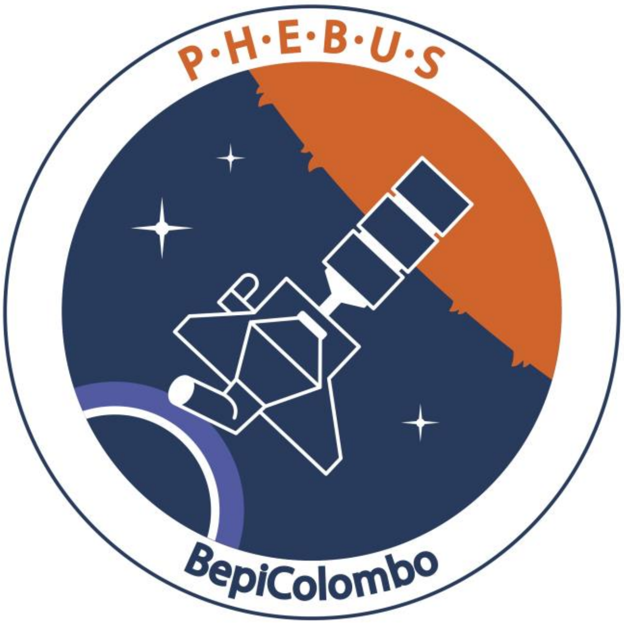
Phebus, a French spectrometer on board the BepiColombo mission soon to be launched towards Mercury



On October 20 at 03:45 (Paris time), the space mission BepiColombo will be launched from the Kourou Space Center in French Guiana, towards the planet Mercury. The mission will carry sixteen scientific instruments, including the PHEBUS spectrometer designed under the scientific and technical responsibility of LATMOS.

Planet Mercury

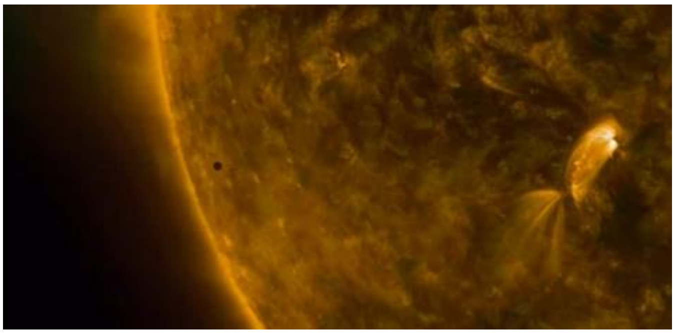


Figure 1. Transit of Mercury across the Sun observed in the UV satellite SDO. Credit: NASA

Mercury is the planet closest to the Sun (Figure 1). Like the Moon, Mercury is an inert and desert celestial body, with a very thin gaseous envelope. Its proximity to the Sun (average 57.9 million kilometers) combined with the absence of atmospheric protection, subjects the planet to extreme temperatures from + 430 ° C on the dayside to -180 ° C on the nightside, as well as a level of solar radiation ten times higher than Earth. Its harsh environment makes it difficult to send space probes and measuring instruments that can withstand extreme temperature differences.

Following the American probes Mariner 10 (1973) and MESSENGER (2004), Bepi-Colombo is the third mission to explore Mercury's surface and environment.

The BepiColombo Mission

Europe's first mission to Mercury, BepiColombo is the result of a collaboration between the European (ESA) and Japanese (JAXA) Space Agencies. This project was born in 2003 and involved 14 European countries and Japan, ready to meet the technological challenges imposed by Mercury’s hostile environment. The mission is composed of two spacecrafts (Figure 2) that will separate from each other as they approach Mercury and will be inserted to their respective orbit in order to achieve their scientific goals.

JAXA is responsible for the MMO probe (Mercury Magnetosphere Orbiter), renamed みお ("Mio") in Japanese, dedicated to the study of the magnetosphere, the planet’s magnetic field, but also to the analysis of interplanetary dust. ESA is responsible for the MPO probe (Mercury Planetary Orbiter), renamed "Bepi" which will examine the surface, the geological composition and the outer atmosphere of Mercury.

