SIMULATING PROGRESSIVE SPACE WEATHERING OF A CARBONACEOUS CHONDRITE VIA PULSED LASER IRRADIATION. M. S. Thompson[1], M. J. Loeffler[2], R. V. Morris[1], S. J. Clemett[3], and R. Christoffersen[3], D. G. Agresti[4], and L. P. Keller[1]. [1]ARES, NASA Johnson Space Center, Houston, TX 77058, [2]Northern Arizona University, Department of Physics and Astronomy, Flagstaff, AZ 86011, [3]Jacobs, NASA Johnson Space Center, Mail Code XI3, Houston, TX 77058, [4]University of Alabama at Birmingham, Department of Physics, Birmingham, AL 35294, michelle.s.thompson@nasa.gov.

Introduction: Grains on the surfaces of airless bodies experience space weathering, a process driven by solar wind irradiation and micrometeorite impacts [1], which alters their chemical composition, microstructure, and spectral properties. Micrometeorite impacts impart these changes through melting, vaporization, and recondensation processes. While much work has been done to understand the effects of space weathering of lunar and ordinary chondritic materials, the effects of these processes on hydrated carbonaceous chondrites are not well-constrained. Consequently, analyses of the space weathering of carbonaceous materials is important for understanding both remote sensing observations made during asteroid encounters, and for investigations of the nature of returned samples from ongoing and potential future missions targeting primitive, organic-rich bodies (e.g., OSIRIS-REx and Hayabusa2, and the proposed CAESAR mission).

Recent work has shown that the spectral properties of carbonaceous materials and associated minerals are altered by simulated weathering events, (e.g., [2-6]). However, the resulting spectral characteristics of weathered samples are not consistent across all experiments. In addition, there is significant work to be done to characterize the microstructural and chemical effects of these experimental samples in order to correlate mineralogical changes with observed spectral characteristics. Similarly, our understanding of the compositional and microstructural effects of progressive space weathering, which simulates a range of surface exposure timescales, is at an early stage. Finally, the effect that space weathering has on the organic components of carbonaceous materials is relatively unknown. Here we report results of three pulsed laser irradiation experiments on chips of Murchison (CM2) to simulate varying exposure timescales on airless surfaces.

Samples and Methods: We performed pulsed laser experiments by rastering a pulsed Nd-YAG laser (λ 1064 nm, ~6 ns pulse duration) under vacuum over each sample. For three individual samples, we rastered the laser 1, 3 and 5 times (1x, 3x, and 5x) over a dry-cut surface at an energy of 48 mJ/pulse, similar to [3]. Reflectance spectra were obtained relative to a 99% Spectralon standard and converted to absolute reflectance using an ASD FieldSpec 3 Spectrometer (0.35–2.5 μm) configured with the Muglight probe. The field of view (~ 1 cm dia.) is larger than the lasered surface (~0.5 cm square) so that small contributions from unaltered surfaces are likely. Organic functional group chemical analysis for altered and unaltered surfaces were performed on the 1x slab by the μL^{2}MS instrument at NASA JSC using two photoionization laser wavelengths, 266 nm for aromatics and 118 nm for overall organic characterization [7]. Detailed characterization of the lasered chips by scanning electron microscopy and transmission electron microscopy are underway in order to determine the morphological, chemical, and microstructural changes that occur with progressive irradiation.

Results from Spectral Analysis: VIS-NIR spectra show that the overall brightness of the spectra increases with increasing laser irradiation (Fig. 1a). There is a progressive weakening of the 0.7 μm band (associated with Fe^{2+} to Fe^{3+} charge transfer in phyllosilicates) with increasing number of laser rasters (Fig. 1b), similar to the observations of [3]. The depth of the absorption band at ~0.48 μm increases between the 1x and 3x

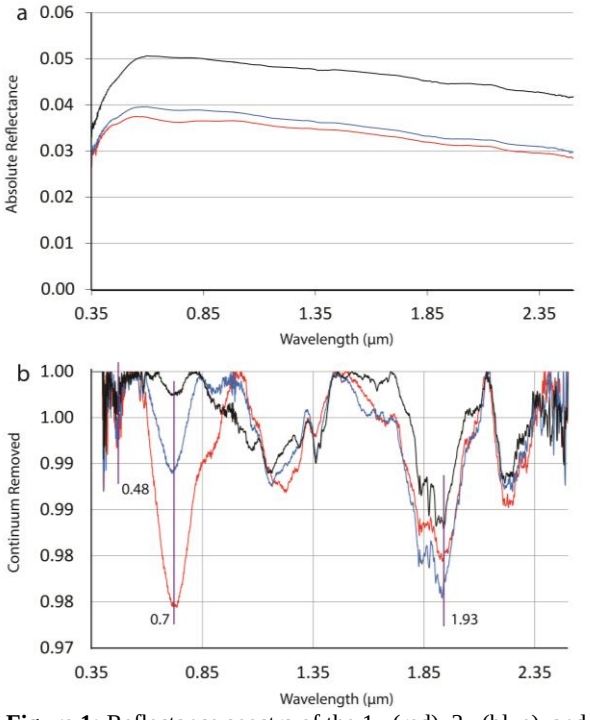

Figure 1: Reflectance spectra of the 1x (red), 3x (blue), and 5x (black) lasered samples showing, a) Absolute reflectance, b) Continuum removed reflectance showing changing strengths of the 0.48, 0.7 and 1.93 μm absorption bands.

rastered samples, and then decreases to a minimum with the 5x rastered sample (Fig. 1b). A similar trend is observed in the strength of the 1.93 µm band (OH-H_2O), increasing between 1x and 3x, and decreasing to its lowest strength in the 5x lasered sample (Fig. 1b).

