ULTRAVIOLET CHARACTERISTCIS OF LOW-ALBEDO CLASS ASTEROIDS.

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Overview: Carbon and carbonaceous species, though ubiquitous throughout the solar system, are not well understood on planetary surfaces due to carbon's spectral blandness at visible-near infrared (VNIR) wavelengths. In the UV, however, carbon is spectrally active and spectrally variable, depending on the amount of processing (thermal, radiolytic) experienced by the surface (e.g. [1]). Thus, the UV is a key region in which we not only identify carbonaceous species but also track the level of processing of different surfaces throughout the solar system. We investigate UV-visible spectral trends among low-albedo class (B, C, F, G types) (presumably carbonaceous) asteroids to understand how spectral characteristics might be linked to composition and weathering.

UV-Visible Data Sets: We utilize data from the International Ultraviolet Explorer (IUE) in the ~210-320 nm region [2]. This is an extension of some of our earlier work [3] in which we focused on S-class asteroids. In this analysis, we combine IUE data of low-albedo class asteroids with ground-based data sets, to understand trends into the visible.

Spectral Characteristics of the Low-Albedo Class Asteroids: Low albedo asteroids are typically rather bland spectrally at VNIR wavelengths. Many of these objects exhibit an absorption near 3 µm, indicative of some type of hydration (OH and/or H_2O). A subset of the asteroids with the 3-µm features also exhibit an absorption near 0.7 µm, due 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). Some asteroids 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 absorb at wavelengths shorter than ~500 nm, attributed to a strong ferric oxide IVCT transition.

The wavelength at which the UV absorption occurs and the slope of the UV portion of the spectrum has been linked to heating [4] and weathering. In terrestrial phyllosilicates, both the 0.7 µm and the UV features are very strong and steep [e.g., 5]. Laboratory research shows that the UV downturn changes with heating of the Murchison meteorite [6], linking the UV slope to heating – however the 0.7 µm feature disappears immediately with heating.

Questions: We are interested in understanding what spectral variation exists in UV reflectance data on these asteroids, and why. These asteroid surfaces likely contain iron. Can we distinguish potential effects of space weathering from metamorphic differences due to heating and/or mixing of other materials on these bodies by studying their UV characteristics? We compare the UV data with available laboratory spectra of meteorites (e.g. [7]) and phyllosilicates and compare with known visible and infrared spectral characteristics (e.g. [8] to look for trends.

We intercompare UV spectra of C-complex asteroids and ask:

- How do they compare with groupings based on 3 µm spectral shape?
- How do they compare with taxonomic classifications?
- How do they compare with lab data of carbonaceous chondrites?
- How do they compare with lab data of phyllosilicates & other candidate species?

New Results: Cloutis et al. [9] point out that in CM chondrites, the 0.7 µm depth is not affected by Fe/(Fe+Mg) abundance. We show that, in phyllosilicates [9], increasing iron abundance generally moves the UV absorption edge to the red, as discussed in the literature for different samples [10]. Phyllosilicates in general exhibit UV absorption edges at longer wavelengths than observed on the C-class asteroids.

In considering asteroids exhibiting a "Ceres-Like" 3 µm band, such as Ceres, Hygiea, Bamberga [11], there is a suggestion of somewhat shallower UV slopes for Hygiea, Bamberga compared with Ceres (e.g. Fig. 1).

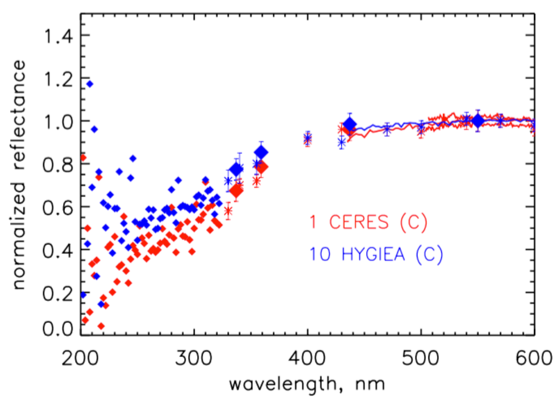

Figure 1a. *Asteroids with "Ceres-like" 3 µm bands. IUE and ground-based spectra of Ceres and Hygiea, displaying diverging spectral shapes <~350 nm.*

In considering asteroids exhibiting a "sharp" 3 µm feature, such as Davida, Alexandra, Interamnia, Polyxo [11] and Pallas [12], we find that 704 Interamnia is definitely different in the UV than other asteroids with a "sharp" 3 µm feature (Fig. 2); 54 Alexandra and 511 Davida are similar to Pallas in the UV.

