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The scientific outcome from BepiColombo flybys at Venus

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Abstract

BepiColombo is a dual spacecraft mission to be launched in October 2018 to explore Mercury and carried out jointly between the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA). During its long cruise to Mercury, BepiColombo will swing-by Venus twice, in 2020 and in 2021. Though the cruise configuration does not allow all the instruments to be operative before Mercury orbit insertion, this is nonetheless a great occasion to obtain interesting scientific outcome. A 'scientific traceability matrix' is presented here.

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 in October 2020 and August 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.

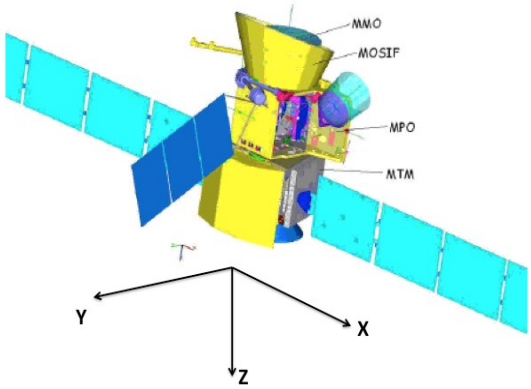

Figure 1: BepiColombo in its cruise configuration (MCS).

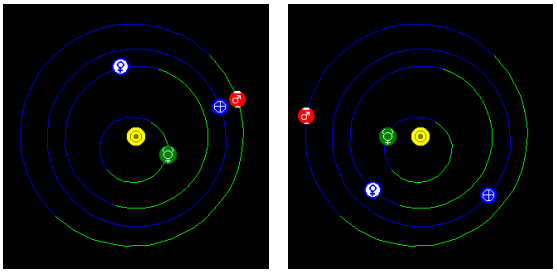

Figure 2: Inner Solar System at the time of the 1st (left) and 2nd Venus flyby (right).

2. Venus Flyby's Analysis

The MCS nominal attitude during cruise will be defined by the +Y axis pointed to the Sun and a rotation of 120 degrees/hour about the Sun vector (which results in approximately 8 full rotations/day). The two Venus flybys geometries can be summarized

in Figure 2 and 3, and will have closest approach altitude of about 11000 and 1000 km, respectively.

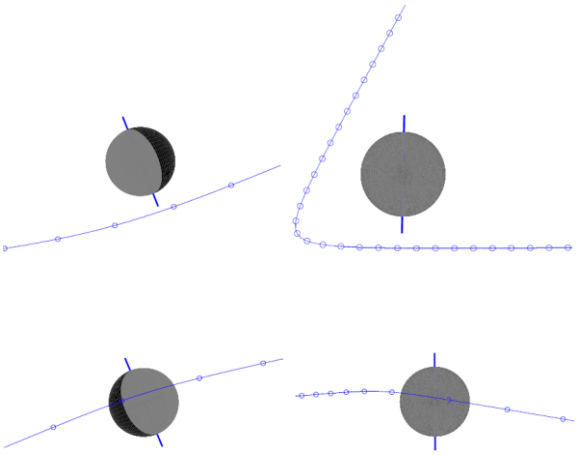

Figure 3: (up) 1st Venus flyby on Oct 12th,2020 as seen from the Earth (left) and from the Sun (right); (bottom) 2nd Venus flyby on Aug 11th, 2021.

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. 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. On the contrary, 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, giving name to the particles entrapped in the local Interplanetary Magnetic Field (first flyby) and induced magnetosphere that will be measured by the magnetometer MAG.

Important support to the MPO measurements of the planetary environment around Venus (both in terms of particles population and magnetic field) 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.

4. Science and Operations

A necessary work of connection between science requirements and spacecraft constraints during the cruise phase (and swing-by in particular) was mandatory to verify real feasibility of such measurements out of the original target for which BepiColombo instruments were designed. This effort included on one side 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]. On the other, the scientific outcome at Venus and the operation modes will be very soon 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