LASER SPACE WEATHERING OF ALLENDE METEORITE. J. J. Gillis-Davis[1], P. G. Lucey[1], J. P. Bradley[2], H. A. Ishii[2], and H. C. Connolly Jr.[4,5,6,7]. [1]University of Hawaii – Manoa, Hawaii Institute of Geophysics and Planetology, 1680 East-West Road, Honolulu, HI 96822, USA (gillis@higp.hawaii.edu); [2]Institute of Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550 USA; [4]Dept. Phys. Sci., Kingsborough Community College CUNY, Brooklyn, NY 11235, USA; [5]Earth and Envi. Sci., CUNY Graduate Center, New York, NY 10016, USA; [6]Dept. Earth and Planet. Sci., American Museum of Natural History, New York, NY 10024, USA; [7]Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Ave., Tucson, AZ 85721, USA.

Introduction: Two future sample return missions are planned to visit C-type asteroids. The primary target of Hayabusa 2 is 1999 JU3. The objective of OSIRIS-REx is to sample 1999 RQ36, which as a B-type asteroid. B-type is a rare subgroup of the dark, carbonaceous C-type asteroids. The goal of both missions is to return a sample of pristine carbonaceous asteroid regolith.

A fundamental question about how C-type or B-type asteroids is: how do they space weather? Space weathering is a term applied to changes in the spectroscopic properties of planetary surfaces due to exposure to the space environment [1,2,3]. Space weathering is expected to have an effect on the spectral properties of carbonaceous asteroids, although the nature of this effect is not fully known. Microsecond pulse laser irradiation of Mighei (CM2) resulted in a redder slope and an increase in overall reflectance [4]. While the microsecond pulsed laser irradiation of a carbonaceous condrite simulant resulted in a decrease in overall reflectance but no change in overall slope [5]. Nanosecond pulse laser irradiations on the Tagish Lake meteorite (C2) produced a bluer (flat) continuum [6]. So knowing the spectra for pristine regolith, in order to sample it, remains to be seen.

We conducted nanosecond pulsed laser irradiation experiments on a powdered sample of Allende meteorite. These experiments are done in order to answer basic question regarding how carbonaceous materials react to space weathering (e.g., are weathered spectra bluer or redder, and darker or brighter) and if nanophase particles other than submicroscopic iron [7] are produced (e.g., Al, C, Mg, Mn).

Methods: The experimental setup is similar to [8]. Space weathering simulation of impact heating produced by high-velocity dust particles was achieved using the facilities at the University of Hawaii, Manoa (Fig 1.) The laboratory equipment consists of a Continuum Surelite I-20, Nd:YAG (1064 nm), pulsed (20-Hz) laser. The pulse duration is 5-7 ns, which is comparable to the timescale of micrometeorite impacts. The samples were irradiated with 30mJ per pulse for 10 minutes using a rastered beam. A vacuum of $2–3\times10^{-6}$ torr was achieved using Pfeiffer Hi-cube turbo and roughing pump combination.

We simulated space weathering of 0.8 grams of powdered Allende meteorite – grain size <500 µm. Allende is a CV3 type a carbonaceous chondrite. Terrestrial weathering of the sample was undetectable. We chose this type of carbonaceous chondrite because it easy to obtain and relatively low cost and is a reasonable analog to C-types in general. Spectra of the C asteroids and the B subtype are generally similar, but the ultraviolet absorption below 0.5 µm is small or absent in b-types. In addition, the near-infrared portion of the spectrum for B-types is slightly bluish rather than reddish, like it is for C-types. Furthermore, spectroscopy of B-class objects suggest major surface constituents of anhydrous silicates, hydrated clay minerals, organic polymers, magnetite, and sulfides [9].

Fig. 1. Space weathering experimental set up. Green line is the illustrated path of laser, which is redirected of 90° mirror and focused by a 300mm lens. Chamber is 8-inches tall by 10-inches long.

