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BepiColombo – ESA's mission to explore Mercury

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Abstract

BepiColombo is an interdisciplinary mission to explore Mercury. Bepi-Colombo is a joint project between ESA and the Japanese Aerospace Exploration Agency (JAXA). From dedicated orbits two spacecraft, the JAXA provided Mercury Magnetosphere Orbiter (MMO) and the European Mercury Planetary Orbiter (MPO), will be studying the planet and its environment. Both spacecraft of BepiColombo will be launched together in July 2014.

1. Introduction

The BepiColombo mission will address a comprehensive set of scientific questions in order to study the planet, its evolution and its surrounding environment. A suite of state-of-art scientific instruments, flying on the two spacecraft, allow a wide range of scientific questions to be addressed that will provide clues on the origin and formation of terrestrial planets and help to answer fundamental questions like: "How do Earth-like planets form and evolve in the Universe?" The MPO will focus on a global characterization of the planet itself, while the second spacecraft, the MMO, will study the environment around the planet including the planet's exosphere and magnetosphere. Upon arrival in the second half of 2020 after a cruise phase of about six years, the Solar Electric Propulsion Module will be jettisoned and chemical propulsion will be used to inject both spacecraft into their dedicated polar orbits. The MMO will be released first, after which an additional thrust phase will insert the MPO into its final orbit. Both orbits are elliptical with eccentricity and inclination optimized for the study of Mercury (MPO orbit: 400×1,508 km) and its magnetosphere (MMO orbit: 400×11,824 km). The base-lined lifetime of the MPO and MMO in Mercury orbit is one Earth year (about four Mercury years, or two Mercury solar days). A mission extension by another Earth year is optional.

Mercury is small compared to the Earth, with a diameter of only 4,878 km. It orbits the Sun in an elliptic orbit between 0.3 and 0.47 AU from the Sun. Mercury is difficult to observe from the Earth, due to its close proximity to the very bright Sun. For an in-depth study of the planet and its environment, it is therefore necessary to operate a spacecraft equipped with scientific instrumentation around the planet. On the other hand the thermal and radiation environment close to the Sun and close to the hottest planet in the solar system is extremely aggressive, which makes this mission technically very challenging.

The mission has been named in honour of the Italian mathematician Giuseppe (Bepi) Colombo (1920–1984), who made many contributions to planetary research, celestial mechanics, including the development of new. space flight concepts. He is well known for explaining that Mercury rotates three times about its axis while it completes two orbits around the Sun.

The BepiColombo mission will provide a rare opportunity to collect multi-point measurements in a planetary environment. This will be particularly important at Mercury because of short temporal and spatial scales in the Mercury's environment. It is foreseen that the orbits of MPO and MMO are selected in a way to allow close encounters of the two spacecrafts throughout the mission. Such intervals are very important for the inter-calibration of similar instruments on the two spacecraft. They also provide scientifically valuable intervals to collect multi-point measurements in an environment where both spatial and temporal scales can be very short.

1.1 Science Background

The main scientific objectives of the BepiColombo mission are to study:

- Origin and evolution of a planet close to its parent star
- Mercury's figure, interior structure, and composition
- Interior dynamics and origin of its magnetic field
- Exo- and endogenic surface modifications, cratering, tectonics, volcanism
- Composition, origin and dynamics of Mercury's exosphere
- Composition, origin and dynamics and polar deposits

- Structure and dynamics of Mercury's magnetosphere
- Test of Einstein's theory of general relativity

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2. MPO and MMO Payload

The MPO will carry a highly sophisticated suit of eleven scientific instruments, ten of which will be provided by Principal Investigators through national funding by ESA Member States and one from Russia:

The **BepiColombo Laser Altimeter** (BELA) will characterise the topography and surface morphology of Mercury. (*Principal Investigators: N. Thomas, University of Bern, Switzerland, and T. Spohn, DLR, Germany*); the objectives of the **Italian Spring Accelerometer** (ISA) are strongly connected with those of the MORE experiment. Together the experiments can give information on Mercury's interior structure as well as test Einstein's theory of the General Relativity (*V. Iafolla, CNR-IFSI, Italy*); the **Mercury Magnetometer** (MERMAG-MAG) will provide measurements that will lead to the detailed description of Mercury's planetary magnetic field and its source, to better understand the origin, evolution and current state of the planetary interior , as well as the interaction between Mercury's magnetosphere with the planet's itself and with the solar wind. (*K.H. Glassmeier, Technical University of Braunschweig, Germany*); the **Mercury Thermal Infrared Spectrometer** (MERTIS) will provide detailed information about the mineralogical composition of Mercury's surface layer. (*H. Hiesinger, University Münster, Germany*); the **Mercury Gamma ray and Neutron Spectrometer** (MGNS) will determine the elemental compositions of the surface and subsurface of Mercury, and will determine the regional distribution of volatile depositions on the polar areas which are permanently shadowed from the Sun (*I. Mitrofanov, Institute for Space Research, Russia*); the **Mercury Imaging X-ray Spectrometer** (MIXS) will use X-ray fluorescence analysis method to produce a global map of the surface atomic composition at high spatial resolution (*G. Fraser, University of Leicester, UK*); the **Mercury Orbiter Radio Science Experiment** (MORE) will help to determine the gravity field of Mercury as well as the size and physical state of its core. (*L. Iess, University of Rome "La Sapienza", Italy*); the **Probing of Hermean Exosphere by Ultraviolet Spectroscopy** (PHEBUS) spectrometer is devoted to the characterisation of Mercury's exosphere composition and dynamics. It will also search for surface ice layers in permanently shadowed regions of high-latitude craters (*E. Quemerais, Université P&M Curie, France*); the **Search for Exosphere Refilling and Emitted Neutral Abundances** (SERENA) will study the gaseous interaction between surface, exosphere, magnetosphere and solar wind (*S. Orsini, CNR-IFSI, Italy*); the **Spectrometers and Imagers for MPO BepiColombo Integrated Observatory System** (SYMBIO-SYS) will examine the surface geology, volcanism, global tectonics, surface age and composition, and geophysics (*E. Flamini, ASI, Italy*); and the **Solar Intensity X-ray Spectrometer** (SIXS) will perform measurements of X-rays and particles of solar origin at high time resolution and a very wide field of view (*J. Huovelin, Observatory University of Helsinki, Finland*).

The MMO will carry five advanced scientific experiments provided by nationally funded Principal investigators, one European and four from Japan:

The **Mercury Magnetometer** (MERMAG-MGF) will provide a detailed description of Mercury's magnetosphere and of its interaction with the planetary magnetic field and the solar wind (*W. Baumjohann, Austrian Academy of Sciences, Austria*); the **Mercury Plasma Particle Experiment** (MPPE) will study low- and high-energetic particles in the magnetosphere (*Y. Saito, ISAS, JAXA, Japan*); the **Mercury Plasma Wave Instrument** (PWI) will make a detailed analysis of the structure and dynamics of the magnetosphere (*Y. Kasaba, Japan*); the **Mercury Sodium Atmospheric Spectral Imager** (MSASI) will measure the abundance, distribution and dynamics of sodium in Mercury's exosphere *(I. Yoshikawa, Univ. Tokyo, Japan*); and the **Mercury Dust Monitor** (MDM) will study the distribution of interplanetary dust in the orbit of Mercury (*K.Nogami, Dokkyo Med. Univ., Japan*).