

Lo studio del nostro Sistema Solare nel futuro dell'INAF



Francesca Esposito e Fabrizio Capaccioni

Riunione Raggruppamento Scientifico Nazionale 3
Napoli 18-19 Ottobre 2022

DART + LiciaCube Mission

NASA mission to fly-by double asteroid Didymos and impact its satellite Dimorphos.

6U LICIACube (Science Team Lead: E. Dotto)

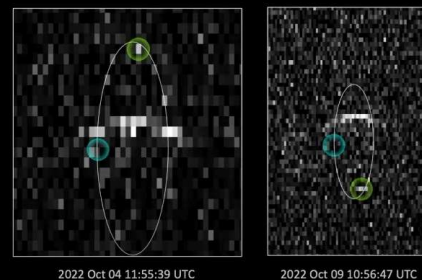
- INAF Contribution: OAR, IAPS, OAPd, OATs, OAA, OACN
- First Italian deep-space mission
- Piggyback of DART (launch Nov. 2021), released 15 days before Dimorphos impact (27/9/2022)
- 2 cameras (Pan + RGB), ~600 images acquired

Mission Success!!

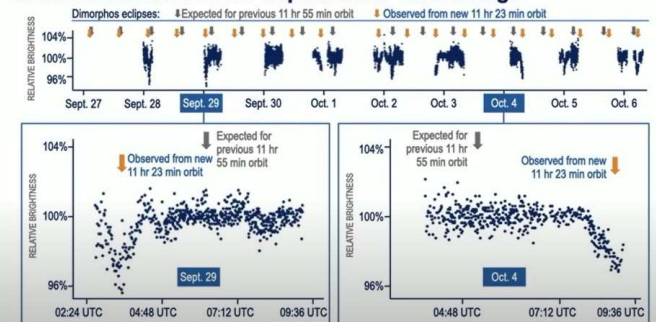
After DART impact, Didymos period has changed by 32 min.

(4 times more than expected)

Radar images detect Didymos and Dimorphos



Observations after DART impact show orbit change



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Solar System Research in INAF

NASA DART Mission and the Italian contribution LICIACube represent the *trait d'union* among the various enterprises and cultural interests of the INAF community in the Solar System research:

- Participation to Space Missions with original instruments. Increasing relevance of mini, micro, nano-sats. ASI leading role
- Technological developments of new P/L concepts to suit large and small sized spacecrafts. ASI, MUR-PON, ESA... INAF must play an important role
- Ground Observations; Support to Space Missions; complementary observations (longer timescale); large telescopes; JWST, LSST, ELT INAF must play a leading role

All of the above represent the “enabling infrastructures” to achieve the scientific advances.

- Interpretation Work (geology, spectroscopy of atmospheres and surfaces, ...)
 - Modeling (radiative transfer in atmospheres and surfaces, thermophysical models, protoplanetary Disks, solar system dynamics, etc.)
 - Laboratory Simulations
- INAF must play a leading role

Interplanetary S/Cs: Operative Missions

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Giove: Juno / JIRAM



Team: ~ 20 Staff, 3 PhD, 2 Associati

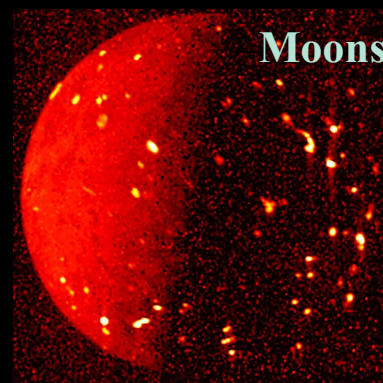
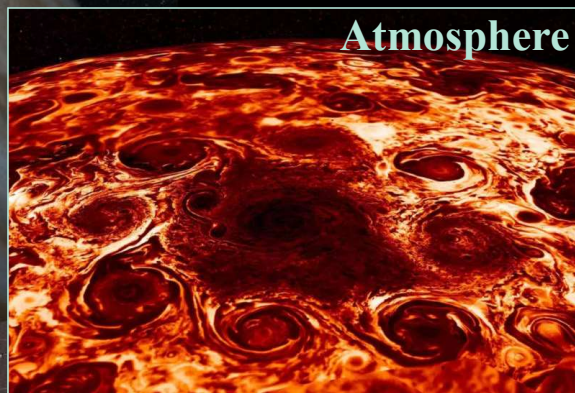
Resp. A. Mura (IAPS)

Istituti: IAPS, OaTo, CNR-ISAC

Sviluppo temporale: 2011 (Lancio)
2016 (BOL) - 2026 (EOL)

Finanziamento: ~2M INAF (+14M industria)

Fondi: ASI (+ PRIN Mainstream)

