Hyperspectral micro-imaging of Martian Shergottite Northwest Africa 8657 fragment in the Visible-Infrared range.

S.De Angelis[1], P.Manzari[1], M.C.De Sanctis[1], E.Ammannito[1,2], T.Di Iorio[1,3] . [1]Istituto di Astrofisica e Planetologia Spaziali, INAF-IAPS, via Fosso del Cavaliere, 100 – 00133, Roma, Italy; [2]University of California Los Angeles, Earth Planetary and Space Sciences, Los Angeles, CA-90095, USA; [3]ENEA SSPT-PROTER-OAC, Roma, Italy. (simone.deangelis@iaps.inaf.it)

Introduction. Analysis of extra-terrestrial samples by means of hyperspectral imaging is a powerful tool to investigate with great detail rock surfaces, combining high spectral resolution and imaging at >10-μm spatial scale. Laboratory investigation of Martian meteorites in the VIS-IR spectral range (0.2-5.1 μm) is useful in supporting remote-sensed observations of Mars, and thus to gain information about surface composition and processes.

In this study laboratory investigation has been carried out on a fragment of Martian meteorite Northwest Africa 8657, classified as Shergottite [1].

Instrument setup. Analyses have been carried out with the Spectral Imaging (SPIM) facility at INAF-IAPS, Rome [2,3].

The imaging spectrometer installed in SPIM is a spare of the spectrometer on Dawn spacecraft [4]. It works in the 0.22-5.05 μm spectral range, with a spatial resolution of 38x38 μm on the target. Two bidimensional focal plane arrays, one for the visible between 0.22 and 1.05 μm (spectral resolution of 2 nm) and one for the IR between 0.95 and 5.05 μm (spectral resolution of 12 nm) allow to obtaining the spectral coverage. Thanks to the alignment of the bidimensional focal planes with the spectrometer' slit axis (the slit is 9x0.038 mm in size), it is possible to acquire the target's image of 0.038x9 mm at different wavelengths. The spectrometer and the IR detector are cooled at 130K and 80K, respectively, in order to reduce the background noise due to thermal emission. The spectrometer is installed inside a thermo vacuum chamber (TVC) cooled with liquid nitrogen in order to avoid vapour condensation. The optical layout of the spectrometer is based on an Offner configuration. Hyper-spectral cubes are built up observing the target moving on a scanning sample holder. Two lamps provide the light sources for the VIS channel (120 W) and the IR channel (108 W). The illuminating system supports two distinct optical fibres for the VIS and IR channel; the illumination and emission angles are 30° and 0° with respect to the normal to the sample surface, respectively.

Sample description. The analysed meteorite fragment (Northwest Africa 8657 - NWA 8657) is about 4x10 mm^2 in size, with a thickness of about 2 mm. By taking 100 acquisitions, we scanned a surface area of approximately 3.8x9 mm^2. In fig.1 an RGB colour image of the scan is shown (R:0.70 μm, G:0.53 μm, B:0.44 μm). According to Meteoritical Bullettin classification [1] this Shergottite has a diabasic texture, and is mainly constituted by clinopyroxene and plagioclase (maskelynite) laths, with accessory phases ilmenite, ulvospinel, pyrrhotite, merrillite, chlorapatite and vesicular glass. Geochemically the meteorite is composed by subcalcic augite ($Fs_{20.8-21.8}Wo_{36.4-34.1}$), ferroan subcalcic augite ($Fs_{39.1}Wo_{30.7}$), pigeonite ($Fs_{33.7-53.1}Wo_{11.8-11.6}$), ferropigeonite rims ($Fs_{65.1-67.1}Wo_{18.7-14.4}$), ferrosilite ($Fs_{75.4}Wo_{2.0}$), plagioclase (maskelynite, $An_{42.3-45.3}Or_{2.8-2.7}$), anorthoclase ($An_{33.4}Or_{15.0}$) [1].

