

Spectral reflectance library of Mercury analogue materials and the role of viewing geometry in analysis of remote TIR emission spectra

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Abstract

We present our spectral reflectance library of natural and synthetic Mercury analogue materials, collected to support the development/data analysis of the MERTIS instrument onboard the ESA's BepiColombo mission. In particular, we demonstrate that viewing geometry of supporting laboratory reflectance measurements is critical for the correct analysis of the TIR spectra of the hermean surface, expected from the MERTIS spectrometer. The issues discussed here are equally valid for all other spacecraft and groundbased TIR observations of planetary surfaces.

1. Introduction

MERTIS (Mercury Thermal Infrared Imaging Spectrometer) is a part of ESA's BepiColombo mission payload [1] and will map Mercury's surface from 7 to 14 μm with high spatial resolution. Interpretation of TIR remote spectra of planetary surfaces involves spectral deconvolution procedures helping to extract compositional and mineralogic information. Such an analysis requires the use of a TIR spectral library, ideally consisting of the laboratory emission spectra of end-member components (minerals, glasses) of suitable particle sizes, and acquired at suitable viewing geometries, temperatures and pressures. Such a challenging spectral emission library is being created at the Planetary Emission Laboratory (PEL) in Berlin [2]. In reality, however, the available amount of an analogue material is often insufficient to perform reliable spectral emission measurements. This especially concerns synthetic minerals, pure natural minerals free of inseparable accessories, meteorite

separates, products of space weathering- or shock laboratory simulations. In the latter cases, one has to use the available reflectance spectra (converted to emission via Kirchhoff's law) as the "end-member components" for spectral deconvolution. Therefore, it is important to understand the limitations of this approach. Salisbury [3] concluded that laboratory reflectance spectra of quartz powders and slabs, recorded at biconical viewing geometry could not be successfully converted to spectral emissivity, while the hemispherical TIR reflectance measurements showed much smaller discrepancies with the measured emission spectra. We obtained the opposite results, showing that our own inverted biconical reflectance spectra of Mercury analogue minerals and quartz powders did not show systematic deviations from the measured normal emissivity of the same samples, at least at ambient temperatures and pressures [4]. The contrasting differences between the Salisbury's and our conclusions will be addressed and explained in this presentation.

Although MERTIS spectrometer will perform between 7 and 14 μm , we acquire biconical reflectance spectra of Mercury analogue materials in the wide spectral range (0.4-25 μm). This will enable us (1) to set additional constraints on the future fits to the MERTIS spectra (since the Hermean surface spectra are featureless or nearly-featureless in the visible and near-infrared); (2) to detect/characterize minor impurities/accessories in the samples; (3) to provide cross-calibration with other instruments onboard BepiColombo (SYMBIO-SYS) and MESSENGER (MASCS).

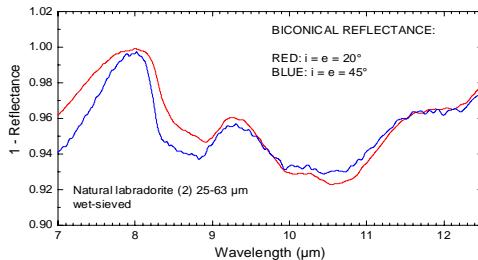


Figure 1: Biconical reflectance spectra of a labradorite wet-sieved separate, acquired at two different viewing geometries.

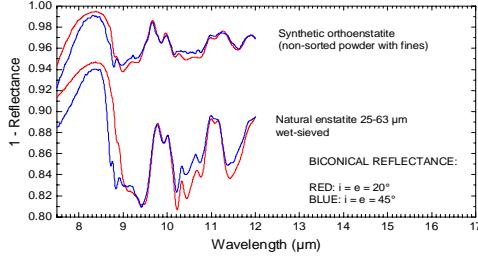


Figure 2: Biconical reflectance spectra of enstatite wet-sieved separates, acquired at two different viewing geometries.

2. Experimental

We measured biconical reflectance spectra of selected Mercury analogue materials from [5] (selected feldspars, pyroxenes, olivine, elemental S and the Apollo 16 lunar highland soil 62231). We ground and sieved the samples to size fractions of <25, 25-63, 63-125, and 125-250 μm (except for the lunar soil). The separates >25 μm were wet-sieved. The samples were characterized in terms of chemistry, mineralogy, and grain size distributions. Biconical reflectance spectra were acquired from 0.5 to 18 μm at the DLR Institute of Planetary Research using a Bruker IFS88 FTIR-spectrometer. Biconical reflectance measurements (0.4-25 μm) of synthetic Fe-free silicates (pyroxenes, feldspars and forsterites) and the viewing geometry tests were performed using a Bruker VERTEX 80v FTIR- and an Ocean Optics USB 4000 spectrometers at the Helmholtz Centre

Berlin for Materials and Energy. All the spectra were measured using “Seagull™”, variable angle biconical reflectance accessories.

