United Nations / Jordan Workshop: Global Partnership in Space Exploration and Innovation

Amman, Jordan 25-28 March 2019

Italian scientific contribution to Space Exploration

An overview on main instruments for planetary exploration missions

agenzia spaziale italiana

Raffaele Mugnuolo, Italian Space Agency

The approach to Planetary Exploration over 30 years of activities, started taking into account:

- ❑ Scientific community interest and expertise
- ❑ Technologies readiness level

Topic of interest

- ❑ Surface mapping
- ❑ Geo-evolution, Geo-composition
- ❑ Atmosphere/Exosphere analysis
- ❑ Dust composition
- ❑ Drilling&Sampling device
- ❑ General relativity
- ❑ Geophysic
- ❑ Gravity Field

Promising tegnologies

- ❑**Imaging system**
- ❑**Spctrometer**
- ❑**Radar**
- ❑**Dust analyzer**
- ❑**Drilling-sampling mechanisms**

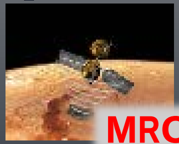
National effort to

- ➢ Consolidate the science community
- ➢ Improve technology performances
- ➢ Establish basis for international cooperation in planetary exploration

esa 2003

Mars Express

2005



MRO

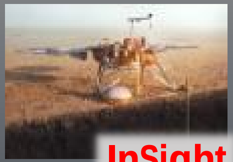
2011

JUNO

esa 2016

ExoMars TGO

2018



InSight

esa 2018

Bepi Colombo

esa 2020

ExoMars 2020

2020

Mars 2020

2020

SLS EM1

2021

DART

esa 2022

JUICE

esa 2019

CHEOPS

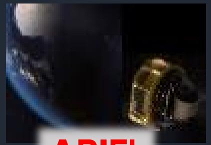
esa 2020

Solar Orbiter

esa 2026

PLATO

esa 2028



ARIEL

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Overview on the Italian participation to current and planned missions

Image & graphics credits: NASA, ESA, Roscosmos

Mars

- *MARSIS, sounding radar*
- *PFS, Fourier spectrometer*

mars express

- *SHARAD, shallow radar*

ExoMars TGO

- *NOMAD, IR-UV spectrometer*
- *CaSSIS, Color/Stereo Camera*

ExoMars 2020

- *INRRI, Laser retroreflector*
- *Ma_MISS, Vis-IR spectrometer*
- *MicroMED, dust analyzer*
- *AMELIA, Atmophere study*

- *LaRRI, Laser retroreflector*

- *LaRA, Laser retroreflector*

Mercury

bepicolombo

- SIMBIOSYS, *3-channels imaging*
- SERENA, exosphere refilling
- MORE, radioscience
- ISA, accelerometer

Sun

solar orbiter

- *METIS, Vis-UV imaging*
- *SWA sensors suite for plasma analysis*

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Jupiter System

JUNO

- JIRAM,

juice

- JANUS, *camera system*
- RIME, *radar*
- 3GM, *radioscience package*
- MAJIS, *imaging spectrometer*

Exo-Planets

cheops

CHaracterising ExOPlanet Satellite

- 30cm telescope

plato

PLAnetary Transits and Oscillations of stars

- Telescope Optical Units

ARIEL

Atmospheric Remote-sensing Infrared Exoplanet Large-survey

- Contribution to the Telescope Assembly

Planets & small bodies

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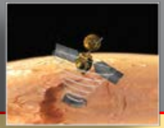







	esa MEX	NASA MRO	esa TGO	NASA InSight	esa ExoM 2020	NASA Mars 2020	esa JAXA BepiColombo	NASA JUNO	esa JUICE
Topic\Target	**Mars**						**Mercury**	**Jupiter & Icy moons**	
Interior structure Subsurface investigation	MARSIS	SHARAD					ISA MORE		RIME
Surface Mapping Morphology Geology/composition Volcanism Global Tectonics			CaSSIS (Swisse)		MaMISS		SIMBIO- SYS	JIRAM	JANUS MAJIS (France)
Atmopshere Dust composition Habitat/Environment Exosphere Magnetosphere	MARSIS PFS	SHARAD	NOMAD (Belgium)	LaRRI	MicroMED	LaRA	SERENA		JANUS MAJIS 3GM
Sub-Surface Sampling and Characterization					MaMISS				
General Relativity Gravity field Geophysics				LaRRI		LaRA	ISA MORE		3GM

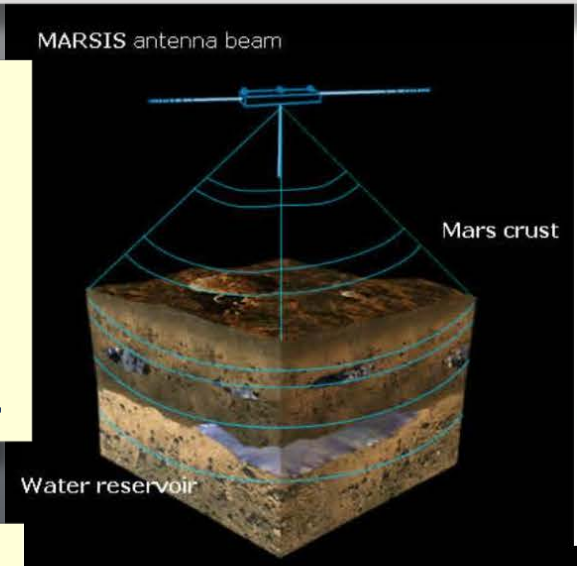
MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding)

