**MERTIS SEEING THE MOON IN THE TIR: RESULTS FROM THE FIRST BEPICOLOMBO FLYBY.** A. Maturilli[1], J. Helbert[1], H. Hiesinger[2], G, Alemanno[1], S. Schwinger[1], M. D'Amore[1], A. Neumaier[1], [1]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, 12489 Berlin, Germany (alessandro.maturilli@dlr.de), [2]Wilhelms Universität Münster, Germany.

**Introduction:** The Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS) is part of the ESA BepiColombo Mercury Planetary Orbiter (MPO) payload and consists of a push-broom IR-spectrometer (-TIS) and a radiometer (-TIR) [1]. MERTIS-TIS and -TIR make use of the same optics, electronics, and in-flight calibration components [2, 3]. MERTIS-TIS operates at wavelengths of 7-14 µm, has 78 spectral channels, and a spectral resolution of $\lambda/\Delta\lambda$=78-156. The radiometer operates between 7 and 40 µm with 2 spectral channels. Depending on surface characteristics, MERTIS spectral resolution is adapted to optimize the S/R ratio. Thus, the instrument is capable of resolving weak spectral bands with less than 1% contrast.

During the long cruise to Mercury, and before its arrival on December 5th 2025, BepiColombo will perform 9 flybys: among them, the Earth/Moon flyby on April 10$^{th}$ 2020. Due to the flight configuration, not all the instruments onboard BepiColombo are able to operate during cruise and flybys. Among the instruments that can operate is MERTIS. The MERTIS imaging spectrometer will provide the first hyperspectral observation of the Moon in the thermal infrared (TIR) wavelength range from space.

At the Planetary Spectroscopy Laboratory (PSL) of DLR in Berlin, a spectral library for lunar analog rocks in the TIR spectral range, measured under simulated Moon surface conditions, has been built to help the interpretation of MERTIS' Moon spectra.

**BepiColombo Earth/Moon flyby:** Shortly after launch, MERTIS underwent a Near-Earth Commissioning Phase on Nov. 13-14 2018 during which the instrument was turned on for the first time in space. The goal of this phase was to verify the instrument functionality and science performance by using the in-flight calibration devices and to verify their performance. As a result of the commissioning, MERTIS was found to be fully operational [4]. The radiometer was also found fully functional with an excellent correspondence of the 2013 preflight sensitivity measurements and the 2018 in-flight measurements.

Although most instruments on the BepiColombo MPO are blocked by the Mercury Transfer Module (MTM) during cruise and flyby operations, including the MERTIS planetary baffle, MERTIS will be able to acquire data through its space baffle. In fact, the MERTIS pointing device allows viewing the planet (planet-baffle), deep space (space-baffle), and two internal black bodies at 300 K and 700 K temperature, respectively. We adapted the MERTIS operations software to allow for this unique opportunity. Especially the Earth/Moon fly-by is of interest, as the surface composition of the Moon and Mercury have been frequently compared in the literature [5-10]. Observing the Apollo and Luna landing sites with MERTIS, in combination with laboratory studies, will provide extremely valuable ground truth for our MERTIS measurements.

The attitude profile for the flyby has been already generated by ESA Mission Control. The time allocated for MERTIS pointing to the Moon is 4 hours and starts 1 day before closest approach. During this slot it is feasible to have the Moon in the FoV of MERTIS. The 4 hours visibility slot is divided in 4 segments of 1 hours approximately connected by short slews. The attitude in each segment will be quasi inertial (no tracking, keeping the Sun within illumination constraints) with the Moon slowly drifting in the FoV such that it is aligned with the boresight right in the middle of the segment. Within the 4 hours allocated for observations the Moon is nearly fully illuminated; the angle between Moon and Earth (from limb to limb) is 8.5 in the beginning and increases up to 10.64 degrees; the apparent size of the Moon starts at 0.268 degrees and increases up to 0.2927 degrees. The Moon moves 1.6 degrees in these four hours.

