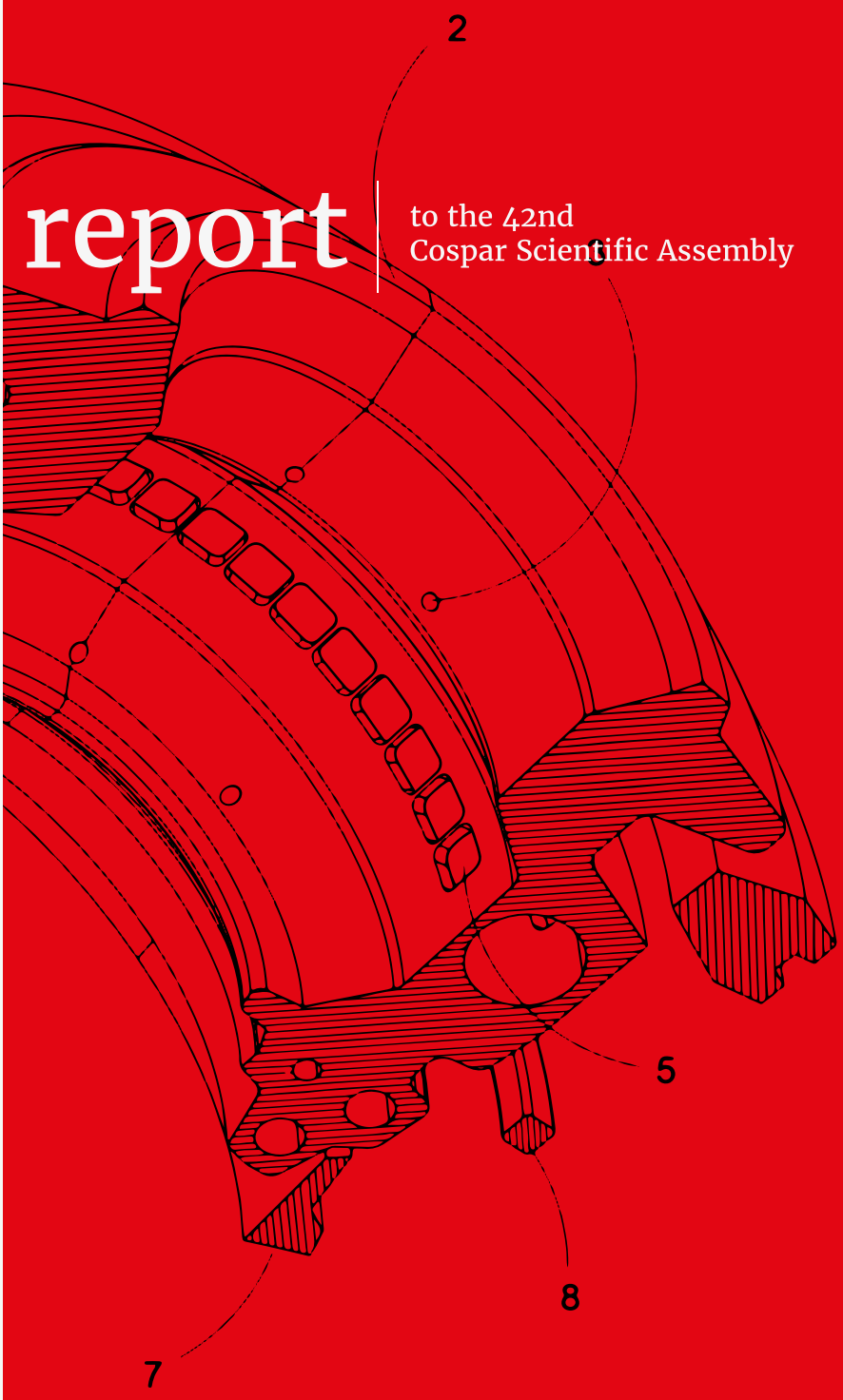
italian report

to the 42nd
Cospar Scientific Assembly



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index

editorial

The recent extraordinary campaign devoted to the electromagnetic follow up of the first detection of gravitational waves from a NS-NS merger, provided an unprecedented evidence of the unique role of multi wavelength astronomy, from ground and from space, in our understanding of the Universe. The Italian National Institute for Astrophysics (INAF) has shown a leading role at world level, because is the only national institute possessing at its internal all the instruments and knowledge for observing the Universe, at all wavelengths, from ground and from space.

INAF is composed of sixteen Research Structures spread throughout Italy, the majority of them having multidisciplinary skills. This includes the development of new instruments and techniques, coupled to a systematic transfer of knowledge towards the national industry. We own and manage the National Telescope Galileo (TNG) at the Canary Islands; we are members of the Large Binocular Telescope (LBT) Foundation in Arizona; we own and manage three radio telescopes of the European VLVBI Network (EVN); we represent the Country in the Council of the European Southern Observatory. Furthermore, we directly support the design and construction of one most challenging telescope ever conceived so far: the "European Extremely Large Telescope" (E-ELT) and we are involved in the Cherenkov Telescope Array (CTA) project, hosting the headquarters of the CTA Organization in Bologna (Italy). We are also involved in the Square Kilometer Array project, and we have led the political negotiations to transform the SKA Organization in an Intergovernmental Organization (IGO).

Of course INAF is also involved in astronomy from space, and the information provided in this report prove that the involvement is massive, covering almost all the fields of space research. We have a solid collaboration with the Italian Space Agency (ASI) and we are proud to be involved into space missions of the European Space Agency (ESA) and NASA. The Italian Government has recently allocated significant resources of the national long-term development plan to the large astronomical infrastructures and to space research, so we can safely predict a strong engagement of our Institute into the future of modern astronomy and space research.

Nicolò D'Amico
President of the Italian National
Institute for Astrophysics

foreword

The Italian Report to the 42nd COSPAR General Assembly to be held in Pasadena is edited by the National Institute of Astrophysics (INAF), the formal Italian national body that by the law supports the COSPAR activities, with the collaboration of ASI, the Italian Space Agency, and the other stakeholders playing a major role in the Italian scientific space programmes (INFN, CNR, INGV, etc.).
This Report summarizes the last two years of space science activity in Italy. In view of the appreciation received for the edition of 2016, this year the Report has been formulated in a similar condensed form to give the relevant information in a snapshot, though providing a full overview of the current Italian research programmes carried out from space. In the present edition we added, as an appendix, the activities correlated with European H2020 grants, at the best of the editor knowledge at the time of this booklet printing. We apologise for any omission or misunderstanding.
The Report is organised with the description of the scientific goals, technical requirements and actual realization of the space missions, enumerated following the COSPAR Scientific Commissions scheme:

Commission A:	Space Studies of the Earth's Surface, Meteorology and Climate;
Commission B:	Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System;
Commission C:	Space Studies of the Upper Atmospheres of the Earth and Planets Including Reference Atmospheres;
Commission D:	Space Plasmas in the Solar System, Including Planetary Magnetospheres;
Commission E:	Research in Astrophysics from Space;
Commission F:	Life Sciences as Related to Space;
Commission G:	Materials Sciences in Space, and
Commission H:	Fundamental Physics in Space

The aim is to provide an overview of the main involvement or commitment of the Italian community in the space programmes, mission by mission. We have limited the descriptions of the missions to

those that are still on-going, approved or formally proposed for selection at national and international level, at the best level of knowledge at the time of this edition.

The main research programmes are in the field of observation of the Universe science including cosmology, planetary science, fundamental physics, Earth observation, climate and meteorology, life science in space, and space related new technologies.

ASI is delegated by the Italian government to lead and support the Italian space science programme, including the mandatory contribution to the European Space Agency (ESA). Other relevant contributions are provided by the national research bodies (INAF, CNR, INFN, etc.) proposing space programmes, missions, satellites and observatories in different research fields. When the relevant peer committees approve a programme, the above mentioned bodies provide staff scientists, engineers, technologists and management on contracts as well laboratories and dedicated financial support on ground and operations in space.
The majority of the Italian scientific space programmes are carried out in the framework of the European Space Agency funding, via the mandatory and optional programmes. Italy has also a well-consolidated partnership with NASA. In addition, has a history of on-going programmes with the Russian and Japanese space agencies and other international space organisations via bilateral or multilateral agreements. More recently a broad range of programmes have started with China in different scientific fields, materialised the last 2nd of February 2018 with the successful launch of the CSES (China Seismo-Electromagnetic Satellite), carrying on board the Italian HEPD, a High Energy Particle Detector, built under the lead of INFN, and the EFD, the Electric Field Detector, a Sino-Italian effort lead by INFN and INAF. Since the injection in the polar orbit, CSES is monitoring electromagnetic field and waves, plasma and particles perturbations of the atmosphere, ionosphere and magnetosphere induced by natural sources and anthropocentric emitters, and to study

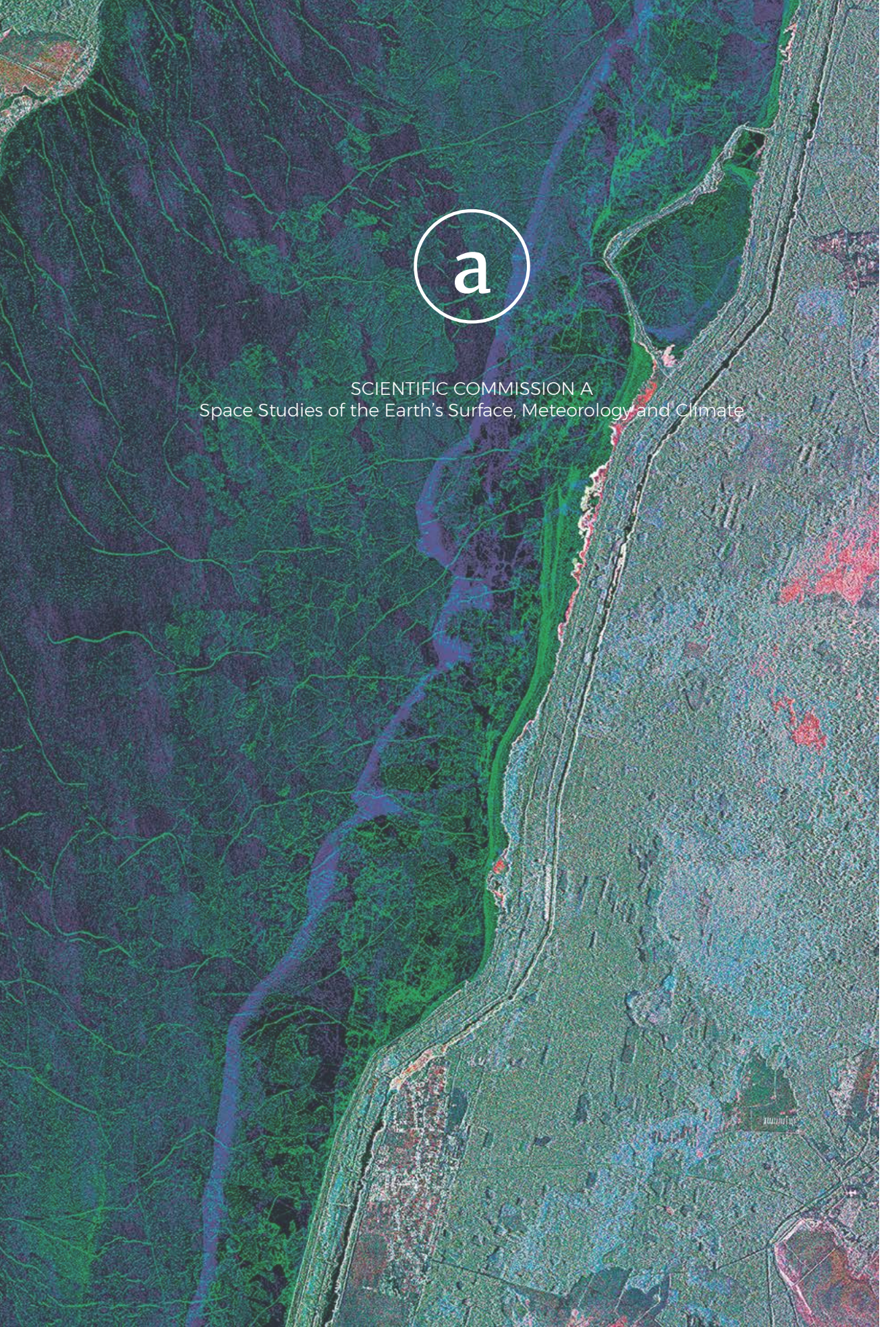
their suggested correlations with the occurrence of seismic events. A solid national programme, including dual missions, complements these international endeavours.

Italy is playing a major role in the ESA Cosmic Vision programme, participating with PIs and Co-Is in the next large mission to Mercury, BepiColombo (launch planned in 2018), Small mission for exoplanet search, CHEOPS (2018), Medium size missions M1-Solar Orbiter (2018), M2-Euclid (2020), and M3-PLATO (2024). The Italian community is also committed to the exploitation of the ESA first Large mission L1-JUICE (2022), to the Jupiter's icy moons, as well as L2-ATHENA (2028), to study the hot and energetic Universe, and in the forthcoming LISA: the Gravitational Wave Observatory (early 2030) to be realised with an important US participation. Among the ESA optional programme, Italy participates to the ExoMars programmes, with the first spacecraft already orbiting Mars and the second one (2020), featuring a rover: a scientific exploration mission lead by ASI to bring a rover to Mars, a joint venture between Italy, ESA and Russia.

Italy has entered the its 55th year of space scientific exploration: since 1964 (launch of the San Marco 1 satellite), the national scientific and industrial community has continued its path toward space science and exploration building up on the achieved record of success, investing in space programmes and cooperation with other Space-Faring nations pushing to the extremes our frontier of knowledge. Italy also has a relevant participation to the International Space Station with flight hardware already delivered and an important astronauts crew, committed to the success of the Italian and international manned space programmes during the years to come.

Finally, it is worth to mention that in the last two years the Italian scientific community has gained its leadership in the discoveries of Gravitation Waves (GW) from binary black holes mergers via the LIGO-VIRGO Collaboration, and of the first gamma-ray counterpart detected contemporary by INTEGRAL and FERMI in coincidence with the GW170817 signal from two coalescent neutron stars, starting the era of the "multi-messenger" astronomy: a success of our ground and space community expected to continue in the future decades.

Pietro Ubertini
Italian National Committee
Delegate to COSPAR



a

SCIENTIFIC COMMISSION A
Space Studies of the Earth's Surface, Meteorology and Climate

Previous page: Dnieper River (Russia, Belarus, Ukraine, Black Sea).
Credit: COSMO-SkyMed/ASI/e-GEOS.

cosmo sky-med

COSMO-SkyMed is a constellation of four radar satellites for Earth Observation funded by the Italian Space Agency and the Italian Ministry of Defense.

COSMO-SkyMed is at the forefront of technology and uses high-resolution radar sensors to observe the Earth day and night, regardless of weather conditions. The constellation is fully operational since 2008. Its purpose is to monitor the Earth for the sake of emergency prevention (management of environmental risks), strategy (defense and security), scientific and commercial purposes, providing data on a global scale to support a variety of applications among which risk management, environment protection, natural resources exploration, land management, defense and security. The constellation consists of 4 medium-size satellites, each one equipped with a microwave high-resolution synthetic aperture radar (SAR) operating in X-band, having ~600 km single side access ground area, orbiting in a sun-synchronous orbit at ~620km height over the Earth surface, with the capability to change attitude in order to acquire images at both right and left side of the satellite ground track (nominal acquisition is right looking mode). The Ground Segment is responsible for managing the constellation and granting ad-hoc services for collection, archiving and delivery of products to the users.

ENVIRONMENTAL DISASTERS - Data and products supplied by the satellite system represent a valid and important instrument, to carry on studies about causes and phenomena preceding environmental disasters as well as to improve the monitoring and evaluation of damages in case, for examples, of landslips, flood, earthquakes and volcanic eruptions. Observation within a specific area can be made during day or night and even in case of clouds, thus allowing to evaluate superficial alterations of the territory and providing institutions in charge of managing the risk with a new and useful instrument of prevention and control. Furthermore, the system represents a precious help for sea traffic control.

OCEANS AND SEACOASTS - The satellite system can provide continuous and accurate information about conditions of seacoasts, seas and inland waters, so as to evaluate phenomena of coast erosion and pollution.

AGRICULTURAL & FOREST RESOURCES - The satellites are capable to use (both to transmit and to receipt) horizontally and vertically polarized signals. This skill strengthens the possibility to classify soils as well as to monitor cultures during their phase of growth. Of particular interest is the possibility to monitor forests, which destruction has a strong impact on the quality of air and on earth resources.

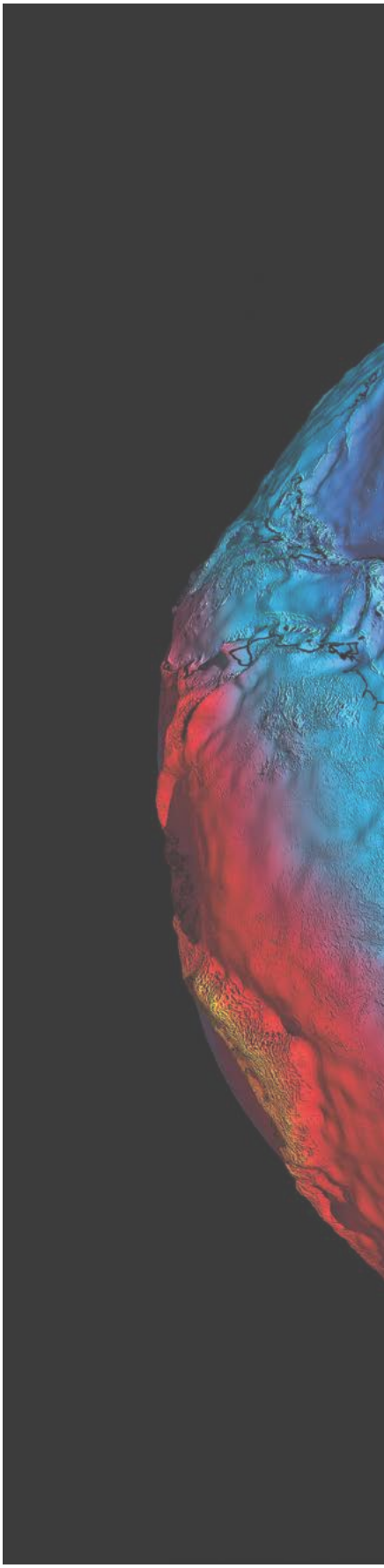
BUILDINGS - The high geometric accuracy of COSMO-SkyMed images as well as its space and temporal high resolution are incisive instruments for monitoring new settlements or soil and subsoil collapses, which are usually considered as the main cause of framework downfalls.

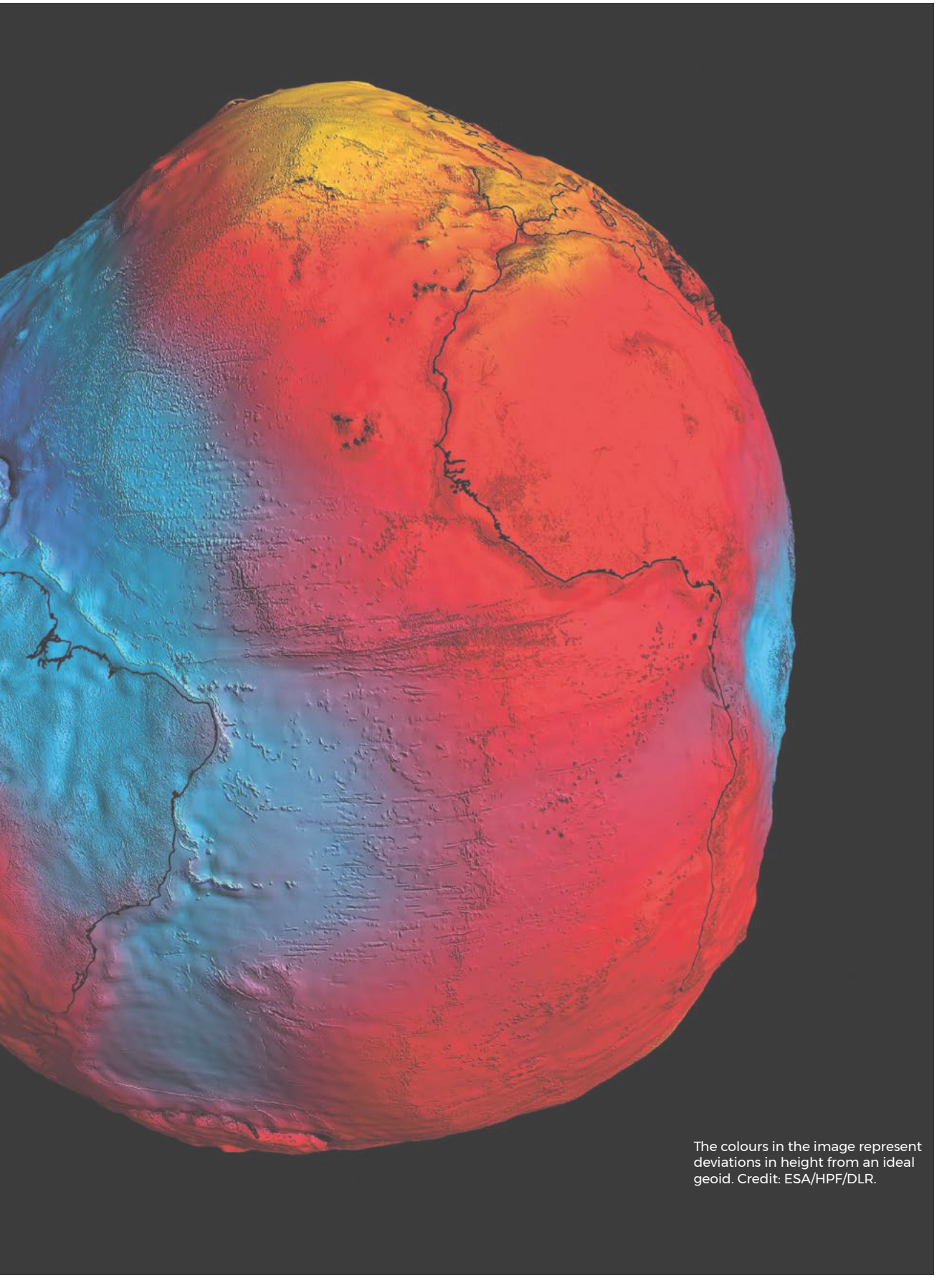
CARTOGRAPHY - These images may allow a new high resolution technical and thematic cartography and the accomplishment of a deeply accurate soil 3D digital model for various applications.

goce

GOCE is a mission devoted to measuring the Earth gravitational field.

GOCE (Gravity field and steady-state Ocean Circulation Explorer) mission has been the first ESA Earth Explorer mission in orbit. Italy, has contributed to the satellite construction through Thales Alenia. Moreover, Politecnico of Milan has been a fundamental part of the Consortium called HPF (High Level Processing Facility) which has the task of transforming the satellite data into the estimation of the Earth gravity field. Finally, ASI has funded the GOCE-ITALY project that has enabled the investigation of the GOCE data by the Italian scientists. GOCE payloads are: the Electrostatic Gravity Gradiometer (EGG) and the Satellite to Satellite Tracking Instrument (SSTI), based on precise GPS receiver.





The colours in the image represent deviations in height from an ideal geoid. Credit: ESA/HPF/DLR.

prisma

PRISMA is an Earth Observation system with innovative, electro-optical instrumentation that combines a hyperspectral sensor with a medium-resolution panchromatic camera.

PRISMA (PRecursore IperSpettrale della Missione Applicativa - Hyperspectral Precursor of the Application Mission) is an earth observation satellite for monitoring of natural resources and atmospheric characteristics (information on land cover and crop status, pollution quality of inland waters, status of coastal zones and the Mediterranean Sea, soil mixture and carbon cycle).
PRISMA combines an innovative hyperspectral camera (~ 250 bands in the range 400-2500 nm) with a panchromatic (0.4 - 0.7 μm) medium-resolution camera.

SCIENTIFIC COMMISSION B
Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System

Previous page: A photomosaic of Mercury images taken by Mariner 10. Credit: NASA/JPL.

