MACHINE LEARNING APPROACH TO DECONVOLUTION OF THERMAL INFRARED (TIR) SPECTRUM OF MERCURY SUPPORTING MERTIS ONBOARD ESA/JAXA BEPICOLOMBO. I. Varatharajan[1], M. D'Amore[1], A. Maturilli[1], J. Helbert[1], H. Hiesinger[2] [1]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstrasse 2, 12489 Berlin, Germany (indhu.varatharajan@dlr.de), [2] Wilhelms Universität Münster, Germany

Introduction: Spectroscopy is the powerful technique to study the surface mineralogy of any planetary body from its orbit. Spectrometers with wide spectral range, greater spectral and spatial resolution with repeated orbital coverage are helping us to map the surface mineralogy of planets in greater detail. Various spectral ranges tell different stories and properties of the surface we look at. For eg., VIS-IR spectroscopy for a rocky planet would tell us about the distribution of Fe,Ti,Mg,Ca rich minerals for both its igneous and sedimentary phases whereas thermal IR spectroscopy reveals the Si-O abundance on the bulk mineralogy of the pixel we look at. By carefully understanding the spectral behavior of various planetary analogues in laboratory experiments at the planetary surface and environmental conditions, one can map the mineral abundance and distribution globally from orbit.

Challenges in Spectroscopy: Many factors imparts changes to spectral behavior of a mineral such as grain size, phase angle of observation, slope, and abundance of the mineral. Though these factors affecting the spectra can be understood in a controlled environment, the real challenge comes in understanding the spectra can be addressed in two parts: 1. spectral behavior of minerals in their related planetary environment and 2. understanding the mixture spectra containing more than one mineral.

Planetary Spectroscopy Laboratory (PSL): Over the last 10 years the Planetary Spectroscopy Laboratory (PSL) located at the Institute of Planetary Research (PF) at the German Aerospace Center (DLR) in Berlin, Germany has been operating in various configurations to provide emissivity, reflectance, and transmission spectra of various rocks/minerals for the study of planetary and minor bodies surfaces [1,2,3,4].

PSL operates two identical FTIR (Fourier transform infrared) spectrometers (Bruker Vertex 80V); one spectrometer is equipped with aluminum mirrors optimized for spectral measurements in the ultraviolet (UV), visible and NIR (near infrared) wavelength region (say, 0.2 – 25 μm), and the second one is equipped with gold-coated mirrors optimized for measurements in near- to far-IR spectral range (1 - 100 μm) (Fig. 1). Both the spectrometers use a Bruker A513 variable-angle reflection accessory allowing biconical reflectance measurements under vacuum conditions for phase angles between 26° and 170° (Maturilli et al., 2014). The second spectrometer is also attached to an external chamber for direct emissivity measurements by heating the samples under vacuum to required temperature (~320 K – 1000 K) using a high efficiency induction heating system. The emissivity chamber is equipped with temperature sensors (thermopiles) for tracking the temperature of the sample and the surrounding environment during the measurements along with a webcam for monitoring the experiment. Thermal infrared spectral studies of a variety of mineral analogues to Mercury and other planetary bodies have been conducted in varying temperature conditions at PSL using this facility [5].

Figure 1. Laboratory set-up at PSL

Approach: The Mercury Radiometer and Thermal Imaging Spectrometer (MERTIS) payload of ESA/JAXA BepiColombo mission to Mercury will map the thermal emissivity at wavelength range of 7-14 μm and spatial resolution of 500 m/pixel [6]. Mercury was also imaged at the same wavelength range using the Boston University's Mid-Infrared Spectrometer and Imager (MIRSI) mounted on the NASA Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii with the minimum spatial coverage of 400-600 km/spectra which blends all rocks, minerals, and soil types [7] (Fig. 2). Therefore, the study [7] used quantitative deconvolution algorithm developed by [8] for spectral unmixing of this composite thermal emissivity spectrum from telescope to their respective areal fractions of endmember spectra; however, the thermal emissivity of endmembers used in [7] is the inverted reflectance measurements (Kirchhoff's law) of various samples measured at room temperature and pressure.

This compels us to re-examine the results by only considering the endemember spectra measured from simulated environment of Mercury.

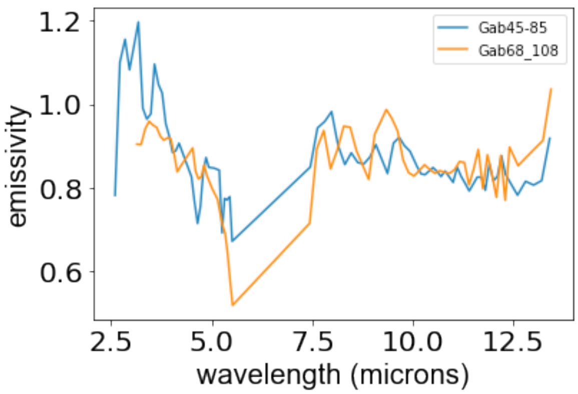

Figure 2. Telescopic spectra of Mercury [7]

Over a decade, the Planetary Spectroscopy Laboratory (PSL) facilitates the thermal emissivity measurements under controlled and simulated surface conditions of Mercury by taking emissivity measurements at varying temperatures from 100° to 500°C under vacuum conditions supporting MERTIS payload. The measured thermal emissivity endmember spectral library therefore includes major silicates such as bytownite, anorthoclase, synthetic glass, olivine, enstatite, nepheline basanite, rocks like komatiite, tektite, Johnson Space Center lunar simulant (1A), and synthetic powdered sulfides which includes MgS, FeS, CaS, CrS, TiS, NaS, and MnS. Using such specialized endmember spectral library created under Mercury's conditions significantly increases the accuracy of the deconvolution model results.

In this study, we revisited the available telescope spectra and redeveloped the algorithm by [8] by only choosing the endmember spectral library created at PSL for unbiased model accuracy with the RMS value of 0.03-0.04. Currently, the telescope spectra are investigated for its calibrations. Also, machine learning and Monte Carlo method is being studied for effective selection of endmembers from the large endmember spectral library of PSL and the results will be presented at PSIDA.

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