UNMIXING OF LABORATORY IR SPECTRAL REFLECTANCE MEASUREMENTS OF LOW-MG NORTHERN VOLCANIC PLAINS ANALOGS. K. E. Bauch[1], A. Morlok[1], H. Hiesinger[1], M. P. Reitze[1], N. Schmedemann[1], A. N. Stojic[1], I. Weber[1], J. H. Pasckert[1], M. D'Amore[2], J. Helbert[2], A. Maturilli[2], K. Wohlfarth[3], C. Wöhler[3], [1]Institut für Planetologie (IfP), Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (karinbauch@uni-muenster.de), [2]DLR-Institute for Planetary Research, Rutherfordstrasse 2, 12489 Berlin, Germany, [3]Image Analysis Group, TU Dortmund University, Otto-Hahn-Str. 4, 44227 Dortmund, Germany.

Introduction:

The MErcury Radiometer and Thermal Infrared Spectrometer (MERTIS) is part of the payload of ESA/JAXA's BepiColombo mission, launched in October 2018 [1-4]. MERTIS will observe the surface of Mercury in the wavelength range of 7 µm to 14 µm (IR spectrometer) and 7 µm to 40 µm (radiometer) [1,3]. This range covers several spectral features, such as the Christiansen feature (CF), Reststrahlen bands (RBs), and Transparency feature (TF), which allow the determination of Mercury's surface mineralogy.

MERTIS' scientific objectives [1,3] are to

a) study Mercury's surface composition,

b) identify rock-forming minerals,

c) globally map the surface mineralogy, and

d) study surface temperature and thermal inertia.

During its cruise to Mercury, the spacecraft has already completed five swing-by maneuvers at Earth/Moon (2020), Venus (2020&2021), and Mercury (2021&2022). In the following years it will perform further swing-by maneuvers at Mercury [4].

MERTIS already operated during the first swing-by maneuvers and acquired thermal infrared spectra of the lunar surface and Venus. Thus, these flybys offered the first opportunity to test the instrument under 'real' planetary observation conditions and allowed a first in-flight calibration [4-6].

Starting orbital measurements in 2026, MERTIS will be the first instrument to observe the surface of Mercury in the IR wavelength range [3]. The current knowledge of IR spectroscopy of Mercury is based on terrestrial telescopic observations [7]. Based on observations from the MESSENGER spacecraft several chemically distinct regions have been identified: Low-Mg Northern Volcanic Plains (Low-Mg NVP), High-Mg NVP, Smooth Plains (SP), Inter Crater Plains and Heavily Cratered Terrains (IcP-HCT), and High-Mg Province [8].

The surface rocks are composed of a variety of different minerals. The ~500 m/pixel ground resolution of MERTIS will therefore depict a mixture of these minerals. In order to quantify the mineral abundances, we use a non-linear unmixing model, based on the Hapke reflectance model [9,10]. The "single-scattering albedo" describes the intrinsic reflectivity of an average single surface [9]. Multiple scattering within a surface is governed by the incidence and emission angle, which also depends non-linearly on the single-scattering albedo. The scattering behavior of an individual particle is described by a "single-particle scattering function". The full set of equations is provided by [9].

The unmixing model we use in this study has previously been used for spectral unmixing of NASA RELAB data [11] and lunar analog materials [12]. In the framework of MERTIS it is applied to laboratory mineral mixtures, including glasses and varying grain sizes [13-16].

IR spectroscopy:

The mineral mixtures were prepared and analyzed at the IRIS (Infrared and Raman for Interplanetary Spectroscopy) laboratory of the Institut für Planetologie at the Westfälische Wilhelms-Universität Münster [3]. Here we investigate a wide range of natural minerals, rock samples (including impact rocks and meteorites), synthetic analogs, and glasses [3,7,8,17]. With the results of these investigations we established a mid-IR reflectance database, which covers the wavelength range from 2 µm to 18 µm (http://bc-mertis-pi.uni-muenster.de/). This database enables the qualitative, but also quantitative interpretation of future MERTIS spectra once in orbit around Mercury.

