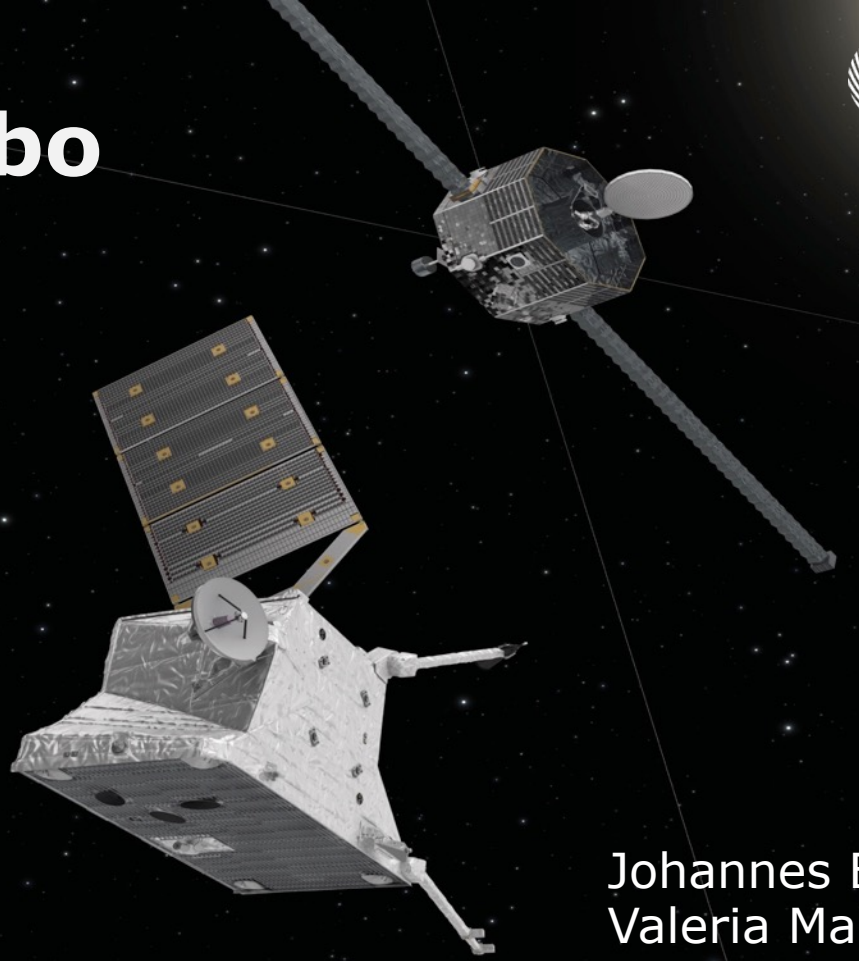
BepiColombo
Venus flybys

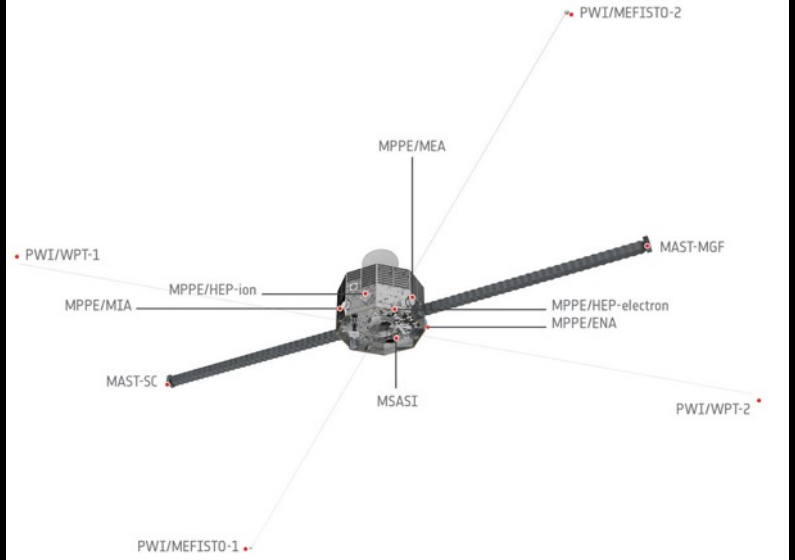


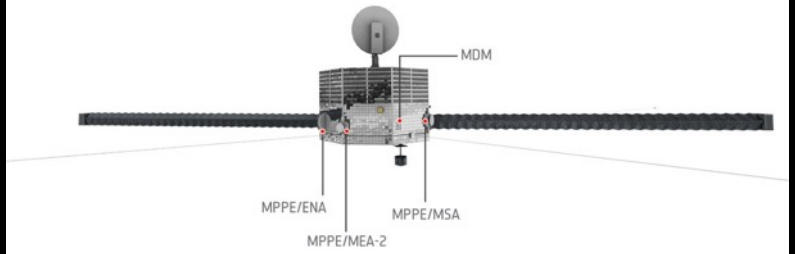
Johannes Benkhoff
Valeria Mangano

27 Oct. 2020

BepiColombo - short overview

- Joint ESA & JAXA mission to explore Mercury
- Launched: 20 October 2018
- Arrival at Mercury: end 2025
- Solar Electric Propulsion
- 9 planetary flybys – 1 @ Earth, 2 @ Venus, 6 @Mercury
- Two Spacecraft stacked together during cruise on a Transfer craft called MTM
- Comprehensive Science Payload
- Enthusiastic Science Team

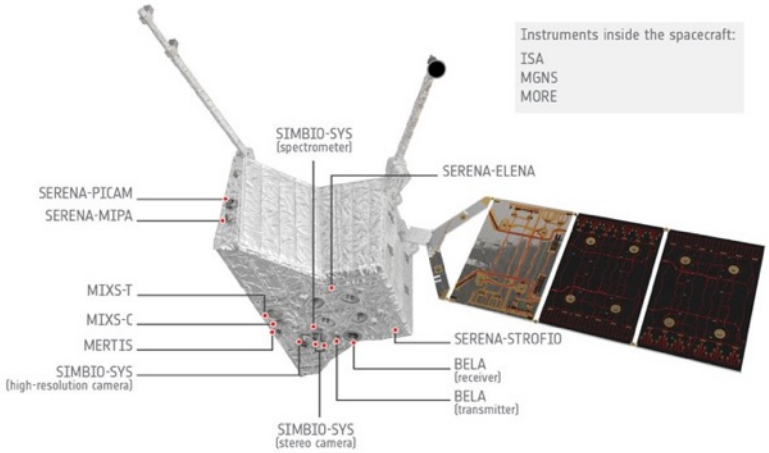


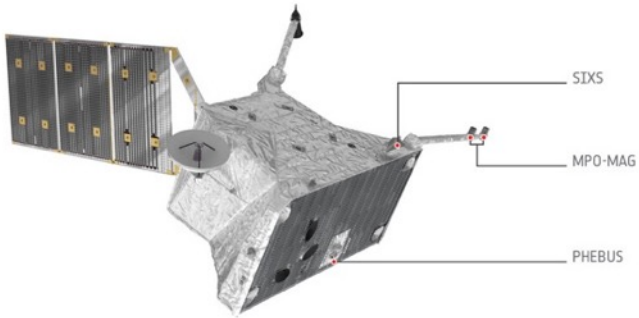


Mio – Instruments

	Instrument description
MGF	Provide a detailed description of Mercury's magnetosphere and of its interaction with the planetary magnetic field and the solar wind.
MPPE	Study low- and high-energetic particles in the magnetosphere. MEA- Electron Analyzer MIA – Ion Analyzer HEP-ion – High Energy Particles HEP-electron – High Energy Particles ENA – Energetic Neutrals Analyzer MSA – Mass Spectrum Analyzer
PWI	Make a detailed analysis of the structure and dynamics of the magnetosphere. MEFISTO, WPT – two sets of electric field sensors LF-SC and DB-SC -- two kinds of magnetic field sensors
MSASI	Measure the abundance, distribution, and dynamics of sodium in Mercury's exosphere.
MDM	Study the distribution of interplanetary dust in the orbit of Mercury.

