ULTRAVIOLET REFLECTANCE SPECTROSCOPY OF CONDENSED CARBONACEOUS MATERIALS. D. M. Applin1*, M. R. M. Izawa1,2,3, and E. A. Cloutis1,2HOSERLab, Department of Geography, University of Winnipeg, 515 Portage Ave., Winnipeg, Manitoba, Canada, R3B 2E9., 2Dept. Earth Sciences, Brock University, 1812 Sir Isaac Brock Way, St. Catharines’s, ON, L2S 3A1, 3Planetary Science Institute, 1700 E Fort Lowell Rd #106, Tucson, AZ 85719, USA daniel.m.applin@gmail.com

Introduction: Although there has been renewed interest in the ultraviolet (UV) spectral properties of carbonaceous planetary bodies [1], laboratory reflectance investigations are still somewhat sparse. Many planetary surfaces within the solar system contain significant fractions of carbonaceous phases, for which UV reflectance spectra may provide compositional insights.

The lack of UV laboratory studies occurs for multiple reasons, which include the difficulty in acquiring high signal-to-noise ratio (SNR) reflectance spectra on dark materials; the absence of calibrated, photochemically stable reflectance standards that are not compromised by contamination and/or decomposition; and an unfortunate general perception that the UV region is spectrally uninteresting. Despite this, telescopic observations continue [2, 3], and missions continue to fly far to near UV imaging systems [4-6]. Although carbonaceous materials are well studied in the UV by transmission, few reflectance investigations have been undertaken [e.g. 7]. Most laboratory studies to date have also been hampered by low SNR, coarse sampling intervals, or both.

Methods: Reflectance spectra (0.2-0.5 μm) were measured with an Ocean Optics (Dunedin, Fl) Maya2000 PRO – a symmetric crossed Czerny-Turner miniaturized spectrometer with a sampling interval of 0.45 nm and resolution of 1.8 nm. Sample illumination was provided with a 30 W deuterium lamp fed through a bifurcated fibre optic bundle. Rigorous testing has shown all tested deuterium lamps to require warm-up times of at least 6-12 hours in order to collect accurate reflectance spectra <0.25 μm, and white references must be repeated often due to slowly increasing radiance with decreasing wavelength. We integrate over time intervals that produce a signal of about ~85% of the pixel-saturation level on that of the highest quantum efficiency – at about ~0.24 μm, which represents about ~90% of the full well depth. Spectra are collected in biconical geometry, and at least 750 spectra are averaged for all measurements including dark currents. The instrument is not thermoelectrically cooled, so we also use optically masked pixels to subtract real time dark currents from each spectrum. Because no perfect UV reflectance standard exists, we use a contamination-controlled [8] calibrated Spectralon puck, and correct its irregularities by using an UV enhanced mirror. We have confirmed the reflectance properties of both the mirror and the Spectralon standard by using standardless measurements. These calibrations are done before every run, because we find that contamination and decomposition effects occur with all tested standards (BaSO4, MgF2, CaF2, etc), and in the absence of clean rooms, must be done consistently.

Results and Summary: Graphites are dominated by a Fresnel peak (strong surface scattering due to a strong absorption coefficient (k) and a rapid deviation of the real refractive index (n) from 1) near ~0.245 μm due to the π→π* transition (Fig. 1). This feature varies from 0.245 μm in pure graphite, to 0.261 μm in shungite, a highly carbonaceous (97% C) amorphous material. Therefore, amorphous carbon exhibits this
feature at longer wavelengths than crystalline graphite. Anthraxolite, a graphic coal with high fixed carbon exhibits this feature at 0.247 µm, but it is present in the toluene-insoluble fraction at 0.259 µm. This may indicate that a soluble crystalline component in the anthraxolite specimen is spectrally dominant. Anthracite, a high carbon content coal, does not exhibit this feature.

Submicroscopic amorphous carbon does not exhibit the Fresnel peak, most likely due to enhanced volume scattering (Figs. 1 and 4). Amorphous glassy carbon (SHUNG102; Fig. 1) does, which is in agreement with spectral contrast decreasing with grain size.

Some extracts and highly bitumen-rich materials exhibit spectra that show evidence of both a graphitic component in addition to other peaks which may be associated with PAHs or related materials (Fig. 4).

Spectra of various grain sizes of a coal roughly show volume-scattering dominated behaviour until ~0.29 µm, below which the spectra appear to be dominated by surface scattering, which causes blue-sloping. The low overall reflectance of the 250-500 µm sample is likely due to surface roughness.

These results, as well as those derived from the many other samples measured should be helpful in the attempt to characterize the many carbonaceous planetary surfaces in the solar system with UV spectroscopy.

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**Figure 3.** UV reflectance of a medium-volatility bituminous coal baked in air.

Fresnel reflectance computed from optical constants [9] is shown in Fig. 2. All of our samples appear slightly narrower, and with lower spectral contrast surrounding the Fresnel peak, the latter perhaps due to surface irregularities.

The spectral progression of thermally altered coal in air shows that the shape becomes progressively more concave and blue-sloped, until near-total organic loss. This is likely due to graphitization, most probably in the form of fine-grained amorphous graphite, given the appearance. The resulting spectrum appears silicate-like and the blue-sloping trend reverses.

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**Figure 4.** UV reflectance amorphous graphites and oil/tar sands.

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