



# BepiColombo



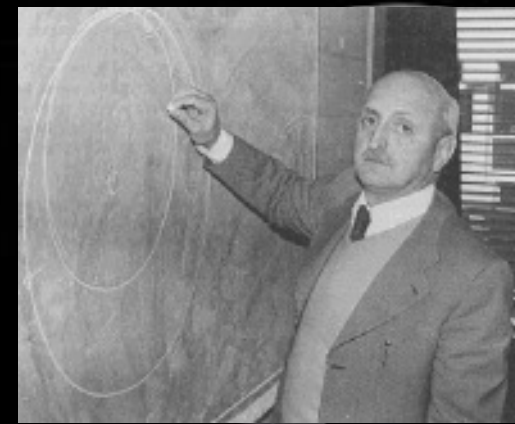
G.Cremonese, A. Milillo, F. Santoli



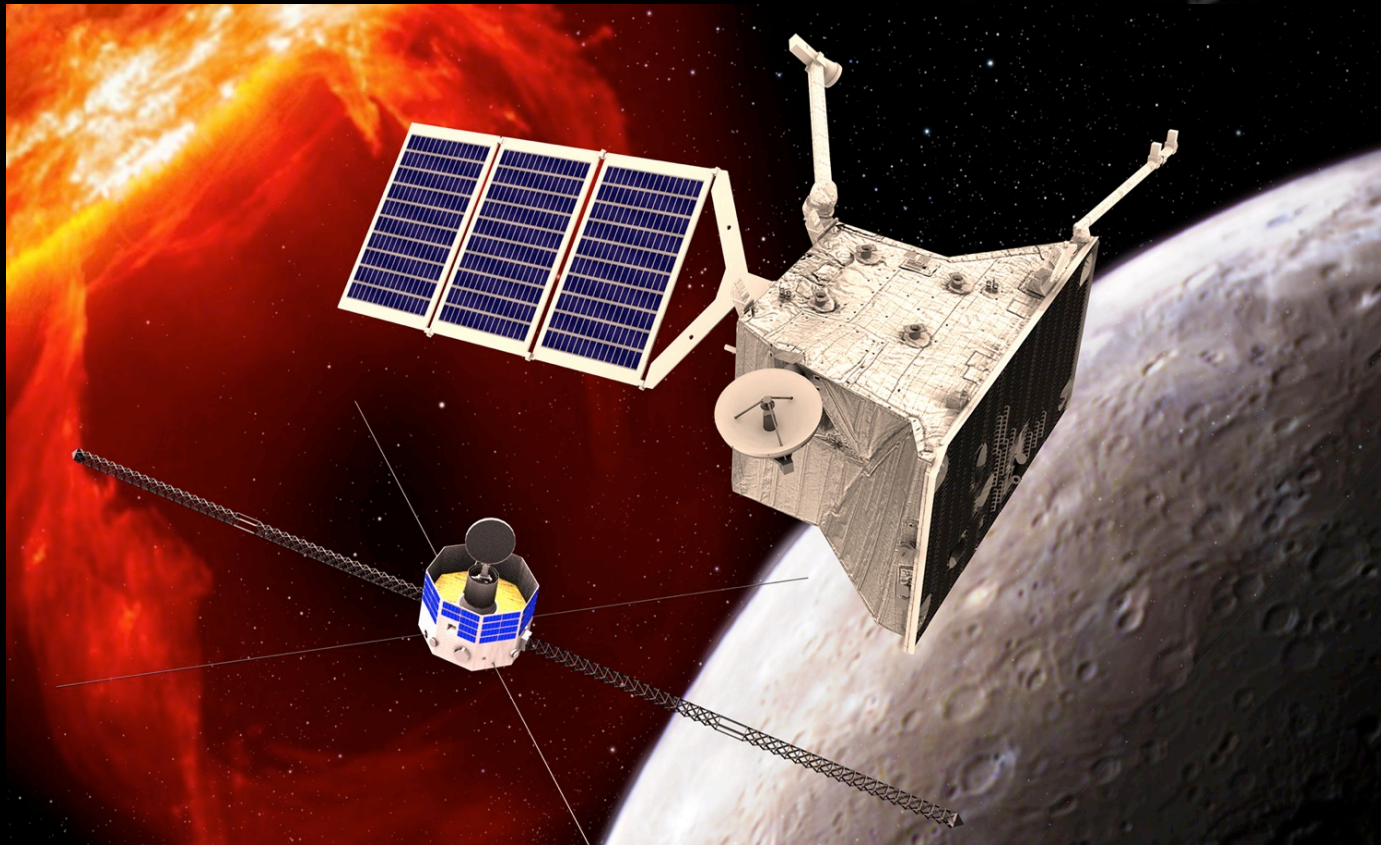
# BepiColombo

ESA Cornerstone n.5

ベピ・コロombo



*Professor Giuseppe Colombo*

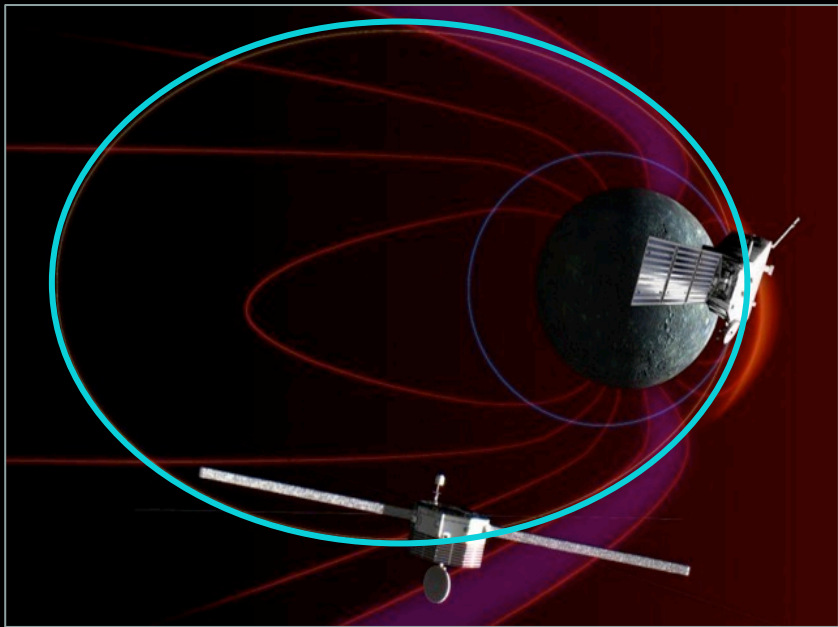


# BepiColombo

## a dual spacecraft mission

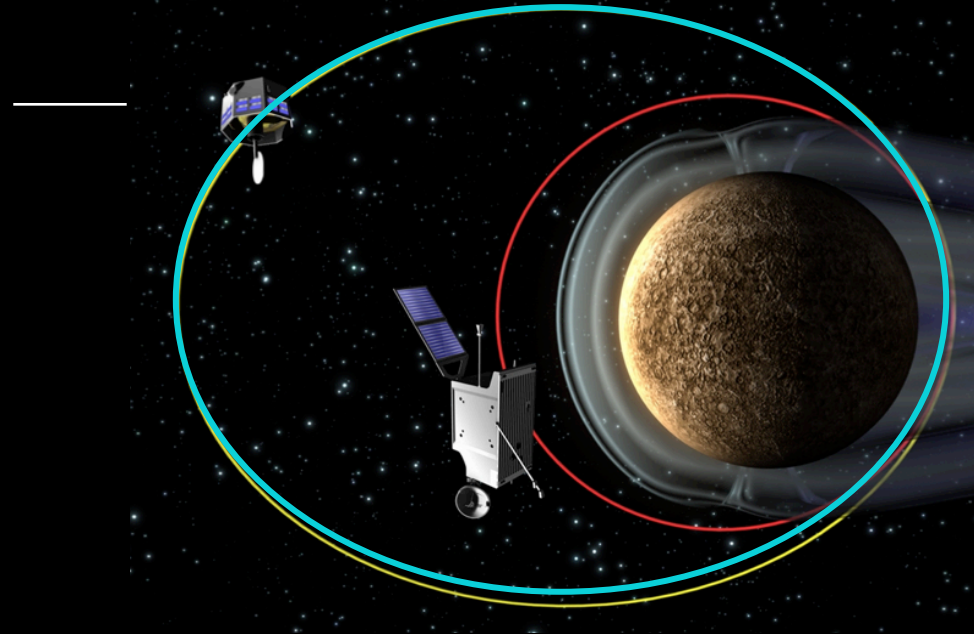
### Mercury Planetary Orbiter

- 480 km x 1500 km
- 2.36h period
- 3-axes attitude control



### Mercury Magnetospheric Orbiter

- 590 km x 11639 km
- 9.30h period
- Spin axis: N-S direction (4s period)



# Main mission phases

BepiColombo has been launched on 20 October 2018.