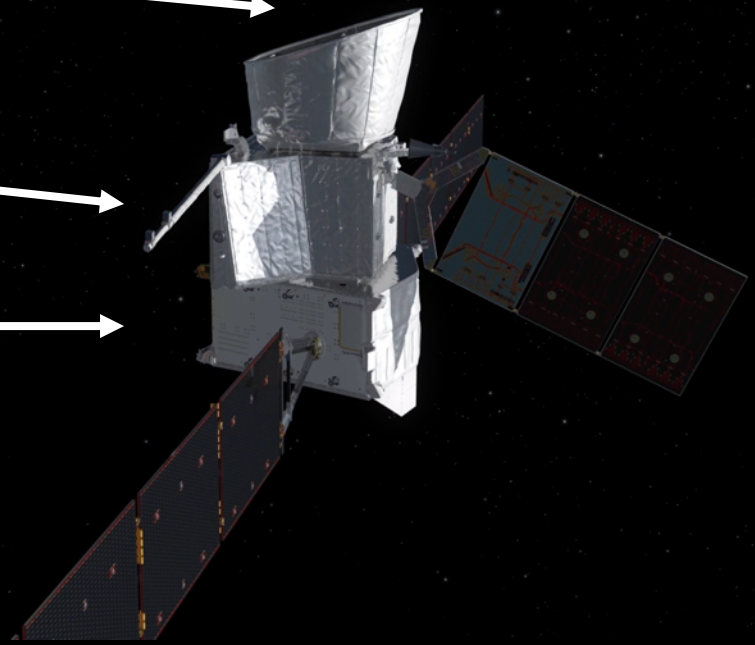
MPO – Instruments



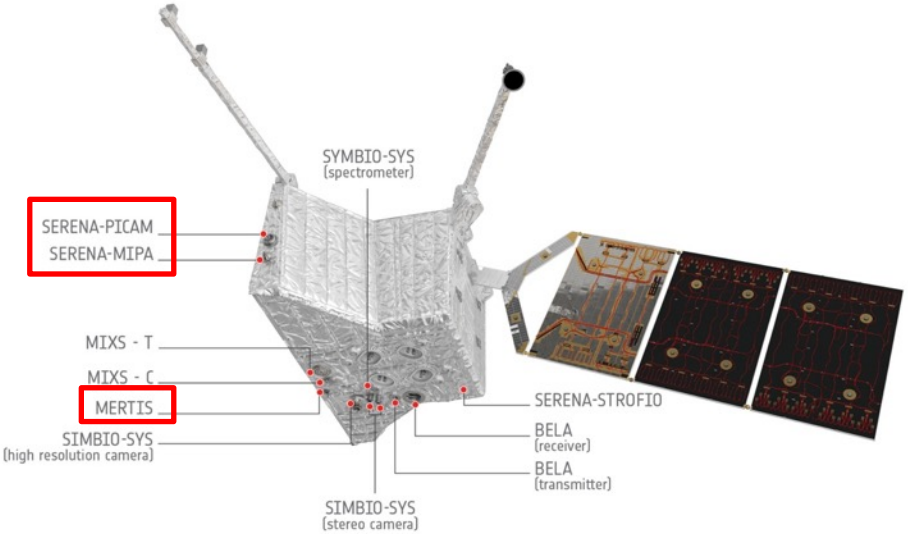


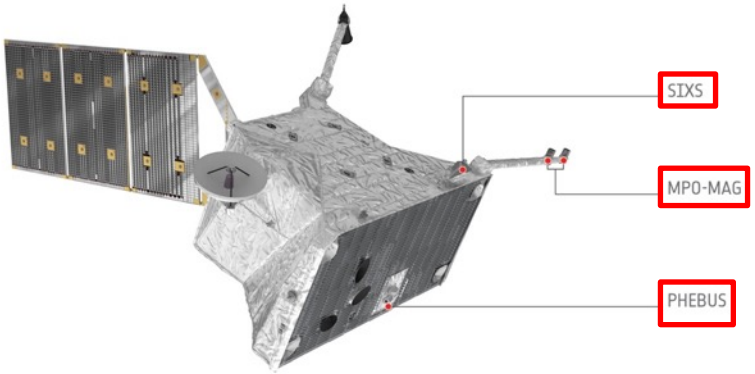
	Instrument description
BELA	Characterise the topography and surface morphology of Mercury.
MORE	Determine Mercury's gravity field as well as the size and physical state of its core.
ISA	Study Mercury's interior structure and to test Einstein's Theory of Relativity.
MPO-MAG	Describe Mercury's magnetic field and its source.
MERTIS	Study of Mercury's mineralogical composition, global temperature maps.
MGNS	Elemental composition of Mercury's surface distribution of volatiles in polar areas
MIXS	Use X-ray fluorescence analysis a global map of the surface atomic composition.
PHEBUS	Characterisation of the composition and dynamics of Mercury's exosphere.
SERENA	Study the interactions between the surface, exosphere, magnetosphere & the solar wind.
SIMBIO-SYS	Provide global, high-resolution, and IR imaging of the surface
SIXS	Perform measurements of solar X-rays and particles at high time resolution.

BepiColombo: cruise configuration



BepiColombo – MPO Instruments (cruise)

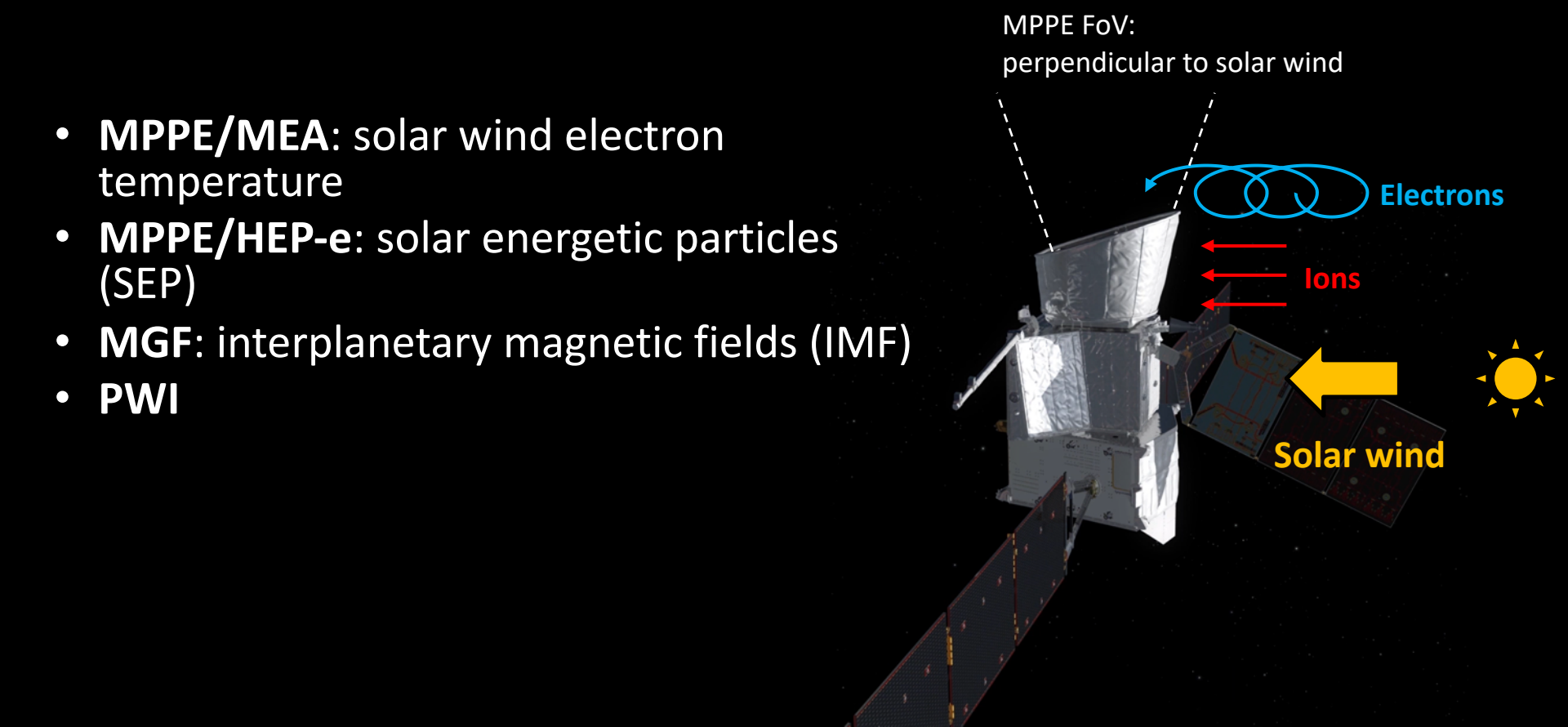




MGNS ISA MORE

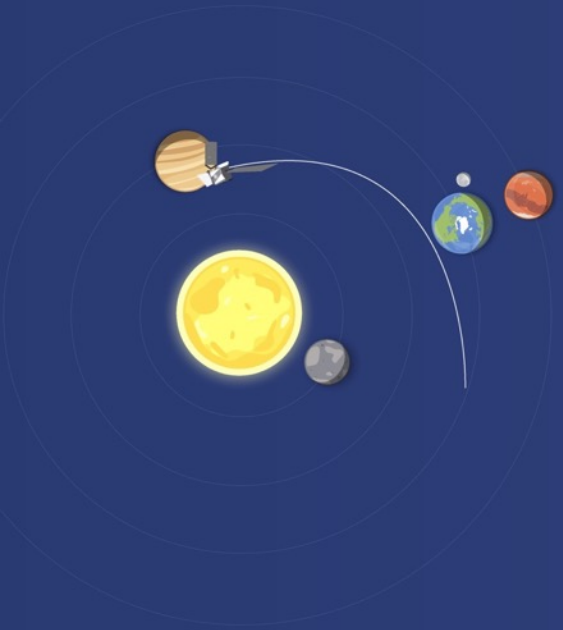
BepiColombo: Mio cruise science

- **MPPE/MEA**: solar wind electron temperature
- **MPPE/HEP-e**: solar energetic particles (SEP)
- **MGF**: interplanetary magnetic fields (IMF)
- **PWI**