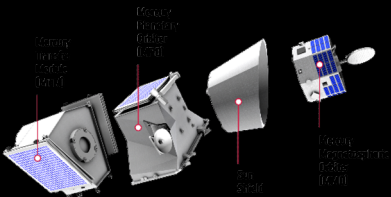


Juno: missione NASA per lo studio della formazione e l'evoluzione di Giove

JIRAM: spettrometro ad immagini nell'IR (2-5 μm)

Obiettivi di JIRAM:

- **Atmosfera:** retrieval delle abbondanze, dinamica, cicloni.
- **Satelliti di Giove:** composizione superficiale (Europa, Ganymede), vulcanismo (Io)
- **Magnetosfera:** studio della precipitazione **Aurorale** attraverso l'emissione dell' $\text{H}^+\text{3}$; studio del CH_4



BepiColombo: ESA's exploration of Mercury

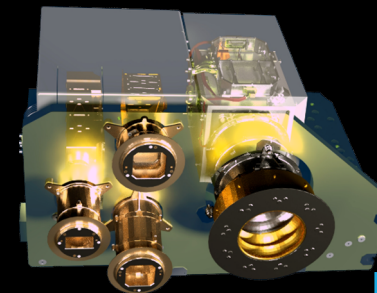
Launched 2018 – Start Mission Operations 2025

SERENA is an international experiment with Italian PI-ship, it consists of 2 neutral particle detectors (**ELENA** e **STROFIO**) and 2 ion analysers (**MIPA** e **PICAM**). Study of the interaction between Sun and Mercury



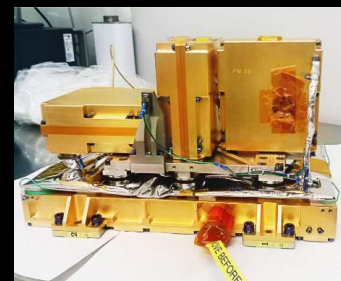
PI: Stefano Orsini (INAF/IAPS), Deputy PI: Anna Milillo (INAF/IAPS)
CO-PI: S. Livi (SwRI, S. Barabash (IRF), H. Lichtenegger (IWF)

SIMBIO-SYS is the suite of cameras (HRIC and STC) and spectrometer (VIHI) devoted to the study of the surface geology and composition.

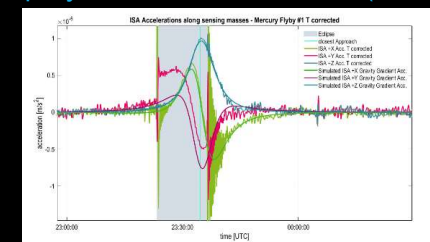


PI: Gabriele Cremonese (INAF/OaPd)
Co-Pis: Fabrizio Capaccioni (INAF/IAPS); Pasquale Palumbo (UniParthenope); A. Doressoundiram (ObPM), M. Vincendon (IAS-Orsay)

ISA is a triaxial accelerometer devoted to the measure of all the nongravitational forces acting on the S/C. Will support the General relativity Test.



PI: Valerio Iafolla (IAPS-INAF)
Deputy PI: Francesco Santoli (IAPS-INAF)



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Interplanetary S/Cs: Missions in Preparation

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JUICE: JUpter ICy moons Explorer

ESA's first L mission of Cosmic Vision program devoted to the study of Jupiter (Atmosphere, Magnetosphere, rings, etc.) and of his icy satellites with major emphasis on those potentially capable of hosting biological activities: Ganymede and Europa.

Launch **April 2023** with arrival at **Jupiter in 2031**, **end of mission 2035**

The payload consists of **11 instruments**, from *in situ* measurements of Jupiter's atmosphere and plasma environment, to remote observations of the surface and interior of the three icy moons.

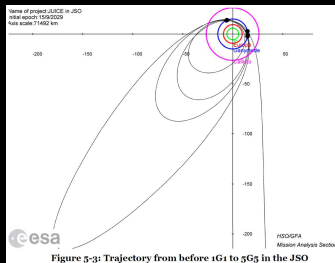
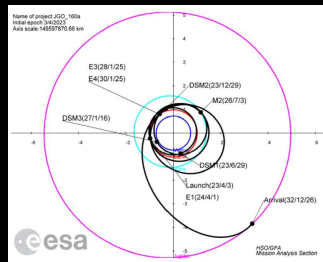


