angle, in the case of the spectro-goniometer the angle is <1°; in the case of Ma_Miss the angular diameter of the source is about 124°. Finally the two instruments have spatial resolutions very different (6 mm (spectro-goniometer) versus 0.1 mm (Ma_Miss)).

Conclusions. Six samples (two carbonates and four volcanic rocks) have been analysed here with the Ma_Miss breadboard. The analyses of two spectral parameters (the continuum slope in the VIS, NIR and VNIR range, and the reflectance in the VIS and NIR) in function of the grain size show that the trends observed with Ma_Miss are consistent with the ones obtained with the Spectro-goniometer set-up; all trends obtained with Ma_Miss show an expected behaviour: the continuum slope (VIS, NIR and VNIR) decreases with increasing grain size, gradually shifting from positive values (red slope), for fine grain sizes, towards negative values (blue slope), for grains with diameter >0.2-0.5 mm. The VIS-slope of a sample (JOR1) shows an unexpected behaviour: the slope increases with increasing grain size. Concerning the reflectance (at 0.8 μm and 1.62 μm) the trends obtained with the two instruments are mutually consistent. Thus putting together the information obtained from the analyses of the continuum slope and the reflectance level will be possible to gain information about the grain size of the observed material. The Ma_Miss instrument will provide an essential contribution to the ExoMars mission with the investigation of the Martian subsurface materials.

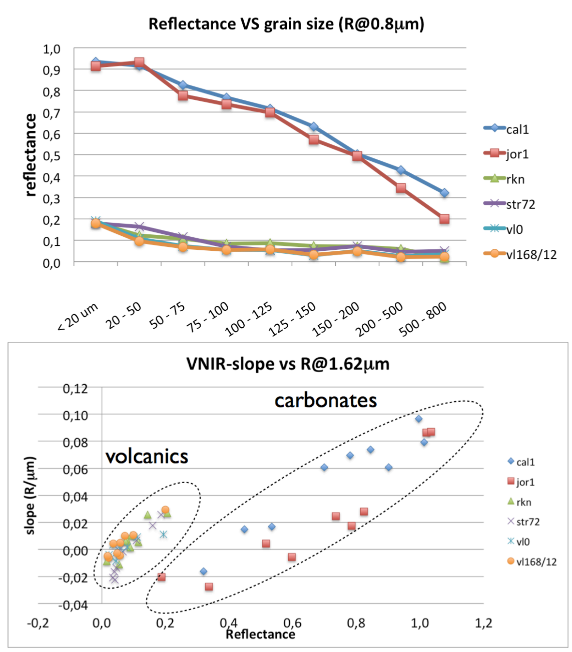

Fig.2: (top) reflectance (0.8μm) vs grain size; (bottom) VNIR-slope vs. NIR-reflectance (Ma_Miss BB).

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] Coradini, A. et al, Asteroid, Comets, Meteors – IAU Symposium 229, Rio de Janeiro, 2005. [4] Hapke B., JGR, vol. 68, n.15, 1963. [5] Hapke, B., JGR, vol. 86, n. B4, 1981 (a). [6] Hapke, B., JGR, vol. 86, n. B4, 1981 (b). [7] J. Harloff, G. Arnold, Planet Sp Sci, Vol.49, Iss.2, 2001, [8] Hunt G.R., Geophysics, Vol.42, No.3, pp. 501-513, 1977.

Acknowledgements. ASI, INGV (Aeolian Samples), Selex ES (BB design and manufacturing)