SPECTRAL CHARACTERIZATION OF NORTHWEST AFRICA 12184 METEORITE: FT-IR AND μ-IR INVESTIGATION AS PART OF SIMULATION OF SPACE WEATHERING ON AIRLESS BODIES OF SOLAR SYSTEM. A. Galiano[1], F. Dirri[1], M. Ferrari[1], S. Stefani[1], G. Piccioni[1], M.E. Palumbo[2], C. Scirè Scappuzzo[2], G. Baratta[2], C. Carli[1], A. Musolino[1,3], [1]INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy (anna.galiano@inaf.it), [2]OACT-INAF, Osservatorio Astrofisico di Catania, Italy, [3]Università di Napoli "Parthenope", DIST, Centro Direzionale Isola C4, I-80143 Naples, Italy.

Introduction: Airless planetary bodies of the Solar System are exposed to constant space weathering processes, such as solar wind irradiation and micrometeoritic impacts, resulting in an alteration of spectral properties of surface materials. Ion bombardment experiments performed on carbonaceous chondrites (CC) meteorites to simulate solar wind irradiations produced a spectral darkening and reddening or a spectral brightening and bluing depending on the meteorites types [1,2].

We plan to observe spectral variations caused by ion irradiation on airless bodies of the Solar System such as the Near-Earth Asteroid 162173 Ryugu (1999 JU3). To obtain this, we will perform an ion irradiation process on meteorite samples spectrally similar to Ryugu, such as CI and CM carbonaceous chondrites, containing phyllosilicates and organics [3,4,5].

In this work, we spectrally characterized the Northwest Africa 12184 (NWA 12184), a CM2 meteorite, at a high spatial resolution to have mineralogical information of both matrix and chondrules, whose spectral variations will be observed after the ion irradiation process planned in the future.

The Hayabusa2 mission: The JAXA Hayabusa2 mission investigated Ryugu from June 2018 to November 2019. Images acquired by ONC (Optical Navigation Camera) revealed a dark top-shaped asteroid, with a round shape and an equatorial ridge [4]. The low bulk density (1.19±0.02 g/cm3) suggests that Ryugu is a rubble pile object likely formed from the reaccumulation of fragments generated by a catastrophic disruption of its parent body [3]. The data acquired by NIRS3 (Near-Infrared Spectrometer) spectrometer revealed a dark surface with reflectance at 2.0 μm of 0.017 [5], a positive spectral slope, and the occurrence of a weak absorption band at 2.7 μm, related to the symmetric stretching of the hydroxyl group (OH) [5]. The Ryugu surface shows a variation of NIRS3 spectral slope in the 1.9-2.5 μm range, suggested to be the result of space weathering processes [6].

On 2018 October 3, the lander MASCOT was released by Hayabusa2 on the Ryugu surface, and the images of the rocks acquired by MASCam in the visible-to-near-infrared range revealed bright multicolor inclusions (most of them smaller than 1 mm and several with a dimension of millimeters across). The dimension of inclusions is like the calcium- and aluminum-rich inclusions (CAIs) present in some carbonaceous chondrites and other refractory inclusions observed in CI2 (Tagish Lake), CM, CO, and CV groups. [7] MASCAm did not reveal fine materials on boulders, which should be present on Ryugu for the exposure to space environment: dust particles are probably removed, either lost to space or entrapped in the porous interior [7].

Meteorite sample: NWA 12184 is a CM2 carbonaceous chondrite, collected in Algeria in 2018. It experienced a low degree of weathering [8], making it a good sample to be processed and to study spectral variations produced by processes simulating space weathering. The meteorite shows an Fe-rich matrix also composed of Ca-carbonates, sulfides, and phyllosilicates with chondrules of a 0.3 mm mean diameter. The meteorite shows chondrule pseudomorphs, CAIs, and mineral fragments set in a Fe-rich matrix [8].

Procedure description: NWA 12184 was purchased from an authorized seller as a solid sample with dimensions of 24.5 x 17.6 mm (and 1.9 mm thick). The sample's dimensions are too large for the setup that will be used for the future ion irradiation experiment, therefore we obtained a small section of the meteorite with dimensions of 14x20 mm. The "dry-cut" of meteorite was performed with a blade of 600 μm thick at "Laboratorio Sezione Sottili del Dipartimento di Scienze della Terra", University of La Sapienza, Rome.

For the characterization of the meteorite slab in the infrared range, we performed FT-IR analyses by using a Fourier transform interferometer (mod. Bruker Vertex 80) operating in the range from 1.7 to 15 μm with the MCT detector, using an incidence angle (i) of 30° and an emission angle (e) of 0°. We first acquired a bulk spectrum of the sample from a representative area of 1 cm^2 containing several chondrules embedded in the matrix. Then, in the same region, we defined a grid of 800x800 μm (Fig.1) and collected 180 spectra with a spot of 60x60 μm using an IR microscope (mod. Bruker Hyperion 3000) connected to the Vertex 80 interferometer.

