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Deconvolution of Mid-Infrared Telescope Spectra of Mercury using Machine Learning: Supporting MERTIS onboard ESA/JAXA BepiColombo mission

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Abstract

The Mercury Radiometer and Thermal Imaging Spectrometer (MERTIS), onboard the ESA/JAXA BepiColombo mission to Mercury, will map the thermal emissivity at wavelength range of 7-14 µm (mid-infrared; MIR) and a spatial resolution of 500 m/pixel [1].

Mercury has been studied via MIR spectroscopy from ground/telescopic observations over three decades [2-8]. However, the total number of observations made is still quite small (Fig. 1). Over the past decade, the Planetary Spectroscopy Laboratory (PSL) at German Aerospace Center (DLR) Berlin obtained experimentally thermal emissivity measurements of analog materials under controlled and simulated surface conditions of Mercury from 100° to 500°C under vacuum conditions in support of MERTIS (Fig. 2) [9]. Using a specialized endmember spectral library created under Mercury's conditions will increase significantly the accuracy of the deconvolution model results of not only MERTIS but also telescopic observations of Mercury.

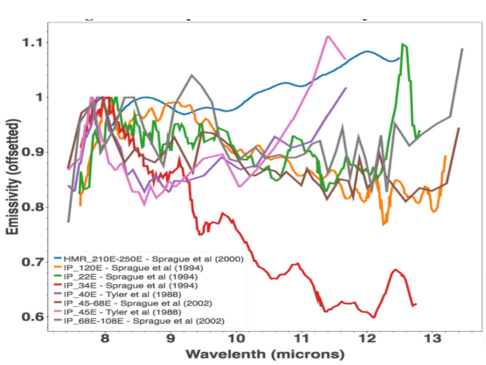

Figure 1: Published telescope spectra [3-8], digitised by the author [12].

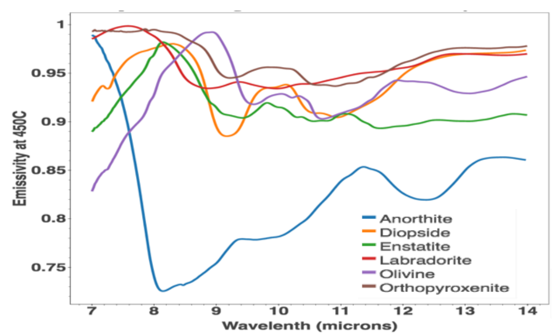

Figure 2: MIR spectra of analogue minerals under simulated conditions of Mercury at PSL.

1. Introduction

Spectroscopy is powerful technique to study the surface mineralogy of any planetary body from its orbit. By carefully understanding the spectral behavior of various planetary analogues in laboratory experiments at the planetary surface and environmental conditions, the mineral abundance and distribution globally can be mapped from orbit.

1.1 Challenges in Spectroscopy

Many factors influence the spectral behavior of a planetary surface 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 remote sensing spectra and can be split in two main parts: 1. spectral behavior of minerals in their related planetary environment, 2. understanding the mixture spectra from mineral assemblages.

2. Methods

In this study, we revisited the available telescope spectra and adapted the algorithm by [10,11] by only choosing the endmember spectral library created at PSL for unbiased model accuracy. The unmixing algorithm is based on a least square inversion of the system, Y = AX, where Y is a vector containing the telescope spectrum, A is a NxM matrix filled with the endmembers spectra (N) number of endmembers and M is a the number of spectral channels), and X is a vector containing the coefficients of each components of the input library. The solution of this linear system is given by,

$$X = (A^T A)^{-1} A^T Y \qquad (1)$$

As we have a large endmember library, the selection of set of endmembers (A) is carried out by systematic exploration of whole set of combinations of four components, i.e., ${}^{N}C_4$ = N!/(4! x (N-4)!). The final accuracy of the linear fit is evaluated by computing the χ^2 residuals between the model and the data and the endmember combination giving the minimum χ^2 is the best fit to the telescope spectra. This spectral unmixing method is successfully tested on the powdered samples which include endmembers and their mixed proportion, see Fig. 3.

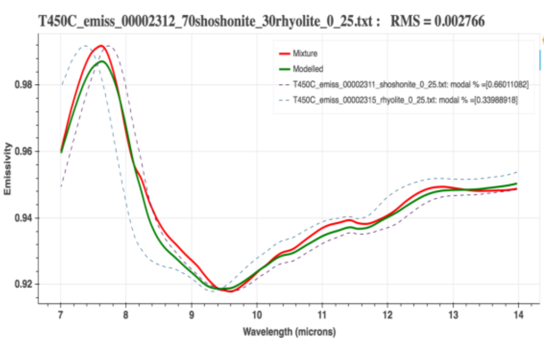

Figure 3: Linear unmixing algorithm is applied to laboratory sepctra of the mixture (solid red) containing 70% shoshonite and 30% rhyolite; and the resulting modelled spectra (green spectra) estimates to 66% shoshonite and 34 % rhyolite with RMS of 0.003.

3. On-going work

Comparison of different spectral unmixing algorithms (Monte Carlo – Bayesian algorithm, and genetic algorithm) is being tested to increase the confidence of unmixing results of the endmember counterparts.

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