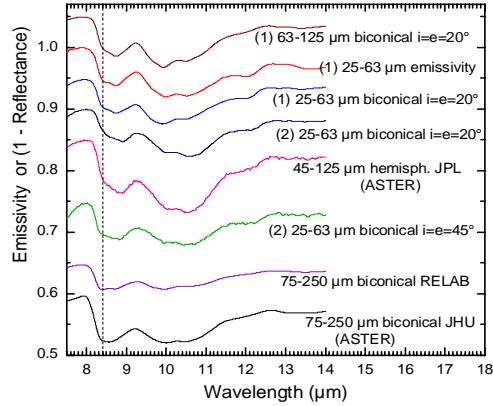


Figure 3: Inverted reflectance spectra of coarse labradorite separates, acquired at different viewing geometries and compared to an emission spectrum taken at temperature of 90° at normal emission angle (see [6] for details). (1) and (2) are different labradorite samples. Note that the observed spectral differences are not due to grain size variations, because TIR spectra of coarse wet-sieved separates do not show significant spectral variations in the Reststrahlen region.

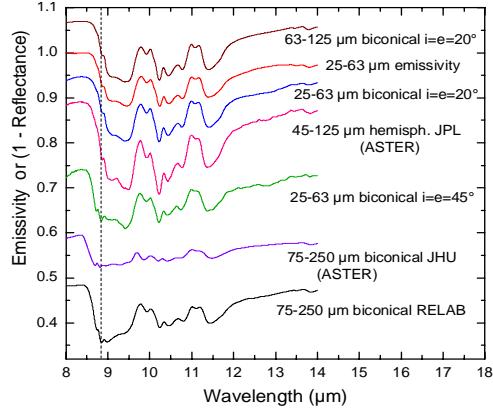


Figure 4: Inverted reflectance spectra of coarse enstatite separates, acquired at different viewing

geometries and compared to an emission spectrum taken at temperature of 90° at normal emission angle.

3. Effects of Viewing Geometry on TIR spectra

Although mineralogy of Mercury is poorly understood, a mixture of labradorite feldspar with enstatite provided the best fits to the telescopic TIR observation of Mercury [7] and might be major silicate constituents of its surface. Figs. 1 and 2 show our biconical reflectance spectra of labradorite and enstatite powders (25-63 μm) recorded at relatively small average phase angle of 40° ($i=e=20^\circ$) and a larger phase angle of 90°. The spectral shapes change significantly with increasing phase angle especially in the vicinity of Christiansen features. Physical reasons for these effects will be discussed in this presentation. One can see (Figs. 3, 4 – red and blue curves) that the emission spectra (taken at normal emission angle) are similar in shape and contrast to the biconical spectra of the same samples acquired at relatively small phase angles of 40°. Hemispherical reflectance spectra of somewhat coarser labradorite and enstatite powders show comparable shapes, but demonstrate some mild contribution from larger phase angles. In contrast, the reflectance spectra taken using some other biconical attachments, where the phase angle is fixed and the detected radiation shows high contribution from near-grazing angles, are significantly different from TIR emission measured at normal angles of emission. The RELAB TIR spectra and the spectra from [8], included into the ASTER spectral library as “JHU bidirectional reflectance spectra” were measured at such viewing geometries. Therefore, in cases, where real emission spectra are unavailable, biconical reflectance spectra can be converted to TIR emissivity, if they are measured at reasonably small phase angles, using variable angle biconical reflectance attachments. The phase angles effects addressed here are not distortions typical only for reflectance and have nothing to do with possible deviations from Kirchhoff's law. They are also observed in TIR emission spectra taken at large emission angles [e.g., 9]. Thus, the TIR biconical spectra from RELAB and ASTER libraries may be useful to predict spectral shapes observed by TIR emission spectrometers onboard spacecraft/rovers at grazing emission angles. If nadir emission observations are planned, like in the case of MERTIS, one should avoid using such biconical data as end-member spectra for

deconvolution procedures. It should be noted, however, that not all minerals are strongly affected by the spectral effects observed in the TIR at large phase angle.

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