BepiColombo & MERTIS @Moon: A very first comparison of mid-infrared (7-14 µm) spectra. Andreas Morlok[1], Bernard Charlier[2], Maximilian P. Reitze[1], Christian Renggli[3], Stephan Klemme[3], Olivier Namur[4], Martin Sohn[5], Dayl Martin[6], Iris Weber[1], Aleksandra N. Stojic[1], Karin E. Bauch[1], Kay Wohlfarth[7], Christian Wöhler[7], Katherine H. Joy[8], Roy Wogelius[8], Christian Carli[9], Harald Hiesinger[1], Joern Helbert[10], [1]Inst. für Planetologie, Wilhelm-Klemm-Strasse 10, 48149, Germany [2]University of Liege, Dep. of Geology, 4000 Sart-Tilman, Belgium [3]Institut für Mineralogie, Corrensstrasse 24, 48149 Münster [4]Dept. of Earth and Environmental Sciences, KU Leuven, 3001 Leuven, Belgium [5]Hochschule Emden/Leer, Constantiaplatz 4, 26723 Emden, Germany [6]Martin European Space Agency, Fermi Avenue, Harwell Campus, Didcot, Oxfordshire, OX11 0FD, UK [7]Technische Universität Dortmund 44221 Dortmund [8]School of Earth and Environmental Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL,UK [9]IAPS-INAF, Rome, Italy [10]Inst. for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany.

Introduction: The purpose of the IRIS (Infrared and Raman for Interplanetary Spectroscopy) laboratory at the Institut für Planetologie in Münster is to produce spectra of analog materials for the ESA/JAXA BepiColombo mission to Mercury [1,2]. The mid-infrared spectrometer MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer) will map spectral features in the 7-14 µm range, with a spatial resolution of ~ 500 meters [1,2]. These infrared features will permit the large scale determination of Mercury's surface mineralogy.

Since the inception of the IRIS laboratory, we have studied a wide range of natural mineral and rock samples such as impact rocks and meteorites under varying conditions [e.g. 3-5]. Synthetic glasses mimicking compositions measured by MESSENGER and laboratory experiments were also studied [6-9]. The lunar flyby of BepiColombo in April 2020 provided a first opportunity to test the instrument under 'real' planetary (actually even more difficult compared to the final Mercury orbit) observation conditions. It is also an opportunity to compare the spectral data accumulated so far for the IRIS database with real mission results.

Samples & Techniques:

Samples: Spectra selected to interpret the lunar flyby measurements are pure mineral end-members based on known lunar soil composition (i.e. anorthite and enstatite) [10]. Since pure end-members probably do not reflect the characteristics of the complex lunar regolith, we also analyzed Apollo samples. Furthermore, synthetic analogs for the Moon are considered to cover compositional gaps as well as to integrate the composition of larger areas. These are glasses based on bulk compositions of lunar highlands, mares and bulk silicate moon. Synthetic analogs with mafic compositions are also considered [11,12]. Finally, synthetic/terrestrial feldspars are used as analogs for the highland spectra.

Infrared Spectroscopy: For the bulk powder FTIR diffuse reflectance analyses, powder size fractions of all presented samples (0-25 µm, 25-63 µm, 63-125 µm, and 125-250 µm, and sometimes larger) were measured.

For mid-infrared analyses from 2-20 µm, we used a Bruker Vertex 70 V infrared system with a MCT detector at the IRIS laboratory. Analyses were conducted under 10^{-3}bar to reduce atmospheric bands. Expected features are the Christiansen Feature (CF), a characteristic reflectance low, the Transparency Feature (TF) typical for the finest size fraction and the Reststrahlen Bands (RB), the vibrational modes of the materials.

FTIR microscope analyses of spots in polished blocks and thin sections of some samples were conducted on the experimental runs using a Bruker Hyperion 1000/2000 System at the Hochschule Emden/Leer. We used a 250×250 µm sized aperture. A Perkin-Elmer Spotlight-400 FTIR spectrometer at the University of Manchester was used to map samples using an adjoining Focal Plane Array (FPA) mapping unit with a resolution of 6.25 µm × 6.25 µm in the reflectance mode.

Lunar Spectra: Lunar spectra were extracted and stacked from the flyby data. Spectra typical for the highland regions are averages from a southern central highland region centered around Abenezra crater. The Mare regions were extracted from data of the Central Imbrium region**.** The emission data is calculated in reflectance like the laboratory data, using Kirchhoff's law (R=1-E).

Results & Comparison:

Highlands: The mean lunar Highland MERTIS-spectrum (Figure 1) features potential RBs at ~7 and ~9 µm, and at 10.3 µm, 11.2 µm, and 11.7 µm. Further potential TF are at 12.6 – 13.1 µm. A unclear CF is at ~9 µm, which would point towards a very mafic composition, which is unlikely for the feldspar-rich Highlands [13]. The TF would be similar to that of enstatite, which also has RB features similar to the 10.3 – 11.2 µm positions. However, a third enstatite RB at ~9.3 µm does not appear in the lunar spectrum. The expected feldspars [10] i.e. labradorite ($An_{80\text{-}90}$) and anorthite ($An_{90\text{-}100}$) have a strong RB in the 10 - 11 µm area, overlapping with the highland features, but with TF at shorter wavelengths. A synthetic glass with lunar highland composition [12] has a broad RB feature between 10 and 11 µm.

It is particularly difficult to reproduce the CF. The feldspars, however show a low point between RBs in that area. Shock darkened material from the Chelyabinsk meteorite [15] is one of the few materials in our database to show a CF at such a long wavelength.