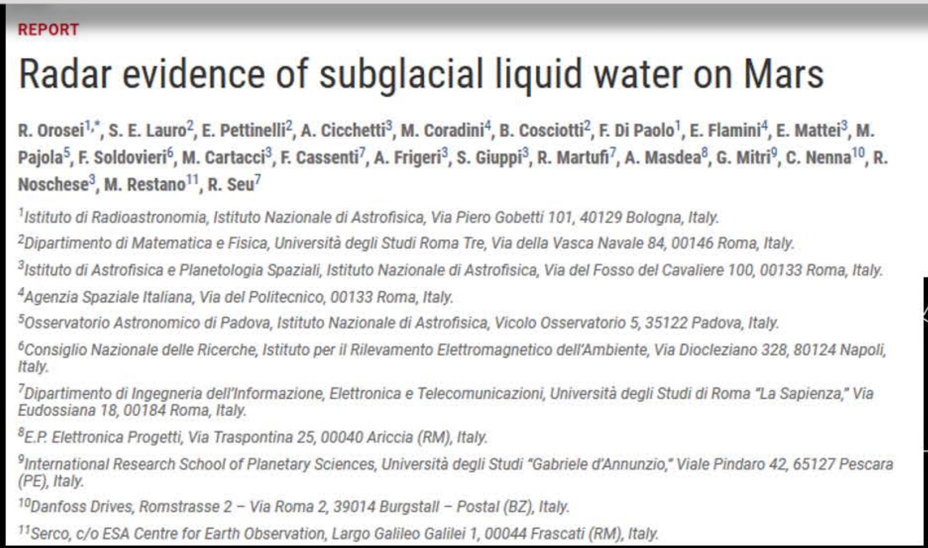
Operating since July 2005, MARSIS is a low-freq radar (1-4.5 MHz) suitable for subsurface layers mapping including ice, soil and rock

Main achievement: detection of a subglacial liquid water at ca. 1.5 km under Mars surface, on an area of 20 km² in the south polar region icy area

Courtesy of Roberto Orosei, MARSIS P.I.

Mars Express, **rapid and streamlined development time, represents ESA's first visit to another planet in the Solar System. Launched on 3/12/2003**



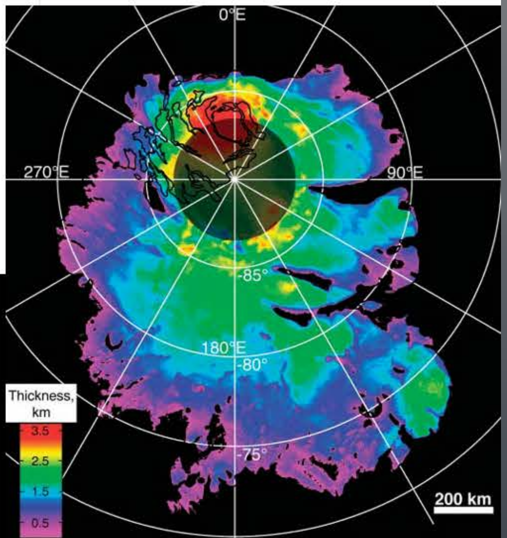

REPORT

Radar evidence of subglacial liquid water on Mars

R. Orosei[1,*], S. E. Lauro[2], E. Pettinelli[2], A. Cicchetti[3], M. Coradini[4], B. Cosciotti[2], F. Di Paolo[1], E. Flamini[4], E. Mattei[3], M. Pajola[5], F. Soldovieri[6], M. Cartacci[3], F. Cassenti[7], A. Frigeri[3], S. Giuppi[3], R. Martufi[7], A. Masdea[8], G. Mitri[9], C. Nenna[10], R. Noschese[3], M. Restano[11], R. Seu[7]

[1]Istituto di Radioastronomia, Istituto Nazionale di Astrofisica, Via Piero Gobetti 101, 40129 Bologna, Italy.
[2]Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre, Via della Vasca Navale 84, 00146 Roma, Italy.
[3]Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, Via del Fosso del Cavaliere 100, 00133 Roma, Italy.
[4]Agenzia Spaziale Italiana, Via del Politecnico, 00133 Roma, Italy.
[5]Osservatorio Astronomico di Padova, Istituto Nazionale di Astrofisica, Vicolo Osservatorio 5, 35122 Padova, Italy.
[6]Consiglio Nazionale delle Ricerche, Istituto per il Rilevamento Elettromagnetico dell'Ambiente, Via Diocleziano 328, 80124 Napoli, Italy.
[7]Dipartimento di Ingegneria dell'Informazione, Elettronica e Telecomunicazioni, Università degli Studi di Roma "La Sapienza," Via Eudossiana 18, 00184 Roma, Italy.
[8]E.P. Elettronica Progetti, Via Traspontina 25, 00040 Ariccia (RM), Italy.
[9]International Research School of Planetary Sciences, Università degli Studi "Gabriele d'Annunzio," Viale Pindaro 42, 65127 Pescara (PE), Italy.
[10]Danfoss Drives, Romstrasse 2 – Via Roma 2, 39014 Burgstall – Postal (BZ), Italy.
[11]Serco, c/o ESA Centre for Earth Observation, Largo Galileo Galilei 1, 00044 Frascati (RM), Italy.

Science
Vol 361, Issue 6401
03 August 2018



Mars Express was designed to study all aspects of the Red Planet, including its atmosphere and climate, and the mineralogy and geology of the surface and subsurface.

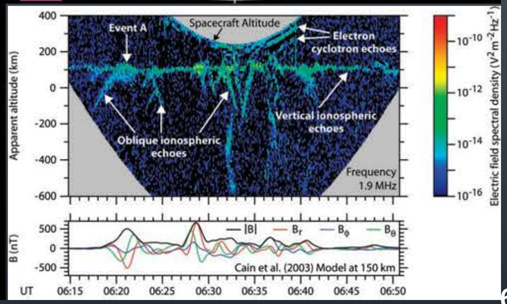


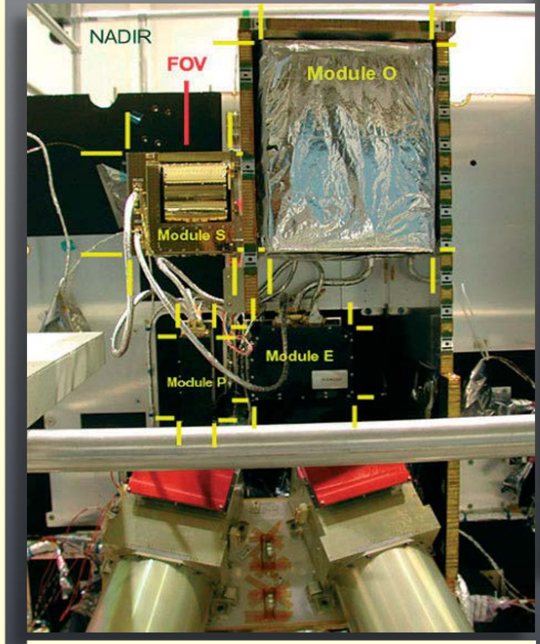
Image & graphics credits: NASA, ESA, Roscosmos