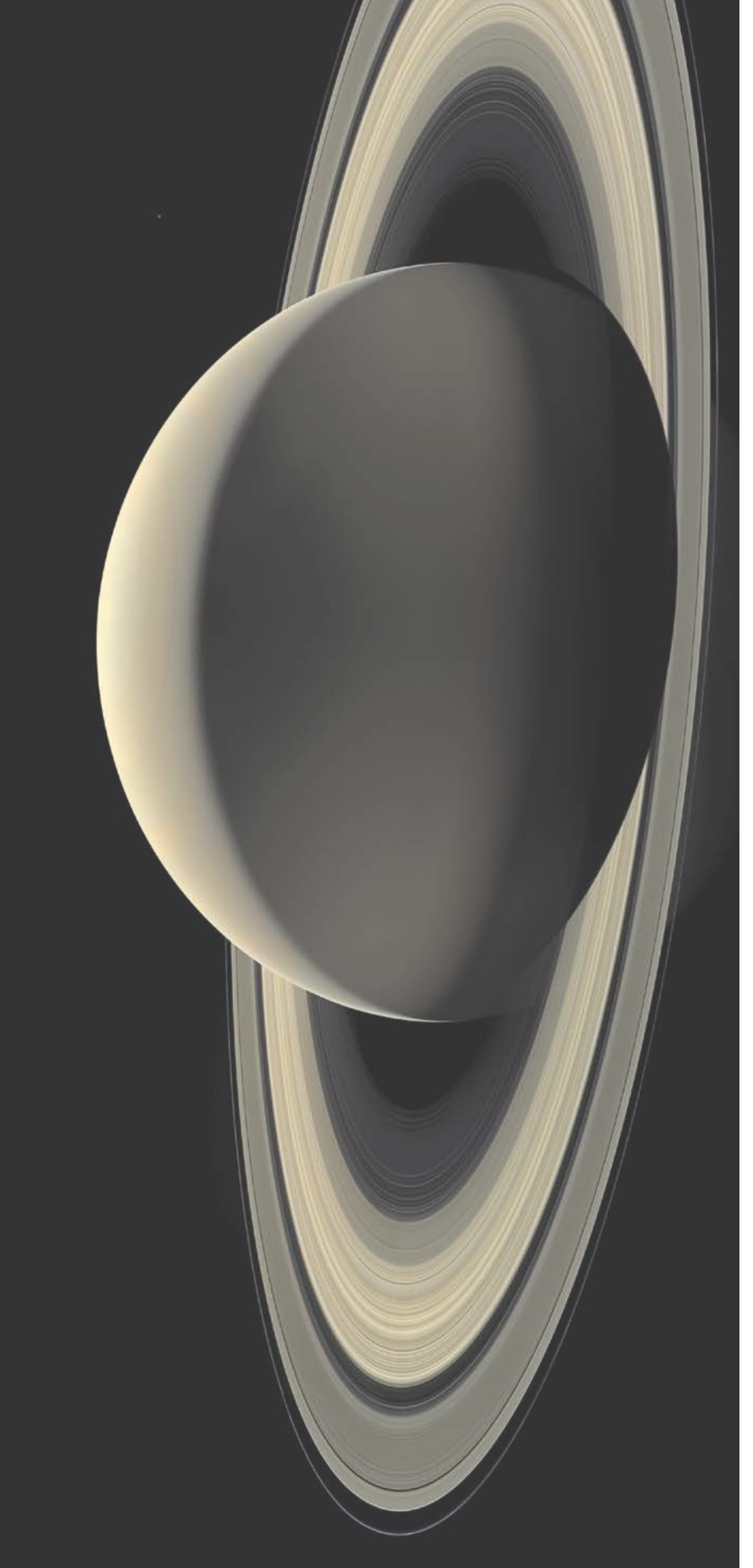
bepi colombo

BepiColombo is an ESA/JAXA mission devoted to the exploration of Mercury and to fundamental physics quests. It is composed of two spacecrafts: MMO and MPO. It will be launched in the 2018 arriving at Mercury in 2025. Italy is contributing with four instruments: ISA, MORE, SERENA, SIMBIO-SYS.

BepiColombo is the fifth ESA Cornerstone mission and its name is due to prof. Giuseppe Colombo who discovered the spin-orbit resonance between Mercury and the Sun. The BepiColombo mission is composed of two modules: the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). In MPO, 11 european instruments are integrated. The main scientific objectives are related to the surface and composition of Mercury, to its internal structure and environment and to the test of Einstein's theory of General Relativity. MMO includes 10 sensors realized and integrated in Japan by JAXA. The main scientific objectives are related to the magnetosphere and exosphere of Mercury and to the interplanetary medium. The launch will be in 2018, with an Ariane 5, and the two modules will be inserted in orbit around Mercury at the end of 2025.

The Italian contribution is very important, including four PI instruments on the MPO plus minor participation on other instruments on both modules. The accelerometer ISA, with the responsibility of INAF-IAPS, will measure with high accuracy non-gravitational accelerations.

The radio science experiment MORE, with the responsibility of the University of Sapienza in Rome, will provide very accurate position of MPO with respect to the Earth and the Sun, in order to determine the parameters of the theory of General Relativity and the internal structure of Mercury. The four sensors of the SERENA instrument, with the responsibility of INAF-IAPS, will monitor neutral energetic atoms and ions of the planet exosphere. Finally the suite SIMBIO-SYS, with the responsibility of INAF-Astronomical Observatory of Padua in collaboration with INAF/IAPS and the Parthenope University (Naples), composed of a stereo camera, an high resolution camera and a hyperspectral Vis-NIR imager, will provide 50% of the data volume of the entire mission through images and spectra of the entire surface of Mercury, even in 3D.



Cassini probe captures its final portrait of Saturn. Credit: NASA/ JPL-Caltech/SSI/Ian Regan.

cassini huygens

Cassini-Huygens has conducted in-depth studies of Saturn, its moons, rings and magnetic environment and has landed on Titan, the planet's largest moon.

Cassini-Huygens is a joint NASA/ESA/ASI robotic spacecraft mission that studied the planet Saturn and its moons. The spacecraft consisted of two main elements: NASA's Cassini orbiter and the Huygens probe. It was launched on October 15, 1997 and entered into orbit around Saturn on July 1, 2004. On January 14, 2005 the Huygens probe reached Saturn's moon Titan.
When its initial four-year tour of the Saturn system was completed in 2008, the Cassini- Huygens mission had already changed our understanding of the complex and diverse Saturn system. The first two-year extension, Cassini Equinox Mission, allowed the spacecraft to obtain observations of Saturn's rings as the sun lit them edge-on, revealing a host of never-before-seen insights into the rings' structure of great relevance for planetary formation and planetary science in general. Since 2010, the spacecraft has conducted a second, seven-year-long, extended mission called the Cassini Solstice Mission. This final mission ended on September 15, 2017 with a phase known as The Grand Finale and a final plunge into Saturn's atmosphere.
Among the remarkable discoveries obtained by Cassini: the fantastic world of Saturn's rings, a first understanding of Titan's surface and atmosphere and of its Earth-like processes, and the observation of water ice jets on the small moon Enceladus, produced by a hot-spot at its southern pole, which allowed to deduce the presence of liquid water beneath its surface.
Italy supplied the main part of the telecom system: the high-gain antenna HGA realized by TAS-I. The Italian scientific contribution to Cassini's probe has been very important too: Italy contributed with the visible channel of the Visual/Infrared Mapping Spectrometer VIMS- V, contributed to the radio detection and ranging instrument RADAR, to the radio science instrument and provided the PI instrument HASI, the Huygens Atmospheric Structure Instrument.

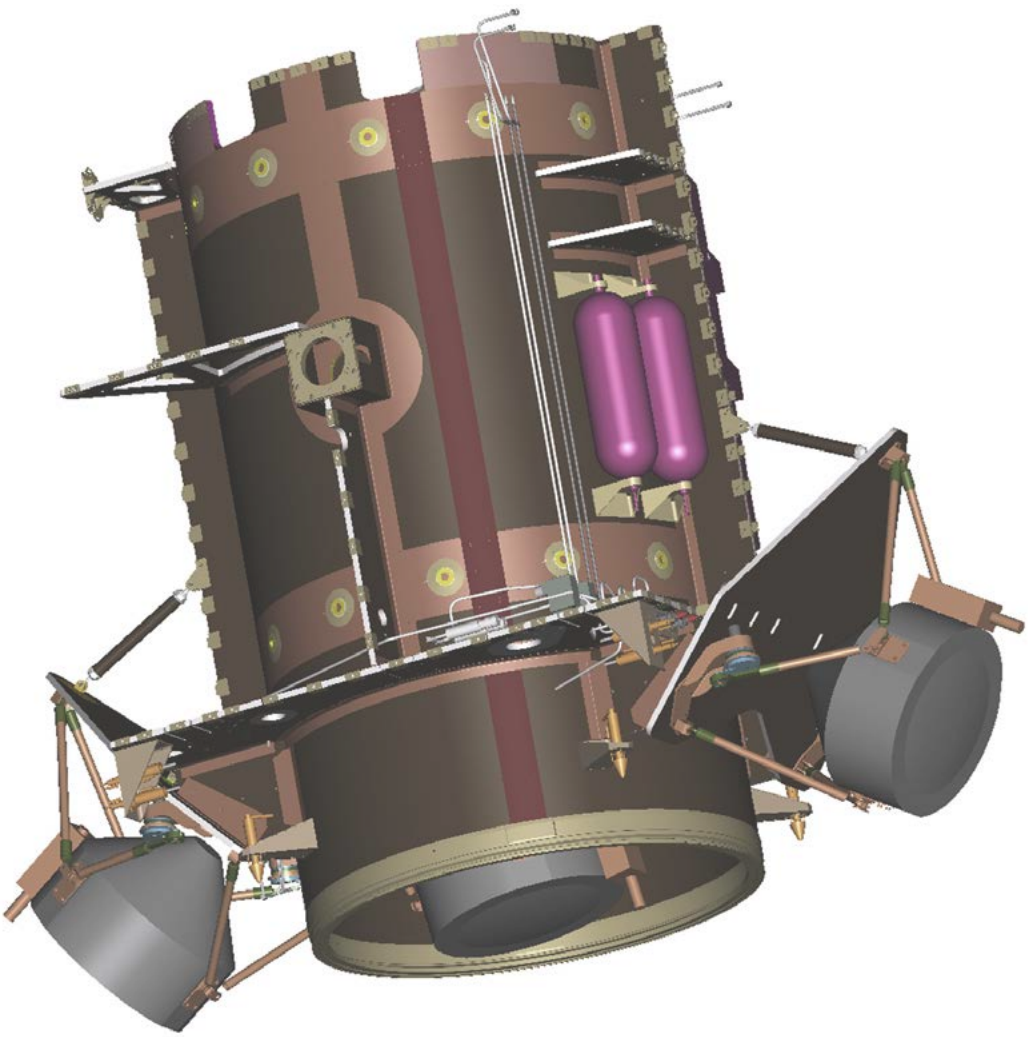
dawn

Dawn orbited and explored the giant protoplanet Vesta in 2011-2012, and now it's orbiting a new world, the dwarf planet Ceres.

Dawn orbited the protoplanet Vesta and is now in orbit around the dwarf planet Ceres as part of its mission to characterize the conditions and processes that shaped our Solar System. Vesta and Ceres are the two most massive bodies in the main asteroid belt between Mars and Jupiter. By studying these two giant remnants from the epoch of planet formation, Dawn will provide scientists with new knowledge of how the solar system formed and evolved. Dawn is a NASA Discovery mission launched on September 27, 2007. It has reached and successfully explored the asteroid Vesta in 2011. It orbited around Vesta for more than one year, giving important clues on the primordial Solar System. It reached Ceres in early 2015 and is now orbiting around it, collecting data of the innermost dwarf planet.

The Dawn mission has achieved several important firsts in space exploration. It is the only spacecraft ever to orbit two destinations beyond Earth and the only to orbit an object in the main asteroid belt between Mars and Jupiter. The giant protoplanet Vesta was confirmed to be a fascinating world more closely related to the terrestrial planets (including Earth) than to typical asteroids. Like planets, it has a dense core, surrounded by a mantle and a crust. Vesta is also the source of more meteorites on Earth than Mars or the moon. Dwarf planet Ceres, larger yet less dense, is believed to have a large amount of ice and may even have subsurface liquid water. Ceres was the first dwarf planet discovered and Dawn is now studying it in detail. The findings indicate that Ceres is more closely related to the outer Solar System bodies than to the typical asteroids. The mission represents the ideal bridge between the exploration of the inner Solar System dominated by rocky bodies and the external gaseous/icy bodies and it will allow to complete the exploration providing fundamental data on the role that water had during the early period of the planetary evolution.

The payload is composed of 3 instruments, plus radio science. Italy provides the imaging spectrometer VIR (Visual and Infrared Spectrometer), its PI (INAF-IAPS) and several mission CO-I and team members. VIR has been built by Selex-ES.

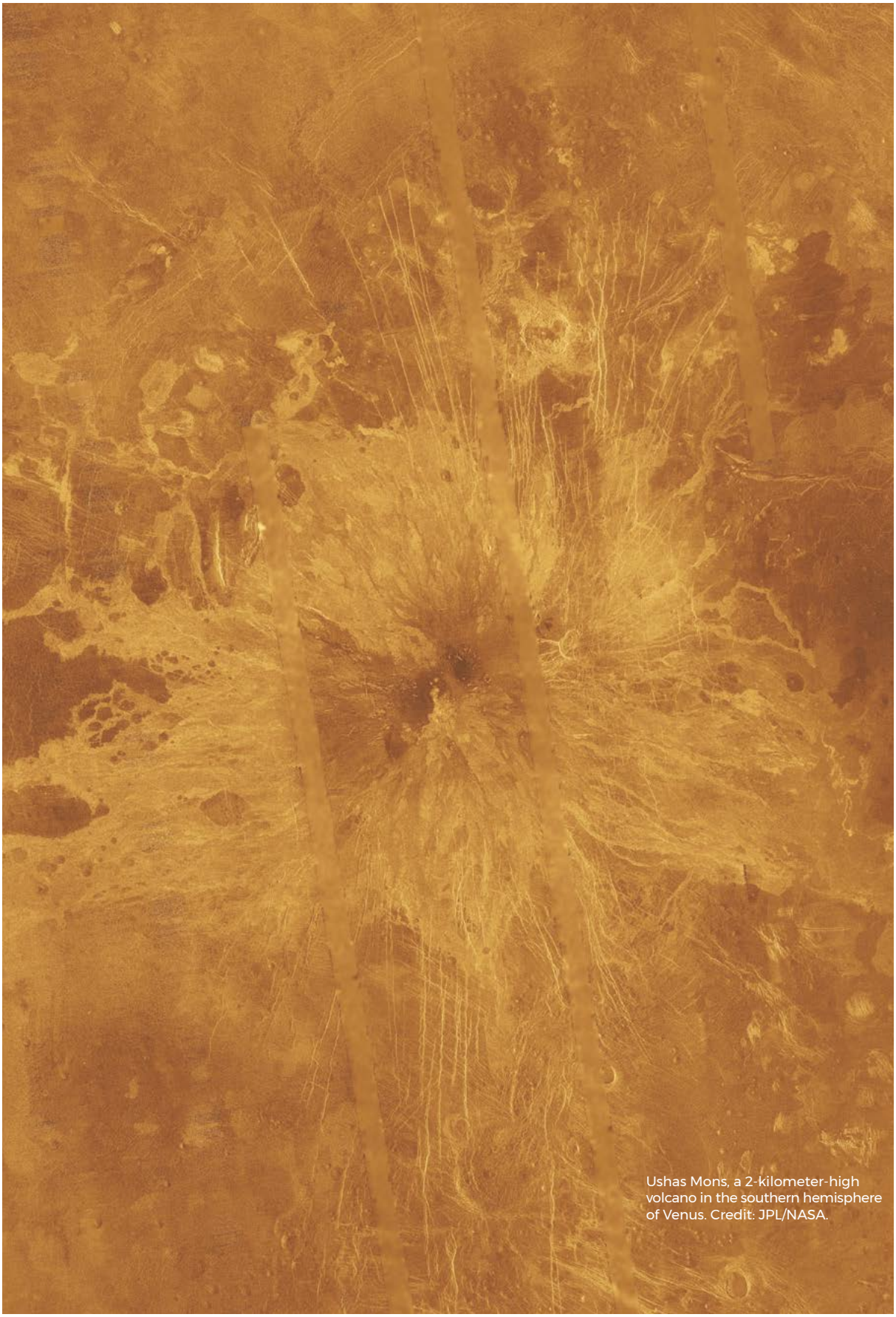


Dawn spacecraft, core structure
with ion propulsion system installed.
Credit: Orbital Sciences Corporation.

envision

EnVision mission will explore Venus with particular emphasis on the study of the state of geological activity and its relationship with the atmosphere. Italy contributes with one PI instrument.

EnVision has been selected as one of the three candidate missions in the framework of the fifth call for Medium-class missions (M5) in ESA's Cosmic vision 2015-2015 programme. The mission, if finally selected, is planned for launch in 2032. It consists on an orbiter for Venus with three science payloads (Synthetic Aperture Radar, Subsurface Radar Sounder, IR mapper and IR and UV spectrometer suite) and a Radio Science investigation.
EnVision will contribute to answer the crucial question on the reasons why Venus and Earth (the terrestrial planets) could have evolved so differently. It will determine the nature and current state of geological activity on Venus, and its relationship with the atmosphere. It will provide global image, topographic, and subsurface data at a resolution rivalling those available from Earth and Mars, inspiring the next generation of European scientists and engineers. The Italian contribution to EnVision is on the payload and consists in the Subsurface Radar Sounder, which is a low frequency nadir looking radar for subsurface measurements.



Ushas Mons, a 2-kilometer-high volcano in the southern hemisphere of Venus. Credit: JPL/NASA.

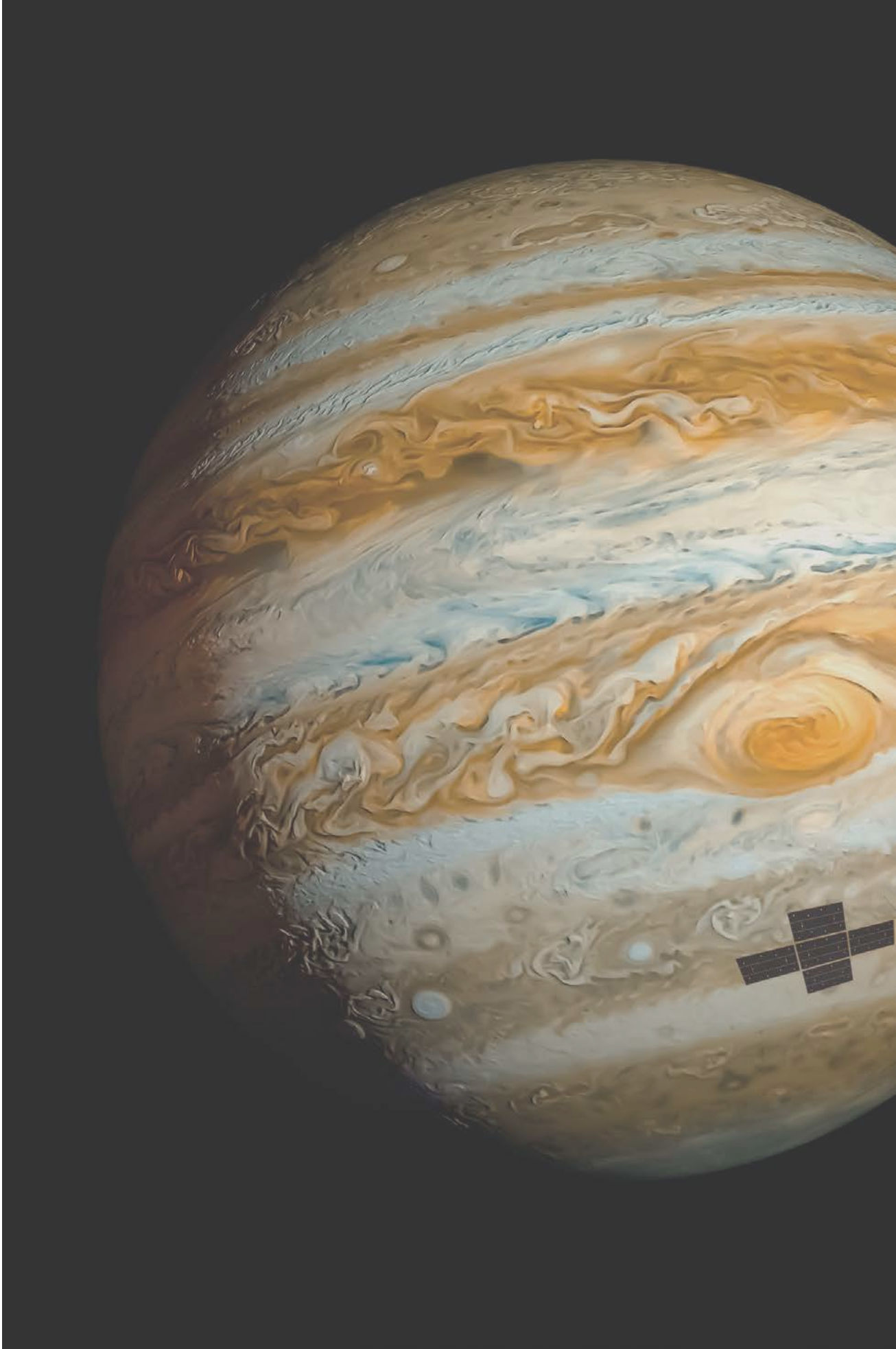
exomars

ExoMars includes two missions: one consisting of an Orbiter plus an Entry, Descent and Landing Demonstrator Module, launched in 2016. The other featuring a rover that will be launched in 2020.

ExoMars is an ESA scientific programme. Divided in two distinct missions, it will investigate the Martian environment, its geochemical and geophysical characteristics, including traces of past and present life on Mars and it will help gather information for future manned missions to the Red Planet. The first mission in 2016 had two main elements, the Trace Gas Orbiter (TGO) and Schiaparelli, the Entry, Descent and Landing Module (EDM), that unfortunately crashed on the surface on September 19, 2016. The TGO, with the Italian instrument NOMAD on board, is led by France and will study the gas composition of the atmosphere of Mars, looking for possible biological and geological activities.
The second mission, expected for 2020, will have a European rover and a Russian surface platform. The rover, led by the UK, combines the capacity of movement to that of drilling the surface up to 2 meters in depth. The main objective of the rover is to find evidence of past or present life, thanks to sample analysis drilled from the ground. The Russian surface platform will transport the German landing module, and once the rover will be released, it will study the surrounding environment.
Italy has a leadership position for both missions, with the responsibility over all the elements of the system. Italy is also responsible for the RROC in Turin, the center from which the rover will be operated. The camera, called CaSSIS (Colour and Stereo Scientific Imaging System), is designed by the University of Bern with the help of INAF-Astronomical Observatory of Padua and ASI. CaSSIS will provide stereo colour high resolution images of Martian regions. It will also support other instruments of the TGO in the search for biologically relevant gases, like methane. DREAMS (Dust Characterization, Risk Assessment and Environment

Analyser of the Mar tian Surface) is a suite of sensors to measure meteorological parameters (pressure, temperature, humidity, wind velocity and direction, solar radiation) and the electric field of Mars' atmosphere next to the Martian surface. It is a collaboration among ASI, INAF-Astronomical Observatory of Naples and University of Padua/ CISAS. AMELIA (Atmospheric Mars Entry and Landing Investigation and Analysis), will provide a model of Martian atmosphere. It is a collaboration with University of Padua/CISAS. MA_MISS (Mars Multispectral Imager for Subsurface Studies) is a spectrometer inside the rover's drill, that will analyze the geological and biological evolution of the subsurface of Mars, providing the context necessary for the sample analysis. It is provided by ASI under the scientific leadership of INAF-IAPS. INRRI (Instrument for landing-Roving laser Retroreflector Investigations) is a Cube Corner laser Retroreflector produced by ASI and the Italian National Institute for Nuclear Physics (INFN).

Next page: Artist's impression of the JUICE spacecraft, as of July 2017. Credit: ESA/ATG medialab.



juice

JUICE will explore the Jupiter system with particular emphasis on the planet's moons Ganymede, Callisto and Europa. Italy contributes with three instruments.

JUICE is the first Large-class mission in ESA's Cosmic Vision 2015-2025 programme and it is planned for launch in 2022 and it will arrive at Jupiter in 2029. The total mission duration is close to 11 years and with the currently envisaged launch opportunity, the nominal mission would end in June 2033.

It will spend at least three years making detailed observations of the biggest planet in the Solar System and of three of its largest moons, Ganymede, Callisto and Europa.

The moons are thought to harbour vast water oceans beneath their icy surfaces and JUICE will map their surfaces, sound their interiors and assess their potential for hosting life in their oceans. The studies of the Jovian atmosphere will be focused on the investigation of its structure, dynamics and composition. The focus on the Jovian magnetosphere will include an investigation of the three-dimensional properties of the magnetodisc and in-depth study of the coupling processes within the magnetosphere, ionosphere and thermosphere. Within the Jupiter's satellite system, JUICE will also study the moons' interactions with the magnetosphere, gravitational coupling and long-term tidal evolution of the Galilean satellites.

JUICE will have a complement of instruments on board that includes cameras and spectrometers, a laser altimeter, an ice-penetrating radar, a magnetometer, plasma and particle monitors, radio science hardware.

The Italian contribution to JUICE is relevant for the payload, in particular for the camera (JANUS), the spectrometer (MAJIS), the ice-penetrating radar (RIME) and the radio science experiments (3GM). The main italian industrial prime contractors are Leonardo S.P.A. (for JANUS and MAJIS) and Thales Alenia Space - Italia (for RIME and 3GM).

The mission has been adopted by ESA at the end of 2014 and the programme has successfully passed the Preliminary Design Review, ready to go toward the Critical Design Review expected at the end of this year.

mars express

Mars Express is an ESA mission at Mars. Italy participates in five of the seven scientific experiments: the PFS spectrometer, the MARSIS radar, the OMEGA imaging spectrometer, the ASPERA plasma instrument and the HRSC camera.