Monitoring Camera Observations

BEPICOLOMBO'S FIRST VENUS FLYBY



Venus flyby
15 October 2020
10 720 km

Coordinated observations
by JAXA's Venus Climate Orbiter,
Akatsuki

Coordinated Venus observations
from Earth

22 October
Orbit correction manoeuvre

10 720 km

Closest approach to Venus
05:58 CEST

Imaging opportunity
40 min before to 15 min after
close approach

Imaging opportunity
20 h to 14 h before close approach

Dedicated science observations

Instruments during flyby:
ACTIVE, *SOME SENSORS ACTIVE*, *NOT ACTIVE*

Mercury Planetery Orbiter

BELA
BERM
ISA
MERTIS
MGNS
MIXS
MORE
MPO-MAG
PHEBUS
SERENA
SIMBIO-SYS
SIXS

Mercury Transfer Module

M-CAM 2, 3

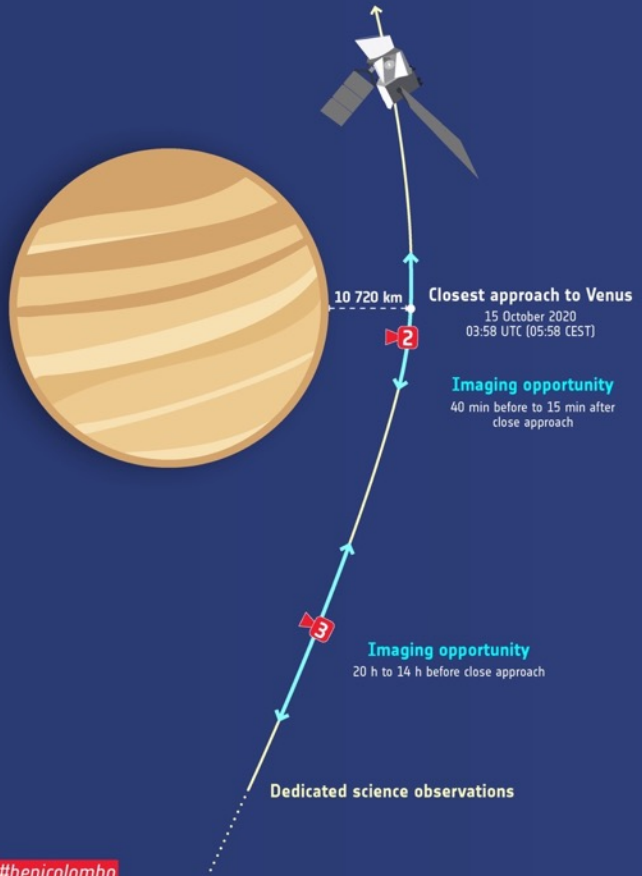
Mercury Magnetospheric Orbiter

MDM
MGF
MPPE
MSASI
PWI

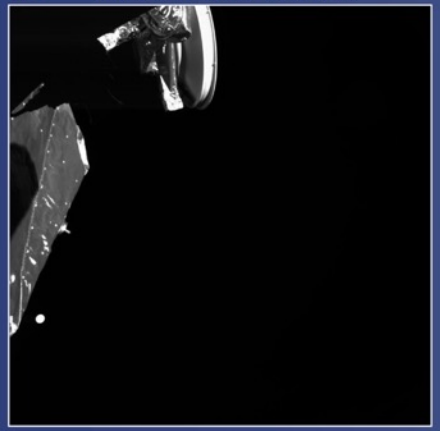
#bepicolombo

BEPICOLOMBO'S FIRST VENUS FLYBY IN IMAGES

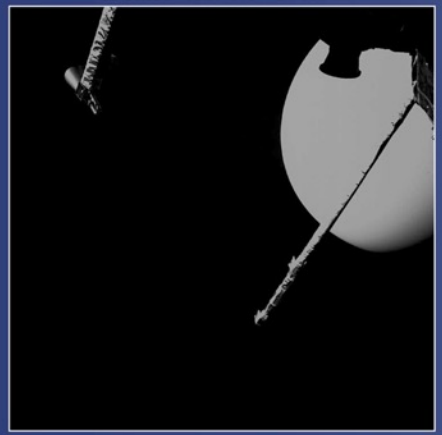
esa

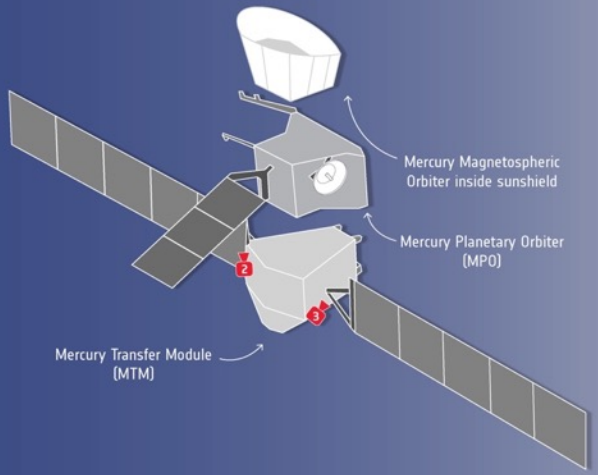


3 MTM monitoring camera 3 – M-CAM 3
14 October 07:25 UTC – 600 000 km



2 MTM monitoring camera 2 – M-CAM 2
15 October 03:37 UTC – 14 000 km





ESA | JAXA
bepicolombo

#bepicolombo

VENUS FLYBY SCIENCE OPERATIONS

BepiColombo teams are planning to operate up to eight out of eleven science instruments on the Mercury Planetary Orbiter and three out of five on the Mercury Magnetospheric Orbiter during the two flybys of Venus

First flyby
15 October 2020
10 720 km

Second flyby
10 August 2021
552 km

Flyby distances at closest approach

ATMOSPHERE STUDIES

- Temperature and density profiles
- Chemical composition
- Global circulation
- X-ray emissions

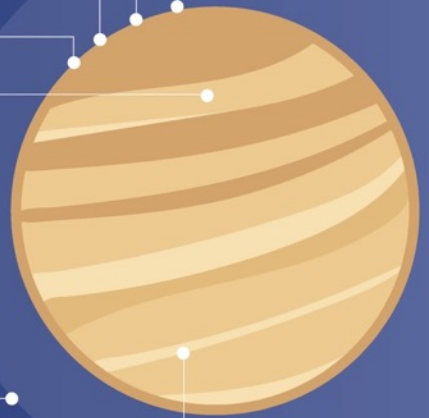
INTERNAL STRUCTURE

INTERACTIONS BETWEEN THE SUN AND VENUS

- Solar wind interactions
- Energetic particles
- Plasma interactions
- Magnetic field and magnetosphere
- Electric field, plasma and radio waves
- Bow shock and magnetopause

VENUS AS AN EXOPLANET

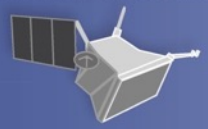
- Phase curve and rotation rate



BepiColombo will also take images with its monitoring cameras, and will collect data with its radiation monitor, BERM.