Planetary Fourier Spectrometer (PFS)

PFS is an infrared spectrometer optimized for atmospheric studies in the spectral range 1.2 to 45 µm (Thermal+Near Infrared) with a relatively high spectral resolution of 1.3 cm^{-1} and a sampling step of 1 cm^{-1}

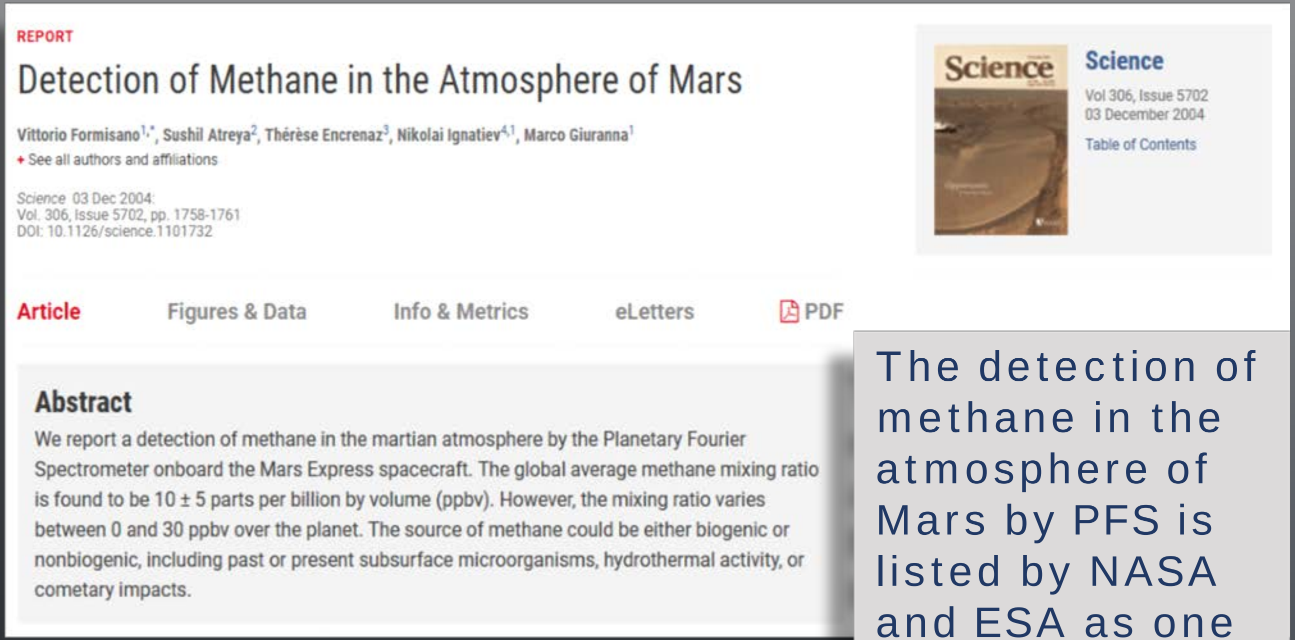
15 years of atmospheric monitoring by PFS-MEX building the most comprehensive database of atmospheric parameters for mars

- Vertical Profiles of Temperatures (0-50 km)
- Dust opacity
- Ice opacity
- Surface Temperature
- Water Vapor
- Carbon monoxide



PFS Flight Model integrated on MEx

Courtesy of Marco Giuranna, PFS P.I.



REPORT

Detection of Methane in the Atmosphere of Mars

Vittorio Formisano[1,*], Sushil Atreya[2], Thérèse Encrenaz[3], Nikolai Ignatiev[4,1], Marco Giuranna[1]

+ See all authors and affiliations

Science 03 Dec 2004:
Vol. 306, Issue 5702, pp. 1758-1761
DOI: 10.1126/science.1101732

Science
Vol 306, Issue 5702
03 December 2004
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Article | Figures & Data | Info & Metrics | eLetters | PDF

Abstract

We report a detection of methane in the martian atmosphere by the Planetary Fourier Spectrometer onboard the Mars Express spacecraft. The global average methane mixing ratio is found to be 10 ± 5 parts per billion by volume (ppbv). However, the mixing ratio varies between 0 and 30 ppbv over the planet. The source of methane could be either biogenic or nonbiogenic, including past or present subsurface microorganisms, hydrothermal activity, or cometary impacts.

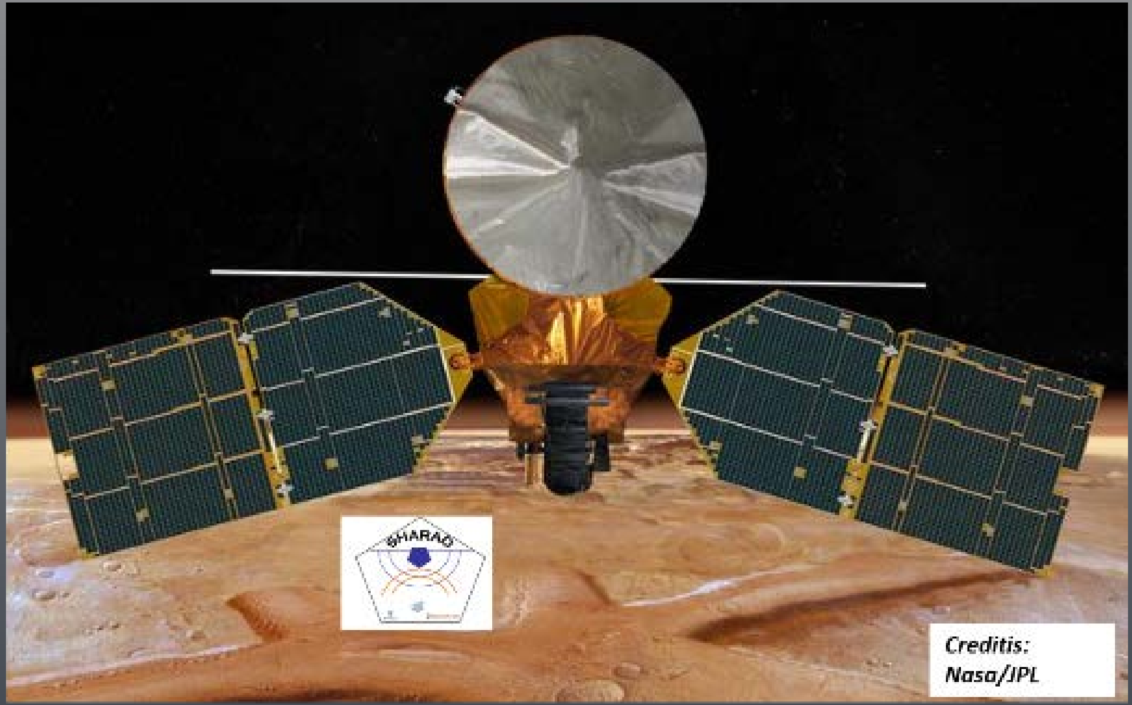
The detection of methane in the atmosphere of Mars by PFS is listed by NASA and ESA as one of the 10 most important discoveries of the last years and of Mars Express

