MERTIS ON BEPICOLOMBO CRUISE OPERATIONS: FLYBYS TO THE MOON AND VENUS. A. Maturilli[1], J. Helbert[1], H. Hiesinger[2], M. D'Amore[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, the BepiColombo spacecraft is performing 9 flybys: among them, the Earth/Moon flyby on April 10th 2020, and the Venus flyby on October the 15th 2020. The second flyby at Venus will be around August 10th, 2021, this time with a much lower altitude above the surface (550 km), and approaching Venus from the nightside, even if still approaching the planet from the evening terminator.

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. With the first Earth/Moon flyby the MERTIS imaging spectrometer provided the first hyper-spectral observation of the Moon in the thermal infrared (TIR) wavelength range from space. With the successive Venus flyby MERTIS provided observations of the Venus atmosphere down to 50 km altitude in the TIR spectral range, 35 years after the last available remote sensing data from space.

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 was 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, would provide extremely valuable ground truth for our MERTIS measurements. However, the special resolution of MERTIS data is too low to resolve the landing site.

The attitude profile for the flyby was generated by ESA Mission Control. The time allocated for MERTIS pointing to the Moon was 4 hours and started 1 day before closest approach. During this slot it was feasible to have the Moon in the FOV of MERTIS. The 4 hours visibility slot was divided in 4 segments of 1 hours approximately connected by short slews. The attitude in each segment was kept 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 was nearly fully illuminated; the angle between Moon and Earth (from limb to limb) was 8.5 in the beginning and increased up to 10.64 degrees; the apparent size of the Moon started at 0.268 degrees and increased up to 0.2927 degrees. The Moon moved 1.6 degrees in these four hours.

BepiColombo Venus flyby: The first BepiColombo flyby at Venus was on October 15th, 2020, almost 2 years after launch. It has been the first occasion to use its instruments for scientific purposes in a planetary environment. BepiColombo approached the planet from the dayside and – given the retrograde rotation of Venus - it had the closest approach on the evening side, almost at the time of crossing the bow-shock. The minimum distance from the center of the planet was 16771 km (that is an altitude of 10720 km above the planet surface). Distance from the Earth was 1.16 AU and from the Sun 0.71 AU. The apparent angular size of the planet at closest approach was about 42°.

This flyby configuration was optimal for both atmospheric and ionospheric/magnetospheric investigations of the Venus close environment.

Two of the three monitoring cameras onboard the Mercury Transfer Module were activated during dedicated imaging slots from 20 hours before closest approach through to 15 minutes afterwards. Seven of the eleven science instruments onboard the European Mercury Planetary Orbiter, plus its radiation monitor, and three of five onboard the Japanese Mercury Magnetospheric Orbiter were active during the flyby. While the suite of sensors are designed to study the rocky, atmosphere-free environment at Mercury, the flyby offered a unique opportunity to collect valuable science data at Venus.

MERTIS observed Venus during 2 time slots before closest approach (CA). Slot1 is from CA-48 hours to CA-23 hours and Slot2 is from CA-11 hours to CA-4 hours. The spacecraft was inertially pointed to Venus during the whole Slot 1 and Slot 2, so Venus was in our FOV the whole time. We took 10 minutes real deep-space calibration measurements each before and after Slot 1 and 2. The altitude of MPO respect to Venus surface was changing from 1389008 km (CA-48 hours) to 116811 km (CA-4 hours).

The MERTIS pixel size (not FOV size) on Venus decreased from 970 to almost 80 km in size.

During Slot 1 MERTIS was taking 15 minutes of continuous observations each 2 hours. During Slot 2, we measure continuously for the whole period.

MERTIS sensed Venus' middle atmosphere and cloud layers, providing temperature profiles and detecting CO_2, SO_2, and H_2SO_4 cloud aerosol properties. MERTIS observations and its data analysis will contribute to studies of Venus' radiative balance, atmospheric structure, cloud level chemical processes, and to understand the impact of global-scale atmospheric waves on Venus' weather patterns.

Summary and Outlook: MERTIS will have the opportunity to observe Venus from long distance, in a configuration similar to observation of exoplanets, again in March 2021, when we will have spacecraft resources for a slot of 5 hours. The Venus 2021 flyby, planned for 10 August, will see the spacecraft pass within just 550 km of the planet's surface. The much lower altitude above the surface will allow a different range of investigations that will be addressed in detail in the near future. Another feature that distinguishes the second flyby from the first is that Venus will be approached from the nightside, even if still approaching the planet from the evening terminator.

Along its cruise to Mercury, BepiColombo will perform 6 flybys at Mercury itself on the following dates: October 2nd 2021, June 23rd 2022, June 20th 2023, September 5th 2024, December 2nd 2024, and January 9, 2025.

References:

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