Figure 5-3: Trajectory from before 1G4 to 3G5 in the JSO

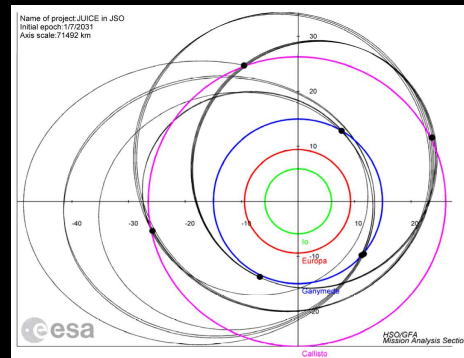
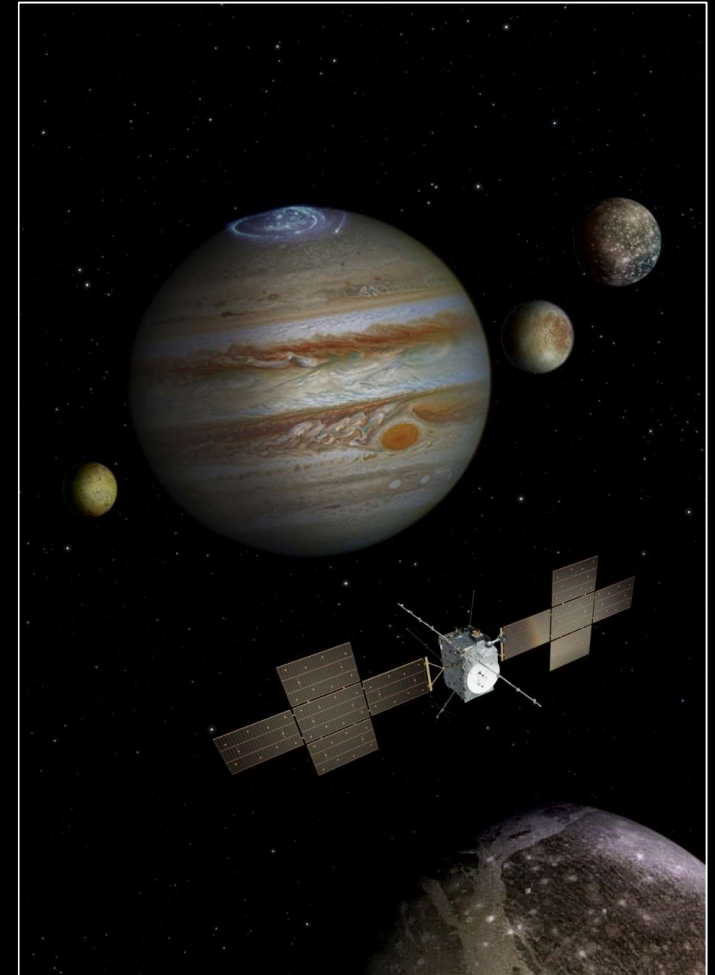


Figure 8-1: Trajectory from 18C10 to 24G10 in the JSO



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JUICE Payload

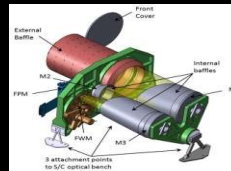
Major INAF contribution

JANUS: Visible Camera System

PI: Pasquale Palumbo, Parthenope University, Italy.

Co-PI: Thomas Roatsch, DLR, Germany

- ≥ 7.5 m/pixel
- Multiband imaging, 380 - 1080 nm
- Icy moon geology
- Io activity monitoring and other moons observations
- Jovian atmosphere dynamics

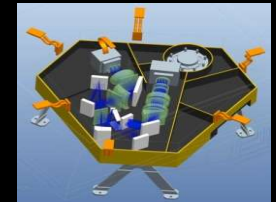


MAJIS: VIS-NIR Imaging spectrometer

PI: Francois Poulet, IAS, France

Co-PI: Giuseppe Piccioni, INAF, Italy

- 0.5-2.35 and 2.25-5.54 μm
- ≥ 25 m/pixel
- Surface composition
- Jovian atmosphere



RIME: Ice Penetrating Radar

PI: Lorenzo Bruzzone, Trento, Italy

Co-PI: Jeff Plaut, JPL, USA

- 9 MHz
- Penetration ~ 9 km
- Vertical resolution 50 m
- Subsurface investigations



3GM: Gravity, Geophysics, Galilean Moons

PI: Luciano Iess, Rome, Italy

Co-PI: Y. Kaspi, Weizmann Institute of Science, Israel

David J. Stevenson, CalTech, USA

- Ranging by radio tracking
- $2 \mu\text{m/s}$ range rate
- 20 cm range accuracy
- Gravity fields and tidal deformation



Budget for Science from ASI (to the 4 italian led instruments). New Contract under discussion: 3.5years 3.8Meuro

