

# ESA BepiColombo Mission

Sara de la Fuente



North

BepiColombo, Monitoring Camera #2

1 October 2021  
23:44:12 UTC

**Mercury**

**Venus**

**Earth**

**Mars**

**Jupiter**

**Saturn**

**Uranus**

**Neptune**

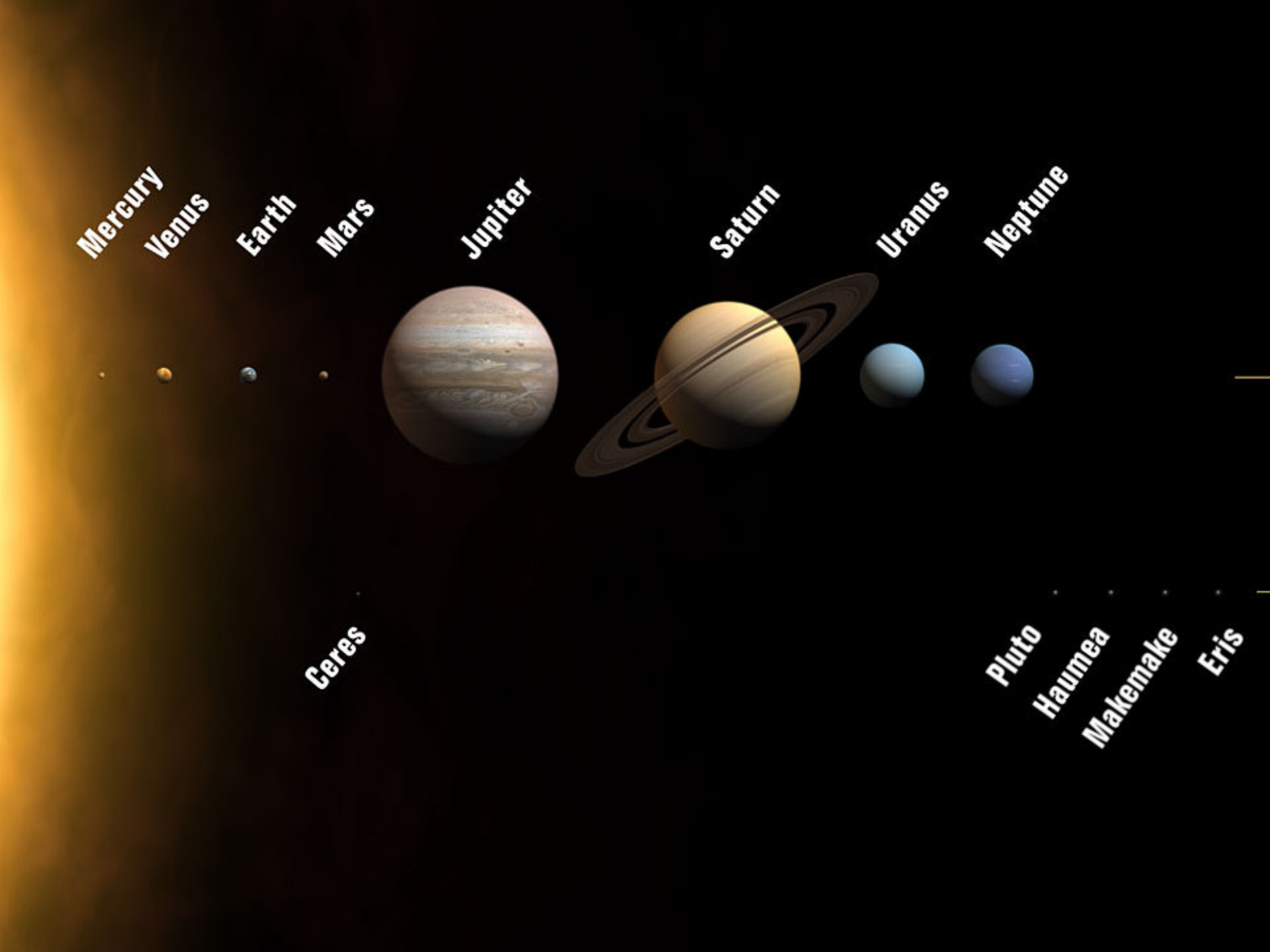
**Ceres**

**Pluto**

**Haumea**

**Makemake**

**Eris**





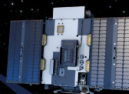


**soho**  
Facing the Sun

**venus express**  
Studying Venus' atmosphere



**proba-2**  
Observing coronal dynamics and solar eruptions



**juice**  
Characterising the conditions of ocean-bearing moons around Jupiter



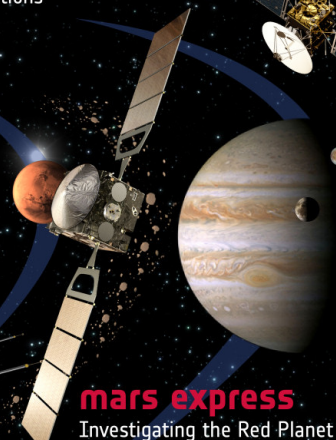
**bepicolombo**  
Exploring Mercury



**cassini-huygens**  
Studying the Saturnian system and landing on Titan



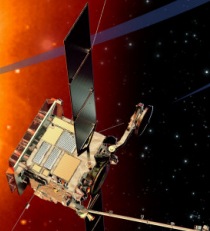
**mars express**  
Investigating the Red Planet



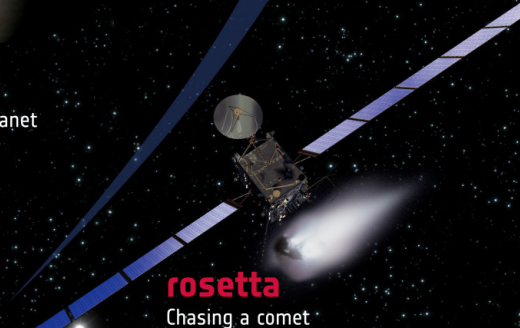
**cluster**  
Measuring Earth's magnetic shield



**solar orbiter**  
The Sun up close



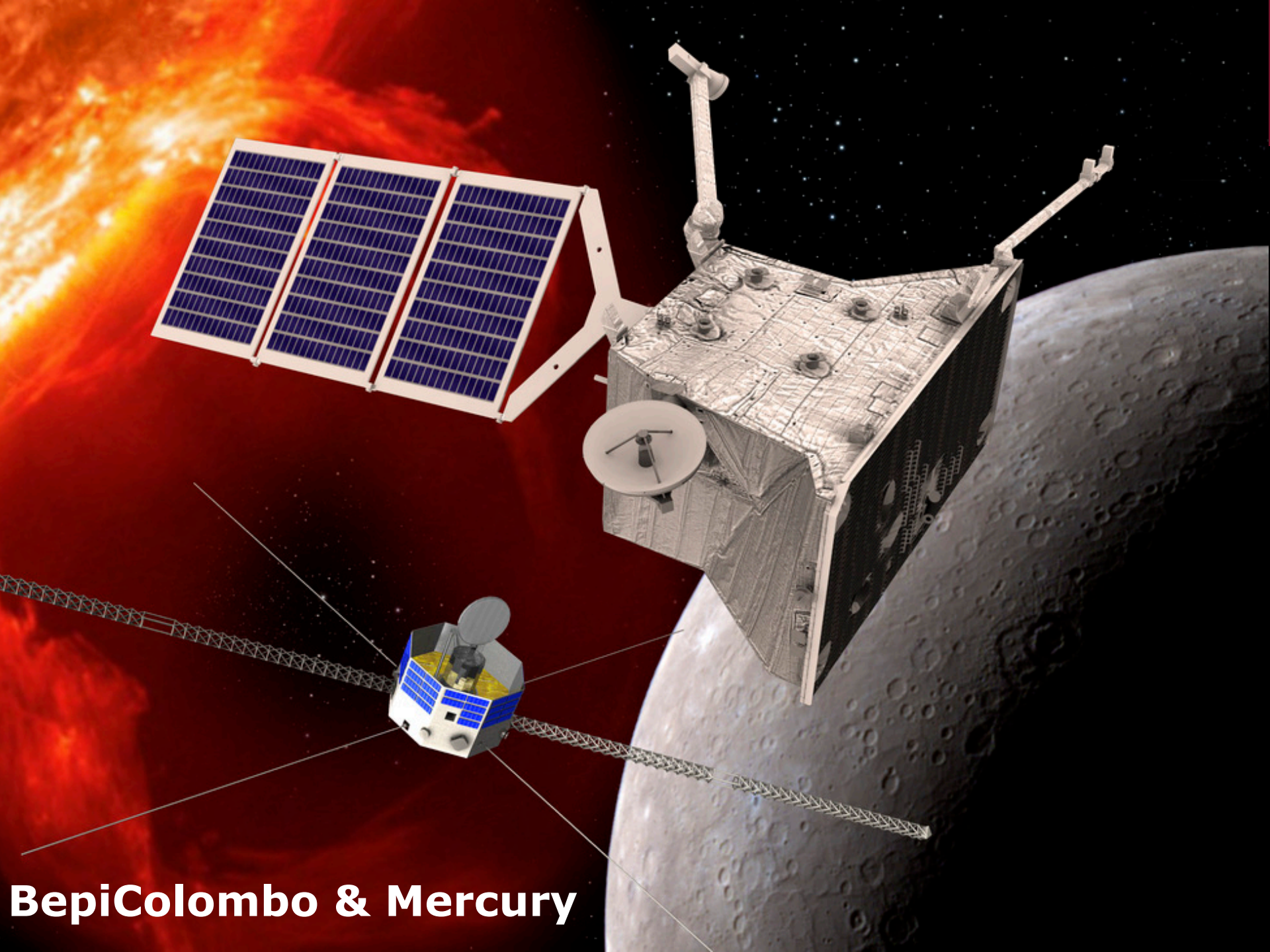
**rosetta**  
Chasing a comet



# → ESA'S FLEET IN THE SOLAR SYSTEM

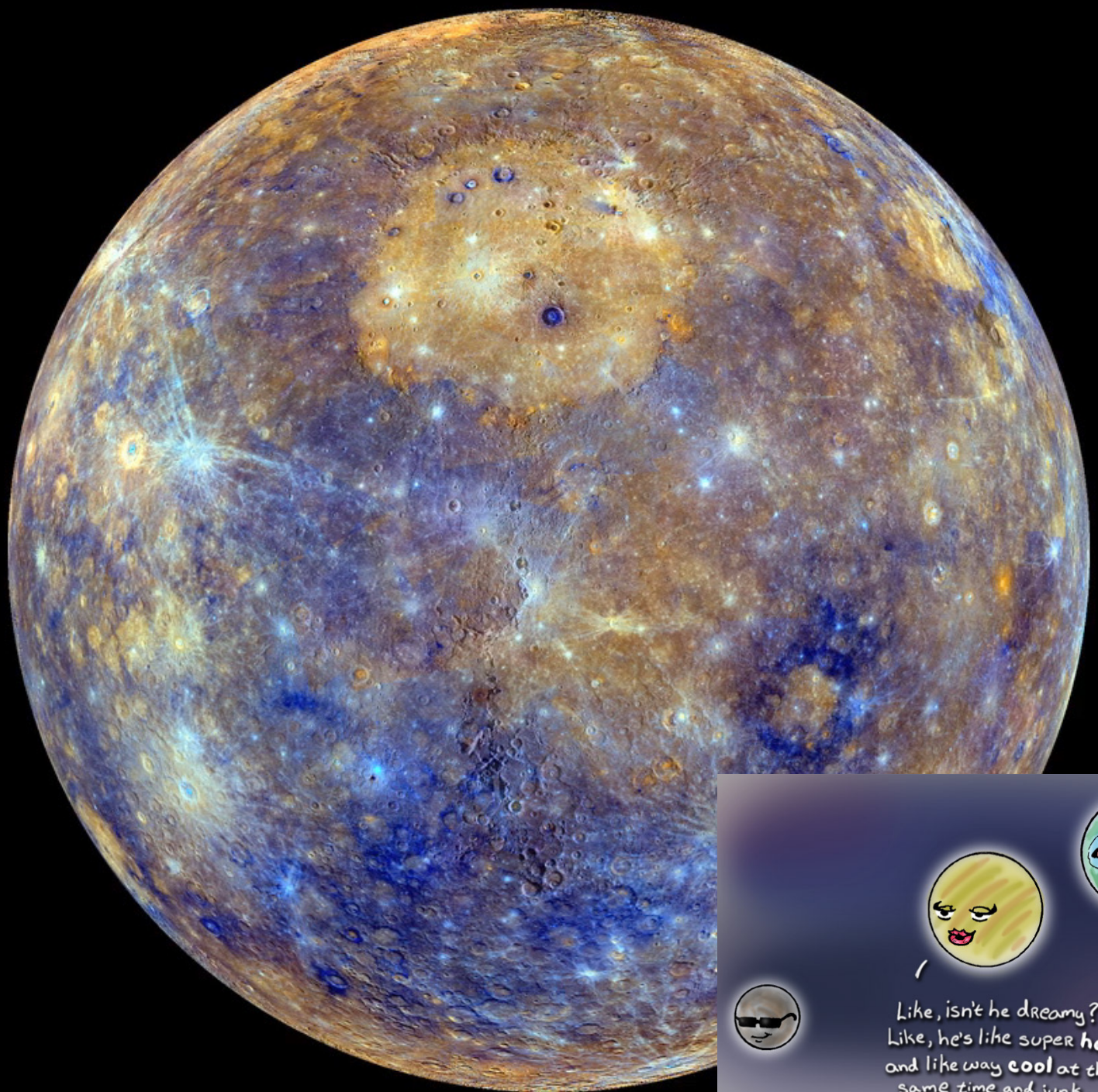
The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.





**BepiColombo & Mercury**



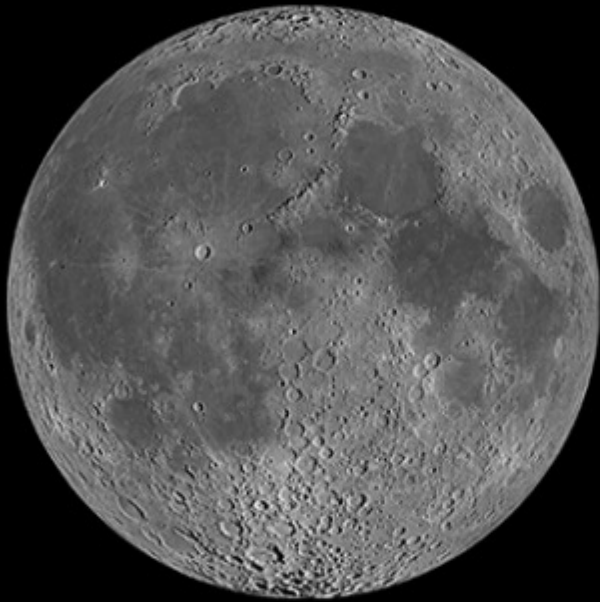


Like, isn't he dreamy?  
Like, he's like super **hot**  
and like way **cool** at the  
same time and junk.

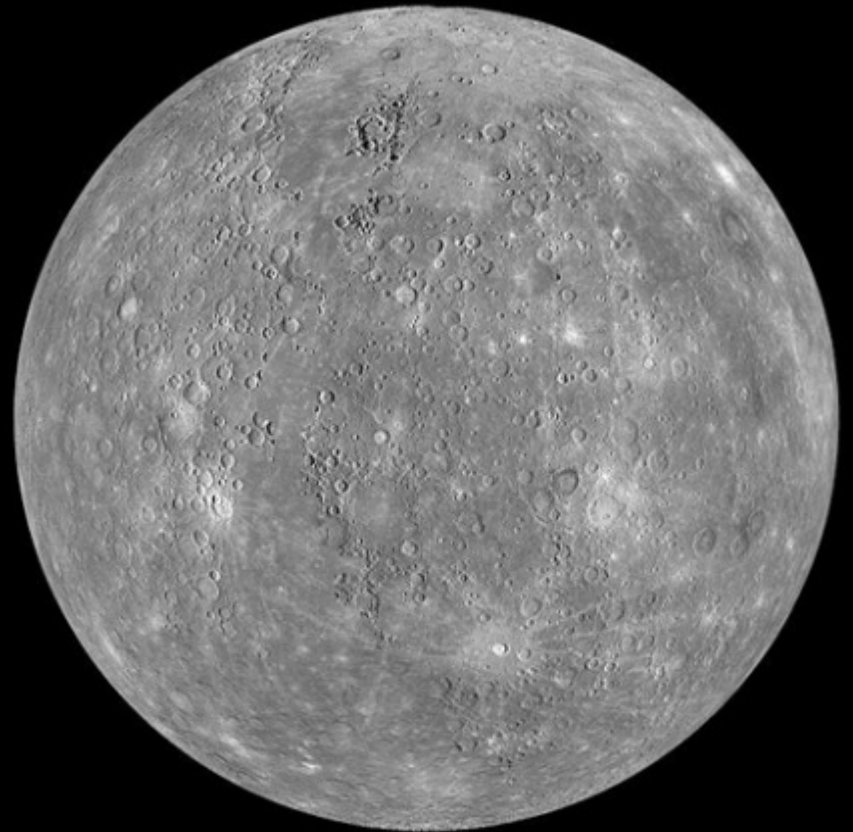
# Terrestrial Planets



# Mercury vs The Moon



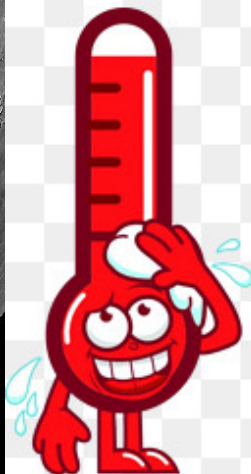
**Moon (3476 Km)**



**MERCURY (4880 Km)**



- Mercury is the planet closest to the sun (the sun looks 3 times bigger than on Earth)
- Temperatures from -170 deg to + 440 deg
- Has no atmosphere
- Magnetic field like Earth (but 100 times weaker)





# Mercury vs. the Earth



I'm pretty small.

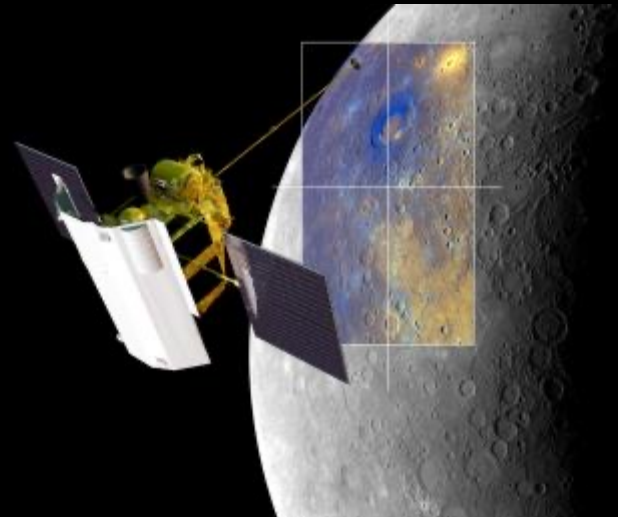




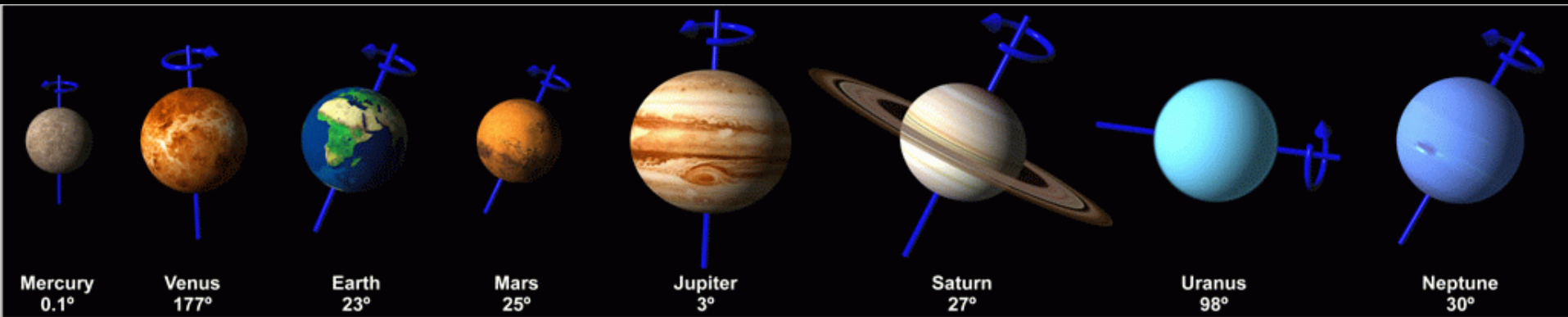


# Mercury from Space

- NASA Mariner 10 (1974-1975), 3 fly-bys
- NASA MESSENGER (2004, 2011-2015), orbital
- Why only a few missions to Mercury?
  - Costly, since requires a lot of fuel
  - Harsh environment, quick degradation of the instruments



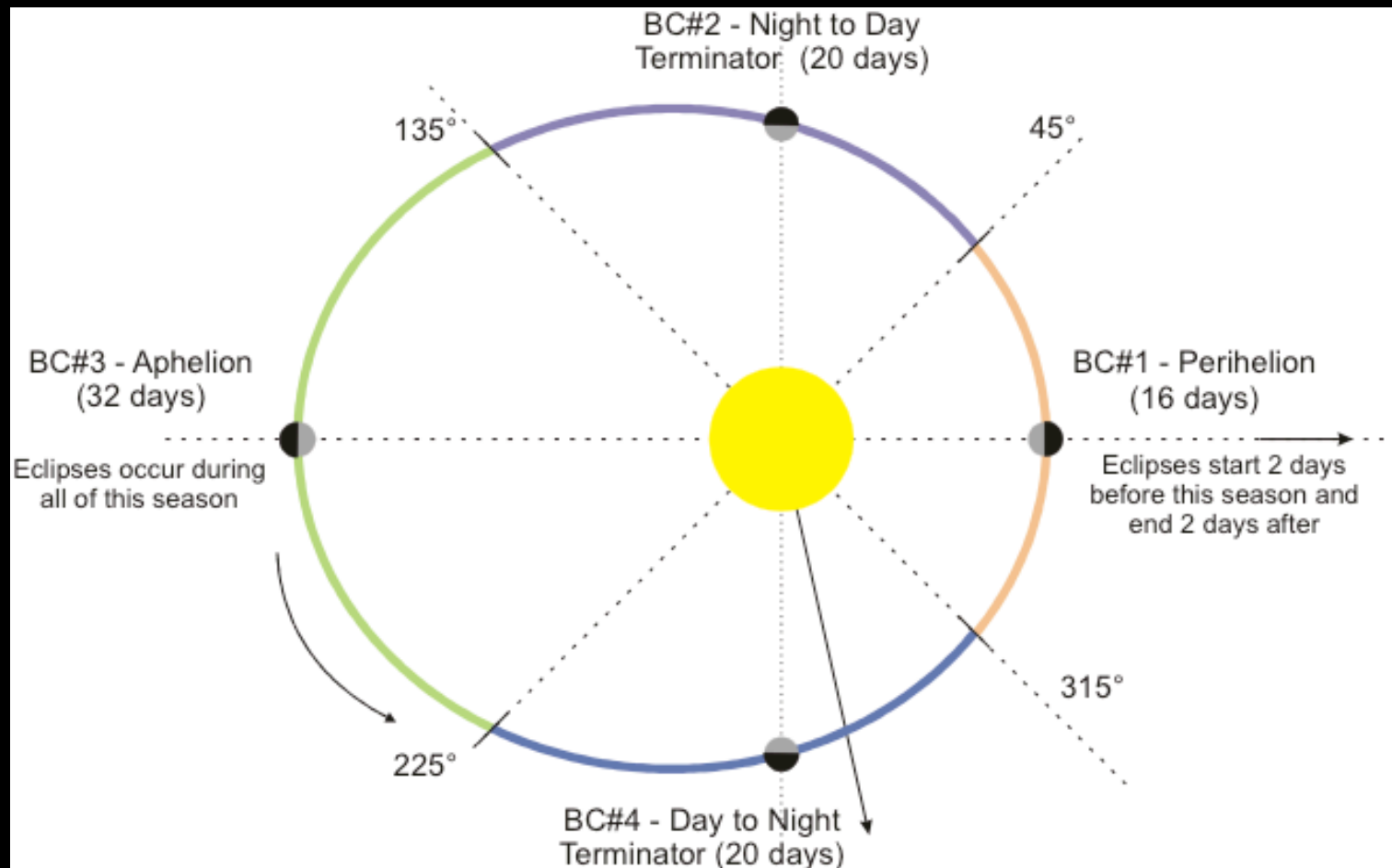
# Rotation axis, days and years



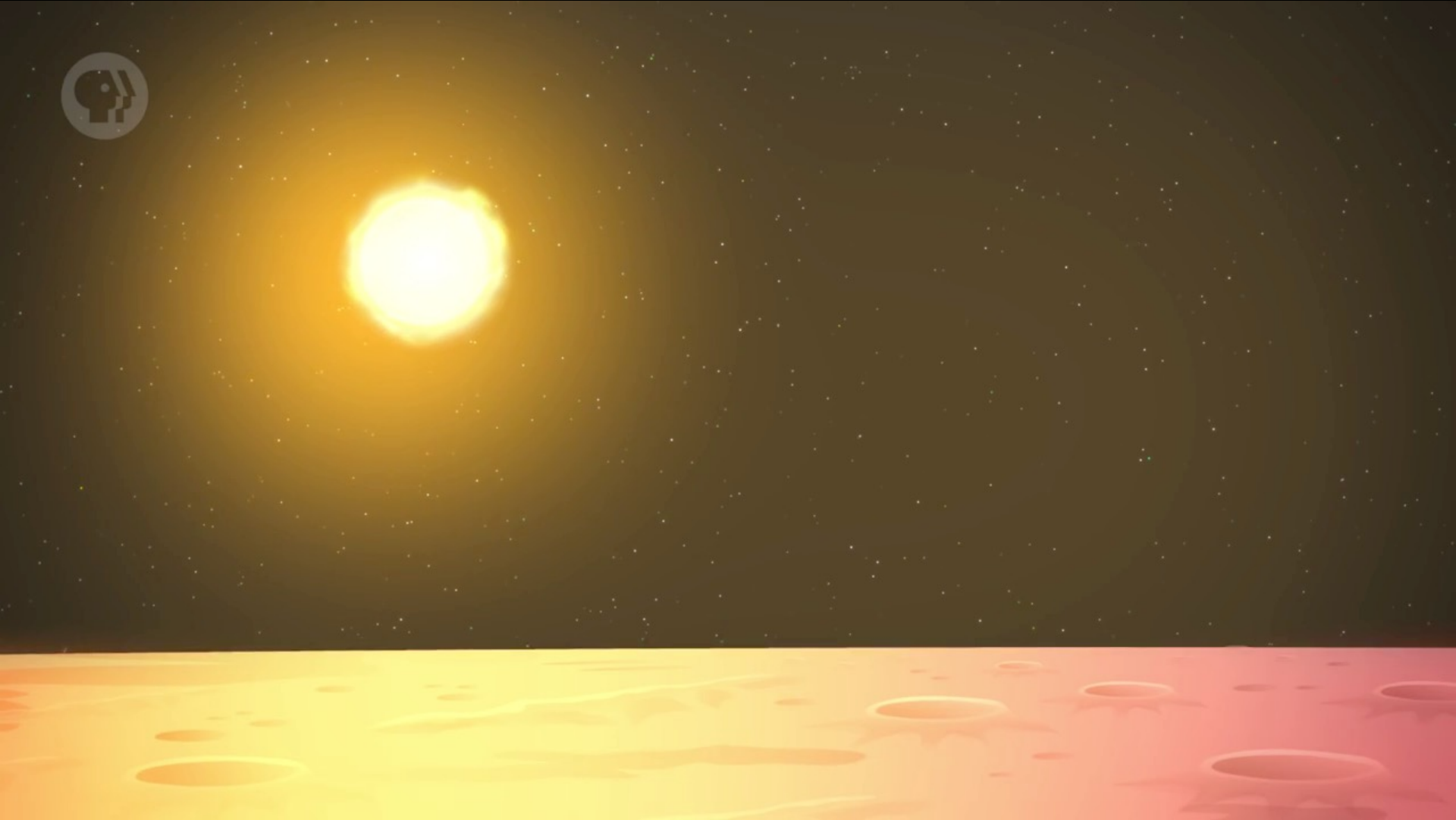
- 1 Hermean day: 59 Earth Days
- 1 Hermean year: 88 Earth Days



