MERQUY’S SURFACE COMPOSITION FROM SURFACE SPECTROSCOPY. Ann L. Sprague, Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd. Tucson, AZ 85721 – 0092. sprague@lpl.arizona.edu.

Introduction: During our 15 year quest to augment vis-near infrared spectroscopic (0.4 – 2.5 µm) discoveries with mid-infrared (2.5 – 13.5 µm) spectroscopic discoveries at Mercury, we have achieved much and learned even more. This talk (and paper) will describe some of those discoveries and lessons learned.

Methods used to interpret mid-infrared spectra include 1) identification of key spectral features diagnostic of composition. This has been achieved in the laboratory using terrestrial and lunar rocks, minerals, powders, and glasses. 2) comparison of laboratory and telescopic mid-infrared spectra of lunar soils from similar locations on the Moon. 3) use of the same spectrograph to obtain spectra of rocks, minerals, and powders to compare to spectra of the Moon’s and Mercury’s surface and thus calibrate spectrograph performance and resulting spectral character. 4) comparison of spectra obtained from spacecraft above all of the Earth’s atmosphere of objects in the solar system (Jupiter, Saturn, asteroids) to those obtained from mid-infrared instruments from ground-based observatories.

Near-infrared and mid-infrared diagnostics contrasted: The power of visible and near-infrared spectroscopy (0.4 – 2.5 µm) has been demonstrated throughout the solar system for decades. For example, the size and shape of absorption bands in reflected light from the surface caused by crystal field transitions, metal-metal intervalence charge transfer transitions, and oxygen-metal charge transfer transitions of the materials in the regolith, are very diagnostic. The best known of these are probably the lunar olivine and pyroxene bands which permitted mapping of near-side abundance of these minerals and identification of the lunar mantle in Copernicus [1].

From 2.5 – 7 µm, volume scattering of light from regoliths becomes important. There are absorption (and emittance) features associated with photons scattering in individual grains. Many silicates, sulfates, and carbonates have diagnostic features in this spectral region. Most of this spectral region is available to spectrographs at high altitude at ground-based observatories and from stratospheric observatories like the Kuiper Airborne Observatory (KAO--retired) the Stratospheric Observatory for Infrared Astronomy (SOFIA--to be commissioned in 2005).

Major rock-forming minerals have their fundamental molecular vibration bands in the region from 7.5 – 11 µm (the Reststrahlen bands). The transparency feature between 11 and 13 µm is associated with the change from surface to volume scattering. There are also major features associated with the bending, twisting modes of silicates, and other solar system materials occurring in the region from 13 - 40 µm.

An emissivity maximum (EM) associated with the principal Christiansen frequency, usually between 7 and 9 µm is a good diagnostic of specific mineral identity and also bulk regolith or rock type in mixed mineralogic and textural assemblages common in regoliths.

Two good reviews for more details regarding the above highly-condensed and incomplete discussion above may be found in [2] and [3].

VIS/Near-infrared Discoveries at Mercury: Visible and near-infrared (0.4 – 1.5 µm) spectroscopy has been successful in documenting the extremely low probability of presence of the Fe²⁺ charge-transfer absorption band in reflected light from Mercury’s surface. This means that FeO in the regolith is very low in abundance, if present at all. [4], [5], [6], [7]. In addition, the regolith, while mature, is more transparent than the regolith of the Moon, thus indicating low abundance of Fe blebs and other opaques that are characteristic of the lunar mature soils [8], [9].

Reflectance spectroscopy is useful on Mercury wherever there is reflected light. Of course spatial resolution is limited by the spectrograph aperture size, the plate scale of the telescope and detector, and Earth’s atmospheric turbulence.

Mid-infrared Discoveries at Mercury: This spectral range is dominated by thermal emission. The location on the planet, for all data, is biased toward the hottest regions in the footprint of the spectrograph aperture. The other caveats of spatial resolution mentioned above for vis-near-ir observations also hold. In addition, spatial resolution is limited by the diffraction limit of the telescope.