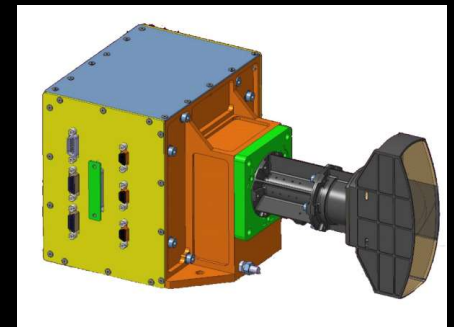
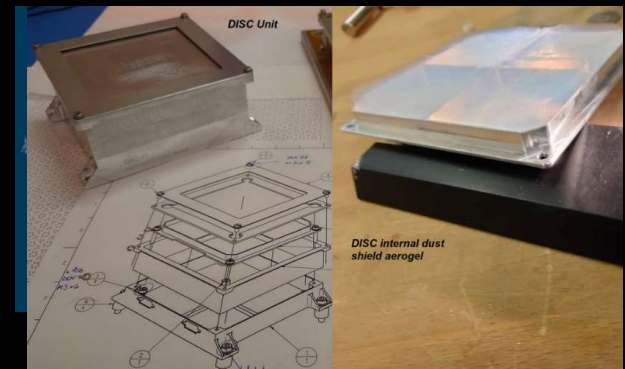
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ESA's **Comet Interceptor** mission

Visting a pristine comet



- The comet will contain material not undergone processing since the dawn of the Sun and planets
- First ESA F Class Mission; To be launched Piggyback with ARIEL in 2029; waiting in L2 until a new comet enters the Solar System.
- 1 mothership (S/C A ESA) + 2 sub-S/C (S/C B1 jaxa e S/C B2 ESA)
- Italian responsibilities:
 - **DISC (Dust Impact Sensor and Counter) 2 units on S/C A and S/C B2 (PI V. Della Corte INAF-IAPS)**
 - **EnVisS (Entire Visible Sky) on S/C B2 wide field camera for coma studies a (PI Vania Da Deppo CNR)**



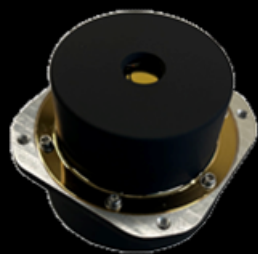
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VISTA (Volatiles In-Situ Thermogravimeter Analyser)

PI E. Palomba IAPS-INAF



- Application of Quartz Crystal Microbalances to the study of the molecular contamination in space.
- ESA's HERA-Milani (Launch 2024); evaluate DART impact effect on Didymos
- CNSA TIANWEN-2 (Launch 2025) to rendez-vous and sample asteroid 2016H03 and fly-by 311P/Panstarr comet
- VISTA (aim to detect the presence of dust particles smaller than 5-10 μm ; the volatiles (e.g., water) and light organics characterization (e.g., carboxylic acids with low carbon chain) and to monitor the contamination processed in support to other instruments.



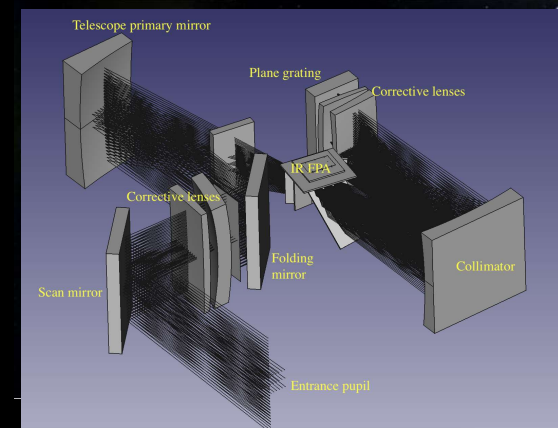
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MIST-A for Emirates Asteroids Mission

PI G. Filacchione – IAPS/INAF

- Mission to main belt asteroids (**launch 2026, 6 asteroids flybys in 2030-2033**, arrival at **target asteroid in 2033** with landing); UAE Space Agency in collaboration with University of Colorado - LASP
- Scientific objectives: Understand the origins and evolution of water-rich primitive asteroids.
- Space resources objectives: Assess the resource potential of asteroids
- MIST-A (**Mwir Imaging Spectrometer for Target-Asteroids**) is the re-flight model of the JIRAM instrument (2-5 μm spectral range) on Juno; selected in October 2022.
- Will detect: **Mg-phylosilicates**, **NH₄-phylosilicates**, **Ca-carbonates** and **Organic matter**.