esa

Instruments active during flyby



Mercury Planetery Orbiter

BELA
ISA
MERTIS
MGNS
MIXS
MORE
MPO-MAG
PHEBUS
SERENA
SIMBIO-SYS
SIXS

Mercury Magnetospheric Orbiter

MDM
MMO-MGF
MPPE
MSASI
PWI

#bepicolombo

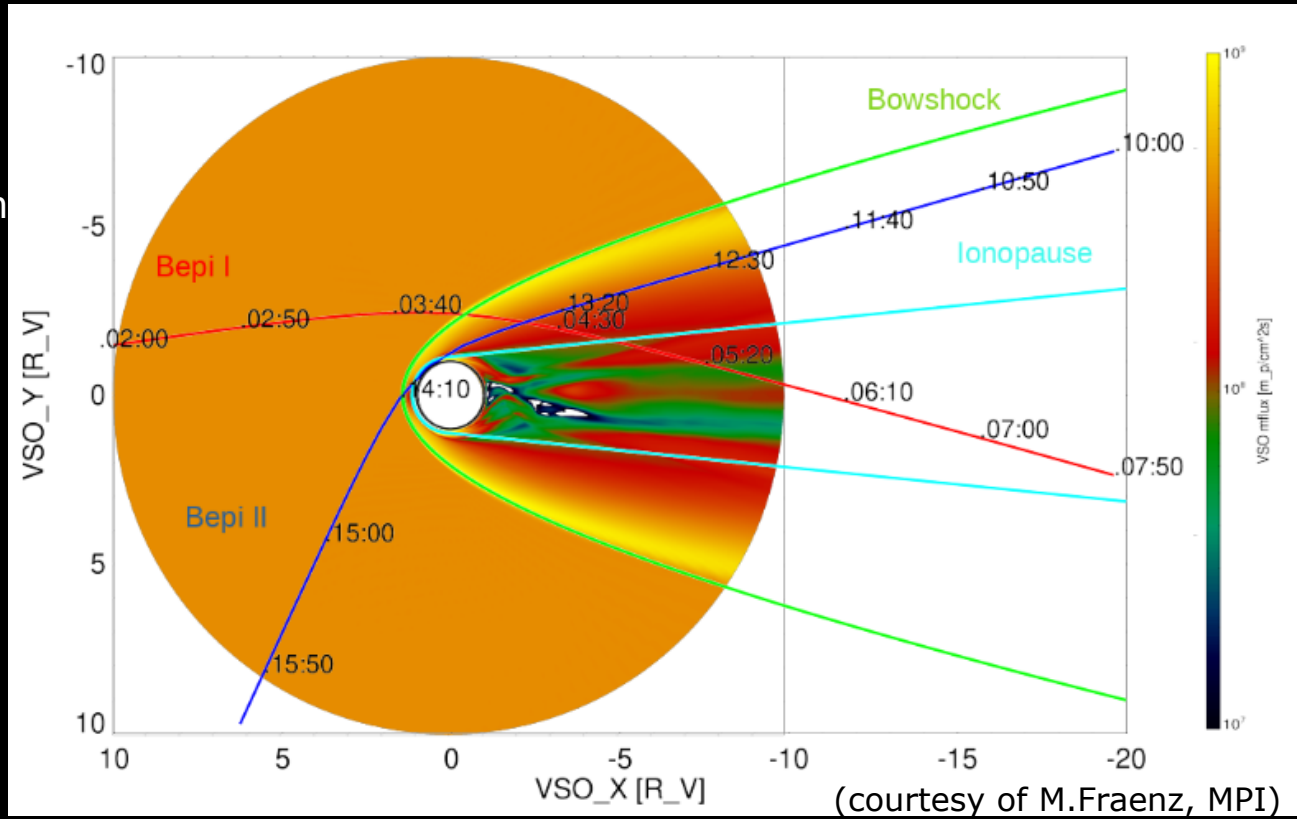
Flybys geometry (X-Y plane)

First flyby (Bepi I)

- October 15th 2020
- Closest approach: 10671 km
- Time of CA: ***03:58 UTC***
- Approaching from dayside

Second flyby (Bepi II)

- August 11th 2021
- Closest approach: 552 km
- Approaching from nightside



(courtesy of M.Fraenz, MPI)

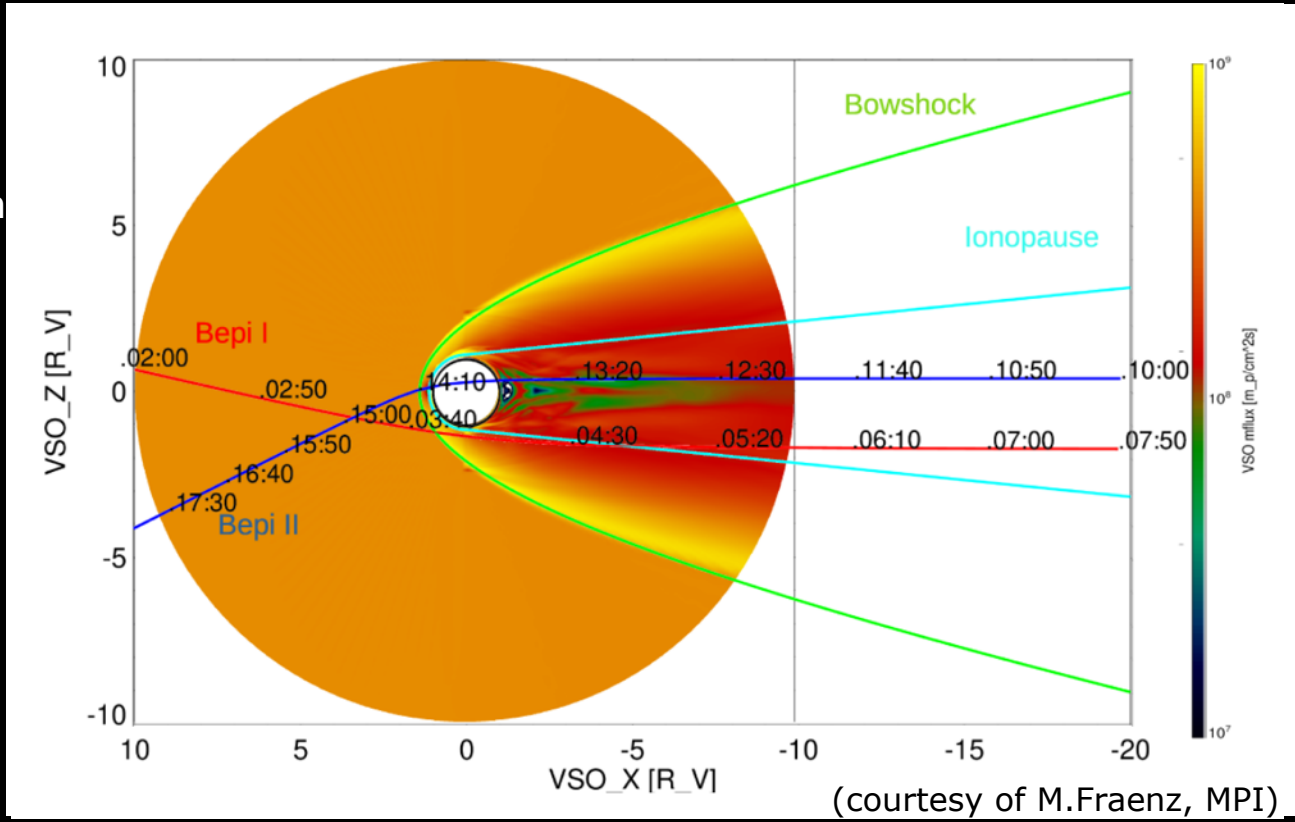
Flybys geometry (X-Z plane)

First flyby (Bepi I)

- October 15th 2020
- Closest approach: 10671 km
- Time of CA: ***03:58 UTC***
- Approaching from dayside

Second flyby (Bepi II)

- August 11th 2021
- Closest approach: 552 km
- Approaching from nightside



(courtesy of M.Fraenz, MPI)

Operating instruments at Venus

MPO:

BERM

ISA

MERTIS

MGNS

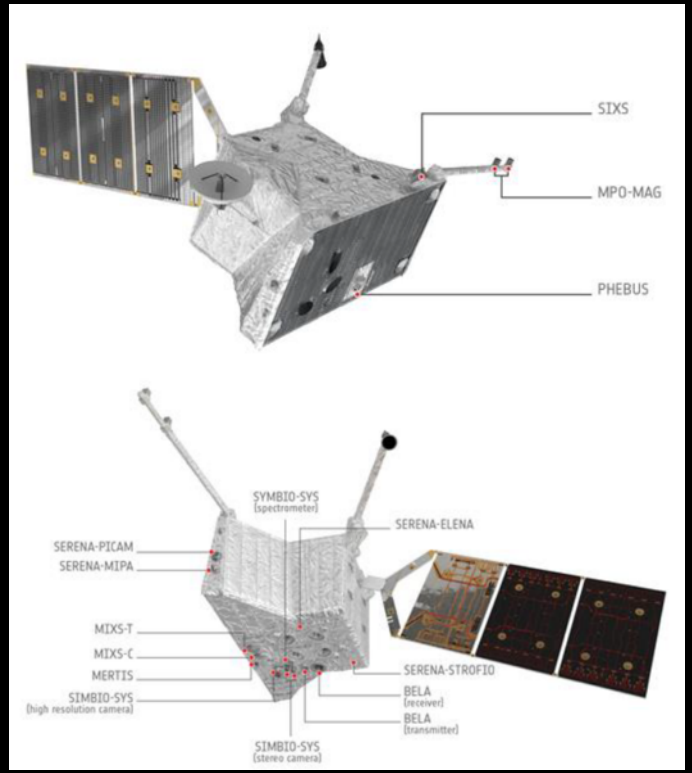
MORE

MPO-MAG

PHEBUS

SERENA

SIXS

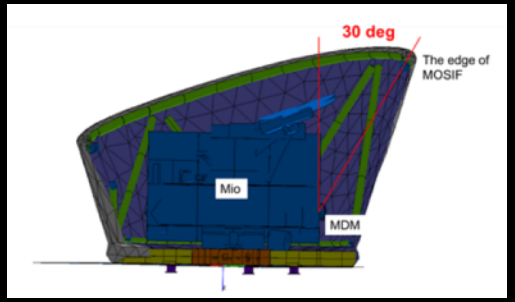


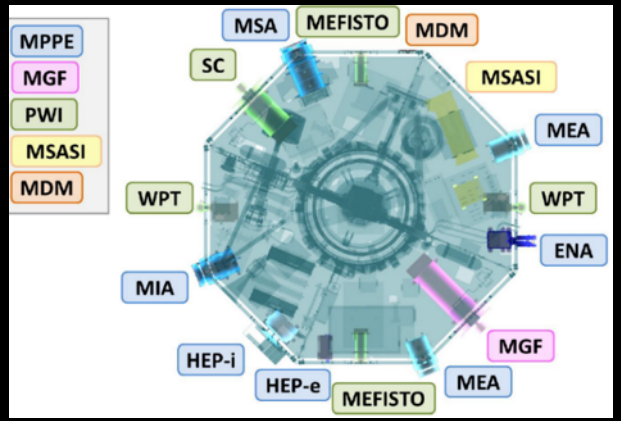
MMO:

PWI

MPPE

MGF





Instrument operations plan

MPO:

MERTIS: from 12-Oct 20.58.32 to 15-Oct 01.14.32
PHEBUS: from 15-Oct 03.44.42 to 04.30.52 (observation starts at 03.58.32)

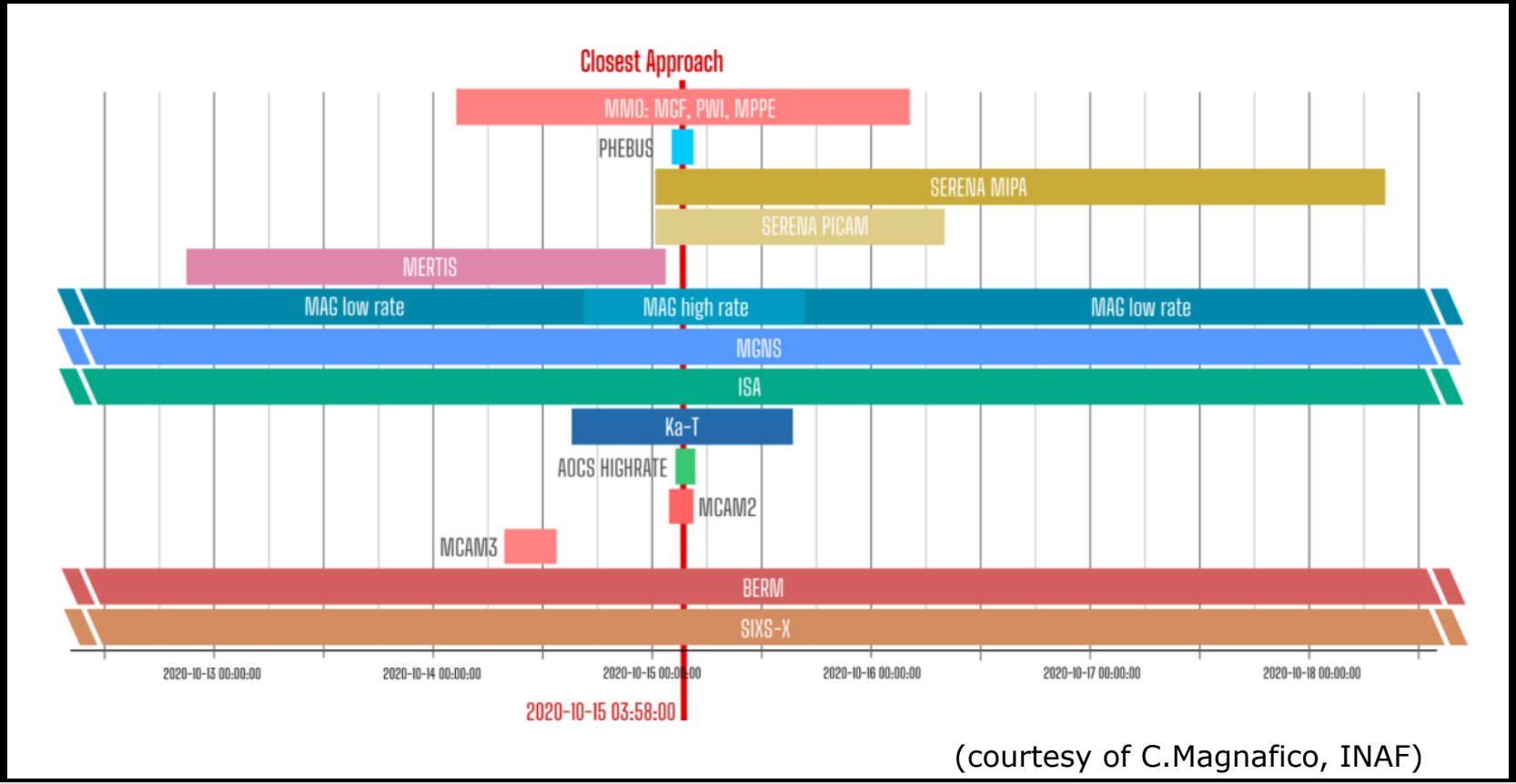
MPOMAG remains ON in background science configuration (at 16Hz); on 14-Oct 03.48.32 at 03.53.32 was configured at 128Hz 16-Oct at 03.58.32, then back to 16Hz

MGNS: remains ON throughout in background science configuration.
ISA: remains ON throughout in background science configuration. Special S/C data is activated on their request on 15-Oct from 03.58.31 to 04.18.31

SERENA: from 15-Oct 00.13.32 to 18-Oct 03.53.32
SIXS-X: from 8-Oct until 19-Oct at 23.59.30

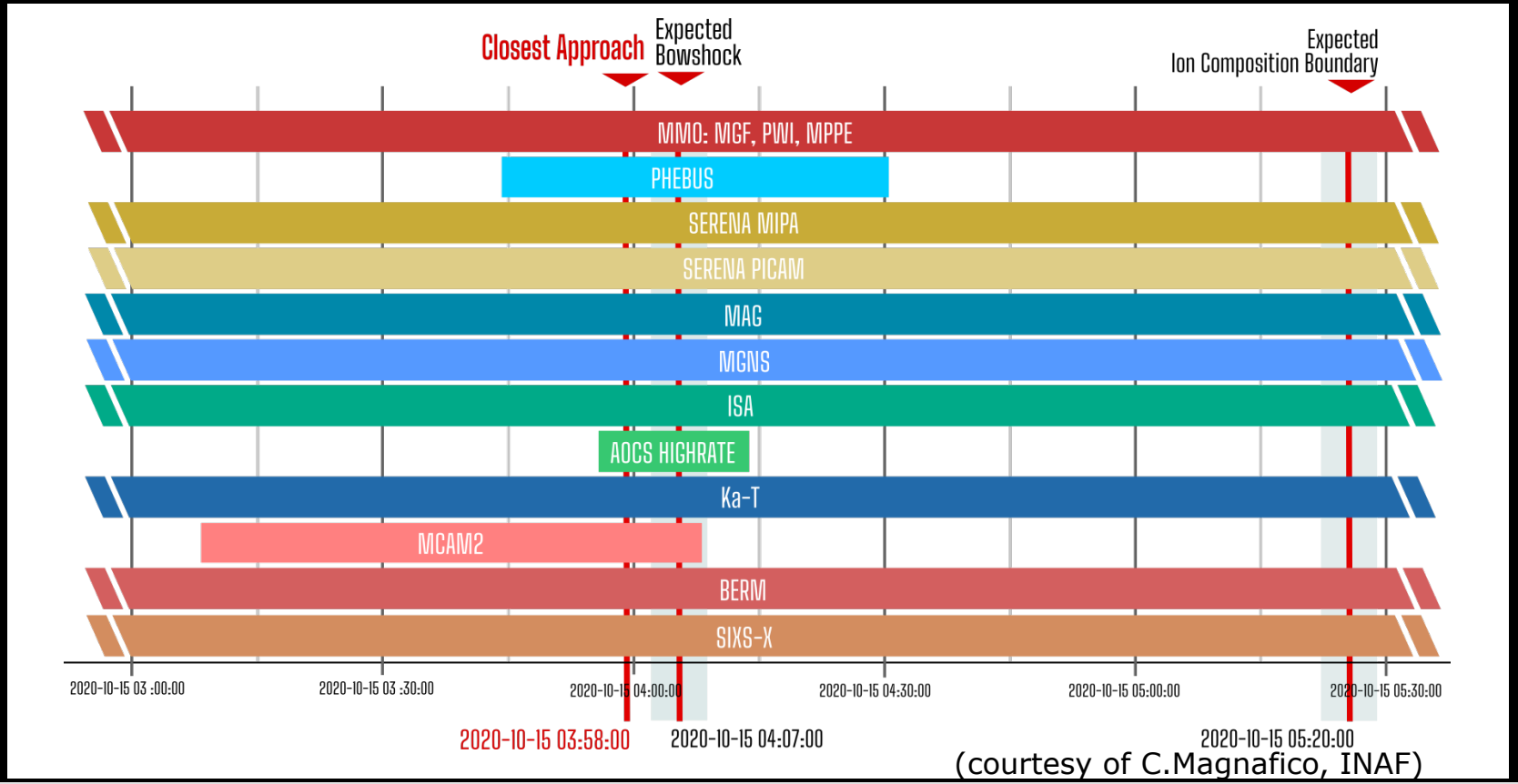
MMO (MGF, PWI, MPPE): 14-Oct 02.45 to 16-Oct 04.43

