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Exploring Mercury's space environment and inner heliosphere by BepiColombo/Mio

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Abstract

Mercury has the weak planetary magnetic field and forms its magnetosphere, which is exposed to the most extreme solar wind in the solar system. Thus, Mercury's magnetosphere is one of the best targets to study exoplanetary environments rotating just close to the stars. The first Mercury orbiter MESSENGER explored this region and discovered a wide variety of phenomena. However, due to the highly ecliptic orbit with north-south asymmetry and limited capability for plasma measurements, many science topics remain unsolved. The Mercury Magnetospheric Orbiter (MMO), currently named as "Mio", for the BepiColombo mission was successfully launched on 20 October 2018. The Mio spacecraft has a complete package of plasma instruments, a spectral imager for the exosphere, and a dust monitor. Here we present the updated status of the spacecraft and the future operations plans, especially during the cruise phase.

1. Introduction

Mercury has the weak planetary magnetic field stands against the intense solar wind in the close distance to the Sun (0.3-0.5 AU). Mercury's plasma environment is quite different in the parameters from the well-studied terrestrial magneto-sphere. In addition, recently many Earth-type exoplanets orbiting in habitable zones very close to cool stars (M-dwarfs) were found. Such exoplanets are exposed to extreme stellar winds and ultraviolet radiations. Thus, Mercury's magnetosphere is the best step to understand the planetary environment and its habitability against strong stellar winds.

The first Mercury orbiter MESSENGER [1] explored this region and discovered a wide variety of phenomena. For example, Mercury's magnetosphere is much more dynamic than one had predicted. However, due to the highly ecliptic orbit with north-south asymmetry and limited capability for plasma measurements, many science topics remain unsolved.

The next Mercury exploration mission BepiColombo [2], which is the international joint project between ESA and JAXA, was successfully launched on 20 October 2018 by Ariane-5. The JAXA's spacecraft "Mio": Mercury Magnetospheric Orbiter (MMO) is equipped to study the space environment of Mercury. Mio is mainly designed for plasma observations with the complete package of plasma instruments consortium and is expected to extract essential elements of space plasma physics that become visible in the Hermean environment. In addition, ESA's Mercury Planetary Orbiter (MPO) also has several instruments for plasma measurements, so we can investigate Mercury's environment with two points measurements.

In addition to the Mercury science, the BepiColombo mission can contribute to the heliospheric physics in the inner solar system. NASA's Parker Solar Probe [3] was launched in 2018 and it is orbiting around Sun (~0.05 AU at perihelion). ESA's Solar Orbiter [4] will be launched in 2020 and will have a highly elliptic orbit between 1.2 AU at aphelion and 0.28AU at perihelion. Therefore, after the Mercury orbit insertion of BepiColombo in December 2025 (and even during the cruise phase), we will have a chance to investigate the inner heliosphere with three points measurements.

2. BepiColombo/Mio

The Mio spacecraft will have an ecliptic polar orbit with a period of 9.3 hours, a periapsis of 590 km (1.2 Mercury radii, Rm, from the Mercury center), and an apoapsis of 11640 km (5.8 Rm). Mio's orbital plane is always same as that of MPO, so there will be many chances to perform joint observations with two spacecraft. The Mio spacecraft will be spin-stabilized with a rotation rate of 15 rpm and a spin axis almost

perpendicular to the orbital plane of Mercury around the Sun.

Mio has a complete package of plasma environment measurements: Magnetic Field measurement (MGF), Plasma Wave Instrument (PWI), and Mercury Plasma Particle Experiment (MPPE). Especially PWI and MPPE have many sensors to cover wide ranges of frequency, energy, and electron/ion/neutral particles. These instruments will be operated as a plasma measurement consortium. In addition, two more instruments are installed onboard Mio to investigate Mercury's exosphere and dust environment: Mercury Sodium Atmospheric Spectral Imager (MSASI) and Mercury Dust Monitor (MDM). All the instruments onboard Mio are listed in Table 1 and their layout is shown in Figure 1. Table 1 also includes the comparison with the similar instruments onboard MESSENGER. It is clear that Mio can perform quite new investigations around Mercury and has wider energy/mass range or higher resolutions.

Table 1: Science instruments list onboard Mio

	BepiColombo/MMO				MESSENGER	
Plasma (SW, MS)	MPPE	MEA	Low-energy electrons	3eV-26keV	-	
		MIA	Low-energy ions	15eV-29keV	FIPS	50eV-13keV 1-40 amu/e
		MSA	Ion mass spectroscopy	1eV-38keV 1-60 amu/e m/Δm = 40 (<13keV) m/Δm = 10 (>13keV)		
		HEP-ion	High-energy ions	30keV-1.5MeV	EPS	25keV-1MeV
		HEP-ele	Hihg-energy electrons	30keV-700keV	EPS	25keV-1MeV
		ENA	Plasma imaging	10eV-3.3keV	-	
	MGF		Magnetic field	DC - 64Hz L: <0.25Hz, M: 8Hz	MAG	DC - 20Hz
	PWI		Electric field, plasma wave, radio wave	DC - 10MHz (E) few - 640kHz (B)	-	
Exosphere	MSASI		Na-exosphere image	Spatial resol.: 3-30km R = 65000	MASCS	Spatial reol.: 25-800km R = 1000
Dust	MDM		Dust environment	10s pg*km/s	-	

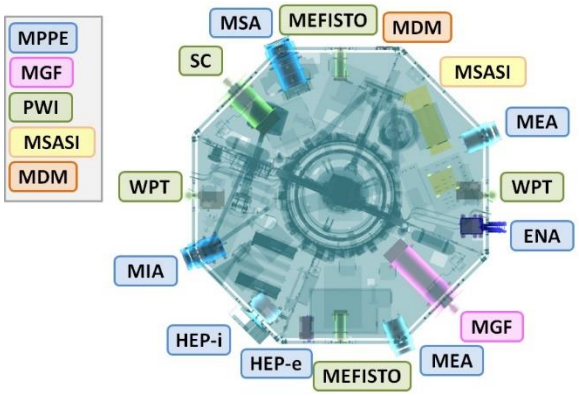

Figure 1: Layout of the science instruments of BepiColombo/Mio.

3. Initial commissioning

The BepiColombo spacecraft was launched in 20 October 2018 and then we performed the initial commissioning operations. We first turned on the Mio spacecraft in November 2018 and checked out the bus system and all the science instruments without applying high voltage to avoid discharge issues due to outgassing from the spacecraft. We will perform the delta commissioning operations including the instruments with high voltage in June-August 2019. Then Mio will be ready for science observations during the planetary flybys.

4. Cruise operations plan

We plan to perform science observations by Mio during planetary flybys with some instruments: MPPE-MEA, -MIA, -MSA, -HEP (only electron), MGF, and PWI (only magnetic field). Though Mio is covered by the sun-shield (MMO Sun-shield and Interface Structure: MOSIF), MPPE sensors still have open field of views in the top direction above MOSIF. In the near future BepiColombo will have a flyby at the Earth in April 2020 and two Venus flybys in October 2020 and in August 2021. Currently we plan to perform science observations only during the flybys, but after the delta commissioning with high-voltage instruments we will start to study the feasibility of solar wind observations during the cruise phase.

References

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