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The High Resolution Imaging Channel of the SIMBIO–SYS instrument for the BepiColombo mission to Mercury

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Abstract. ESA BepiColombo space mission, to be launched in 2013, shall visit Mercury planet, carrying a complex of instruments with very high performances. The results of the mission shall certainly provide a fundamental jump in our knowledge about the planet closest to the Sun. The SIMBIO–SYS instrument is a system integrating a stereoscopic imaging channel, a high spatial resolution imaging channel and a visual and infrared hyper–spectral imager channel. SIMBIO–SYS has been selected by ESA in the payload of the Mercury Planetary Orbiter (MPO) of the BepiColombo mission. The high spatial resolution imaging channel will have the primary task to provide images with 5 m pixel scale from periherm (400 km from planet surface). This approach will allow us to identify key surface features (craters, scarps, lava flows and plains) and to study their relation with internal processes, as well as the effect of external processes, such as meteor bombardment.

Key words. Planets: Mercury – Space missions: BepiColombo – Instruments: SIMBIO–SYS – Instruments: High Resolution Imaging Channel

1. Introduction

Mariner 10 mission photographed in 1974 about 45 % of Mercury surface with resolution between 1 and 1.5 km, and less than 1 % with resolution between 100 and 500 m. All images were obtained at phase angle between 80° and 100° and they are not well suited for topographic investigation. Starting from 2008, the NASA MESSENGER mission, launched in 2004, among other tasks will map the planet in colour and will image most of the areas unseen by Mariner 10 (Solomon et al. 2001). The ESA BepiColombo mission to Mercury will be launched in 2013 and will host a complement of instruments with very high performances (Anselmi & Scoon 2001). The SIMBIO–SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory SYStem) suite (Principal Investigator: E.

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Flamini), selected by ESA in the payload of the Mercury Planetary Orbiter (MPO), includes a STereoscopic imaging Channel (STC), a High spatial Resolution Imaging Channel (HRIC) and a Visual and Infrared Hyper–spectral Imager channel (VIHI). The primary goal of HRIC will be to provide images at very high spatial resolution: 5 m per pixel from periherm (400 km from planet surface). This approach will allow us to identify surface features and to study their relation with internal processes, as well as the effect of meteor bombardment.

The surface morphology of Mercury bears evidence of endogenic and exogenic processes relevant during planet geological evolution (Vilas et al. 1988). The role of extreme body that Mercury plays in our Solar System suggests that improving our knowledge on its formation and evolution will help to constrain and test dynamical and compositional theories of planetary formation. Typical geological surface features are (Neukum et al. 2001; Watters et al. 2001): heavily cratered regions (record of the period of late heavy meteoroid bombardment), hilly and lineated terrains (results of seismic waves generated by the Caloris impact), smooth plains (possibly volcanic deposits erupted late in planet history), intercrater plains (either impact basin ejecta or lava plains). Key open questions concern the knowledge of the mineralogical, chemical and isotopic composition of Mercury surface, the similarities with the Moon and the properties of the fine–grained regolith distributed on the surface, probably 5 to 10 meter thick on average, which is probably more mature than the Moon surface, due to the continuous micro–bombardment and gardening (Langevin 1997). The small colour differences on the surface of Mercury suggest a more homogeneous distribution of materials, while the spectra have an average behaviour that implies a sodium abundance higher than on the lunar surface.

2. Scientific objectives of HRIC

Within the previous scientific framework, HRIC will act to characterise the main features of the surface, to identify craters, scarps, lava flows and plains. This will allow us to address past volcanic and tectonic history of the planet and to help answering to some key questions:

- did the effusive volcanic activity last much longer than on any other planet?
- is the evidence of a giant volcanic dome on the unknown hemisphere confirmed?
- is the wide spreading of basin ejecta an efficient mechanism for resurfacing?
- are the NW–SE and NE–SW lineaments a general feature confirming the braking of the planet rotation period?
- are the lobate scarps the result of the cooling of planet mantle?

In addition, it will be possible to correlate surface features and composition to a scale comparable with the regolith mixing length. It will be possible to identify different surface compositions at very small scale and their relation to the observed morphology and/or individual landmarks by means of imaging with different specific filters and to assess the low abundance in ferrous iron (Fe^{2+}) and the metal–to–silicate ratio on Mercury.

The combination of high spatial resolution, stereo and spectroscopic information will allow us to characterise geophysical and geo–chemical features of the planet surface at large, regional and small scales. High spatial resolution images will be also essential to support the radio science experiment (requiring precise signature identification and localization).

3. HRIC optical design

The HRIC optical design has been optimised to provide the required high spatial resolution and a very light, compact and chromatically corrected solution. The optics is based on a catadioptric system with a modified Ritchey–Chretien design plus corrector. Other characteristics are summarised in Table 1.

4. Conclusions

HRIC will provide images that no other instrument on board presently foreseen space missions to Mercury will guarantee. Thus, the expected progress of knowledge about geophysical properties and geochemical evolution

Table 1. Optical characteristics of the HRIC for SIMBIO–SYS

OPTICS		
Type of camera	Matrix scanner	
Aperture	100	mm
Focal length	800	mm
Focal number	8	
λ for diffraction limit	400	nm
Field of view	1.47	deg
Central obstruction	10	% of area
IFOV	12.5	μm/rad/px
Ground pixel scale	5	m/px @ 400 km
Spectral range	$400 - 900$	nm
Filter bandwidth	500 / 40	nm
Spectral channels	Panchromatic (650) + 550, 700, 880 Filters	nm
Mirror efficiency	98	%
Mirror Material	Al	
IMAGE QUALITY		
Energy encircled (EE) in 1 pixel	> 67	%
MTF at F(Nyquist)	> 57	%
Distortion	< 0.6	%
APS SENSOR		
Array size	2048×2048	pixels
Pixel pitch	10	μm
Pixel fill factor	80	%
Quantum efficiency	55	% @ 500 nm
Full well capacity	10^5	e-

of Mercury is unique. SIMBIO–SYS includes several aspects of technological innovation, at system and channels levels. The limited resources (mass, first of all) and the expected harsh working conditions (e.g., thermal environment) during mission operation around Mercury drive the instrument design towards a very high integration. The optical design of the HRIC channel is original and satisfies the requirement of a very high spatial resolution. Moreover, the sensor type selected for this channel (and for the STC) is a CMOS APS with 2048 x 2048 10 μm–sized pixels: this is an innovative device, that shall provide, among other advantages, low power consumption, high radiation tolerance and easy handling of the commanding / signal acquisition sequences. Finally, the development of an innovative system such as SIMBIO–SYS may lead to applications of the know–how and the developed technologies to other research and application fields requiring high spatial resolution and stereoscopic imaging, as well as hyper–spectral investigation.

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