Results: The spectrum of NWA 12184 obtained from a spot of 1 cm was smoothed with a Savitsky-Golay filter on 41 channels to reduce oscillations in the signal. The reflectance at 2.0 μm of the meteorite is 0.06, about 3.5 times brighter than Ryugu, whereas the spectral slope in the 1.9-2.5 μm range is flat. A broad band at about 3 µm is also present, suggesting hydration of the sample [9], in addition to a peak at 11.34 µm.

The area of NWA 12184 in the 800x800 µm grid is shown in figure 1: it includes 3 chondrules, which we term Chondrule1 (C1), Chondrule2 (C2), and Chondrule3 (C3), and the matrix. The scaled mean spectra of C1 (red), C2 (green), C3 (blue), and matrix (black) are in Figure 2, where also the spectrum of forsterite (violet) and enstatite (yellow) are shown for comparison.

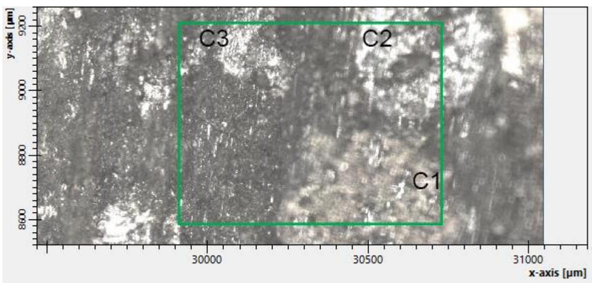

Fig. 1: Area of NWA 12184 spectrally investigated and whose µ-IR spectra were acquired with a spot of 60x60 µm.

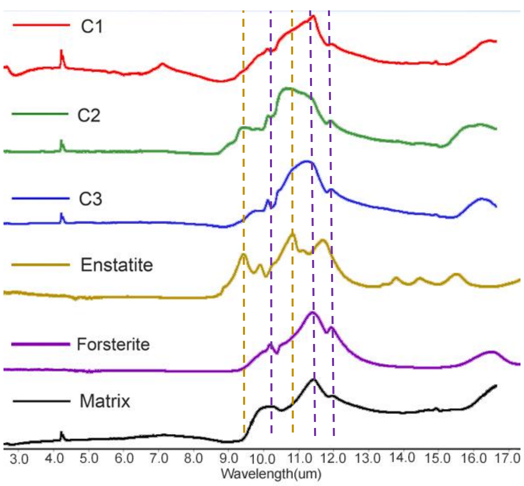

Fig. 2: Mean spectra of matrix and analyzed chondrules of NWA 12184 compared with laboratory spectra of solid enstatite and forsterite.

Chondrules and Matrix have absorption bands at about 2.7 µm (suggesting the occurrence of phyllosilicates) and 3 µm (related to hydration): the depth of 2.7 µm band is 6% for C2 and C3 and about 2% for C1 and Matrix; the depth of 3.0-µm band is 23% in the case of C1 and about of 11% for C2, C3 and Matrix. The mean spectrum of the matrix shows a spectral reddening in the 3.0-7.0 µm range that lacks in the mean spectra of chondrules.

The main Reststrahlen peak (RP) occurs at 11.4 µm for C1 and Matrix, at 11.2 µm for C3 and 10.7 µm for C2: the peak of C1 and Matrix can be ascribed to forsterite (Fig. 2), whereas the shift of the RP for C2 suggests a contribution of a different mineral. Furthermore, the analyzed chondrules and matrix show a minor peak at 11.9 µm ascribed to forsterite, too while spectral similarities with enstatite are observed in chondrules C2 (i.e., peaks at 9.5 µm and 9.8 µm) and C3 (for the shoulder at 10.8 µm). By preliminary analysis, the chondrules and matrix probably contain olivine (with a different Mg/Fe ratio) since the position of CF in olivine spectra is strongly dependent on its chemistry [10] and in support of the analysis, the calculated Christiansen Feature (CF) of C1, C2, C3, and Matrix are 8.8, 8.5, 8.9, 9.0 µm, respectively.

Future experiments: We plan to characterize the NWA 12184 meteorite also through Raman microspectroscopy to make compositional maps with a spatial resolution of fewer than 30 microns.

Later, we will perform an ion irradiation process on the selected area of the meteorite at INAF-OACT in Catania, Italy, by exposing the sample to a flux of 200 keV He^+ ions. After the irradiation, we will repeat the acquisition of FT-IR, µ-IR, and µ-Raman spectra of the sample and we will investigate spectral variations. We expect that because of the ion irradiation experiment, the IR spectra of the meteorite will result in a darkening and reddening. Furthermore, the effects of irradiation on the IR spectral features will be also investigated, as well as the variation of mineralogy will be inferred by the Raman spectra.

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