Venus as seen by the MErcury Radiometer and Thermal infrared Imaging Spectrometer (MERTIS) during the first flyby of the ESA-JAXA Bepicolombo spacecraft J. Helbert[1], R. Haus[1], M. D'Amore[1], A. Maturilli[1], G. Arnold[1], H. Hiesinger[2] [1]Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany (joern.helbert@dlr.de), [2]Institut für Planetologie, Westfälische Wilhelms-Universität, Münster, Germany

Introduction: BepiColombo [1] is a dual spacecraft mission to Mercury launched in October 2018 and carried out jointly between the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA). BepiColombo uses a solar electric propulsion system. The trajectory is a combination of low-thrust arcs and flybys at Earth (1), Venus (2), and Mercury (6) and will be used to reach Mercury with low relative velocity. BepiColombo performed a successful Venus flyby on October 15, 2020 and will perform a second flyby in August 2021.

The MERTIS instrument [2,3] obtains observations of Venus in the spectral range from 7-14 µm. This range is highly sensitive for studies of Venusian atmosphere. This includes analyses of the 15-µm CO_2 band short wavelength flank as well as analyses of aerosol properties around 10 µm. These measurements will be the first spectrally resolved observations in this spectral range since the Venera 15 mission in 1983. The Venera 15 dataset has recently been archived at DLR and will allow a direct comparison to the MERTIS observations [4-7].

In addition, MERTIS will acquire in during cruise data of "Venus as an Exoplant", observing the planet from a large distance with sub-pixel resolution. The first such opportunity is in April 2021. MERTIS will obtain time series of spectra that will be analyzed to test retrieval algorithms commonly used for determining the (cloud) rotation period as well as information about the cloud structure.

Observational constraints: BepiColombo was launched by an Ariane 5 from the ESA launch facility in Kourou (French Guyana) in October 2018. The ESA Mercury Planetary Orbiter (MPO) and the JAXA Mercury Magnetospheric Orbiter (MMO) were launched in a composite with a propulsion element - the Mercury Transfer Module (MTM) and a sunshade cone (MOSIF) to protect the MMO (see Figure 1).

In this configuration the nadir (z-axis) of the spacecraft points towards the MTM. Therefore, most instruments cannot operate during cruise. However, the MERTIS instrument has a viewport through the radiator which in nominal operations is used for deep space calibration. During the Venus flybys this port can be used for the observations. It has already been used successfully to perform observations of the Moon on April 9, 2020.

The MERTIS instrument: MERTIS (Figure 2) combines a push-broom IR grating spectrometer (TIS) with a radiometer (TIR). TIS operates between 7 and 14 µm and will record the day-side emissivity spectra from Mercury, whereas TIR is going to measure the surface temperature at day- and night side in the spectral range from 7-40 µm corresponding to temperatures from 80-700 K. TIR is implemented by an in-plane separation arrangement. TIS is an imaging spectrometer with an uncooled micro-bolometer array. The optical design of MERTIS combines a three mirror anastigmat (TMA) with a modified Offner grating spectrometer. A pointing device allows viewing the planet (planet-baffle), deep space (space-baffle), and two black bodies at 300 K and 700 K temperature, respectively. During the Venus flybys planetary radiation spectra are obtained through

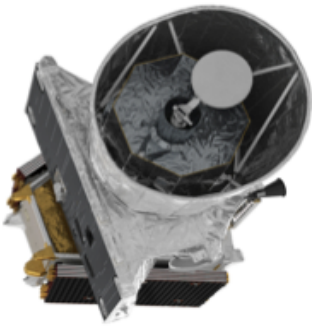

Figure 2 Rendering of the BepiColombo stack seen from top with MMO in the MOSIF, below that the MPO and the MTM

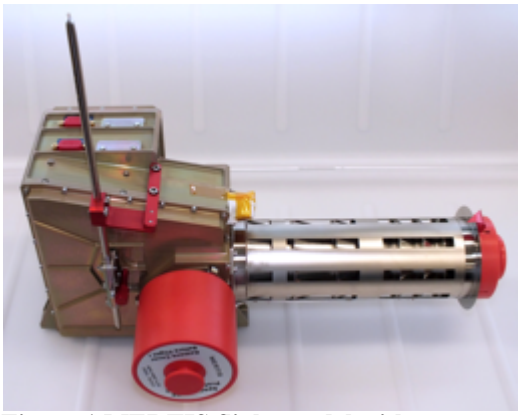

Figure 1 MERTIS flight model with spaceport in front and planet baffle to the right

the space baffle, deep space observations are performed before the flybys.

Flyby operations for MERTIS: During the first flyby the spacecraft approached the planet from the solar direction, over the dayside. The closest approach (CA) occured above the evening terminator of the planet, and then the spacecraft moved away from the planet to the anti-solar direction, over the night side. MERTIS observed the planet from about 48h out until about 23h out. In this time the apparent size of Venus increased from slightly larger than on MERTIS TIS pixel (0.7 mrad) to more than 1 degree. From about 11h out up to 4h before CA, MERTIS performed close-up dayside observations from late morning to late afternoon via noon time on Venus at latitudes between 55°S and 55°N.