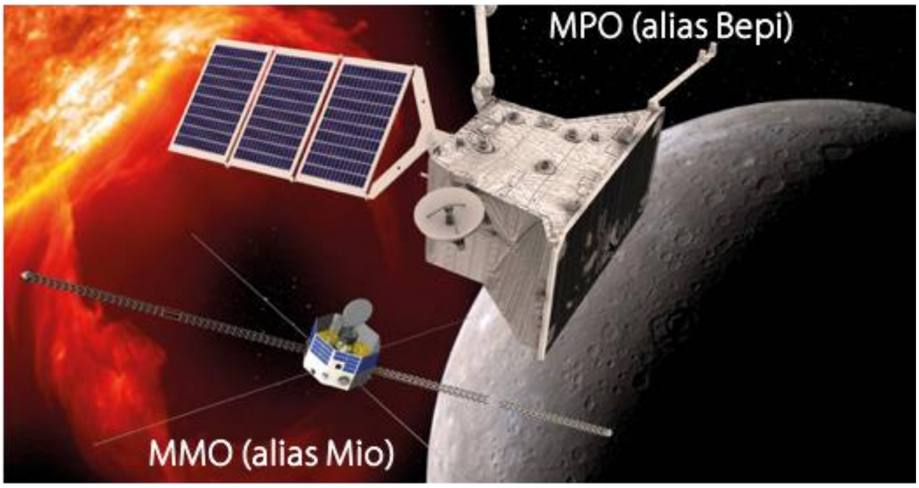


Figure 2 Artist view of the MMO and MPO probes of the BepiColombo mission as they approach Mercury. Credit: ESA

ESA is also in charge of the launch, the navigation to Mercury, and the injection of the two probes in their respective orbits around Mercury in late 2025.

Before starting its nominal mission around Mercury, BepiColombo will orbit the Sun 18 times, and perform 1 flyby of the Earth, 2 flybys of Venus and 6 flybys of Mercury during a trip that will last 7 years. The nominal mission duration is 1 year plus 1 optional year.

The PHEBUS instrument is on board the European probe BEPI, formerly called Mercury Planetary Orbiter. It was delivered and built in the satellite in April 2015, at the ESA test center (ESTEC) in Noordwijk, the Netherlands.

The European-Japanese probe is currently in Kourou, Guiana Space Center for final tests and preparations (Figure 3).