# Mercury orbit and “seasons”

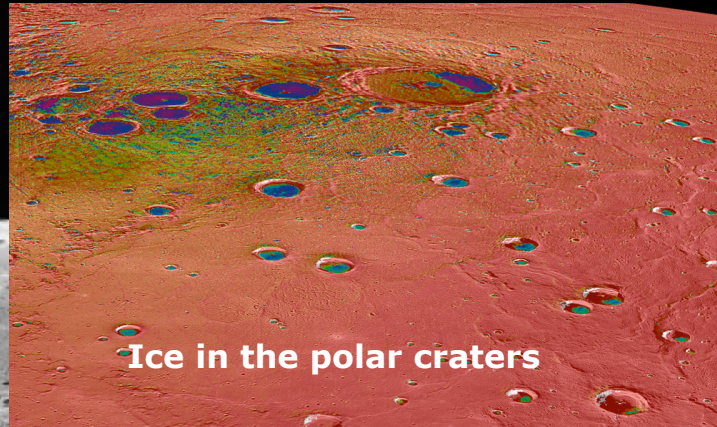


# Days at Mercury





# Craters



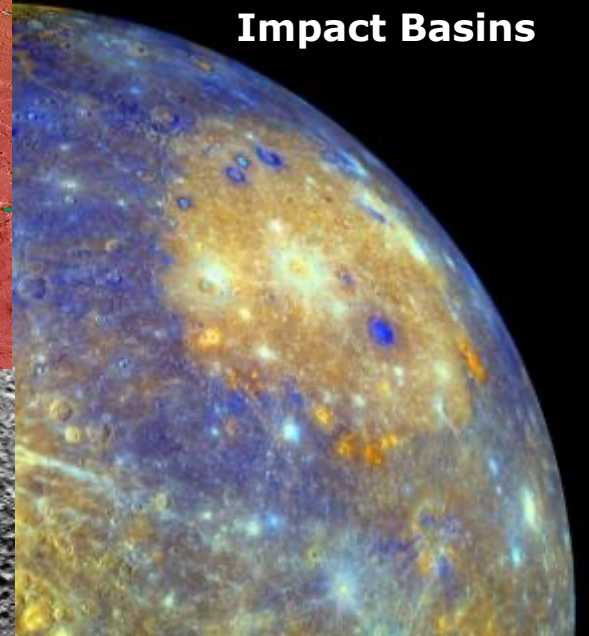
Ice in the polar craters



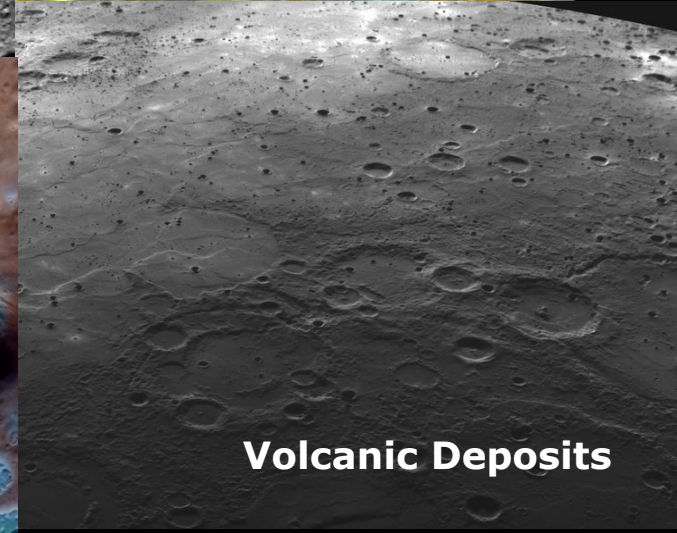
Scarps



Hollows



Impact Basins

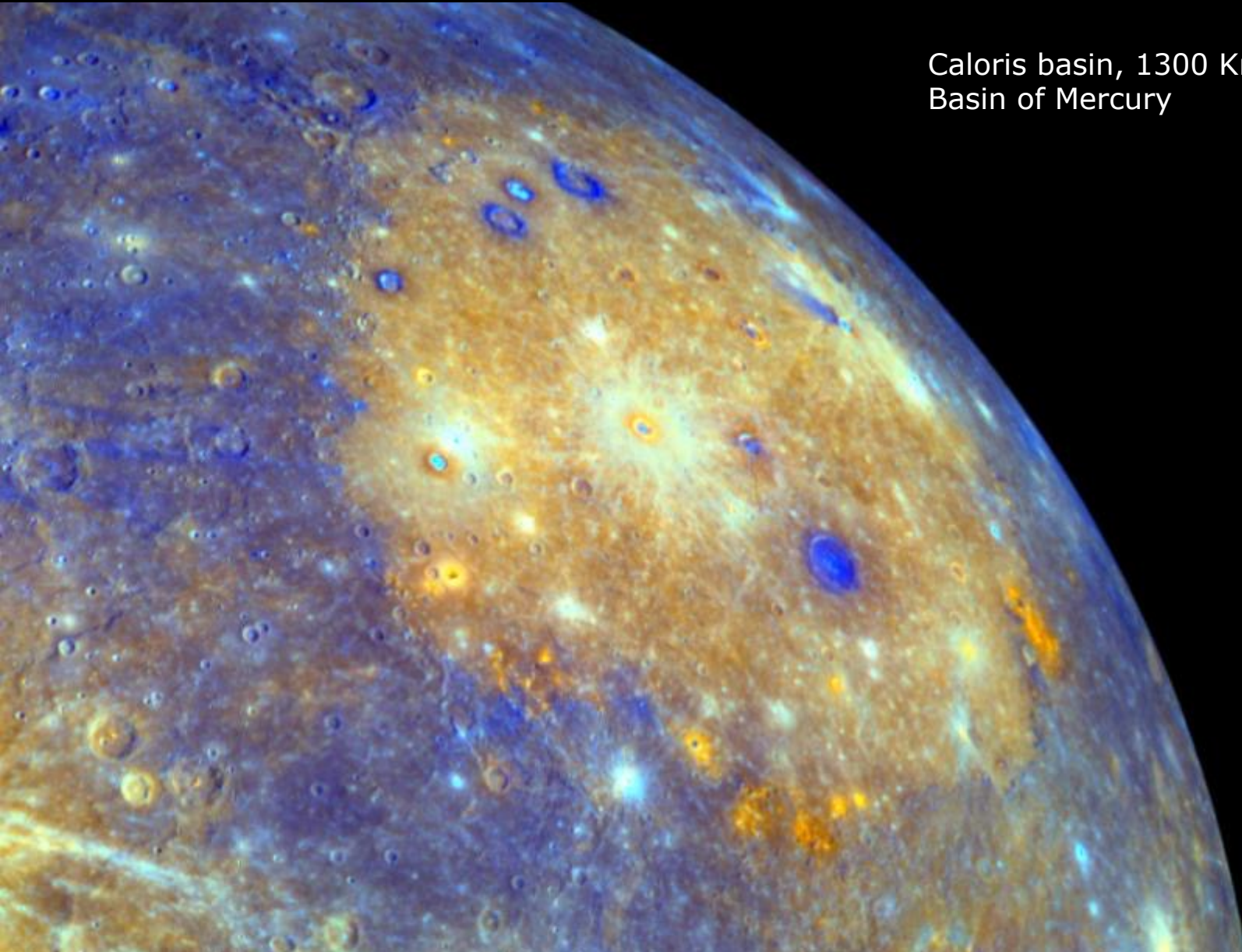


Volcanic Deposits



## Craters and Impact Basins (I)

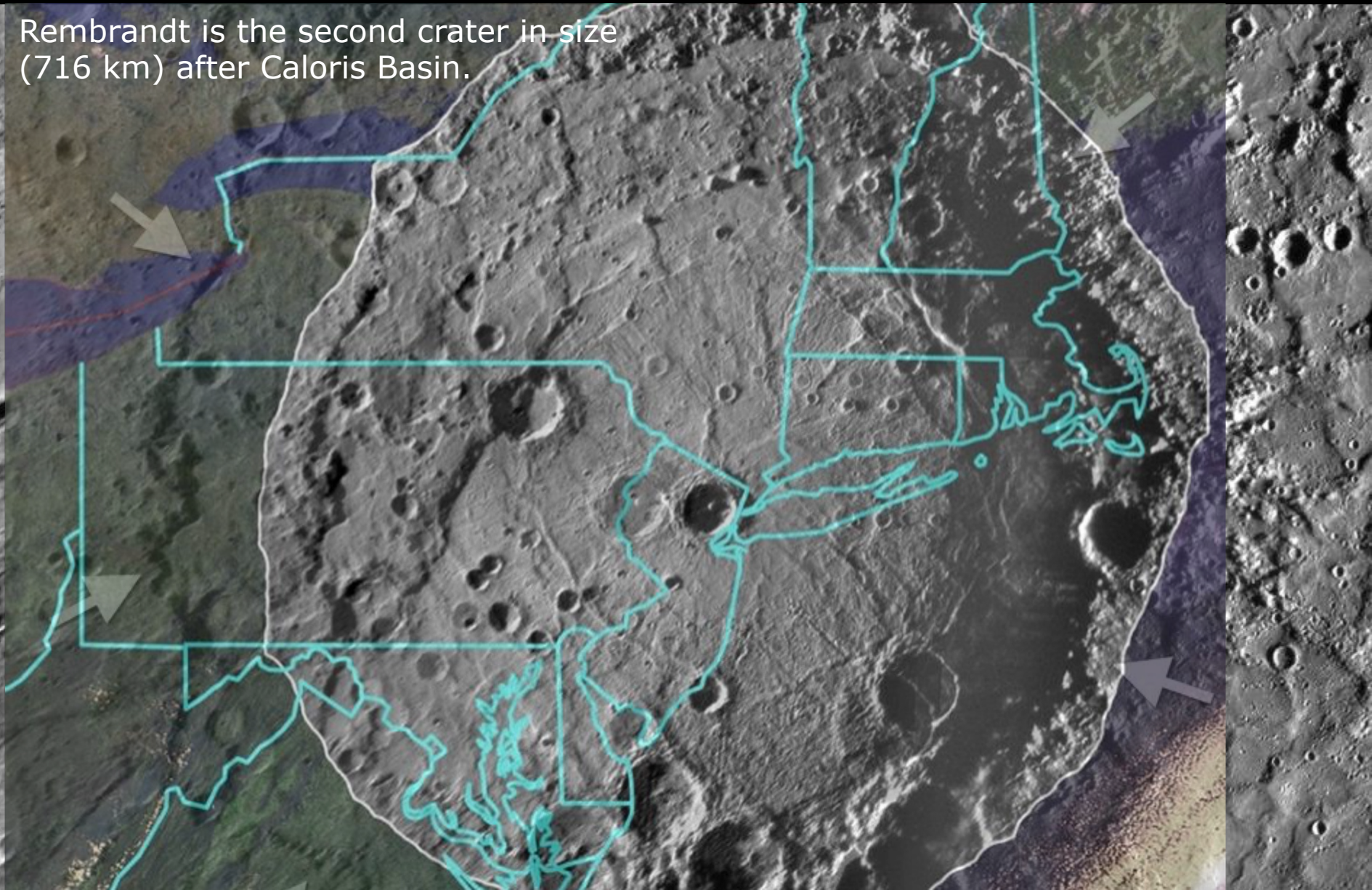
Caloris basin, 1300 Km, Biggest  
Basin of Mercury





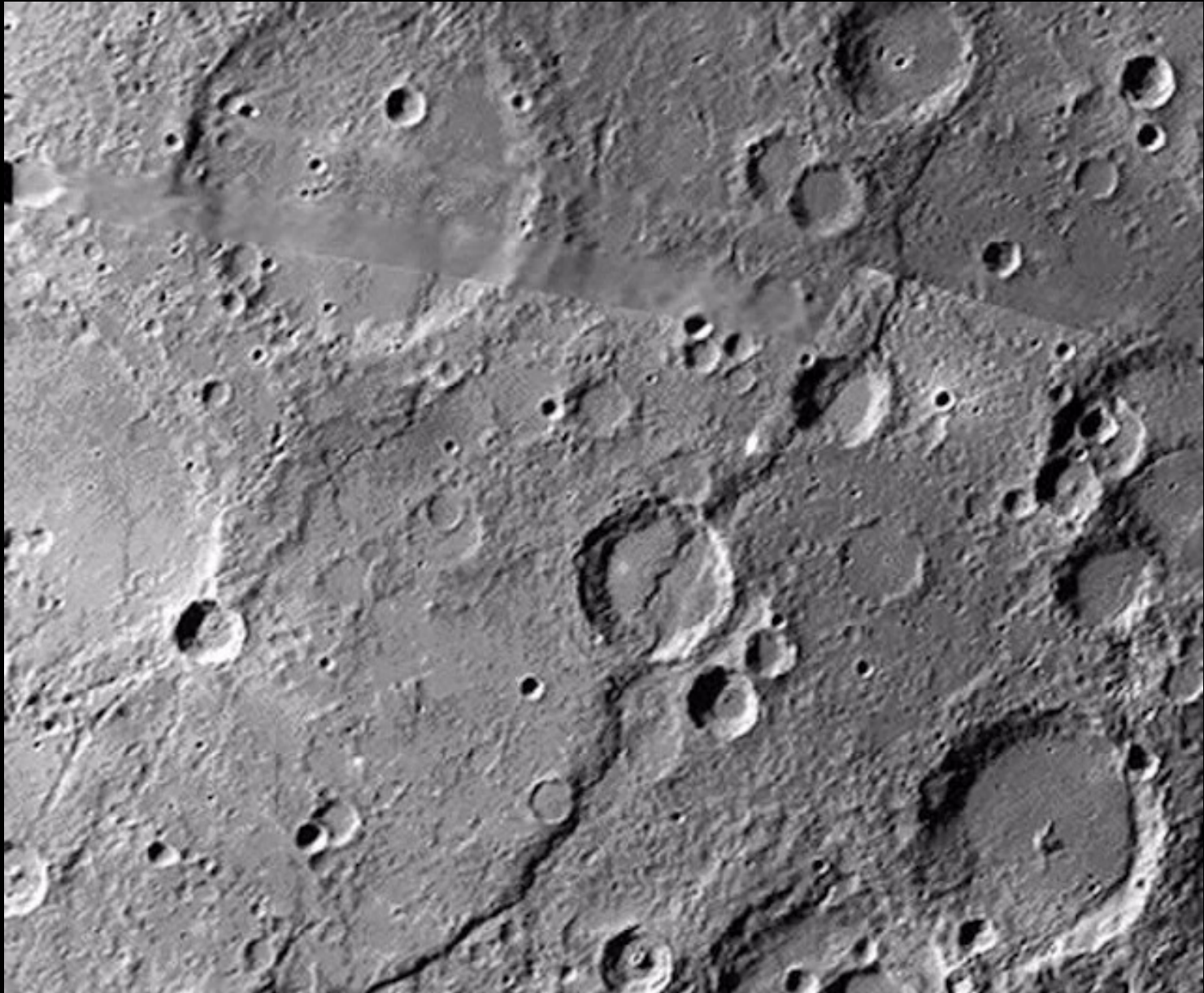
## Craters and Impact Basins (2/3)

Rembrandt is the second crater in size (716 km) after Caloris Basin.



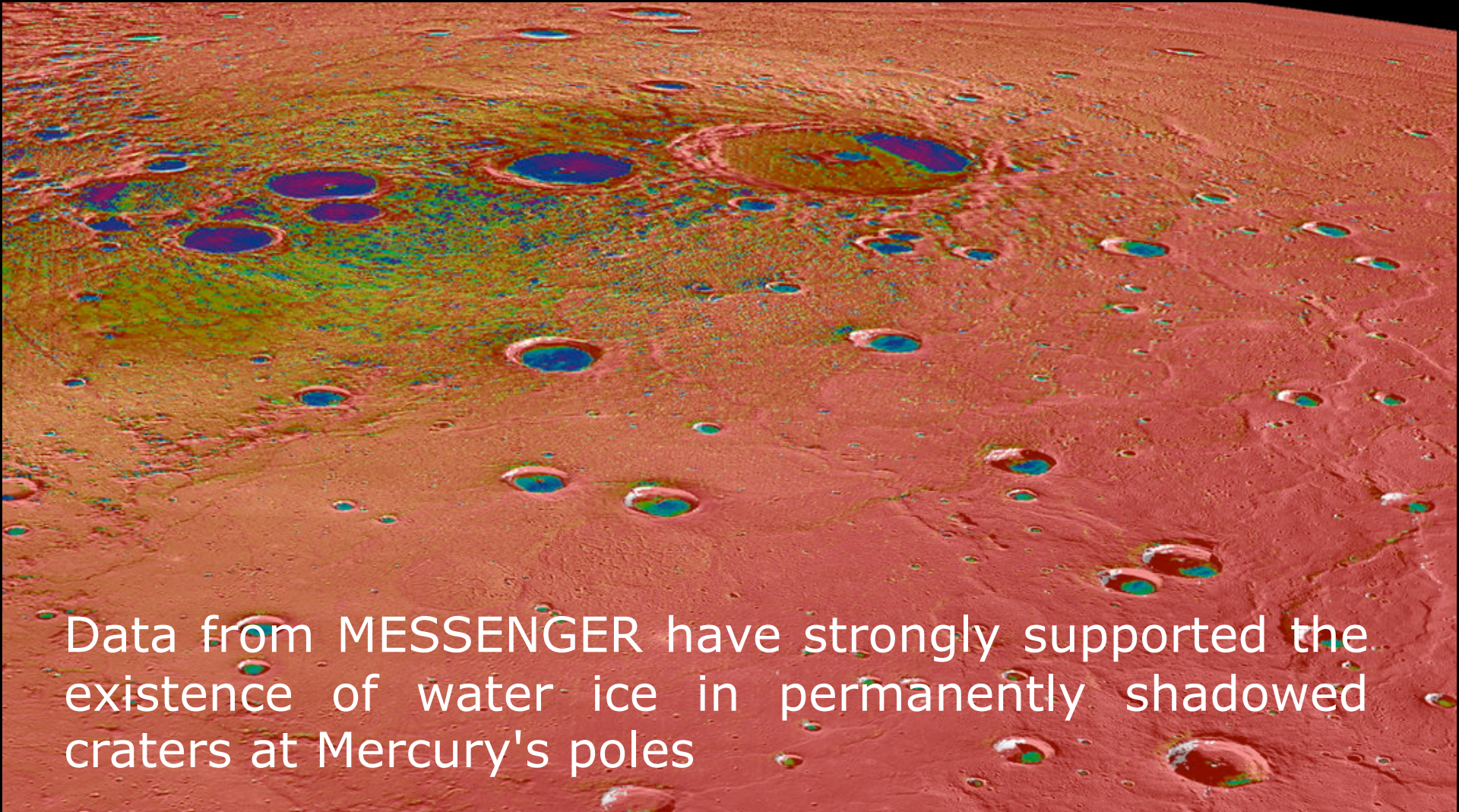


# Sharps: A Shrinking Planet?



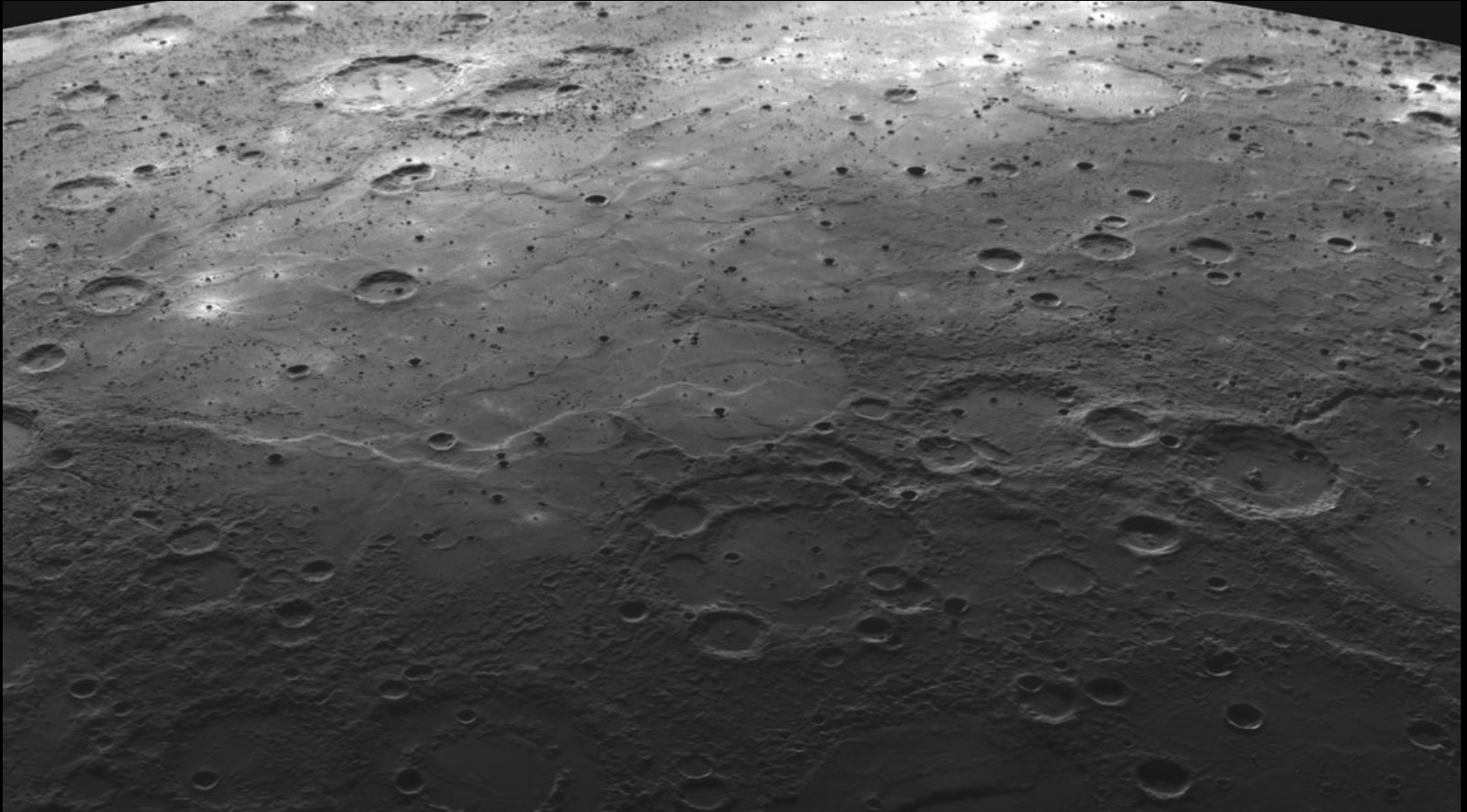


# Ice in the poles



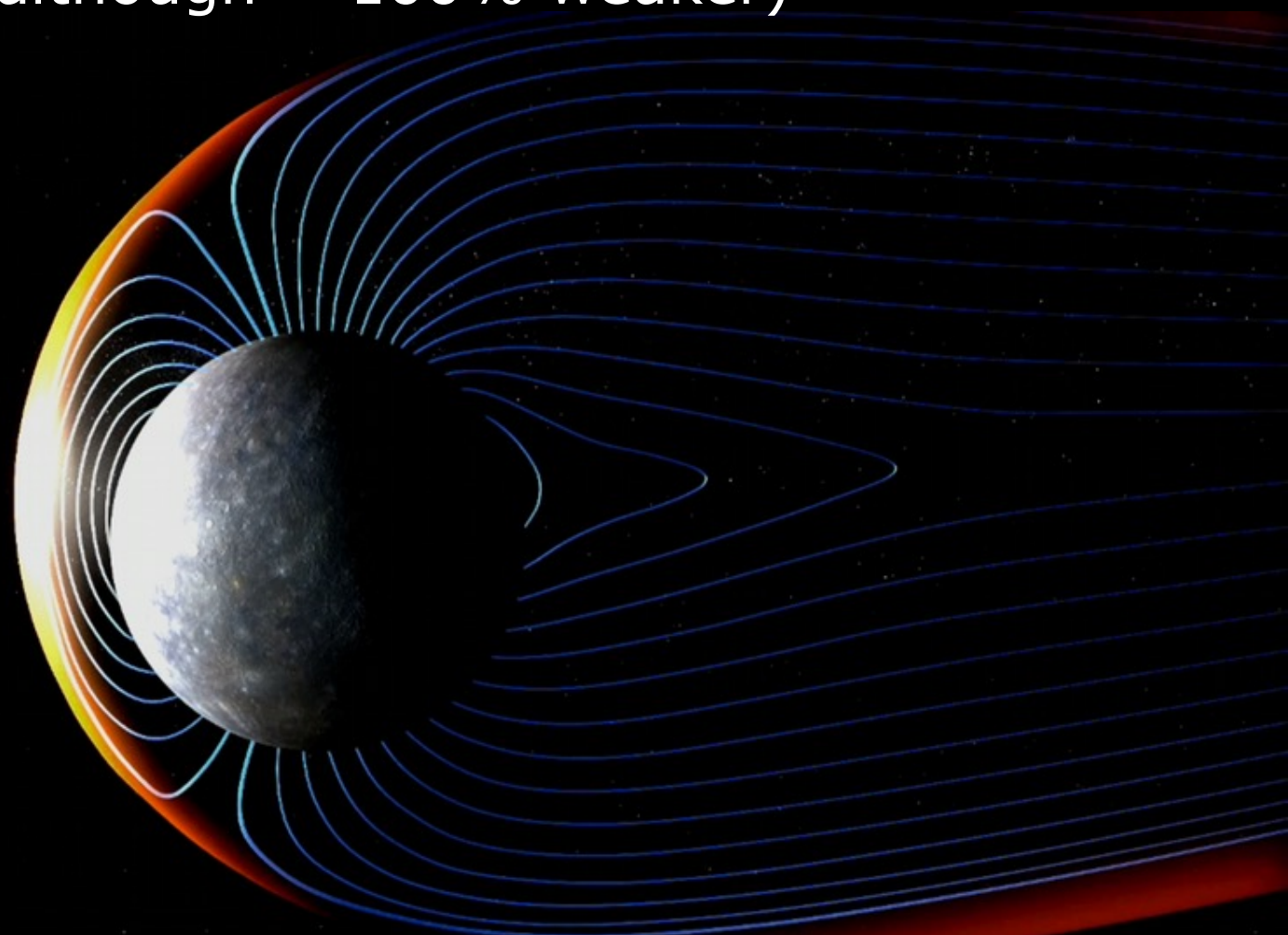
Data from MESSENGER have strongly supported the existence of water ice in permanently shadowed craters at Mercury's poles