Small Missions

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ABCS - AstroBio-CubeSat

PI: John R. Brucato

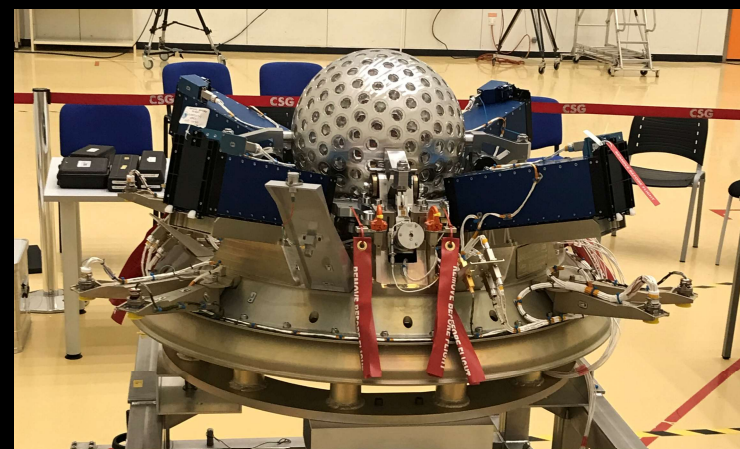


ABCS is 3U cubesat which was launched 13th July 2022 by Vega-C maiden qualification flight as secondary payload of the LARES 2 satellite at 5857 km altitude and 70° inclination within the internal Van Allen belt.

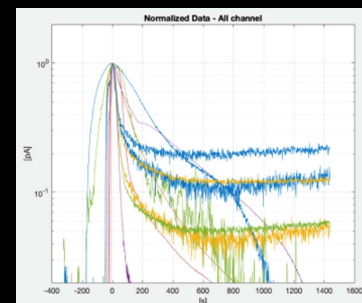
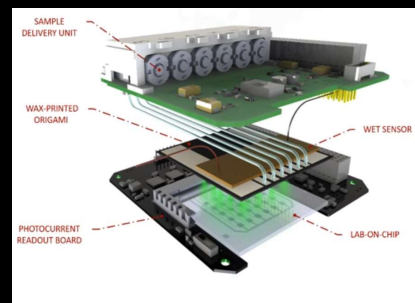
ABCS hosted a miniaturized laboratory based on Lab-on-Chip technology providing a platform to search for signs of life in planetary exploration missions through an automatic bioanalytical experiment

For the first time, 6 quantitative **chemiluminescence-based** experiments **were successfully executed in space**.

Liquid reagents were used in space to solubilize and transport the organic molecules, and trigger **chemiluminescent reactions** detected by a matrix of silicon-based photosensors.



Chemiluminescence signals

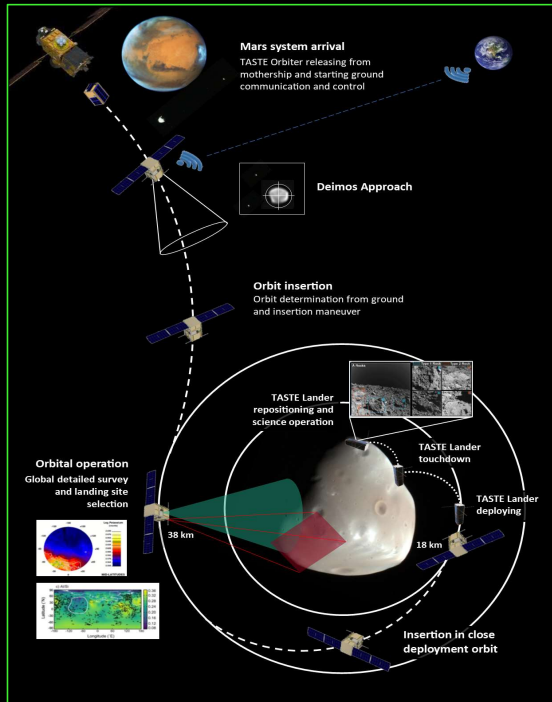


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ASI ALCOR Program

TASTE - Terrain Analyser and Sample Taster Explorer

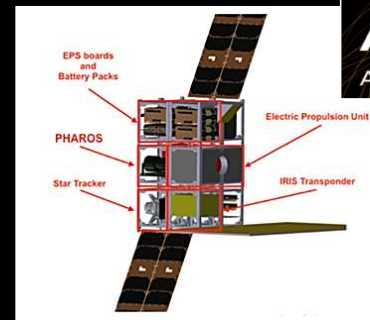


(PI: J.R. Brucato
OAA/INAF)
Deimos Martian Moon studies:

- global morphology and composition from a close orbit
- local surface elemental, organic and mineralogic composition with a lander

- Miniaturised Sampling System
- Image based navigation
- Cubesat in Cubesat (Orbiter+lander)

Objective is to guarantee Italy a leadership in the nano-satellites segment. Call issued in 2021; Selected 20 mission out of 49. Funding from ASI and GSTP (General Support Technology Program) ESA



