**THE MERCURY RADIOMETER AND THERMAL INFRARED IMAGING SPECTROMETER (MERTIS) ONBOARD BEPI COLOMBO: LATEST DATA FORMAT IN VIEW OF UPCOMING FLYBYS DATA.** M. D'Amore[1], J. Helbert[1], A. Maturilli[1], J. Knollenberg[1], R. Berlin[1], G. Peter[1], T. Säuberlich[1], H. Hiesinger[2] , [1]German Aerospace Center, Berlin, Germany (mario.damore@dlr.de), [2]Westfälische Wilhelms-Universität Münster, Institut für Planetologie, Münster, Germany.

**Introduction:** The MErcury Radiometer and Thermal Infrared Spectrometer (MERTIS) is an instrument to study the mineralogy and temperature distribution of Mercury's surface in unprecedented detail [1]. During the nominal mission, MERTIS will map the whole surface at 500 m scale, combining a push-broom IR grating spectrometer (TIS) with a radiometer (TIR) sharing the same optics, instrument electronics, and in-flight calibration components for the whole wavelength range of 7-14$\mu$m (TIS) and 7-40$\mu$m (TIR) [1]. MERTIS successfully completed its planned tests of the Near-Earth Commissioning Phase (NECP) in November 2018 and several checkouts, collecting thousands of measurements of its internal calibration bodies and deep space. Those data show a performance comparable with ground-based measurements. Scientific data will arrive well before the 2025 arrival at Mercury: MERTIS will be observing the Earth-Moon system in April 2020 and Venus in October 2020. Venus will be visited again on August 2021 and the first Mercury flyby will occur on October 2021. MERTIS archival data are stored in Planetary Data System v4 format (PDS4) [2] format, that actually describe 2 physical formats for each MERTIS channel. Each channel will be stored in Flexible Image Transport System (FITS) [3] and in pure ASCII, to maximize both machine and human interaction.

**The Mission and the Instrument:** BepiColombo [2] is a dual spacecraft mission to Mercury that has been launched in October 2018 and is jointly carried out by the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA).

The spacecraft comprises two separate orbiters: the Mercury Planetary Orbiter (MPO), focused on observations of the surface and internal composition, and the Mercury Magnetospheric Orbiter (MMO), which will study the particle science in the extreme thermal environment. In addition to a suite of instruments complementary to the NASA MESSENGER mission, BepiColombo will be able to observe both the northern and southern hemispheres at high spatial resolution. BepiColombo uses an innovative solar electric propulsion system and its trajectory toward Mercury is a combination of low-thrust arcs and flybys at Earth, Venus, and Mercury. This will allow us to reach Mercury with low relative velocity. The spacecraft was successfully launched on the 20th of October 2018, 01:45 UTC, from the ESA Guiana Space Centre using an Ariane 5 rocket and will reach its mappings orbit at Mercury in 2026. The MERTIS instrument was proposed in 2003 as payload of the Mercury Planetary Orbiter spacecraft of the ESA-JAXA BepiColombo mission and the final Flight Model (FM) was delivered in 2013. MERTIS is an innovative and compact spectrometer, that combines a push-broom IR grating spectrometer (TIS) with a radiometer (TIR) with only 3kg of mass and an average 10 W power consumption [1,4]. 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 the 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, while TIS is an imaging spectrometer with an uncooled microbolometer array. The optical design of MERTIS combines a three-mirror anastigmatic lens (TMA) with a modified Offner grating spectrometer. A pointing device allows viewing the planet (through the planet-baffle), deep space (through the space-baffle), and two internal black bodies at 300 K and 700 K temperature, respectively. MERTIS was developed at DLR in collaboration with the Westfälische Wilhel-Universität Münster and industry partners. The MPO operational plan foreseen a 2.3 hour low eccentricity orbit that allows MERTIS to achieve its 500 meters global mapping scientific goal. MERTIS' design and performance drivers have been changed and fine-tuned in response to the NASA/MESSENGER mission and with the data obtained from the Planetary Spectroscopy Laboratory and IRIS laboratories. As confirmed by the NASA MESSENGER mission, due to the iron-poor nature of the surface the thermal infrared is the most useful wavelength range to study Mercury's surface composition. Silicates as well as sulfides have characteristic spectral features in this range that MERTIS can map with high signal-to-noise ratio. MERTIS scientific objectives are: 1. Study of Mercury's surface composition; 2. Identification of rock-forming minerals; 3. Mapping of surface mineralogy; 4. Study of surface temperature and thermal inertia. The MERTIS spectrometer aims to capture data on the mineralogy whereas the radiometer surveys the thermal inertia of the planet. The incoming radiation is guided via a baffle, protruding from the instrument [5]. The radiation is then fed to the spectrometer and bolometer in the instrument. Thermal instability can affect the accuracy of the measurements; hence MERTIS' mode of operation is designed to avoid this.

