UV signatures of carbonaceous species on low-albedo asteroids

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Asteroids in the low-albedo classes (C, B, G, F) are known to have spectra that are relatively feature-free in the visible/near-infrared (VNIR) spectral region, making them classically difficult to study in terms of surface mineralogy. Many of these bodies exhibit a 3-micron absorption band (e.g., [1]), which can be used to study hydration and organics. The primary other spectrally active region — less well studied so far — is the ultraviolet (UV). In this study, we utilize UV spectra of low-albedo asteroids (C, B, G, and F class) to study surface composition. In particular, we investigate implications for the presence of carbonaceous compounds, including tholins and Polycyclic Aromatic Hydrocarbons (PAHs), which have unique spectral features in the UV.

Low-albedo asteroids are typically rather bland spectrally at VNIR wavelengths. Many of these objects exhibit an absorption band near 3 microns, indicative of some type of hydration (OH and-or H_2O). A subset of the asteroids with the 3-micron features also exhibit absorption near 0.7 microns, 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 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 $\sim$500 nm. This has been generally attributed to a ferric-iron intervalence charge-transfer transition absorption.

Carbon-bearing phases have long been assumed to be important on low-albedo asteroids (e.g., [2]) due to the dark, mostly-featureless VNIR spectra of these bodies. However, there are many forms of carbonaceous species and the species are expected to undergo phase modifications (e.g., due to thermal, aqueous, and radiation processes) that affect the spectra [3,7]. Tholins are residues remaining after irradiation of different ice combinations. The fundamental subunits of tholins are PAHs — small clusters of 5–10 carbon rings. Tholins often produce a C-H stretch feature near 3.3–3.4 microns; a feature closer to 3.3 microns could be due to aromatics [4]. Existing laboratory spectra of tholins show that they absorb strongly in the UV and are featureless in the visible. So far, organics have only been decisively detected on (24) Themis ([4,5]) using the 3.4-micron feature. However, most primitive meteorites (especially CM2 carbonaceous chondrites) have abundant organic molecules, as evidenced by the 3.4-micron feature.

We utilize data from the International Ultraviolet Explorer (IUE) in the $\sim$210–320 nm region. This is a continuation of some of our earlier work [6]; we also combine these data with new UV/blue wavelength data from MMT 6.5-m telescope Blue Channel spectrograph, as well as from other asteroid data sets, to understand trends into the visible. Ceres is the only low-albedo asteroid for which far-UV data exist (from Hubble Space Telescope [8,9]), so we can use this body to check spectral effects at shorter wavelengths. We compare the UV-visible asteroid spectra with those of tholins (ice tholin and ice tholin II), graphites, coal, anthracite, graphite, kerogen, amorphous carbon, and PAHs which have been extensively studied in the UV due to the ISM "bump" in extinction near 217.5 nm.

References: [1] Jones, T. D., L. A. Lebofsky, J. S. Lewis, M. S. Marley 1990. Icarus 88, 172. [2] Gaffey, M. J., J. F. Bell, D. P. Cruikshank 1989. In Asteroids II, pp. 98–127. [3] Cloutis, E., M. J. Gaffey, T. F. Moslow 1994. Icarus 107, 276. [4] Rivkin, A. S. and J. P. Emery 2010. Nature 464, 1322. [5] Campins, H., K. Hargrove, N. Pinilla-Alonso, E. S. Howell, M. S. Kelley, J. Licandro, T. Mothe-Diniz, Y. Fernandez, J. Ziffer 2010. Nature 464, 1320. [6] Hendrix, A. R. and F. Vilas 2006. Astron. J. 132, 1396. [7] Cloutis, E. A., T. Hiroi, M. J. Gaffey, C. M. O.'D. Alexander, P. Mann. 2011. Icarus 212, 180. [8] Parker, J. W., S.A. Stern, P.C. Thomas, M.C. Festou, W.J. Merline, E.F. Young, R.P. Binzel, L.A. Lebofsky 2002. Astron. J. 123, 549. [9] Li, J.-Y., L.A. McFadden, J.Wm. Parker, E.F. Young, S.A. Stern, P.C. Thomas, C.T. Russell, M.V. Sykes 2006. Icarus 182, 143.