Image & graphics credits: NASA, ESA, Roscosmos

SHARAD (shallow radar))

Operating fro 2026 in Mars Orbit, the Shallow Radar (SHARAD) sounder onboard the Mars Reconnaissance Orbiter seeks geologic boundaries in the first tens to thousands of meters (up to 4 kilometers or 2.5 miles) below the surface of Mars.

The radar waves are sensitive to changes in electrical properties, typically associated with changes in density and composition, that they encounter within or between layers of rock, sand, water ice, and carbon-dioxide ice. In context with other data, the layering and structures revealed by the radar reflections provide insight into the geological and climatological processes that formed them



SHARAD (SHAllow RADar)
Subsurface investivation by cross section mapping (crust, layers, reservoir of Ice and/or liquid water)
Along track 0.3-1.0 km; Cross track 3-6 km; Vertical 15-20 m.

P.I: Roberto Seu (*“La Sapienza” University of Rome*) and US participants for operations and scientific investigations

JIRAM (Jovian Infrared Auroral Mapper)

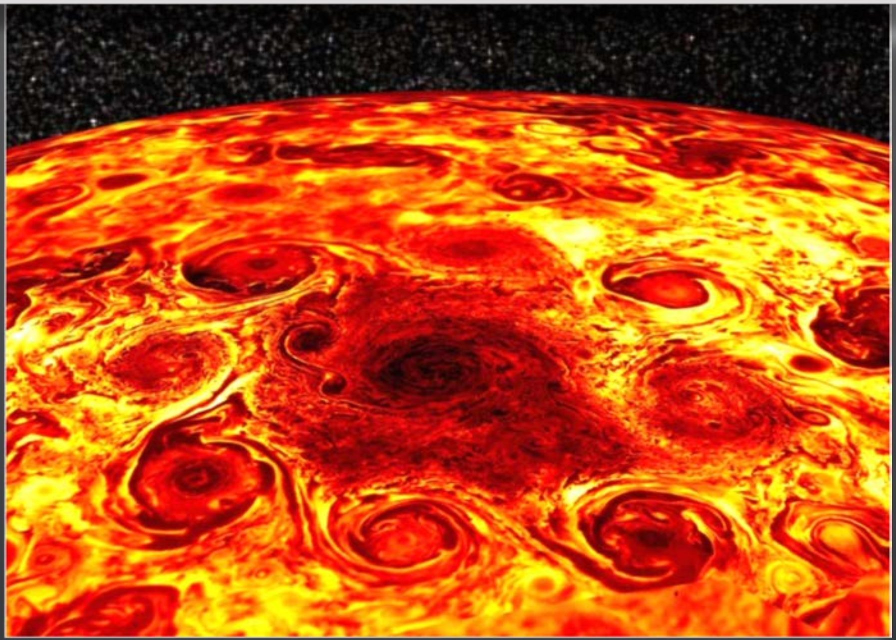
Imager and Spectrometer to investigate the upper layers of Jupiter's atmosphere in infrared spectral range (2–5 μm)

JUNO, launched on August 2011, is improving our understanding of the solar system's beginnings by revealing the origin and evolution of Jupiter

- Origins and Interior
- Atmosphere
- Magnetosphere

JIRAM Main goal

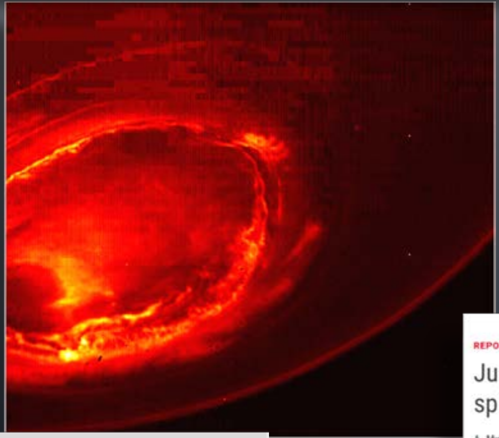
- Jupiter's atmosphere and auroral regions
- dynamics and chemistry in the atmosphere
- Jovian hot spots formation process
- Vertical profile of troposphere
- Jupiter clouds composition



Infrared image of Jupiter's north pole from data collected by JIRAM aboard NASA's Juno spacecraft.

Infrared cameras are used to sense the temperature of Jupiter's atmosphere and provide insight into how the powerful cyclones at Jupiter's poles work.
The yellow areas are warmer (or deeper into Jupiter's atmosphere) and the dark areas are colder (or higher up in Jupiter's atmosphere). In this picture the highest temperature is around 260K (about -13°C) and the lowest around 190K (about -83°C)

Image credit: NASA/JPL-Caltech/SwRI/ASI/INAF/JIRAM



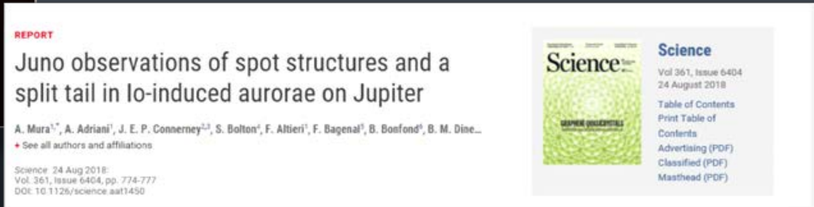
Aurora observed by JIRAM in Jupiter southern region
Image credit: NASA/JPL-Caltech/SwRI/ASI/INAF/JIRAM