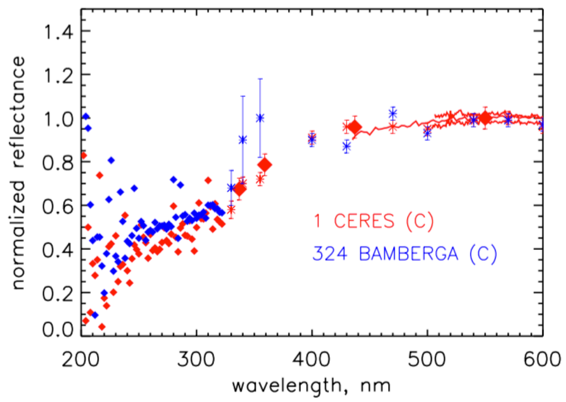

Figure 1b. *Asteroids with "Ceres-like" 3 μm bands. IUE and ground-based data of Ceres and Bamberga; Bamberga displays a slightly less steep UV spectral slope than Ceres (<350 nm).*

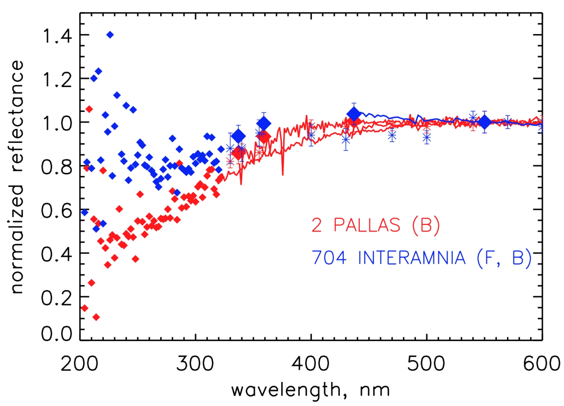

Figure 2. *IUE and ground-based data of asteroids with "sharp" 3 μm bands. Pallas and Interamnia display very different UV spectra.*

In comparing Ch asteroids, we find that 654 Zelinda, 410 Chloris and 41 Daphne are all rather spectrally similar (and similar to Pallas too) in the UV/blue.

In comparing the asteroids classed as Cgh, we find that 51 Nemausa and 54 Alexandra are significantly spectrally different in the UV/blue (Fig. 3). Both have 0.7 μm features. Why so different in the UV?

Summary: Considering the bodies with "Ceres-like" 3 μm absorptions, there's a suggestion of somewhat shallower UV slopes for Hygiea, Bamberga compared with Ceres; thus, though these bodies exhibit similar spectral characteristics in the 3 μm region, they are different in the UV/blue. Considering the bodies with "sharp" 3 μm absorptions, we find that Interamnia is unique in the UV/blue.

Considering the bodies classed as "Cgh", we find that Nemausa & Alexandra are significantly spectrally different in the UV/blue.

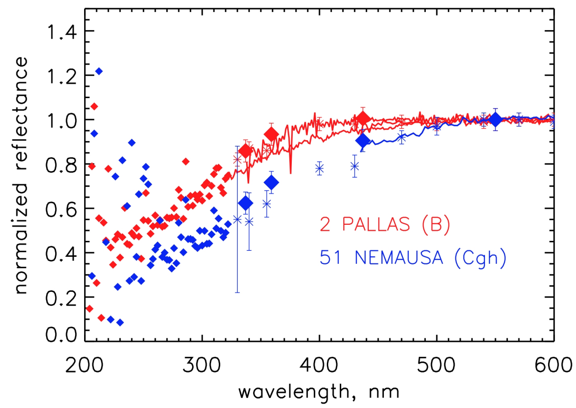

Figure 3a. *IUE and ground-based data of asteroids classed as "Cgh," compared with Pallas.*

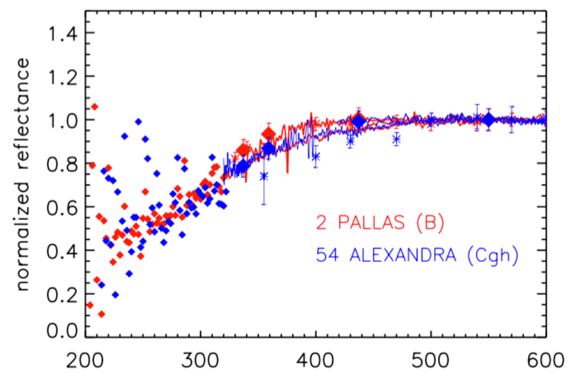

Figure 3b. *IUE and ground-based data of asteroids classed as "Cgh," compared with Pallas. Comparison of Fig. 3a and Fig. 3b show that Cgh asteroids Nemausa and Alexandra are very different spectrally in the UV blue.*

We find that CM, CI carbonaceous chondrites and phyllosilicates largely have UV absorption edges at longer wavelengths (closer to 0.5 μm) than C-complex asteroids (closer to 0.4 μm). Could this be due to weathering products (SMFe? Amorphous carbon?) on asteroid surfaces?

Finally, the UV spectral shapes don't totally correlate with hydration (as indicated by the 0.7 μm feature), suggesting that the UV spectral shape is rooted largely in another property of the asteroids' surfaces, such as different composition/weathering products.

References: [1] Hendrix, A.R et al. (2016) *MaPS, 51,* 105-115.. [2] Roettger, E. and Buratti, B. (1994) *Icarus, 112,* 496-512. [3] Hendrix, A. and Vilas, F. (2006) *AJ, 132*, 1396. [4] Hiroi, T. et al. (1996) *Met. & Planet. Sci, 31,* 321-327. [5] Vilas, F. et al. (1997) *Icarus, 129,* 440-449. [6] Hiroi T. et al. (1993) *Science, 261,* 1016-1018. [7] Wagner J. K. (1987) *Icarus, 69,* 14–28. [8] Takir, D. and Emery, J.P. (2012) *Icarus, 219*, 641-654. [9] Cloutis et al. (2011) *Icarus 216,* 309-346. [10] Cloutis et al. (2008) *Icarus 197,* 321-347. [11] Takir, D., J. Emery (2012) *Icarus 219,* 641-654; [12] Rivkin, A. et al. (2015) *AJ 150,* 198.