Observing Venus with the MErcury Radiometer and Thermal infrared Imaging Spectrometer (MERTIS) during the flybys of the ESA-JAXA Bepicolombo spacecraft .

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Introduction: BepiColombo [1] is a dual spacecraft mission to Mercury to be 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 (5) and will be used to reach Mercury with low relative velocity. Before arriving at Mercury, BepiColombo will perform Venus flybys in 2019 and 2020.

The MERTIS instrument [2,3,4] will obtain observations of Venus in the spectral range from 7-14µm. This range is highly sensitive for studies of Venusian atmosphere. This includes analyses of the 15-µm CO2 band short wavelength flank as well as analyses of aerosol properties below 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 The Venera 15 dataset has recently been archived at DLR and will allow a direct comparison to the MERTIS observations.

In addition, MERTIS will acquire data of "Venus as an Exoplant", observing the planet from the distance with sub-pixel resolution. 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 will be launched by an Ariane 5 from the ESA launch facility in Kourou (French Guyana). The ESA Mercury Planetary Orbiter (MPO) and the JAXA Mercury Magnetospheric orbiter will be 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 instuments can not 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 flyby this port will be used for the observations.

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 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 we will use the deep space view for Venus observations and obtain deep space observations before and after the flybys.

Observations of Venus in the thermal IR: The infrared spectrometry of Venus in the range 7–40 µm allows one to sound the middle atmosphere of Venus in the altitude range 55-100km and its cloud layer.

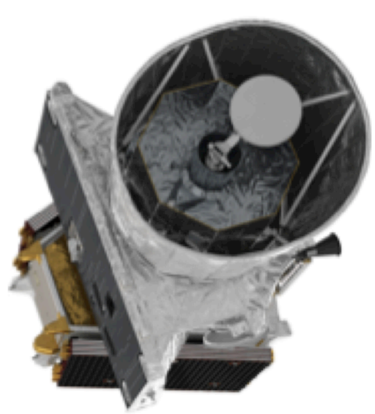

Figure 1 Rendering of the BepiColombo stack seen from top with MMO in the MOSIF, below that the MPO and the MTM

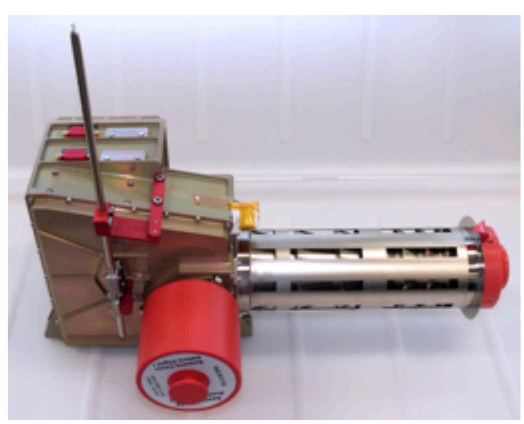

Figure 2 MERTIS flight model with spaceport in front and planet baffle to the right

Specifically CO_2, SO_2, and H_2SO_4 have absorption bands in the 7-14 µm range covered by the spectral channel of MERTIS. Only a very limited set of observations of Venus in the thermal infrared spectral range is available to date. Venera 15 carried an IR Fourier Spectrometer, which covered the spectral range from 6-40 µm [5]. The instrument was developed at the East German predecessor institute to the Planetary Research institute of DLR. The data of the Fourier spectrometer on Venera 15 is stored at DLR and can be used for comparison with MERTIS observations of Venus [6]. The observations continued only for two months. The sectors of local time near the noon (10:30–16:00 LT) and near the midnight (22:30–04:00 LT) have remained uncovered by measurements. Despite incomplete coverage, these measurements have shown the efficiency of the method of IR spectrometry for investigation of the middle atmosphere of Venus, its thermal structure, thermal wind, vertical profiles of aerosol, and minor constituents [7,8].

Pioneer Venus carried an instrument called VORTEX (Venus Orbiter Radiometric Temperature EXperiment), a ten-channel IR radiometer [9]. Primary goal of the instrument was the measurements of the vertical temperature profile by IR remote sensing techniques. Observations of the atmosphere were made from 5 December 1978 until 14 February 1979, during seventy-two orbits around the planet. During the seventy-two orbits about Venus, some 800,000 temperature soundings with associated albedo and humidity measurements were made. Nearly all these appertained to the northern hemisphere, with some coverage of the southern hemisphere near the equator. The measurements of the Venus atmosphere in the 60- to 140-kilometer region show very small diurnal temperature differences near the cloud tops, increasing somewhat at higher levels. The equator-to-pole contrasts are an order of magnitude larger, and the temperatures unexpectedly increase with increasing latitude below 80 kilometers. An isothermal layer at least two scale heights in vertical extent is found near the 100-kilometer altitude, where the temperature is about 175 K. Structure is present in the cloud temperature maps on a range of spatial scales. The most striking is at high latitude, where contrasts of nearly 50 K are observed between a cold circumpolar band and the region near the pole itself [10].

The ESA VenusExpress mission carried the Planetary Fourier Spectrometer (PFS), which would have provided unprecedented thermal infrared spectra of Venus. Unfortunately failed the pointing unit on PFS and no observations of Venus could be acquired.

MERTIS Observing strategy and constraints at Venus MERTIS is a pushbroom instrument, that can obtain data on the nightside of Venus as well as on the dayside. MERTIS starts to resolve Venus at a distance of 8 Mio km, giving 2 pixels across the disc. At a distance of 6000km MERTIS will have a spatial resolution of 4km already exceeding the existing datasets. At the closest flyby distance of 307km MERTIS will have a spatial resolution of 200m providing an unprecedented detailed look at the distribution of minor species and the cloud structure in the atmosphere of Venus. The radiometric data obtained in parallel will allow retrieving temperature profiles both on the illuminated and the non-illuminated hemisphere. MERTIS will start operation while the disc of Venus is still sub-pixel size and operate through closest approach.

MERTIS observing Venus as an exoplanet: During the cruise phase up to five opportunities have been identified where Venus will pass through the field of view of the MERTIS instrument and the solar electrical propulsion is not operating. During these opportunities MERTIS will obtain timeseries of Venus consisting of up to 60 blocks of 5 minutes of observations with 30 minute spacing. This dataset is comparable to typical observations of exoplanets and will provide a blind-test for retrieval algorithms for rotation rate and cloud structure.

Conclusions: MERTIS can obtain 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. The MERTIS observations will complement the data acquired by Venera 15 and Pioneer Venus with a much higher sensitivity.

References: [1] Benkhoff, J., et al. (2010) Planetary and Space Science 58(1-2): 2-20. [2] Hiesinger, H. and J. Helbert (2010). Planetary and Space Science **58**(1-2): 144-165. [3] Helbert, J., et al. (2010). SPIE **7808**: 78080J. [4] Hiesinger, H. et al (2018) this meeting. [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] Zasova, L.V et al. (1999), Adv. Space Res., 1999, vol. 23, no. 9, pp. 1559–1568. [9] F.W. Taylor et al. (1979) Applied Optics, Vol. 18, Issue 23, pp.3893-3900 [10] F.W. Taylor et al., (1979) Science, Vol. 203 no. 4382 pp. 779-781