Mare: For the mare region (Figure 2) observed with MERTIS, a potential CF at 9.2 µm, with a RB feature around 8 µm was observed. Further RB – or TF at 11.4 µm, 11.7 µm, 12.2 µm and 12.8 µm were also found.

The latter features all fall in the range typical for TFs of feldspars, especially for albite. The similarity to enstatite is less pronounced compared with the Highlands. Again, the CF-like 'low' at 9.2 µm is best explained by a low or range of decreased reflectance between features in feldspars, otherwise highly mafic material comparable to the shocked Chelyabinsk sample would be necessary.

Summary & Conclusions:

In our first attempt to identify features in the mid-infrared lunar flyby spectra, of all features in the two lunar spectra, the CF is particularly difficult to interpret.

If the feature at ~9 µm is the 'real' CF, only highly mafic materials apply; for example; the analogue sample used that has the most similarity to this feature (i.e., the Chelyabinsk meteorite [15]) is a chondrite sample, and, thus, not directly relatable to the Moon. A potential CF at very short wavelengths (~7 µm) would indicate a very unrealistic SiO_2 rich material.

Feldspars like labradorite, anorthite and albite show a general similarity to the lunar spectra, which was expected in the petrologic context of the lunar surface [10]. And yet, the remaining insecurity in identifying the features unambiguously indicates that further material have to be considered as a potential source for the obtained spectra. Furthermore, alternative interpretation of the raw spectra may have to be taken into account (see abstract [16], same session). Effects of lower pressure and higher temperature are also possible [e.g. 17], but probably would shift features to longer wavelengths. Also, effects of e.g. space weathering need also to be considered [18,19].

References: [1] Benkhoff J. et al. (2020) Planetary and Space Science 58, 2-20 [2] Hiesinger H. et al. (2020) Planetary and Space Science 58, 144–165 [3] Morlok et al. (2020) Icarus 335, 113410 [4] Morlok et al. (2019) Icarus 324, 86-103 [5] Weber et al. (2020) Earth and Planetary Science Letters 530, 115884 [6] Weider S.Z. et al. (2015) Earth and Planetary Science Letters 416, 109-120 [7] Namur and Charlier (2017) Nature Geoscience 10, 9-15 [8] Namur O. et al. (2016) Earth and Planetary Science Letters 448, 102-114 [9] Namur O. et al. (2016) Earth and Planetary Science Letters 439, 117-128 [10] *Lunar Sourcebook* [11] Morlok A. et al. (2017) 296, 123-138 [12] Morlok et al. (2019) Icarus 324, 86-103 [13] Cooper et al. (2002) JGR Planets 107, 5017-5034 [15] Morlok et al. (2017) Icarus 284, 431-442 [16] Wohlfarth K. (2021) LPSC 2021 Submitted [17] Donaldson-Hanna et al. (2017) Icarus 283, 326-342 [18] Weber et al. (2020) EPSL 530, 115884 [19] Stojic et al. (2020) Icarus, In Press 114162

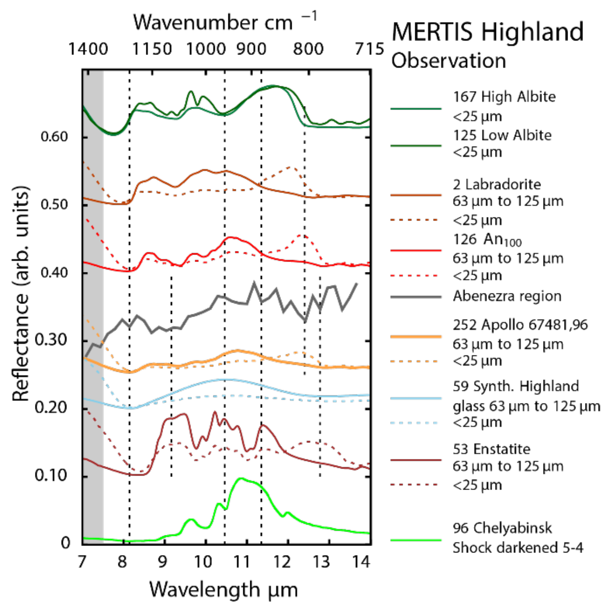

Fig.1: Comparison of stacked lunar flyby spectra of the Abenezra crater region to laboratory data.

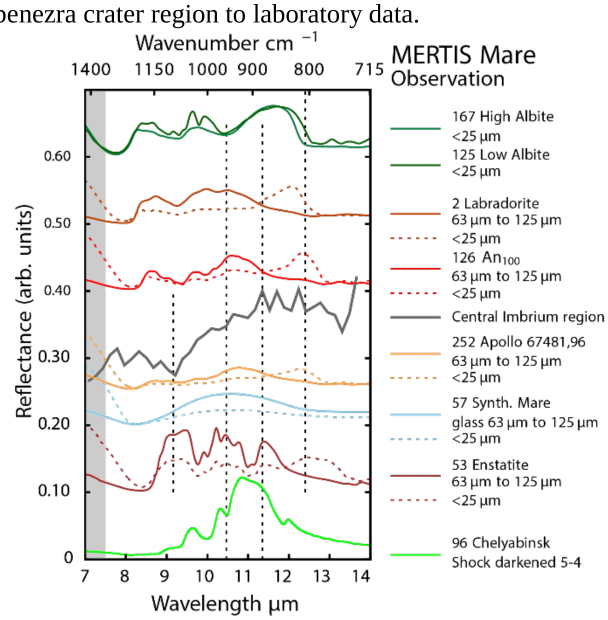

Fig.2:Comparison of stacked lunar Central Imbrium region spectra to laboratory data.

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