**Lunar surface analogs:** In the last decades orbital spectroscopic observations of the lunar surface have greatly advanced our understanding of the global distribution of different rock types and their chemical compositions. This vast dataset is now complemented by the first in situ reflectance spectra from the lunar surface obtained by the recent Chang'E 3 and current Chang'E 4 missions, which provide more detailed information about the mineralogy of local surface materials and the geological context of the landing sites.

The material analyzed by Yutu-2 at the Chang'E 4 landing site includes not only regolith but also a fragment of rock with a small- to medium grained plutonic texture, that has most likely been excavated by a nearby impact crater [11]. Due to its deep-seated origin, the composition of such a rock fragment is of particular importance for understanding the underlying stratigraphy of the landing site.

A reliable quantification of mineral modal abundances from measured reflectance spectra requires the availability of laboratory spectra of comparable samples. However, current spectral databases primarily contain spectra measured on powder samples, while spectra of coarse grained rock samples are rare. Since reflectance spectra are sensitive to grain size and surface roughness [12], the available powder spectra might not be sufficient for a quantitative interpretation of measured rock spectra.

Rock samples obtained during the Apollo missions indicate that lunar anorthosites are typically coarse grained and can reach grain sizes of more than 1 cm. Hence, the global abundance of anorthosite as the dominant rock type of the lunar surface suggests that such coarse grained rocks are ubiquitous.

Therefore the extension of the current spectral databases by new spectral data of whole rock samples is crucial for the interpretation of current remote and in-situ measurements.

**Set-up description:** The Planetary Spectroscopy Laboratory (PSL) of DLR in Berlin is a spectroscopy facility providing spectral measurements of planetary analogues from the visible to the far-infrared range for comparison with remote sensing spacecraft/telescopic measurements of extraterrestrial surfaces [13-17]. Three identical FTIR instruments are operating at PSL, in an air-conditioned room (Figure 1). The spectrometers are Bruker Vertex 80V (high-end model) that can be evacuated to ~.1 mbar. One spectrometer is equipped with aluminum mirrors optimized for the UV, visible and near-IR, the second features gold-coated mirrors for the near to far IR spectral range.

**Spectral measurements:** External simulation chambers are attached to the FTIR spectrometer to measure the emissivity of solid samples. One chamber features a high efficiency induction system to heat the samples under vacuum to temperatures from 320K up to above 900K, while keeping the chamber at almost ambient temperature. A shutter allows separating the spectrometer from the external chamber. Sample cups are made of stainless steel and have elevated rims enclosing the samples heating it from all sides, effectively supressing thermal gradients within. A sample carousel driven by a highly precise stepper motor allows measuring several consecutive samples without breaking the vacuum. A large number of temperature sensors in the emissivity chamber are allocated to measure the sample temperature as well as monitoring the range of equipment and chamber temperatures. A webcam is mounted in the emissivity chamber to monitor the heated sample and its vicinity.

With the Bruker A513 accessory bi-directional reflectance of samples, with variable incidence and emission angles between 0° and 85° (minimum phase angle is 26°) is measured. Integrating spheres (with gold or PTFE mirrors) allow for hemispherical reflectance measurements. Bi-directional and hemispherical reflectance are measured under purging or vacuum conditions, covering the 0.2 to above 200 µm spectral range.

**Sample preparation and measurements:** The initial suite of samples selected for this work includes: -slabs and stone chunks of plagioclases bearing rocks such as anorthosite, diorite, monzodiorite, gabbro and diabas; several basalts, rhyolite, olivine, granite, andesite, labradorite, obsidian.

Samples are placed in the emissivity chamber at PSL and heated in vacuum slowly and gradually up to 400° C. Measurements were taken at 100° C, 200° C, 300° C and 400° C in the MIR and FIR spectral ranges.

Each sample has been cooled in vacuum down to $T_{room}$. Thermally processed samples are measured in hemispherical and bi-directional reflectance in the full spectral range from UV to FIR.

A sample of graphite measured in emissivity at increasing T, adopting the same configuration and procedure used for the samples was used as blackbody for emissivity calibration.

**Conclusion:** MERTIS on ESA BepiColombo will be the first instrument to obtain hyperspectral measurements of the Moon in the TIR spectral range from space. Here we present the first results combined with a spectral library of emissivity for lunar analog rocks measured under simulated Moon conditions.

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