Instrument operations timeline at CA



(courtesy of C.Magnafico, INAF)

Instrument operations timeline at CA



(courtesy of C.Magnafico, INAF)

Scientific objectives at Venus

#1 Atmosphere:

MERTIS → radiometer TIR (7-14 μm) + spectrometer TIS (7-40 μm)

- Upper-cloud SO2, cloud aerosol properties, temperature

+ research for phosphine signatures at IR

PHEBUS → spectrometers NUV (55-155 nm), FUV (145-315 nm) + 2 NUV (404 and 422 nm)

- global average cloud top SO2 abundance, bulk and trace gas species profiles, NO emission (in occultation)

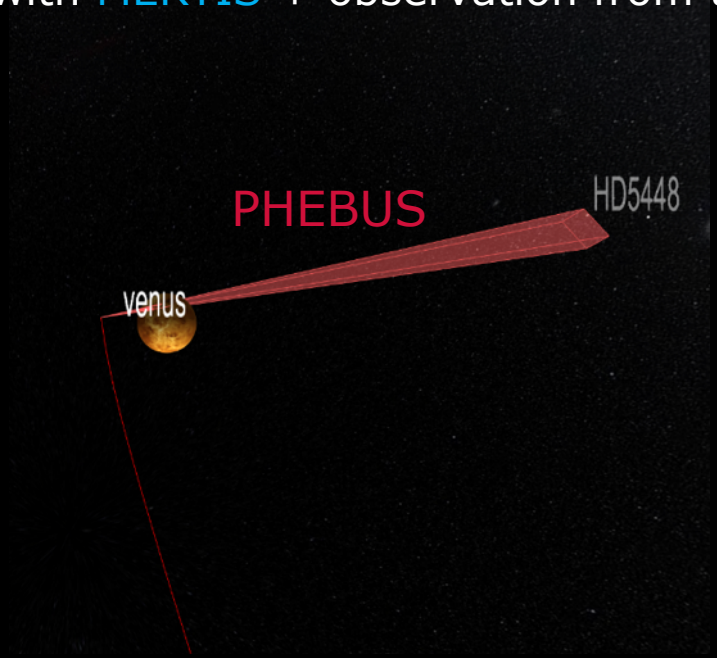
+ Dayside disk integrated albedo (faraway from Venus)

MGNS → neutron (10-3 eV – 10 MeV) and gamma-ray (100 keV-10 MeV) spectrometers

- Identification of C, O, N and H2O profiles through the neutron escape

Atmospheric Investigations

→ Direct observations of Venus atmosphere with MERTIS + observation from the evening limb with PHEBUS



(from http://bepicolombo.esac.esa.int/itl-viewer/venus_flyby_1/)

Atmospheric Investigations

2020 August- October Science Summary (Bepi Instruments):

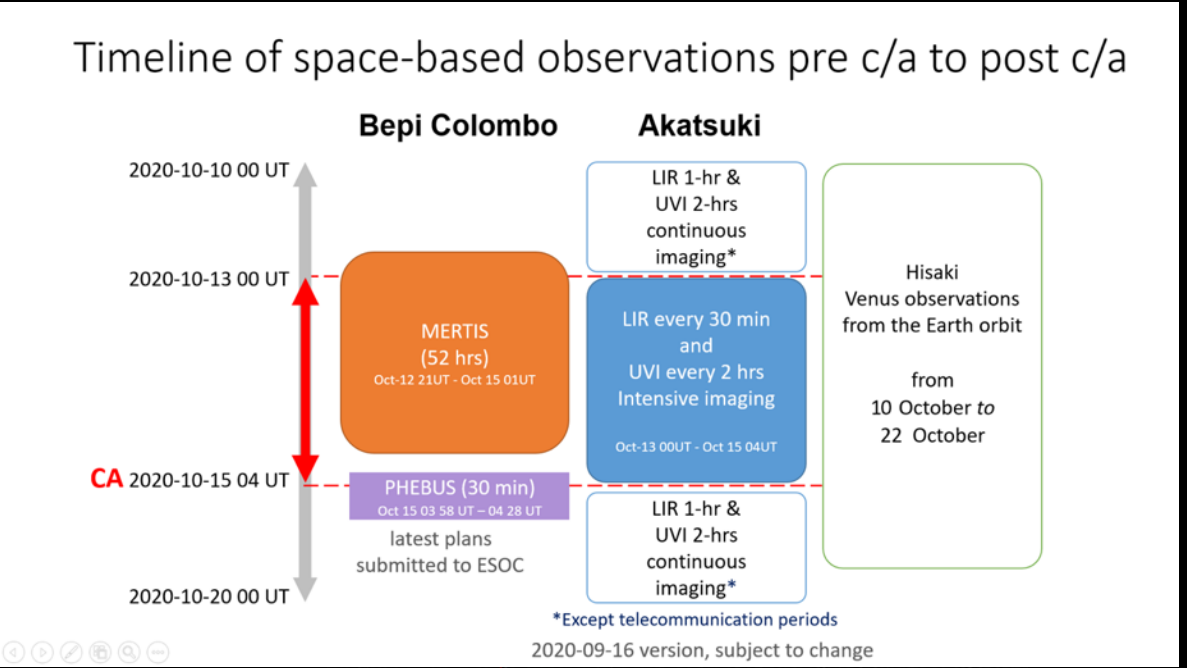
	Instrument	Date; Δ to CA(*)	Mode	Sequencing	Key Observable	Science goal
Venus Farr-Away Campaign	PHEBUS FUV channel Visible channel	28 August – 2 September 2020	Nadir observing of Venus disk averaged flux	6 consecutive days	Disk integrated albedo, global average cloud top SO_2 abundance	Multi wavelength study of long-term albedo variation and its impact on solar heating rates; SO_2 and NUV albedo relationship
Venus Close Encounter Campaign	MERTIS	12-15 October, 2020;	Nadir	CA -55 to CA -3 hours	Upper-cloud SO2, cloud aerosol properties, temperature	Impact of convection on absorber distribution in upper cloud; data needed to study correlation with NUV albedo (from Akatsuki)
	PHEBUS-FUV channel	15 October, 2020; Ingress	occultation	@CA *to* +30 min from c/a	Bulk and trace gas species profiles NO emission	Atmospheric structure between 80-200 km Identity and trace zonal transport processes in thermosphere (~110 km)
	MGNS	12-15 October, 2020;		continuous	Neutron escape	Identification of C, O, N and H_2O profiles indicative of the balance of chemical processing, vertical mixing and diffusion processes

→ Coordinated observations of Venus atmosphere of MERTIS, PHEBUS and MGNS started already in August → 2 periods

(from https://www.cosmos.esa.int/web/bepicolombo-flyby/atmospheric-investigations)

