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Unveling Mercury surface composition: results from MESSENGER and future outlooks from the SIMBIO-SYS Visible and Infrared Hyperspectral Imager (VIHI)

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Introduction

October 2018 marks the lunch of BepiColombo, the first ESA/JAXA mission devoted to the study of Mercury. Because of its extreme environment, only other two spacecrafts explored Mercury, Mariner 10, which carried out only few flybys of the planet, about 37 years ago, and the NASA MESSENGER mission entered in orbit around Mercury in March 2011. During four years of operating life, MESSENGER allowed for mapping the entire surface of Mercury at different spatial scales, revealing aspects hitherto hidden, but arising new questions. In this regard, the future BepiColombo mission, will answer questions still unsolved. BepiColombo mission consists of two modular orbiters: a Mercury Planetary Orbiter (MPO) provided by ESA and a Mercury Magnetospheric Orbiter (MMO) by the Japan Aerospace eXploration Agency (JAXA). The Spectrometer and Imagers for MPO BepiColombo-Integrated Observatory SYStem (SIMBIO-SYS) consists of three channels the high-resolution imager (HRIC), the stereo imaging system (STC) and the visible-near-infrared imaging spectrometer (VIHI), all together these three instruments will give new information regarding the surface composition and the geology of Mercury [1].

Mercury's surface composition: MDIS-WAC and MASCS-VIRS onboard MESSENGER mission

Mapping Mercury's surface composition was one of the goal of the MESSENGER mission, for this purpose the Mercury Dual Imaging System (MDIS), and the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) were included in the spacecraft [2]. MDIS, the MESSENGER camera, consists of two instruments: a Narrow Angle Camera (NAC) centered at ∼747 nm, which acquired high-resolution images for the geological analysis, and the Wide Angle Camera (WAC), provided with 11 filters dedicated to the compositional analysis, operating in a range of wavelengths between ∼395 and ∼1040 nm. MASCS-VIRS is a spectrograph fixed concave grating with focal length of of 210 mm, composed by a solid-state detector with 512 elements silicon for the visible channel (215-1050 nm), and a indium-gallium-arsenide near infrared detector (850-1450 nm) of 256 elements [3]. Both MDIS and MASCS cover the overall Mercury surface revealing color variations which correspond with variation in composition. The first MASCS-VIRS global RGB map (Fig. 1) shows regional variation in reflectance or spectral slopes [4]. In particular, reflectance spectra show no clear evidence of any absorption bands, including the band centered near 1 μm that would be associated with the presence of ferrous iron in silicates, indicating a very low iron content (2-3 wt% FeO or less). Furthermore, the compositional analysis supported by the X-ray and gamma-ray observations confirm the results obtained by VIRS [4]. Similarly, the MDIS-WAC color maps revealed a color variation related to differences in spectral slopes, which allow for discriminating different type of terrains and features, such as smooth plains, intercrater plains and pyroclastic deposits [5]. On the other hand, thanks to MDIS color filter data, an absorption feature centered in the 629 nm filter has been observed in reflectance spectra of Dominici's south wall/rim hollows [6], and a broad, shallow band near 600 nm is found in the Low Reflectance Material (LRM) [7]. In this standpoint, the availability of the data acquired by MESSENGER may therefore be considered an opportunity not only for the planning and the selection of scientific targets for BepiColombo, and in particular for SIMBIO-SYS, but also to improve the knowledge of Mercury surface from the geological and compositional point of view. In this regard, we are working to produce quadrangles color mosaics (Fig. 2) and high resolution color mosaics of smaller areas to define color products and obtain an "advanced" geologic map. The mapping process permits integration of different geological surface information [8] to better understand the planet crust formation and evolution. Merging data from different instruments provides

additional information about lithological composition, contributing to the construction of a more complete geological map.

SIMBIO-SYS and the Visible and Infrared Hyperspectral Imager (VIHI)

SIMBIO-SYS is the first integrated suite containing two cameras and an imaging spectrometer. STC will perform the global mapping in stereo mode, providing the DTM of the entire surface, and color images of a small percentage of the planet, HRIC channel has the primary task to provide images at 5m/pixel scale from periherm (400 km from planet surface), in different bands in the visible, while VIHI channel is an advanced hyperspectral imager realized to study Mercury's surface composition [1]. VIHI channel concept is based on a collecting Schmidt telescope and a diffraction grating spectrometer (Littrow configuration) joined at the telescope focal plane where the spectrometer entrance slit is located [9]. The image of the slit is dispersed by the diffraction grating on a 2-D 256x256 pixels cadmium-mercury-telluride (HgCdTe) detector [9]. Conversely to MASCS-VIRS, which is a pointer spectrometer, VIHI is an imaging spectrometer covering a spectral range between 400 and 2000 nm, with a spectral sampling of 6.25 nm/band, and a FOV of 64 mrad with 256 pixels having each a IFOV of 250 μrad. Since the instrument shall operate in push-broom mode, these characteristics allow to acquire a 25.6 km-wide swath on ground at 100 m/pixel resolution from a 400 km polar orbit. According to the Bepi-Colombo mission science requirements, VIHI must complete a global mineralogical mapping with spatial resolution better than 500 m and local mapping of selected regions of about 10% of the surface with a spatial sampling of 100 m [9]. Considering the characteristics of the instrument and the mission requirements, VIHI will allow for producing compositional map of Mercury never achieved before. VIHI has been fully characterized during an extensive pre launch campaign where the geometric, spectral, radiometric and linearity responses have been determined for the expected range of operative temperatures [10,11]

Acknowledgements

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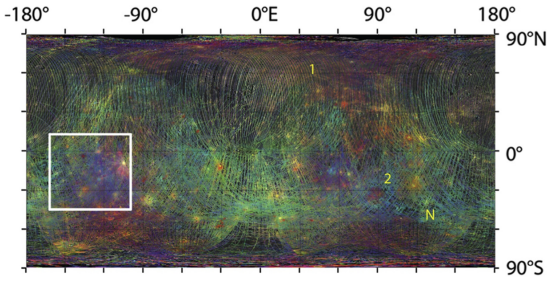

Figure 1: Color composite in simple cylindrical projection maps obtained by MASCS-VIRS data (See [4]). Red channel is the reflectance at 575nm, green channel is 415/750 nm, while Blue channel is 310/390 nm ratio.

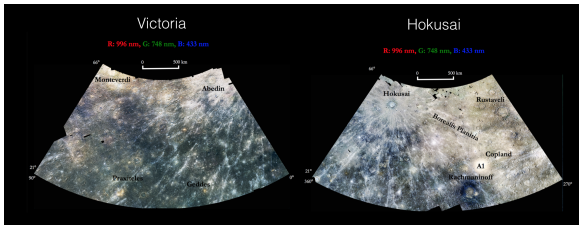

Figure 2: RGB (R: 996nm, G: 748 nm; B: 433 nm) maps of Victoria and Hokusai quadrangle obtained from MDIS-WAC data.

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