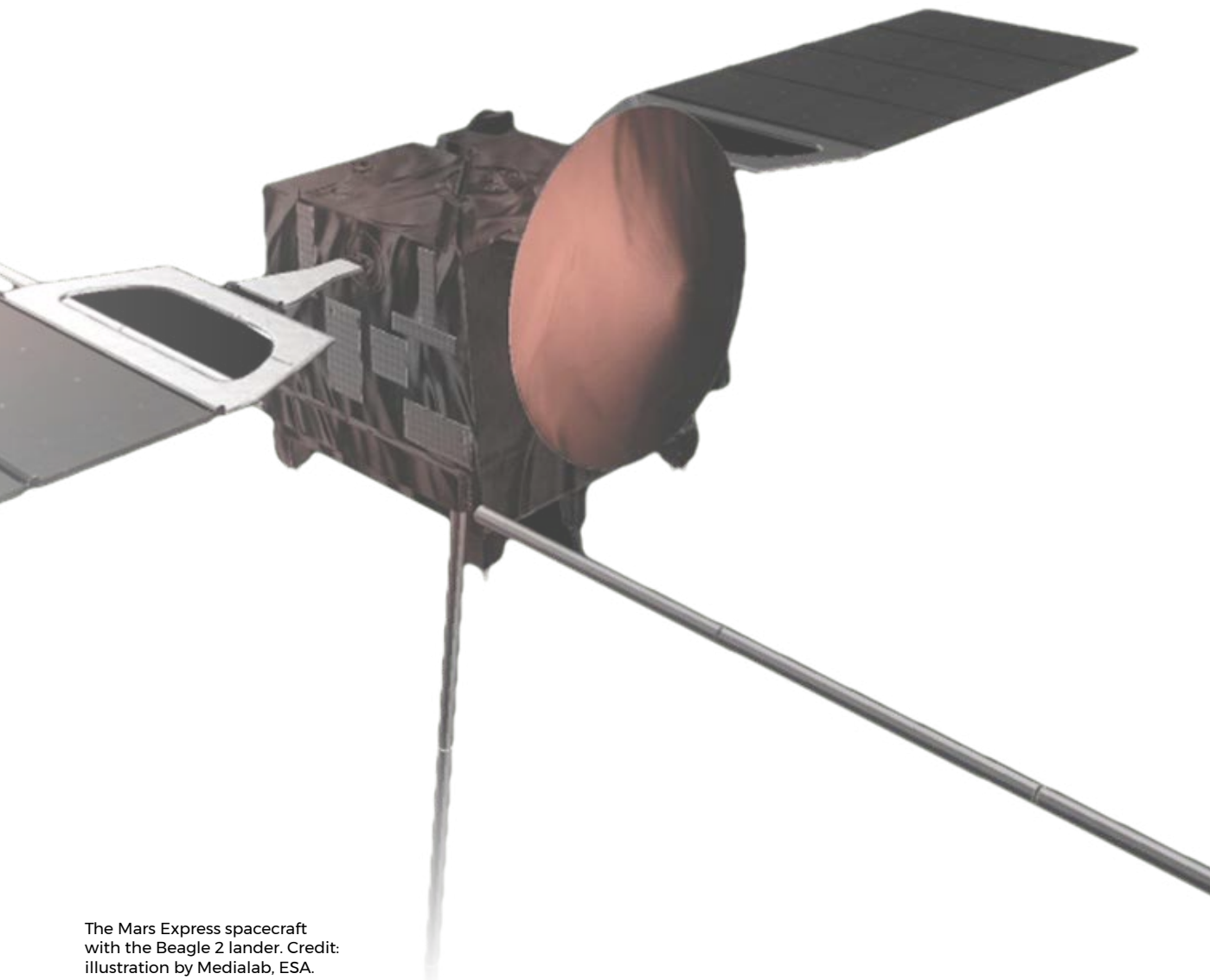
Mars Express is a space exploration mission conducted by ESA. Launched in 2003, Mars Express is still exploring the planet Mars, and was the first planetary mission attempted by the agency. In addition to global studies of the surface, subsurface and atmosphere of Mars with unprecedented spatial and spectral resolution, the unifying theme of the Mars Express mission is the search for water in its various states, everywhere on the planet, using different remote sensing techniques with each of its seven instruments. The exploration of the martian moons, Phobos and Deimos, is a secondary objective of the mission, achieved via multiple flybys of Phobos about every five months.

Italy participates in five of the seven scientific experiments: the PFS spectrometer, the MARSIS radar, the OMEGA imaging spectrometer, the ASPERA plasma instrument and the HRSC camera. The first two experiments have been developed under Italian leadership, OMEGA and ASPERA see a significant Italian contribution both in hardware and science, while the participation in HRSC is solely scientific.

The Planetary Fourier Spectrometer (PFS) has made the most complete map to date of the chemical composition of the atmosphere, revealing the presence of methane. If confirmed by the Exomars Trace Gas Orbiter mission, this could indicate geological processes that are still active today, or even active biochemical processes. PFS also produced temperature maps from the surface up to an altitude of about 50 km.

The subsurface sounding radar (MARSIS) identified the presence of water-ice deposits underground and revealed the internal structure of polar deposits. The radar has also been probing the upper atmospheric layer (the ionosphere) and shown interesting structures associated with localised magnetic fields in the Martian crust, which originate near the surface of Mars. The Infrared Mineralogical Mapping Spectrometer (OMEGA) has provided unprecedented maps of water-ice and carbon dioxide-ice in the polar regions. It also determined that the presence of phyllosilicates in some areas of the surface is a sign that abundant liquid water existed in the early history of Mars.

The Energetic Atoms Analyser (ASPERA) has identified solar wind scavenging of the upper atmospheric layers as one of the main culprits of atmospheric degassing and escape. The High-Resolution Stereo Camera (HRSC) has shown very young ages for both glacial and volcanic processes, from hundreds of thousands to a few million years old, respectively.

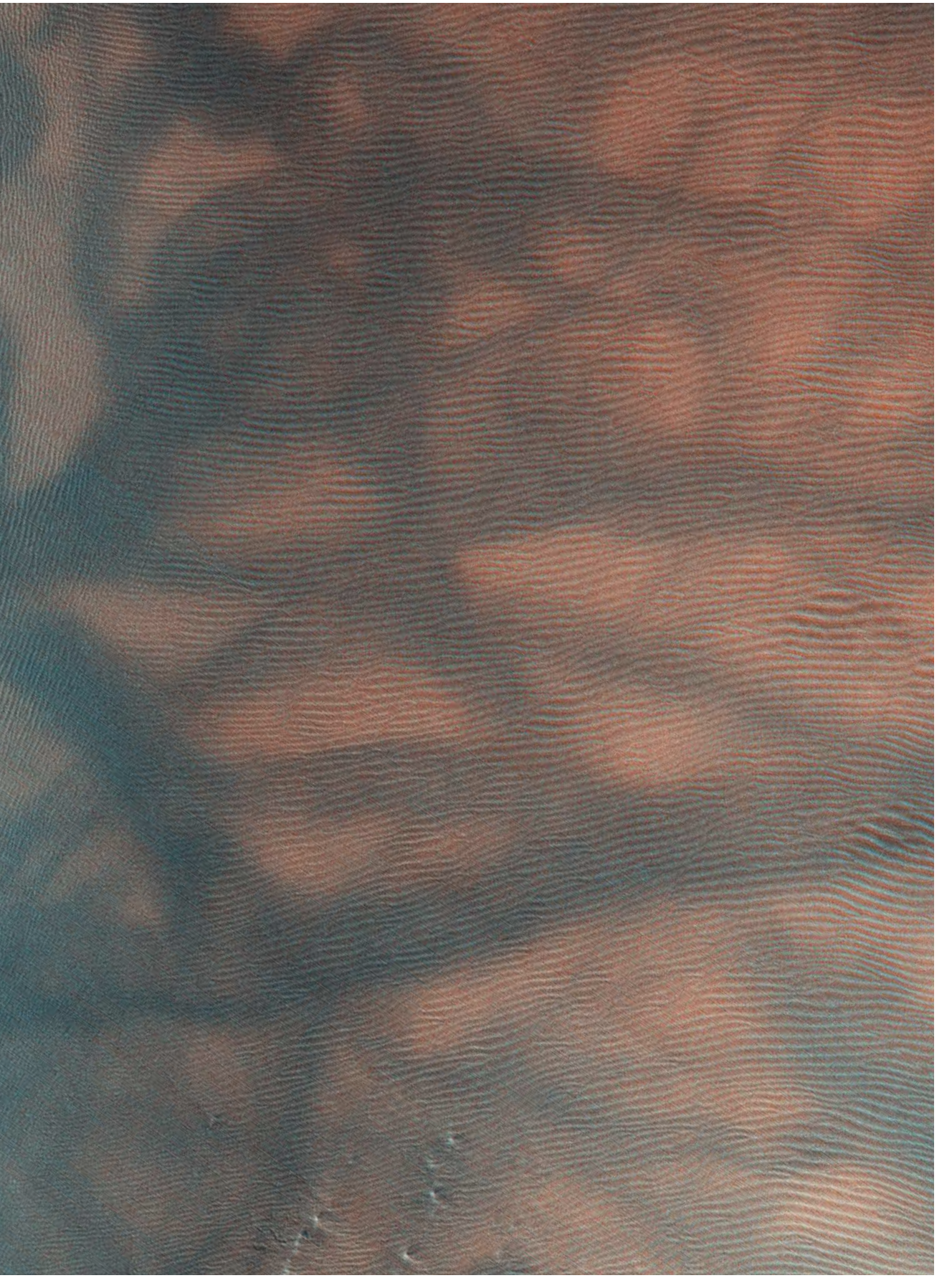


The Mars Express spacecraft with the Beagle 2 lander. Credit: illustration by Medialab, ESA.

mro

MRO is a NASA planetary mission carrying SHARAD, an Italian low-frequency radar that probes the Martian subsurface to depths of up to 1 km to detect ice or water.

MRO (Mars Reconnaissance Orbiter) is a NASA planetary mission that aims to determine whether life ever arose on Mars, to characterize the climate and geology of the planet, and to prepare for human exploration.
The payload consists of six scientific instruments for the study of the atmosphere, the surface and the subsurface from orbit. The probe was launched in August 2005 and began operations at Mars in early 2006. The mission has been extended well past its original intended lifetime and it is expected to continue at least until 2019.
ASI provided the SHARAD facility instrument, a low-frequency radar that can probe the Martian subsurface to depths of up to 1 km to search for ice or water. SHARAD has studied the fine internal layering of the Martian polar caps with unprecedented detail, providing insight into its geological history and climate cycles on Mars. It also detected debris-covered glaciers at mid latitudes, which will constitute a fundamental resource for future colonists. It also probed young lava flows and revealed retreating ice sheets in parts of the northern plains of Mars.



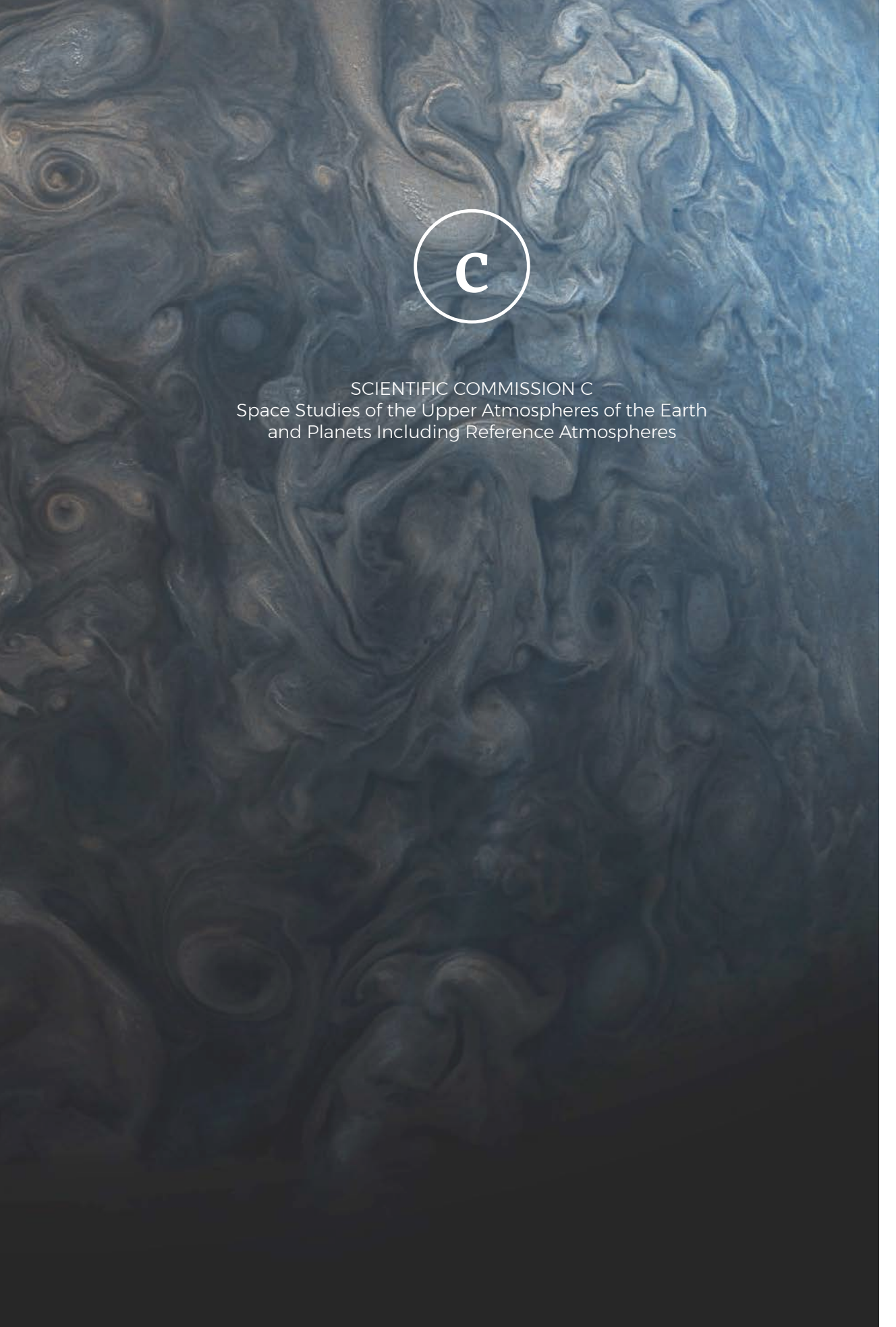
rosetta

Rosetta is the ESA cornerstone mission devoted to the study of comet 67P/ Churyumov-Gerasimenko. Launched in 2004, the mission ended in September 2016. Italy was participating to several instruments: the imaging spectrometer VIRTIS, the camera OSIRIS, the dust analyzer GIADA and SD2, the driller on-board the lander.

Rosetta, a cornerstone ESA mission, has been launched on March 2, 2004 and orbited for two years the comet 67P/ Churyumov-Gerasimenko. The comet was reached on 6 August 2014, after two successful fly-bys with the asteroids Steins (2008) and Lutetia (2010). On 12 November 2014, Rosetta's lander Philae, a joint realization by DLR-CNES-ASI aimed at the detailed in-situ analysis, was deployed on the surface. Rosetta has been following and studying the comet through perihelion (August 2015) with its remote sensing and in-situ instruments and continued until the end of the extended mission, September 30, 2016, with a spectacular hard-landing on the surface. The observations performed by Rosetta changed many of our views on the nature of comet nuclei and shed light on their formation processes.

Italy contributed or participated to various instruments. The visible and infrared thermal imaging spectrometer VIRTIS, under the responsibility of INAF-IAPS, was devoted to the study of the composition of the surface and the coma of the comet, and the derivation of surface temperature. OSIRIS was a camera system operating in the near ultraviolet, visible and near infrared range. It was composed of two independent cameras, wide angle and narrow angle, and the wide-angle camera has been built under the responsibility of the University of Padua/CISAS. The dust analyzer GIADA, devoted to the study of the dust in the coma, has been built by the Parthenope University (Naples) and INAF-Astronomical Observatory of Naples and is managed by INAF-IAPS. SD2, the driller and sample retriever on-board the lander Philae, has been built by the Politecnico of Milan. The Italian instruments provided important results on the composition of the surface and on the gas, dust in the coma and on the physical processes acting on the nucleus.

Previous page: The Russell Crater dune field seasonally covered by carbon dioxide frost. Credit: NASA.



C

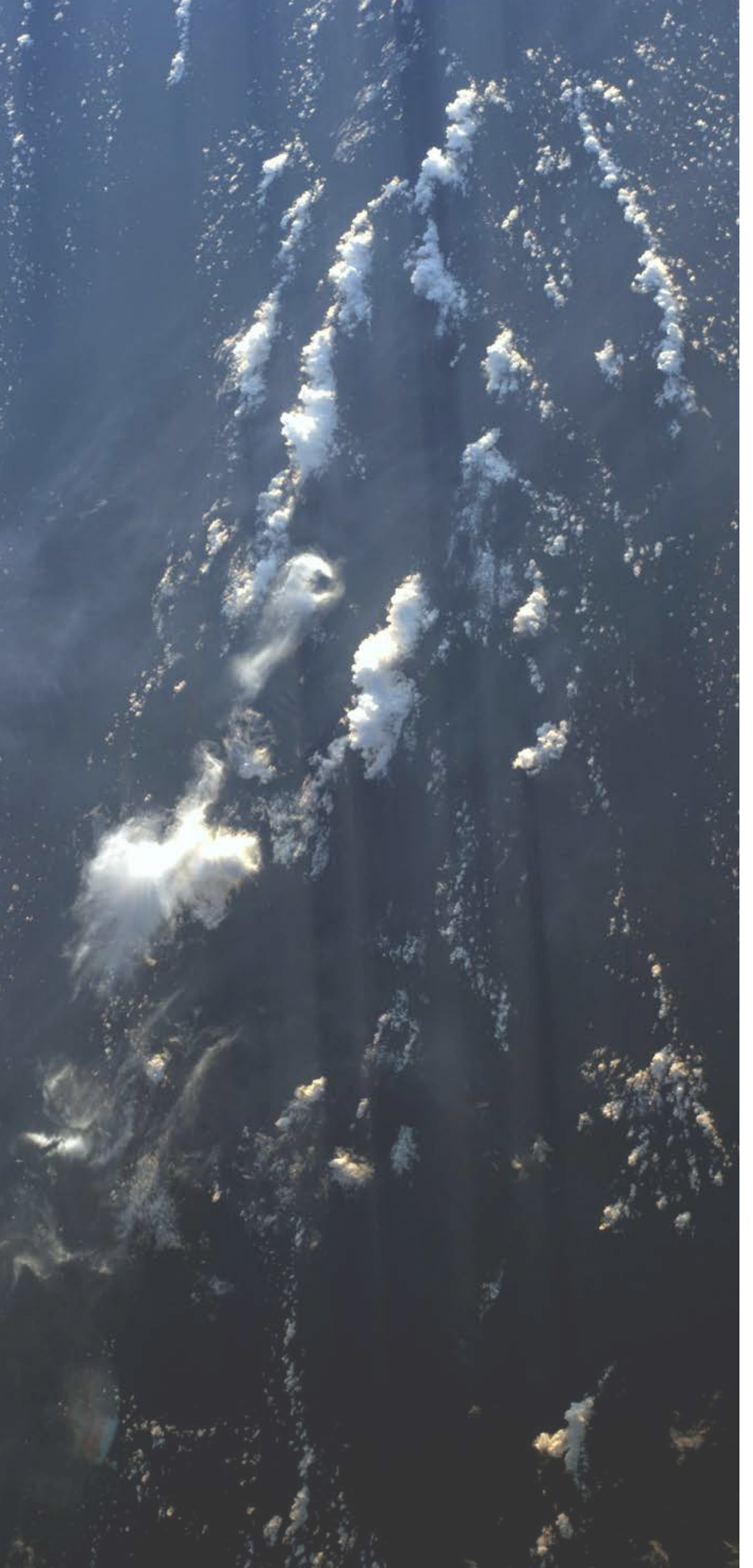
SCIENTIFIC COMMISSION C
Space Studies of the Upper Atmospheres of the Earth and Planets Including Reference Atmospheres

Previous page: A complex storm on Jupiter. Credit: NASA/SwRI/MSSS/Gerald Eichstädt/Seán Doran.

cses

A scientific mission to monitor perturbations in the ionosphere, the magnetosphere and the Van Allen belts due to electromagnetic phenomena and to study their correlation with seismic events. CSES operates in a Sun-syncronous circular orbit at an altitude of 500 km.

CSES (China Seismo-Electromagnetic Satellite) is a mission of China National Space Administration and ASI. The satellite, 3-axis attitude stabilized, is based on the Chinese CAST2000 platform. It operates in a 98° Sun-syncronous circular orbit at an altitude of 500 km, since February 2, 2018, and its expected lifetime is 5 years. The main objectives of the mission are to monitor perturbations in the ionosphere, the magnetosphere and the Van Allen belts due to electromagnetic phenomena of natural and anthropogenic origin, and to study their correlation with seismic events. Furthermore, the CSES mission allows to study the physical properties of the ionospheric plasma at the satellite altitude, to characterize the ionosphere in quiet and disturbed conditions. Cosmic and solar physics studies, namely Coronal Mass Ejections (CMEs), solar flares, solar energetic particles (SEPs), cosmic ray modulation, X-rays variation are other relevant topics that can be covered by the mission as well. Italy participates with several universities and research institutes. the Italian National Institute for Astrophysics (INAF) and the Italian National Institute for Nuclear Physics (INFN) are directly involved in instrumental development and test respectively. The High-Energy Particle Detector (HEPD), developed by INFN and several Italian universities, detects high energy electrons, protons and light nuclei. Its main objective is to measure the increase of the electron and proton flux due to short-time perturbations of Earth's environment caused by cosmic, solar, and terrestrial phenomena. The energy range explored is 5-100 MeV for electrons and 15-300 MeV for protons.
Four Electric Field Detectors (EFD) have been specifically designed to monitor electromagnetic fields (from DC to 3.5 MHz) for the study of ionospheric disturbances possibly related to seismic activity and earthquake preparation mechanisms. In particular, the mission aims at analyzing the temporal correlation between seismic events and the occurrence of electromagnetic perturbations. The environmental plasma parameters, including ion density, ion temperature, ion drift velocity, ion composition and ion density fluctuation, are monitored by the CSES Plasma Analyser (PA) and by two Langmuir probes (Lp) developed by CSSAR-CAS. The EFDs have been designed in collaboration between the Lanzhou Institute of Physics and the Italian National Institute for Nuclear Physics (INFN-Rome Tor Vergata) and INAF-IAPS. Two versions of EFD with different electronics have been developed by Chinese and Italian teams and their functionalities compared to each other and tested at the Plasma Chamber at INAF-IAPS as well as the Plasma Analyzer and Langmuir probes, in order to check their sensitivity in detecting the ionospheric plasma parameters. Other CSES satellites are planned to be launched starting from 2020. Italian collaboration will be renewed for instrumental development and calibration, and for the data analysis.



Clouds spotted during a pass over the Earth by the crew aboard the ISS. Credit: NASA.

duster

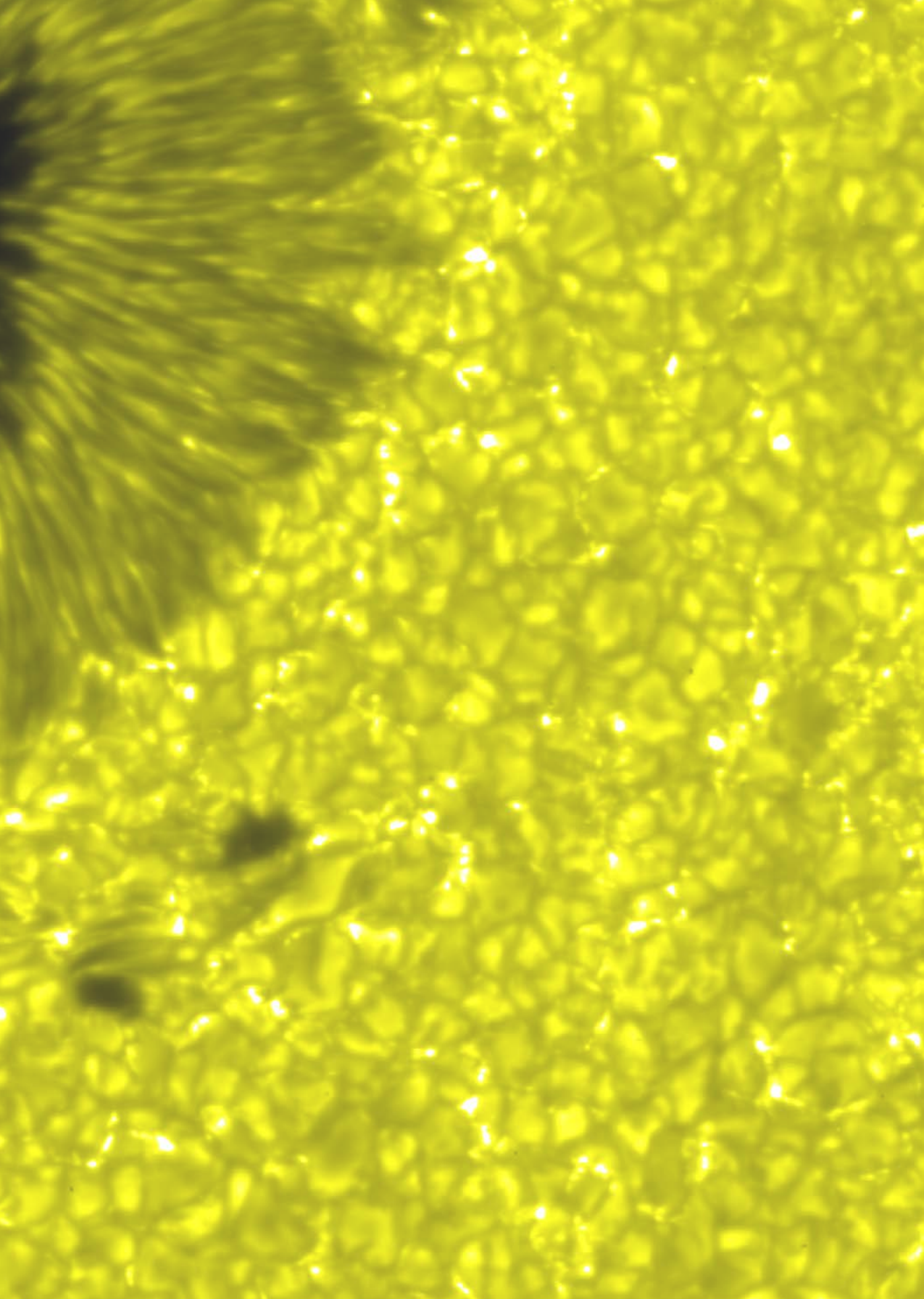
DUSTER is aimed at uncontaminated collection, retrieval and laboratory analysis of stratospheric solid aerosol particles from the upper stratosphere. The approach implies: in-situ particles collection and store in controlled conditions; sample recovering; and laboratory analyses.