LETTER

doi:10.1038/nature2549

Clusters of cyclones encircling Jupiter's poles

A. Adriani[1], A. Mura[1], G. Orton[2], C. Hansen[3], F. Altieri[1], M. L. Moriconi[4], J. Rogers[5], G. Eichstädt[6], T. Momary[2], A. P. Ingersoll[7], G. Filacchione[1], G. Sindoni[1], F. Tabataba-Vakili[2], B. M. Dinelli[4], F. Fabiano[4,8], S. J. Bolton[9], J. E. P. Connerney[10], S. K. Atreya[11], J. I. Lunine[12], F. Tosi[1], A. Migliorini[1], D. Grassi[1], G. Piccioni[1], R. Noschese[1], A. Cicchetti[1], C. Plainaki[13], A. Olivieri[13], M. E. O'Neill[1] D. Turrini[1,15], S. Stefani[1], R. Sordini[1] & M. Amoroso[13]


REPORT

Juno observations of spot structures and a split tail in Io-induced aurorae on Jupiter

A. Mura[1,*], A. Adriani[1], J. E. P. Connerney[2,3], S. Bolton[4], F. Altieri[1], F. Bagenal[5], B. Bonfond[6], B. M. Dine...

+ See all authors and affiliations

Science 24 Aug 2018:
Vol. 361, Issue 6404, pp. 774-777
DOI: 10.1126/science.aat1450

Science
Vol 361, Issue 6404
24 August 2018
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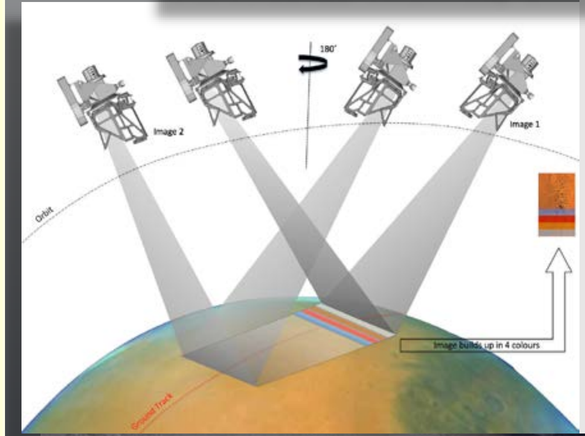
Classified (PDF)
Masthead (PDF)

ExoMars Trace Gas Orbiter (TGO) contribution

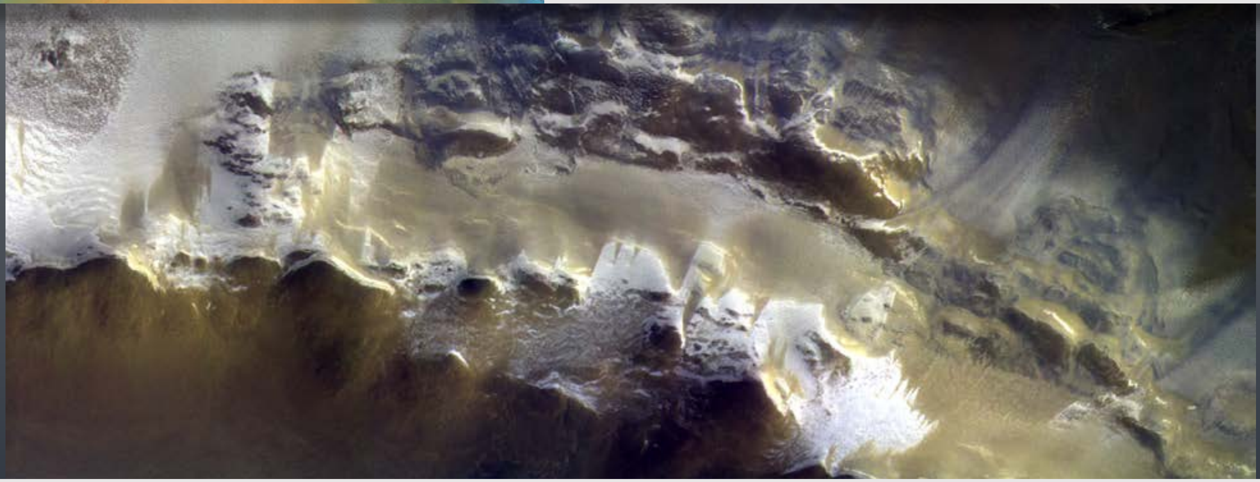
Searching for signature gases in the Martian atmosphere. Launched on March 2016, is the first in a series of Mars missions to be undertaken jointly by ESA and Roscosmos. Scientific Investigation is the top priority for TGO, that will become a Mars telecommunications asset, providing communication services to the Rover operating on the surface of Mars.

CaSSIS - Colour and Stereo Surface Imaging System

PI: Nicolas Thomas, University of Bern, Switzerland



Color and stereoscopic images of surface features, will allow scientists to investigate specific geological processes associated with trace gas sources and sinks. The CaSSIS pixel scale is 4.6 m /pixel and the DTM ground sampling is 10-15 m. INAF-OAPD is in charge for generation and archiving of the DTM



CaSSIS sent first color images (April 2018) - This image is from the rim of Koralev crater (165.9 E, 73.3 N) at 5.08 m/px with a ground track velocity of 2.90 km/s. The solar incidence angle was 76.6° at a local solar time of 07:14:11. Copyright: ESA/Roscosmos/CaSSIS

NOMAD - Nadir and Occultation for MArs Discovery

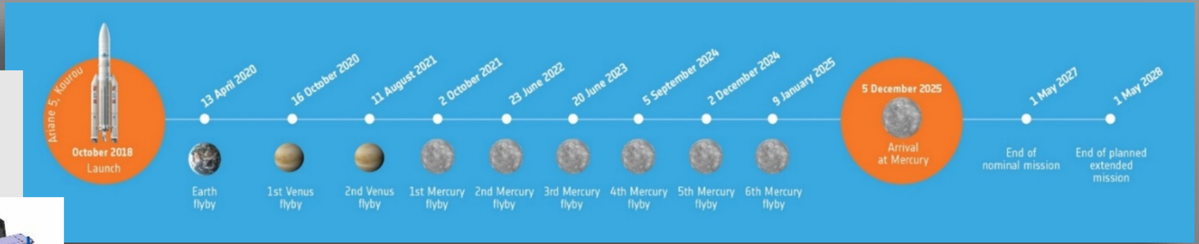
P.I.: Ann Carine Vandaele, Belgian Inst.for Space Aeronomy, BE