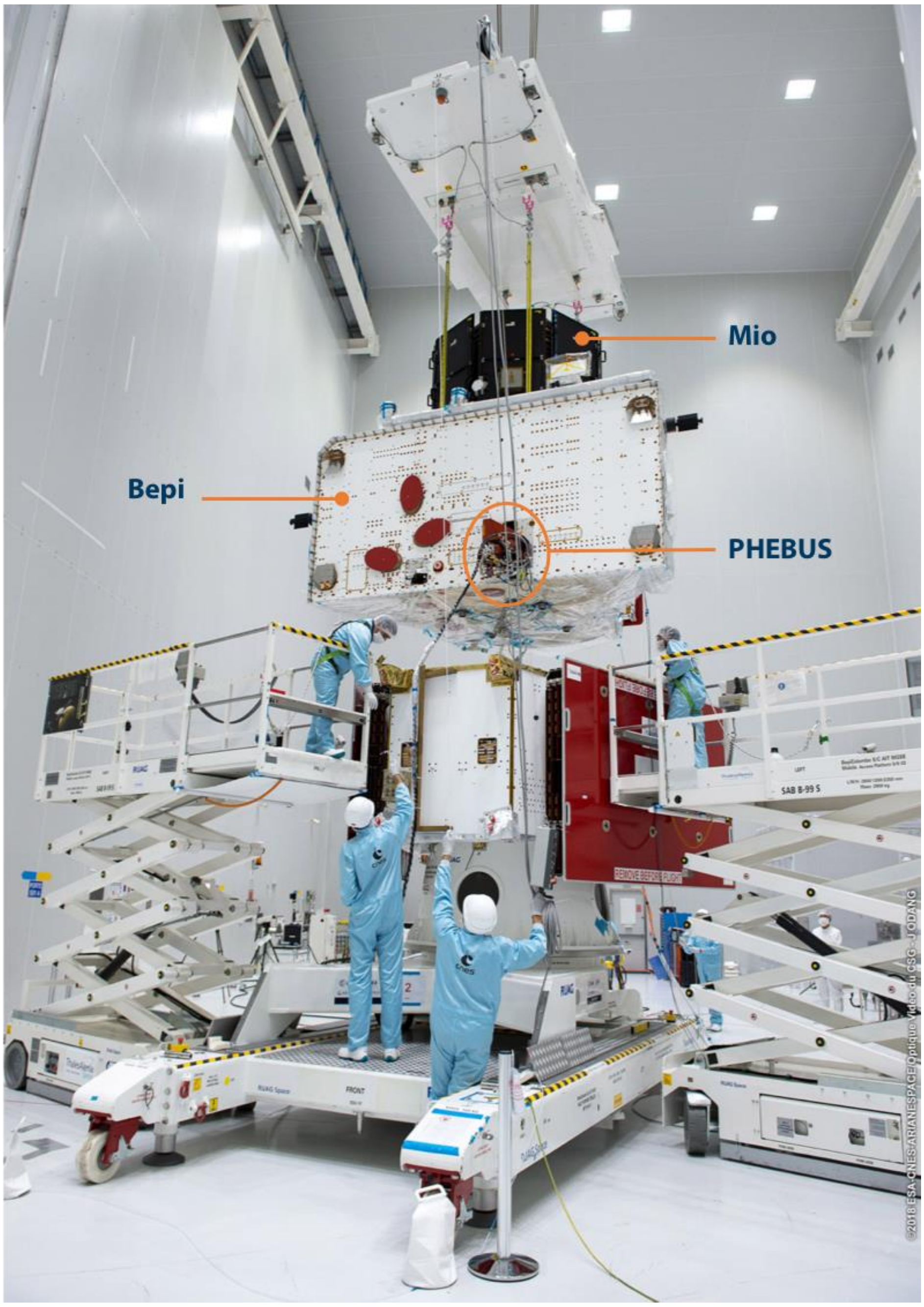


Figure 3. Checking the adjustment module of the BepiColombo mission to the Guiana Space Center in Kourou. Credit: ESA

The PHEBUS instrument

PHEBUS (Probing of Hermean Exosphere By Ultraviolet Spectroscopy) is a double optical spectrometer covering the spectral ranges from the extreme ultraviolet (EUV: 55-155 nm) to the far ultraviolet (FUV: 145-315 nm). It is dedicated to the characterization of Mercury's exosphere composition and dynamics, and the interactions between the surface and the exosphere.

Compared to its predecessors (e.g. MESSENGER / NASA), PHEBUS has the specificity to be sensitive to very short wavelengths allowing us for the first time to survey Mercury’s environment down to 55 nm, and thereby to detect additional species such as metals (Si, Mg, Fe), rare gases (Ar, Ne) and traces of hydrogen and helium in the exosphere.

To detect the very faint emissions of the constituents of Mercury's exosphere, PHEBUS needs a very high sensitivity and strong attenuation of stray light. To achieve these objectives, the light collecting system of the instrument includes a stray light deflector (baffle), and a parabolic mirror off-axis made of silicon carbide, acting as an entrance telescope (Figure 4). The observed photons are focused by the mirror onto a slit, and then impact two holographic gratings that separate photons according to their wavelength (Figure 5). Two detectors (EUV detector: [55 - 155 nm], FUV detector: [145 -315 nm]) are placed at the gratings' focal plane and will produce the image of the spectrum obtained (Figure 6).