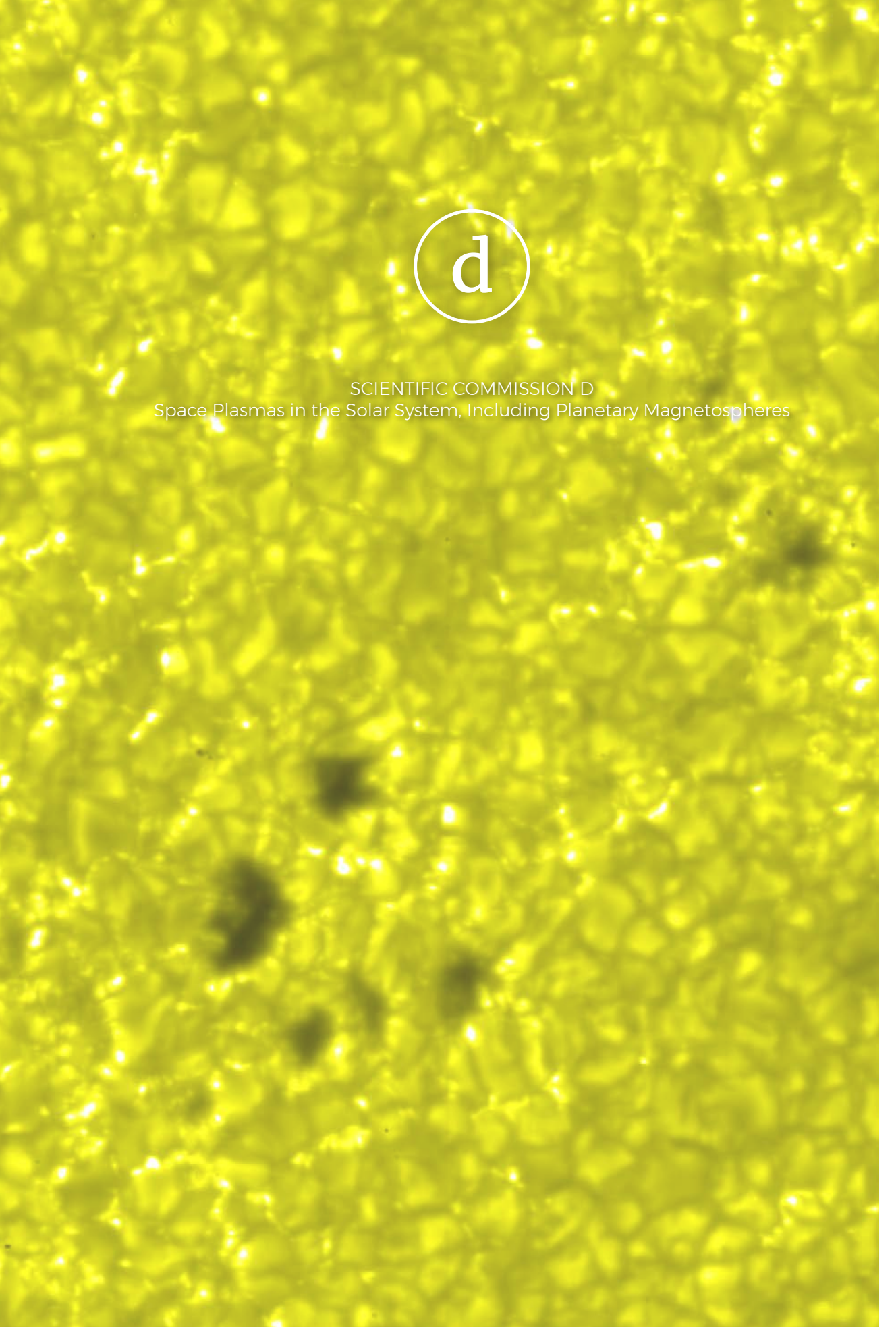
DUSTER (Dust in the Upper Stratosphere Tracking Experiment and Retrieval) is a multinational project aimed at collection and retrieval of solid micron-submicron dust from upper stratosphere (altitude >30km). Dust particles are collected and analysed in laboratory by state of the art analytical techniques for a physico-chemical characterization and disentanglement of the terrestrial and extra-terrestrial component. DUSTER results are related with planetology, astrophysics and atmospheric physics. Solid and condensed sub-micrometre particles present in the Stratosphere are a mix of terrestrial and extra-terrestrial dust. The extra-terrestrial component is highly represented in the upper Stratosphere while volcanic eject residues are more prevalent than in lower Stratosphere. The main and most ambitious goal is the collection and characterization of Solar System debris particles <3 microns not sampled by the stratospheric aircraft/NASA collection facility. In addition, no other instrument/facility does currently sample the upper stratosphere. DUSTER provides a record of the amount of solid aerosols, their size distribution, shapes and chemical properties in the upper stratosphere, for particles down to about 0.5 micron in size. Two fully successful DUSTER flights were performed from the Stratospheric Base in Svalbard Islands, Norway in June 2008 and July 2009, supported by ASI and a third flight was performed in 2011 from Kiruna, Sweden, thanks to CNES. The National Antarctic Research Project (PNRA) funded a DUSTER launch campaign from Antarctica, which took place at the end of 2016. Compositions, morphologies and structure of the analysed particles, which were randomly collected in the upper Stratosphere during the 2008 and 2011 flights, are consistent with ultra-rapid, non-equilibrium processes and fragmentation of extra-terrestrial bolides entering the Earth atmosphere. Thanks to DUSTER for the first time extra-terrestrial dust from these sources has been intercepted while settling in the Earth's Stratosphere. The project has been supported by ASI, PNRA, CNES, the Italian Ministry of the Environment, the Italian Ministry of Instruction, Research and University, the Foreign Ministry and Regione Campania. DUSTER could become a permanent facility for extra-terrestrial dust collection in the upper Stratosphere. The Italian man power contribution is assured by INAF-IAPS and Dipartimento di Scienze e Tecnologie, Parthenope University (Napoli).

juno

Juno's goals are to understand the evolution of Jupiter, to look for a solid core, to map its magnetic field, to measure water and ammonia in the planet's deep atmosphere and to observe its auroras.

Juno is a NASA New Frontiers mission devoted to an in-depth study of Jupiter, launched in 2011. Juno scientific objectives are the study of the planet's magnetosphere, its radiation environment and the electromagnetic fields, the auroras, the atmospheric composition and structure, the gravitational field and the planet interior.
Italy is participating with two instruments funded by ASI: JIRAM, led by INAF-IAPS, and KaT, proposed by a team led by the University La Sapienza in Rome. JIRAM (Jovian InfraRed Auroral Mapper) is an imager and a spectrometer able to acquire images and spectra in the range of wavelengths 2-5 μm to study infrared auroras and the planet's atmosphere. KaT (Ka-Band Translator) is the K-Band transponder dedicated of the Gravity Science experiment.





d

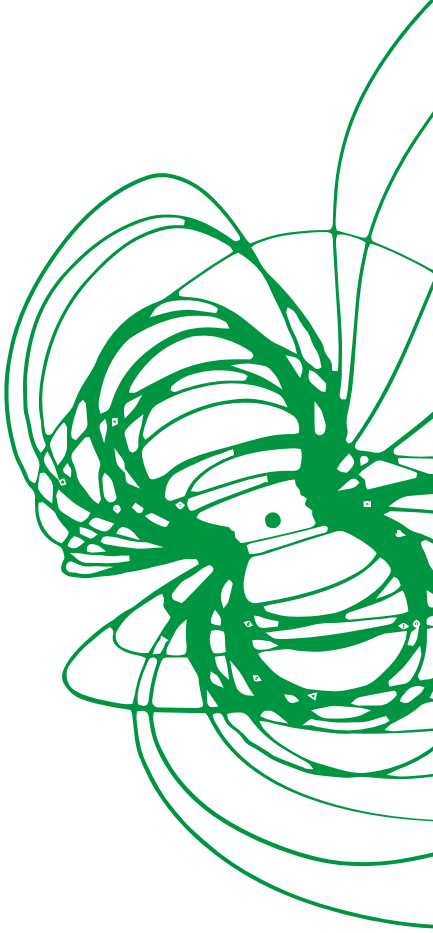
SCIENTIFIC COMMISSION D
Space Plasmas in the Solar System, Including Planetary Magnetospheres

Previous page: Bright threads of solar materials visible over the sunspots. Credit: NASA/JAXA.

aspiics

The ASPIICS coronagraph is the guest payload of the ESA's Proba-3 technological mission. ASPIICS is formed by two spacecrafts in flight formation and is developed by a European consortium including ASI.

ASPIICS is a coronagraph imaging the solar corona out to 3 solar radii, under development for ESA Proba-3 technological mission, which is devoted to prove high-precision formation-flight technologies. A pair of satellites will fly together maintaining a fixed configuration as a large rigid structure in space. The two satellites will form a 150-m long solar coronagraph to study the Sun's faint corona closer to the solar limb than has ever been achieved before from space in visible light. ASI and INAF, as part of a large European consortium, are responsible for coronagraphic calibrations, optimization of the occulter and for contributing the spectral filters. The launch is foreseen in 2020.



cluster

The first space mission composed by a fleet of four spacecrafts which provided in situ tridimensional measurements permitting significant advance in the knowledge of fundamental space plasma processes.

CLUSTER is an ESA Horizon 2000 cornerstone mission launched in 2000 and extended until December 31, 2018. CLUSTER comprises four spacecrafts, flying in a tetrahedral formation, which carry an identical set of instruments for the in situ measurements of charged particle and fields. Italy, in the framework of an international collaboration, contributed to the development of the mechanics and the onboard SW of the Cluster Ion Spectrometry (CIS) experiment. CLUSTER scientific data analysis in Italy pertains to the study of fundamental plasma processes as magnetic reconnection and turbulence occurring in the key regions of the magnetosphere.

The explosive realignment of magnetic fields. Credit: NASA Goddard/SWRC/CCMC/SWMF.

hinode

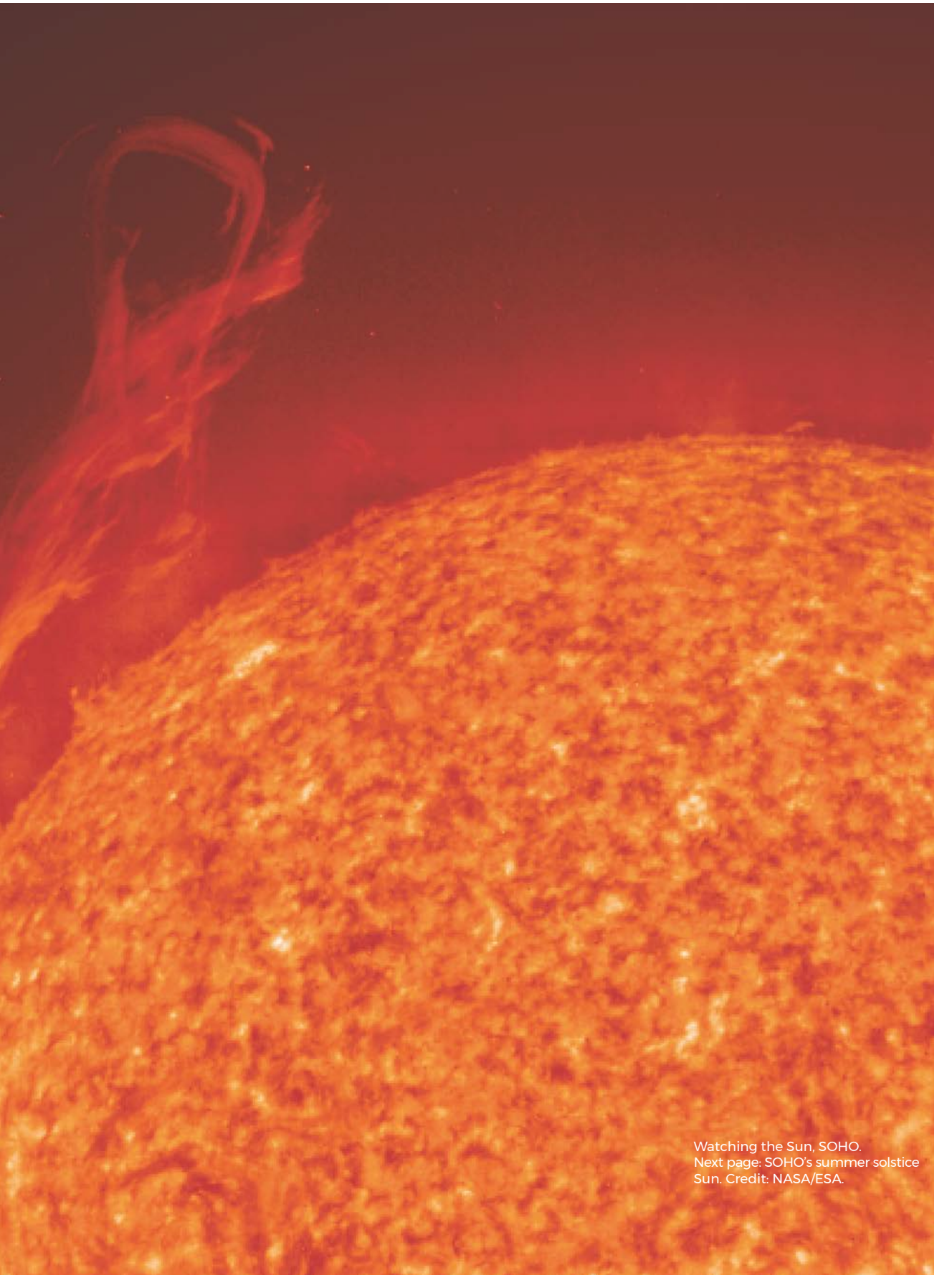
Hinode is a Japanese mission observing the Sun in the optical, EUV and X-ray band. Italy has worked on the instrument calibration and studied the magnetic photosphere and the hot and dynamic corona.

Hinode is a JAXA solar mission (Japan), with USA and UK contributions, devoted to study solar activity, since 2006. A set of instruments in the optical (SOT), EUV (EIS) and X-ray band (XRT) are on-board Hinode. INAF has been directly involved in the calibration of the XRT telescope, with its XACT/OAPA laboratories. Hinode scientific data analysis in Italy pertains to the study of the fine magnetic dynamics and structure of the active photosphere (SOT), of the eruptions and holes, the hot intermittent components and the fine thermal structure of the corona (EIS, XRT). The transit of Venus observed also with the XRT has been used to probe the upper planetary atmosphere.

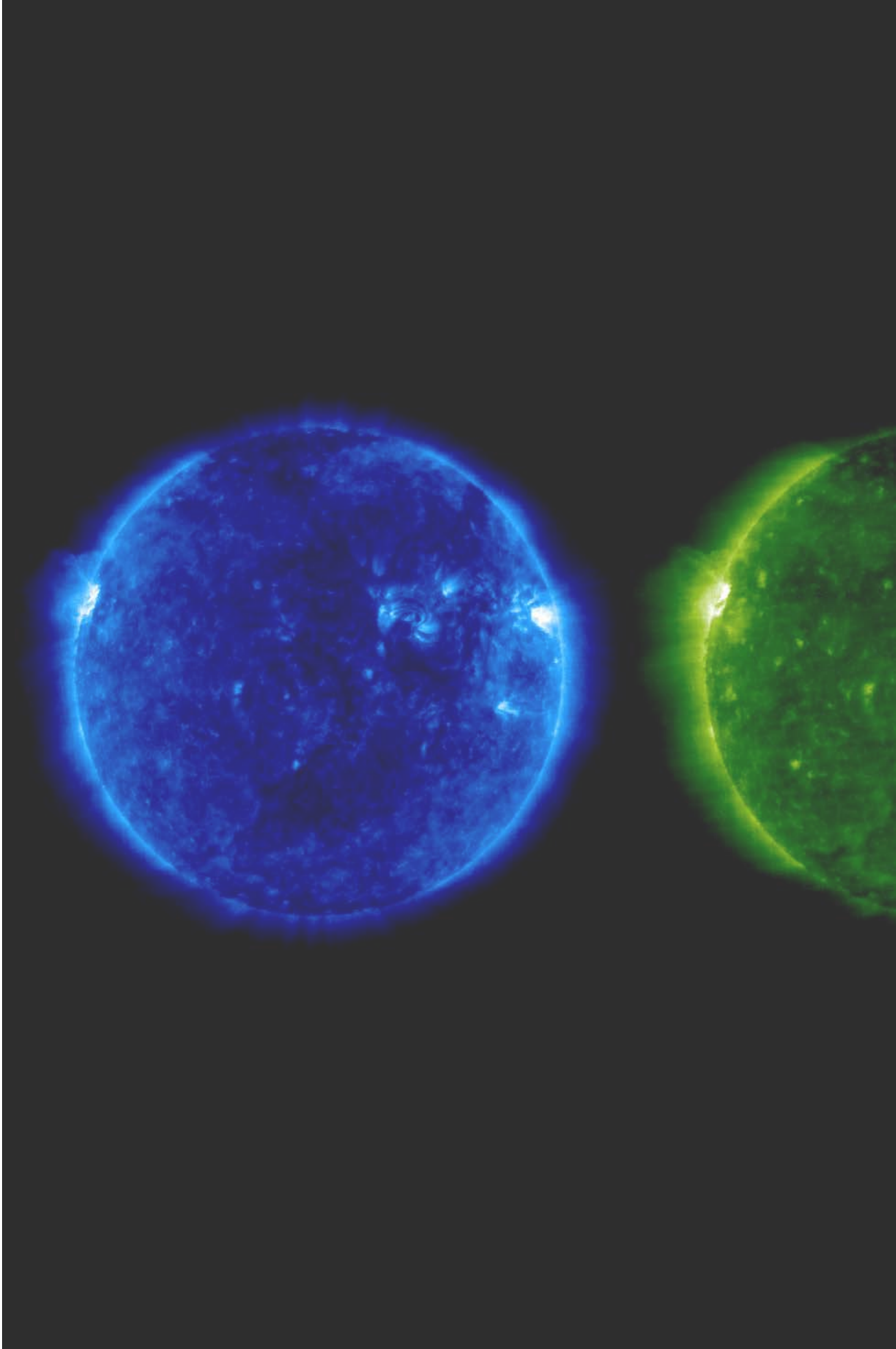
score

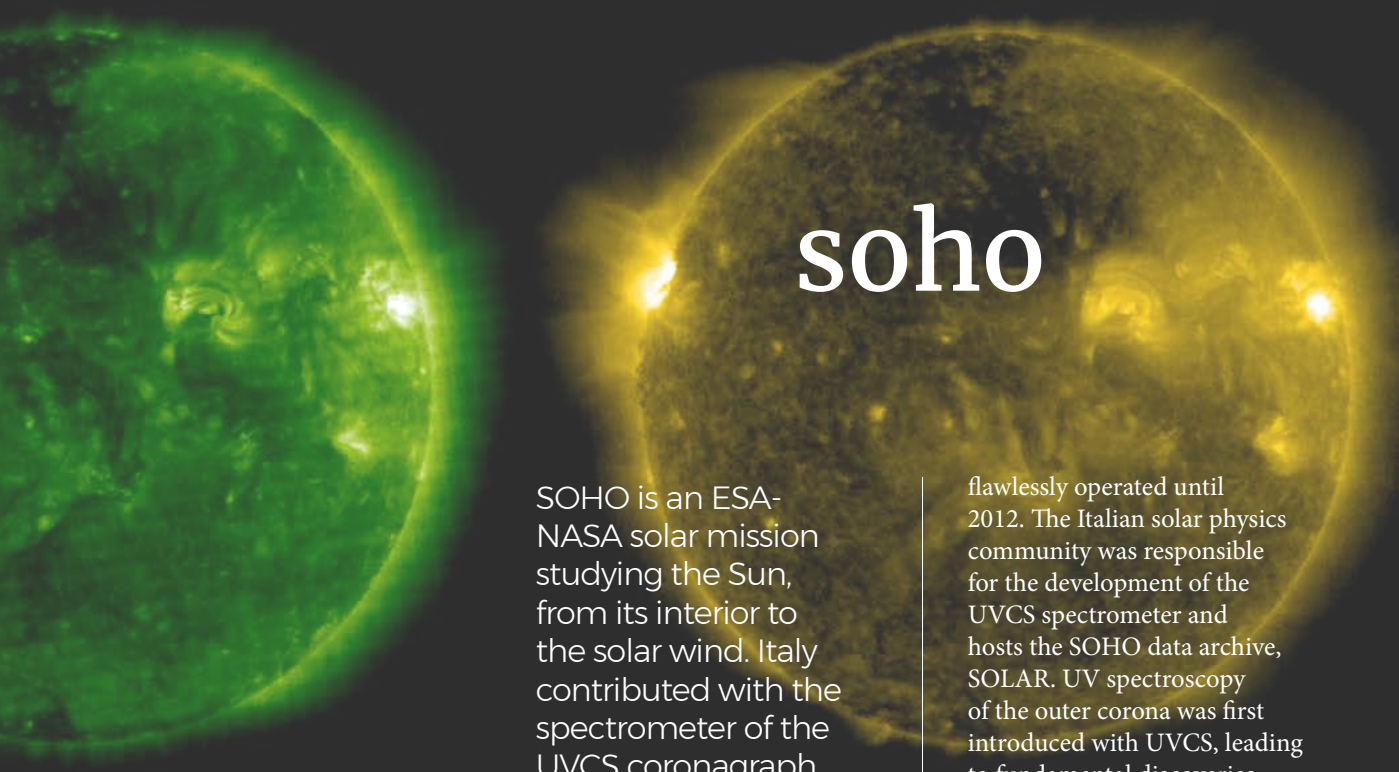
Prototype of the Solar Orbiter coronagraph Metis, SCORE was successfully launched in 2009 as part of the NASA suborbital flight program HERSCHEL, with a second flight foreseen in 2018.

SCORE, prototype of the Solar Orbiter coronagraph Metis, was successfully launched in a suborbital flight in 2009 from the White Sands Missile Range, US. SCORE is part of the HERSCHEL program approved by NASA and led by the Naval Research Laboratory, US. Its second flight, in 2018, is in preparation. SCORE is the first multi-band coronagraph obtaining simultaneous images of the solar corona in polarized visible light and in the UV and EUV Ly alpha lines of H and He, respectively. In the 2009 flight, the first maps in Helium emission and abundance of the solar corona have been obtained. SCORE, an INAF-ASI instrument, has been developed by INAF-Astronomical Observatory of Turin and by the University of Firenze.



Watching the Sun, SOHO.
Next page: SOHO's summer solstice Sun. Credit: NASA/ESA.





soho

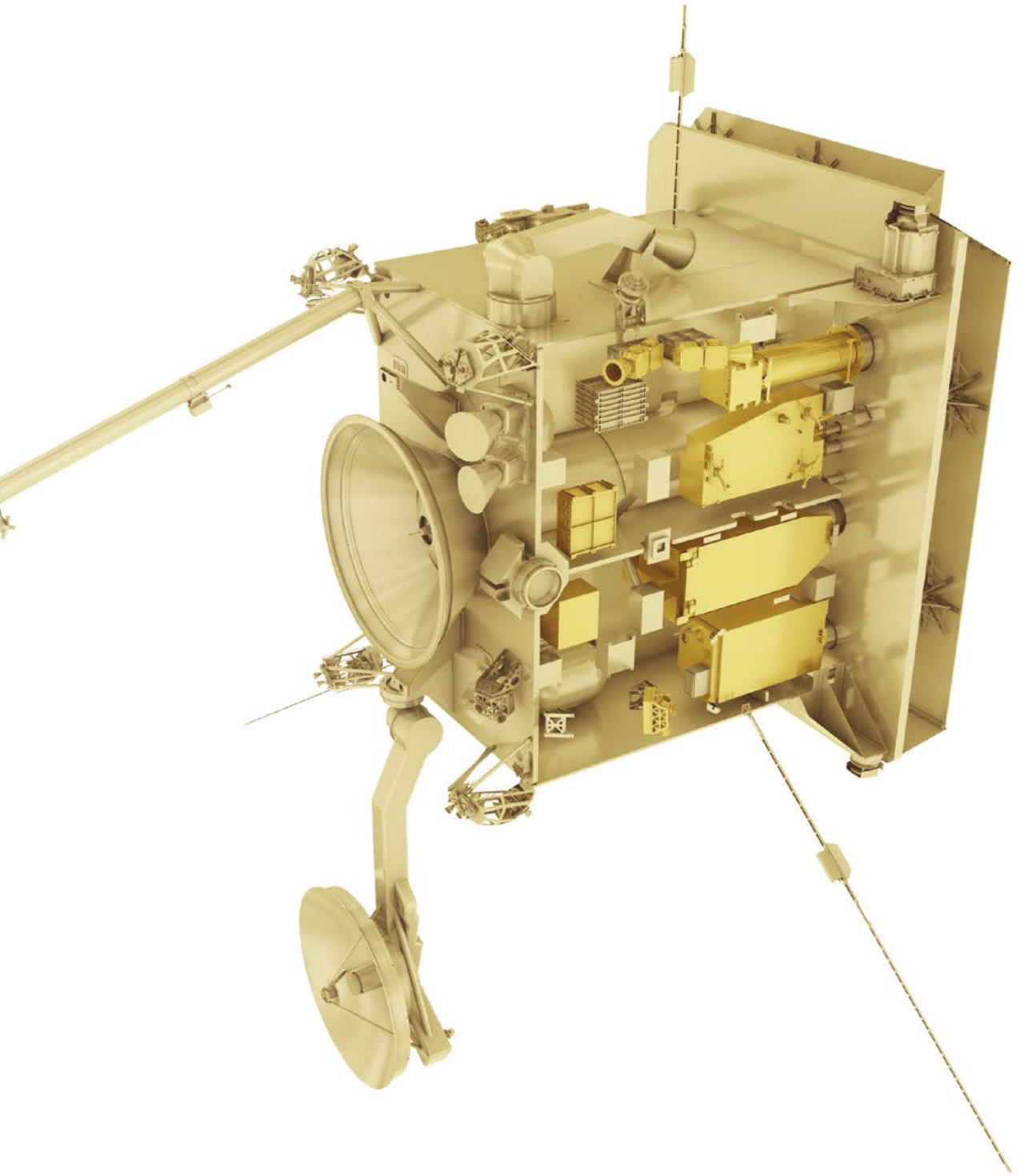
SOHO is an ESA-NASA solar mission studying the Sun, from its interior to the solar wind. Italy contributed with the spectrometer of the UVCS coronagraph and hosts SOLAR, one of SOHO data archives.

The solar observatory SOHO, an ESA-NASA mission launched in 1995, monitors the Sun from L1 since 1996 with twelve instruments, in part still operative. The SOHO UltraViolet Coronagraph Spectrometer, UVCS, a NASA-ASI collaboration, flawlessly operated until 2012. The Italian solar physics community was responsible for the development of the UVCS spectrometer and hosts the SOHO data archive, SOLAR. UV spectroscopy of the outer corona was first introduced with UVCS, leading to fundamental discoveries on energy deposition in the coronal wind and on solar eruptions. Data are at present actively studied also in view of developing planning tools for Solar Orbiter and for space weather forecast.

solar orbiter

Selected as the Cosmic Vision M1 mission, Solar Orbiter is ESA's primary contribution to ILWS. It will contribute to reveal how the Sun creates and drives the heliosphere.