Spectrometer suite to cover a broad range spectrum of sunlight (infrared, ultraviolet and visible), enabling the detection of the components of the Martian atmosphere, even in low concentrations. NOMAD will also map locations of identified constituents of the Martian atmosphere

Bepi Colombo: Investigating Mercury

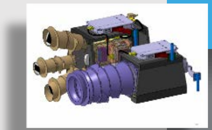
bepicolombo

agenzia spaziale italiana



Geology, Volcanism, Global tectonics

SIMBIO-SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory)



SIMBIO-SYS

HRIC (Hi-Res Colour Camera) 5-10 m/pixel @ periherm

STC (Stereo Camera) DTM up to 50 m/pixel

VIHI (Vis-IR spectrometer) 100 m/pixel; 0.4-2.0 µm 6.25nm

P.I. Gabriele Cremonese, INAF-Osservatorio Astronomico di Padova, Italy.

BepiColombo Mission Topics:

- **formation and evolution**
- **interior and composition**
- **orbit**
- **subsurface Geology**
- **crater history**
- **water and ice**
- **atmosphere**
- **magnetic environment**
- **cosmic environment**

BepiColombo is Europe's first mission to Mercury

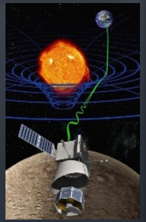
MORE

Gravity field, Interior Structure

MORE (Mercury Orbiter Radio science Experiment)

P. I.: Luciano Iess, University of Rome 'La Sapienza', Italy

SERENA



Exosphere, magnetosphere, solar wind and interplanetary medium

SERENA (Search for Exosphere Refilling and Emitted Neutral Abundances)

P.I.: Stefano Orsini, INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy

General Relativity, Interior Structure

ISA (Italian Spring Accelerometer)

P.I.: Valerio Iafolla, INAF-IAPS Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy.

ISA

Image & graphics credits: NASA, ESA, Roscosmos

ExoMars 2020: two science elements on Mars surface

agenzia spaziale italiana

Nominal Mission: 218 sols
Nominal Science:
- 6 Exp. Cycles
- 2 Vertical Survey

Exp. Cycle duration: 20 sols
Rover Mass: 300Kg
Dimensions:
- 1.5x1.4x0.7 m (stowed)
- 2.5x1.5x2 m (deployed)

- ✓ Travel back 4 billion years to explore the bottom of a Mars ocean
- ✓ Drill deep below the organics degradation horizon
- ✓ Look for traces of life beyond Earth
- ✓ Study the surface geology and environment
- ✓ Add building blocks to prepare the next step (MSR, Human missions)

The *Surface Platform*, under responsibility of Roscosmos and the Space Research Institute of Russian Academy of Sciences (IKI), will remain stationary and will investigate the surface environment at the landing site, having on board several instruments/sensors

Rosalind Franklin rover under ESA responsibility, will leave the surface platform and travel across the surface of Mars equipped with 9 instruments (Pasteur Payload) to search for signs of well-preserved organic material, particularly from the early period of the planet

Image & graphics credits: NASA, ESA, Roscosmos

Surface Platform

Dust Complex is a suit of sensors to investigate the dust dynamics near Mars surface
P.I. - A. Zakharov (IKI, Russia).

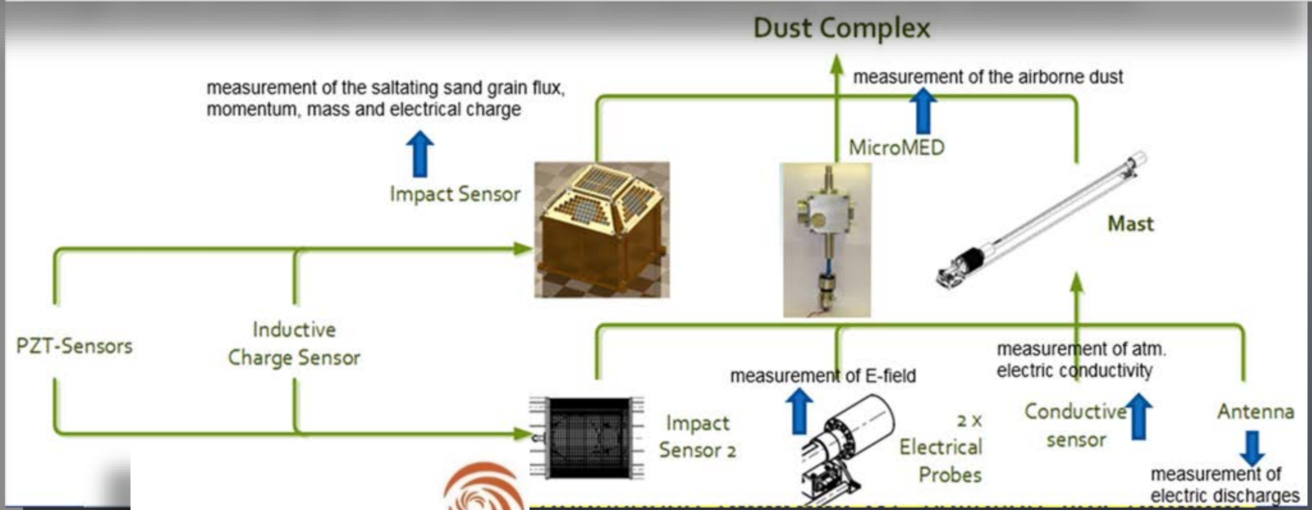
The Dust Complex will help in understanding dust lifting process by monitoring (daily and seasonally) airborne dust granulometry and abundance (MicroMED), saltation flux (Impact sensors) and the role of electric field in dust lifting processes (Electrical Probe). Also grain charge and atmospheric electric conductivity will be measured

Investigating Dust in Martian environment

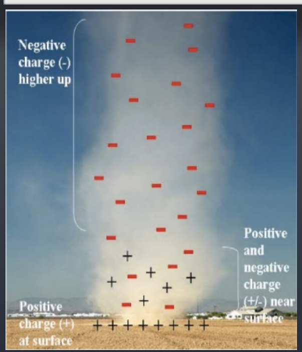
Martian atmosphere contains significant load of suspended dust
Airborne dust has important effects on morphological evolution of the surface and severely impacts on the climate of Mars, influencing the thermal behaviour of the troposphere.