MERTIS obtained more than 60000 hyperspectral observations with the spectrometer channel (Figure 3) as well as several thousand measurements with the radiometer channel. Data analysis is currently ongoing. Due to the dense cloud cover on the planet, most of thermal emissions are corresponding to temperatures at the upper cloud level atmosphere (60-70 km) [4, 5]. The shorter wavelength edge of the 15-µm CO_2 band covered by TIS/MERTIS should be useful to retrieve temperature profiles in this altitude range using the inversion methods of radiative transfer. This is limited by the signal-to-noise ratio at the long wavelength end of the MERTIS detector.

Venus observing campaign: An International collaboration on Venus observations is under way during the flybys of BepiColombo (ESA-JAXA), on its way to Mercury. The collaborative observations have been planned and performed between BepiColombo and the operating Venus orbiter, Akatsuki (JAXA), during the cruise and the 2 times of Venus flybys on October 15, 2020 and August 10, 2021. This represents unique Venus observation opportunities, perhaps in coming decades, to be coordinated with two spacecraft. More details can be found at http://bit.ly/BepiVenus .

Conclusions: Cloud top structures as well as the SO_2 gas abundance above the clouds can be observed in the MERTIS spectra. We report here on the MERTIS observations acquired during the first Venus flyby of BepiColombo. MERTIS has obtained valuable data both with the spectrometer channel, covering the range from 7-14 µm in 80 spectral channels, as well as with the radiometer channel providing highly accurate temperature readings. During the second, closer flyby in August 2021, these results will be completed and more data on the upper cloud level atmosphere of Venus will be obtained.

References: [1] Benkhoff, J., et al. (2010) Planetary and Space Science 58(1-2): 2-20. [2] Hiesinger, H. and J. Helbert et al. (2020). Space Science Reviews, 10.1007/s11214-020-00732-4. [3] Helbert, J., et al. (2010). SPIE **7808**: 78080J. [4] Zasova, L.V et al. (1999), Adv. Space Res., 1999, vol. 23, no. 9, pp. 1559–1568. [5] Oertel, D. and V. I. Moroz (1984). Pisma v Astronomicheskii Zhurnal **10**: 243-252. [6] http://s.dlr.de/5l53. [7] Moroz, V.I., et al., (1990) Adv. Space Res., vol. 10, no. 5, p. 77 [8] R. Haus, D. Kappel and G. Arnold (2013), Planetary and Space Science, 10.1016/j.pss.2013.09.020 [9] R. Haus, D. Kappel and G. Arnold (2017), Icarus, 10.1016/j.icarus.2016.11.025

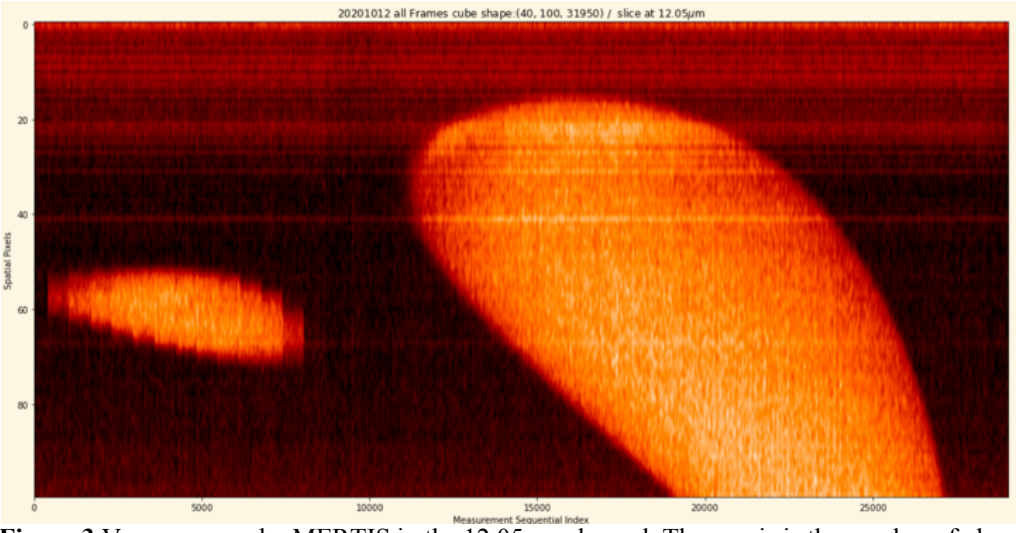

Figure 3 Venus as seen by MERTIS in the 12.05µm channel. The x-axis is the number of observations and the y-axis is the number of pixel on the MERTIS detector. Visible are the observation slots, the first slot from CA-48h to CA-23h and then the second slots starting at CA-11h and ending at CA-4h. BepiColombo was in inertial pointing, so the MERTIS could scan the planet due to the spacecraft motion, however with strongly changing geometries.