Solar Orbiter (European Space Agency) provides the unique opportunity to discover the fundamental links between the magnetized solar atmosphere and the dynamics of the solar wind that, ultimately, is the source of space weather. In October 2011, Solar Orbiter was selected as the Cosmic Vision M1 mission and entered the implementation phase in 2012. The Solar Orbiter unique mission profile allows the investigation of the Sun at very high spatial resolution by taking advantage of a close-by vantage point at a perihelion of 0.28 AU and of an orbital inclination exceeding 30°, towards the end of the mission, which will allow to observe the polar regions from above. These observations from remote, together with the measurements provided by the in-situ instruments will represent the necessary ingredients to unravel the mechanisms at the basis of generation and heating of the solar corona. The scientific payload includes the Metis coronagraph, consisting in a coronal imager working in both polarized VL and UV light. This coronagraph has an Italian PIship (INAF-Astronomical Observatory of Turin) and is realized in Italy under ASI contract. Germany (MPS) and Czech Republic (Academy of Sciences) provide a HW contribution. Metis can simultaneously image the visible and ultraviolet emission of the solar corona and diagnose, with unprecedented temporal coverage and spatial sampling element (down to about 4000 km), the structure and dynamics of the full corona in the range from 1.6 to 3.0 solar radii at minimum perihelion (0.28 AU), and from 2.8 to 5.5 solar radii at 0.5 AU. This region is crucial in linking the solar atmosphere phenomena to their evolution in the inner heliosphere, and the study of its properties is very important in meeting the Solar Orbiter fundamental science goals. The scientific payload of Solar Orbiter also includes Solar Wind Analyser (SWA), a plasma analyser suite with 4 sensors and a single, common Detector Processing Unit (DPU). SWA will measure particle velocity distribution functions of protons, helium, minor ions and electrons of the solar wind with unprecedented sampling time resolution, of the order of the proton scales. There is also a participation of the group of Genoa (University, CNR/SPIN) to the Spectrometer Telescope for Imaging X-rays (also supported by ASI). The italian contribution (CoIship) consists in the flight software for flare detection and real-time science data analysis.

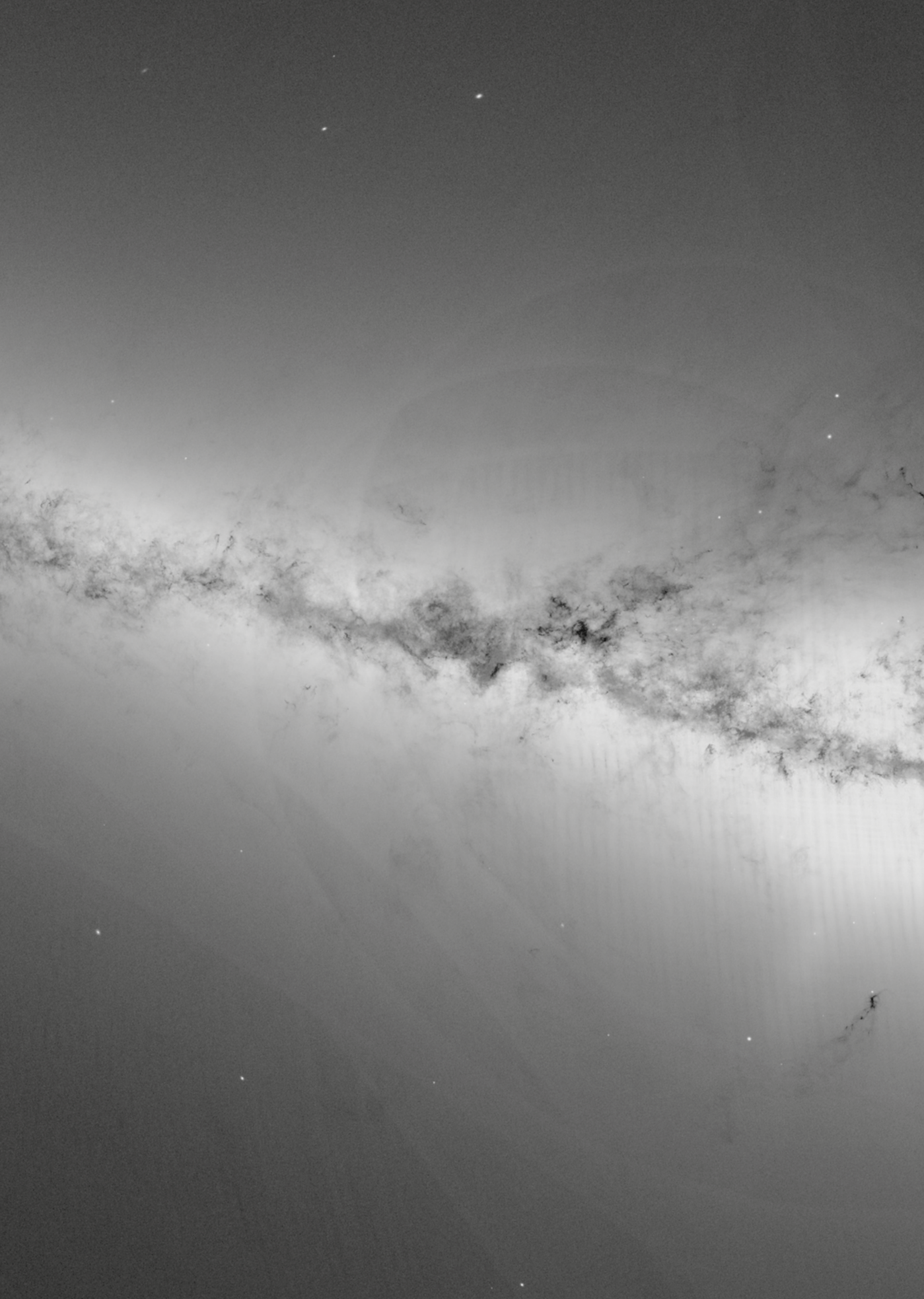


stereo

Two space-based observatories, one ahead of Earth in its orbit, the other trailing behind. Their goal is to study the structure and evolution of solar storms.

STEREO has been launched in 2006. It consists of two spacecrafts that separate from Earth in opposite directions at a rate of 22° per year, in order to obtain a stereoscopic view of the solar atmosphere. The two spacecrafts are equipped with the same set of instruments for remote sensing and in situ observations of the Sun and of the heliosphere. The Italian solar physics community is involved in the analysis of data from the instruments SWAVES and IMPACT, finalized to the investigation of turbulence in the solar wind and particle acceleration, and from the instruments COR2 and HI, designed to study the solar wind acceleration with correlation tracking techniques and the physics of coronal mass ejections.

Previous page: The payload accommodation onboard Solar Orbiter. Credit: ESA.



SCIENTIFIC COMMISSION E
Research in Astrophysics from Space

Previous page: An all-sky view of our Milky Way Galaxy, obtained by the Gaia satellite. Credit: ESA/Gaia/DPAC.

agile

An X-ray and gamma-ray astronomical satellite of the Italian Space Agency.

AGILE is an ASI space mission dedicated to high-energy astrophysics. The main goal is the simultaneous detection of hard X-ray and gamma- ray radiation in the energy bands 18-60 keV and 30 MeV - 30 GeV with optimal imaging and timing capability. The AGILE satellite was launched on April 23, 2007 from Sriharikota (India) in an equatorial orbit. Since then, AGILE contributed very significantly to the study of Galactic and extragalactic cosmic sources. We mention here the surprising discovery of transient gamma-ray emission and extreme particle acceleration in the Crab Nebula, the direct evidence for hadronic cosmic-ray acceleration in Supernova Remnants, the detection of intense gamma-ray flares from blazars (e.g., 3C 454.3 and 3C 279), observations of pulsars and pulsar wind nebulae, the discovery of transient gamma-ray emission from the microquasars Cygnus X-3 and Cygnus X-1, the observations of GRBs as well as the detection at the highest energies of Terrestrial Gamma-Ray Flashes (TGFs). Particular care is devoted to multi-frequency programs in synergy with radio, optical, X-ray and TeV observations. AGILE has a great capability for the detection of counterparts of gravitational wave sources.

ariel

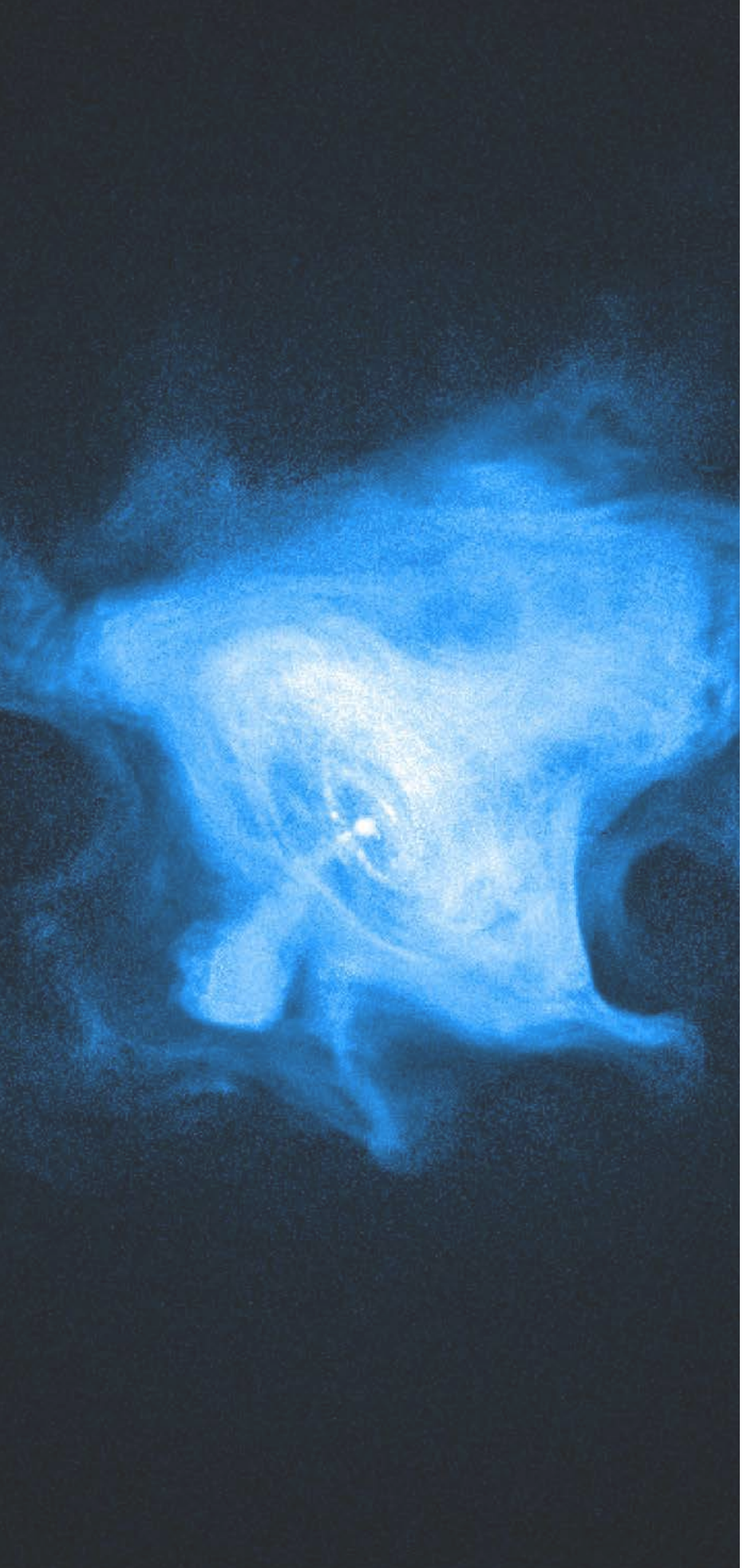
Selected as ESA M4 mission for a launch in mid-2028, it is devoted to study the atmospheres of a large number of exoplanets with the transit spectroscopy technique, in the spectral range from optical to infrared.

ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) will observe a large number (~1000) of warm and hot transiting gas giants, Neptunes and super-Earths orbiting a range of host star types using transit spectroscopy in the ~2-8 μm spectral range and broadband photometry in the optical. The planets hotter than 600K that ARIEL will observe, due to their well-mixed atmospheres which should show minimal condensation and sequestration of high-Z materials, will reveal their bulk and elemental composition (especially C, O, N, S, Si). Observations of the exo-atmospheres will allow the understanding of the early stages of planetary and atmospheric formation during the nebular phase and their subsequent evolution, contributing to put our own Solar System in context. ARIEL will thus provide a truly representative picture of the chemical nature of the exoplanets and relate this directly to the type and chemical environment of the host star, exploring the interaction of stars with their planets in a large range of star-planet configurations. For this ambitious scientific programme, ARIEL is designed as a dedicated survey mission for transit and eclipse spectroscopy, capable of observing a large and well-defined planet sample within its 3.5-year mission lifetime. The Italian contribution to ARIEL is relevant, with two Co-PIs of the mission and important contribution for the hardware of the telescope, including the realization of an innovative 1-m primary mirror, entirely built in aluminum, electronics, software, and ground segment. Several scientific institutes and laboratories, participate to the scientific and technological activities.

astrosat

Astrosat opens a window onto X-ray fast timing, with an interactive software developed by INAF.

Astrosat was launched on 2015 September 28 into a LEO. It carries on board two 38-cm optical/UV telescopes, an array of 3 proportional counters (3-80 keV, 8000 cm2 @ 10 keV), a soft X-ray telescope (0.3-8 keV, 120 cm2 @ 1 keV), a CZTI coded-mask imager (10-150 keV, 480 cm2) and an All-Sky monitor. It is operated as an observatory. An open AO for 10% of observing time has been released in 2017, increased to 20% in 2018. The Italian participation is through the software for timing analysis GHATS, developed at INAF-Astronomical Observatory of Brera, for the analysis of bright X-ray sources. One Italian scientist is part of an instrument team and currently collaboration projects with INAF-Astronomical Observatory of Brera scientists are under way.



A rapidly rotating neutron star in the Crab Nebula. Credit: NASA/CXC/SAO/F.Seward et al.

athena

Most pressing questions in Astrophysics for the late 2020s can uniquely be addressed with the X-ray observations by Athena.

ATHENA (Advanced Telescope for High-Energy Astrophysics) is a large X-ray observatory and the second large-class ESA mission (L2), planned for a launch towards the end of the next decade. It will continue the series of large X-ray observatories inaugurated by Chandra and XMM-Newton, offering transformational capabilities in several key areas. It is conceived to answer some of the most pressing questions in Astrophysics for the late 2020s that can uniquely be addressed with X-ray observations.

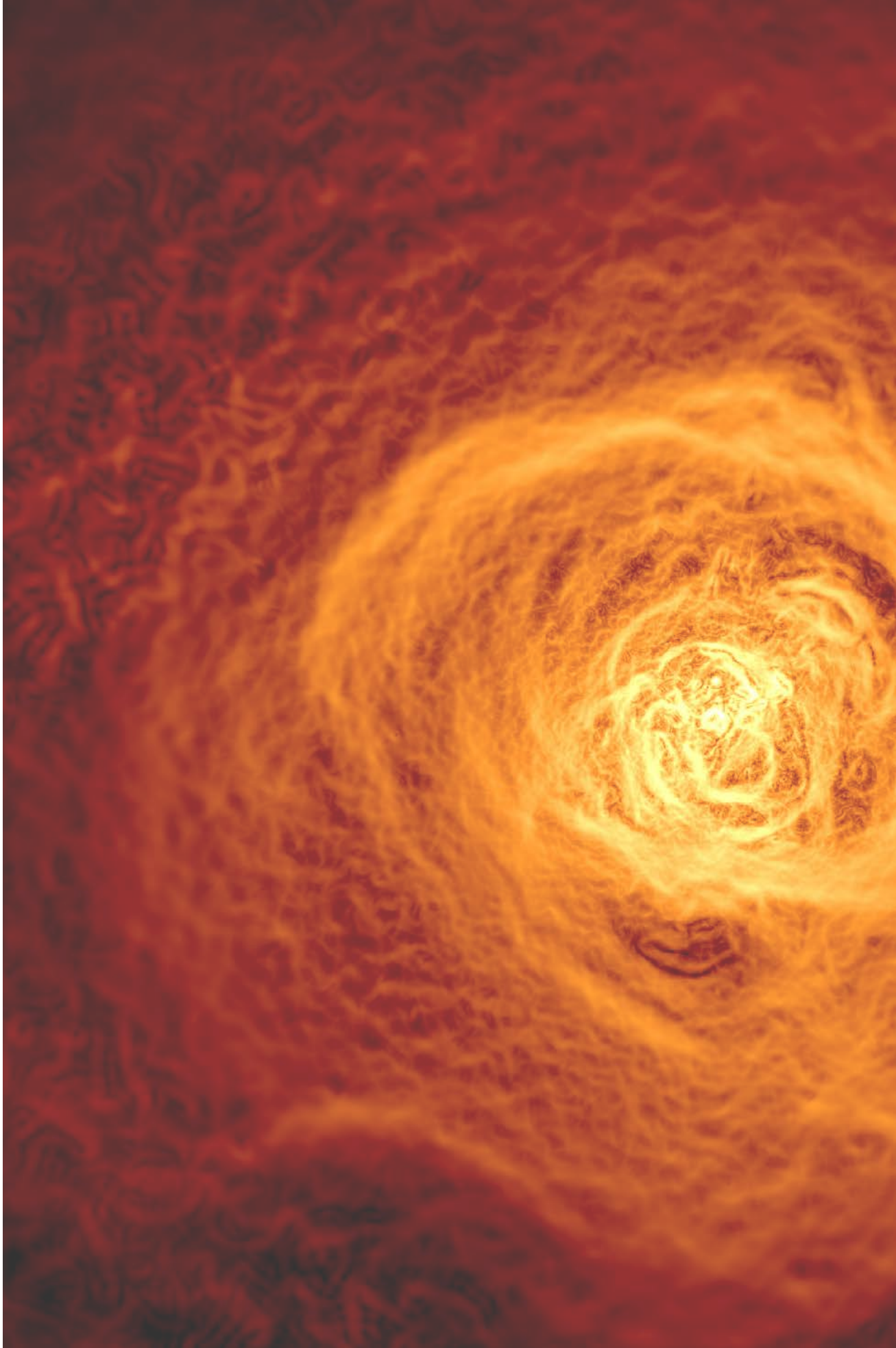
Athena will transform our understanding of two major components of the Cosmos. The Hot Universe: the bulk of visible matter in the Universe comprises hot gas which can only be accessed via space-based facilities operating in the X-ray band. Revealing this gas and relating its physical properties and evolution to the cosmological large-scale structure and to the cool components in galaxies and stars, is essential if we want to have a complete picture of our Universe. The Energetic Universe: accretion onto black holes is one of the major astrophysical energy generation processes, and its influence via cosmic feedback is profound and widespread. X-ray observations provide unique information about the physics of black hole growth and the causes and effects of the subsequent energy output, as well as revealing where in the Universe black hole accretion is occurring and how it evolves to the highest redshifts.

calet

CALET is searching for possible signatures of dark matter in the spectra of electrons and gamma rays.

CALET (CALorimetric Electron Telescope) reached the ISS in August 2015 starting an initial 5 year period of data taking on the JEM-EF exposu- re facility. CALET is a mission of the Japanese Aerospace Agency (JAXA) in collaboration with ASI and NASA. CALET main science objective is the exploration of the electron spectrum above 1 TeV whose shape might reveal the presence of nearby acceleration sources at kpc distance from Earth. With excellent energy resolution, proton rejection capability and low background contamination, CALET is searching for possible signatures of dark matter in the spectra of electrons and gamma rays. Deviation from a simple power-law in proton and He spectra will be studied with high precision in the region of a few hundred GeV and extended to the multi-TeV region and to heavier nuclei. Energy spectra, relative abundances and secondary-to-primary ratios of cosmic nuclei from proton to iron will be measured. Heavier elements up to Z=40 will be studied. To date, CALET has contributed to several gamma-ray transients detections by mean of the dedicated Gamma-ray Burst Monitor (GBM) as well to the interpretation of the Cosmic Ray e+/e− Spectrum from 10 GeV to 3 TeV and other cosmic ray studies.

The CALET experiment, docked with the International Space Station. Credit: NASA.



chandra

Chandra is a high-resolution X-ray telescope to detect emission from very hot regions of the Universe such as exploded stars, clusters of galaxies, and matter around black holes.

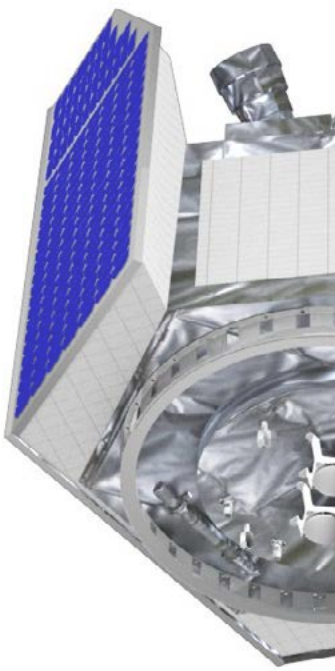
The Chandra X-ray observatory has been launched July 23, 1999. Since the launch, scientists all over the world took advantage of the excellent imaging capabilities of the observatory. These were used to perform deep pencil beam surveys in order to disentangle the origin of the X-ray background. Moreover, Chandra allowed to separate close-by double AGN in merging galaxies and to detail AGN eclipses due to gas and dust clouds in close AGN. Chandra was also used to study galaxy clusters and in particular the interactions between the central giant galaxy and the intra-cluster medium.

Chandra was fundamental to study celestial objects in the crowded fields of the Milky Way. In particular, Chandra gave a fundamental contribution in the study of the present and past activity of the nucleus of our own Galaxy, and the discovery of the first X-Ray counterpart to a Gravitational Wave event. The INAF-Astronomical Observatory of Palermo has been involved in the instrumental development and calibration of the filters of the High Resolution Camera on board Chandra.

cheops

CHEOPS is the first Small mission in ESA Cosmic Vision 2015-25 program, selected for launch in 2018.

CHEOPS is dedicated to the determination of the internal structure of small-size transiting planets by means of ultrahigh precision photometry of their parent stars. It will provide the targets to the future ground (e.g. E-ELT) and space-based (e.g. JWST) facilities, that will be used to characterize the exoplanet atmospheres. CHEOPS is a joint ESA-Switzerland mission, with important contributions from Italy and other ESA member states. Funded by ASI, the italian contribution to the payload is the integration and testing of the telescope, with the optical parts designed and produced in Italy, the preparation of the scientific program and the realization of the mirror archive for the scientific data. CHEOPS in Italy is made by the collaborative efforts of INAF (Catania and Padua), University of Padua, and ASI.



Artist's impression of the CHEOPS satellite. Previous page: The Perseus Cluster Waves. Credit: ESA/NASA.

dampe

DAMPE is a space telescope for high energy gamma-rays, electrons and cosmic rays detection, in a sun-synchronous orbit at the altitude of 500 km.

DAMPE (Dark Matter Particle Explorer, also known as Wukong), is a Chinese Academy of Sciences (CAS) satellite launched on December 17, 2015, with main scientific objective to measure electrons and photons with much higher energy resolution and reach than currently achievable, in order to identify possible Dark Matter signatures. DAMPE is composed by a double layer plastic scintillator, a silicon-tungsten tracker-converter (STK), made of 6 tracking double layers of silicon strip detectors with three layers of Tungsten plates for photon conversion, and an imaging calorimeter (BGO) of about 31 radiation lengths thickness, made up of 14 layers of Bismuth Germanium Oxide bars in a hodoscopic arrangement. The Italian contribution, under the leadership of the Italian National Institute for Nuclear Physics (INFN-Perugia), has been in the design and construction of the STK, and is currently focused on the detector calibration and data analysis.

euclid

Euclid will investigate the distance-redshift relationship and the evolution of cosmic structures, galaxies and clusters of galaxies.

Euclid will investigate the evolution of the Universe during the last 10 billion years, by accurately tracking gravitational effects on expansion rate and cosmic structure growth. Tiny distortions, induced on galaxies shape by the presence of Dark Matter along the line of sight, will allow gravitational field to be reconstructed with 3-D maps. Baryonic Acoustic Oscillations and redshift-space distortions, derived from the spatial distribution of galaxies as a function of redshift (i.e. of Universe time evolution), will be used to study Universe expansion rate. This is supposed to be governed by Dark Energy, which represents almost 75% of the matter-energy content of the Universe today. Two cryogenic instruments detect radiation collected simultaneously over more than 0.5 sq deg on the sky by a 1.2 m diameter telescope made of SiC: a visible panoramic camera (VIS) and a near–IR spectro-photometer (NISP).
VIS, with its 36 4Kx4K CCDs (0.1 arcsec/pixel) will be able to measure the shape of 1.5 billion galaxies down to magnitude 24.5. NISP will provide photometric redshift (Y, J, H) for the imaged sources and more than 30 million accurate redshifts from slitless spectroscopy using H-alpha emission lines.
Euclid, to be launched in 2021 to an L2 orbit, will observe more than 15000 square degrees of extragalactic sky in a 6 year long mission. The Euclid Consortium is composed of more than 120 institutes from 14 European countries, with the participation of NASA. Italy is leading the Science Ground Segment and it is procuring instrument control and data processing units, HW and SW, for both instruments and an on-board opto-mechanical element (Grism Wheel). Italian scientists contribute to several scientific activities and two of them are members of the ESA Euclid Science Team.

fermi

Fermi observes the cosmos using the highest-energy form of light. Mapping the entire sky every three hours, Fermi provides an important window into the most extreme phenomena of the Universe, from gamma-ray bursts and black-hole jets to pulsars, supernova remnants and the origin of cosmic rays.