It will arrive to Mercury in December 2025

The nominal science phase will start in April 2026 and will last one year; possible extension up to 3 years

The cruise phase 2018-2025 is characterized by one flyby with Earth, two with Venus and 6 with Mercury, more than 9 billions km

Some instruments, as ISA, SERENA, MORE, will acquire science data during the flybys, solar conjunctions, and interplanetary cruise





# Italian contribution to BepiColombo

- Instrument PIs
  - ISA (INAF),
  - MORE (Univ.La Sapienza),
  - SERENA (INAF),
  - SIMBIO-SYS (INAF)
- UV calibration and Cols of PHEBUS (IFN-CNR, Univ.Padova, INAF)
- Col
  - MPPE (INAF)
  - MSASI (INAF)
  - SIXS (INAF)
  - PWI (Univ.Pisa)





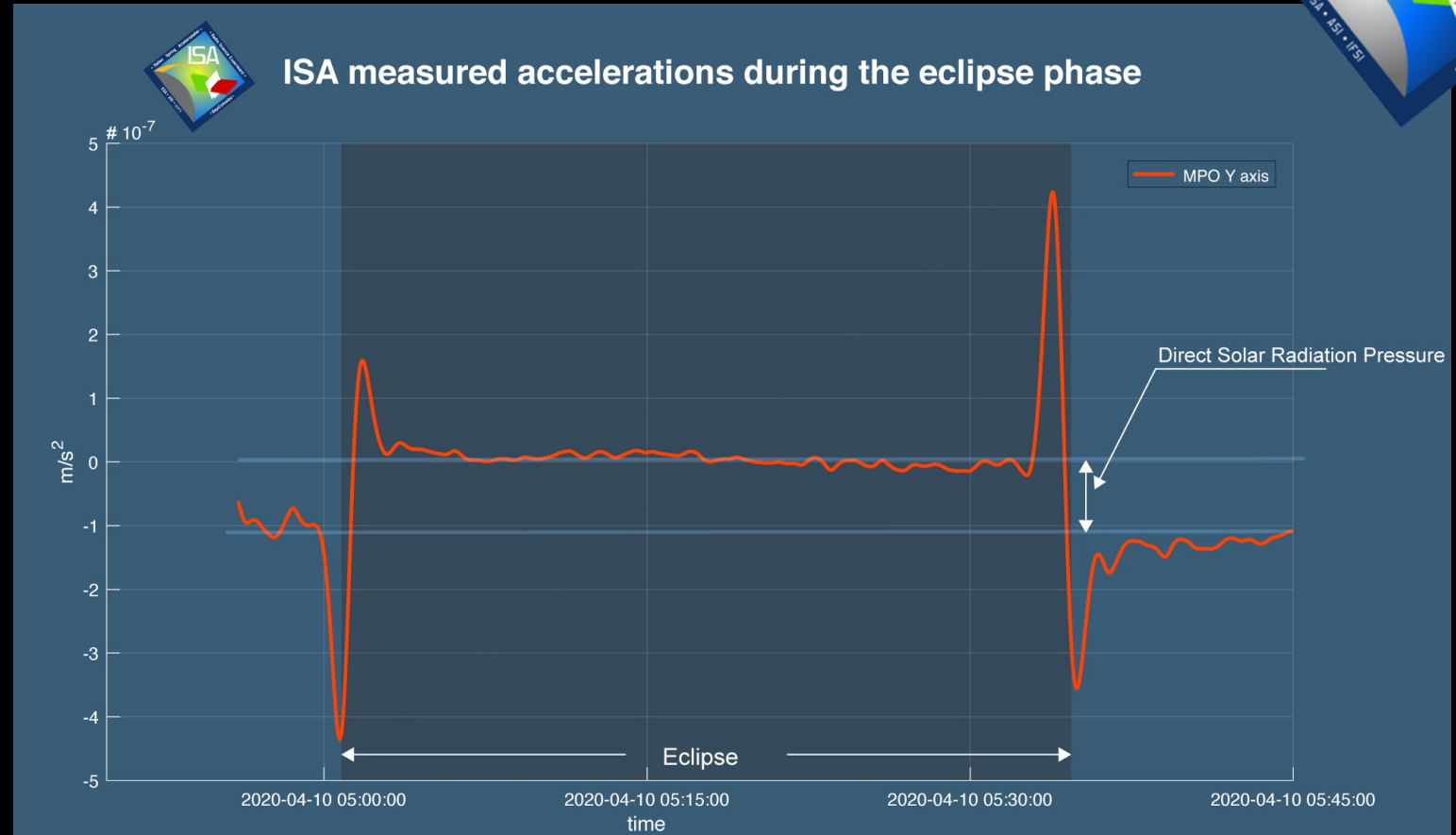
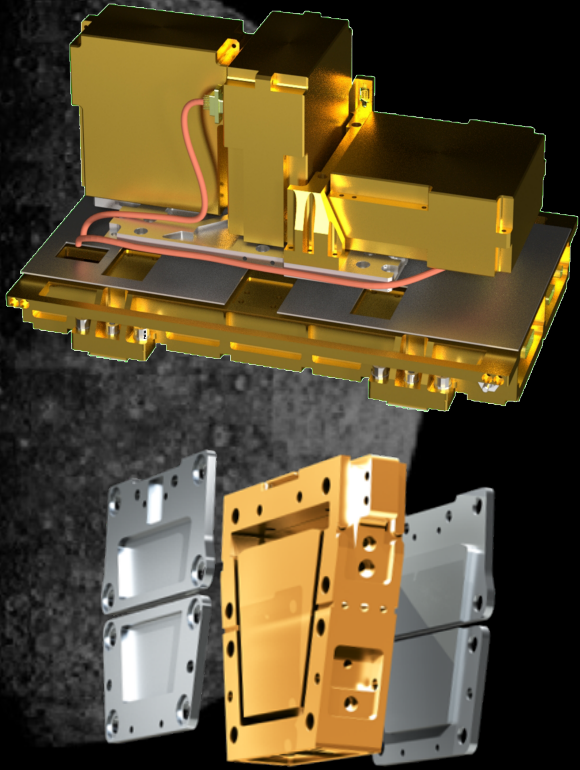
# ISA PI Team