Atmospheric Investigations

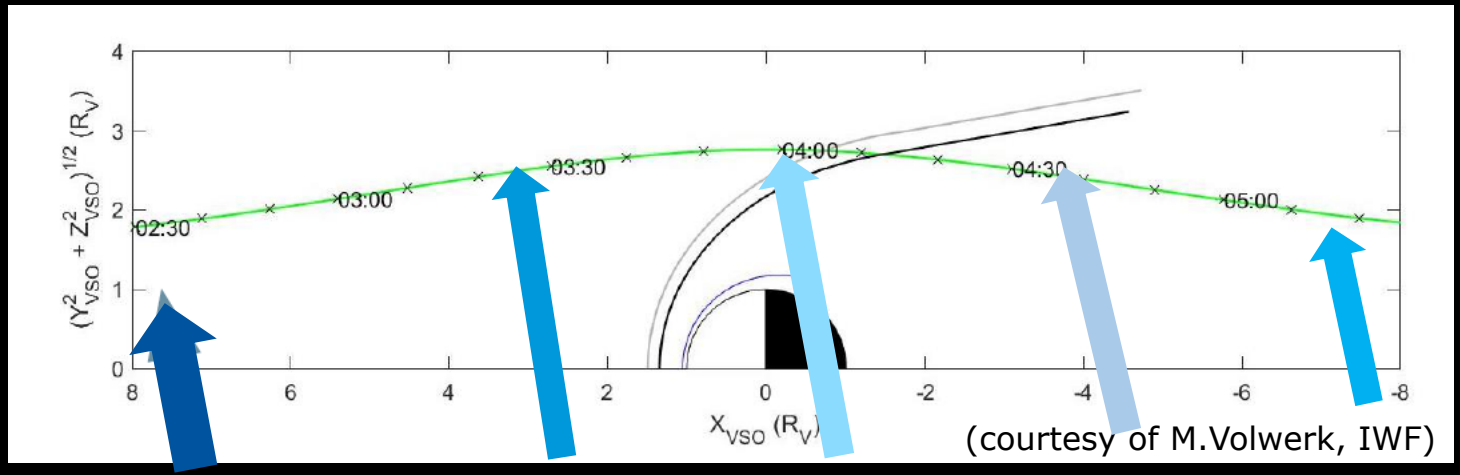
- Coordinated observations with JAXA Akatsuki, Hisaki and Earth-based telescopes (here only for CA): multi-vantage point measurements of Venus atmospheric properties



(from https://www.cosmos.esa.int/web/bepicolombo-flyby/atmospheric-investigations)

Magnetospheric Investigations

→ Crossing of many different magnetospheric regions and boundaries gives the possibility to investigate different mechanisms and structures



Exosphere Foreshock Bow shock IC Boundary Tail

Scientific objectives at Venus

#2 Ionosphere & Induced Magnetosphere:

MPO:

MER-MAG → magnetometer (16-128 Hz)

- discontinuities of bow shock and other boundaries crossings; measurements of draped dayside magnetic field, low frequency wave activity inside the ion composition boundary; potential measurements of flux ropes, possible confirmation of the tail lobes with opposite magnetic field polarity;

SERENA → ion monitors (few eVs - 15 keVs) with mass, direction and energy range detection

- density and velocity of the ions populating the different regions crossed

SIXS-X → X-ray sensors (~1s @ 1- 20 keV)

- monitor the flare activity on the Sun, weak charge exchange induced X-ray emission from the interaction between the solar wind and the Venus exosphere

Scientific objectives at Venus

#2 Ionosphere & Induced Magnetosphere:

MIO:

MPPE → ion electron sensors (5 of 7 operating)

PWI → plasma wave sensors (2 operating)

MGF → magnetometer

- electron shielding effects, atmospheric pick-up ions and energetic neutral atoms as derived from solar wind backscattering and/or ion sputtering over the exobase;

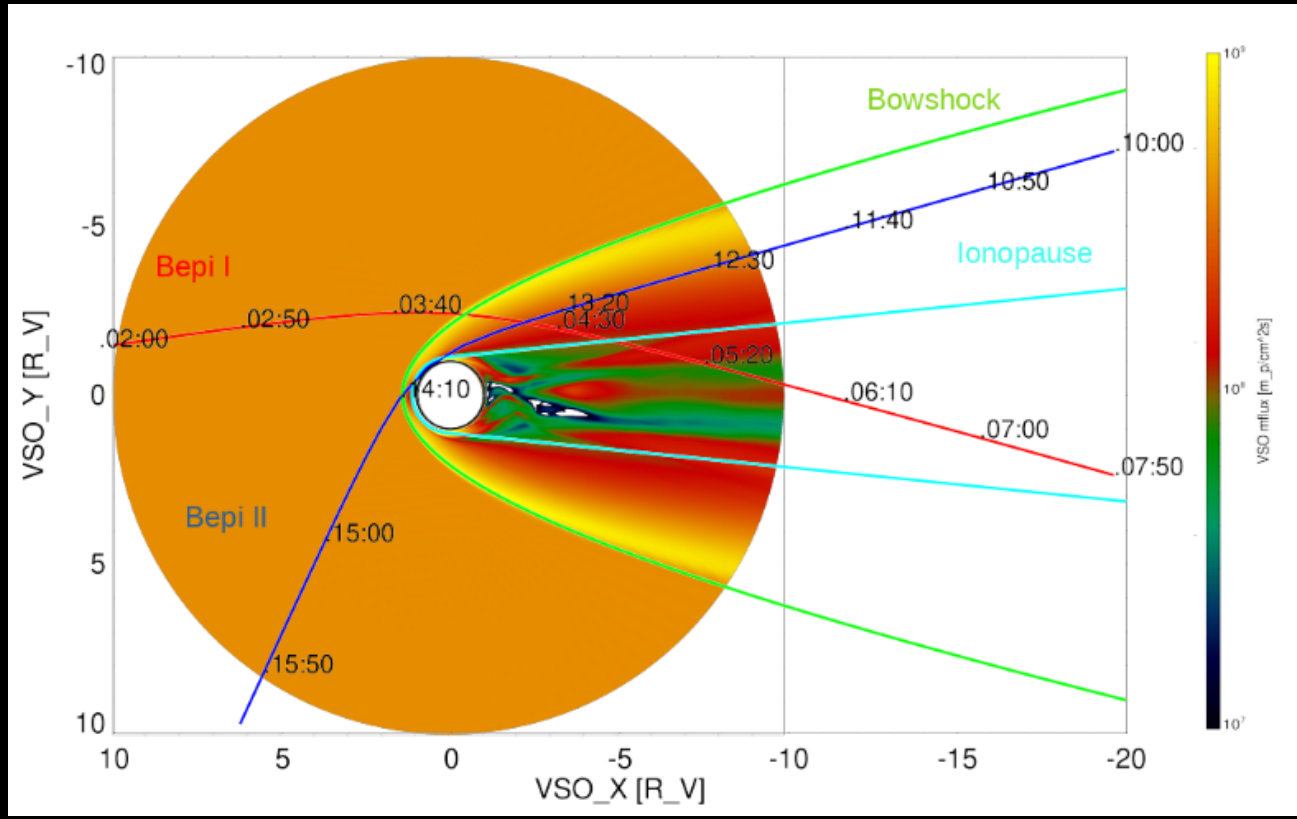
- magnetic and electric fields around Venus (with possible detection of upstream foreshock waves, proton cyclotron waves, magnetosheath turbulence…)

+ ISA accelerometer → may measure possible acceleration effects derived from the crossing of bow shock and other boundaries

2nd Venus flyby

Second flyby (Bepi II)

- August 10th 2021
- Closest approach: 552 km
- Approaching from nightside



2nd Venus flyby

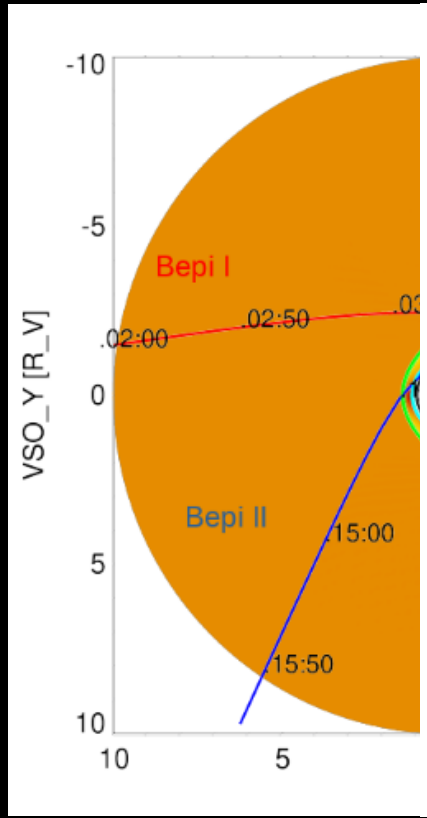
Second flyby (Bepi II)

