



Mercury-Y: A preparatory laboratory study for BepiColombo mission

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Introduction. The ESA-JAXA BepiColombo mission consists of two scientific spacecraft that, after arrival at Mercury, will be placed in separate polar orbits [1, 2]. The Mercury Planetary Orbiter (MPO) will focus on Mercury's surface while the Mercury Magnetospheric Orbiter (MMO-Mio) will focus on Mercury's environment and interactions with the Sun. The instruments of most relevance to studying Mercury's surface are the BepiColombo Laser Altimeter (BELA), the Mercury Radiometer and Thermal Imaging Spectrometer (MERTIS), the Mercury Gamma-Ray and Neutron Spectrometer (MGNS), the Mercury Imaging X-ray Spectrometer (MIXS), and the Spectrometers and Imagers for MPO BepiColombo Integrated Observatory System (SIMBIO-SYS) [3]. Additionally, BepiColombo will study the surface-environment interactions of Mercury with the Hermean Exosphere by Ultraviolet Spectroscopy (PHEBUS) and the Search for Exosphere Refilling and Emitted Neutral Abundances (SERENA) instruments, as well as MIXS [4]. Laboratory studies of Mercury analogs under simulated conditions are crucial for interpreting future remote-sensing data. The Mercury-Y Lab project was launched at the Mercury Laboratory Workshop (MLW) 2024, held at the Institute of Planetary Research of the German Aerospace Center (DLR) in Berlin (09/2024). The project consists of creation of a unique blind analog sample named 'Mercury-Y', distributed to MPO research partners, and laboratory analysis of the blind analog under conditions similar to the future observations of the BepiColombo MPO instruments, using representative instrumentation where possible. The primary objective of the various laboratory teams will be to determine the mineralogical and elemental composition alongside the physical properties of the blind sample. Here, we present the protocol for creating Mercury-Y, the laboratories and instrumental teams involved, the objectives of the project and the first results..

Blind sample. The Mercury-Y blind sample was designed to replicate the regolith of Mercury, leveraging our current understanding of Mercury's surface composition derived from NASA MESSENGER observations [e.g., 5] and petrological studies [e.g., 6]. It was developed in collaboration with the Planetary Spectroscopy Laboratory (PSL) at the Institute of Planetary

Research, DLR Berlin, and the Infrared and Raman for Interplanetary Spectroscopy (IRIS) laboratory at the Institute for Planetology at the University of Münster, following extensive discussions on the experimental constraints of each laboratory during and following MLW2024. Mercury-Y comprises a mixture of terrestrial and synthetic components and was delivered to participating teams as a powder. Its bulk chemical composition, including trace and volatile elements, has been characterized at the Service d'Analyse des Roches et des Minéraux (SARM, CRPG, Nancy), and will form the basis of comparison for the project. **The composition of the sample will not be revealed to the teams until the completion of the project.**

Experimental procedure. The experimental procedure implemented for this project consists of performing laboratory measurements similar to BepiColombo experiments. Visible to near-infrared bi-directional reflectance is measured to simulate SIMBIO-SYS and BELA observations. Thermal infrared emissivity is measured at surface temperatures up to 700 K and under environments simulating near-surface conditions of airless bodies to simulate MERTIS observations. X-ray fluorescence experiments are performed which mimic the interaction between MIXS, the solar flux and the Mercury surface using the MIXS qualification model detector within a ground reference facility (GREF). Particle back scattering and sputtered ions are measured in-situ after ion bombardment to simulate future observations by SERENA. Finally, high-temperature evaporation processes are simulated and analyzed at Mercury surface conditions, supporting the anticipated measurements from the BepiColombo SERENA and PHEBUS instruments.

Preliminary results. The primary objective of the measurements is to determine the blind sample's mineralogical and chemical composition, alongside its physical properties. The first reflectance measurements in the SIMBIO-SYS domain do not show significant absorption by mafic minerals such as olivine or pyroxene (Fig 1a). A strong drop in reflectance is observed at shorter wavelengths, with a blue slope in the visible and near-infrared (reflectance decreases as the wavelength increases). At 400°C, the emissivity measurements in the domain of MERTIS exhibits several spectral features, including multiple vibrational bands (Reststrahlen bands) and a highly contrasted emission maximum (Christiansen feature) just before 8 μm (Fig 1b). Preliminary X-ray fluorescence measurements with MIXS-GREF show the presence of Na, Mg, Al, Si, K, Ca and Fe (Fig 2). In comparison to other terrestrial silicate materials analysed previously on MIXS-GREF, Mercury-Y is enriched in Na and Mg, whilst being depleted in Al and Fe. We observed K to be significantly enriched compared to measured Mercury abundances, while S is entirely absent [5].