(PI: D. Perna – OAR-INAF)

Science objectives plus planetary protection:

Fly-by of 2 potentially hazardous asteroids + rendez-vous with NEA (at 50m for cohesive forces analysis)

Launch date >2026

Autonomous propulsion; interplanetary trajectory

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Technological Developments

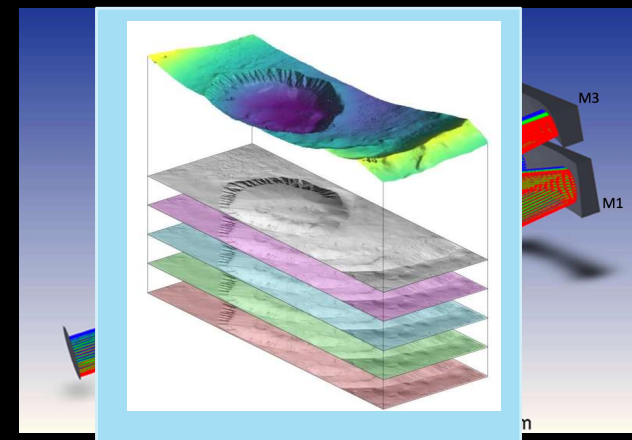
These are activities that aim at developing enabling technologies to increase the competitiveness of INAF researcher in proposing new instrumentations for the Solar System studies.

RSN3 or RSN5?

HYPSONS (HYPerspectral Stereo Observing System) – PI G. Cremonese OaPd-INAF

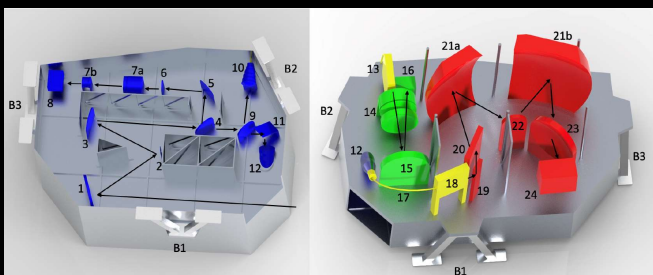
UniPd, CISAS, EIE, CNR, UniChie, UniCa, Parthenope

- Funded by ASI “Attività di Studio Sole, Sistema Solare ed Esopianeti”
- Pushbroom stereocamera coupled to a grating spectrometer; same detector and optical path.
- Compact instrument, compatible with small satellite applications,
- Planetary exploration and terrestrial environmental monitoring.
- 4D information of each resolved element of the observed surface.



fISPEX Integral field Imager and Spectrometer for Planetary Exploration –

PI G. Filacchione IAPS-INAF – PoliMi, OAR, IFAC-CNR, Leonardo Co., Parthenope



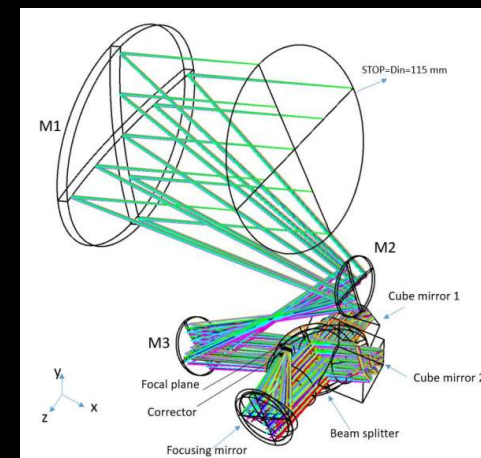
- Highly innovative; Single front-optics feed light to a camera and imaging spectrometer
- The Camera uses a Liquid Crystal Tuneable Filter (LCFT)
- The integral field imaging spectrometer obtains the hyperspectral cube) through a Coded-Mask Optical Reformatter (CMOR) of custom-design (4000 fibers bundle.)

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RIIFS (Rugged Imaging Infrared Fourier Spectrometer) – PI G. Bellucci IAPS-INAF

UniPd, CISAS, EIE, CNR, UniChie, UniCa, Parthenope

- Compact Fourier Spectrometer for the 2-50 μ m spectral range with imaging capabilities
- Heritage MEX/PFS, ExoMars/MIMA
- Less than 3kg including telescope (FS 750g)



TRIS Optical Fibers for IR Spectrometer Applications PI M.C. De Sanctis IAPS-INAF