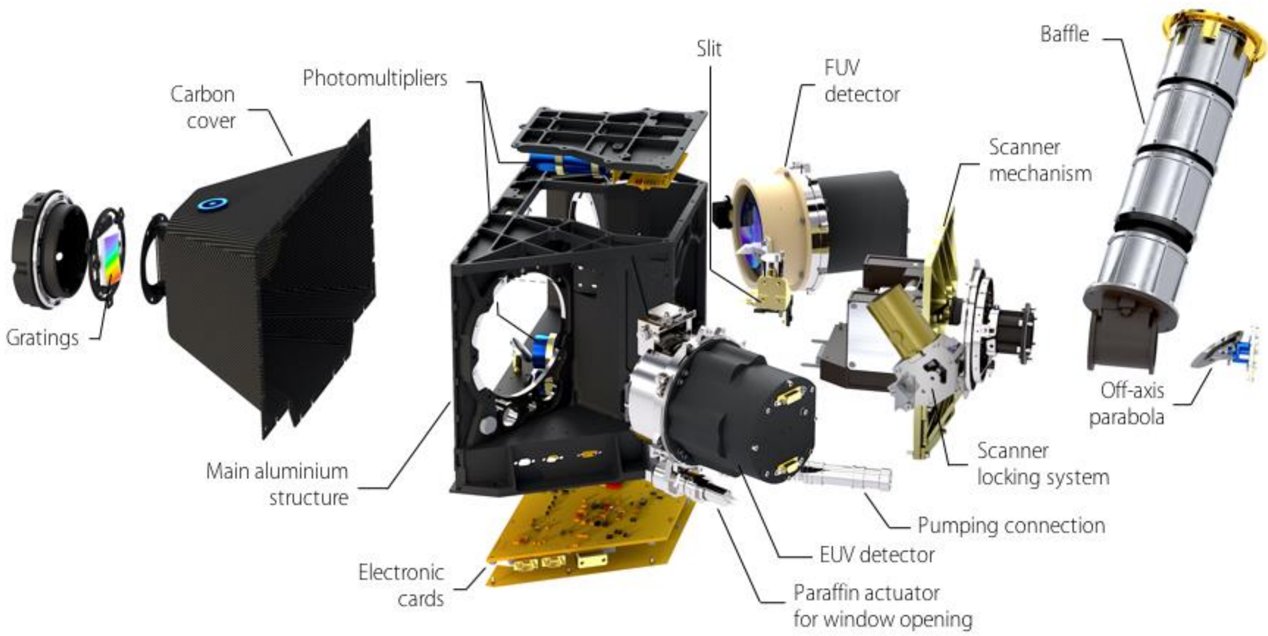


Figure 4. Exploded View of the main PHEBUS subsystems. Credits: PHEBUS / LATMOS.

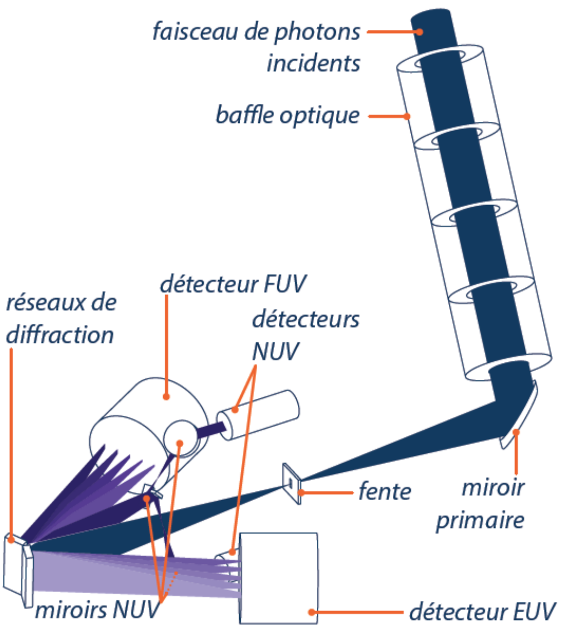


Figure 5. Optical design of PHEBUS. Credits: PHEBUS / LATMOS/ L. Meghraoui.

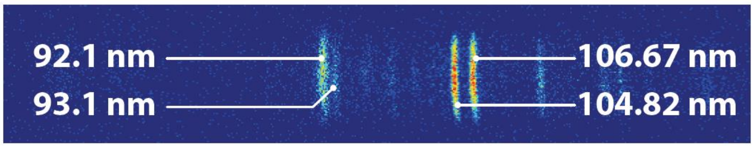


Figure 6. Photo of the Argon spectrum in the ultraviolet, obtained during the ground calibration of PHEBUS. Credit: PHEBUS / LATMOS.

The detection is based on the photon counting principle and performed using microchannel plate detectors (MCP - Micro Channel Plate) associated with resistive anodes (RAE - Resistive Anode Encoder). This combination (MCP + RAE) confers on the instrument a very high sensitivity and extremely low noise, without the need for a cooling system, as may be the case on other instruments.

