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# The BepiColombo flyby at Venus in 2020: analysis of the scientific outcome

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## Abstract

The BepiColombo mission was succesfully launched on October 20th 2018, at 01:45 UTC. It is a jointly project between the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA) and it is made by two different orbiters designed to explore Mercury and its environment. Mercury's orbit insertion will be in December 2025. During its long cruise, BepiColombo will swing-by the Earth, Venus and Mercury itself. Though the cruise configuration does not allow all the instruments to be operative, a big part of them will be able to work. Hence, this is a great occasion to obtain interesting scientific outcome, especially from the Venus flybys. Venus, in fact, at the moment is explored only by the Japanese mission Akatsuki, and no other devoted mission to this planet are presently approved by the space agencies.

## 1. Introduction

The Mercury Planetary Orbiter (MPO) payload comprises 11 experiments and instrument suites. It will focus on a global characterization of Mercury through the investigation of its interior, surface, exosphere and magnetosphere. In addition, it will test Einstein's theory of general relativity. The second spacecraft, the Mercury Magnetosphere Orbiter (MMO), will carry 5 experiments or instrument suites to study the environment around the planet including the planet's exosphere and magnetosphere, and their interaction processes with the solar wind. MPO and MMO will be launched in a composite with a propulsion element, the Mercury transfer module (MTM) and a sunshade cone to protect the MMO (MOSIF).

During the long cruise to Mercury (7.2 years), BepiColombo will have 1 flyby at the Earth in April 2020, and two fly-by's at Venus on October 15th 2020 and August 10th 2021, before arriving close to Mercury with the first of 6 flybys two months later. The launch and cruise configuration (MCS) will not allow full operability of all instruments onboard. In fact, MMO will be partly shielded by MOSIF, thus allowing instruments to detect signals only within a conical field-of-view around the MCS's –Z axis, and on-board the MPO all the instruments obstructed by the MTM (+Z axis) will not be able to operate. Nevertheless, all the instruments not requiring pointing or with apertures in the other directions will be operative.

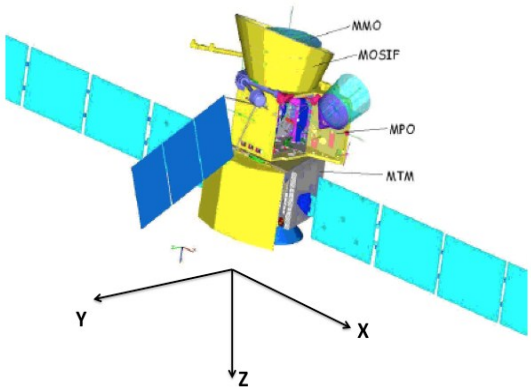


Figure 1: BepiColombo in its cruise configuration (MCS).

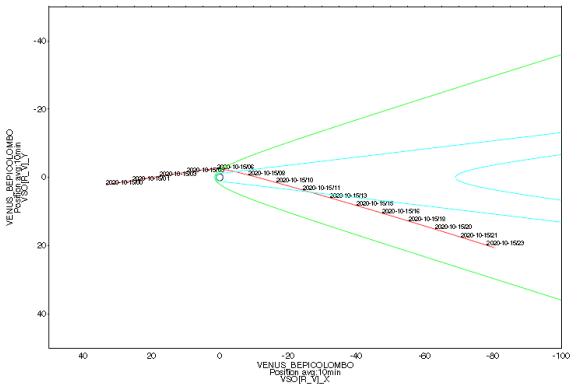

Figure 2: MCS trajectory at the time of first Venus flyby (red, from left to right), in Venus Solar Orbital coordinates (Sun to the

left). In green the bowshock, in blu the magnetic pile-up boundaries.