Reflectance spectra of the samples were taken before and after irradiation. We measured UVVIS-NIR (0.4-2.5 mm) spectral reflectance using Analytical Spectral Devices Inc. (ASD) FieldSpec® FR spectrometer. The full-width half-max spectral resolution is 3 nm for 350-1000 nm, and 10 nm for 1000-2500 nm. The ASD spectrometer contains three detectors: one

512 element photo diode array for 350-1000 nm, and two thermoelectrically cooled "graded index" extended range InGaAs photo diodes for 1000-1800 nm, and 1800-2500 nm. We used near standard observational geometry with an incidence angle of 0^o, and an emission angle of 40^o. Reflectance is measured relative to spectralon standards (99%, 10% and 5%). The 10% and 5% reflectance standard bracket the average reflectance of the ground Allende sample.

Discussion: The spectrum of the fresh, unweathered sample displays typical overall low reflectance (Fig. 2), a ultraviolet absorption below 0.5 μm causing a steep continuum, a broad 1-μm band absorption due to olivine, and an absorption at about 1.8-μm due to pyroxene. A 0.7-μm-absorption feature, due to $Fe^{2+} \rightarrow Fe^{3+}$ charge-transfer in oxidized iron in phyllosilicates, is not observed.

Spectrum of the after irradiation sample show considerable darkening (~20% at 0.7 μm), but not reddening (Fig 2). In fact, studying the reflectance normalized plot shows that the spectrum of the weather sample actually became slightly bluer in the visible wavelengths. This is in contrast to the near infrared wavelengths. In the near infrared the weathered Allende powder actually became spectrally redder than it unweathered precursor. Furthermore, absorption features of both iron silicates have decreased, with the 1.8-μm band also broadening. The broadening of the 1.8-μm band could be due to the production of vapor glass, by the laser irradiation.

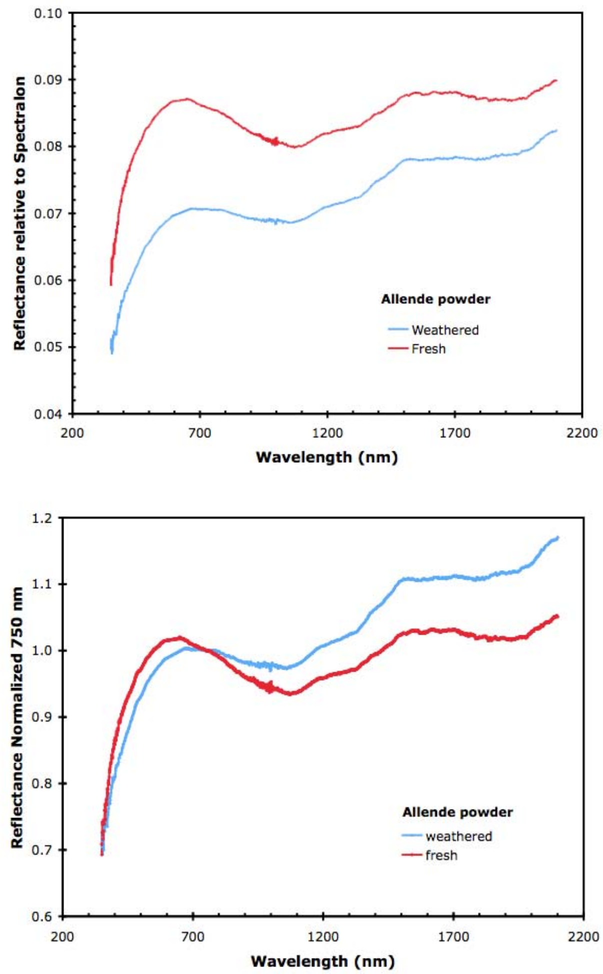

Fig. 2. comparison of reflectance changes between fresh and space weathered Allende. Top: reflectance relative to spectralon. Bottom: reflectance normalized to 750 nm.

Conclusions: Laser space weathering of Allende CV3 carbonaceous chondrite caused three fundamental changes in its spectrum: (1) at all wavelengths it became darker but the most substantial change was in the visible; (2) the weathered material is spectrally bluer in visible; (3) in the infrared, the weathered material became spectrally redder than the fresh sample. These last two spectral changes are the result of differential darkening of the visible portion of spectrum over the UV or near infrared.

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