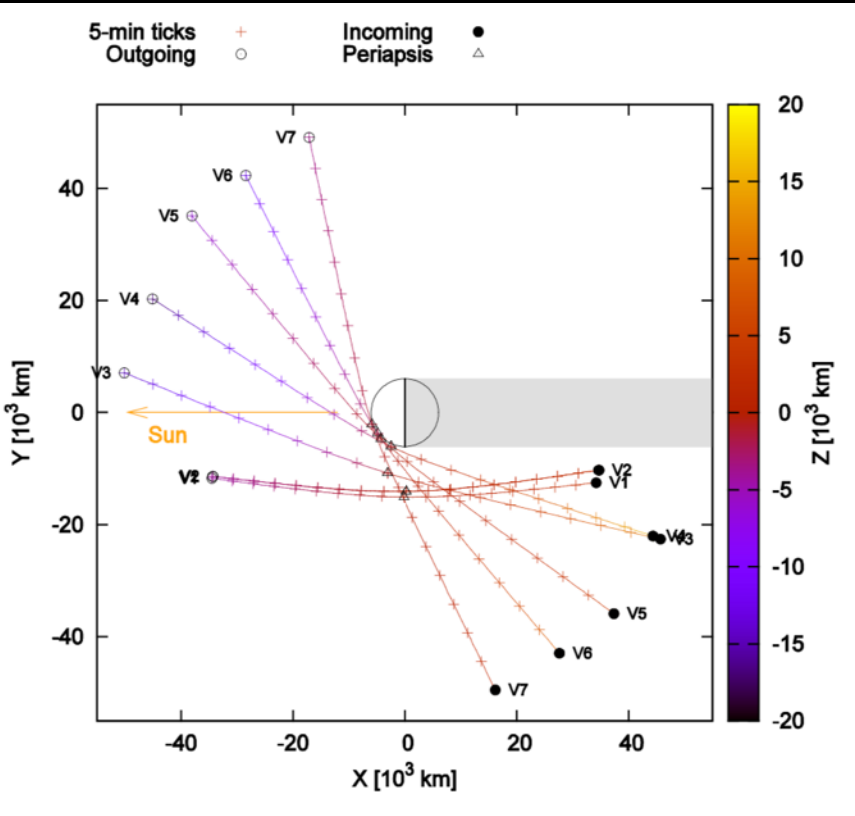
- August 10th 2021
- Closest approach: 552 km
- Approaching from nightside

Solar Orbiter will also have a flyby at Venus on:

- August 9th 2021
- Closest approach: ~8000 km
- Approaching from nightside

  (with similar trajectory)



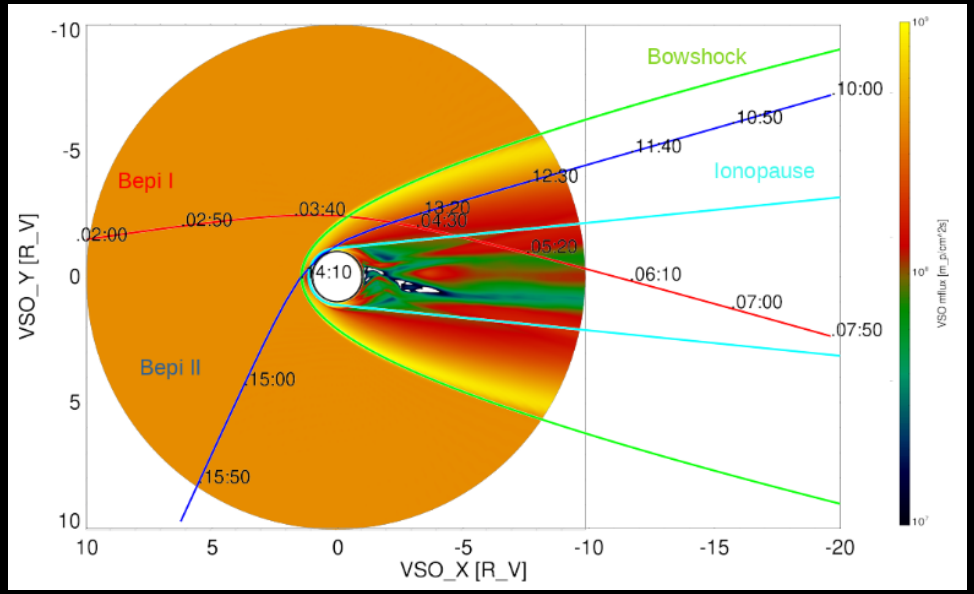


Bepi and SolO: coordination plan

→ A great occasion to coordinate observations from two different points of view (in space and in time)

- Possibility to monitor SW upstream when Bepi is inside the magnetosphere
- Possibility to monitor effects of SW-induced magnetosphere interactions at different locations in the tail and in the boundary crossings
- …

Similarly for Bepi-PSP!

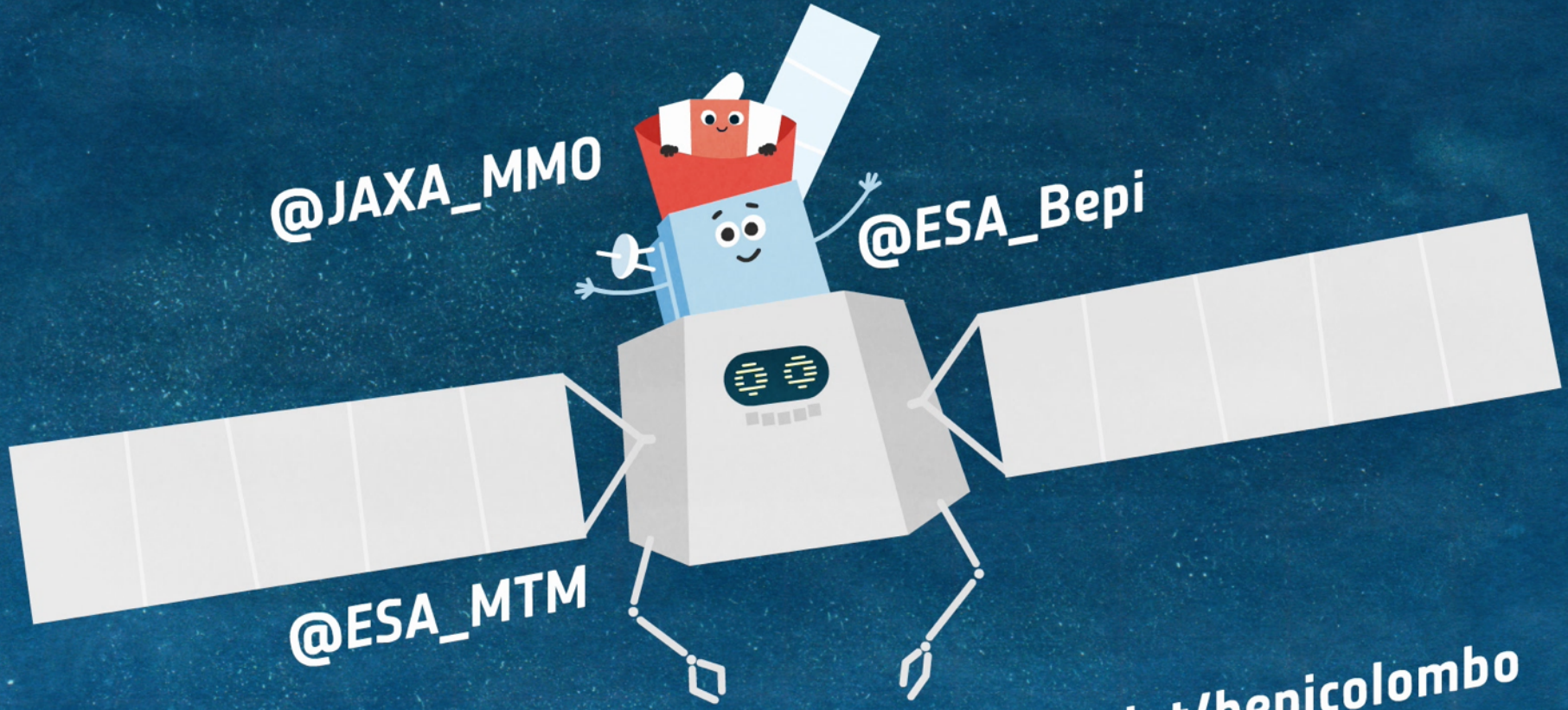


NB. Solar Orbiter Venus flyby geometry is very similar to the Bepi I shown here

Bepi flybys: info & coordination

Visit and/or contact us at:

https://www.cosmos.esa.int/web/bepicolombo-flyby/venus1flyby


@JAXA_MMO
@ESA_Bepi
@ESA_MTM
www.esa.int/bepicolombo
#bepicolombo