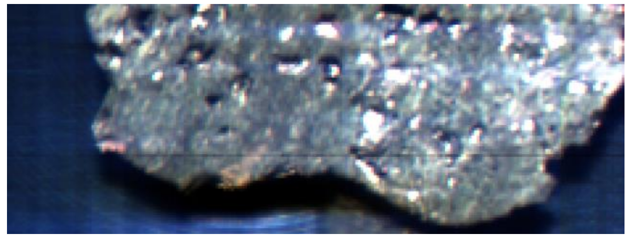

Fig.1. RGB image acquired with SPIM on the meteorite fragment (R:0.70 μm, G:0.53 μm, B:0.44 μm).

Analysis and results. Seven different spectral classes have been identified in the scan image: these have been used as endmember spectra for supervised classification with the Spectral Angle Mapper (ENVI-SAM) tool. Measured spectra chosen as endmember are shown in fig.2 (VNIR range 0.4-2.5 μm) and fig.3 (IR range 2.5-5.0 μm). Because a greater spectral variability is observed approximately in the VNIR range, only the 0.4-3-μm spectral subset has been used in order to apply SAM classification. Spectral classes have been identified as (i) pyroxene (pigeonite), (ii) plagioclase (anorthitic), (iii) chromite, (iv) plagioclase (maskelynite), (v) pyroxene (augite), (vi) rutile and (vii) iron-titanium oxide (ilmenite) (fig.2).

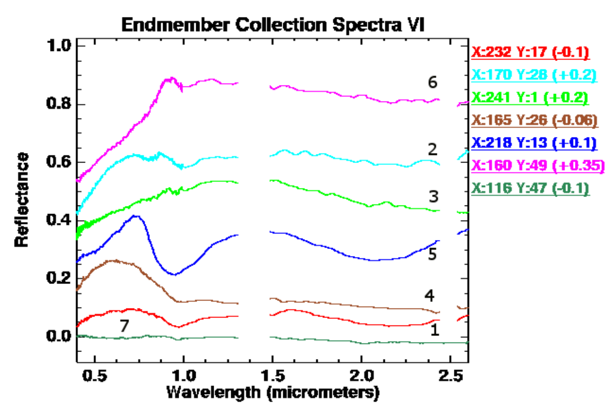

Fig.2. Endmember spectra selected for SAM classification, VNIR range 0.4-2.5 μm. Spectra are numbered according to the seven classes of fig.4 (shifted in reflectance for clarity). Data at 1.4 and 2.5 μm have been cancelled because of overlapping with instrumental artifacts.

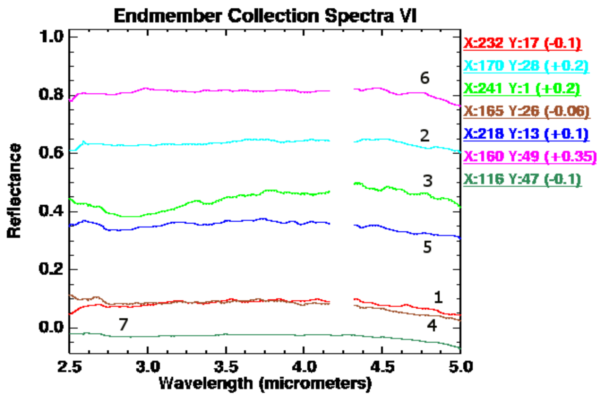

Fig.3. Endmember spectra selected for SAM classification, IR range 2.5-5.0 μm. Spectra are numbered according to the seven classes of fig.4 (shifted in reflectance for clarity).

In fig.4A library spectra (USGS) are shown for comparison. In fig.4B and 4C spectra from selected pixels are compared with library maskelynite (RELAB). Library spectra of maskelynite containing few percents of pyroxene (fig.4B, blue and green lines) show more or less weak Fe^{2+} absorptions at 1 μm and 2 μm. Measured spectra (red and cyan lines) also show very weak similar absorptions. Differences in the slope must be attributed to differences in both instruments and sample grain sizes. In fig.4C the library spectrum of maskelynite (blue line) is very similar to a mixture containing (measured) plagioclase (70%) and ilmenite (30%). Areal distributions of the spectral classes overlaid on the meteorite surface are shown in fig.5. The major part of the surface is constituted by the phases identified as plagioclase maskelynite (class 4) and iron oxide (class 7). The bright grains are identified as plagioclase phase (class 2), perhaps with more anorthitic composition.

