**IMPLICATIONS FOR IRON AND CARBON IN MERCURY SURFACE MATERIALS FROM ULTRAVIOLET REFLECTANCE.** Rachel E. Maxwell¹, Noam R. Izenberg², and Gregory M. Holsclaw³.

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**Introduction:** The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) on the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft conducted orbital observations of Mercury’s surface from 29 March 2011 to the end of the mission on 30 April 2015 [1]. The Visible and Infrared Spectrograph (VIRS) and the Ultraviolet and Visible Spectrometer (UVVS) made up the two components of MASCS [2]. Analysis of VIRS data [3,4] has shown Mercury to have a slightly varying but universally “red” spectral slope (Fig. 1), i.e., reflectance increases with wavelength, indicative of a space-weathered surface [5]. UVVS surface reflectance is an underutilized dataset that extends the VIRS spectral range of 300–1450 nm into the middle ultraviolet (MUV), 210–300 nm, in Mercury’s southern hemisphere [6].

We have used UVVS spectral reflectance in combination with VIRS to improve constraints on the surface mineralogy of Mercury. We compare the MUV reflectance from UVVS to near-ultraviolet (NUV) to near-infrared observations of VIRS and global image data from the Mercury Dual Imaging System (MDIS) [7], discuss the implications of variations in iron and carbon abundances, and compare these findings with other observations.

**UVVS Observations:** During MESSENGER’s orbital phase, UVVS acquired approximately 5700 surface spectra (Fig. 2) over the wavelength range 210 to 300 nm. UVVS was a scanning grating monochromator that obtained a continuous spectrum of a single spatial position over tens of seconds. Because of spacecraft and instrument constraints, UVVS observations were conducted one at a time, targeting single ~10–40 km² areas on the surface, with focused campaigns to obtain a “grid” of spectra spaced by 200 km or less across Mercury’s southern hemisphere [6]. Each of the several hundred grating steps had a spectral bandwidth of a ~0.7 nm, and multiple steps were binned to synthesize 46 2-nm-wide spectral bands between 210 and 300 nm [6].

Most UVVS grid observations were accompanied by contemporaneous VIRS observations with the same viewing geometry and instrument conditions, allowing the UVVS and VIRS data to be tied together for comparisons, including ratios of targeted terrain to the surrounding area. As a result of spacecraft motion, some UVVS observations may be inappropriate for ratio or band-depth parameter analysis because footprints for different wavelengths may have fallen on different materials or terrain. For ratios and band depths we used observations with projected boresight drifts less than ~5 km.

![Fig. 1. (a) Photometrically corrected UVVS spectra of selected areas on Mercury. Black: southern hemisphere average, green: intercrater plains (IP), orange: high-reflectance red plains (HRP), blue: low-reflectance material (LRM), red: pyroclastic deposits. (b) Photometrically corrected VIRS spectra of the same areas shown in (a).](image1)

![Fig. 2. Reflectance at 255 nm. Blue to red corresponds to reflectance values from 0.01 to 0.02, respectively.](image2)

**Extending the MASCS Spectrum:** Because the UVVS and VIRS spectra are dominated by the red continuum, we accentuate spectral differences by expressing the data as ratios to the planetary average. Relative reflectance reveals trends in spectral slope related to terrain type. Regions of low-reflectance material (LRM) and low-reflectance blue plains (LBP) have high NUV ratios (310-nm/390-nm), whereas pyroclastic deposits have low NUV ratios. Ratios tend to reverse in the MUV, especially for LRM. LRM and LBP tend to have higher 220-nm/290-nm MUV ratios, and higher-reflectance plains have lower MUV ratios [6]. Extending the available spectrum for modeling by adding UVVS reflectance data down to 210 nm will...
improve modeling constraints and possibly support the argument for the presence of carbon [6, 8].

![Fig. 3. Ratios of the spectra in Fig. 2 to the southern hemisphere average.](image)

**Analysis:** The relatively “red-sloped” nature of the pyroclastic material observed and the relatively “blue-sloped” nature of LRM are illustrated in Figure 3. This “blueness” was also seen by VIRS [4] and MDIS at longer wavelengths and provides a constraint on the proportions of microphase and nanophase iron [9]. The figure also shows a spectrum for high-reflectance red plains (HRP) and an intercrater plains spectrum that is similar to the southern hemisphere average. Carbon has also been proposed as a potential darkening agent [9] and constrained by thermal neutron observations as a global constituent of up to a few wt% [9, 10].

Radiative transfer modeling suggests that darkening and reddening effects of microphase and nanophase iron and carbon may control or influence curvature and the appearance of bands in reflectance spectra [6, 8, 11, 12, 13]. Iron as the primary darkening agent results in a stronger modeled spectral band at UV wavelengths than carbon. The band is related to the oxygen-metal charge-transfer (OMCT) absorption caused by minor abundances of Fe$^{3+}$ and Fe$^{2+}$ [4, 11]. Modeling of VIRS data at wavelengths down to 300 nm produces lower residuals with microphase and nanophase iron (at 1 wt% or less) for some materials (e.g., HRP and IP in Fig. 4) despite small differences at NUV wavelengths between modeled and observed spectra because of the OMCT band feature [6, 8]. In contrast, other materials (e.g., LRM and LBP in Fig. 4) are better fit by microphase and nanophase carbon (at similar wt%).

Appending the UVVS MUV wavelengths onto VIRS where available completes the full range of the OMCT band, allowing for improved modeling of constituents. In the MUV, the darker and bluer materials such as LRM and LBP have lower MUV ratios (blue-cyan in Fig. 5), and the brighter and redder materials such as HRP and pyroclastic material have higher ratios (red-yellow in Fig. 5). Low MUV ratios imply a steeper spectral downturn into the UV and are better fit with carbon as the darkening agent. Higher ratios will be better fit by relatively less carbon and/or more iron.

![Fig. 4. Radiative transfer modeling of microphase and nanophase iron and carbon contributions to spectral reflectance [from 6, 8], from near-UV to near-IR.](image)

![Fig. 5. Map of 220-nm/290-nm reflectance ratio. Blue to red corresponds to ratio values from 0.05 to 0.2, respectively.](image)

Reflectance spectroscopy that extends to MUV wavelengths from UVVS improves our ability to model Mercury’s surface composition and its spatial variation. Incorporating MUV spectra into radiative transfer models that treat the effects of microphase and nanophase amorphous carbon and graphite as well as iron [13] will improve the fitting constraints for different surface materials and thus our understanding of the distribution and relative abundance of darkening agents on Mercury.