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Surface Composition of Mercury from NIR (0.7-4.2 μm) Ground-Based IRTF/SpeX Spectroscopy

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Abstract

On December 16-18, 2018, we obtained global disk-resolved NIR spectroscopic data of Mercury at the Infrared Telescope Facility (IRTF) on Mauna Kea, HI, using the SpeX 0.7-5.3 μm Medium-Resolution Spectrograph and Imager. During the observation, Mercury was ~63-70% illuminated. We observed geochemical terrains including high-Mg regions (HMR) where the largest abundances of Ca and S are found (HMR-CaS), northern volcanic plains (NVP), and intermediate terrain (IT) [1] in the spectral region spanning 0.6 – 4.2 μm. These observations will not only yield new information of the surface mineralogy of Mercury for different geochemical terrains but will also help improve our preparations and planning for BepiColombo data acquisition and science for both spectroscopy and thermal inertia studies.

1. Introduction

MESSENGER data revealed that Mercury's surface is rich in Mg but poor in Al and Ca compared to terrestrial or lunar crustal materials [2] and is composed of various geochemical terrains with considerable differences in the mineral composition and abundances among different terrains [1, 3].

On October 20, 2018, ESA/JAXA's BepiColombo mission was successfully launched to Mercury. Part of its payload is the visible-infrared (V-NIR) spectrometer VIHI as part of the SIMBIO-SYS suite. VIHI covers the spectral region from 0.4 – 2 μm. In contrast, MESSENGER's Mercury Atmospheric and Surface Composition Spectrometer (MASCS), mapped Mercury only in the wavelength range from 0.4 to 1.45 μm [4]. Both these spectrometers do not cover the spectral regions longward of 2 μm as thermal emission from the hot surface of Mercury during daytime starts to contribute longward of ~1.5 μm. However, for Mercury the 0.7 – 4.2 μm spectral region encompasses characteristic spectral features such as (1) reflectance absorptions due to the Fe^{2+} electronic transfer in mafic silicates near 0.9 and 2.0 μm, and (2) volume scattering emission features longward of 2.8 μm, particularly important for understanding the iron-poor lithology of the planet [5]. Therefore, this study enables us to re-visit Mercury's geochemical terrains for its surface mineralogy beyond the 2 μm spectral region.

2. Telescope Facility

In this study, we obtained NIR spectra with almost complete longitude coverage of the surface of Mercury using SpeX, which is a 0.7 – 5.3 μm spectrograph on NASA's Infrared Telescope Facility (IRTF) on Mauna Kea, upgraded in 2014 (http://irtfweb.ifa.hawaii.edu/~spex/). Among the different spectral modes, in this study we used both the SXD mode, which covers the 0.7 – 2.55 μm range at a spectral resolution of R~2000, and the LXD_short mode, covering the 1.67 – 4.2 μm spectral range at a spectral resolution of R~2500. Both modes have a slit width and height of 0.3x15".

3. Data Acquisition

Due to the small elongation angle of Mercury with respect to the sun, it is favorable to perform ground-based observations of Mercury during daytime. This is, however, not possible with many telescopes [6]. In this study, however, because of the unique daytime capabilities of the IRTF, we obtained observations during daytime on three consecutive days from 16-18 Dec 2018. At the time, Mercury was illuminated by ~63-70%.

For each spectral mode, the spectrograph slit (0.3x15") was placed perpendicular to the central meridian near the poles, and after each spectral measurement the slit was moved systematically step-by-step across Mercury's disk from pole to pole to cover the entire surface, thereby producing global coverage for our NIR spectra. In order to remove the telluric absorption bands, standard stars corresponding to the spectral mode were analyzed simultaneously.

4. Calibration

The surface temperature (Fig. 1b) according to the approach of [7] with a grossly estimated directional-hemispherical albedo of 0.04 and resulting radiance spectra (Fig. 1c) have been calculated for geometry encountered during our observations, assuming a piecewise linear uniform surface reflectance approximating the measurements in [8] (Fig. 1a).

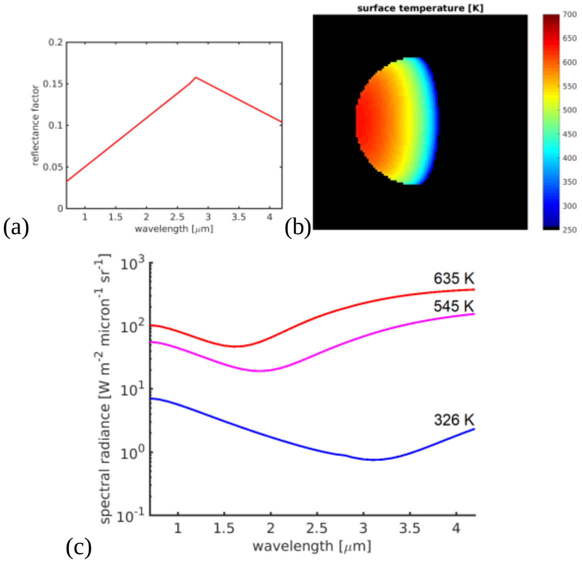

Figure 1: (a) Assumed surface reflectance. (b) Simulated surface temperature distribution over the Mercury disk during the observation. (c) Simulated radiance spectra derived for the indicated surface temperatures.

The pronounced minimum seen in Fig. 1c shows where the contributions from reflectance and thermal emission are identical and also shows that thermal contributions/thermal emissivity start at shorter wavelengths for the surfaces with higher temperature. Therefore, pixelwise thermal correction is required while calibrating the acquired SpeX data.

5. Data Analysis and Expected Science Return

The data are currently being reduced using Spextool [9] for inherent and thermal corrections and the global spectral characterization of Mercury according to the geochemical terrain of the illuminated region will be presented at the meeting. The SpeX-derived mineralogy beyond 2 µm for these geochemical terrains will help to carefully choose the corresponding Mercury analogues to be studied over a wide spectral range under Mercury's extreme daytime temperature conditions [10]. Such a specialized spectral library will allow for a spectral characterization of previous (MESSENGER) and future datasets (BepiColombo).

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