COMPARISON OF LASER SPACE WEATHERING FLUX ON THE SPECTRAL CHANGES OF OLIVINE. Matthew M. Markley (markley@higp.hawaii.edu)[1], Jeffrey J. Gillis-Davis[1], and John P. Bradley[2]. [1]Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i – Mānoa, 1680 East-West Road, Honolulu, HI, 96822, USA. [2]Institute of Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA, 94550, USA.

Introduction: Space weathering is a term applied for the darkening, reddening, and reduction in absorption band depths in the optical reflectance spectra of planetary surface minerals [1]. The ascribed changes are due to micrometeorite impacts and electromagnetic radiation occurring on all airless bodies in the Solar System [2].

Micrometeorite impacts produce physical products within planetary surface grains, namely submicroscopic metallic iron (SMFe) [3]. The variations in sizes and populations of micrometeorite-derived SMFe are thought to differ as a function of impact energy and flux [4]. As a result, the process and products of space weathering could be fundamentally different from Mercury to the Asteroid Belt [5–7].

Our proposed experimental setup is designed to examine whether a link between SMFe size/population and resulting spectral changes are controlled by different fluxes of simulated micrometeorite impacts. Our pulsed laser irradiation laboratory, will examine whether differing simulated impact fluxes will produce different morphologies/populations of SMFe. These differences are, for this abstract, measured through the spectral variations of our olivine samples.

Methods: In this work, we first simulated lunar space weathering with a laser flux corresponding to 90 J/mm^2/Mya (This equates to 2.5 minutes of irradiation, initially set to match calculations on sample volume and energy output,see the Discussion for more details). We acquired spectra after each irradiation, up to 810 J/mm^2/Mya. In the future once a set of lunar-simulated space weathering spectra is recreated, we would then investigate fluxes at other solar distances. For Mercury and the Asteroid Belt, we would only increase or decrease laser flux to match the micrometeorite flux near these solar distances. We would then compare those sets of spectral characteristics to the lunar case.

The experimental setup at the University of Hawai‘i at Mānoa is similar to [8] (Fig. 1). Space weathering simulation was achieved using a Continuum Surelite SL-I20 Nd:YAG pulsed laser with a fundamental wavelength of 1064 nm and frequency of 20 Hz. Pulse duration is 5-7 ns, which is comparable to the timescale of micrometeorite impacts [9]. The samples were irradiated with a pulse energy of 30 mJ to ensure vaporization [10]. The beam was rastered across the sample to ensure even weathering. All samples were irradiated from 2.5 minutes (or 90 J/mm^2/Mya) up to 22.5 minutes (or ~810 J/mm^2/Mya [8]). All irradiation is done under a vacuum of $2\text{-}3 \times 10^6$ torr with a Pfeiffer Hi-cube dry roughing and turbo pump.

The samples for this project were natural olivine (Fo-93). Olivine was chosen because it is a common forming mineral in the Solar System (next to plagioclase and pyroxene [11]). The olivine was powdered and sieved to 45-53 µm to simulate the mean-grain size of the lunar regolith [12]. For each experiment, 2g of unpacked olivine powder was used, unlike previous experiments which pressed the powder [8,13].

Reflectance spectra of the sample were taken before and after irradiation and at ambient atmosphere and under vacuum (Fig 1c). We measured spectral reflectance from 0.35 to 2.5 µm with an Analytical Spectral Devices Inc. (ASD) FieldSpec FR spectrometer. We used an observational geometry with an incidence angle of 0°, and an emission angle of 40°. Reflectance is measured relative to a spectralon standard (99%).

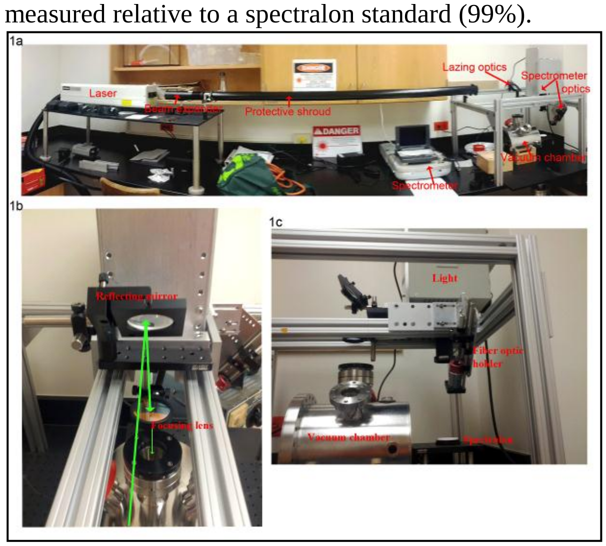


Fig. 1. (a) Overal lab configuration highlighting main components. **(b)** Downrange view of lazing optics components **(c)** Side view of spectrometer optics while in lazing position.