# Volcanic Deposits





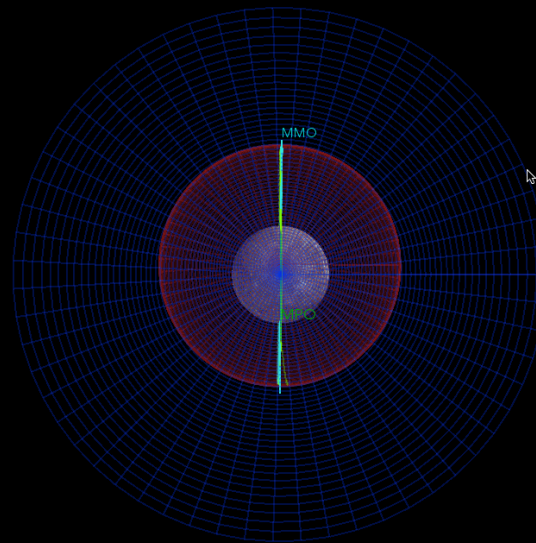
It is the only planet with a magnetic field similar to that of Earth (although  $\sim 100\%$  weaker)



The magnetic field shows a North-South asymmetry on the surface

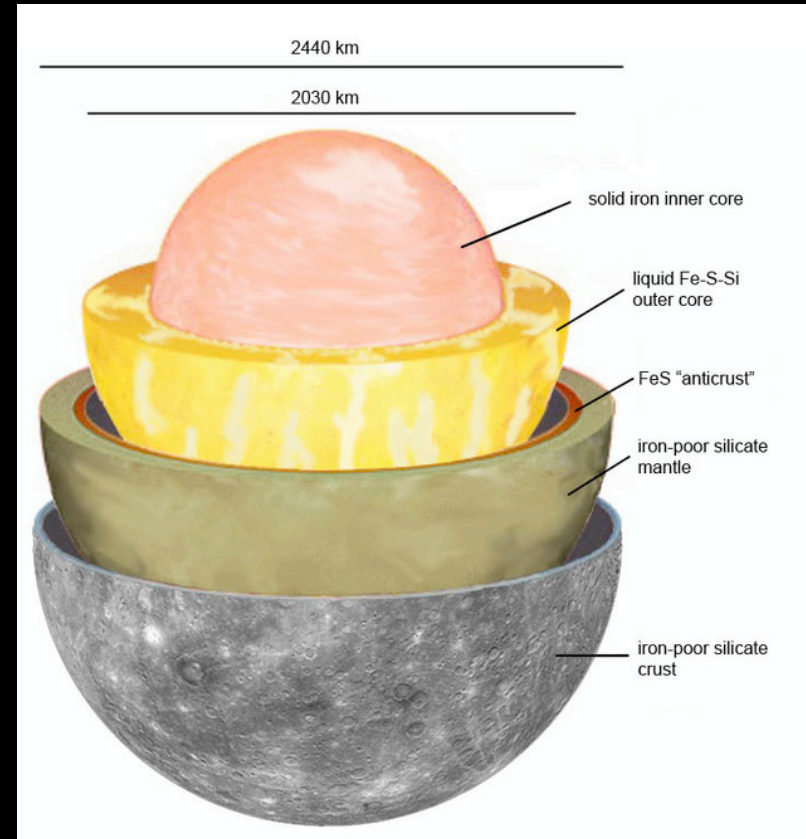
# Mercury Magnetic Field

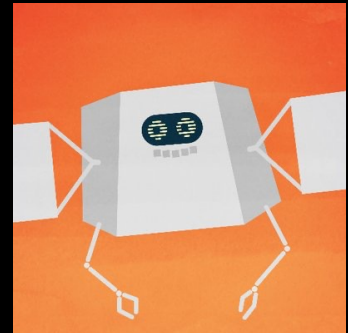
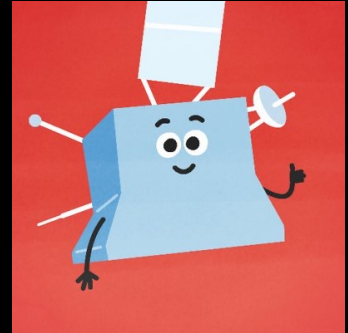
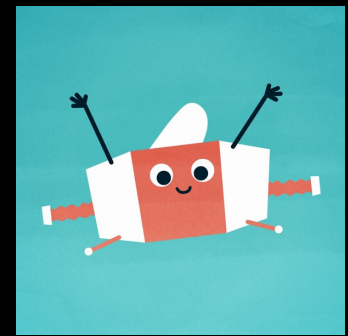
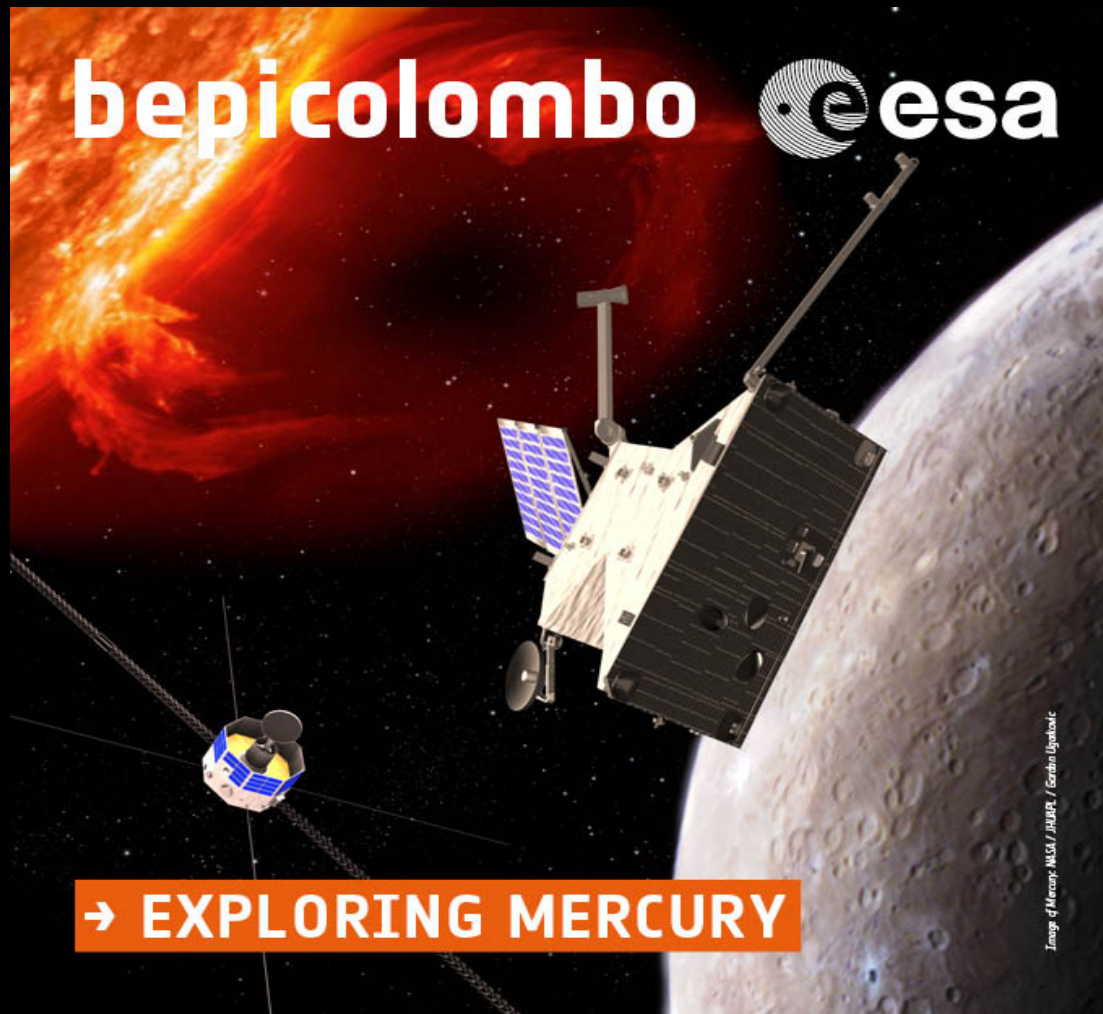
PERIHELION SEASON



# Mercury Interior

- ❑ Mercury is the second most dense planet in the Solar System (after Earth)
- ❑ Iron-rich core that occupies more than 80% of the planet.
- ❑ The outer part of the core is believed to be made of cast material. This is where Mercury's magnetic field is generated - a characteristic shared with Earth, unlike Venus, Mars, or the Moon.

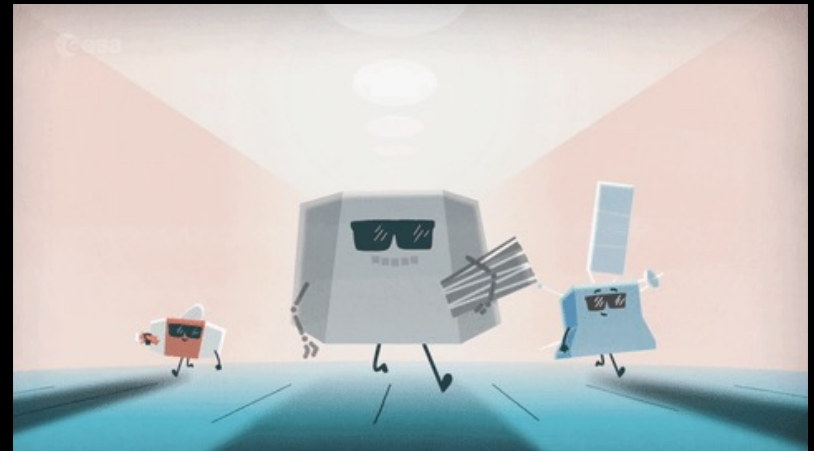




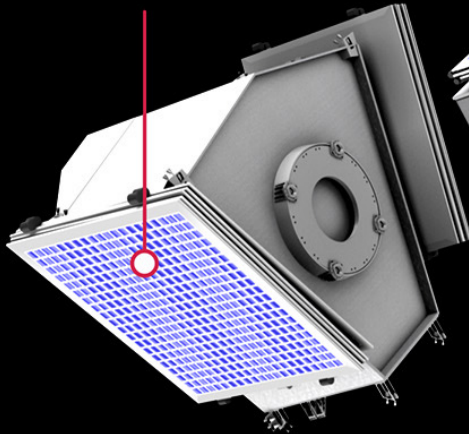
## European-Japanese Mission to Mercury



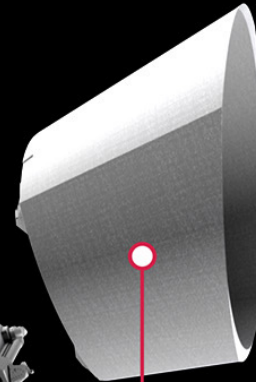
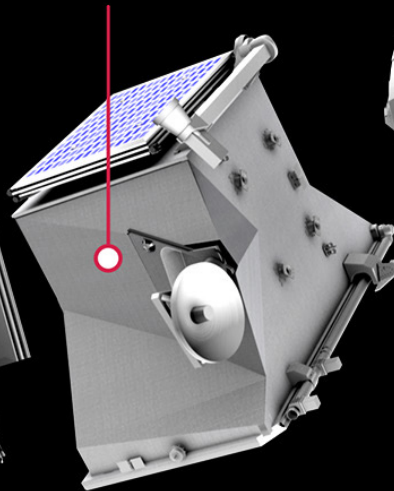
# 3 in 1!



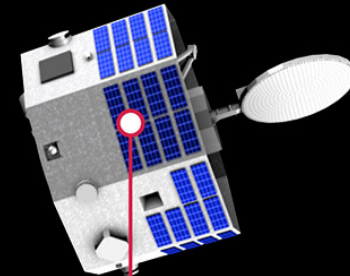
Mercury  
Transfer  
Module  
(MTM)



Mercury  
Planetary  
Orbiter  
(MPO)



Sun  
Shield



Mercury  
Magnetospheric  
Orbiter  
(MMO)

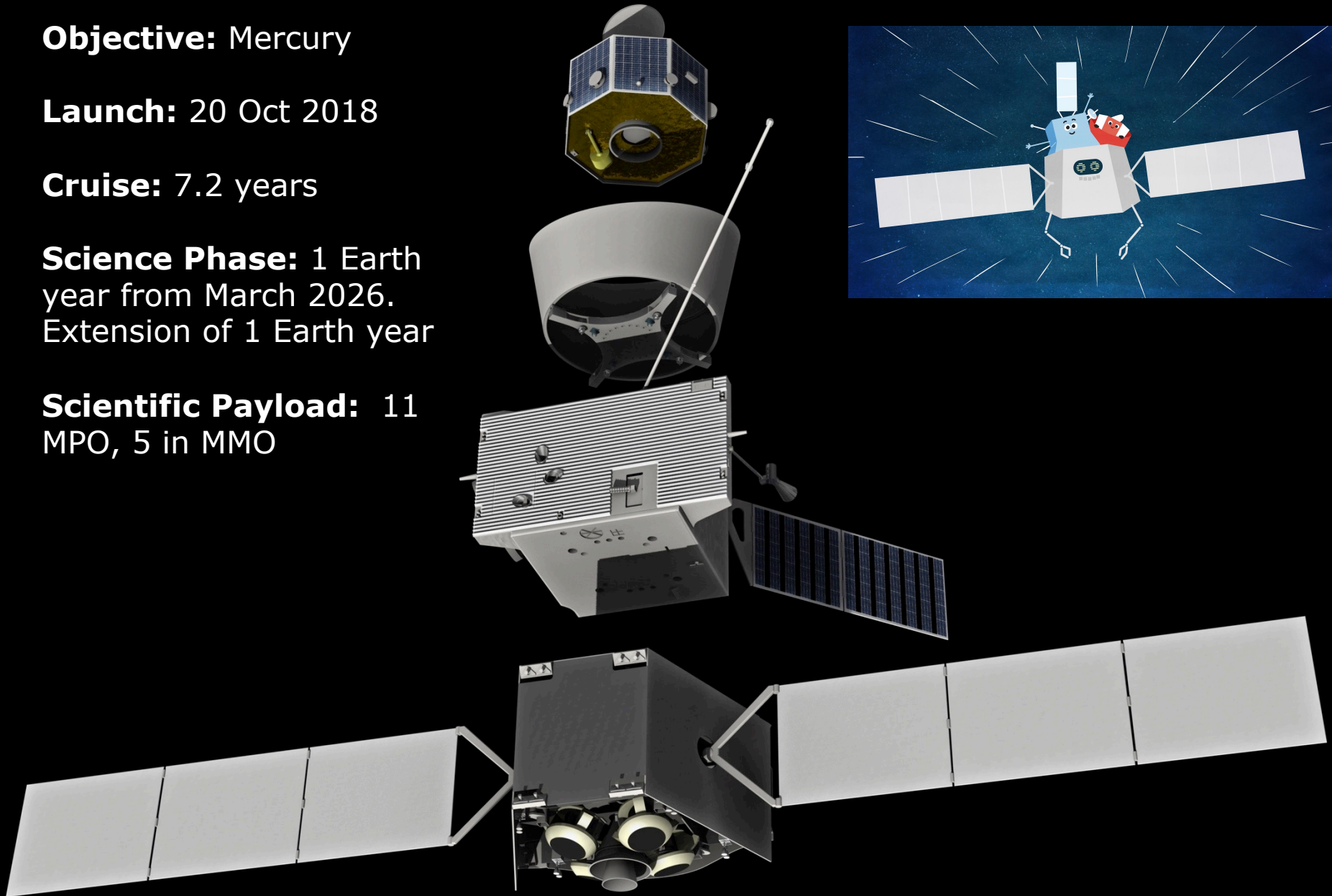
**Objective:** Mercury

**Launch:** 20 Oct 2018

**Cruise:** 7.2 years

**Science Phase:** 1 Earth  
year from March 2026.  
Extension of 1 Earth year

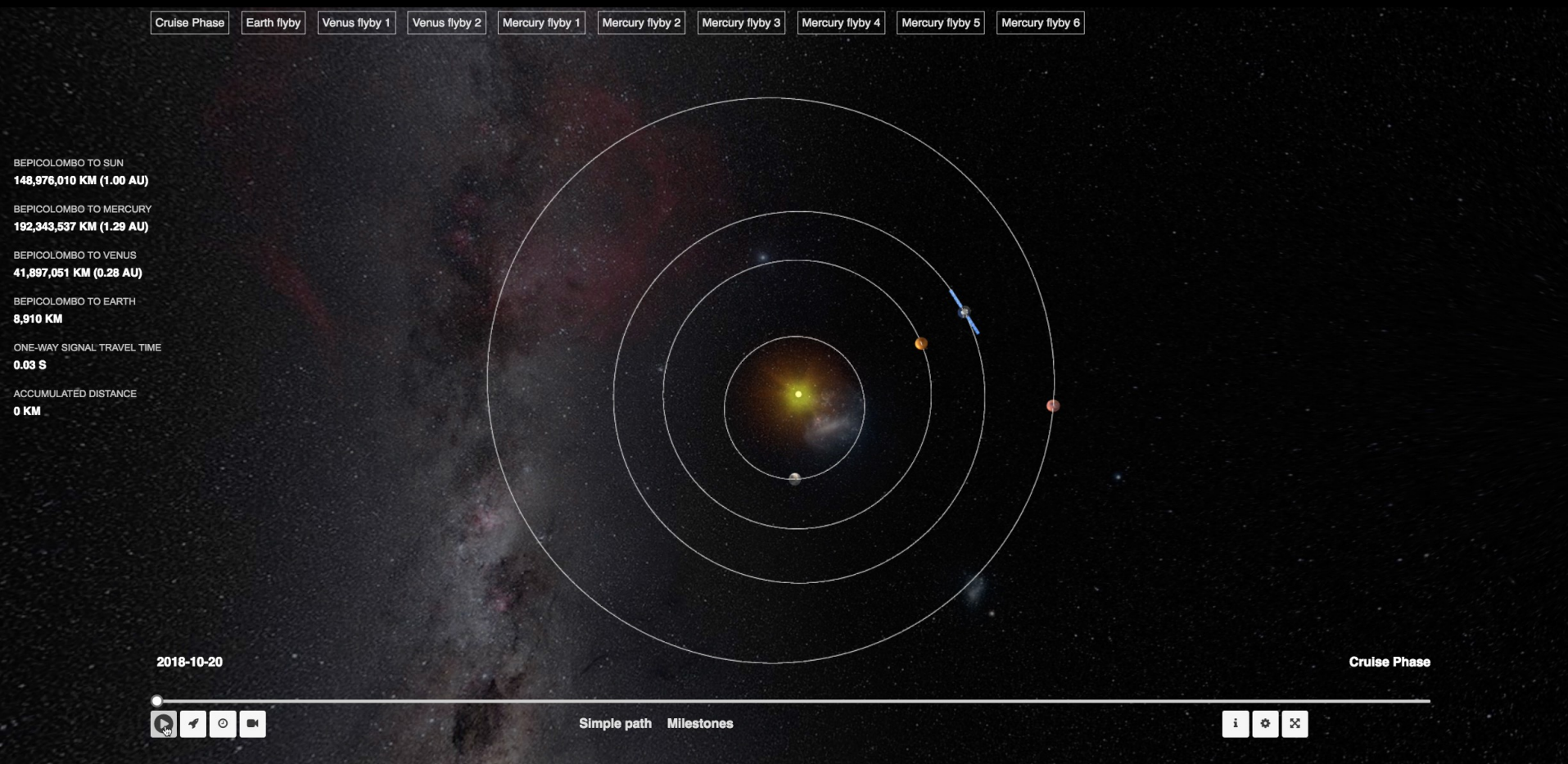
**Scientific Payload:** 11  
MPO, 5 in MMO





# Route to Mercury

- **Launch:** 20 October 2018
- **Interplanetary Cruise:** 7.2 years, 9 billions kms, 18 loops to the Sun
- **9 “flybys”:** 1 Earth, 2 Venus y 6 Mercury



# Mercury Planetary Orbiter (MPO) (ESA)

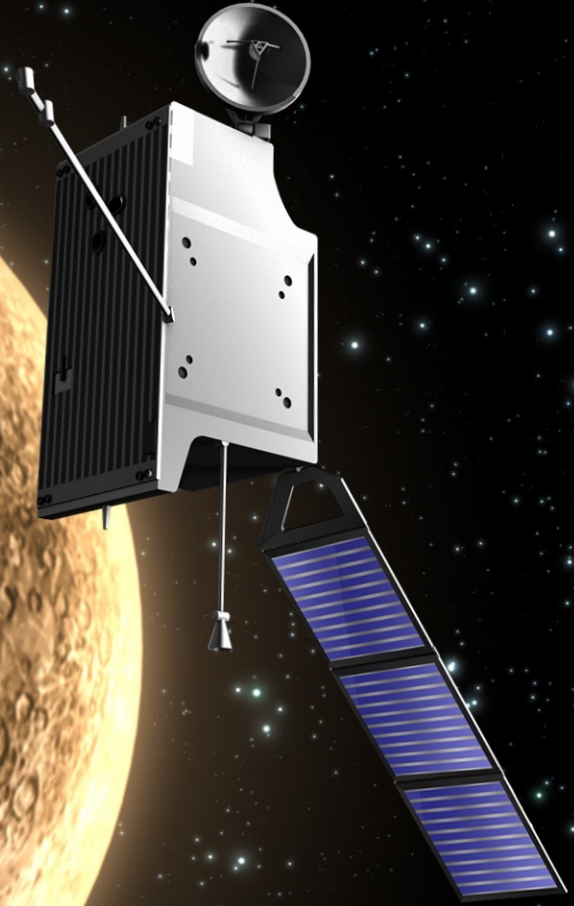
Study of the surface and interior of Mercury.

Built by the European Space Agency (ESA).

Polar orbit 480x1,500km,  
period 2.3 h

Data volume: 1550Gbits /  
year.