# ISA (Italian Spring Accelerometer)

## High sensitivity accelerometer for NGPs measurement



ISA is the first high sensitivity accelerometer onboard an interplanetary mission; it will be followed by an almost identical one, named HAA, onboard the JUICE mission.



**PI:** V. Iafolla (INAF/IAPS); **Deputy PI:** F. Santoli (INAF/IAPS); **Co-Is:** E. Fiorenza (INAF/IAPS), C. Lefevre (INAF/IAPS), D. Lucchesi (INAF/IAPS), M. Lucente (INAF/IAPS), C. Magnafico (INAF/IAPS), R. Peron (INAF/IAPS)

# ISA team, leadership and management

The **ISA team is fully established @INAF-IAPS**; it is made of 14 people covering all the areas of instrument management and scientific data exploitation. Indeed, INAF staff covers the following roles:

- PI and deputy PI
- Instrument Operations Manager
- Instrument Data Handling and Archiving managers

ISA **science performance are comparable to those of the best competitors** available in the international context and, together with MORE team @UNI RM1 led by prof. L. Less, put **INAF and Italy in a leading position for Radio-Science experiments**.

ISA team activities are carried out within two management frames;

the first one, in cooperation with ASI, is mainly related to scientific investigations and instrument performance assurance; the second one, in cooperation with ESA, is focused on instrument operations management and Science Ground Segment development.



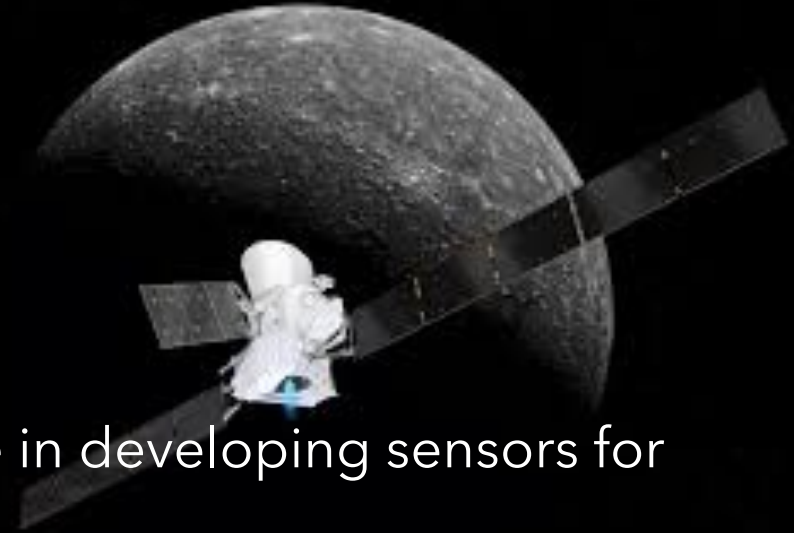


# ISA science objectives

By measuring the Non Gravitational Perturbations acting on the MPO, ISA will play a fundamental role in the execution of the Radio-Science Experiments whose main objectives are:

1. Study of the Mercury gravity field, with the aim to characterize planetary inner structure. ISA measurements will allow to consider the MPO as a drag-free test mass falling in the planetary gravity field.
2. Study of Mercury rotational state in order to investigate the physical status of its core.
3. Perform tests of General Relativity aiming to measure, with unprecedented accuracies, some PPN parameters, the Sun J2 parameter and to set an upper limit to the time variation of gravitational constant  $G$ .

# Results and competencies



Main results (up to now):

- **Instrument conceived at IAPS**, basing on previous experience in developing sensors for gravitational waves antennas.
- IAPS team performed main scientific **on-ground calibrations by developing dedicated facilities**.
- Instrument **successfully operated in flight** (near Earth commissioning and during Earth and Venus fly-bys).
- ISA **data pipeline fully functional** (scientific validation ongoing)

ISA team has developed all the competencies needed to manage a totally 'new' instrument during all the mission phases.

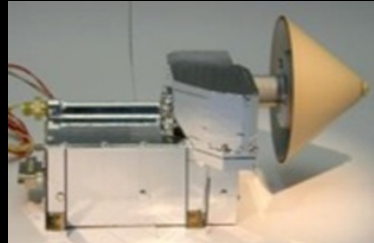




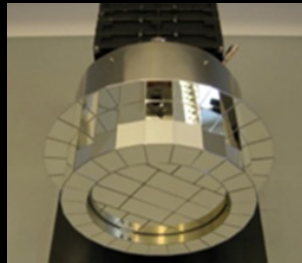
# SERENA PI Team



# SERENA (Search for Exospheric Refilling and Emitted Natural Abundances) particle detector package

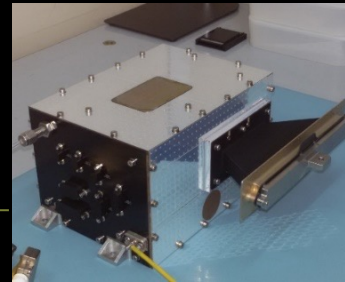


MIPA

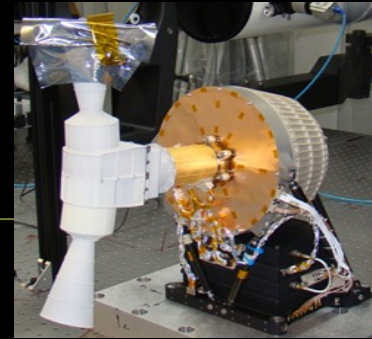


PICAM

Science observations during cruise



ELENA-SCU



STROFIO

**SCU** (System Control Unit) (OHB-I & AMDL srl), inside the ELENA box, provides power supply and organized the telemetry and telecommand flow to all the SERENA units.

All these sensors have **innovative designs**.

**PI:** S. Orsini (INAF/IAPS, Italy), **Deputy PI:** A. Milillo (Italy), **ELENA instr. sci.:** E. De Angelis (Italy), **CO-PIs:** S. Livi (SwRI, USA), S. Barabash (IRF, Svezia), H. Lichtenegger (IWF, Austria)





# SERENA team, leadership and management

The SERENA team includes about **100 scientists** and technologists from **14 countries**

INAF/IAPS (16 people involved) is the PI institute coordinating the SERENA project activities and relationship with ESA.

Currently, the main activities of **SERENA team management** include: science operations, data handling, instrument check outs and performance evaluation.

**Integrated test** with all the sensor simulators or spare models are performed in **IAPS laboratory and TV facility**.

The SERENA PI team is also involved in roles of **coordination and verification at mission level**:

- A. Milillo, Interdisciplinary Scientist since 2019 and coordinator of the Herman Environment WG since 2006.
- V. Mangano, coordinator of the Venus flybys WG and of the Ground-based observation WG.
- A. Aronica, panelist for the Mid Term Review (MTR) of the SGS activities

# SERENA science objectives

Study of whole **surface-exosphere-magnetosphere system**, as well as of the **processes** involved in this system, affected by strong **interaction with the SW and the interplanetary medium**.