- absorbs solar irradiation mainly in the VIS (re-emiting it in the IR), locally warming the troposphere.
- during global dust storms > 80% of sunlight is absorbed by dust

Dust amount and size distribution in the atmosphere is controlled by lifting processes and wind transport



MicroMED, Italian part of Dust Complex, is an optical detector able to determine the abundance and distribution of dust particles near martian surface, and evaluate changes with respect to climate events (dust storm, dust devils)



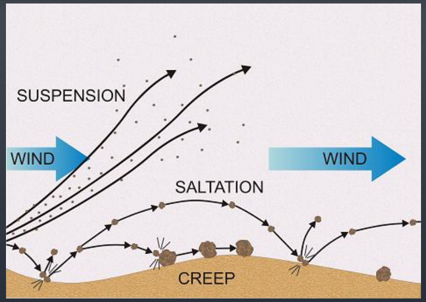


Image & graphics credits: NASA, ESA, Roscosmos exomars

Rosalind Franklin Rover, developed by ESA, provides key mission capabilities: surface mobility, subsurface drilling and automatic sample collection, processing, and distribution to instruments. A suite of instruments is dedicated to exobiology and geochemistry research (*Pasteur* payload)

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PanCam
Wide-angle stereo camera pair
High-resolution camera
Geological context
Rover traverse planning
Atmospheric studies
WAC: 35° FOV, HRC: 5° FOV

ISEM
IR spectrometer on mast
Bulk mineralogy of outcrops
Target selection
λ = 1.15 – 3.3 µm, 1° FOV

WISDOM
Ground-penetrating radar
Mapping of subsurface stratigraphy
3 – 5-m penetration, 2-cm resolution

ADRON
Passive neutron detector
Mapping of subsurface water and hydrated minerals

CLUPI
Close-up imager
Geological deposition environment
Microtexture of rocks
Morphological biomarkers
20-µm resolution at 50-cm distance, focus: 20 cm to ∞

MicrOmega
VIS + IR spectrometer
Mineralogy characterisation of crushed sample material
Pointing for other instruments
λ = 0.9 – 3.5 µm, 256 x 256, 20-µm/pixel, 500 steps

RLS
Raman spectrometer
Geochemical composition
Detection of organic pigments
spectral shift range 200–3800 cm^{-1}, resolution ≤ 6 cm^{-1}

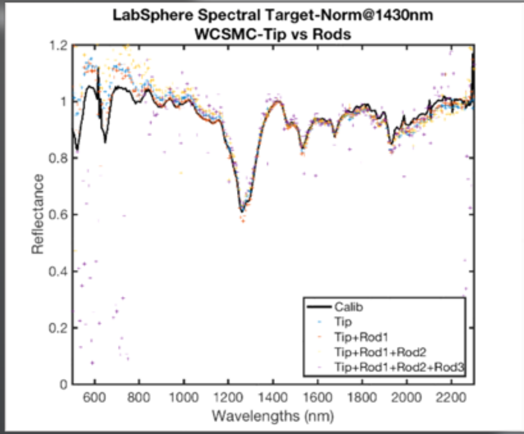
MOMA
LDMS + Pyr-Dev GCMS
Broad-range organic molecules with high sensitivity (ppb)
Chirality determination
Laser desorption extraction and mass spectroscopy

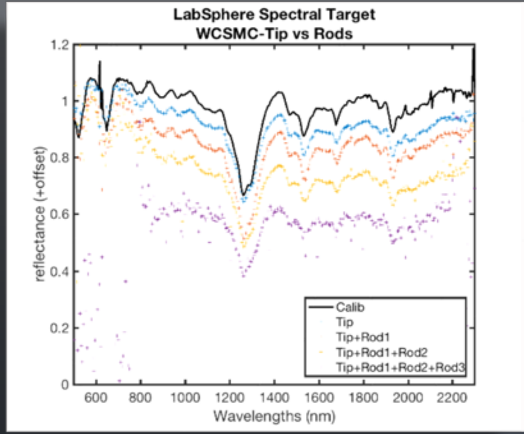
Drill + Ma_MISS
IR borehole spectrometer
In-situ mineralogy information
λ = 0.4 – 2.2 µm

Integrated Drill+Ma_MISS (Mars Multispectral Imager for Subsurface Studies)

Bore-Hole VIS-near IR spectrometer (0.4 – 2.2µm)

- Determining the presence of ice or water at the drilling site.
- Documenting the mineral distribution and composition, and identifying the nature of local geology and chemistry
- Study the samples in their geological context
- Study the mineralogy of the subsoil