Volume Scattering Region: Emissivity peaks at 5.7 and 6 µm, in a spectrum of Mercury from 100 – 160° longitude [10], resemble prominent emissivity maxima at 5.7 and 6 µm exhibited by low-iron olivine powders in laboratory spectra. The exact wavelength of the pair of peaks is seen, in laboratory studies, to shift by small amounts according to FeO content in the olivine.

A strong 5.5 µm emission feature in a spectrum from 45 – 85° longitude closely resembles that of laboratory clinopyroxene powders [11]. The best fit is to diopside and the low-FeO abundance indicated by near-infrared reflectance spectroscopy supports a low-iron bearing clinopyroxene. Spectroscopic observations of
Mercury have been made in this spectral region from the KAO [10], and between 3 and 7 µm from 13,786 ft altitude [11] at Mauna Kea (the NASA Infrared Telescope Facility, IRTF).

**Emission Maximum in region of Principal Christiansen Frequency:** Emissivity maxima (EM) at or close to 7.9 – 8.0 µm and indicative of intermediate silica content (~50 – 57% SiO₂) occur in spectra from 12 – 32° and 22 – 44° [12], 40 – 45°[13], 45 – 85° [11], 10 – 75° [10], and 110 – 120° [12] longitude. These locations fall in the inter crater plains east of the crater Homer. Spectra from 68 – 108° [11] and 100 – 160° [10] longitude have multiple EM indicating a more complicated bulk composition and or mixed mineralogy of more basic composition (45 – 49% SiO₂).

**Reststrahlen features:** Reststrahlen features in spectra from 110 – 120° longitude have been modeled with simple linear spectral mixing of laboratory spectra from 0 – 74 µm powders. A mixture of labradorite (a mineral of the plagioclase feldspar solid solution with Na-rich plagioclase, albite--Ab₄₀ molar abundance) and low-iron ortho-pyroxene powders matches some but not all features in the Mercury spectrum. [14]. The Reststrahlen features in a spectrum from 68 – 108° longitude have not yet been fitted with any model but show three emissivity peaks between 7.8 and 9.3 µm, some of which may be caused by Reststrahlen features. A composite spectrum from CVF spectral imaging at longitude has a doublet transparency minimum with 205 – 240° longitude [15] indicates a probability of about 44% SiO₂ or an ultra-basic composition.

**Transparency minima:** The Mercury spectrum from 110 – 120° longitude has a clear and strong transparency minimum at 12.3 µm that is at the same location as the transparency minimum in a laboratory spectrum of labradorite powders [12]. This is consistent with the location of the EM in the same spectrum as described above. Spectra from longitudes centered on 80°, 256° and 266° have probable transparency minima at 12 µm [16]. The bulk composition associated with a transparency feature at this wavelength is intermediate to basic (45 – 57% SiO₂). Spectra from a region centered on 15° has a minimum at 12.5 µm [16] indicative of about 44% SiO₂ or an ultra-basic composition. A spectrum from a region centered on 229° longitude has a doublet transparency minimum with one at 12.2 µm and another at 12.5 µm. This is indicative of more complex mineralogy in that region.

**Summary:** About 40% of Mercury’s surface has been measured spectroscopically. Roughly speaking the coverage is of the equatorial and low latitude regions at most, but not all, longitudes.

Mercury’s surface composition is heterogeneous.

Regions west of Caloris have mixed mineralogy and a more complex bulk composition with some basic and ultra-basic regolith types. There is evidence for picrite-like soils at 205 – 240° longitude. According to transparency minima, an ultra-basic composition falls east of Homer crater near 15°. Two measurements indicate that ultra-basic regolith types are located far west of Caloris from about 205° longitude perhaps to as far as 15° longitude.

The picture above is painted in the broadest of strokes with the areal extent of the spatial footprint no smaller than 200 km by 200 km for the very best spatially resolved observations [12] and as much as 1000 km by 1000 km for the least spatially resolved [16]. More observations are called for.

**References:***