3-axis stabilized satellite, NADIR attitude guidance  
(one axis points continuously to the center of the planet)





# Mercury Magnetospheric Orbiter - MMO (JAXA)

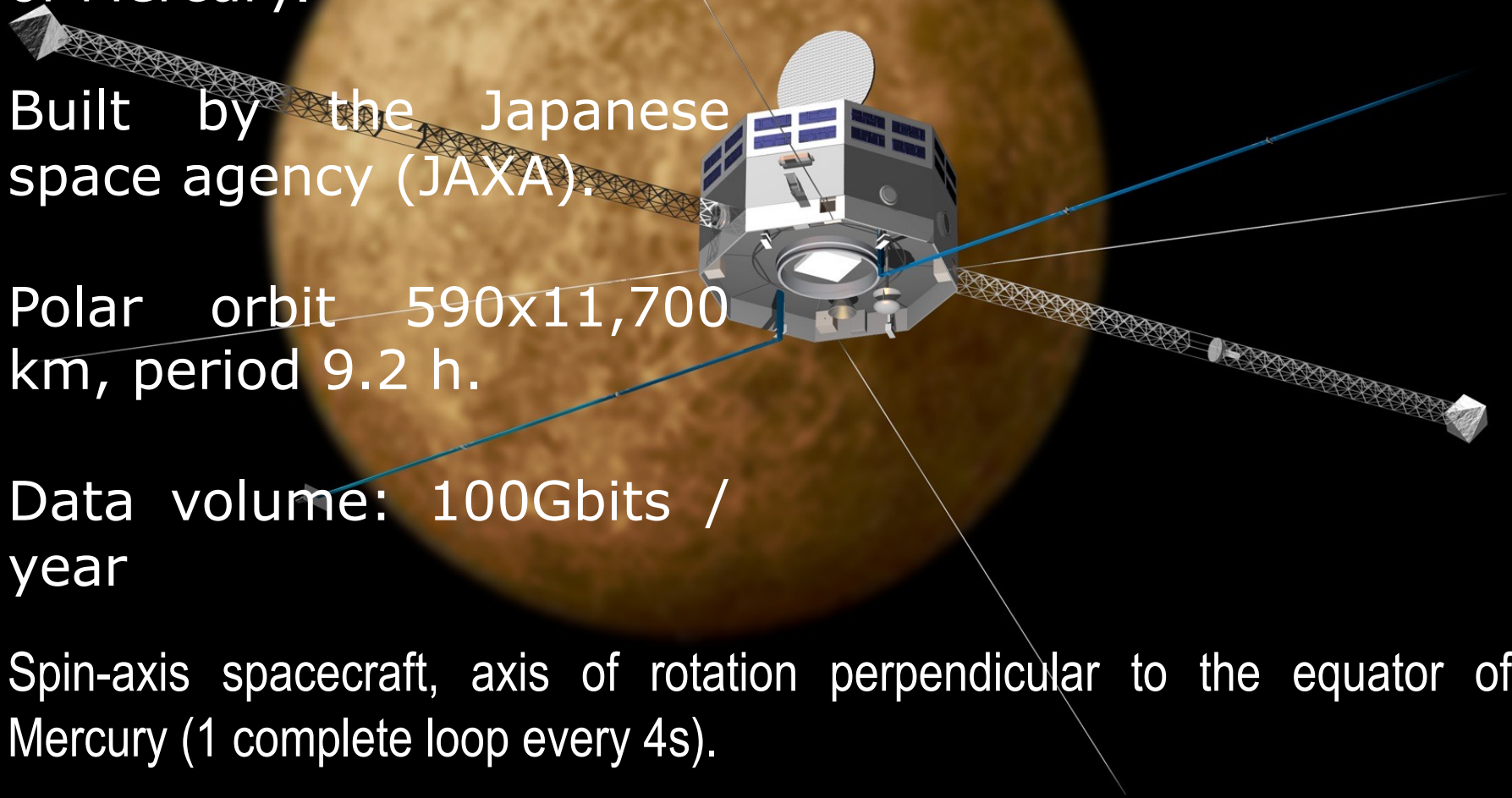
Study of the environment of Mercury.

Built by the Japanese space agency (JAXA).

Polar orbit  $590 \times 11,700$  km, period 9.2 h.

Data volume: 100Gbits / year

Spin-axis spacecraft, axis of rotation perpendicular to the equator of Mercury (1 complete loop every 4s).



# Mercury Transfer Module-MTM (ESA)

Ion thrusters  
(can be  
throttled from  
75 mN to max  
145mN)

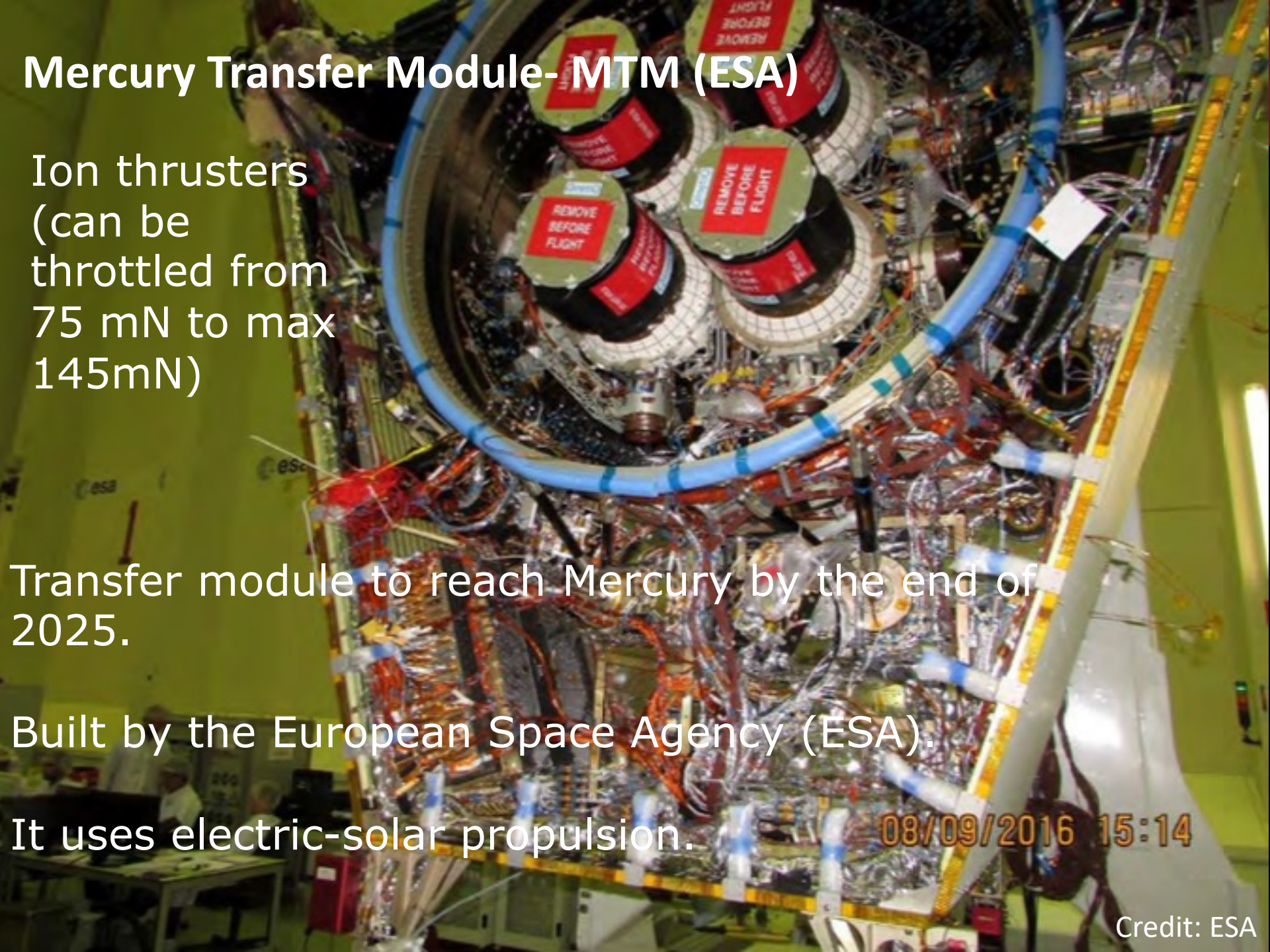
Transfer module to reach Mercury by the end of  
2025.

Built by the European Space Agency (ESA).

It uses electric-solar propulsion.

08/09/2016 15:14

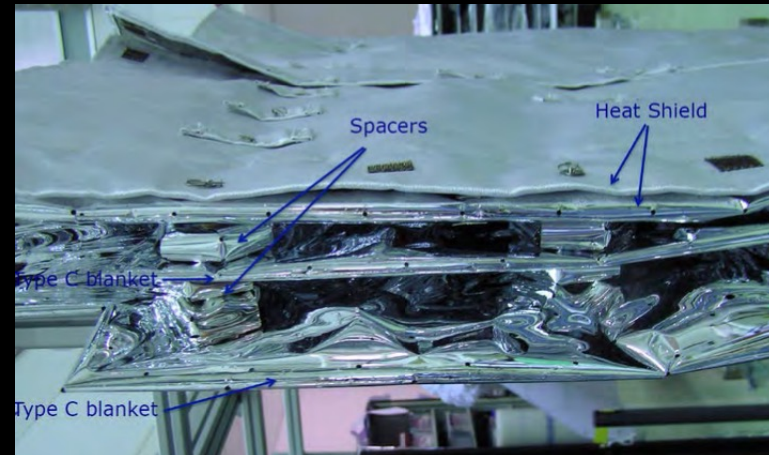
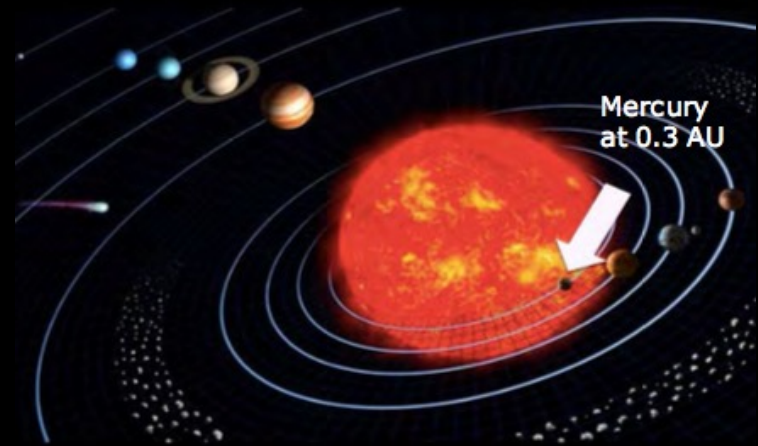
Credit: ESA



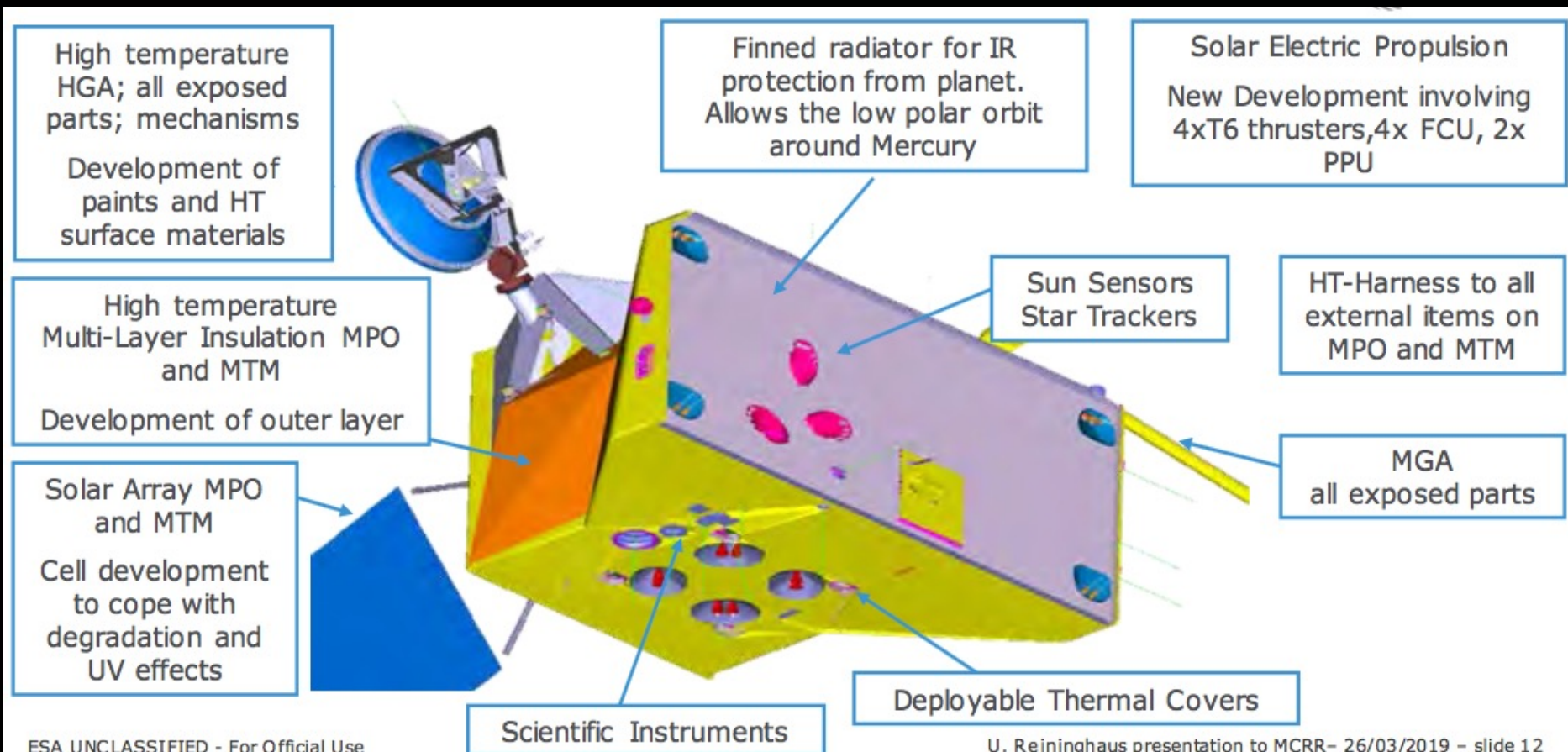


# Mission Challenges

- ❑ Global coverage of the planet => targeted nadir
- ❑ High resolution => low orbit altitude
- ❑ Mercury is at 0.3 AU
- ❑ 10 times solar radiation and surface temperatures up to 450 degrees.
- ❑ 5 of 6 sides and spacecraft antennas facing the Sun and infrared radiation
- ❑ More than 70% of the S/C is a specific development of BepiColombo.
- ❑ The cruise trajectory requires chemical gravity assistance and electric propulsion arches.



# Technology challenges





# Operations: Ground Segment

- BepiColombo is operated and controlled from the European Operations Center (ESOC), in Germany, from launch to arrival at Mercury.
- The JAXA Sagami-hara Space Operations Center, with the Usuda station in Japan, will take over the operation of the MMO once it is in orbit around Mercury.
- The scientific operations of the MPO will be prepared by the scientific operations center (ESAC) located in Villafranca, Madrid, Spain and those of the MMO from the JAXA Sagami-hara Scientific Operations Center (SSOC).



# Communications: Cebreros Station

Cebreros station is located 77 kilometers west of Madrid, Spain. Cebreris is a 35 meter antenna with X band transmission and reception and Ka band reception. Provides communication 8 hours a day.

Provides routine support for missions in space, including Mars Express and Gaia, and BepiColombo.

Malargüe station, in Argentina, will be another station to be used in BepiColombo Mercury Operations.





# BepiColombo – Collaboration

**BepiColombo is an ESA mission to Mercury in collaboration with JAXA. Scientific instruments are supplied by leading researchers, funded by 8 agencies.**



TEKES  
SIXS



UK Space Agency  
MIXS



CNES  
PHEBUS



Swiss Space Office  
BELA



Japan Aerospace  
Exploration Agency  
MMO



Roscosmos  
MGNS



DLR  
BELA  
MERMAG  
MERTIS

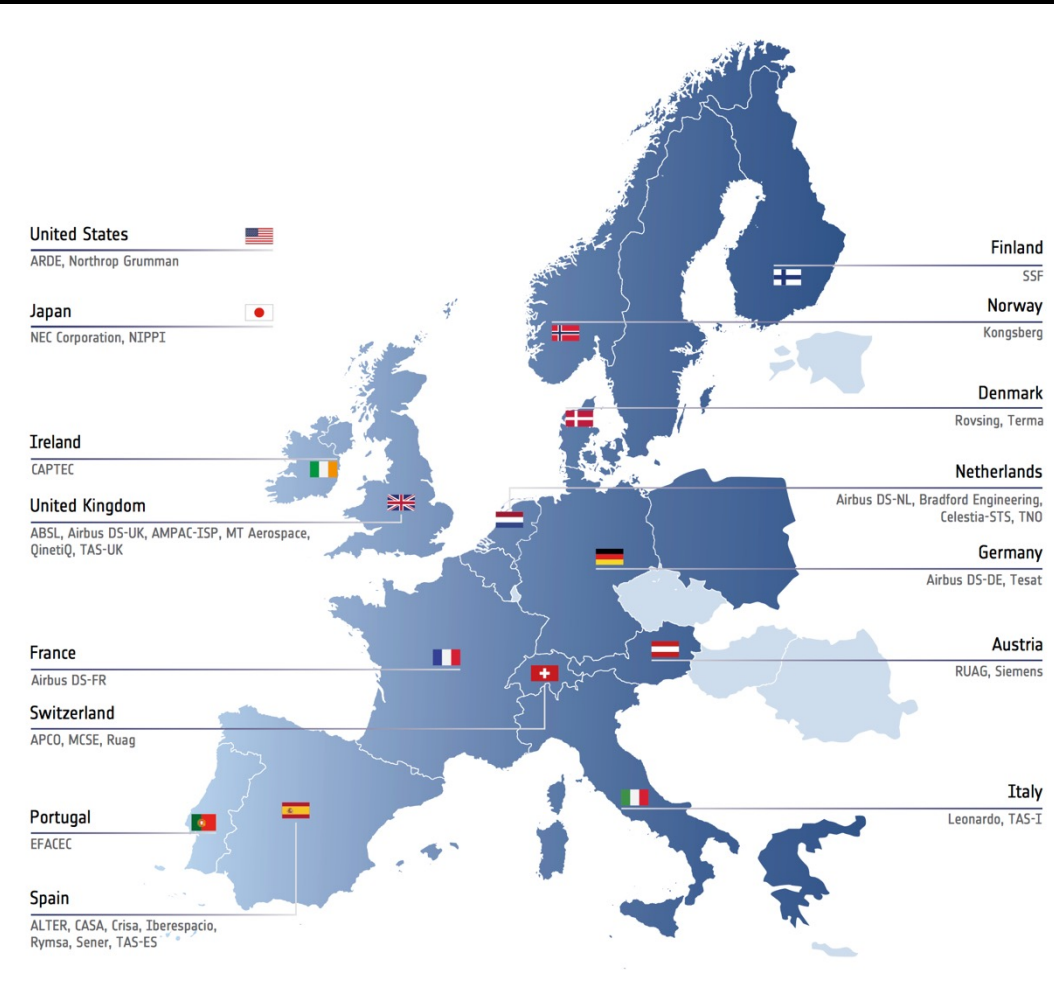


Italian Space Agency  
ISA  
MORE  
SERENA  
SIMBIOSYS



# BepiColombo and Industry

83 companies from 12 countries





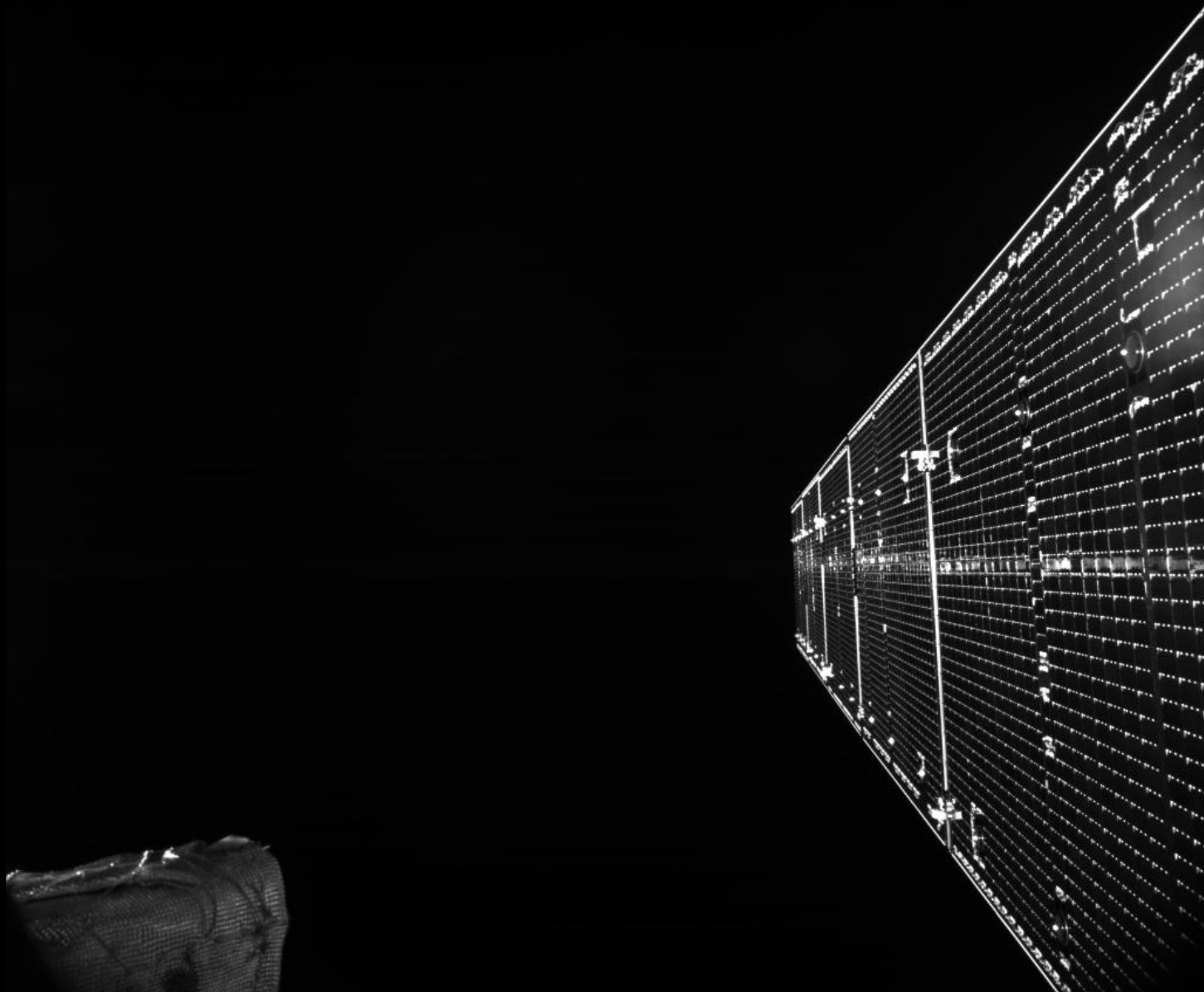
# Launch 20 October 2018

















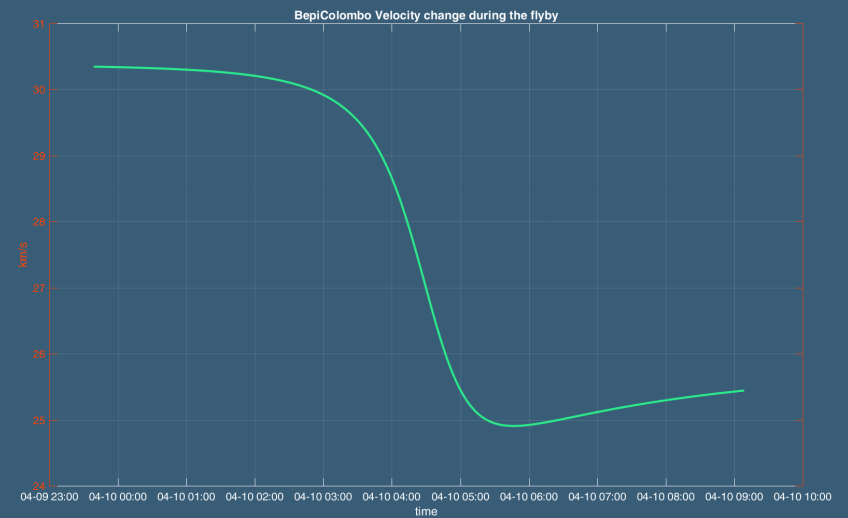
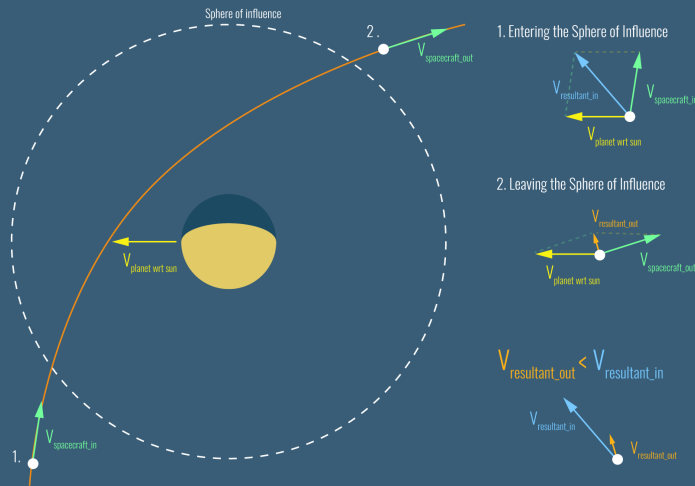


