MOON SPACE WEATHERING INTEGRATED ANALYSIS.

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Introduction: Planetary airless bodies continuously undergo exposure to the space environment. Micrometeorite bombardment, diurnal thermal cycling, and ion implantation due to solar wind, collectively known as space weathering, irreversibly affect the chemical and physical properties of an airless planetary surface over time. On the Moon, the spectral effects of space weathering are threefold: as the lunar surface matures, it becomes darker (the albedo decreases), redder (reflectance increases with increasing wavelength), and the depth of diagnostic absorption bands as observed in the near-infrared reflectance spectrum attenuates [1, 2]. Here we show the integrated analysis between multi- and hyperspectral datasets acquired by remote sensing instruments onboard different space missions (e.g. Clementine and Chandrayaan-1) and laboratory irradiation experiments of lunar analogues. For this work, we exploit the expertice gained by three different projects: 1) "Deciphering compositional processes in inner airless bodies of our Solar System", selected in the framework of the ISSI-call for proposal 2019, 2) "Moon multisEnsor and LabOratory Data analYsis (MELODY)" project selected in 2020 within the PRIN INAF 2019 (RIC) call, 3) Moon Space Weathering Analysis (MoonSWA), belonging to the "Ricerca Fondamentale INAF 2023" program.

Space weathering on the Moon: The lunar surface is composed by different mafic minerals, such as pyroxenes and olivine, at specific locations. In particular the near infrared reflectance spectra of the Moon are characterized by two absorption bands centered at about 1 μm and 2 μm, linked with the presence of pyroxenes. The absorption bands and their shape are due to the relative proportion of Fe^{2+}, Ca^{2+}, and Mg^{2+} in the M1 and M2 sites of the pyroxene and olivine crystal structures, or in glass material [3]. Space weathering effects dominate the lunar surface due to impacts (shock, vaporization, fragmentation, heating, melting, and ejecta formation), radiation damage and sputtering (due to cosmic rays or solar wind), diurnal thermal cycling, and ion implantation. These phenomena generate the formation of nanophase iron particles (npFe0) in both the agglutinates and in the accreted rims on individual grains [1, 2], causing the spectral reddening and the reduction of the band depths [2]. The darkening effects of space weathering on the Moon can be evidenced by the fact that young, fresh craters have bright ray systems of fresh, unweathered material, but those rays darken and eventually disappear over time. Furthermore, the flux and the energy of the protons hitting the Moon surface are influenced by tidal locking of the Moon and the existence of the Earth's magnetosphere, deflecting the flow of the solar wind and producing non-isotropic space weathering effects [4].

Method: For this work, we propose a threefold approach to study the space weathering effects on the lunar surface: 1) spectral analysis of different regions of interest through public multi- and hyperspectral datasets and high level products, 2) irradiation experiments on lunar regolith simulants and analogues to reproduce different space weathering conditions, acquired during the MELODY project 3) Integrated analysis between remote sensing data products and laboratory irradiated samples.

The laboratory irradiation experiments will be performed at the IAS Orsay laboratory considering different ions, energies and fluences. This work is also in support of the LUMIO mission, which will monitor the flashes caused by the impact of meteorites in the lunar farside.

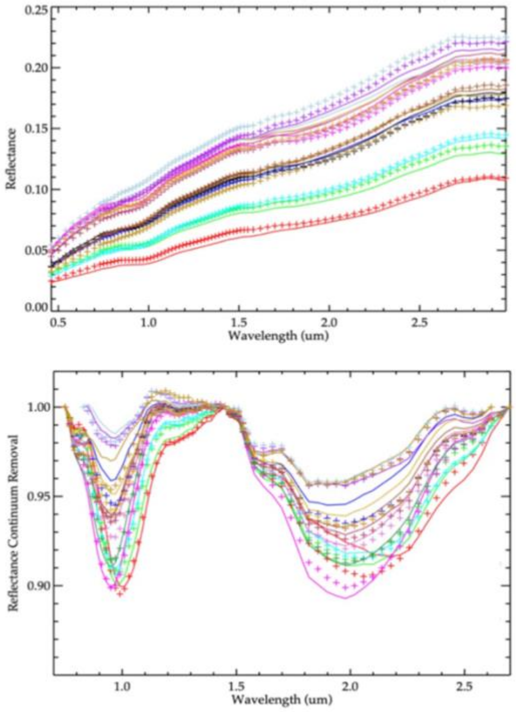

Figure 1: Examples of lunar spectra relative to different type of terrains.

Acknowledgements: This work is supported by the following projects: 1) the International Space Science Institute (ISSI) - Bern (Switzerland), project n°485, "Deciphering compositional processes in inner airless bodies of our Solar System" selected in the framework of the ISSI- call for proposal 2019, 2) the “Moon Space Weathering Analysis (MoonSWA)”, within the “Ricerca Fondamentale INAF 2023” program, 3) the “MELODY” project selected in 2020 in the framework of the PRIN INAF 2019 (RIC) call, 4) the ESA/Lunar Meteoroid Impacts Observer (LUMIO) mission.

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