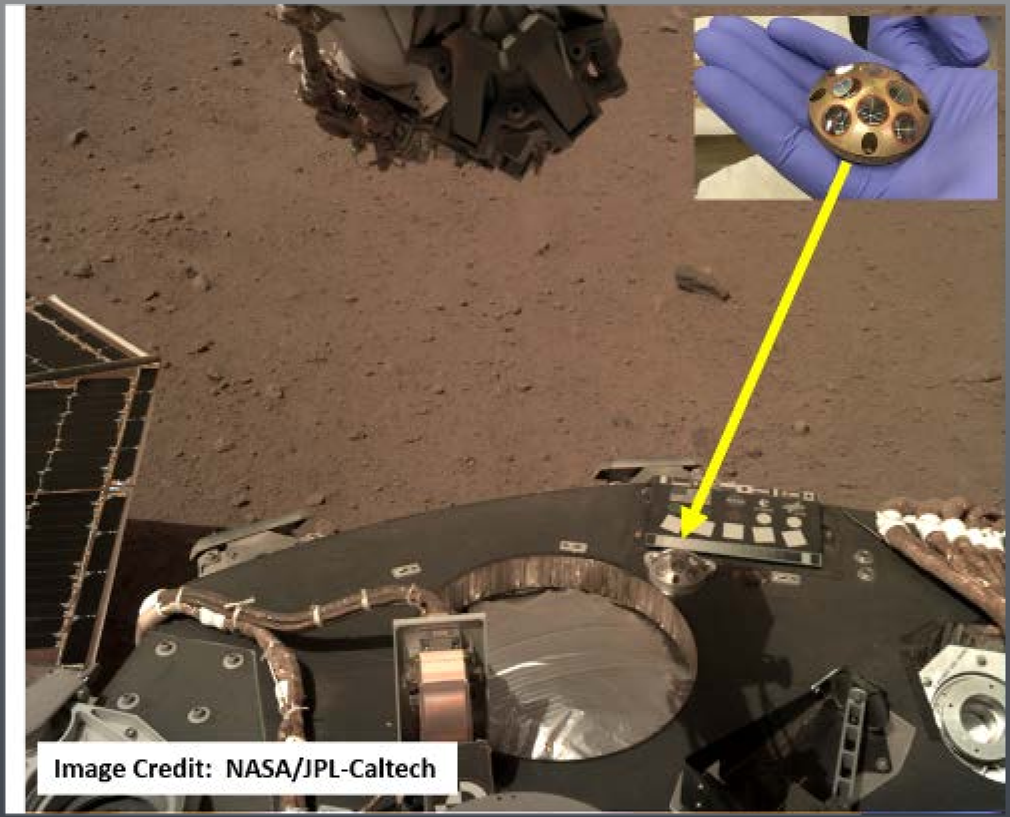


Known target spectra acquired with Ma_MISS (colored) vs the expected spectrum (black)

Participating to NASA InSight and MARS 2020

agenzia spaziale italiana

InSight Lander

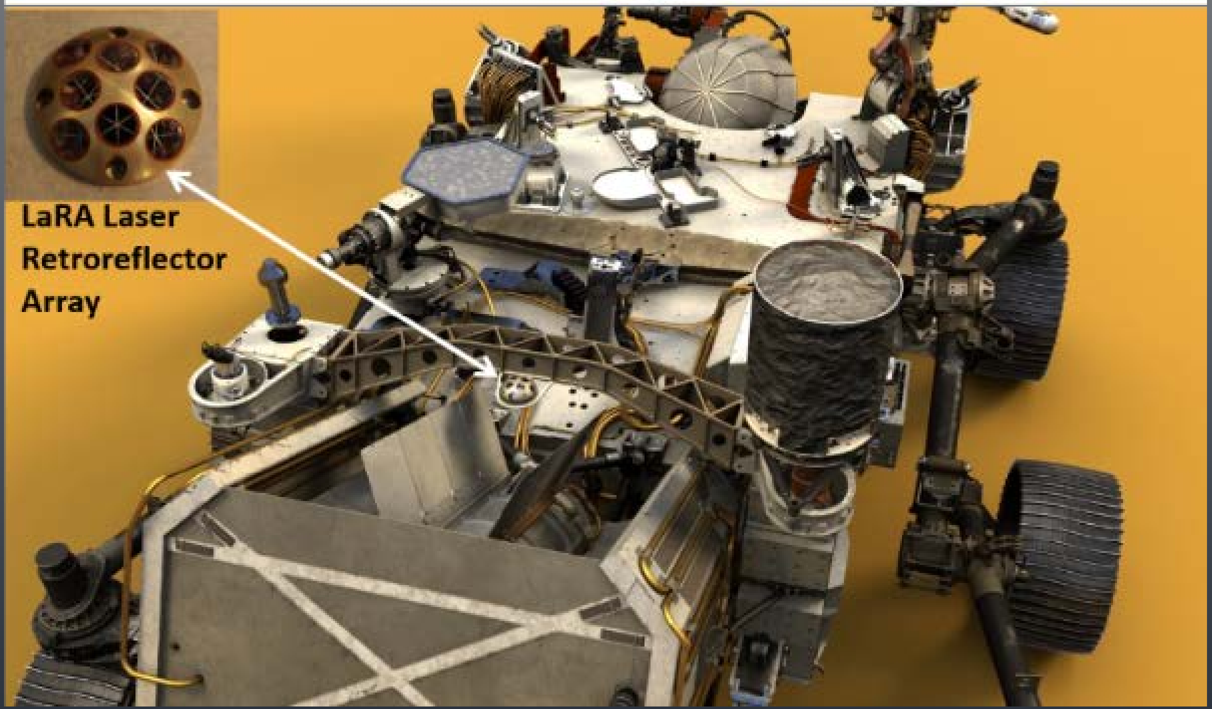


LaRRI = Laser RetroReflector for InSight

Potential applications

- **Laser ranging/altimetry**
- **Atmospheric trace species detection by lidar on orbiter**
- **Mars orbit lasercomm test & diagnostics**
- **General relativity and its extensions**

Mars2020



Jupiter Icy Moons Explorer

agenzia spaziale italiana

The JUICE mission will address two themes of ESA's Cosmic Vision program: *What are the conditions for planet formation and emergence of life? and How does the Solar System work?*

JUICE Mission Topics:

- Interior
- Subsurface
- Geology
- Atmosphere
- Plasma
- Planet, moons, rings
- Habitability
- Link to exoplanets

Launch scheduled in 2022

Icy Moons Fly-by
2 EUROPA @ 400 km
11 GANYMEDE @ 400-33 000 km
13 CALLISTO @ 200-6000 km

Gravity fields & Geophysics

3GM: Gravity, Geophysics, Galilean Moons
PI: Luciano Iess, Rome, Italy
Co-PI: David J. Stevenson, CalTech, USA
Ranging by radio tracking
2 µm/s range rate
20 cm range accuracy

Icy moon Geology, atmosphere dynamics

JANUS: Visible Camera System
PI: Pasquale Palumbo, Parthenope University, Italy.
Co-PI: Ralf Jaumann, DLR, Germany
≥7.5m/pixel
Multiband imaging, 380 - 1080 nm
Io activity monitoring and other moons observations

Subsurface investigations

RIME: Ice Penetrating Radar
PI: Lorenzo Bruzzone, Trento, Italy
Co-PI: Jeff Plaut, JPL, USA
9 MHz
Penetration ~9 km
Vertical resolution 30 m

Surface composition, Jovian atmosphere

<u>Contribution to</u> MAJIS: Imaging VIS-NIR/IR Spectrograph
PI: Yves Langevin, IAS, France
Co-PI: Guiseppe Piccioni, INAF, Italy
0.9-1.9 µm and 1.5-5.7 µm
≥62.5 m/pixel

Image & graphics credits: NASA, ESA, Roscosmos

Conclusions

- Planetary Exloration is one of the most important field for ASI
- Consolidate the national scientific community in the the international cooperation context
- Technology improvement to meet more and more demanding science goal