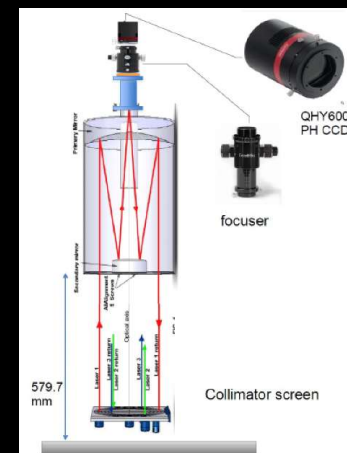
- Built on the experience gained with Ma_MISS, the imaging spectrometer integrated in the ExoMars Drill.
- Will improve on the concept of Miniaturised Modular spectrometer in the IR based on fibers
- Objective to extend the spectral range to 4 μ m for in-situ applications
- Technical challenges: Fiber optics, illumination sources

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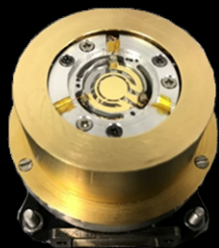
DORA (Deployable Optics for Remote sensing Applications)

PI F. Capaccioni IAPS-INAF Polimi, OaPD-INAF, SITAEI, Parthenope, KAD3,

- MUR-PON 2014-2020 Funding; Partnership Private/Institutional
- Design, realisation and test of a prototype of a deployable optical system
- Project based on terrestrial applications using a non-imaging spectrometer
- Tests performed using a CCD camera to verify the optical performances for future imaging applications.



Quartz Crystal Microbalances PI E. Palomba IAPS-INAF



- Several Projects funded by ESA and ASI
- Molecular Contamination Monitoring in Space and Vacuum Chambers (CAM and CAMLAB)
- Dust Detection, Volatiles in-situ analyzer (VISTA)
- Applications: HERA – Milani mission, Tianwen-2 CNSA Mission

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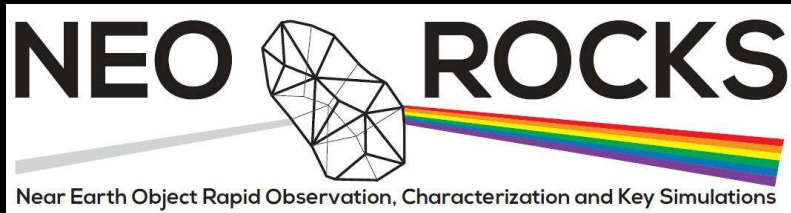
Ground Observations

- Complementary to Space Missions
- Guarantee a longer timescale to observe dynamical processes
- Selection and characterisation of Space mission targets
- Planetary protection

>> In the next years plenty of large telescopes from Ground and Space

- **Leverage of Solar System research in planning timelines?**
- **And the role of INAF?**

Asteroids, Comets and TNO



Horizon 2020 project; 2.1Meuro funds; Leadership OAR-INAF;
14 partners in 7 countries

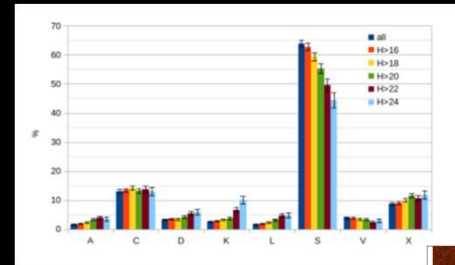
Follow-up studies of physical and dynamical properties of NEO

Database development and international coordination

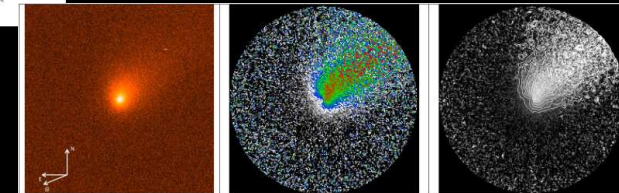
Specific Targets and Populations:

- Formation and evolution of the Solar System
- Pristine material >> astrobiology interest
- Planetary Protection

Major Contribution OAR, OaPd, OaTs



*Ieva et al. (2020):
Taxonomy of NEA*



*Mazzotta Epifani et al. (2021):
LBT Observations Comet 21/Borisov*

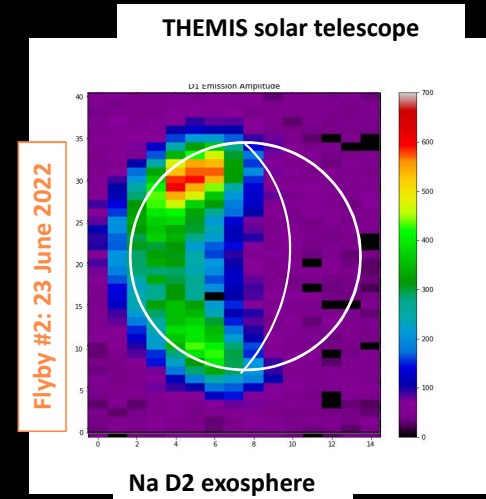
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Mercury & BepiColombo – SERENA Italian Team

Uses Themis Solar Telescope to monitor the hermean Na exosphere to study dynamics and interactions with the Sun and with the IMF and planetary magnetic field.