1 x Earth



# Earth Flyby1: 15 April 2020

Flyby to decrease final Velocity

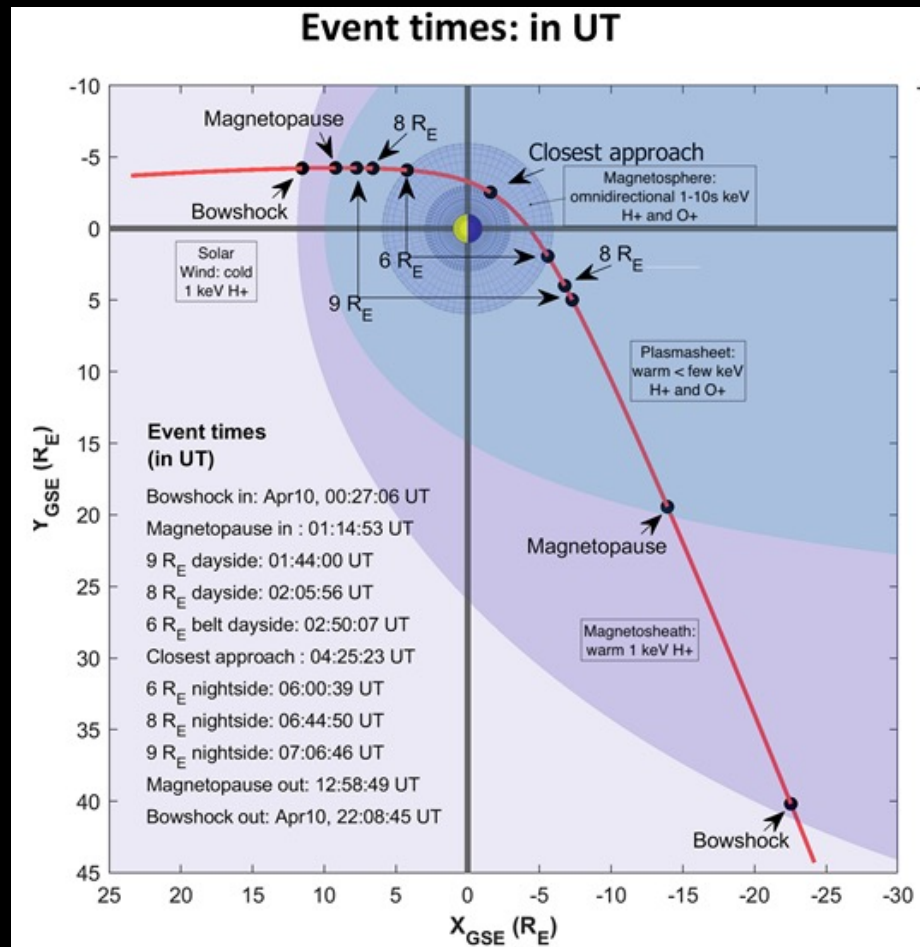




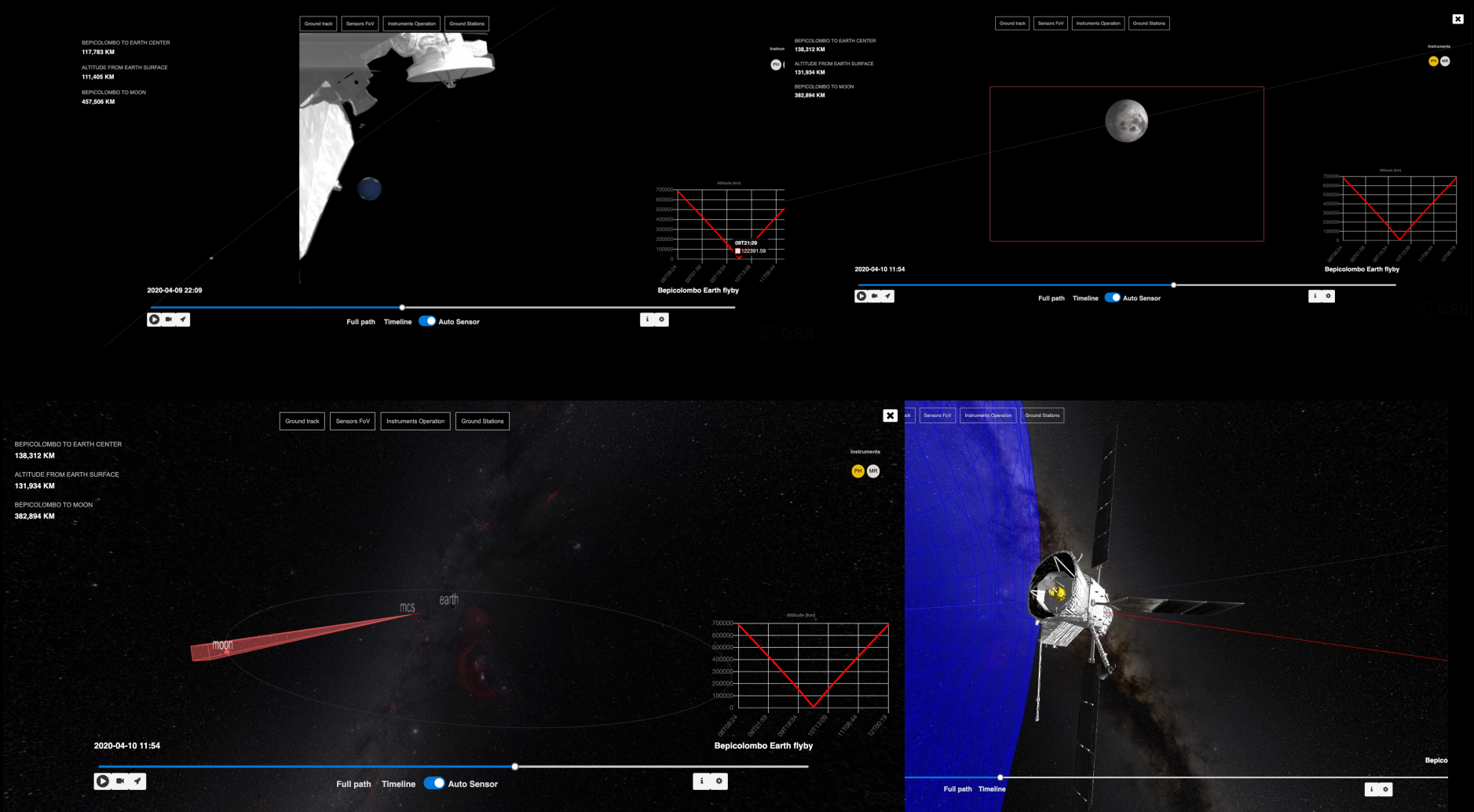
# Earth Flyby1 Geometry

Closest approach = 2020-04-10 04:24:57

Earth flyby S/C Altitude at CA (km): 12692.90



# Earth Flyby#1: Planning the Science Operations





# Earth Flyby video

# BepiColombo Selfies and Earth (I)

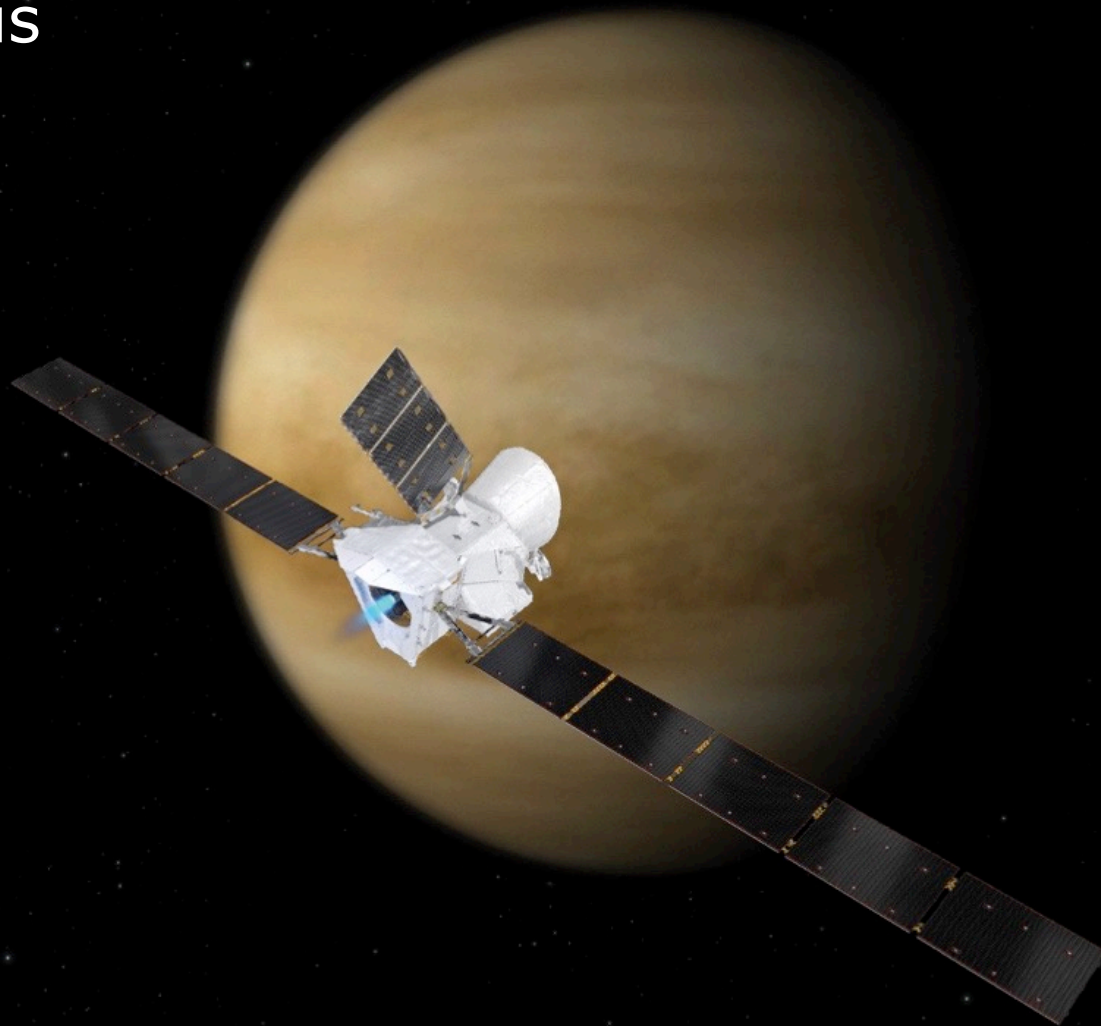


# BepiColombo Selfies and Earth (II)





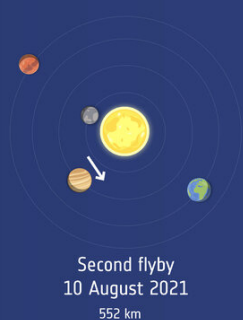
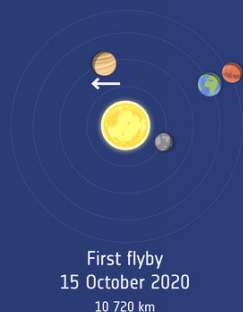
2 x Venus



# Venus Flyby#2: 10 August 2021

## 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



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

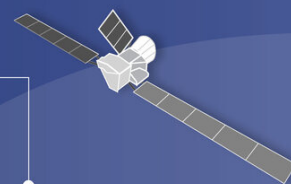
Magnetic field and magnetosphere

Electric field, plasma and radio waves

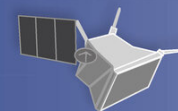
Bow shock and magnetopause

### VENUS AS AN EXOPLANET

Phase curve and rotation rate



Instruments active during flyby



Mercury Planetary Orbiter

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



Mercury Magnetospheric Orbiter

*MDM*  
*MMO-MGF*  
*MPPE*  
*MSASI*  
*PWI*



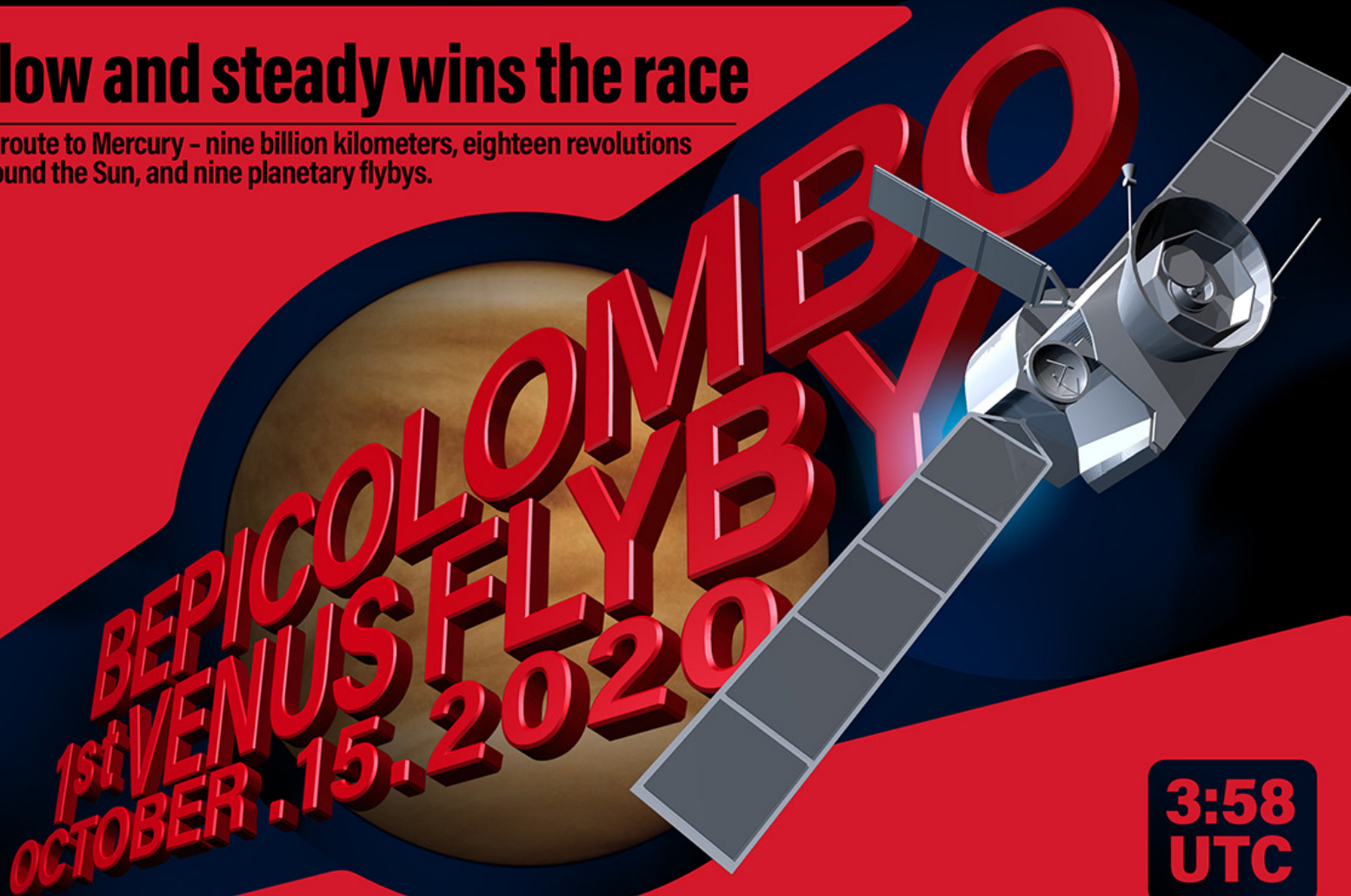
#bepicolombo

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

# Venus Flyby#1: 15 October 2020

## Slow and steady wins the race

En route to Mercury – nine billion kilometers, eighteen revolutions around the Sun, and nine planetary flybys.



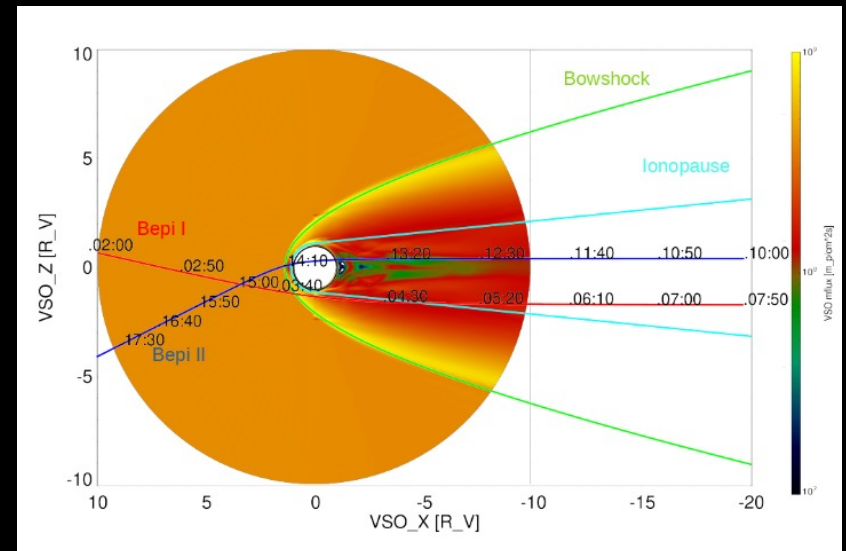
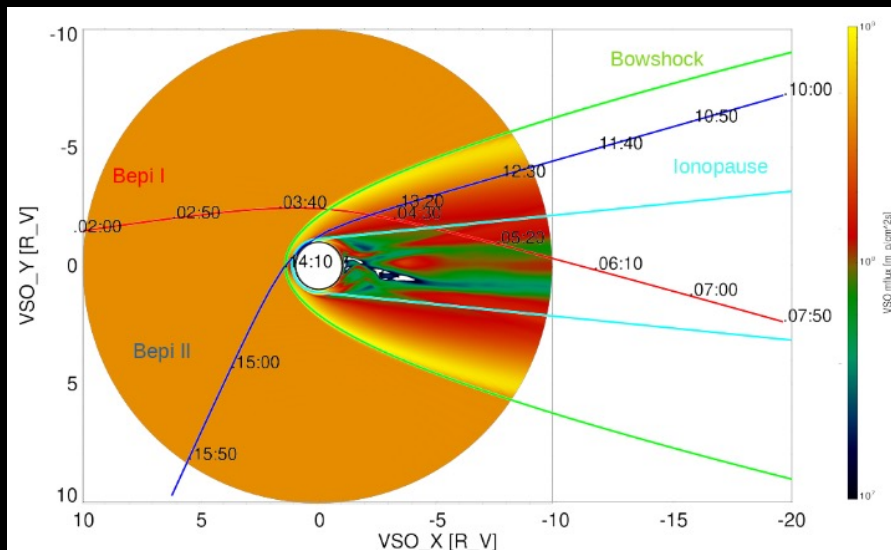
DESIGN BY ALEX LUTKUS

**3:58  
UTC**

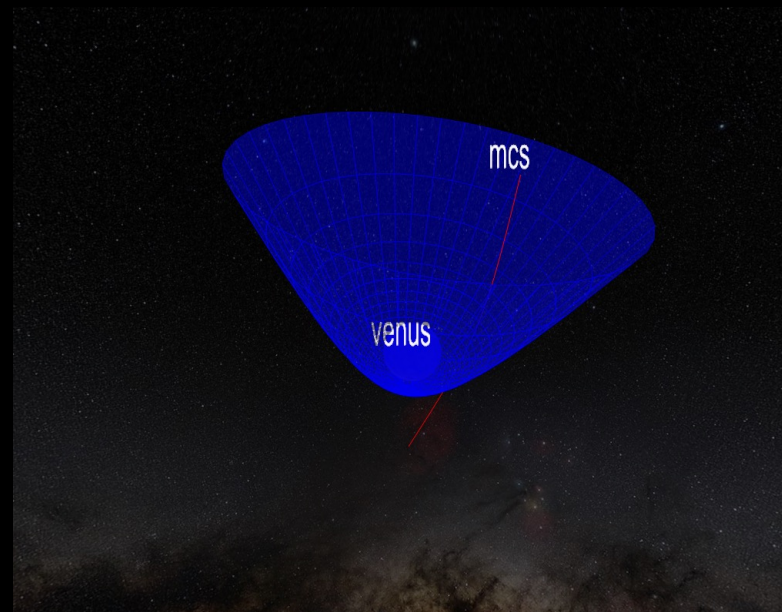
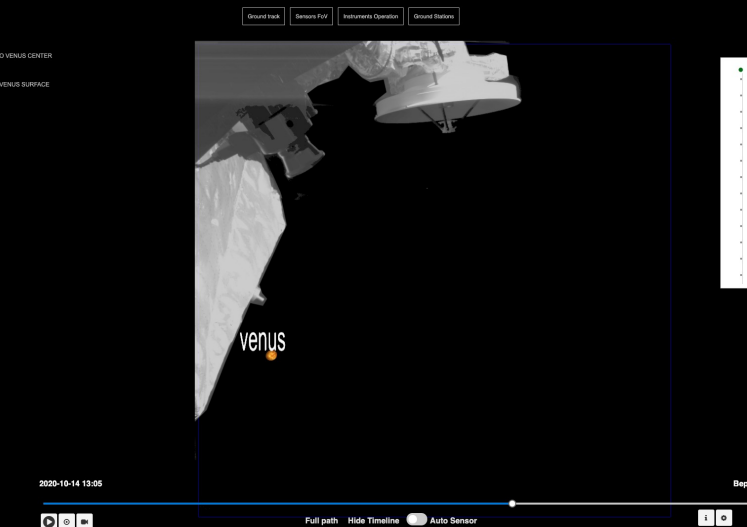
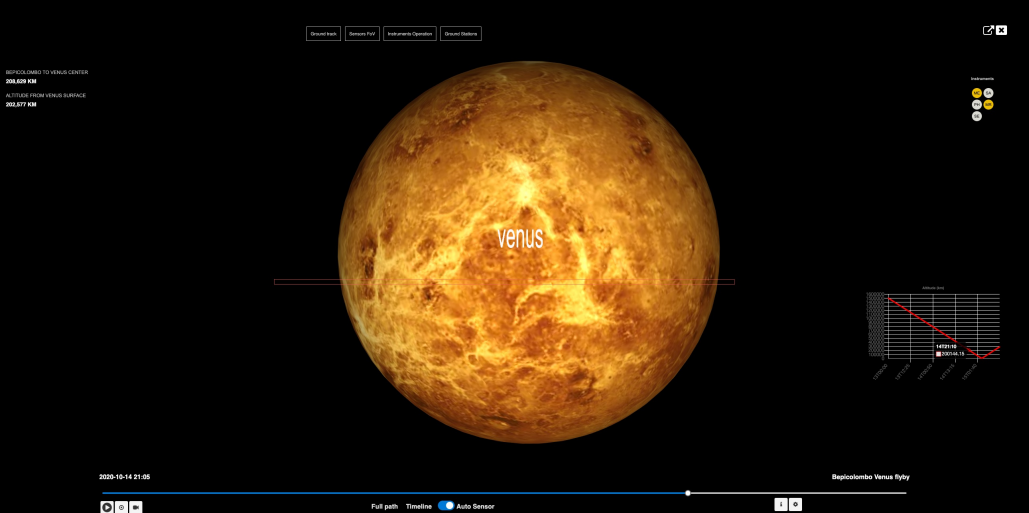


# Venus Flyby#1 Geometry

- Closest approach = 2020-10-15 03:58:32 UTC
- Venus flyby S/C Altitude at CA (km): 10722.464



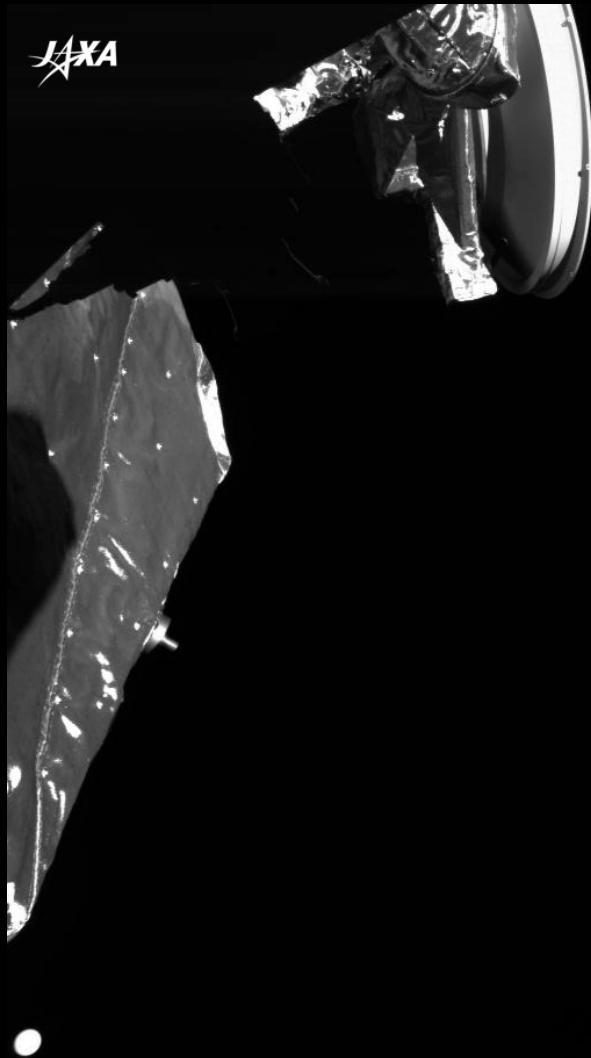
# Venus Flyby#1: Planning the Science Operations