- Chemical and elemental composition of the **exosphere**
- Neutral gas density profiles and asymmetries
- **Planetary ion** composition
- Planetary ion spatial and energy distribution
- **Ion precipitation rate**
- Surface emission rate and **release processes** (both neutrals and ions)
- **Particle loss rate** from Mercury's environment
- **Magnetosphere** structure and dynamics

# Results and competencies

About 46 refereed publications have been published by the PI team on the Mercury's environment subject.

Several technical documents have been delivered to ESA and ASI since the start of the project. In the ESA archive now there are 6 reports, 1 test report, 5 specification documents, 5 user manuals and 3 technical notes.

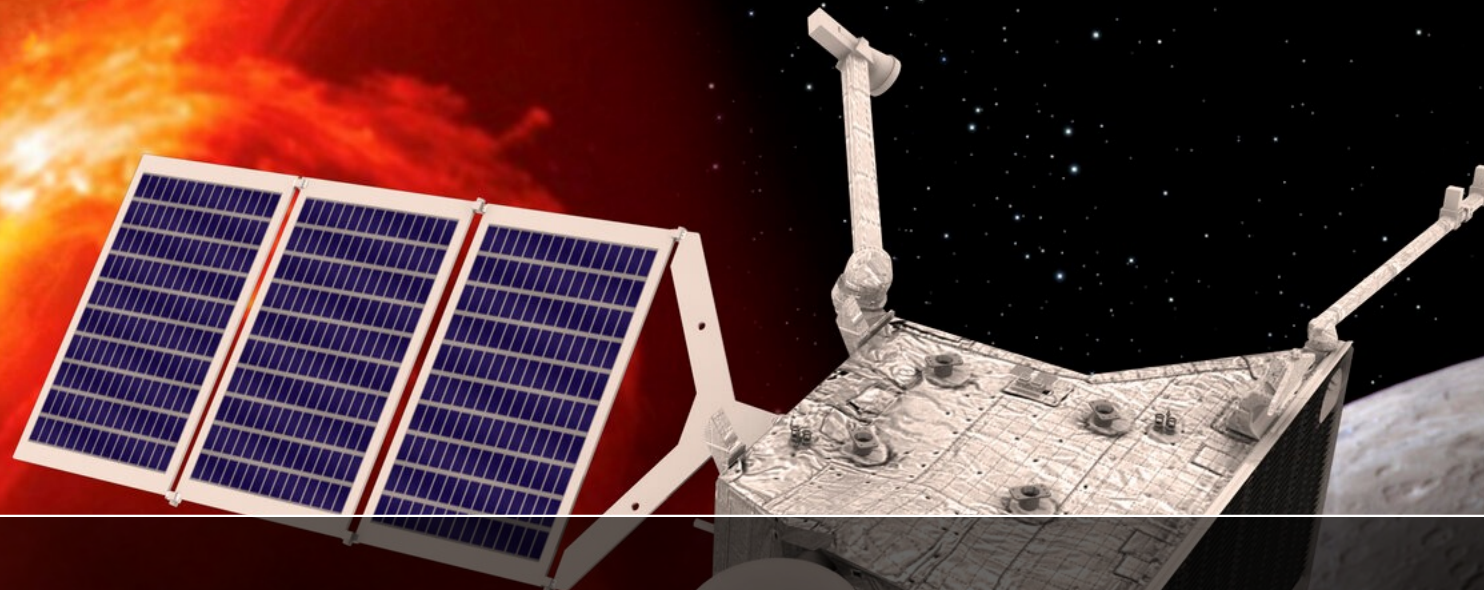
Our team has a recognized experience in planetary environment science.

Our laboratory is well suited for integrated instrument tests.

We are developing an IAPS data archiving and first analysis tool in support of the SERENA team coordinated science.