The Fermi Gamma-ray Space Telescope mission was launched on June 11, 2008 by a Delta II rocket. Fermi is a NASA mission with a wide international collaboration from Italy, Japan, France, Germany and Sweden. The scientific payload is composed of the Large Area Telescope (LAT), operating in the 20 MeV - >300 GeV energy range, and the Gamma-ray Burst Monitor (GBM), operating in the 10 keV - 25 MeV energy range. Fermi is operating in sky survey mode and the LAT observes the entire sky every 3 hours, providing uniform exposure on the timescale of days. The high sensitivity and nearly uniform sky coverage of the LAT make it a powerful tool to investigate the properties of all high-energy astrophysical sources. The Fermi LAT Third Source Catalog lists 3033 sources detected during the first 4 years of operation by the LAT, 167 of which are identified as pulsating neutron stars while about 1590 are associated to active galaxies. Thanks to its capabilities, Fermi has collected 4 Bruno Rossi prizes, the most prestigious acknowledgment in the High Energy Astrophyiscs. The Italian participation encompasses several contributions starting with the design, construction and calibration of the LAT tracker, performed by Italian National Institute for Nuclear Physics (INFN) under ASI responsibility, and the exploitation of the data by INAF, INFN and Italian Universities. Additional tasks such as software development, management of the Italian data archive mirror as well as scientific data analysis are jointly performed by INFN and ASI/SSDC.

A view of M33, also known as the Triangulum galaxy, obtained by the Gaia satellite. Credit: ESA/DPAC.

gaia

The ESA cornerstone mission Gaia is providing a stereoscopic census of over a billion stars in our Galaxy and beyond. The positions, proper motions, radial velocities and astrophysical parameters will unravel the composition, formation, evolution and the history, both chemical and dynamical, of our Galaxy.

Gaia is a major project for the European astronomical community that is deeply changing our view of the Galaxy with a precise and detailed stereoscopic survey of the billion brightest celestial objects (down to V magnitude 20). Gaia was launched in December 2013 and started its all-sky scanning survey, recently extended untill end of 2020. Gaia very high-accuracy global astrometry will allow to measure the 3D position of a star and its movement across the sky. Gaia will also gather spectroscopic data, allowing the determination of the radial velocities for several millions of galactic stars, and spectrophotometric data, measuring the astrophysical properties including luminosity, surface gravity, temperature and chemical composition. The predicted end-of-mission parallax standard errors are of the order of 9-25 μas at V=15 depending on the star color, this will provide a 10% error on distances at 10 kpc. The scientific data processing is a responsibility of the Gaia Data Processing and Analysis Consortium (DPAC), an european consortium of ~450 scientists.
Italy deep involvement in DPAC activities includes contributions to astrometric verification, spectrophotometric data reduction and absolute calibration, variable and special object treatment, sources classification and cross-match with external catalogs. Italy is contributing with one of the six data processing centers and provides one of the four partner data center dedicated to Gaia data access and distribution which will support the scientific data exploitation by the national community. Gaia Data Release 2 was released in 2018 with a total number of sources exceeding 1.5 billions, with 0.5 millions of light-curves for variable stars and 13.000 known asteroids. Gaia DR2 data is based on data collected between 25 July 2014 and 23 May 2016, spanning a period of 22 months of data collection, as compared to Gaia DR1 which was based on observations collected in the first 14 months of Gaia's routine operational phase.

herschel

Herschel opened a new infrared window to study how the Universe has evolved and how the Sun, the Earth, and we ourselves fit in.

Herschel is a Cornerstone mission of ESA science programme, dedicated to far infrared and submillimeter astronomical observations between 60-670μm. It was conceived as a Space Observatory open to the entire astronomical community and it was the largest infrared space observatory launched so far. It is now decommissioned due to end of cryogenics life. Herschel's keystone surveys of cosmological fields, nearby star-forming regions and the entire Galactic Plane provided an unprecedented view of the cold Universe. Herschel unveiled the pervasive filamentary nature of cold interstellar medium and its crucial role for the formation of stellar clusters, while its complete census of stellar nurseries in the Milky Way left an unprecedented legacy view of our Galaxy as a star formation engine. The mass function of dense molecular cores was determined to be similar to the IMF, pointing to the early fragmentation of dense clouds as the event that shapes the stellar IMF. Herschel determined the path of water in the formation of stars and protoplanetary disks. The evolution of the luminosity function of galaxies allowed to reconstruct the star formation history of the Universe up to z=4, identifying different modes of star formation depending on the galaxy environment and formation epoch.

hubble

HST is the most popular NASA/ESA joint mission and has made some of the most dramatic discoveries in the history of astronomy.

Launched in 1990, HST (Hubble Space Telescope) is the most popular NASA/ESA joint mission. After having been serviced several times by the Space Shuttle, allowing repair and substitution of its instruments, it is still working at its best.
Its expected life is planned to last several more years, with significant overlap with JWST operations. Its current instruments are ACS, COS, STIS, FGS and WFC3. Italy has officially contributed to the development of its first instruments. Italians are among the major users of HST.

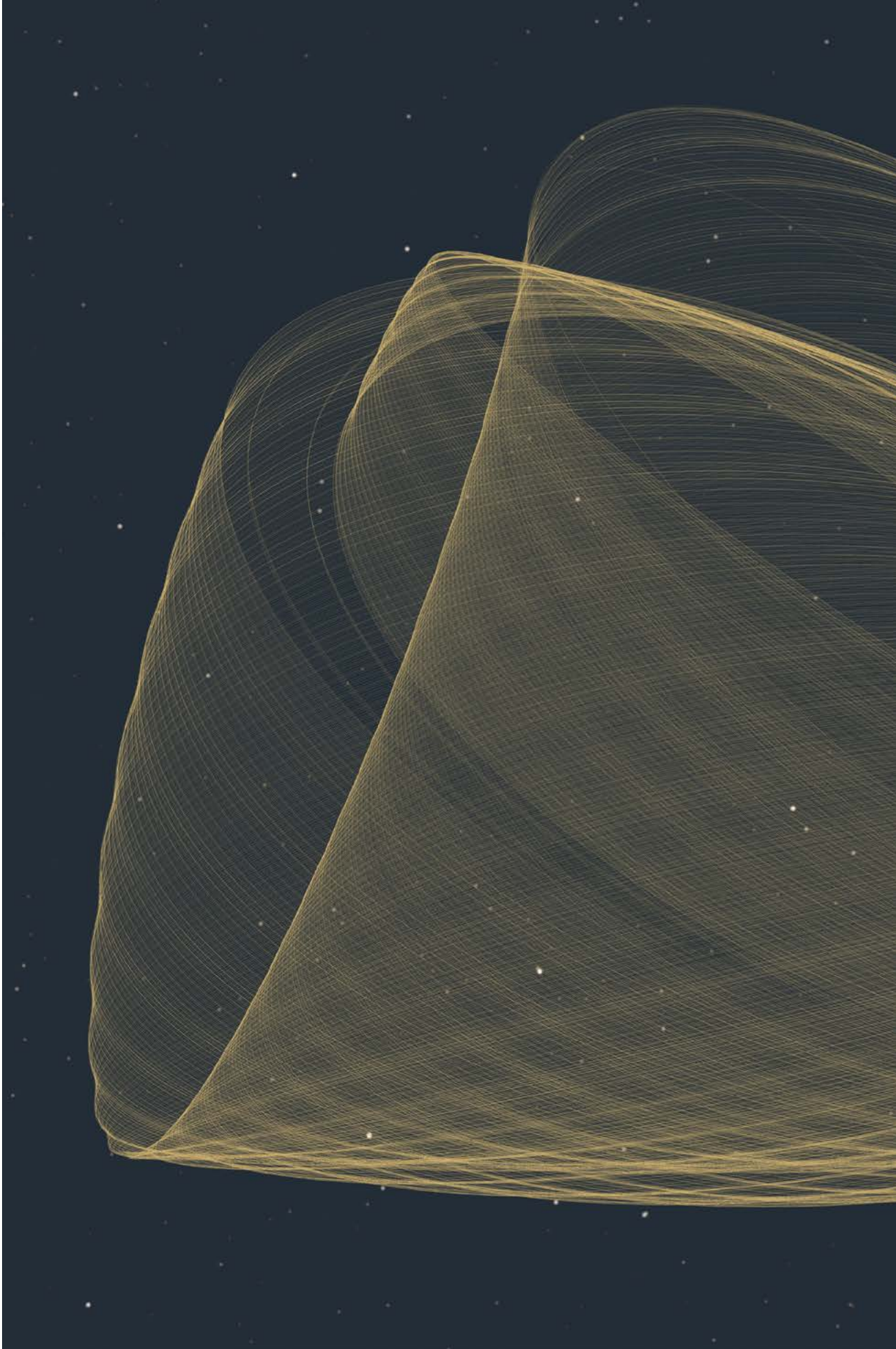
integral

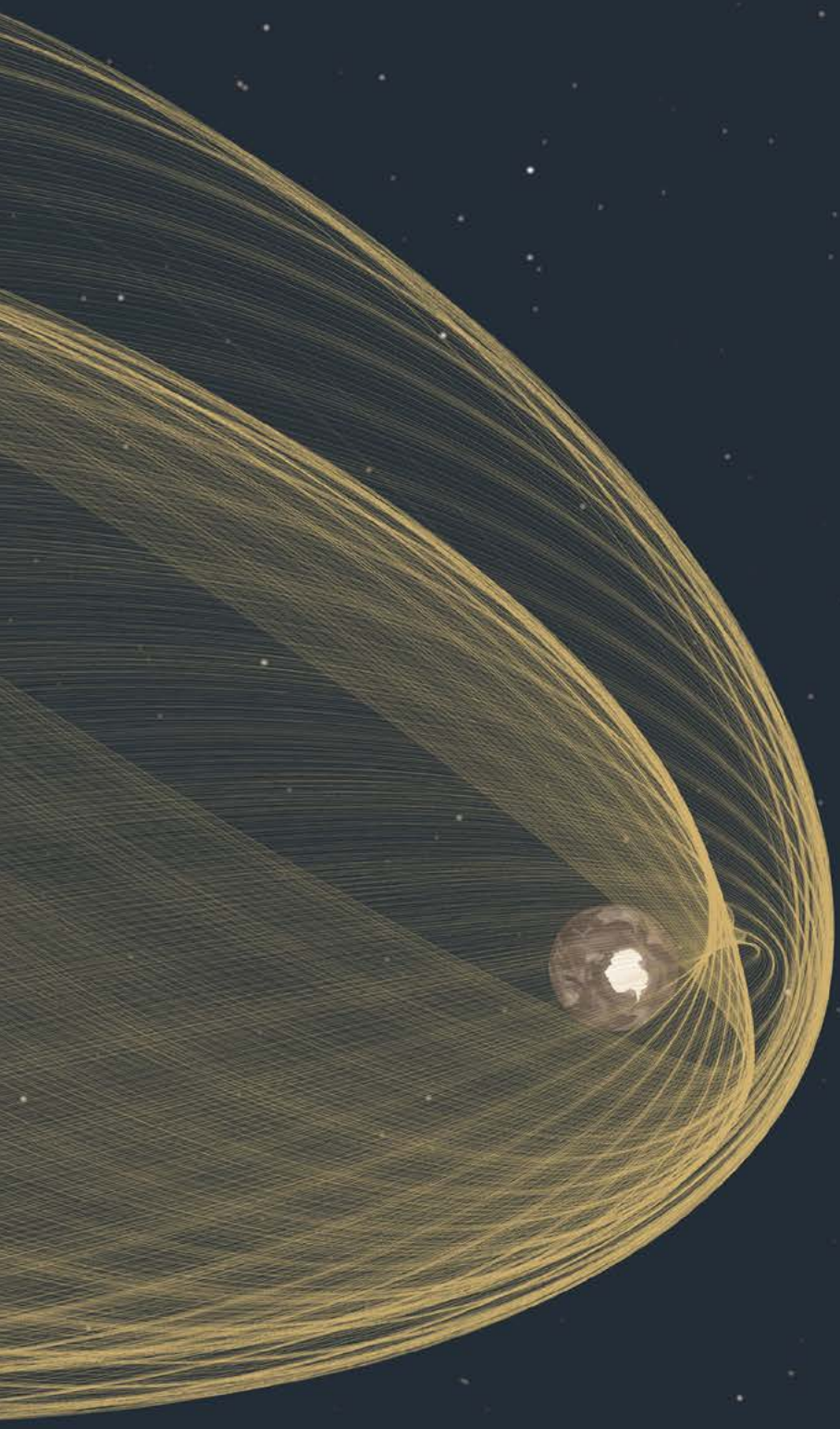
INTEGRAL is an ESA gamma ray Observatory launched in 2002, open to the world wide community, with a strong italian contribution. Integral recently played a crucial role in discovering the first Gamma-ray Burst linked to Gravitational waves, opening the multi-messenger astrophysics era.

The INTEGRAL (INTernationl Gamm-Ray Astrophysics Laboratory) mission was approved as the 2nd medium size ESA project of the Horizon 2000 Scientific Program in April 1993 and successfully launched from Baikonur (Kazakhstan) on 17 October, 2002. INTEGRAL is an observatory type mission and its science payload is designed for the imaging and spectroscopy of persistent and transient cosmic sources in the 10-10000 keV band. There are two main instruments detecting gamma rays: the imager (IBIS) gives the sharpest gamma-ray images yet seen from astronomical targets; meanwhile the spectrometer (SPI) precisely measures Gamma-ray energies. The program is led by ESA, with the instrument complement and the Scientific Data Centre (based in Geneva) provided by five different European consortia with a large contribution from ASI and INAF Institutes (IAPS, IASF Milan, Bologna and Palermo) especially for IBIS and to a minor extent for SPI and Jem-X. Contributions were also provided by Russia, for the Proton launcher, and by the USA which made available a NASA ground station. Besides the two main instruments INTEGRAL offers substantial monitoring capability in the X-ray range, from 3 to 30 keV, and in the optical V band at 550 nm. In view of the impossibility of focusing high energy X-rays and soft gamma-rays, the three high energy instruments are operated with a coded mask to provide good imaging capability over a wide field of view. This technique is a key feature of INTEGRAL to provide simultaneous images of the whole field observed and detection and location of all the sources. INTEGRAL provides almost an order of magnitude improved performance in spectroscopy and imaging

compared to earlier high energy observatories. After more than 15 years of operation, INTEGRAL has detected more than 1000 high-energy emitters of all types, most of which are new detection including many transient sources that shine once in a while in the sky. Because of the high quality scientific results the operative life of the mission has been extended at least up to the end of 2019, possibly 2020, with an on going extension request till 2022.
INTEGRAL, together with Fermi/GBM, played a crucial role in discovering the γ-ray Burst (GRB 170817A) linked to Gravitational waves as result of the collision of two neutron stars. On August 17, 2017 the two observatories recorded a short GRB that was preceded a few seconds earlier by a Gravitational waves signals from LIGO/Virgo (GW 170817). Intense follow-up campaign with ground and space-base telescopes allowed, in about 11 hours, to detected a bright optical transient in the galaxy NGC 4993 at a distance as indicated by LIGO/Virgo. All the performed observation at UV, visible, infrared, X-ray and radio support the hypothesis that GW170817 was indeed produced by the merger of two neutron stars in NGC4993 followed by a the short GRB170817 and a "kilonova" powered by radioactive decay of r-process nuclei synthetized in the ejecta.

Previous page: The Lagoon Nebula as seen by Hubble Space Telescope. Credit: NASA/ESA/STScI.





On 17 August 2017, a burst of gamma rays lit up in space for almost two seconds. It was promptly recorded by INTEGRAL and NASA's Fermi satellite. The detectors of the LIGO experiment, in the USA, recorded the passage of gravitational waves: a ground-breaking discovery, revealing for the first time gravitational waves and highly energetic light released by the same cosmic source.

Integral's orbits since the spacecraft launch on 2002 until October 2017. Credit: ESA/ScienceOffice.org.

ixpe

IXPE is a NASA SMEX mission, devoted to provide imaging X-ray polarimetry of celestial sources, with a large participation of ASI.

IXPE is a SMEX (Small Explorers) mission to be launched in April 2021. The mission, led by NASA-MSFC (Marshall Space Flight Center) is devoted to time-spectrally-spatially resolved X-ray polarimetry. It comprises three Gas Pixel Detectors (GPDs) provided by ASI and three X-ray optics developed at MSFC.

The main contractor for the spacecraft is Ball Aereospace. The italian contribution (INAF and INFN) comprises the whole focal plane: the Detector Unit with the Gas Pixel Detectors, the Back-End Electronics, included the High Voltage Power Supplies, the Filter and Calibration Wheel and the housing. Moreover Italy provides the Detector Service Unit. The Instrument Calibration will be accomplished at IAPS/INAF. ASI will also provide the Malindi primary IXPE Ground Station and contributes to the development of the flight pipeline with its SSDC. IXPE reaches a focal length of 4 meters by means of an extendable boom provided by ATK-Orbital, because of the maximum length allowed by the Pegasus launcher. Indeed the mass of the whole satellite is below 390 kg.

X-ray polarimetry allows for studying black holes and neutron stars binaries in their variable physical conditions for the unstable presence of jets, of coronae and of accretion disks.

Polarimetry, in some cases, represents the only way to have knowledge of the geometry of the systems at angular scales much smaller than those of Chandra (less than 1 arcsec) and to determine the physical

processes at work. IXPE, in addition to the detailed study of isolated celestial point sources, allows for meaningful studies of a much larger classes of sources thanks to: a reduced and controlled background and the consequent smaller measurable flux down to those of AGNs and dim magnetars, the capability to resolve multiple sources in crowded regions, the provision of angularly resolved polarimetry for extended sources such as shell-like Supernova Remnants and Pulsar Wind Nebulae for mapping magnetic fields, determining its uniformity for studying the acceleration mechanisms at the emission site.

One exemplary case where imaging is crucial is the observation of X-rays from cold molecular clouds in the Galactic Center region possibly scattering now the radiation coming from a past flare (106 larger luminosity than today) from Sgr A*. There are three major complexes each one can be studied with a single pointing.

The measure of the polarization angle will pinpoint to the origin of the illuminating radiation confirming this hypothesis and by means of the determination of the degree of polarization, IXPE will measure their true distances from SgrA*. This set the time of this brightening provide the shape of this past flare and confirm the hypothesis that the Black Hole of our own Galaxy was much brighter in a relatively recent past.

jwst

The JWST is an infrared telescope to be launched at the end of 2020. It will be the premier Observatory of the next decade, serving thousands of astronomers worldwide.

JWST (James Webb Space Telescope) is an infrared telescope with a 6.5-meter primary mirror, to be launched at the end of 2020. It will be equipped with 4 instruments: the Near-Infrared Camera, built by the University of Arizona, NIRSpec, provided by ESA with components provided by NASA/GSFC, MIRI, provided by a European Consortium with ESA and by JPL, and FGS/NIRISS, provided by CSA. With its four main science themes, 1) First Light and Reionization, 2) Assembly of Galaxies, 3) Birth of Stars and Proto-planetary Systems, 4) Planets and Origins of Life, JWST will study every phase in the history of our Universe. Italians are participating to the mission, either as ESA members or because of their individual role in international consortia and committees.

Artist's impression of the James Webb Space Telescope. Credit: NASA/ESA/CSA.

lspe

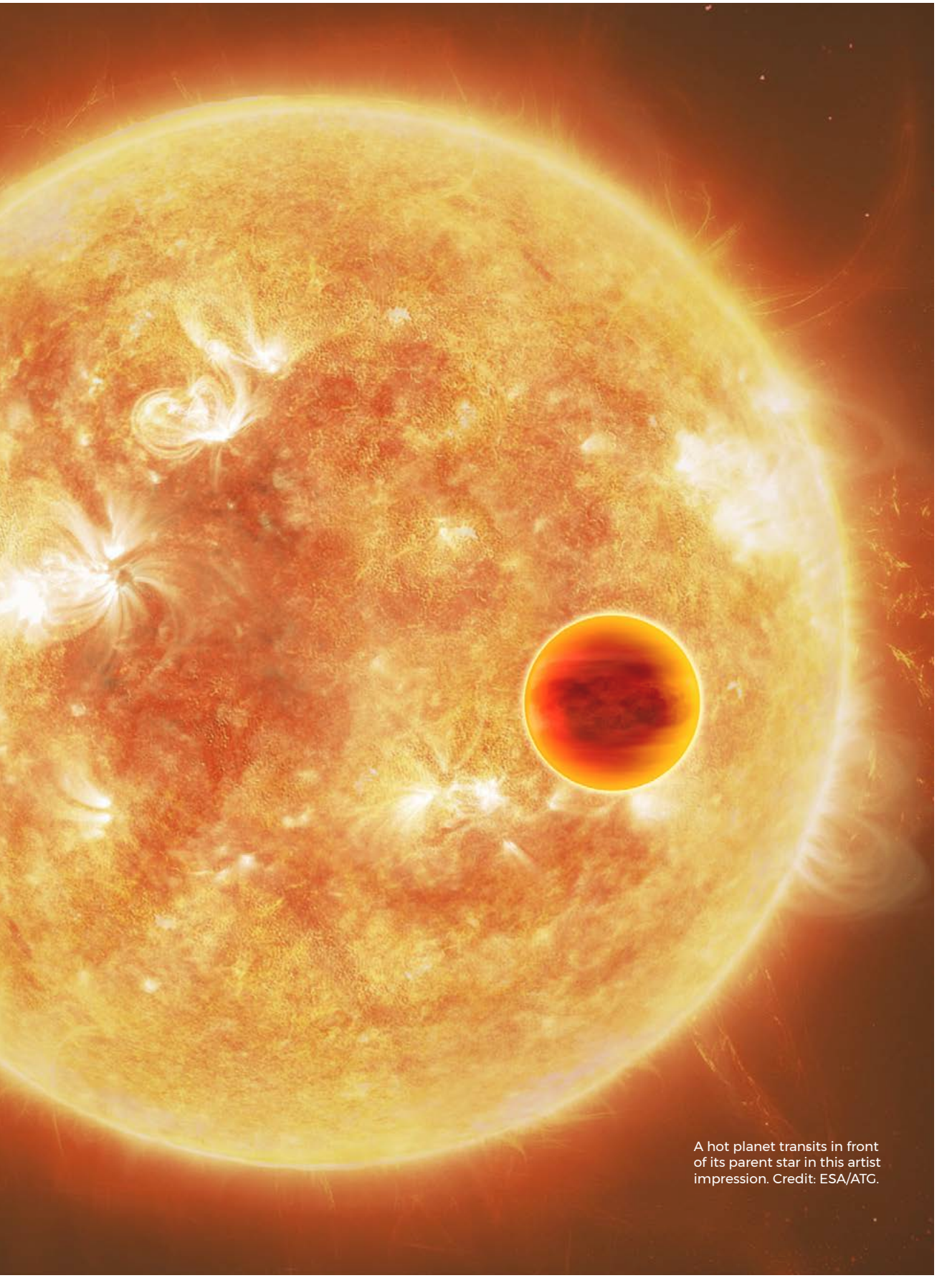
LSPE is a stratospheric balloon mission funded by ASI that will measure the polarization of the cosmic microwave background radiation (CMB) on large angular scales during a long duration flight in the Arctic winter.

Gravitational waves produced during inflation, a split-second after the big-bang, induce linear polarization in the CMB (both E-modes and B-modes). The signal from B-modes is extremely small, <0.1 mK rms and is mainly at large angular scales. LSPE targets are the reionization bump and the recombination bump in the angular power spectrum of B-modes. The LSPE (Large Scale Polarization Explorer) has two polarimeters: SWIPE (with multi-mode bolometers and a rotating HWP) and STRIP (with coherent radiometers) covering the 40-250 GHz range with 5 channels, with an angular resolution of 1.3 deg FWHM and a combined sensitivity of 20 mK arcmin per flight. It is funded by ASI and Italian National Institute for Nuclear Physics (INFN) in Italy. The first flight is planned for 2020.

nustar

The NuSTAR mission is the first hard X-ray focusing telescope to orbit Earth, complementing other missions (such as XMM, Chandra, INTEGRAL and Swift) to explore the energetic Universe.

The NuSTAR mission is a NASA Explorer launched in 2012: is the first hard X-ray focusing satellite. Primary objectives include the census of black hole and stellar compact objects at different scales; the study of relativistic jets in the most active galaxies; the map of radioactive material in Supernova remnants to understand the explosion and nucleosynthesis mechanisms. It can efficiently work in synergy with other X-ray missions as well as HST. The Italian contribution includes: the provision of ASI ground station in Malindi (Kenya), data reduction software support and archival storage at the ASI Science Data Center (ASDC), contribution to the project with a team of INAF scientists that collaborates to the primary scientific mission goals.