At the IRIS laboratory, powder size fractions smaller than 25 µm, 25 µm to 63 µm, 63 µm to 125 µm, and 125 µm to 250 µm are analyzed in addition to thin section and pressed pellets. Every sample receives a unique ID. Powder samples are placed in aluminum cups and analyzed by a Bruker Vertex 70v infrared spectrometer. The use of an A513 variable mirror reflectance stage allows various orbital geometries. For this mineral unmixing analysis we present results of the 63 µm to 125 µm grain size fraction and 20° incidence (i) and 30° emergent (e) angle measurements. After background calibration using a commercial diffuse gold standard (INFRAGOLD™), a total of 512 scans for each analysis were integrated to ensure high signal-to-noise ratios [6].

Samples:

Previous studies identified chemically different regions on the surface of Mercury. Here we focus on analogs of Low-Mg NVP [8,19]. Detailed information about chemical bulk compositions of the endmembers and modal mixtures can be found in [8]. The following endmembers were used to derive mineral mixtures

- diopside from Otter Lake, Quebec,

- labradorite from Ihosy, Madagascar,
- olivine from Dreyser Weiher, Germany,
- and synthetic Low-Mg glass, based on studies by [18,8].

Results:

Reflectance spectra of the endmembers and their mixtures are shown in Figure 1 for the grain size fractions 63 µm to 125 µm. A detailed description and spectra of other grain size fractions is given by [8,19].

ID349 is dominated by glassy material (86.9%), thus showing a relatively simple spectrum with few bands. The CF is between 7.8 µm and 7.9 µm, and the TF is at 11.6 µm. It shows olivine RBs at 9.4 µm and 9.5 µm, and minor features at 10.2 µm, and between 10.5 µm and 10.6 µm.

The spectrum of ID350 (lower glass content) shows the CF between 7.8 µm and 8.1 µm. Several pyroxene RBs are located at 9.4 µm, 9.9 µm, 10.2 µm, and between 10.5 µm and 10.6 µm, and at 10.8 µm and the TF between 11.3 µm and 11.5 µm.

Results of the spectral unmixing procedure of the mixtures are summarized in Table 1.

Summary & Conclusions:

The quantitative analysis of Low-Mg NVP analog ID350 (lower glass content) shows good agreement with the actual proportions of the mixture.

However, the unmixing of ID349 (high glass content), which shows relatively few features results in an overestimation of the glassy material. The other components could be identified, but show deviations from the actual fractions.

These results show that further studies of mineral mixtures including further minerals, but also varying amounts of glasses are needed. These studies will include other terrane analogs of Mercury [8].

With ongoing calibration of MERTIS data, our unmixing routine can also be applied to quantitatively interpret the spectra from the past lunar and hopefully also further swing-by maneuvers at Mercury, and finally orbital measurements, starting in 2026.

Table 1 Spectral unmixing results of Low-Mg NVP analog mixtures. Actual fractions of the mixtures are written in italics.

	ID349		ID350	
	actual	computed	*actual*	computed
Diopside	*4.9%*	2.2%	*17.1%*	22.8%
Plagioclase	-	-	*39.1%*	37.2%
Forsterite	*8.2%*	2.7%	*14.3%*	11.6%
Glass	*86.9%*	95.1%	*29.5%*	28.3%

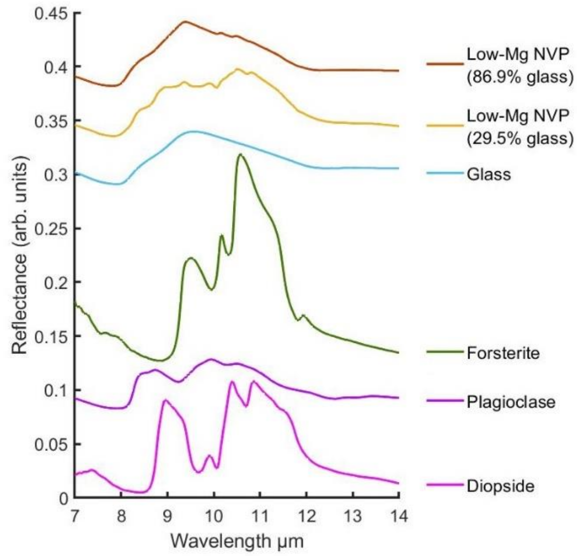

Figure 1 IR reflectance spectra of endmembers and Low-Mg NVP analog mixtures in the MERTIS-relevant wavelength range between 7 µm and 14 µm for 20°(i)/30°(e) for the grain size fraction 63 µm to-125 µm.

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