SMFe characterization [14] will be done in the future using TEM bright field contrast image data. This information will be compared with spectral data in order to correlate spectra with SMFE physical properties.

Discussion: The approximation of the laser flux requires knowledge of interplanetary dust flux and equating them to some amount of laser energy and flux. [8] compared the energy and frequency of their laser pulses with spacecraft data [15] on fluxes and median sizes of dust impactors in the inner Solar System [15,16]. They also calculated a timescale of space weathering done by their experiment. They proposed their laser energy and flux could produce a few Mya's of space weathering on a sample.

Similarly, we can calculate how much flux our laser has performed for a given solar distance. Taking the flux from [15], we can convert these to an impact rate (Eq. 1).

Incorporating the kinetic energy of a micrometeorite impact at each solar distance from [15], we can find the total energy deposition rate or the flux (Eq. 2).

Converting the total energy deposition rate to our 1 mm beam spot size, we can also effectively find how many years of space weathering occurs from the deposited laser energy (Table 1 [15]).

$$Impact\ rate = \frac{impacts}{m^2\ year} \quad \textbf{(Eq. 1)}$$

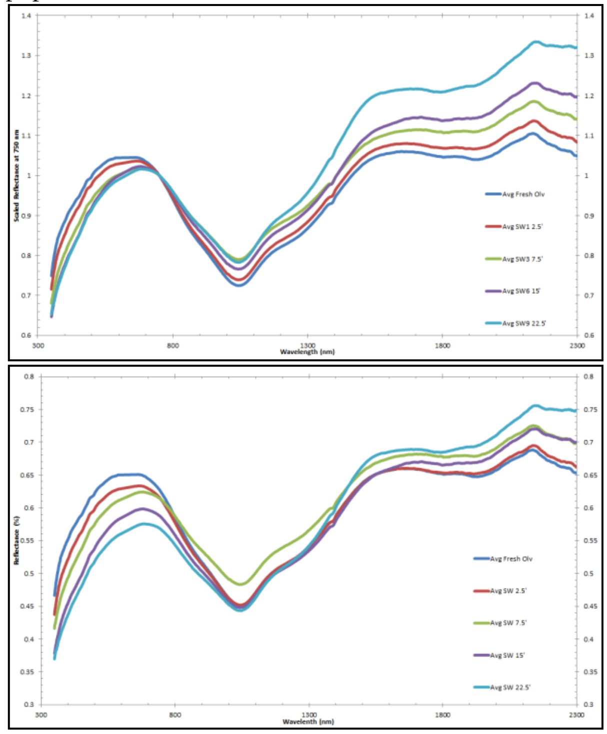
$$Total\ energy\ deposition\ Rate = \frac{Cumulative\ \ J}{m^2\ year} \quad \textbf{(Eq. 2)}$$

Table 1.

Solar Distance (AU)	**Impact Rate** (impacts/m^{2}s), (impacts/m^{2}yr)	**Mass** (g)	**Velocity** (km/s)	**KE** (J)	**Total Energy Deposition Rate** (J/mm^2 yr)
0.4	0.000844, 26634.0455	1E^{-6}	20	0.2	5.33E-03
1	0.0001, 3155.7	1E^{-6}	12	0.072	2.27E-04
2.7	0.0000028, 88.36	1E^{-6}	5	0.0125	1.10E-06

Results: Shown in Figs. 2 and 3 are the obtained Vis-NIR reflectance spectra of fresh and space weathered olivine in the lunar space weathering flux regime. In the absolute reflectance spectra, darkening, reddening, and absorption band loss is more clear between the fresh and first space weathering flux than in the others. The scaled reflectance spectra reveal these features more readily through increasing fluxes. These differences between the two plots are most likely due to saturation of space weathering effects.

Conclusions: Using olivine, we performed pulse laser irradiation to examine varied spectral effects as a function of different space weathering regime. The variations between fresh and lunar space weathered olivine is most evident in the reduction in albedo and increased reddening. Similar to [17], we infer from the spectral reddening that we produced SMFe sizes and populations similar to lunar soils.



Figs. 2&3. Absolute and scaled VNIR reflectance spectra.

Future Work: Our future experiments include varying the laser energy in order to reproduce the range of impact energies from Mercury to the asteroid belt (Table 1). In addition, TEM imaging and analyses will be used to quantify the physical property difference in SMFe as a function of micrometeorite flux and energy.

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