C-COMPLEX ASTEROIDS: UV-VISIBLE SPECTRAL CHARACTERISTICS AND IMPLICATIONS FOR SPACE WEATHERING EFFECTS. Amanda R. Hendrix[1] and Faith Vilas[1], [1]Planetary Science Institute, Tucson, AZ (arh@psi.edu)

Introduction: Space weathering effects on the rocky S-class asteroids are well-understood. However, on the low-albedo C-complex asteroids, such as spacecraft targets Bennu and Ryugu, the situation is more complicated, especially due to a lack of spectral features throughout the visible-near infrared spectral region. Here we show, through a combination of observational data and laboratory data of carbonaceous chondrites, phyllosilicates and mixtures, that the UV-visible spectral region is a diagnostic regime for studying space weathering effects on C-complex asteroids. We show that space-weathering-produced opaque constituents, such as graphitized carbons, darken mixtures with phyllosilicates and weaken the UV absorption, consistent with what is seen on the asteroids compared with carbonaceous chondrites. Furthermore, we show that diagnostic spectral signatures of carbons of varying levels of graphitization can be used to study relative ages of low-albedo surfaces in the solar system.

Background: Low albedo C-complex asteroids are typically rather spectrally featureless at visible-near infrared (VNIR) wavelengths. Roughly half of the low-albedo asteroids in the main asteroid belt exhibit an absorption feature near 3 μm, indicative of some form of hydration (OH and/or H_2O). Roughly half of the asteroids with the 3 μm feature also exhibit a shallow absorption feature near 0.7 μm, attributed to a ferrous-ferric charge transfer transition likely resulting from aqueous alteration (the interaction of material with liquid water formed by melting of water upon a heating event) of iron-bearing phyllosilicates. Some asteroids have spectra that likely do not exhibit these features due to a history of heating that has been experienced at some point in the asteroid's evolution. Despite having little spectral activity in the VNIR, all low-albedo asteroids exhibit a UV absorption (or UV "dropoff") at wavelengths shorter than ~0.5 μm, attributed to a strong ferric oxide intervalence charge transfer (IVCT) transition (e.g. [1][2]).

In spectra of terrestrial phyllosilicates, both the 0.7 μm absorption and the UV absorption are very strong and steep (e.g. [3]). Hiroi et al. [4] compared UV-VIS characteristics of 14 low-albedo class asteroids (using 24-color data) with laboratory spectra of carbonaceous chondrites. They noted that the asteroids exhibited weaker UV absorptions than the meteorites. They suggested this behavior could be due to thermal history, by demonstrating that heating carbonaceous chondrites can diminish the strength of the UV absorption edge. Vilas and Sykes [5], however, pointed out that heating carbonaceous chondrites removes the aqueous alteration spectral feature at 0.7 μm, which is seen in many of the asteroid spectra, suggesting that all of the observed surface material has not been heated to a stage of metamorphosis.

In this study, we combine space-based UV data from International Ultraviolet Explorer (IUE) and Hubble Space Telescope (HST) along with ground-based data and laboratory data of relevant materials and mixtures to show that UV-visible (UV-VIS) spectral differences between C-complex asteroids and carbonaceous chondrites are likely linked to the effects of space weathering. We first demonstrate the UV-VIS characteristics of C-complex asteroids and of CM chondrites and phyllosilicates, to understand relationships. We then look at the UV-VIS characteristics of phyllosilicate-opaque mixtures.

Comparisons with Carbonaceous Chondrites: C-complex asteroids are commonly linked with CI and CM chondrites due to their relatively low albedos and muted spectral signatures at VNIR wavelengths (e.g. [6]). CM chondrites are dominated by serpentine minerals (including cronstedtite), tochilinite and olivine [7]. CI chondrites generally are rich in phyllosilicates (namely serpentine and saponite) and magnetite [8].

As has been shown for a set of asteroids and chondrites [4], C-complex asteroids in general have a less-steep UV dropoff compared to carbonaceous chondrite meteorites. The effect is that the asteroids are relatively bright, compared to the meteorites, at UV wavelengths. At VNIR wavelengths, differences in spectral characteristics between C complex asteroids and CM/CI chondrites are less obvious.

We investigate these meteorite-asteroid UV-VIS spectral differences by inspecting the spectral trends in CM chondrites, using the RELAB library of 39 chondrites (after [7]), many with multiple spectra. Comparing our composite asteroid spectra with the spectra of the CM chondrites, we find that indeed most of the CM chondrites exhibit a stronger UV absorption than the asteroids, though there is clearly variation among these chondrites, where some exhibit stronger UV absorptions and some not as strong.

Links with Space Weathering: A reasonable explanation for the differences between the asteroid spectra and the meteorite spectra (the relative blueness of the asteroids) is space weathering effects, i.e. those due to solar wind and micrometeoroid impacts.

Space weathering effects on asteroids have been studied for decades. On S-class asteroids, the link between parent asteroids and ordinary chondrite meteorites was finally understood to be due to the production of nanophase iron [9] that darkens and reddens spectra at VNIR wavelengths (e.g.[10]) and results in a spectral bluing at UV wavelengths [11]. Weathering effects on C-class and other low-albedo class asteroids have been less well-understood. At VNIR wavelengths, both spectral bluing and reddening of VNIR asteroid spectra have been attributed to weathering (e.g. [12][13][14]).

In the laboratory, several experiments have been performed on carbonaceous chondrites and analog materials to simulate the effects of micrometeoroid bombardment (via laser irradiation) and solar wind exposure (via ion irradiation). A common result of these simulations is the production of opaque materials ([15][16][17]), notably carbonized materials ([18][19][20]). These examples of laboratory measurements of simulated space weathering on C-complex-type materials demonstrate that, analogous to SMFe being a weathering product on S-type asteroids, carbonized/graphitized materials or other opaques are likely to be present on the surfaces of C-complex asteroids as a result of space weathering. We thus look at the spectral effects of mixtures of phyllosilicates and opaques and suggest that a driving difference between the UV-VIS spectral differences in C complex asteroids and CI/CM chondrites is the presence of space weathering-derived opaques on the surfaces of the asteroids, consistent with the results of [21].

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