# SIMBIO-SYS PI Team



# Spectrometer and Imagers for MPO BepiColombo – Integrated Observatory SYStem



3 optical channels sharing the Main Electronics and power supply  
Mass 13 kg

## STC

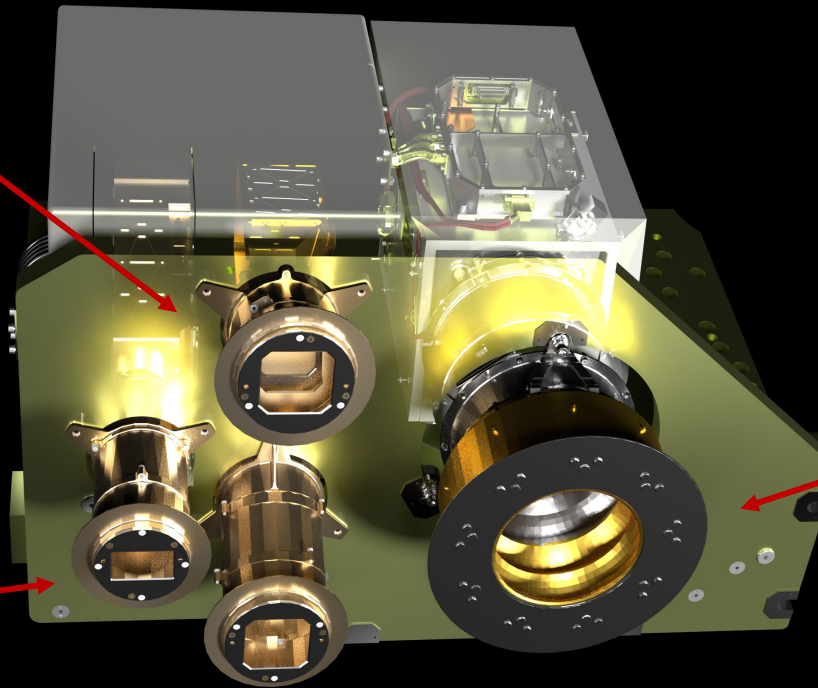
Global stereo mapping  
and DTM generation.  
Pixel scale of 60 m/pixel  
@ perihelion (480 km)  
Filters: pan, 420, 550,  
750, 920 nm.

## VIHI

Global mineralogical  
mapping.  
Pixel scale of 120 m/pixel  
@ perihelion (480 km)  
Spectral range of 0.4-2.0  
 $\mu\text{m}$  with spectral  
sampling of 6.25nm

## HRIC

Local mapping at high  
resolution with colour  
capabilities.  
Pixel scale of 6-12 m/pixel  
@ perihelion (480 km)  
Filters: pan, 550, 750, 880  
nm.





# SIMBIO-SYS team, leadership and management



**PI Gabriele Cremonese** INAF

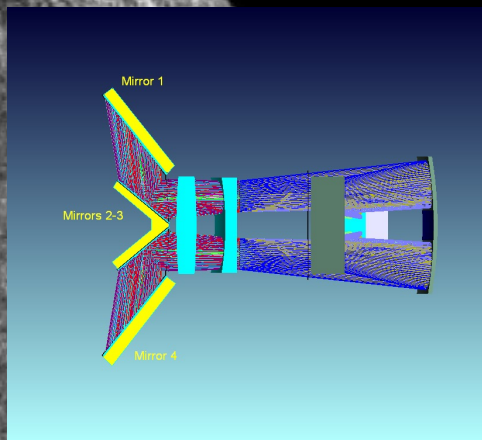
<b>Co-PI Fabrizio Capaccioni</b>	VIHI overall responsibility	INAF
<b>Co-PI Pasquale Palumbo</b>	HRIC overall responsibility	Univ.Parthenope
<b>Co-PI Maria Teresa Capria</b>	STC overall responsibility	INAF
<b>Co-PI Mathieu Vincendon</b>	Main Electronics Calibration at system level	IAS, Orsay
<b>Co-PI Alain Doressoundiram</b>	VIHI proximity electronics. IR FPA proc. and calibration	LESIA, Paris
<b>TM Stefano Debei</b>	Instrument architecture. Thermal and structural design Scientific Req. Implementation	CISAS, Univ.PD

**Industrial prime Leonardo s.p.a.**

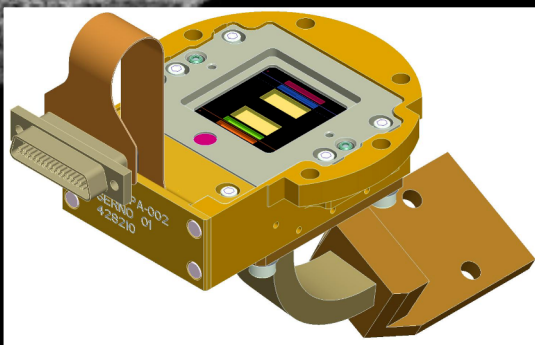
**60 Cols and 25 associates** from 12 countries (Italy, France, Belgium, China, Finland, Germany, Poland, Spain, Switzerland, Taiwan, UK, USA)