The optical design has been achieved using the minimum number of elements to fully optimize the transfer of photons.

Two additional channels based on photomultipliers are dedicated to the detection of emissions from Potassium (404 nm) and Calcium (422 nm).

The light collecting system is also mounted on a single axis scanning mechanism (scanner) giving us the ability to probe regions of interest and altitude ranges regardless of the orientation of the satellite platform (Figure 7).

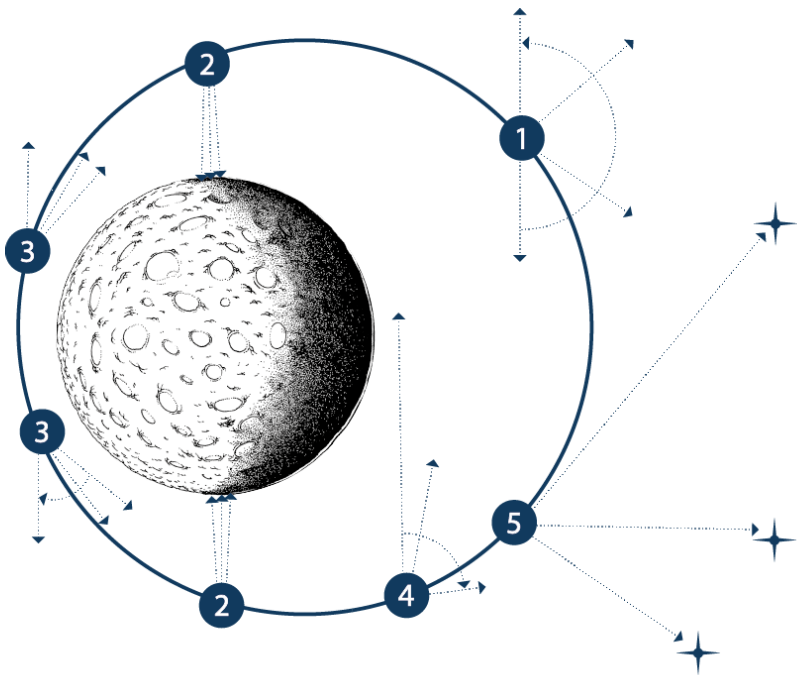


Figure 7. Illustration of different modes of observation of PHEBUS. Credits: Team Phebus / LATMOS L. Meghraoui

Therefore, PHEBUS can simultaneously measure all detectable species to produce three-dimensional maps (altitude, latitude, longitude) of the exosphere, and study its evolution over time in response to the extreme environmental conditions of the planet.

Finally, to meet the requirements imposed by the harsh space environment, LATMOS engineers have designed an instrument that is at the same time compact, lightweight (7.5 kg) and extremely sturdy thanks to the use of a single-block aluminum unit and a carbon shell.

During the mission, the instrument is calibrated regularly on stars chosen correctly, in order to monitor the degradation of the instrument sensitivity over time.

LATMOS and partners

LATMOS (Laboratoire Atmospheres, Environments and Space Observations) is a joint research unit under the National Scientific Research Center (CNRS) and affiliated with the universities of Versailles Saint-Quentin-en-Yvelines and Sorbonne University . The laboratory is member of the Institut Pierre Simon Laplace (IPSL), a federation of nine public laboratories specialized in environmental science research in the Ile-de-France region.

PHEBUS is the main French contribution to the BepiColombo mission. This instrument took nearly 15 years of development, provided by a team of ten engineers from LATMOS (project manager, system engineers, electronic engineers, opticians, mechanics, thermal engineer, product insurance manager, remote control computer scientists, software engineering and scientific computing ...), in cooperation with Japan (Tokyo University , supplying of sensors), the Russian space agency (the IKI , providing the scanning system) and Italy (LUXOR Lab, Padova University , support for the optical calibration of the instrument on the ground), and managed through the Centre National d'Etudes Spatiales (CNES).

To learn more about Phebus:

http://phebus.projet.latmos.ipsl.fr/

To follow the news of the mission:

http://www.esa.int/Our_Activities/Space_Science/BepiColombo

To learn more about Mercury:

https://www.planete-mercure.fr/planete-mercure