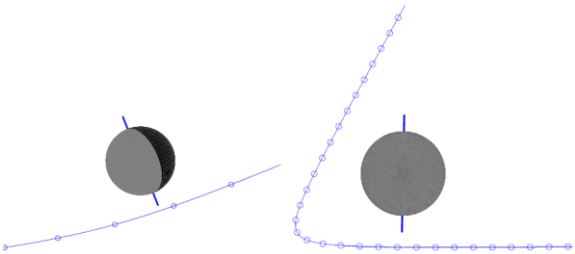

Figure 3: 1st Venus flyby on Oct 15th,2020 as seen from the Earth (left) and from the Sun (right).

## 2. Venus Flyby's Analysis

During interplanetary cruise and outside electric propulsion, the default composite attitude is +Y axis pointed to the Sun. The spacecraft attitude is then adjusted by ground to minimize angular momentum through wheel offloading, but will be relaxed for the short duration of scientific interest around Venus. Offset of the Sun direction in +YZ plane is in the range +27 to -9 degrees. The geometry of the first Venus flyby can be summarized in Figure 2 and 3 (closest approach altitude of about 10000 km).

## 3. BepiColombo science at Venus

8 of the 11 instruments onboard the MPO will be able to operate at Venus. They are: the accelerometer ISA, the magnetometer MAG, the two channels (spectrometer and radiometer) of MERTIS, the neutron and gamma spectrometers MGNS, the radio science experiment MORE, the EUV and FUB spectrometers of PHEBUS, the two ion detectors (MIPA and PICAM) of SERENA, and the two spectrometers of SIXS. The big differences occurring between Mercury and Venus necessarily derive in a different use of some of the instruments in the payload, specifically designed for a planet – Mercury – with much different environment. In fact, Venus possess a very thick, complex and dynamic atmosphere (while Mercury only a tenuous exosphere) that totally hide the surface, and on the contrary does not possess an intrinsic magnetic field that, hence, may protect the planet by the surrounding environment.

Anyway, the MPO instrumentation will be able to give contribution to Venus science. In particular, MERTIS spectrometer and radiometer, devoted to the study of the Hermean surface composition and grain size, on Venus will be used to sound clouds at 55-100 km altitude in the bands of $CO_2$, $SO_2$, $H_2SO_4$, and will be able to provide temperature profiles. PHEBUS, designed to study the exospheric composition of Mercury, will be able to measure Venusian H, He and O hot populations. MGNS at Mercury will sound surface composition, especially in terms of radioisotopes and volatile deposits; at Venus will perform atmospheric analysis to measure leakage flux of neutrons and measure gamma-rays emission. SERENA/MIPA & PICAM together with SIXS will be able to study the planetary environment in terms of solar radiation and energetic particles, as well of lower energy ion population entrapped in the local Interplanetary Magnetic Field and induced magnetosphere that will be measured by the magnetometer MAG. Important contribution on the study of the planetary environment around Venus (both in terms of particles population and magnetic field and parameters) will be given by the 3 (over 5) instruments onboard MMO. MPPE will be able to detect low energy ions and low and high energy electrons, and perform plasma imaging. The magnetometer MGF will corroborate MPO/MAG measurements; and PWI will measure electric field, plasma and radio waves. In addition to this, coordinated measurements from Earth-based telescopes is now being organized (see Y.J.Lee presentation, this session) to obtain the maximum outcome from the great occasion of BepiColombo flybys at Venus.

## 4. Science and Operations

Connection between science requirements and spacecraft constraints during the first Venus flyby was necessary to verify real feasibility of aimed measurements. This effort required the analysis of instrument pointing requirements from ESA/ESAC and ESOC teams and the generation of a 'pointing timeline' to optimize the scientific outcome given the time and attitude restrictions [1]. Now the scientific outcome at Venus and the operation modes for the first flyby are going to be consolidated in a 'scientific traceability matrix' that will be presented at the EPSC conference.

## 5. References

[1] Montagnon, E., De la Fuente, S., BepiColombo – Operational Analysis of Venus Swingby Observation Requests, BC-ESC-TN-10045, issue 1, released 13/03/17