# SIMBIO-SYS, innovative technologies

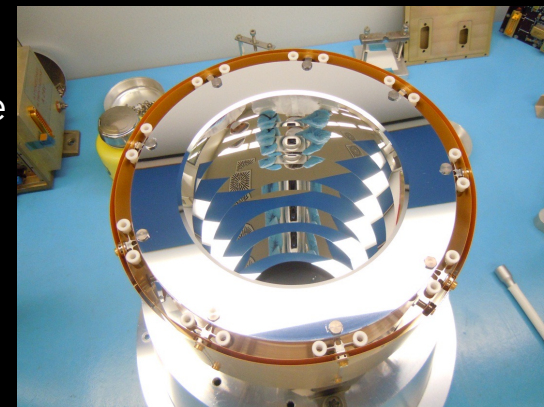


STC original optical design.  
Optical Mirrors are inseparable items of the assembly with respect to the mechanic support (Leonardo patent)



Raytheon:  
*hybrid-SiPin CMOS.*  
100% fill factor and  
peak quantum  
efficiency above  
92%

The HRIC external baffle is based on alternate reflective ellipsoids and circular hyperboloids of one sheet (Stavroudis)



The FPA of VIHI is based on the HgCdTe sensor and cover the spectral range of 400-2000 nm with one detector.



# SIMBIO-SYS scientific objectives



SIMBIO-SYS will perform the global stereo and spectroscopic mapping and will provide very high resolution images of 20% of the surface in the nominal mission.

The main topics can be summarized as follows:

- GLOBAL CONTRACTION OF THE PLANET
- COMPOSITION VARIABILITY OF THE SURFACE
- THE NATURE OF THE HOLLOWS
- ICE DEPOSITS IN THE POLAR REGIONS

50% of the data volume of the entire mission has been allocated to SIMBIO-SYS

# BepiColombo and INAF

The table reports the FTE allocated to BepiColombo in the period 2021-23

	INAF	ASSOCIATI
TI	31,5	3,7
non-TI	24,25	4
TOT	55,75	7,7





# Funding

Funding comes from ASI and ESA.



Total funding from the beginning to the end of the mission: **24,7 Meuro**

Total funding from the beginning to the end of the mission INAF: **20,5 Meuro**

Total funding up to 2020 INAF: **13,5 Meuro**

Total funding 2021-2023 INAF: **2,2 Meuro**

The industrial contracts are not included.



# Activities in the period 2021-2023



The scientific team are mostly involved in the following activities:

- Planning and management of **instrument flight operations**
- Development of the SW for **data management, validation and archiving**
- **Scientific data analyses** for cruise activities and preparation of Mercury orbit campaign.

Moreover, activities aimed at the **fine tuning of the instruments** are performed, in cooperation with the industrial partners.

In this context a dedicated experimental set-up will be installed at IAPS.

The activities will continue similarly up to 2025.



# Criticalities

More than the 50% of the data volume of the entire mission is allocated to the Italian instruments and **it will be crucial to have the manpower** to cover accordingly the following activities:

- Preparation of operations and observing strategies
- Data archiving and first analysis tools
- Maximizing the science outcome, considering the large investment of ASI, INAF and the scientific community.

We started to **train young scientists** to transmit skills on modeling and data analysis in view of the nominal mission phase and of the data interpretation; **such expertise shall be maintained for the next ten years.**





# Bep-it!

## BepiColombo Italian Outreach Group

In April 2018, the four Italian instruments' PIs agreed to create a **communication group**.

- to facilitate relationship between the 4 Italian instrument teams and media for any relevant event related to the mission (launch, flybys, etc) and its instrumentation and science.
- to promote the mission and the Italian contribution to the BepiColombo mission through interviews, seminars in schools, associations, and in public events, and through media (website, twitter, Instagram).
- to produce brochures, press-kits, press release and other material (videos, infographics, etc) useful for Bepi outreach purposes.

### Team:

Carmelo Magnafico, Valeria Mangano, Valentina Galluzzi (INAF-IAPS);  
Cristina Re (INAF-OAPD);  
Fabrizio De Marchi (Univ.Sapienza, Roma)



[www.bepicolombo.iaps.inaf.it](http://www.bepicolombo.iaps.inaf.it)



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