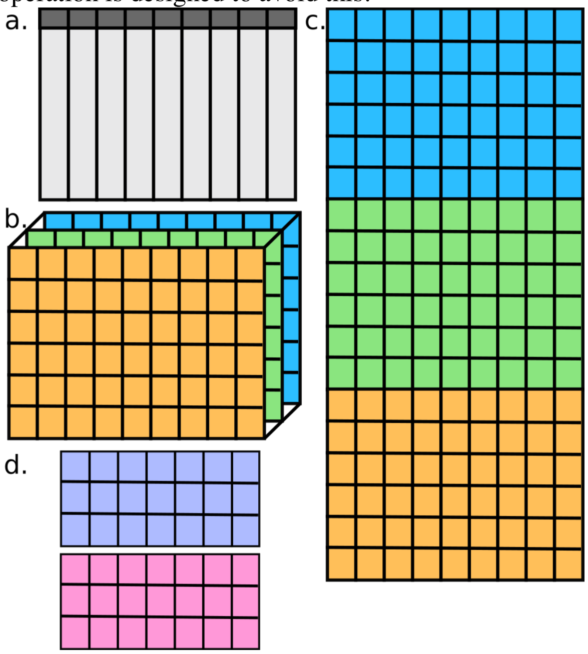


**Fig.1** Graphical representation of the data physical format. **a.** Tabular data **b.** TIS data cube in FITS [spectral, spatial, observation] dimensions **c.** TIS data array in ASCII **d.** TIR data array for channel A and B in both FITS and ASCII (the number of pixels is only for descrpitive purpose).

**Instrument Dataset:** In collaboration with the European Space Agency Science Ground Segment (ESA/SGS), the instrument TIS, TIR data, with all accompanying meta data and House Keeping data (HK) are stored in FITS and ASCII format. PDS4 labels ensure that machines could automatically understand the data and run automatic integrity check against semantic dictionaries, that define type and acceptable range for each data element. This ensure an automatic data quality check at during the data creation stage. FITS is an open standard defining a digital file format optimized for storage, transmission, and processing of data: formatted as multi-dimensional arrays (for example a 2D image), or tables. FITS is the most commonly used digital file format in astronomy and the standard was designed specifically for astronomical data, and includes provisions such as describing photometric and spatial calibration information, together with image origin metadata. On the other end of the spectrum, American Standard Code for Information Interchange (ASCII), is a character encoding standard for electronic communication. ASCII codes represent text in computers, telecommunications equipment, and other devices. This format ensures the readability of the data in the long run, based on the evidence that dataset decades old could be still read today, even in catastrophic case when the original documentation is lost. The data produced by MERTIS per acquisition are[4]:

- TIS Spectrometer channel :
  - metadata (i.e., CCD pixel sampling , **Fig1.a**)
  - TIS CCD 2D Frame (spectral×spatial pixel **Fig1.b**)
- TIR Bolometer channel
  - metadata (i.e. internal blackbody temperature, **Fig1.a**)
  - TIR Bolomert channels A and B, for 7-14um and 7-40um (15 spectral pixels per channel, **Fig1.d**).

Those data are physically organised as:

- TIS channel :
  - one FITS file containing: one metadata row and one CCD Frame per acquisition arranged as 3D data cube (**Fig1.a** and **b**), with accompaying PDS4 label.
  - two ASCII files : 1. metadata table, 2. CCD Frames as flat matrix (**Fig1.a** and **c**) with accompaying PDS4 label.
- TIR channel :
  - one FITS file containing one metadata row and one TIR array per channel per acquisition (**Fig1.a** and **d**), with accompaying PDS4 label.
  - two ASCII files : 1. one metadata row and 2. one TIR array per channel per acquisition (**Fig1.a** and **d**), with accompaying PDS4 label.

This structure will ensure long term usability and quick interaction with the data. Both TIR and TIS channels are being updated to accommodate geometric information. The data will be available for download and quick visualization at the ESA's Planetary Science Archive (PSA) [6]. There are several framework and languages to interact with PDS4 and FITS, the team is developing some data usage examples in python using Python PDS4 Tools, an invaluable resource to create PDS4 dataset, and the Astropy package FITS interface [7].

**References:**

[1] Hiesinger, H. and Helbert, J., Planet. Space Sci. 58, (2010). [2] NASA Planetary Data System, pds.nasa.gov [3] FITS Support Office, fits.gsfc.nasa.gov [4] Instrument User Manual (FM), MER-DLR-MA-001 (2017). [5] Python PDS4 Tools, SBN sbndev.astro.umd.edu/wiki [6] The ESA's Planetary Science Archive PSA, archives.esac.esa.int/psa [7] Astropy Coll. , AJ 156, 123 (2018).