# Venus Flyby#1 video



# BepiColombo Selfies and Venus (I)



BepiColombo, Monitoring Camera #3

14 October 2020  
06:58:33 UTC

European Space Agency

# BepiColombo Selfies and Venus (II)

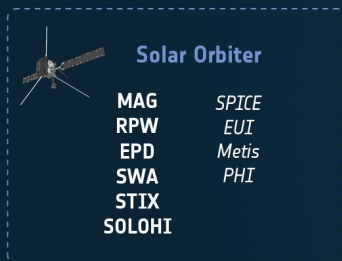


# Venus Flyby#2: 10 August 2021

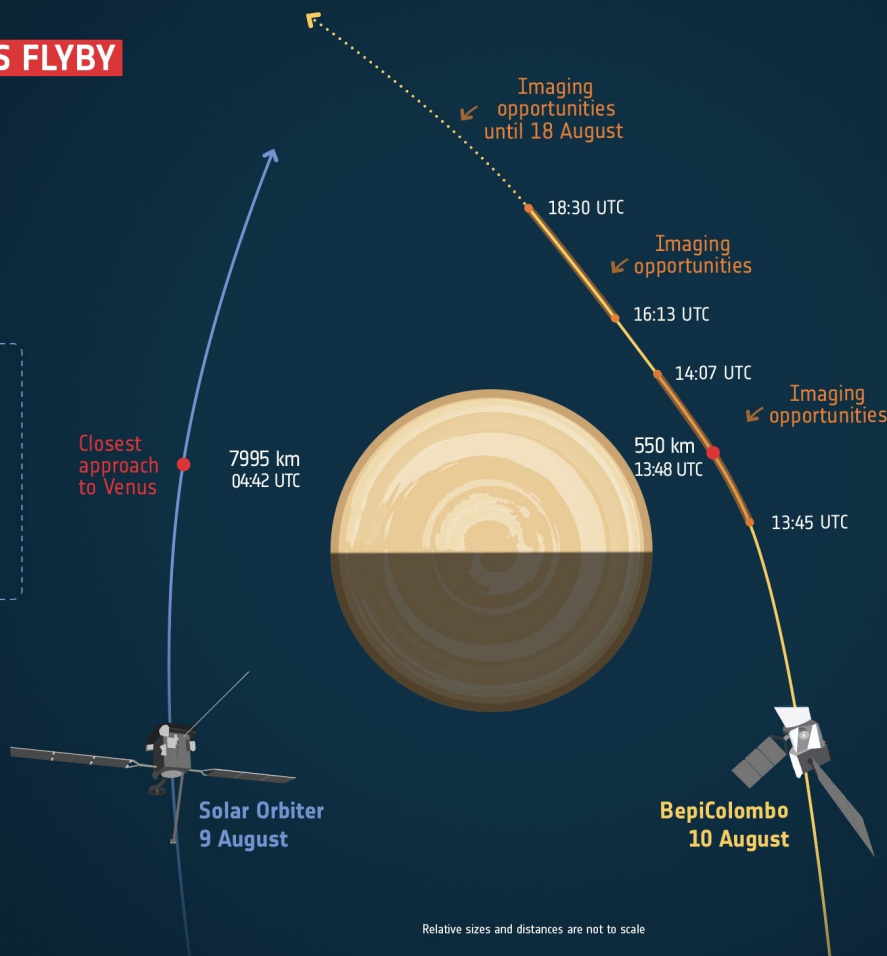
## ESA'S DOUBLE VENUS FLYBY



### Instruments active during flyby

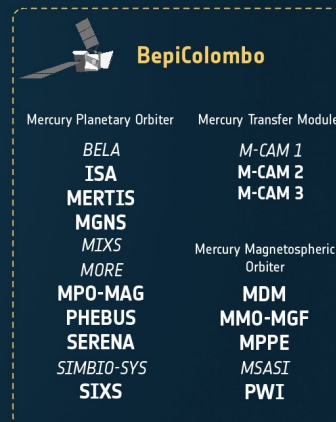


ACTIVE - NOT ACTIVE



Relative sizes and distances are not to scale

### Instruments active during flyby

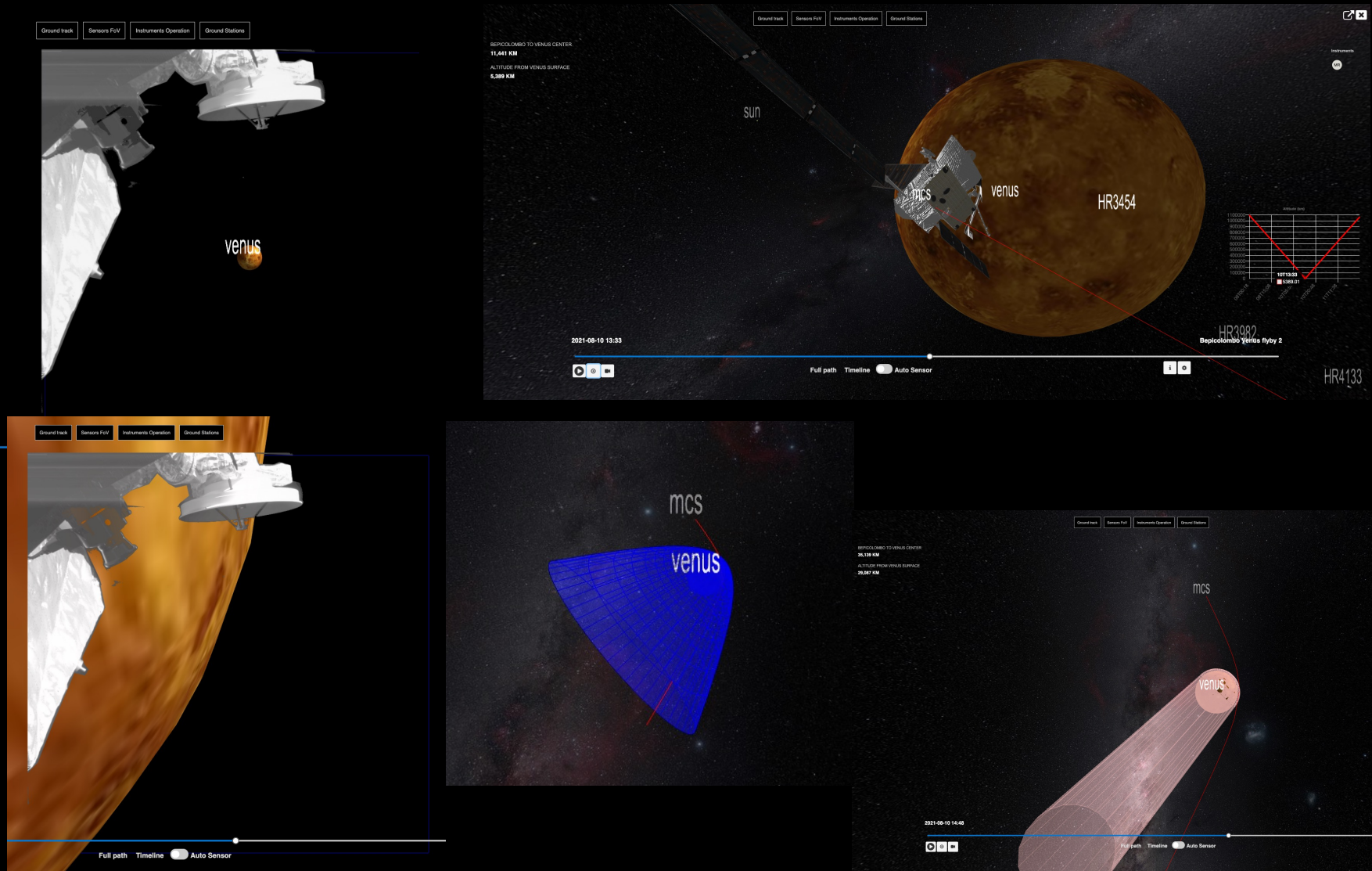


ACTIVE - NOT ACTIVE

#ExploreFarther



# Venus Flyby#2: Planning the Science Operations



# Venus Flyby#2 video

# BepiColombo Selfies and Venus (II)

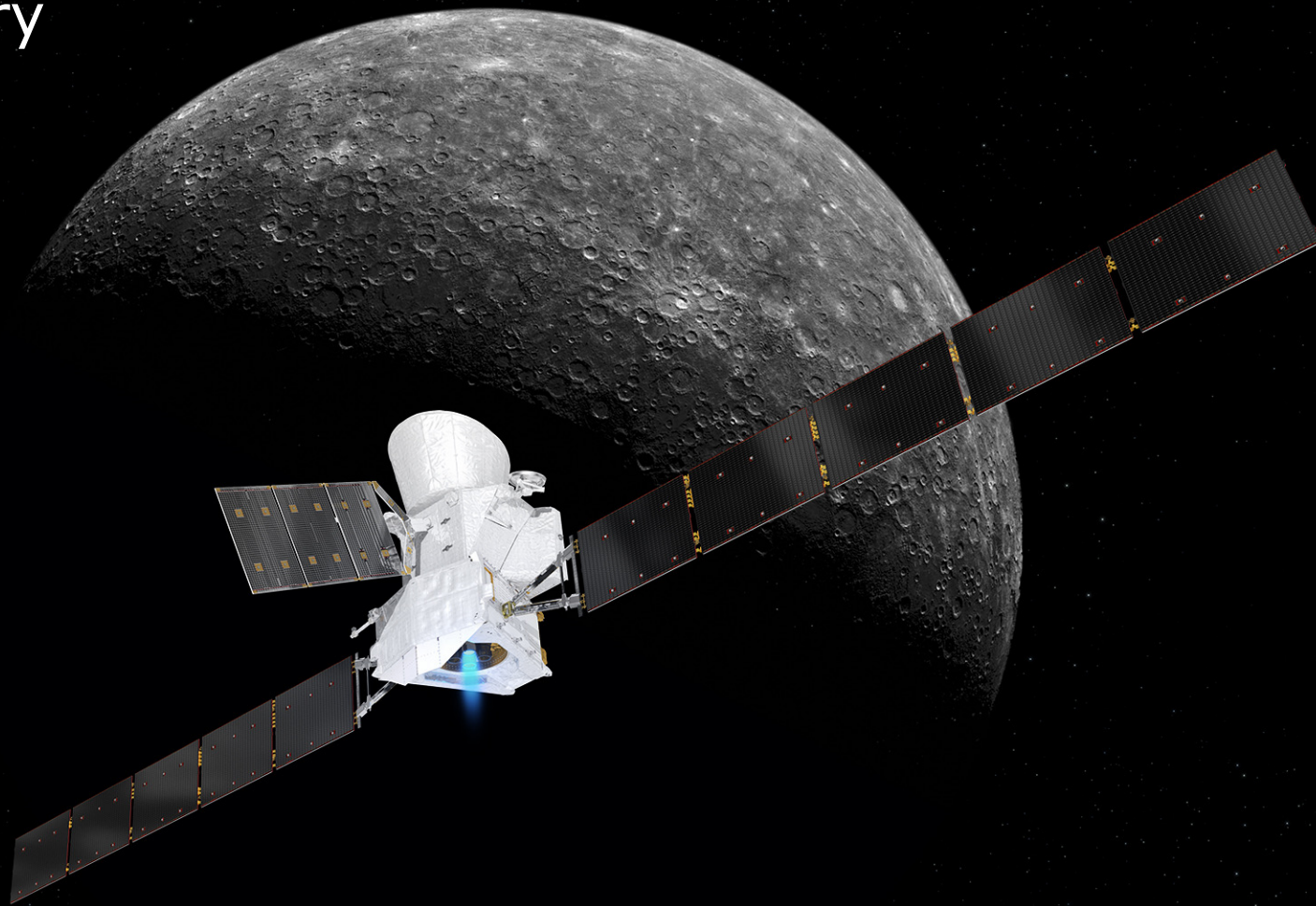


10 August 2021  
13:57:56 UTC

European Space Agency



6 x Mercury

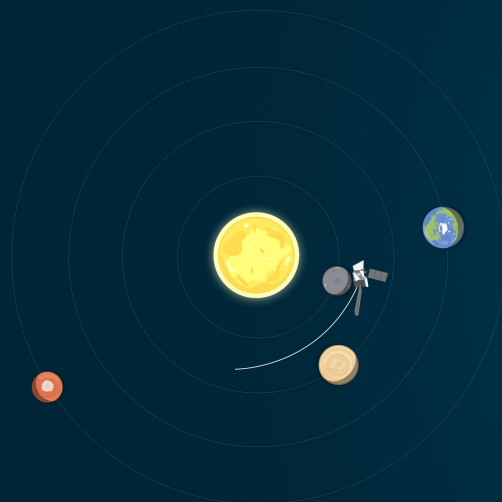


# Bepi Mercury Flybys



# Mercury Flyby#1: 1 October 2021

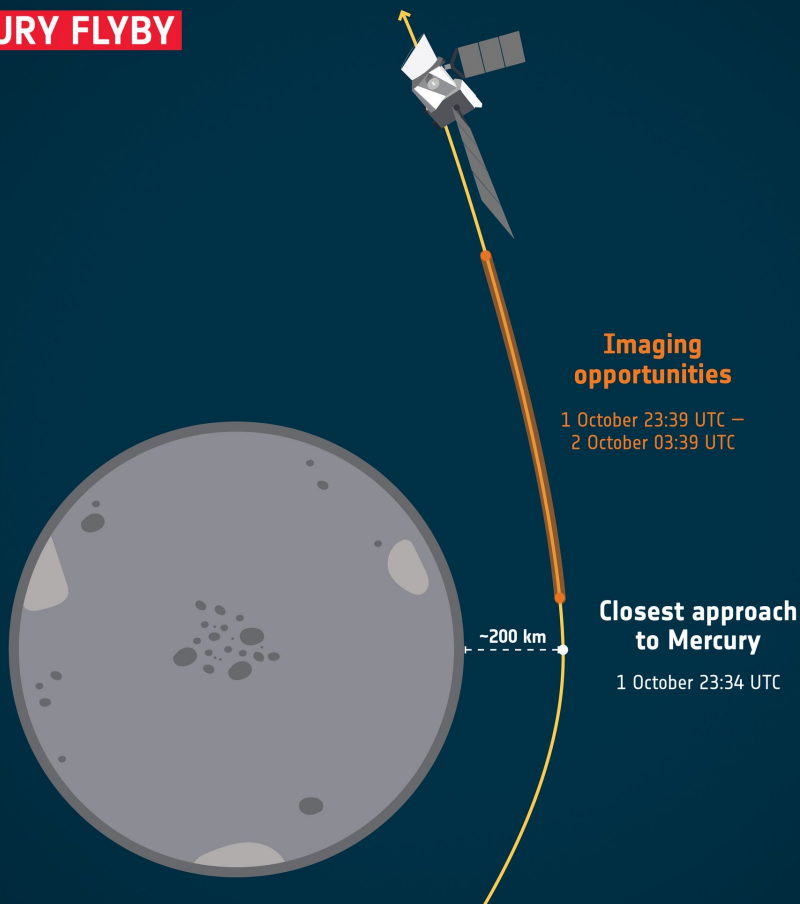
## BEPICOLOMBO'S FIRST MERCURY FLYBY



Mercury flyby

1 October 23:34 UTC  
2 October 01:34 CEST

~200 km



### Imaging opportunities

1 October 23:39 UTC –  
2 October 03:39 UTC

### Closest approach to Mercury

1 October 23:34 UTC

### Instruments active during flyby



#### BepiColombo

##### Mercury Planetary Orbiter

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

##### Mercury Transfer Module

*M-CAM 1*  
**M-CAM 2**  
**M-CAM 3**

##### Mercury Magnetospheric Orbiter

**MDM**  
**MMO-MGF**  
**MPPE**  
*MSASI*  
**PWI**

ACTIVE - NOT ACTIVE

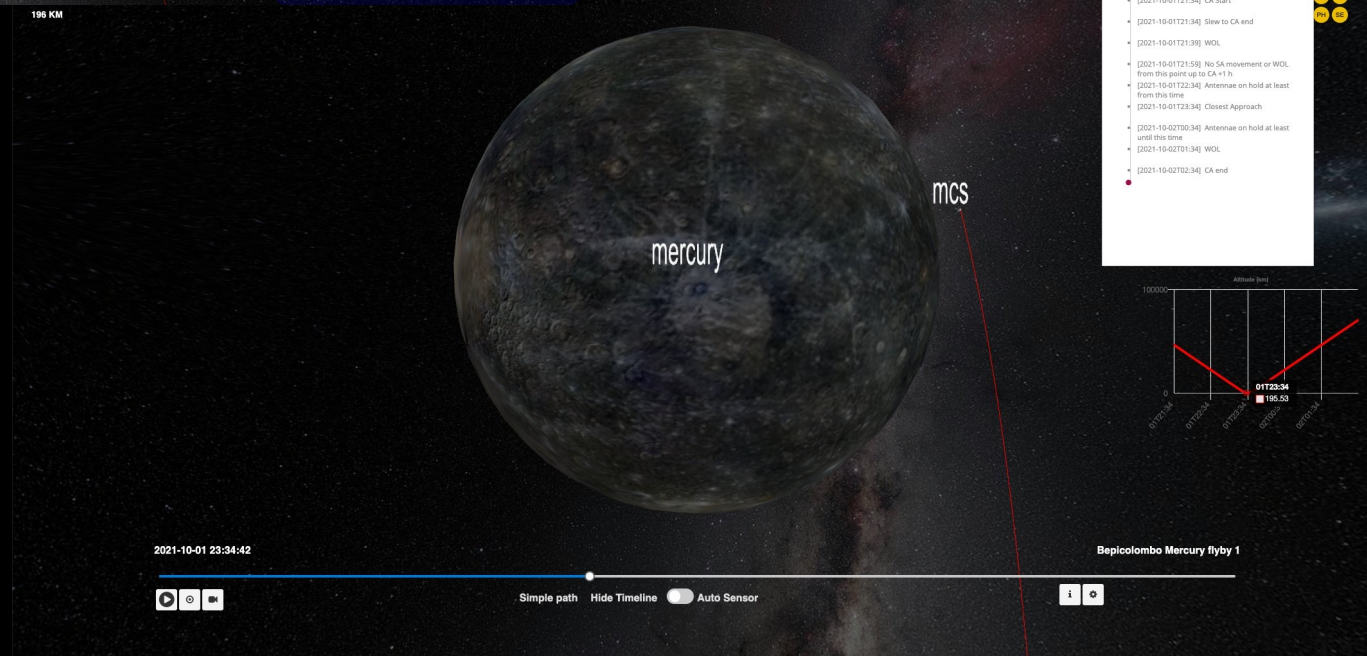
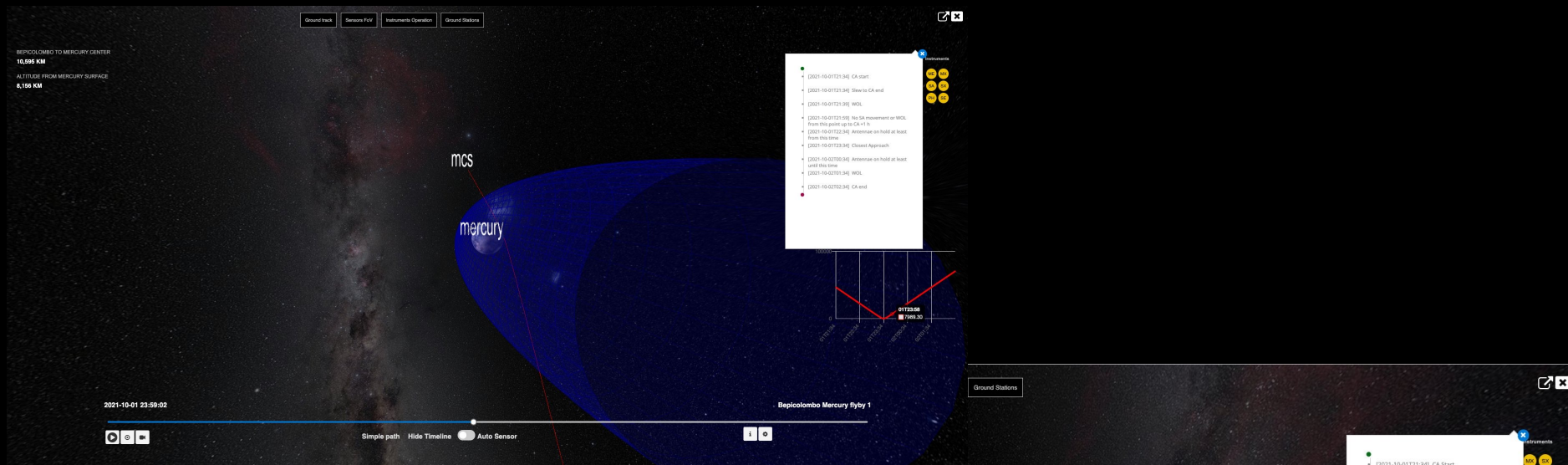
#ExploreFarther

Relative sizes and distances are not to scale

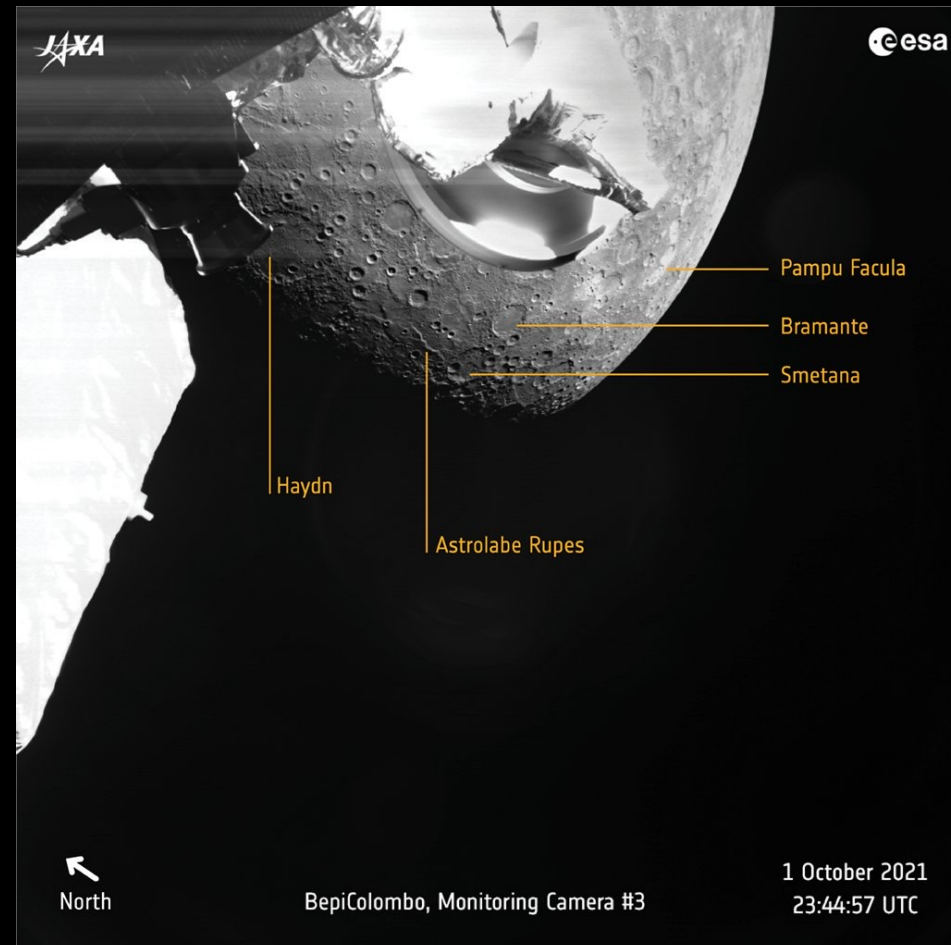
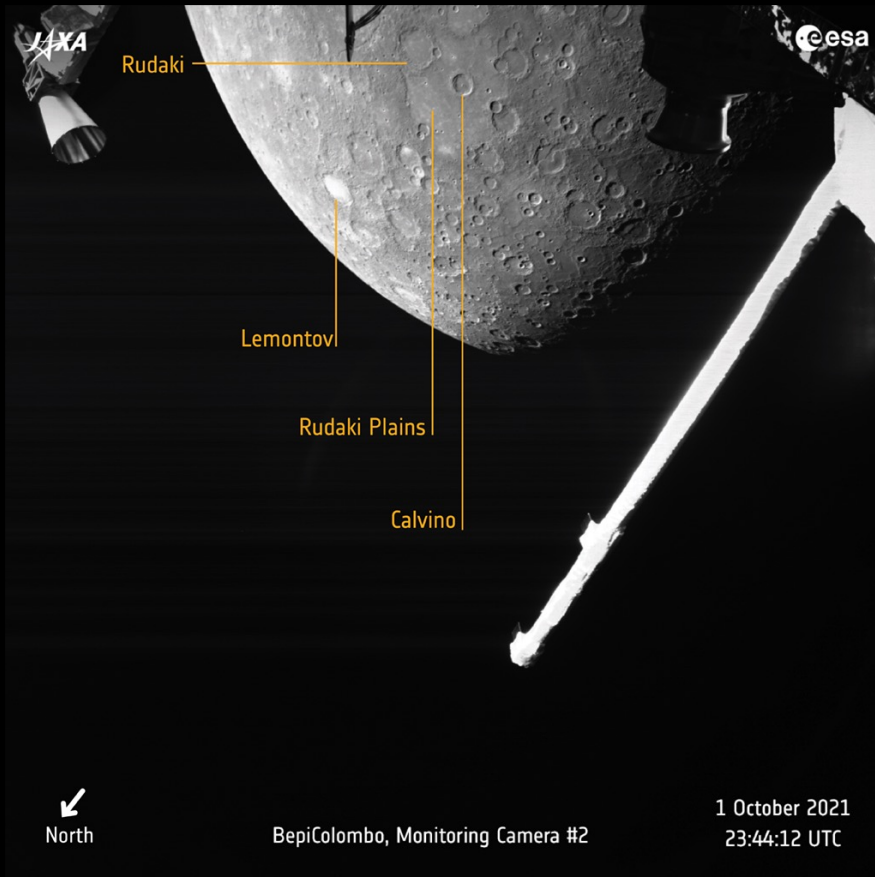