Results from Organics Analyses: µL^{2}MS spectral maps of organics at the boundary of the lasered and raw surface show a greater abundance of free organic species in the irradiated surface compared to the adjacent unaltered material (Fig. 2). In carbonaceous chondrites the vast majority (>95%) of organic material is present as complex polymeric macromolecular material. Our results suggest that irradiation causes the breakdown of these molecules to simpler free species which are more readily detected by µL^{2}MS. As such, the simulated space weathering by 1x laser irradiation acts to depolymerize and fragment meteoritic kerogen. Similar analyses will be made for the 3x and 5x lasered samples.

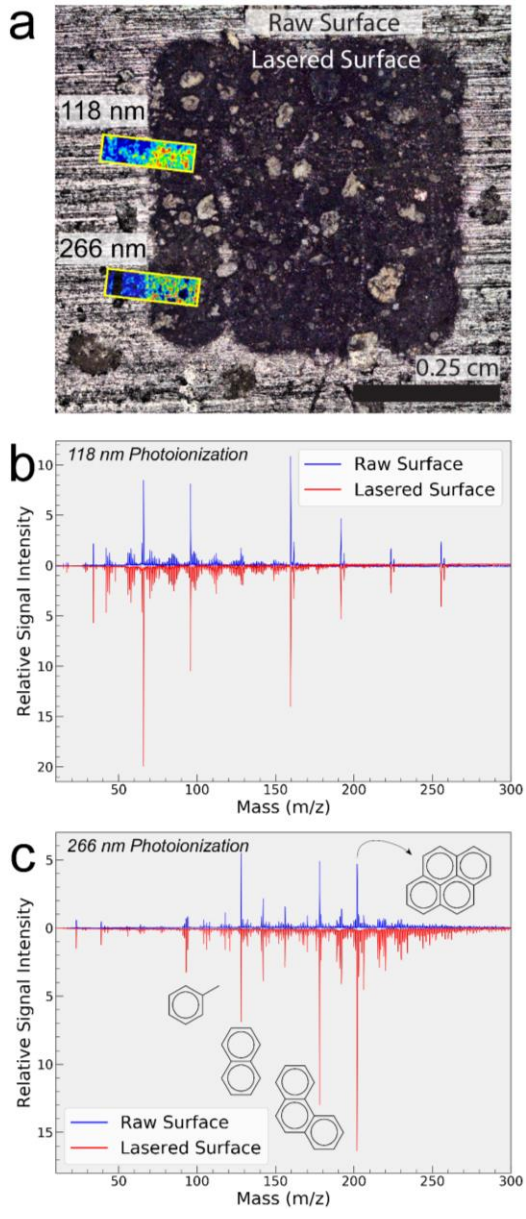

Figure 2: µL^{2}MS data showing a) maps of organic detection at both 118nm and 266 nm wavelengths, and signal intensities observed for b) 118 nm wavelengths and c) 266 nm wavelengths, raw surface (blue) and irradiated (red).

Implications for Space Weathering on Primitive Bodies: The results presented here indicate that the progressive space weathering of carbonaceous chondrites is a complex process. Reflectance spectra indicate that phyllosilicates are decomposing with continued laser exposure, similar to observations made by [3]. Less straightforward however, is the observed initial increase, and then ultimate decrease in the strength of the 0.48 and 1.93 µm bands. These results suggest there may be an 'intermediate phase' forming as a result of irradiation which is ultimately destroyed with continued lasering. As the 0.48 µm band may be attributed to magnetite and the 1.9 µm band is associated with OH/H_2O [8], it is possible that volatile phases like H_2O initially begin vaporizing during the decomposition of phyllosilicate structures and become temporarily trapped in the melt and vapor deposits that are formed via irradiation. This oxidizing component may promote the formation of nano-oxides, including magnetite, in those deposits, similar to those observed in [9]. Vesiculated textures, such as those observed in [9] may indicate a predominance of trapped volatiles in these regions. With continued exposure to the laser, these volatile species ultimately de-gas, and as other nanoparticles form, magnetite may no longer be a significant nanophase. The overall brightening of the spectrum may be the result of the formation and destruction of these nanoparticle phases, and is similar to observations made of the shortest wavelengths in samples from [3]. A contribution to the increased brightening may result from increasing surface roughness with each raster scan, which increases the diffuse relative to the specular part of the reflection. In order to understand the complex spectral effects observed here, we will investigate the microstructural and chemical characteristics of these samples via SEM and TEM.

References: [1] Pieters C. M. and Noble S. K. (2016) *J. Geophys. Res-Planet., 121,* 1865-1884. [2] Kaluna H. M. et al. (2017) *Icarus, 292,* 245-258. [3] Matsuoka M. et al. (2015) *Icarus, 254,* 135-143. [4] Gillis-Davis J. J. et al. (2017) *Icarus, 286,* 1-14. [5] Moroz L. et al. (2004) *Icarus, 170,* 214-228. [6] Keller L. P. et al. (2013) *LPSC XXXXIV*, Abstract #2404. [7] Clemett S. J., et al. (2014) *LPSC XXXXV*, Abstract #2896. [8] Cloutis E. A. et al. (2012) *Icarus 220,* 586-617. [9] Thompson M. S. et al. (2017) *LPSC XXXXVIII* Abstract #2799.