A hot planet transits in front of its parent star in this artist impression. Credit: ESA/ATG.

olimpo

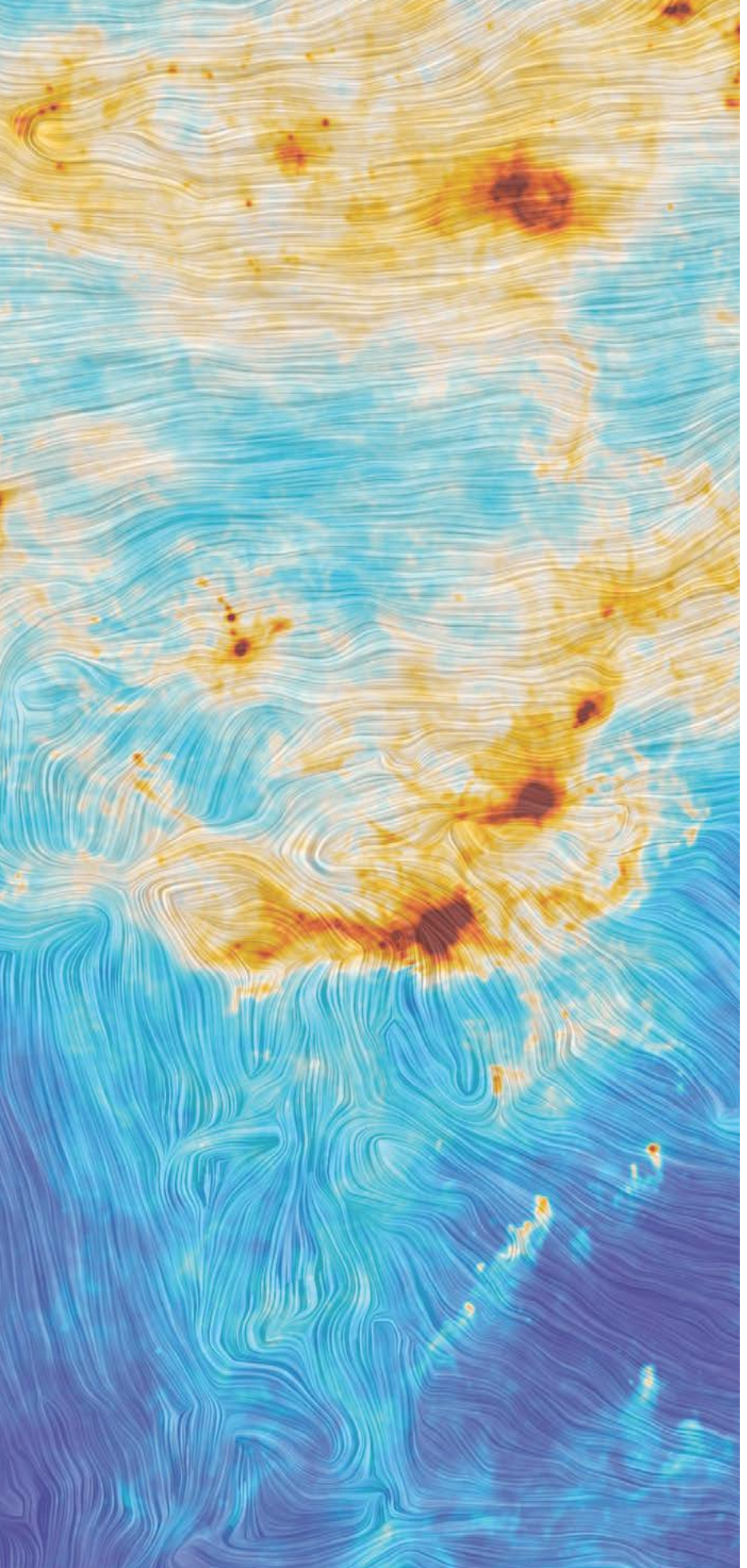
OLIMPO is a balloon-borne telescope measuring the anisotropy of the mm/submm sky and its spectrum. It will be flown with a long duration circumpolar flight in the Arctic.

OLIMPO is a balloon-borne 2.6 m aperture telescope for the measurement of the Cosmic Microwave Background and Cosmic Infrared Background anisotropy, with arcmin resolution. The instrument uses a Differential Fourier Transform Spectrometer (DFTS) and 4 cryogenic detector arrays to obtain spectral capabilities within 4 wide bands around 140, 220, 340, 480 GHz. The DFTS rejects the common-mode signal with high efficiency, extracting tiny spectral anisotropies from an overwhelming background. In a long-duration flight organized by ASI from Svalbard islands, the instrument will map >100 sky areas, including clusters of galaxies (spectroscopic study of the SZ), and blank areas (spectral-spatial anisotropy).

pamela

PAMELA studied the charged component of the cosmic radiation, with particular emphasis on antiparticles.

PAMELA (Payload for Antimatter Matter and Light-nuclei Astrophysics) is a satellite-borne experiment launched from the Baikonur cosmodrome in Kazakhstan in 2006 .
PAMELA consisted in a magnetic spectrometer, an electromagnetic calorimeter, a time-of-flight system, an anticoincidence system, a shower tail catcher scintillator and a neutron detector. It made, for ten years, high-precision measurements of the charged component of the cosmic radiation opening a new era of precision studies in cosmic rays. The measured antiparticle component of the cosmic radiation shows features that can be interpreted in terms of dark matter annihilation or pulsar contribution. The measurements of the energy spectra of protons, electrons, helium and light nuclei and their isotopes challenge our basic vision of the mechanisms of production, acceleration and propagation of cosmic rays in the galaxy. The study of the time dependence of the various components of the cosmic radiations has clearly shown solar modulation effects as well as charge sign dependence. PAMELA measurement of the energy spectra during solar energetic particle events has filled the existing energy gap between the highest energy particles measured in space and the ground-based domain. Finally, by sampling the particle radiation in different regions of the magnetosphere, PAMELA data have provided a detailed study of the Earth magnetosphere. The PAMELA mission ended its life in 2016.

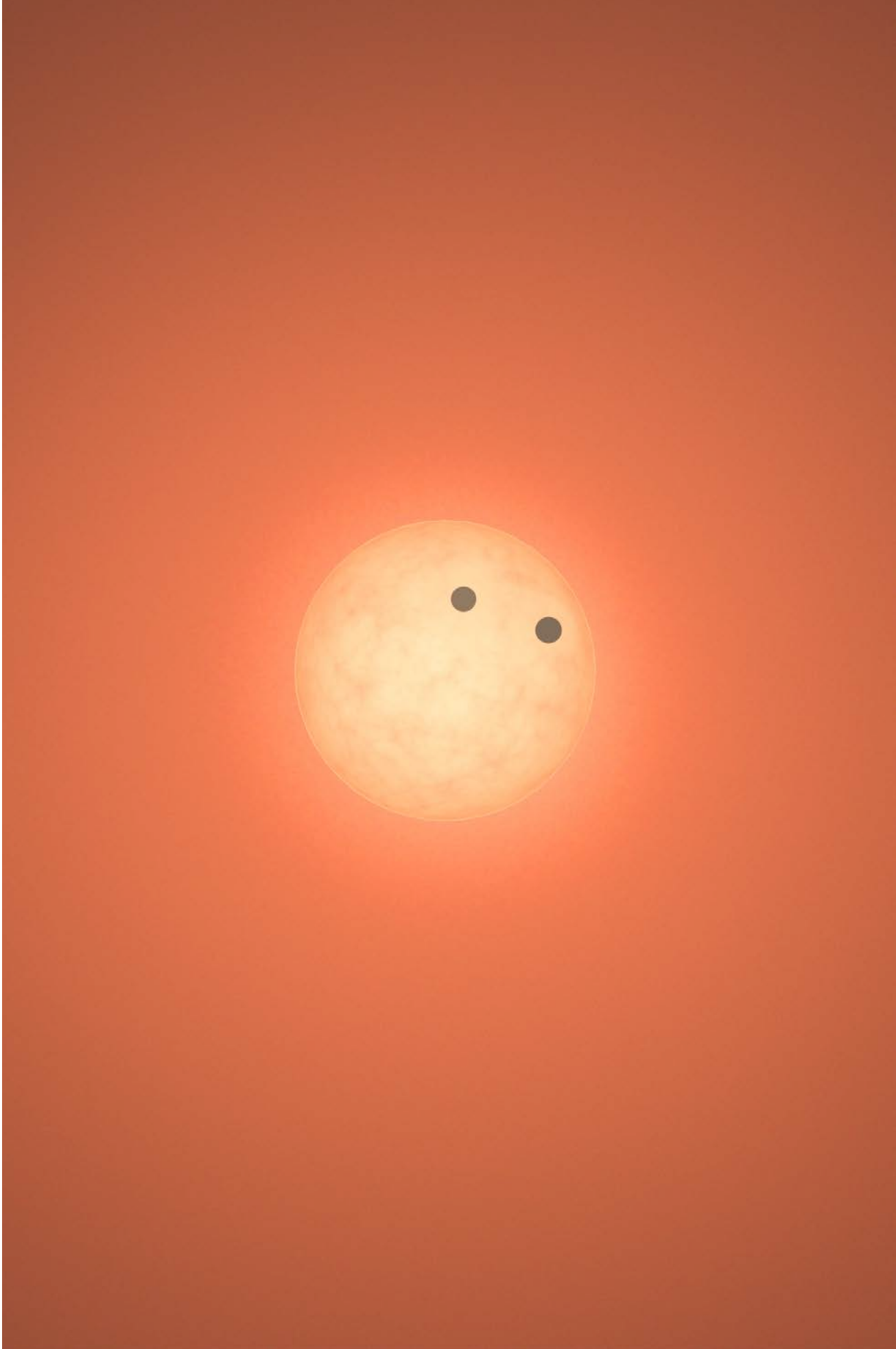


Polarised emission from Orion Nebula. Credit: ESA and the Planck Collaboration.

planck

Planck has provided a new map of the Cosmic Microwave Background anisotropies, covering almost the all sky, providing a snapshot of the early Universe.

Planck, ESA's cryogenic mission, was the third-generation space mission dedicated to measurements of Cosmic Microwave Background (CMB) anisotropies, following COBE and WMAP. The CMB, a pillar of our cosmological view of the Universe, represents the best measured blackbody in nature and its anisotropies, the small deviations from intensity and polarization from point to point on the sky provide the most valuable tests of the cosmological paradigm and the current best measurements on the parameters of the "lambda-cold dark matter" model.
Planck, cryogenically cooled down to 0.1 K, represents an incredible technical success, operating in a challenging environment, like L2, without interruption over three times the initially planned mission duration, with performances exceeding expectations. The low- and high-frequency instruments together contained an array of 74 detectors in nine bands, covering frequencies between 25 and 1000 GHz, imaging the whole sky twice per year with angular resolution between 33 and 5 arcmin.
In addition to the primary CMB anisotropies, the main focus of the mission, Planck was the first satellite to map, at nine different frequencies, the entire sky to mJy sensitivity with resolution better than 13 arcmin, thus providing a wealth of information on many astrophysical components in intensity and polarization.
Planck observed the most accurate map in temperature of the CMB anisotropies (Fig. 1) whose statistical analysis reveals the cosmological scenario of our primordial Universe, back to the inflation and until today. The CMB polarization (Fig. 2) observed by Planck has reinforced the knowledge of the cosmological paradigm, opening in the same time a new window for future more ambitious CMB polarization missions. Planck data provide the strongest evidence that dark matter cannot be entirely baryonic (luminous or dark) and that the observed fluctuations were already frozen at very early times.
Despite the precision cosmology Planck measurements validating the standard cosmological model (Lambda CDM) and possible extension a number questions still remain. For example: how and why fluctuations originated the inflation in the early Universe and how ended; what is the role of primordial gravitational fluctuations and are B modes detectable or too low to be detected; what is the dark matter, and what is the dark energy: accelerating expansion? and what is generating it? ; how and why did the Universe reionize; and do we need a new physics to answer these questions?



plato

PLATO will search for planet transits and asteroseismological measurement of mass and age of hosting stars.

PLATO (PLAnet Transit and stellar Oscillations) is the next generation exoplanet finder, the third medium-class mission in ESA's Cosmic Vision programme to be launched in 2024.
In the current plans, PLATO will obtain light curves of up to one million bright dwarfs and subgiants, covering up to half of the sky, with almost continuous coverage for up to 3 years. Main purpose is the search for exoplanets, including rocky Earths and SuperEarths, and obtain seismic measurement of radii (~3% error), masses (~10% error), and ages (10% error) of hosting stars. PLATO will set the basis for the statistical study of exoplanet and exoplanet system bulk properties, their dependence on the environment, and how they evolve with age. PLATO is the necessary preparatory mission for target selection for following atmosphere studies.

spica

SPICA will perform observations of the Universe in the mid and far infrared with an unprecedented sensitivity .

SPICA (SPace Infrared telescope for Cosmology and Astrophysics) was selected as one of the missions to be studies for M5 selection by ESA. It is a joint European-Japanese project proposed for the 5th Medium Size Mission of the ESA Cosmic Vision competition. It is an infrared space observatory with a 2.5-m primary mirror cooled to below 8 K and new generation detector arrays able to achieve background limited performance. SPICA will be a unique astronomical facility covering the 12-350μm spectral range, designed for deep and wide surveys to unprecedented depths in spectroscopy, photometry and polarimetry. It will reach a spectroscopic sensitivity of two orders of magnitude better than both Spitzer and Herschel, enabling for the first time a physical exploration of the hidden Universe in the infrared.
The main astrophysical questions that SPICA will be able to answer include: What are the roles of star formation, accretion onto and feedback from central black holes and supernovae in shaping galaxy evolution over cosmic time? How are metals and dust produced and destroyed in galaxies? How does the matter cycle within galaxies and between galactic discs, halos and intergalactic medium? How did primordial gas clouds collapse into the first galaxies and black holes? What is the role of magnetic fields at the onset of star formation in the Milky Way? When and how does gas evolve from primordial discs into emerging planetary systems? How do ices and minerals evolve in the planet formation era, as seed for Solar Systems?
The European participation in the SPICA mission is lead by the SRON Institute in The Netherlands, which coordinates a consortium of European institutes, including IAPS-INAF.

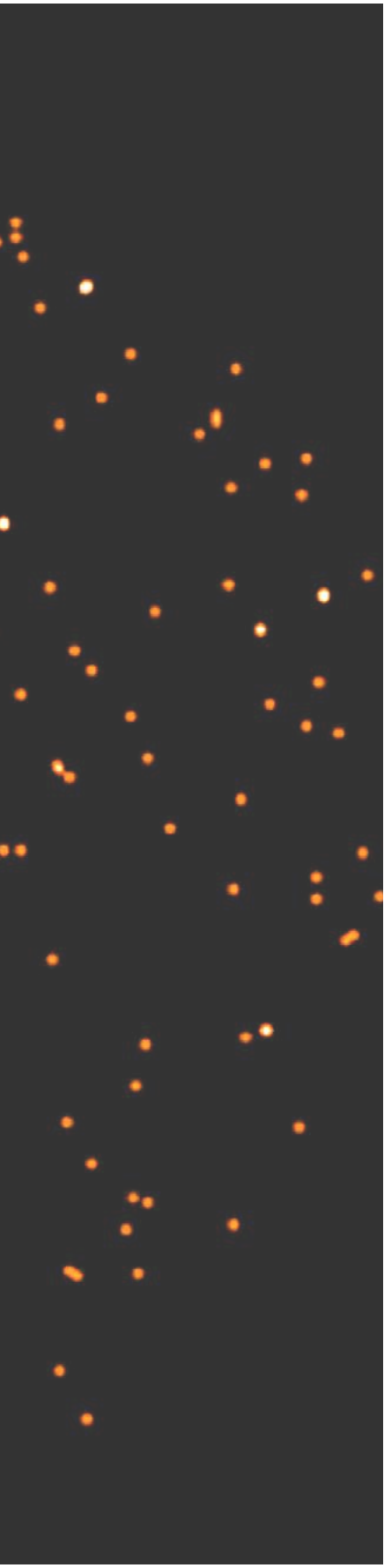
Far infrared map of the Milky Way. Previous page: Artist's impression of the Trappist-1 system. Credit: NASA.

swift

The Neil Gehrels Swift Observatory (previously known as Swift but recently renamed in memory of Neil Gehrels, who helped develop the Swift satellite and served as its principal investigator until his death on Feb. 6, 2017) is a NASA mission with a strong contribution from Italy and UK. It is characterized by multiband good sensitivity and fast autonomous repointing.

Swift is a collaborative MIDEX NASA Mission with Italy and the UK. The Swift satellite, launched on November 2004, has onboard three instruments for the observation of the Gamma Ray Bursts (GRB): the Burst Alert Telescope (BAT), the X-Ray Telescope (XRT) and the Ultraviolet/ Optical Telescope (UVOT).

Swift detects ~90 GRBs a year and since its launch it revolutionized our knowledge of the field. The observing plan has evolved with time and now, although Swift continues to hunt for GRBs, the majority of the time is spent on target of opportunity (TOO) observations, covering all kind of sources, from comets to high redshift quasars.
On average, four TOOs a day are performed.Thanks to its fast and autonomous repointing capability and good sensitivity in the X-ray and optical/UV bands, Swift is also heavily involved in the search of the electromagnetic counterparts of gravitational wave sources.
Italy provides the ASI ground station in Malindi antenna for the uplink/downlink of the data, the Mirror Module of the XRT developed by the INAF-Astronomical Observatory of Brera under an ASI contract, the XRT data analysis software developed by the ASDC. Furthermore, the Italian team participate to the scientific management of the mission, funded by ASI.



theseus

A new window on the early Universe and the multi-messenger transient sky.

THESEUS (Transient High-Energy Sky and Early Universe Surveyor) was selected as one of the missions to be studies for M5 selection by ESA, with a planned launch date in 2032. THESEUS is a project developed in the last years by a large European consortium, with interest in prospective participation by research groups in USA and other non-European countries, in which the Italian National Institute for Astrophysics (INAF) plays a major role. THESEUS aims to explore the early (first billion years) Universe through high-redshift Gamma-Ray Bursts (GRBs), the most extreme explosions in the cosmos, and to provide detection, accurate location and redshift of the electro-magnetic counterparts of gravitational-waves and neutrino sources, as well as of many other transient celestial sources.

The main aim of the mission is to fully exploit the great potential of the GRBs for cosmology purposes, especially in the study of the primordial Universe, and it will provide a fundamental contribution to the time-domain and multi-messenger astrophysics. THESEUS will thus provide a unique and fundamental contribution to several fields of astrophysics, cosmology and fundamental physics and will operate in beautiful synergy with the large worldwide facilities planned for the next decade devoted to the study of the Comsos, such as LSST, ELT/TMT, Ska, CTA, Athena, Ligo, aVirgo, Kagra, Et and Km3NeT.

xmm-newton

XMM-Newton will detail the physical conditions in the star forming regions and the mechanisms acting for the production of X-rays in the magnetosphere of planets.

XMM-Newton was the second cornerstone of the ESA Horizon 2000 program. It was launched on December 10, 1999 and it is still operating perfectly. Taking advantage of its high trough-put, spectral and timing capabilities,XMM-Newton allowed to collect probes of the theory of relativity in AGN and compact Galactic objects. AGN taxonomy and population across cosmic time has been studied using XMM-Newton to survey portions of the sky. It was also fundamental to study galaxy clusters and in particular to study their physics and the effects induced by the "dark matter". Finally, XMM-Newton has been successfully operated to detail the physical conditions in the star forming regions and on the mechanisms acting for the production of X- rays in the magnetosphere of planets. Thanks to the coordinated involvement of its research structures IASF-Milan, OAS-Bologna and INAF-Astronomical Observatory of Palermo is contributing to the realization of the three EPIC cameras. Moreover, INAF-Astronomical Observatory of Brera did significantly contribute, together with the MediaLario industry, to the realization of the large area mirror modules. The INAF Observatory of Palermo has been involved in the development and calibration of the EPIC optical filters. The mission shall operate up to at least 2020.

Previous page: An image from Swift's X-ray Telescope. Credit: NASA/Swift/Stefan Immler.

SCIENTIFIC COMMISSION F
Life Sciences as Related to Space

Previous page: Medical monitoring on board the International Space Station. Credit: NASA.

altea

ALTEA integrates several diagnostic technologies to measure the effect of the exposure of crew members to cosmic radiation.

ALTEA (Anomalous Long Term Effects in Astronauts' Central Nervous System) is an ASI programme realized by the University of Rome Tor Vergata and Italian National Institute for Nuclear Physics (INFN) aimed to study the brain functional effects of the space radiation environment, with a focus on the Light Flashes phenomenon. The Mission ended in August 2007. In 2008 an agreement was signed with NASA to utilize this instrument as a detector for operational purposes. Thanks to this agreement ALTEA is today operative on board the ISS in DOSI mode. ALTEA is composed by six particle telescopes arranged in a helmet shaped support, a visual stimulator, an electroencephalograph, a pushbutton. It features two different main experimental protocols: unmanned one (DOSI) during which the detectors monitor the radiation environment with a real time data downlinking to ground, and a manned one (CNSM) during which the particles passing through the astronaut's head are measured, together with the astronaut brain electrophysiological dynamics, looking for correlations between particle passages and brain electrophysiology.

elite-s2

ELITE-S2 is an analysis facility of human motion for the International Space Station: technological characterisation and potential application for multifactorial movement analysis in microgravity.

Elaborator of Televised Images (ELITE-S2) is an instrument created for gathering and analysing data on man's movement in space. Its objective is to study the strategies and adaptive mechanisms that the central nervous system uses for motor control in the space environment. ELITE S2 is therefore a system centred on human neurophysiology with particular regard to the analysis of three- dimensional movement of man in space. It is based on an optoelectronic system for the quantitative analysis of human movement in three dimensions. The system can reconstruct the astronauts' movements, illuminating with four lasers up to one hundred markers placed on the body in subject, with accuracy less than a millimetre. Astronauts will repeatedly carry out two scientific protocols of the University of Rome Tor Vergata and Politecnico di Milano during that period. ELITE- S2 was brought on board the ISS in August 2007 with the STS 118 Mission. Five experimental sessions have been performed during 2008 and other are foreseen.

hpa

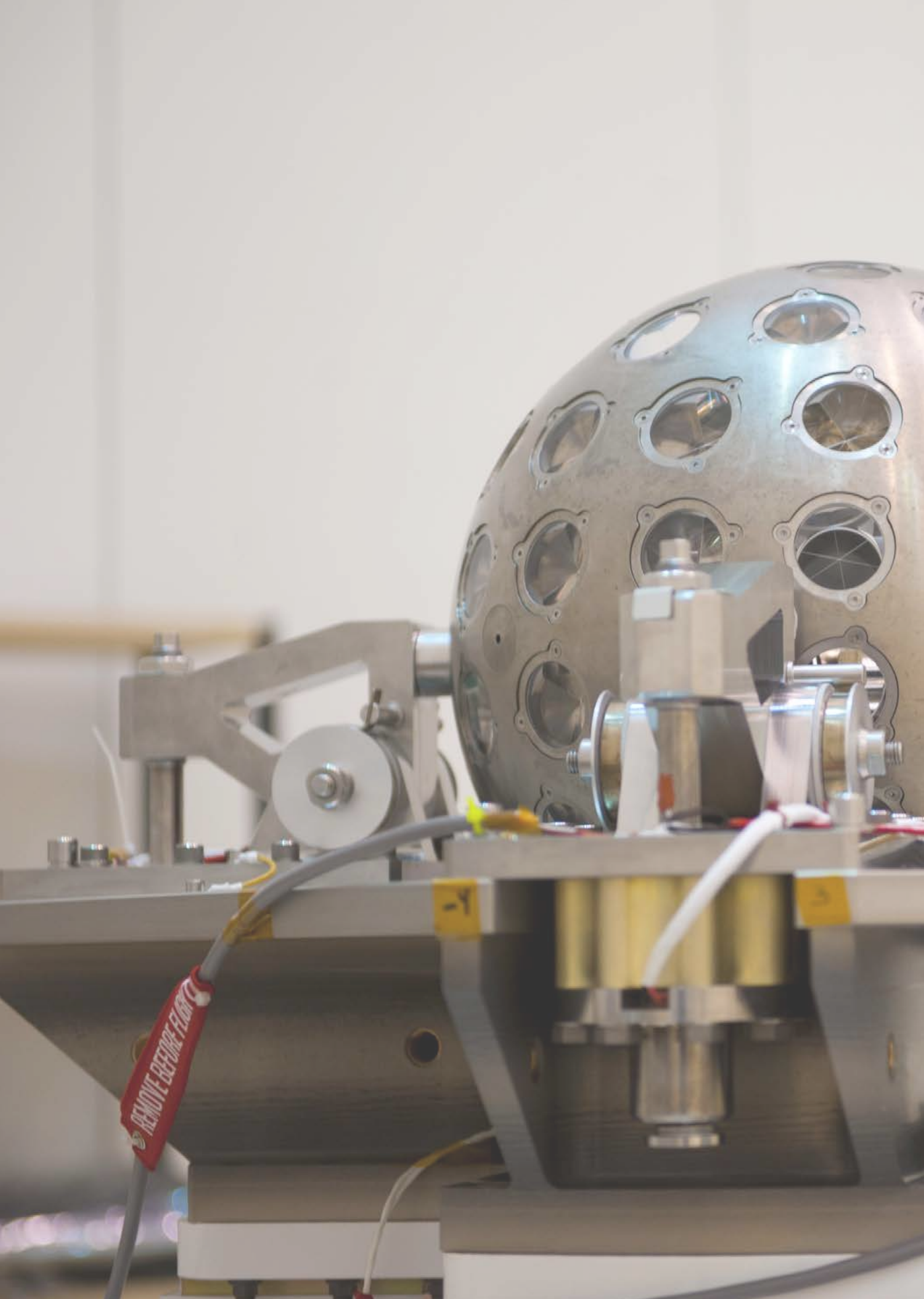
HPA examines the way hand and arm muscles are used in weightlessness, studying the effects of long-duration space flight on muscle fatigue.

HPA (Hand Posture Analyzer) is an ASI instrument developed for evaluating the impairment in performance of the muscular system and to select and define the strategies of movement of the upper arm under prolonged microgravity conditions. HPA has been used in five different missions for carrying out the three experiments selected that concern the area of motor control disturbances (IMAGINE experiment of the University of Rome Tor Vergata, the MAIS experiment of the Hospital Camaiore of Viareggio and the CHIRO experiment of the Hospital S. Chiara of Pisa). The experiments have been carried out during increment 7 of 2003 and 8 of 2004, respectively by American astronauts Ed Lu and Mike Foale. In 2005 it was part of the experiment programme during the "taxi flight" of Soyuz 10S with Italian astronaut Roberto Vittori. In 2007 it was used again during the Esperia mission with Italian astronaut Paolo Nespoli. Hand Posture Analyzer was on board the ISS in 2003. It will possibly be re-utilized to increase the data acquired so far (2010).

mds

An ASI experiment to investigate the genetic mechanisms underlying bone mass loss and other microgravity effect on different tissues such as muscles, glands, brain.