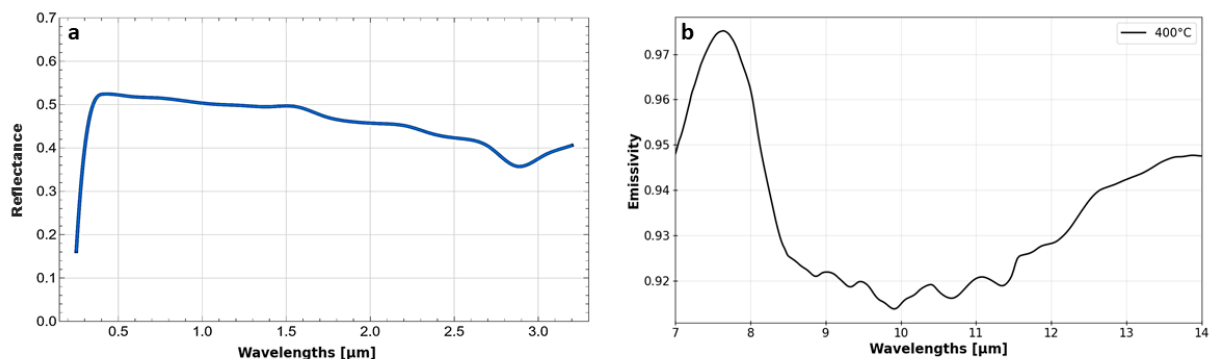


Figure 1: (a) Visible to near-infrared hemispherical reflectance ($i=30^\circ$) measured at University of Helsinki in the wavelength domain of SIMBIO-SYS. (b) Emissivity at 400°C measured at PSL-DLR, Berlin in the wavelength domain of MERTIS.

Next steps. The teams are invited to cross-check the measurements in order to refine each other's results. This analysis stage is crucial to optimize the scientific results obtained by each lab/instrumental team. In a second phase, we will distribute a transformed/altered Mercury-Y sample, created to mimic space-weathering processing (e.g. thermal cycles, irradiation) and will run similar laboratory experiments. This further analysis will allow the teams to investigate the effects of space weathering on BepiColombo measurements, and to determine how these processes need to

be considered when attempting to characterise Mercury's surface composition.

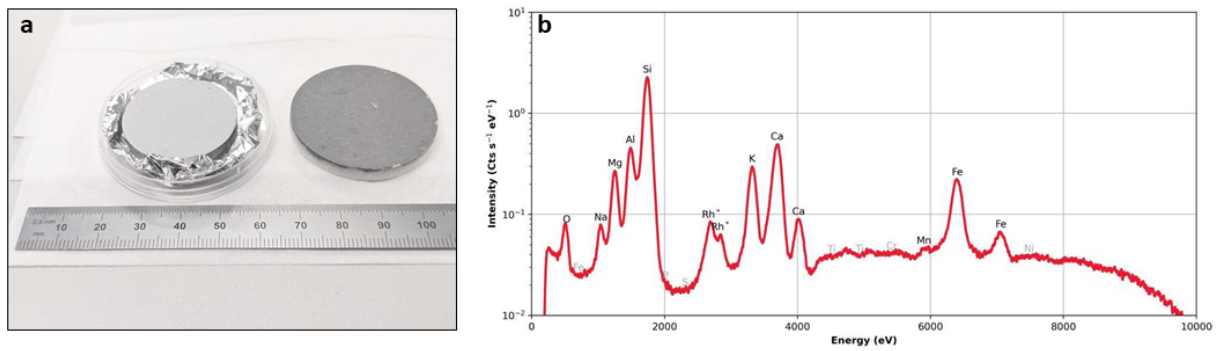


Figure 2: (a) Mercury-Y pellets produced and used by the MIXS team for X-ray measurements. The lighter pellet is composed of the Mercury Y sample only while the darker pellet contains PVA-based binder (b) X-ray fluorescence spectrum recorded with the MIXS Ground Reference Facility (10 kV source, $i=30^\circ$) from a Mercury-Y pressed pellet with a PVA-based binder. Note the Rh peaks are scattered from the X-ray source and do not represent fluorescence from the sample itself.

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