Present/future perspectives: joint observations with in-situ instrumentation by BepiColombo (during 4 flybys in 2023-2025 & from 2026 for nominal mission)



PRISMA: Italian fireball network for recovery of freshly fallen meteorites

- Almost **70 cameras** over Italy, collaboration with research institutes, universities, associations, schools, privates, etc.
- Partner of the European **FRIPON** network
- More than 2000 fireballs observed and 6 meteorite-dropping fireballs, meteorite Cavezzo identified (first in Italy)

>>> Need to become a stable INAF infrastructure



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EuroPlanet 2024 RI – 10Meuro Horizon 2020 project

Europlanet INAF in numbers Funds INAF: 186 k€ (2021-2023); 174 k€ (till 2020) Personnel: 23 TI+TD and 1 AdR

INAF participates in all Virtual Access (VA) Services

PI: M. C. De Sanctis, Dep: S. Ivanovski



WP5/SPIDER Task 2 INAF/IAPS - a service for runs on request of EGEON model of Jupiter's moon exospheres



WP6/VA2, Task 2 & 5 INAF/OATS - new data services related to atmospheres and exoplanets. OATS is one of the three European service data hubs.



WP8/VA3, Task 2, 3, 4 & 5 and WP9/JRA3, Task : INAF/IAPS + GMAP geological maps of planetary surfaces and VNIR spectroscopic data sets and Mercury mapping.



WP10/JRA4, Task 1, 2, 3 & 5 INAF/APS - a machine learning scientific case of mineral identification via reflectance spectra .

Since 1 October 2022 INAF has taken the lead of this VA Service.

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Laboratory of Cartography, Photogrammetry and GIS

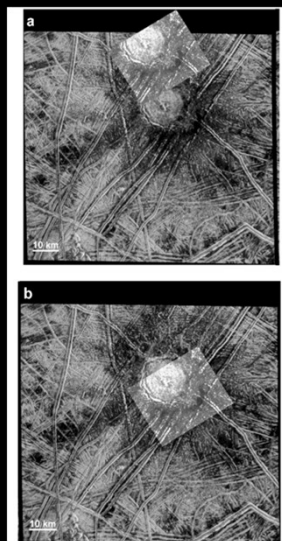
PI Alessandro Frigeri IAPS/INAF

The laboratory for cartography, photogrammetry and GIS develops techniques and data products for the scientific activities related to the space missions exploring the surfaces of the Solar System bodies.

Cartographic and photogrammetric techniques remove distortion and co-register different dataset, from topography to imagery to hyperspectral data

Geologic mapping develops thematic maps devoted to the description of the evolution in time of processes putting in place the materials observed at the surface of the Solar System bodies.

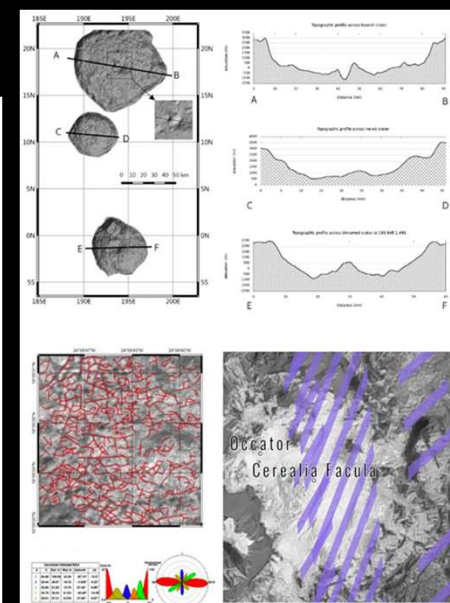
Photogrammetry



Cartography



Geographic Information System



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New Opportunities

Call ASI Topical Teams; Call has been withdrawn; it should be reissued soon; instrumentation for space; 36months activity, 200Keuro budget (total 1Meuro).

Call MUR FISA / PON 2021-2027; aimed at Fundamental and Experimental Research; 2-5 years projects, 1-5Meuro budget (total 50Meuro); deadline 13 December 2022

Call INAF 2023 ?

NASA New Frontier 5 call 2022-2023; proposals due 2024, launch 2031-2034

- Comet Surface Sample Return
- Lunar South Pole-Aitken Basin Sample Return
- Ocean Worlds (only Enceladus)
- Saturn Probe
- Io Observer
- Lunar Geophysical Network