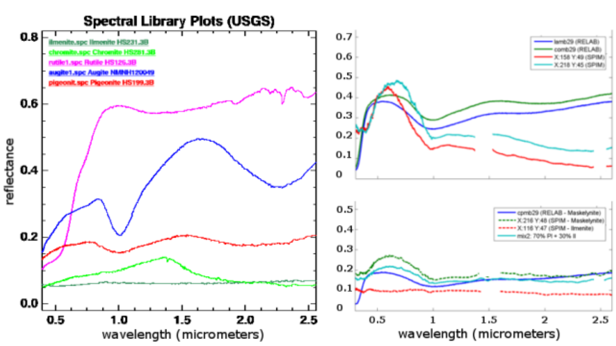

Fig.4. Endmember spectra selected from USGS library (A) and RELAB database (B,C) for comparison. Plagioclase (maskelynite) is identified in numerous grains.

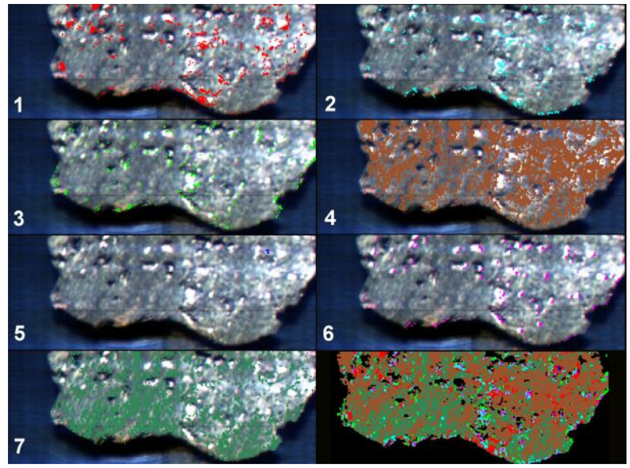

Fig.5. Spectral classes distribution obtained using ENVI Spectral Angle Mapper (SAM) classification. Classes from 1 to 7 are shown. In the last box, all classes are overlaid on the RGB scan image of the meteorite.

Few isolate grains (not included in the classification) have been identified containing hydrous phases, as revealed by the broad H_2O absorption band at 3 μm, and carbonaceous matter, as revealed by numerous features occurring in the 3.1-4.8-μm region (fig.6).

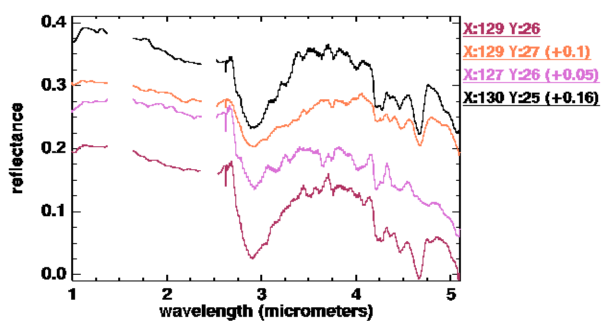

Fig.6. Spectra characterized by hydrous and carbonaceous phases.

Conclusions and future work. The detailed investigation by means of hyperspectral micro-imaging is a powerful tool to study in depth rocks and meteorites. The mineralogical composition of Martian Shergottite NWA 8657 has been retrieved at a few tens of microns-scale. Further detailed analyses is ongoing on this sample and on other meteorites.

References. [1] Meteoritical Bullettin, n.103, 2014. [2] Coradini A., et al., EPSC Abstracts, EPSC-DPS2011-1043, vol.6, 2001. [3] De Angelis S., et al., Rev. Sci. Instrum., 86, 093101, 2015. [4] De Sanctis M.C., et al., Space Sci. Rev., 163, 329-369, 2011.

Acknowledgements. We thanks ASI – Italian Space Agency for supporting this work.