MDS (Mice Drawer System) is an animal room where long-term experiments on small rodents can be performed on board the International Space Station, it has been launched on the STS 128 on August 29, 2010. The idea for a MDS facility comes from a proposal by the Centro di Biotechnologie avanzate (Centre for Advanced Biotechnologies of Genoa) that aims at finding out about the genetic mechanisms that are the basis for the pathophysiology of bone mass. In addition to this experiment, another six experiments are scheduled regarding the study of the muscular, cardiac and endocrine systems. An international "tissue sharing" programme is also planned coordinated by ASI that involves the participation of selected experimenters from NASA, JAXA, ESA and DLR.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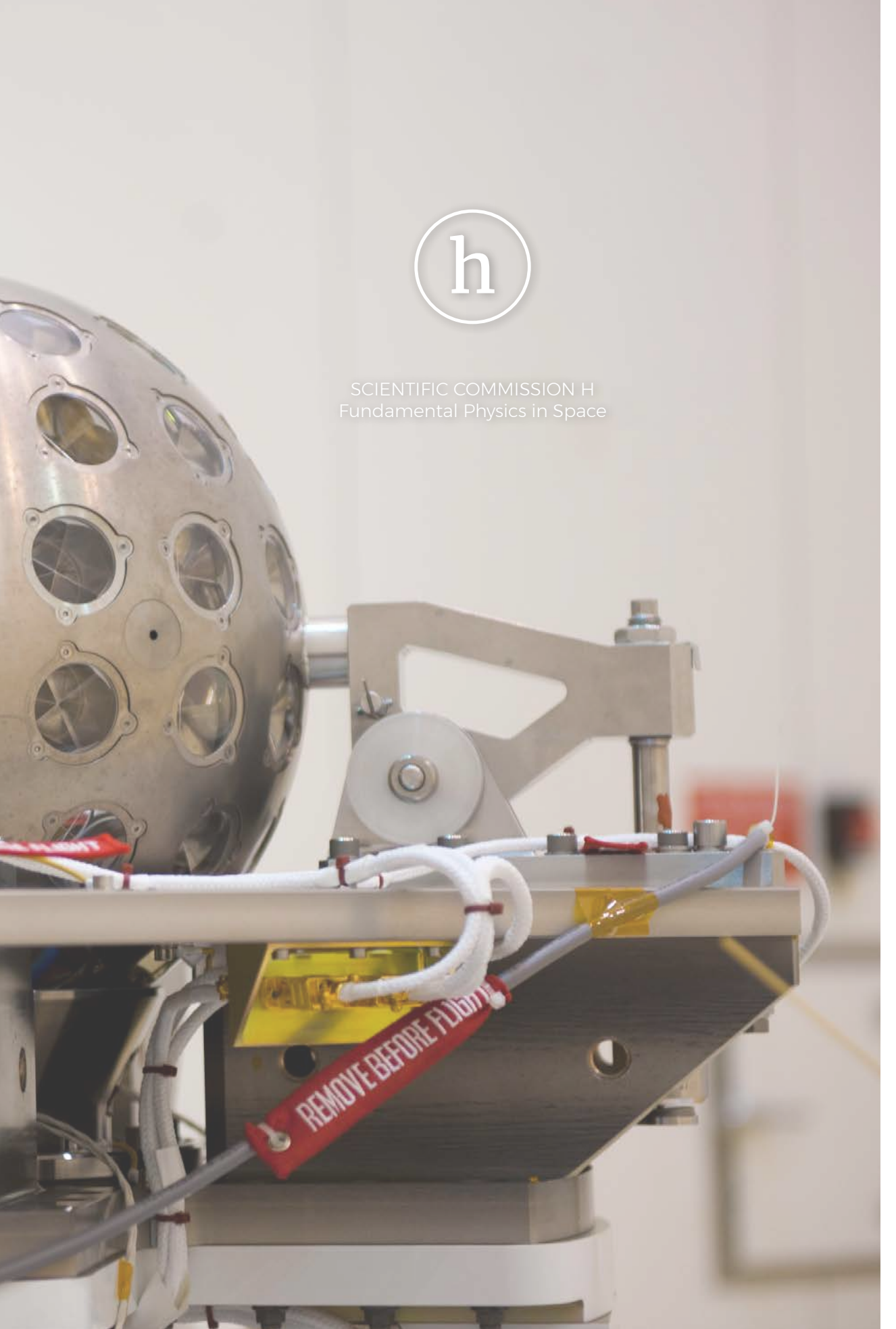
h

SCIENTIFIC COMMISSION H
Fundamental Physics in Space

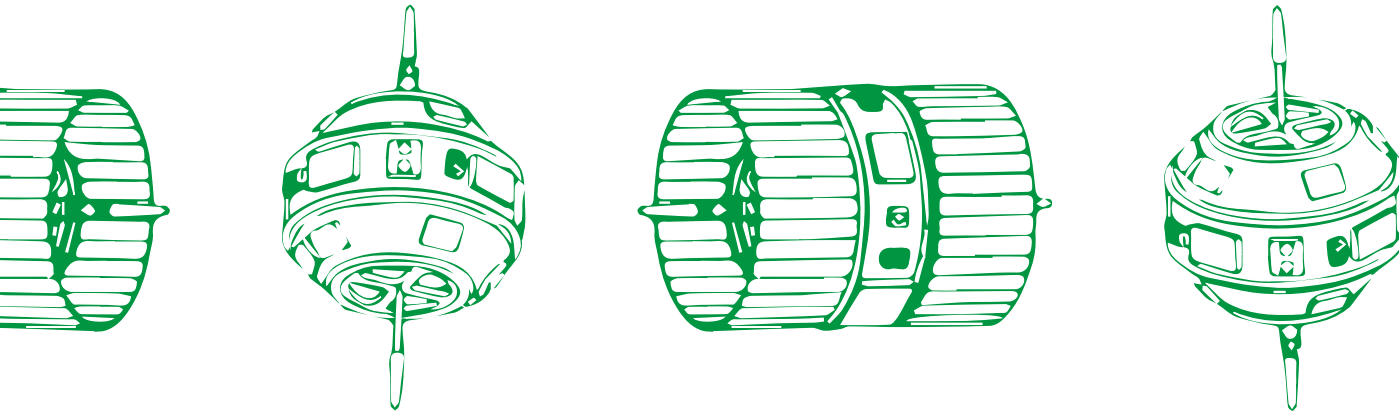


Previous page: The LARES satellite at Europe's Spaceport in French Guiana. Credit: ESA/S. Corvaja.

ams-02

AMS-02 is a detector designed to operate as an external module on the ISS to search for antimatter and dark matter while performing precision measurements of cosmic rays composition and flux.

AMS-02 (the Alpha Magnetic Spectrometer) is a state-of-the-art particle physics detector designed to operate as an external module on the International Space Station. It uses the unique environment of space to study the Universe and its origin by searching for antimatter, dark matter while performing precision measurements of cosmic rays composition and flux. AMS-02 will measure the rigidity and the sign of the cosmic rays particles with its magnetic spectrometer and will separate the electromagnetic from the nuclear part by means of multiple particle identification detectors. The energy of the electromagnetic component will be measured by a dedicated calorimeter. The scientific goals of the AMS-02 experiment include the search for antimatter nuclei, the search for dark matter signatures and the precise determination of the cosmic rays rare components flux. AMS-02 has been launched on the Space Shuttle Endeavour in 2011 and will operate on the International Space Station for at least ten years. The AMS-02 collaboration is an international group of scientists, from 16 countries and 3 continents, working together since 15 years. Italy institutes collaborating to AMS-02 are the Universities and the linked Italian National Institute for Nuclear Physics (INFN) units of Bologna, Milan, Pisa, Perugia, Rome and Siena. The Italian contribution is prominent in 4 out of 5 sub-detectors and covered also a significant part of the space qualification tests that have been performed at the SERMS test facility in Terni. In Italy AMS-02 is funded by ASI and INFN.

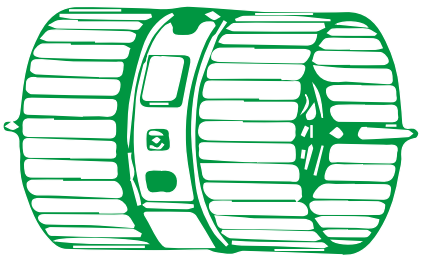


gg

Galileo Galilei is a small satellite to test the Equivalence Principle of Galileo, Newton and Einstein to 1 part in 10^{17} and beyond.

GG is a small satellite to be injected in low Earth orbit by the VEGA launcher with the goal of testing the Equivalence Principle of Galileo, Newton and Einstein to an unprecedented high precision of 10^{17}, and possibly better. Such a result would improve current best tests by more than 4 orders of magnitude and be of crucial importance for both Physics and Cosmology; evidence of a violation would represent a scientific revolution. The feasibility of GG has been confirmed by an ASI funded Phase A- 2 Study completed in 2009 and based on experimental results from the GGG (GG on the Ground) laboratory prototype. A collaboration has initiated in 2010 with NASA JPL which has recently expressed to ASI its interest to collaborate in GG seeking appropriate NASA funding opportunities.

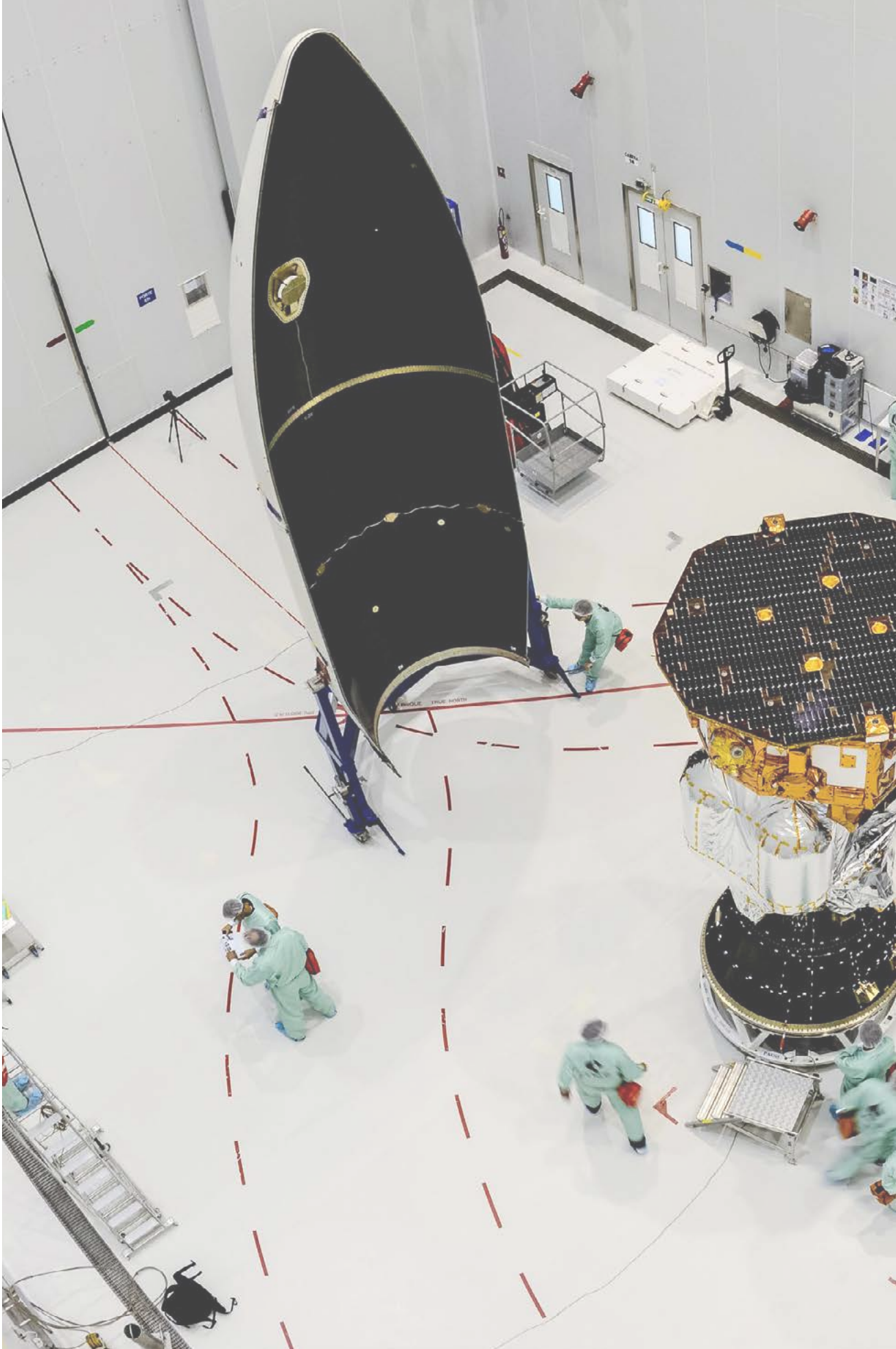
The GG spacecraft prototype with solar panels and without.
Credit: Nobili/Bramanti/Severi.



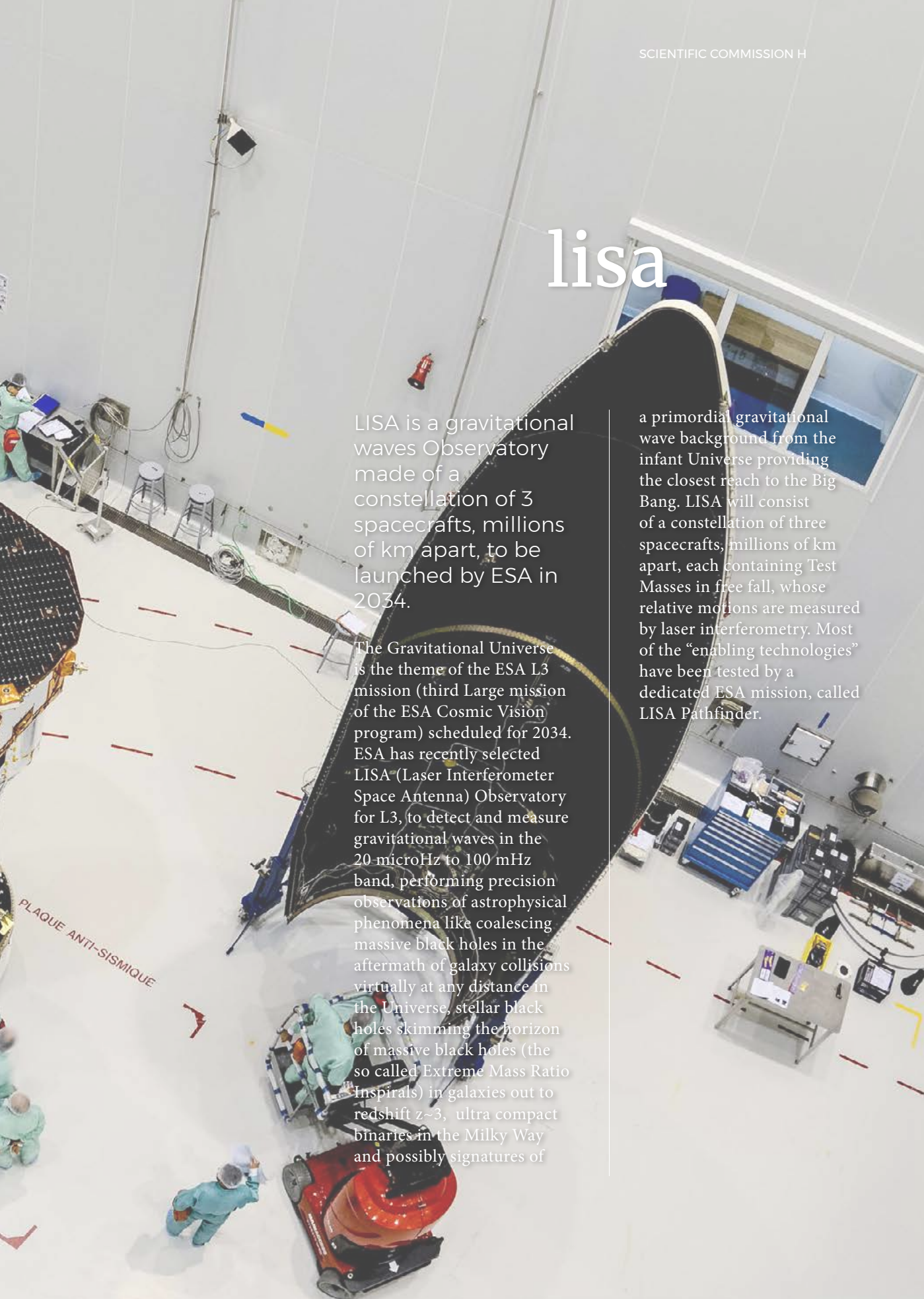
lares

LARES is a passive, laser ranged satellite. The mission's main goal is the measurement of the relativistic frame-dragging effect.

LARES (LAser RElativity Satellite) is an Italian small mission characterized by low cost and fast time of realization, launched in 2012, with the qualification launch of VEGA. The relativistic measurement will be reached thanks to the very precise measurements of the satellite orbit provided by the Satellite Laser Ranging technique and through the scientific analysis of the acquired data combined with the ones given by the LAGEOS (NASA) and LAGEOS-2 (ASI/NASA) satellites. These two satellites have already contributed to measure the Earth gravitational with high precision and have provided a first measurement of the Lense-Thirring precession at a 10% level. The LARES mission has been a collaboration between ASI, Italian National Institute for Nuclear Physics (INFN), University of Rome, and University of Lecce.



lisa



LISA is a gravitational waves Observatory made of a constellation of 3 spacecrafts, millions of km apart, to be launched by ESA in 2034.

The Gravitational Universe is the theme of the ESA L3 mission (third Large mission of the ESA Cosmic Vision program) scheduled for 2034. ESA has recently selected LISA (Laser Interferometer Space Antenna) Observatory for L3, to detect and measure gravitational waves in the 20 microHz to 100 mHz band, performing precision observations of astrophysical phenomena like coalescing massive black holes in the aftermath of galaxy collisions virtually at any distance in the Universe, stellar black holes skimming the horizon of massive black holes (the so called Extreme Mass Ratio Inspirals) in galaxies out to redshift z~3, ultra compact binaries in the Milky Way and possibly signatures of a primordial gravitational wave background from the infant Universe providing the closest reach to the Big Bang. LISA will consist of a constellation of three spacecrafts, millions of km apart, each containing Test Masses in free fall, whose relative motions are measured by laser interferometry. Most of the "enabling technologies" have been tested by a dedicated ESA mission, called LISA Pathfinder.

lisa pathfinder

Lisa-Pathfinder is an ESA space "precursor" mission that opened the way for the LISA observatory.

Lisa-Pathfinder hosts two test masses in near-perfect gravitational free-fall and measures their relative acceleration with unprecedented accuracy. This is achieved through state-of-the-art technology including the electrostatic inertial sensors, the laser metrology system, the drag-free control system and an ultraprecise micropropulsion system.

Launched on Dec 3rd, 2015, LISA is orbiting around the L1 Lagrange Point and has performed an exhaustive series of tests. The results have been so far exceptionally good, demonstrating the feasibility of space-borne interferometry and measuring a quality of free-fall with residual accelerations below the femto-g level. The mission is now in post-operative phase.

Previous page: LISA Pathfinder and the half-shells of the Vega rocket. Credit: ESA/Manuel Pedoussaut.

A QUICK SITOGRAPHY

sitography

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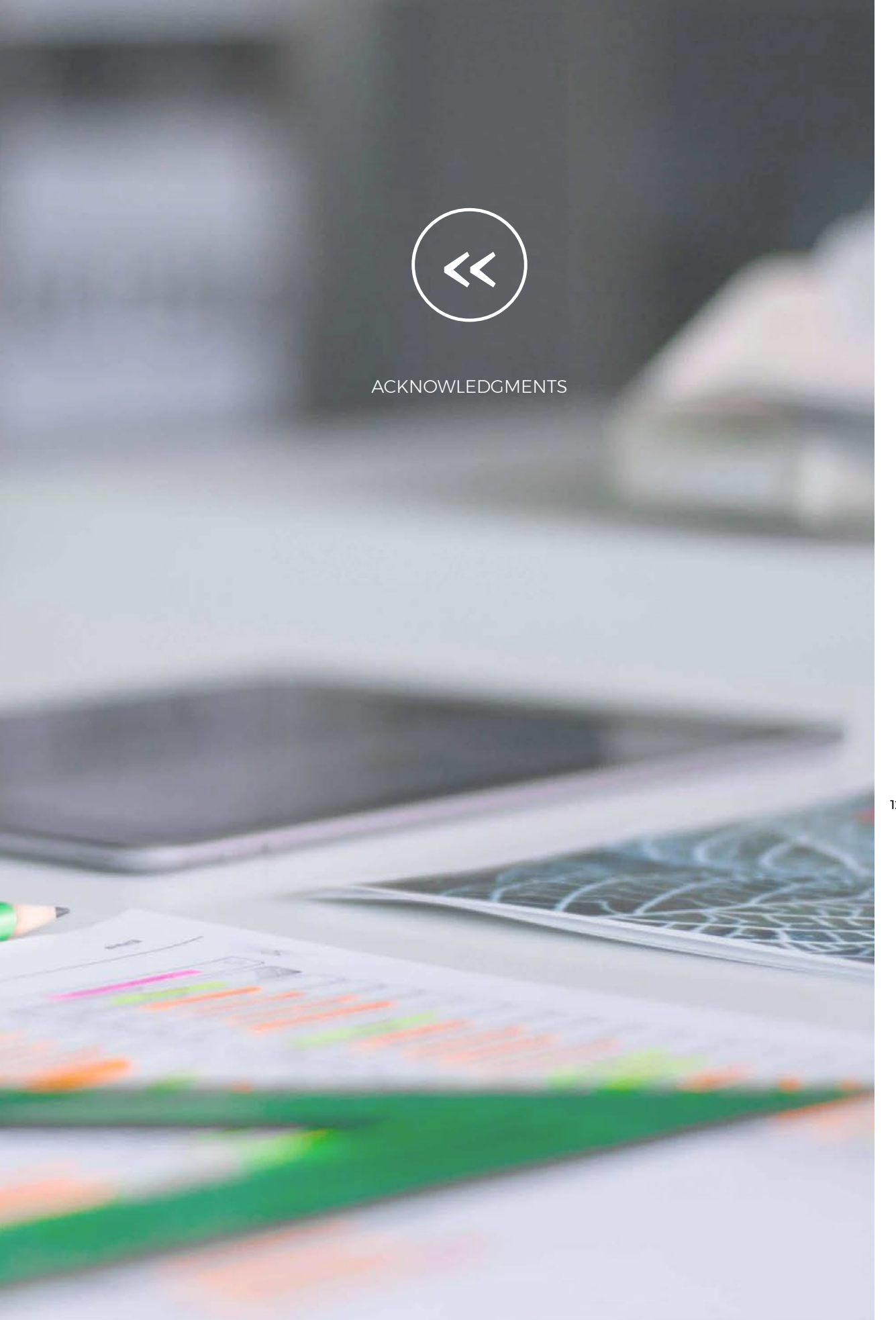

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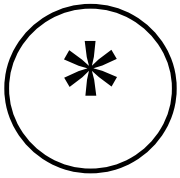

APPENDIX
A few projects among the many funded by the EU Horizon 2020 program, related with space and astrophysics.

ahead

Integrated activities for the high-energy astrophysics domain.

The overall objective of AHEAD is to integrate national efforts in high-energy Astrophysics and to promote the domain at the European level, to keep its community at the cutting edge of science and technology and ensure that space observatories for high-energy astrophysics are at the state of the art. AHEAD will integrate key research infrastructures for on-ground test and calibration of space-based sensors and electronics and promote their coordinated use. In parallel, the best facilities for data analysis of high-energy astrophysical observatories are made available to the European community.
The technological development focuses on the improvement of selected critical technologies, background modeling and cross calibration for the benefit of future high energy missions like Athena, and the best exploitation of existing observatories. The advancement in space oriented instrumentation and cutting-edge sensor technology in Europe will enable the development of new technologies and the growth of the related European market with a dedicated technology innovation package. Through AHEAD, feasibility studies of space-based instrumentation for future gamma-ray missions are also carried out. Finally, AHEAD is supporting the community via grants for collaborative studies, dissemination of results, and promotion of workshops, and a strong public outreach package ensures that the domain is well publicized at national, European and International level.

europlanet

Europlanet is the Europe's community for Planetary science

Europlanet is a project to link research institutions and companies in Europe and around the world that are active in the study of our Solar System and the planetary systems around other stars.
The project addresses key scientific and technological challenges facing modern planetary science like robotic and human exploration of other planets, as well as the search for extra-terrestrial life.
Since 2005 Europlanet has provided Europe's planetary science community with a platform to exchange ideas and personnel, share research tools, data and facilities, provide free access to laboratories, field sites, organize workshops and meetings, define key science goals for the future and engage policy makers and European Citizens.
The Europlanet 2020 Research Infrastructure (RI) was funded by the European Commission under Horizon 2020 with 33 beneficiary institutions from 19 European countries, including Italy that participates with INAF and many other partners. It will run until August 31, 2018, when the new Europlanet Society will be launched.

hemera

HEMERA is a european stratospheric vantage point for research.

HEMERA is a Research Infrastructure that integrates a large starting community in the field of tropospheric and stratospheric balloon-borne research. The project started in January 2018 and its objectives are to make existing balloon facilities available to all scientific teams in the European Union, Canada and associated countries. In Italy, INAF is deeply involved both in the scientific and communication aspects of the project.
A wide range of scientific and technical themes are addressed, such as astronomy, atmospheric physics and chemistry, climate research, fundamental physics, biology, space research and technology.
The consortium dealing with balloon-borne research includes 13 Partners from seven countries, including Space agencies, Companies operating balloons and scientists from the atmospheric sciences, astronomy and astrophysics communities.
HEMERA also aims to develop strong synergies with the European Union programme COPERNICUS, be complementary to the European Space Agency programmes and establish links with other European Commission (EC) infrastructures (e.g. ACTRIS, IAGOS).

upwards

UPWARDS: understanding planet Mars.

The objectives of the project are to address the major challenging open scientific problems in Mars research, to prepare a set of tools for exploitation of data from the future missions and to deliver enhanced scientific context based on the best available data and revised knowledge for the 2018 ExoMars Rover operations and other future Mars missions.
The project aims to answer some of the great questions about the red planet, among which stand out the global water cycle, the exchange of methane and other gases between the atmosphere and the interior of Mars, the behavior of dust storms and the nature of the Martian subsoil.
The UPWARDS project is a European consortium coordinated by the Instituto de Astrofísica de Andalucía (IAA-CSIC, Spain) with an Italian participation led by INAF.

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