# Mercury Flyby#1: Planning the Science Operations

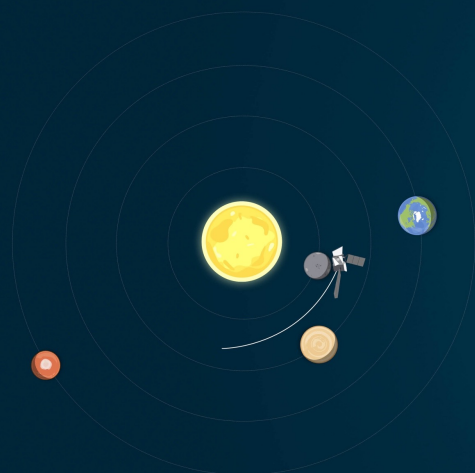


# BepiColombo Selfies and Mercury

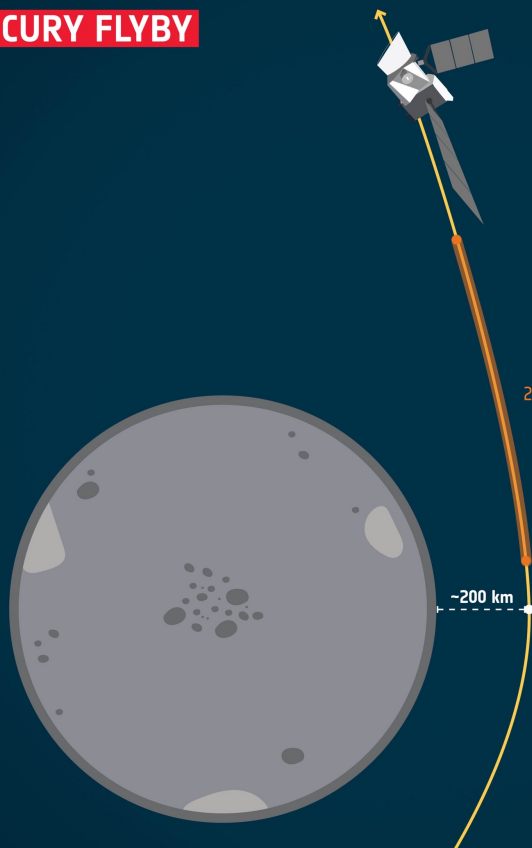


# Mercury Flyby#2: 23 June 2022

## BEPICOLOMBO'S SECOND MERCURY FLYBY



Mercury flyby  
23 June 2022



### Imaging opportunities

23 June 09:41 – 10:24 UTC

### Closest approach to Mercury

23 June 09:44 UTC  
(11:44 CEST)

### Instruments active during flyby



### BepiColombo

#### Mercury Planetary Orbiter

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

#### Mercury Transfer Module

*M-CAM 1*  
*M-CAM 2*  
*M-CAM 3*

#### Mercury Magnetospheric Orbiter

*MDM*  
*MGF*  
*MPPE*  
*MSASI*  
*PWI*

ACTIVE - NOT ACTIVE

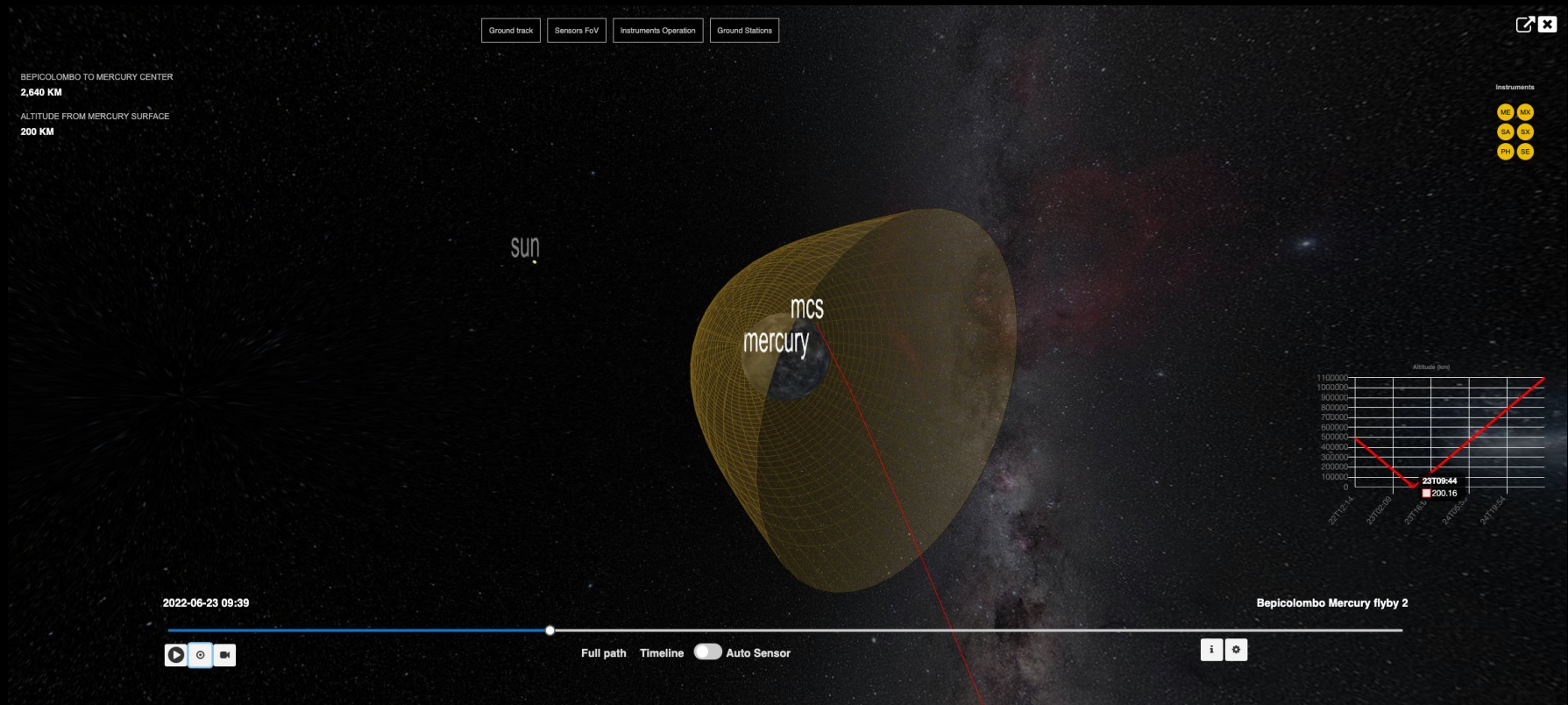
#ExploreFarther

Relative sizes and distances are not to scale

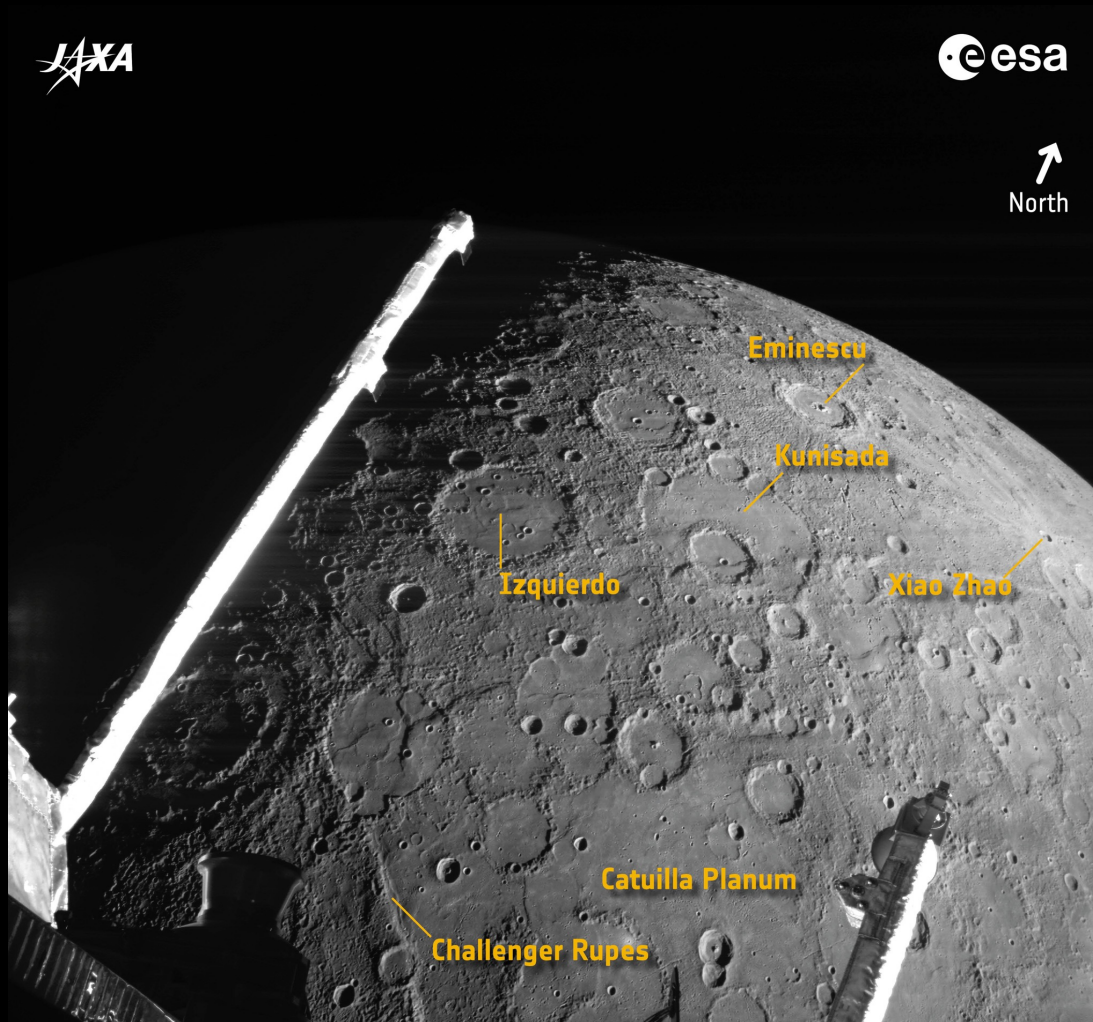




# Mercury Flyby#2: Planning the Science Operations

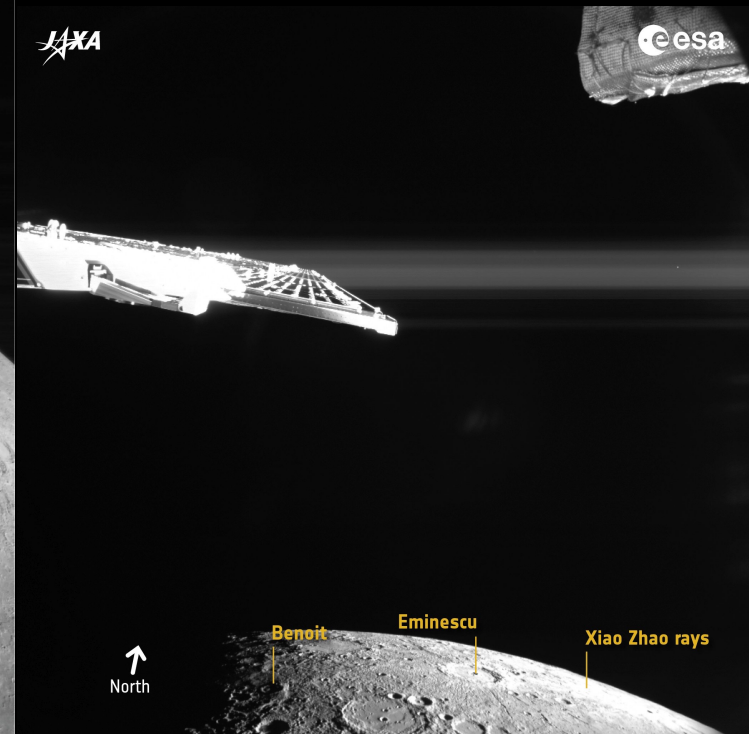


# BepiColombo Selfies and Mercury



BepiColombo, Monitoring Camera 2

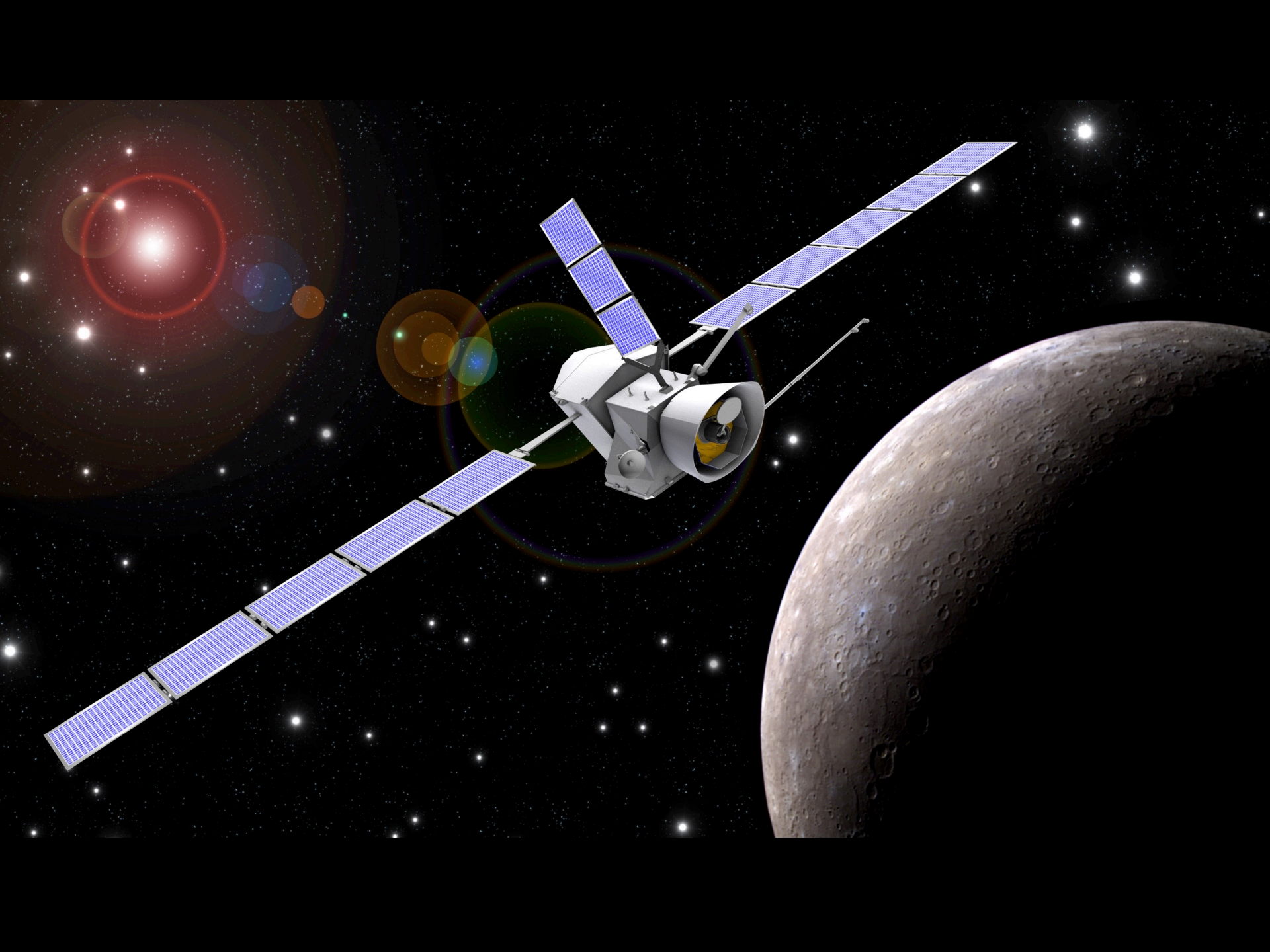
23 June 2022, 09:49:22 UTC



BepiColombo, Monitoring Camera 1

