LASER SPACE WEATHERING OF ALLENDE (CV2) AND MURCHISON (CM2) CARBONACEOUS CHONDrites. J. J. Gillis-Davis¹, P. J. Gasda¹, J. P. Bradley¹, H. A. Ishii¹, and D. B. J. Bussey².¹University of Hawaii at Mānoa, Hawaii Institute of Geophysics and Planetology, Honolulu, HI (gillis@higp.hawaii.edu), HI, ²The Johns Hopkins University, Applied Physics Laboratory, Laurel MD.

Introduction: The ability to connect meteorites with parent bodies is fundamental for understanding asteroids. Asteroid spectra only scratch the surface of what can be known about them, while information about their interiors (e.g., chemistry and thermal history) could be provided by meteorites. Linking the two spectrally, however, is made complicated by a process known as space weathering (SW). SW encompasses several processes that affect regoliths on airless bodies. Two principal processes are solar-wind irradiation and micrometeorite impacts. Together these processes darken, redden (i.e., the Vis-NIR continuum slope steepens), and reduce diagnostic absorption features of the lunar surface as a function of exposure [1,2].

How C-complex asteroids respond to SW is debated. Two recent studies of asteroid families find opposite trends in spectral slope with age. Principal component analyses of Sloan Digital Sky Survey photometric data (5-band spectra with bands centered at 355, 482, 626, 767, and 910 nm) suggest that the mean spectral slopes of C-type asteroids decrease or become spectrally “bluer” with age [3]. An opposite trend was found in a study of spectral slopes of C-type asteroids in the Small Main-Belt Asteroid Spectroscopic Survey II [4]. In the study, C-type asteroids exhibit an increase in spectral slope (become spectrally “redder”) with time. It was suggested by [4] that the decrease in spectral slope with age found by [3] may be a result of compositional differences among different C-type families and not a result of SW but it is then difficult to explain the apparent change as a function of family age, which should not be correlated with compositional difference. Hence the aim of this research is to provide insight as to how the surfaces of C-complex asteroids evolve in response to SW by conducting laser simulated SW experiments on two carbonaceous chondrites and graphite, which we use as a proxy for macromolecular organic material found in the matrix of carbonaceous chondrites. Spectra of iteratively experimentally weathered of carbonaceous materials are vital for spectral interpretation and sample site selection for missions investigating C-complex asteroids (e.g., OSIRIS-Rex [5] and Dawn Hayabusa-2 [6]). These experimental data may also serve as a comparison for spectral data of other potential carbonaceous bodies (e.g., Phobos and Deimos [7], and Trojan asteroids [8]).

Methods: Laser irradiation experiments were performed on Allende, an oxidized CV3 carbonaceous chondrite, Murchison (CM2), and graphite. Allende and Murchison contain 2 and 5 wt% bulk carbon respectively. Hence graphite was SW to investigate the extent to which spectral changes in carbon, as a function of laser irradiation, might be observed in the meteorites. The meteorites were ground in a quartz mortar and pestle. Samples were then dry-sieved to a grain size was <150 µm. In order to characterize experiment reproducibility,
four 0.5 g aliquots each uncompressed powdered sample were used for pulsed laser irradiation experiments.

Micrometeorite impact heating was replicated using a Nd:YAG (1064 nm), pulsed (20 Hz) laser. Each sample was irradiated with 30 mJ laser pulses. The pulse duration is 5–7 ns, which is comparable to the timescale of micrometeorite impacts. Irradiations were done in 1,200 laser shots or 1-minute increments using a rastered beam, for a total of 48,000 laser shots or 40 minutes. A vacuum of 1–2×10⁻⁶ torr was achieved using an oil-free turbo and roughing pump combination.

Vis-NIR spectra were measured using a Analytical Spectral Devices Inc. FieldSpec 4 spectrometer at the University of Hawaii. The spectral range is from 0.4–2.5 μm with 1 nm (Vis) to 10 nm (NIR) spectral resolution. Spectra were acquired using a standard 30° phase angle (30° incidence and 0° emission). Reflectance was measured relative to Spectralon reflectance standards: 99%, 10%, 5% and 2%.

**Spectral Reflectance:** In addition to albedo, the 450/550 nm and 750/550 nm ratios were examined. These ratios were chosen for two reasons: (1) They capture the biggest spectral variations between different asteroid spectral classes in SMASH data, which is normalized to 550 nm; and (2) Because the 450/550 ratio is used to distinguish different C-complex asteroids.

The three samples studied here all exhibit low albedo in the visible (i.e., <9%). Fresh Allende and graphite exhibit similar albedo but different characteristic spectra (Fig. 1). Albedo for weathered Allende and Murchison (both weathered and unweathered) exhibit a similar albedo range, which is lower than Fresh Allende and graphite (Fig. 1). The spectral response of these samples to laser simulated SW is not a carbon copy of lunar model [1,2]. In fact, each sample exhibits some unique spectral variations, similar to [10].

**Allende:** Spectra of laser irradiated Allende respond most like lunar materials (Fig. 1) with one important exception. Over a limited wavelength range (450-550 nm), the visible continuum slope did not vary monotonically with exposure (Fig. 2). The 450/550 continuum increased or became bluer between 6,000-12,000 laser shots. Spectra of weathered Allende are most similar to D-, K-, and T-type asteroids (Fig. 2).

**Murchison:** Vis-NIR spectra do not vary as systematically as the Allende spectra. Spectra became darker and absorption features are reduced but changes in slope are inconsistent (Figs. 1, 2). There is no clear trend of reddening as a function of laser irradiation.

**Graphite:** There is no systematic trend in Vis-NIR color or albedo as function of laser SW (Fig. 1). An interesting spectral feature at ~420 nm appears after 10 min of SW and then disappears after 30 min (Fig. 1).

**Discussion:** Our Allende data show that spectral slopes can be altered by the SW process. The spectral bluing, in this narrow spectral range, is possibly due to a carbon phase being deposited within grain boundaries and vesicles as observed using TEM x-ray mapping (Fig. 3). This observed variation in color as a function laser SW could explain observational differences between [3] and [4]. In contrast, the samples of Murchison and graphite both show a lack of systematic spectral variation as a function of SW. Murchison contains about twice as much carbon as Allende. Thus, the spectral changes observed in Murchison may be driven by SW of graphite/carbon in its matrix. However, the 420 nm feature noted in the spectra of laser SW graphite, could potentially explain the spectral bluing of the more extensively SW Allende sample.

**Conclusions:** Murchison and Allende exhibit distinct spectral responses to laser SW. These distinctions may stem from differences in mineralogy, petrographic grade, and status of carbon in SW rims. Spectra of laser weathered meteorite materials are most appropriate to compare with telescopic spectra of asteroids.

**References:**


![Fig. 3 HAADF TEM image merged with an X-ray map of carbon for a laser produced SW rim on Allende. Red areas depict zones of elevated carbon.](image)