23 June 2022, 09:48:22 UTC

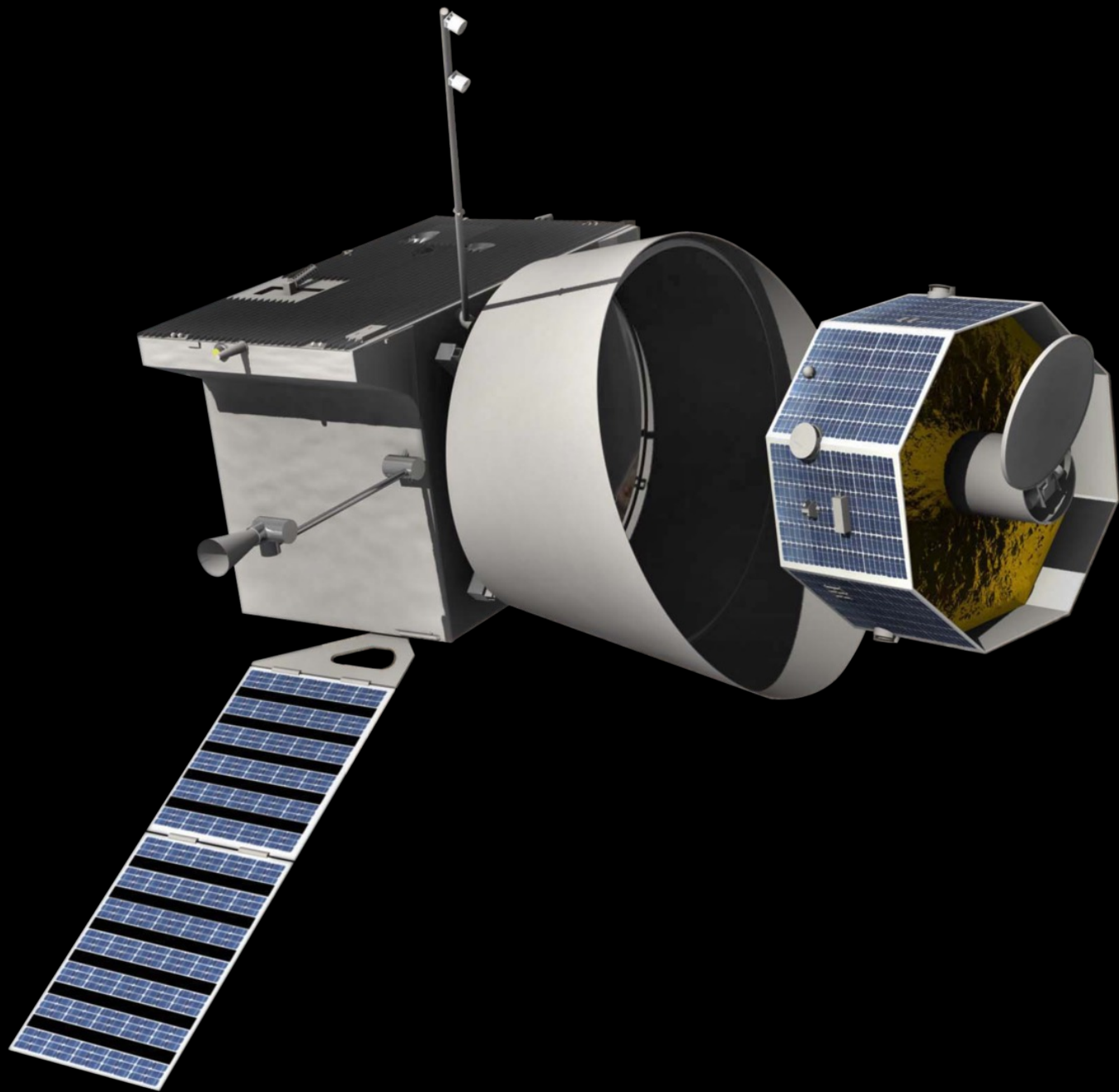




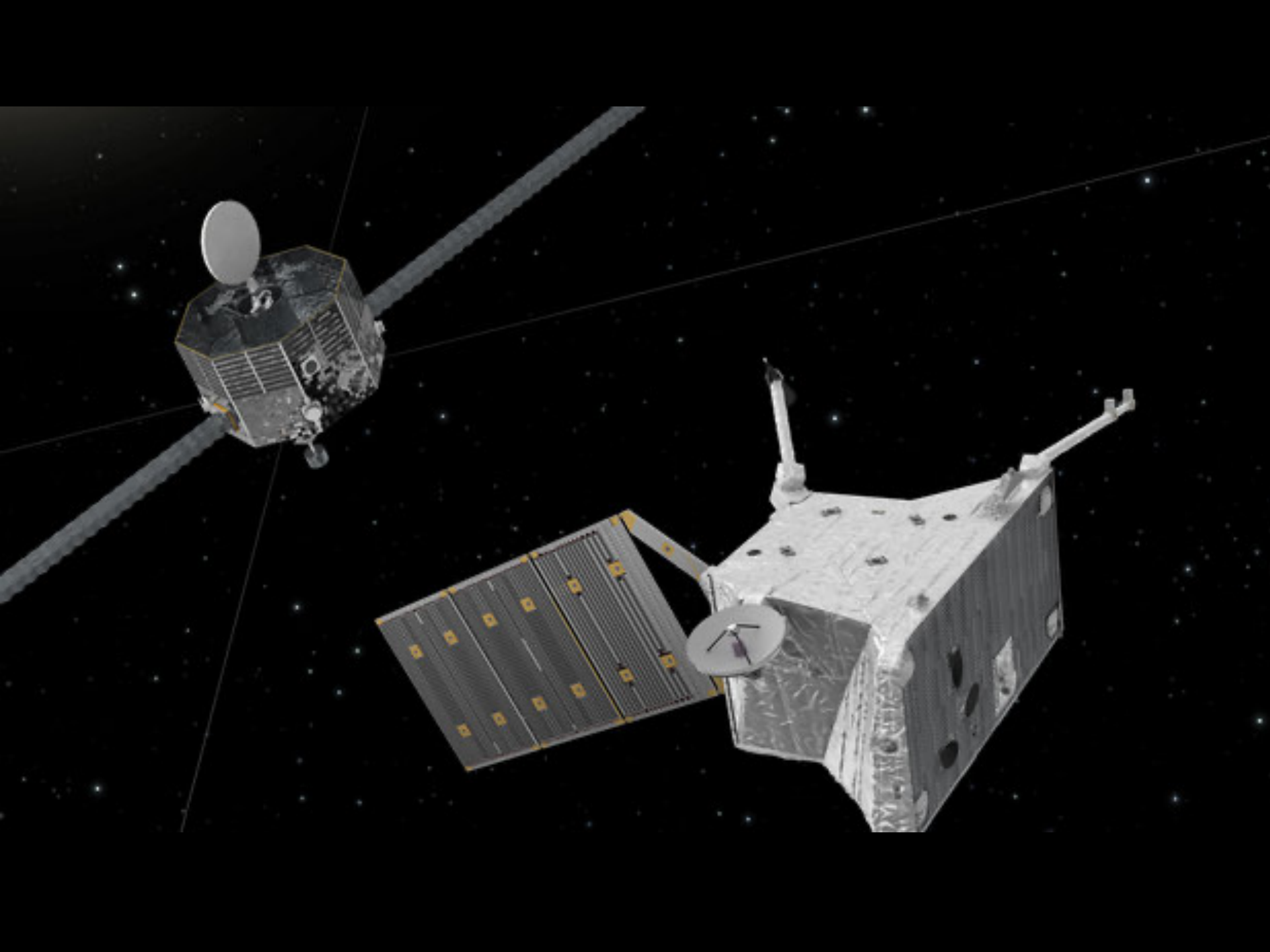


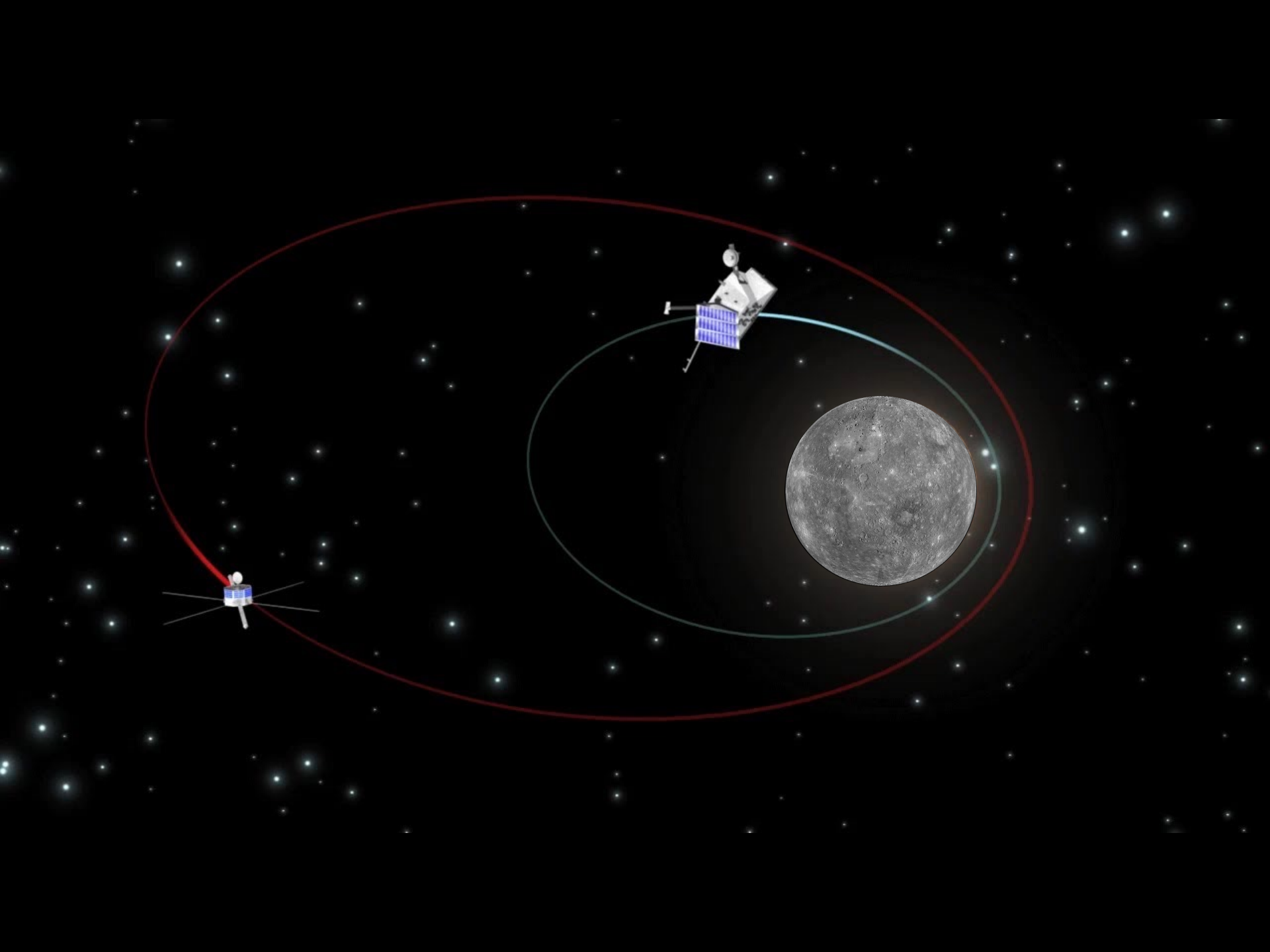


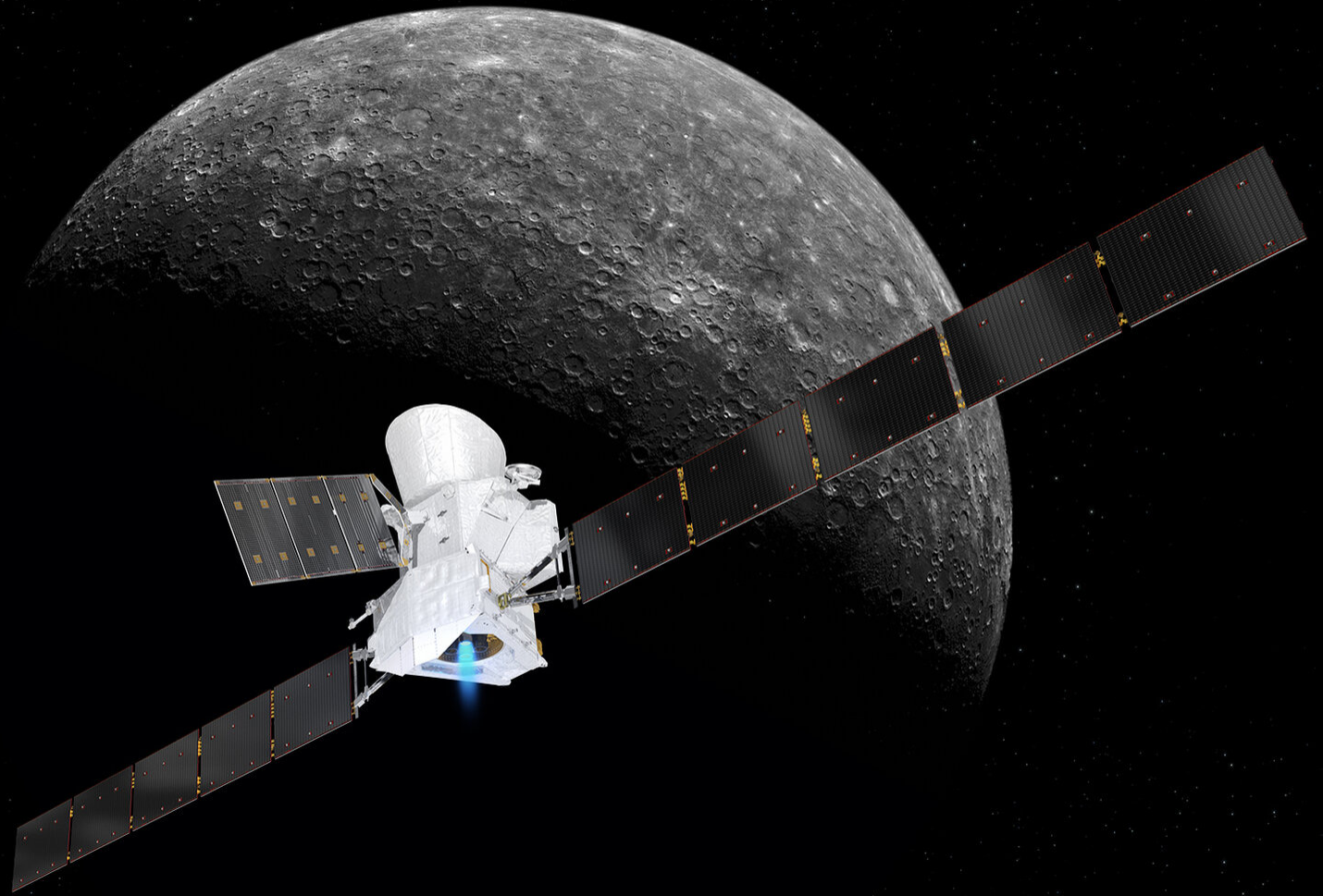








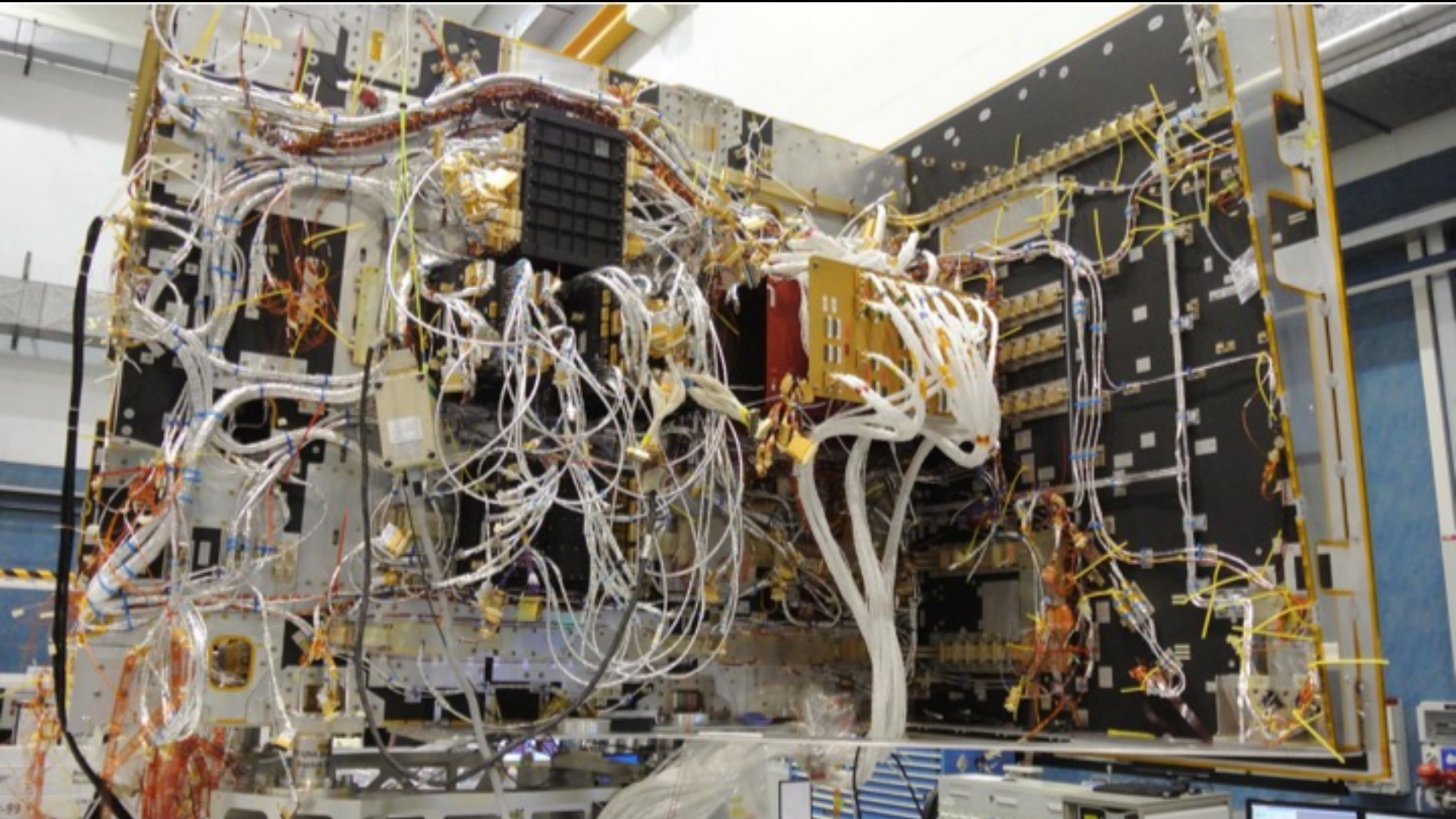




# EXTRA SLIDES



# MPO electrical Model





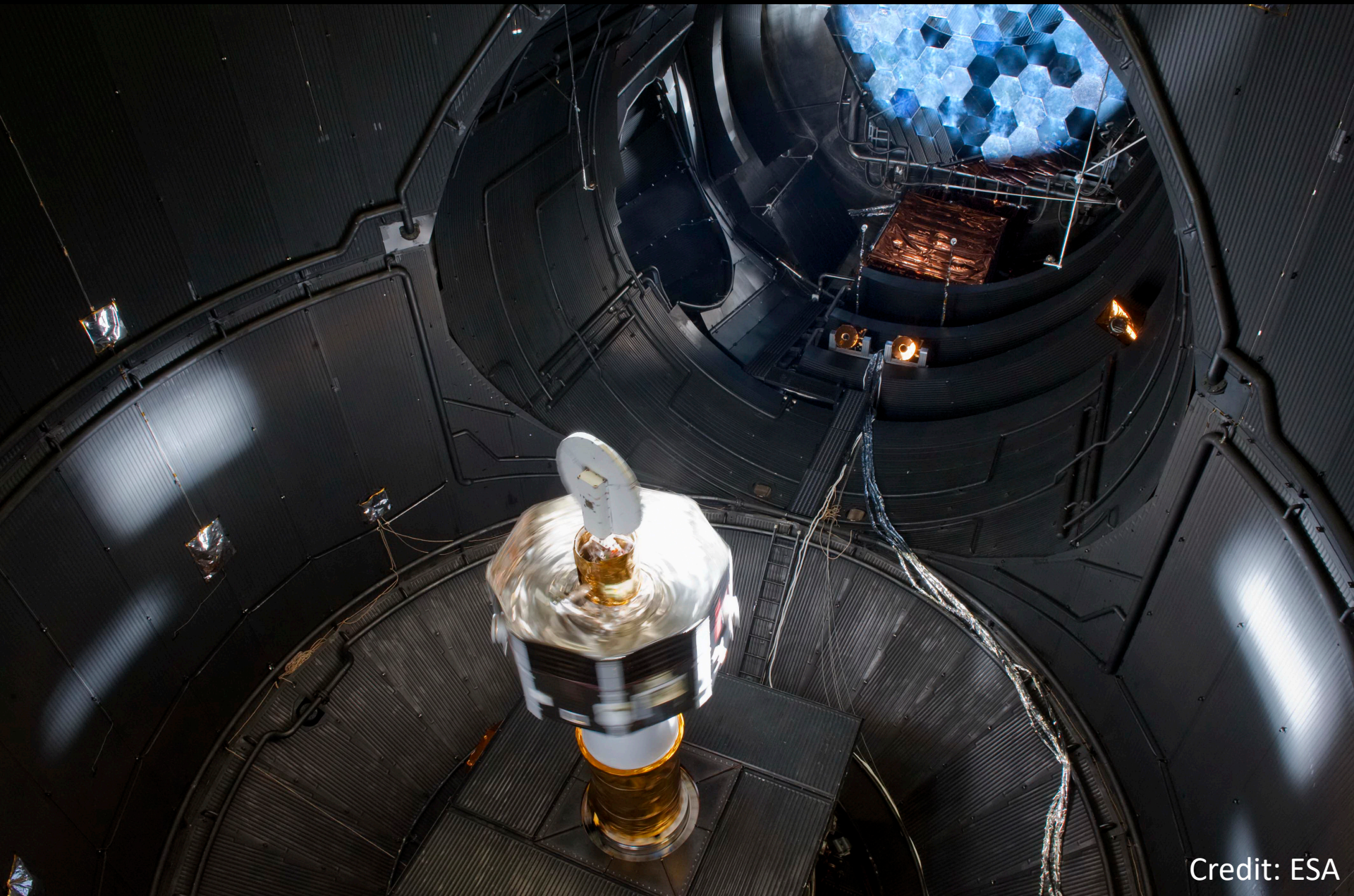
# MPO model testing



Credit: ESA



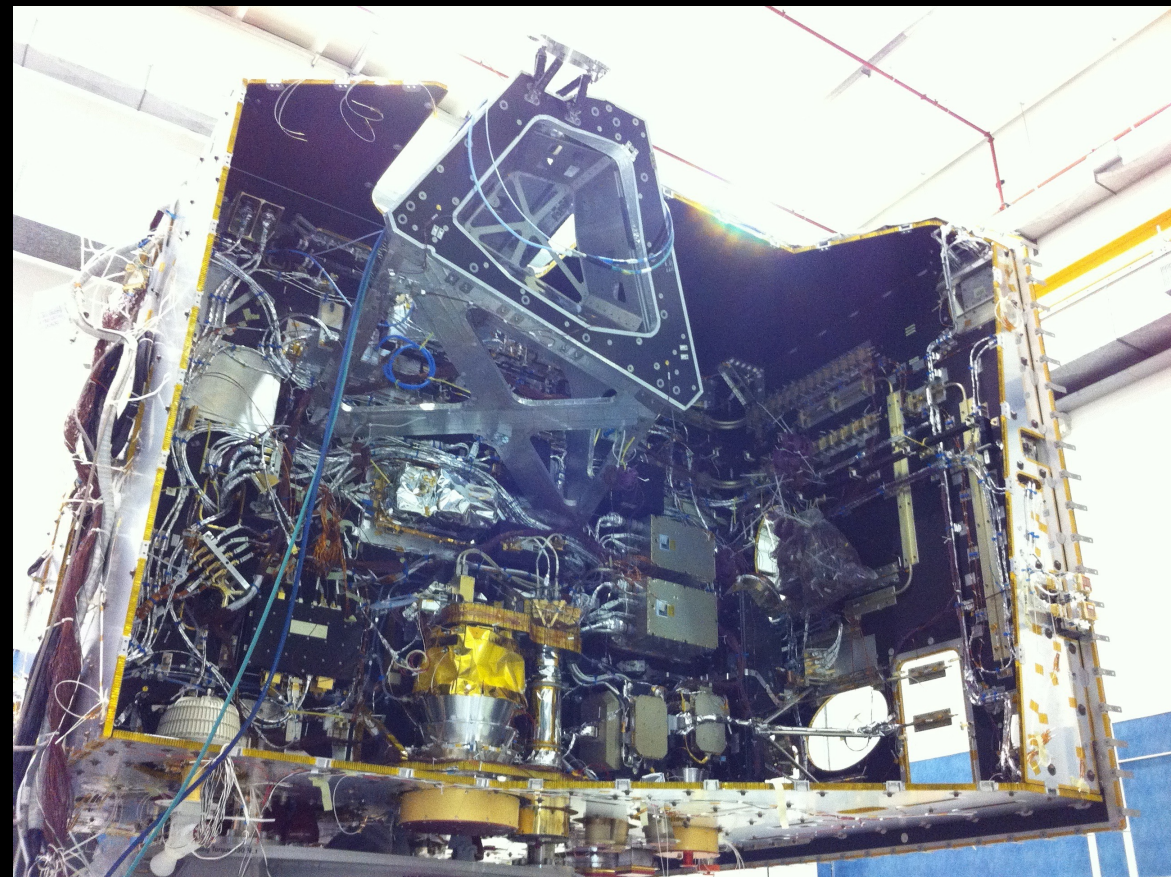
# MIO testing in Simulator



Credit: ESA



# MPO testing in TAS-I, Italy





# MPO testing in TAS-I, Italy



# MPO at ESTEC: Entering the simulator





## MPO inside simulator



# MIO testing at ESTEC testing Floor



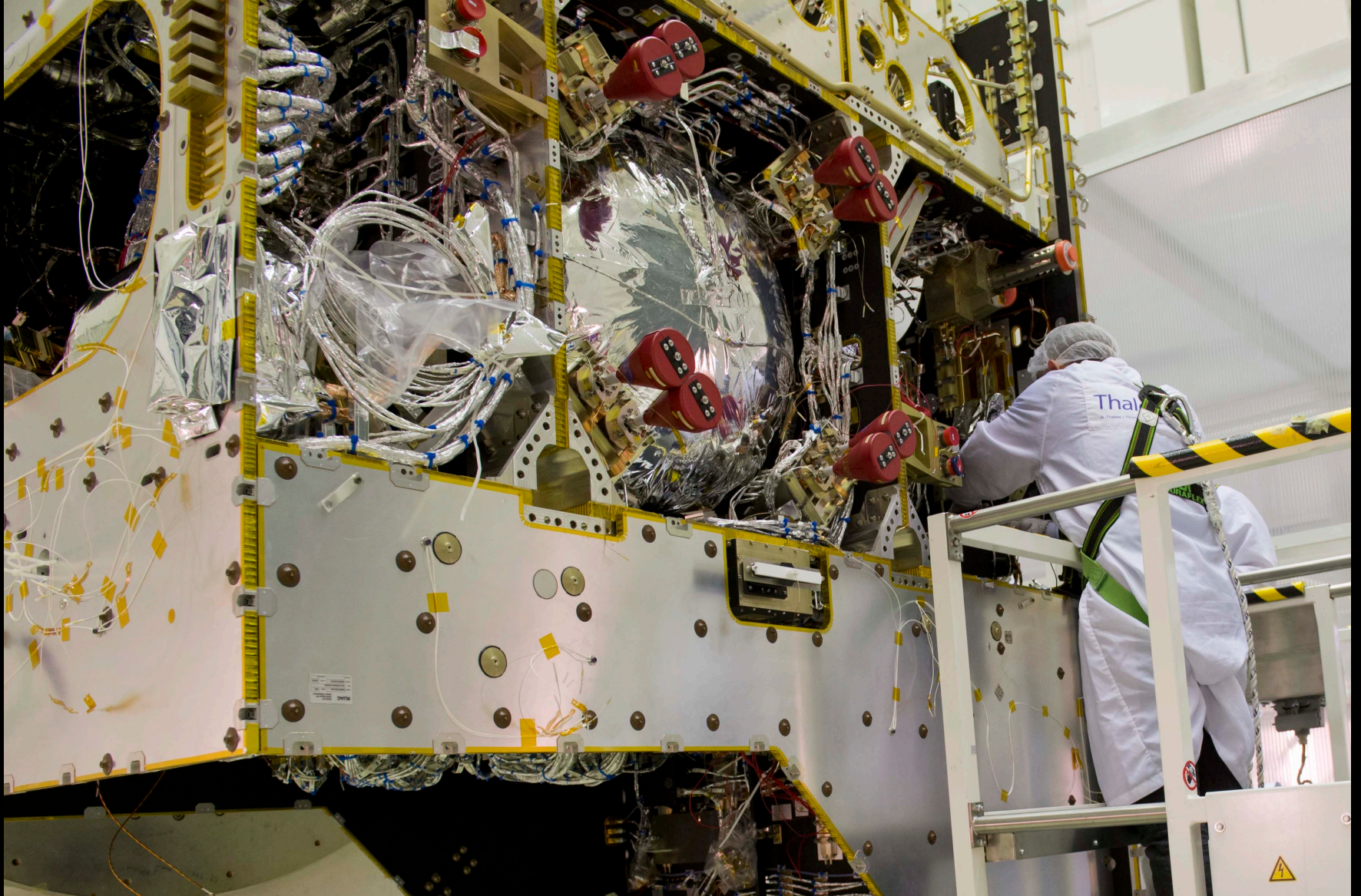


# MPO Test in ESTEC testing floor





# Wiring and parts integration





# Kourou Arrival

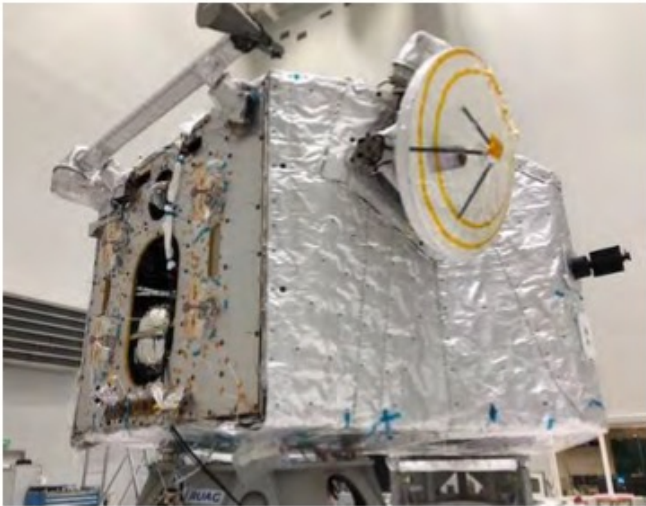


# Solar panel deployment at 0g

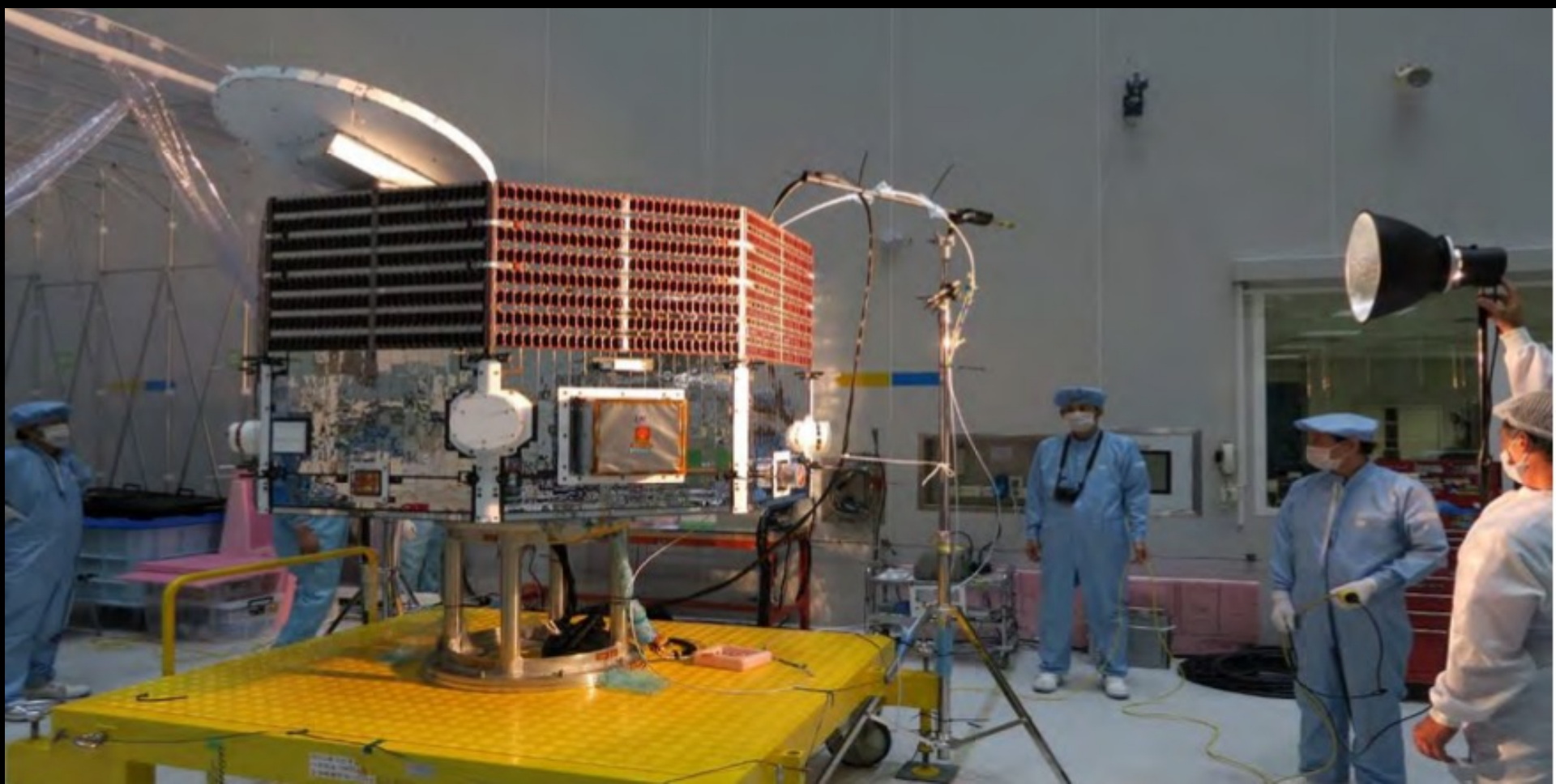




# MPO under testing



## MMO: Light test





# Arianne V Integration





# Before Launch

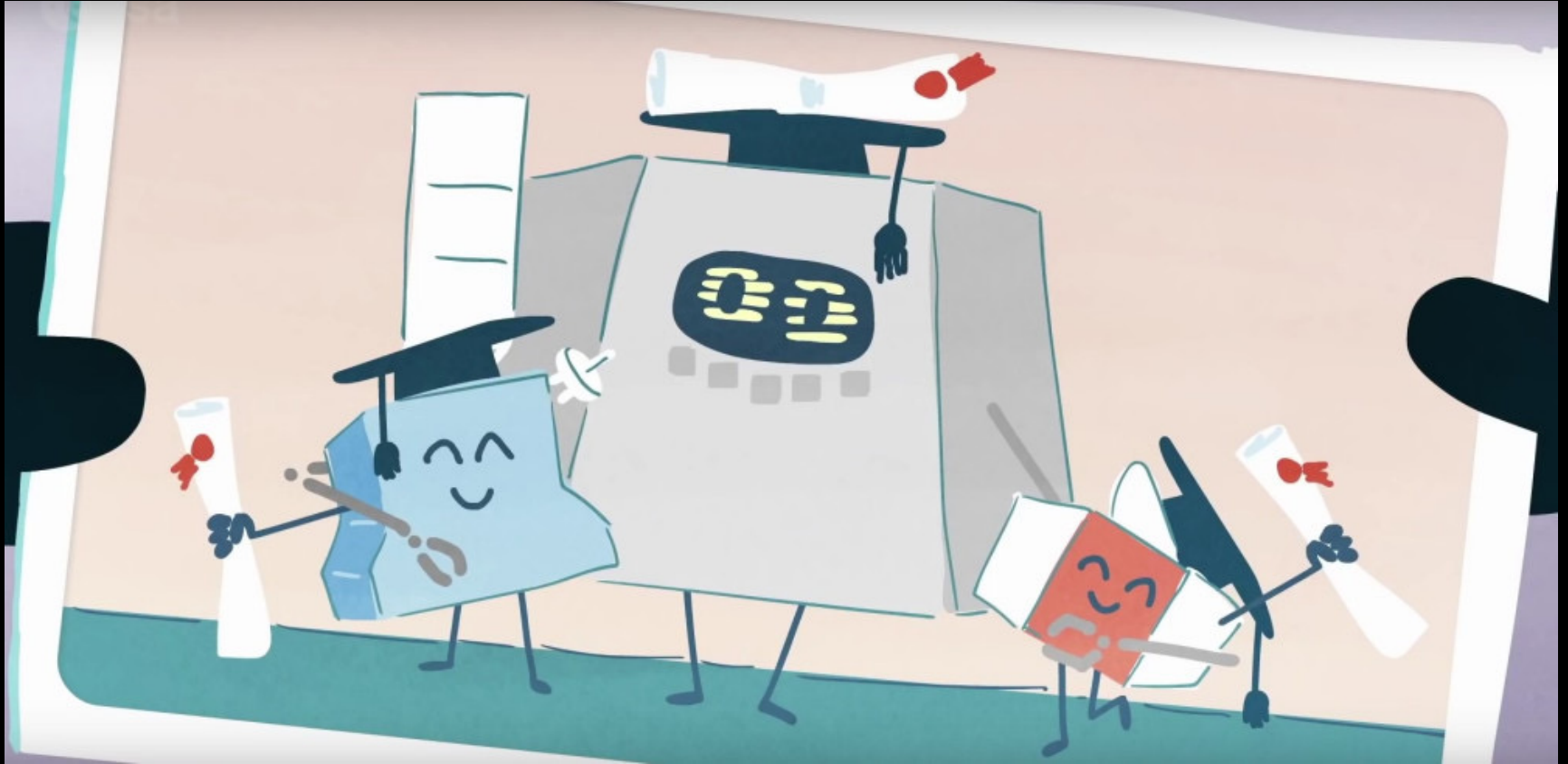


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**THANKS!!**



# The EPIC adventures of BepiColombo

