italian report

to the 44th
Cospar Scientific Assembly

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index

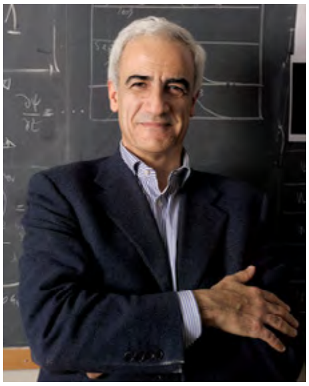
editorial

Italy plays a major role in space physics. Italian researchers are currently engaged in a large number of projects in astrophysics and space physics as a result of the wide interests and implementation capabilities of its scientific community. Since the launch of the first San Marco satellite on 1964, space research in Italy has been supported first through special programs and then by the Italian Space Agency (ASI). Today, space projects in Italy involve all main research Institutes and Universities.

The Italian Institute of Astrophysics (INAF) is a major player in the field of space research. INAF is spread out in 16 research branches and laboratories throughout Italy and supports about 1400 researchers and engineers. The Institute operates several research infrastructures (the Galileo National Telescope in the Canary Islands, a substantial fraction of the Large Binocular Telescope in Arizona, a network of radiotelescopes including the antennas in Medicina and Noto and the Sardinia Radio Telescope). It is worth mentioning Italy's very active participation in the scientific and technological programs related to the European Southern Observatory (projected towards E-ELT), the Square Kilometer Array Observatory, and the Cherenkov Telescope Array Observatory. INAF entirely manages the ASTRI Cherenkov Array project at the Canary Islands.

INAF is crucially engaged in a large number of space research projects as outlined in this Report. An impressive set of Italy-led instruments are on board of satellites already operating or soon to be completed. This is the result of the excellent collaboration between the Italian space research community, ASI, and other international partners (ESA, NASA, JAXA, CAS, and until recently Roskosmos). The Italian community operates with its own satellites and infrastructures and in collaboration with international partners. Italy's space science objectives range from Earth observations to space weather, from solar to planetary science, from optical astronomy to high-energy astrophysics, from cosmic rays to magnetospheric studies. These activities are performed by INAF in collaboration with Italian universities, INFN, CNR, INGV and international partners. This Report summarizes the main programs

and aims at providing a hint of the scientific excitement behind each of the projects.
It is also very important to consider the role of space science in this critical historical moment. The Italian space science community is working hard to make sure that the superior goals of scientific knowledge and peaceful use of space research are endorsed once more without hesitation. Space science is a most wonderful human activity: it has to promote peace and international collaboration. Space scientists know in their hearts that this is a very valuable concept. Let us work every day to reinforce it very strongly.



Marco Tavani
President of the Italian National Institute for Astrophysics

foreword

The Italian Report to the 44rd COSPAR General Assembly is edited by INAF, the Italian National Institute for Astrophysics (INAF), the national body that by the law supports the COSPAR activities. INAF space programs are developed and realized in collaboration with ASI and other stakeholders playing a major role in the Italian scientific space programs: among others the National Institute for Nuclear Physics (INFN), National Research Council (CNR), National Institute of Geophysics and Volcanology (INGV), and Academia. This Report summarizes the past two years of space science activity in Italy and has been formulated in a similar condensed form of the past editions. The aim is to make available to the readers the relevant information in a snapshot, though providing a fully updated overview of the Italian research programs carried out from space. The editor apologizes for any possible omission or misunderstanding, clearly not intentional.

The Report is organized 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

Commission H
Fundamental Physics in Space

The aim of this Report is to provide an overview of the main involvement or commitment of the Italian community in the space programs, 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 our best level of knowledge at the time of this edition.

COSPAR Scientific Commissions

Two primary types of scientific body are active in COSPAR: Scientific Commissions and Panels. The general responsibilities of Scientific Commissions and Panels include, but are not limited to, the following:

- To discuss, formulate and coordinate internationally cooperative experimental investigations in space,
- To encourage interactions between experimenters and theoreticians, in order to maximize space science results, especially interpretation arising out of analyses of the observations,
- To stimulate and coordinate the exchange of scientific results,
- To plan scientific events at the biennial Assemblies where discussions will be held concerning the results of recent space research, with an appropriate mixture of review and contributed papers,
- To carry out these tasks in the closest possible association with other organizations interested in these and related tasks,
- To prepare a brief report on the open business meeting for presentation to the Council,
- To communicate regularly with COSPAR Associates through contributions, scientific or otherwise, to Space Research Today, COSPAR's information bulletin. Deadlines: 1 February for the April issue, 1 June for the August issue, 1 October for the December issue.

Scientific Commission officers are elected by COSPAR Associates present at the open business meetings held during Assemblies.

The main research programs 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, space related new technologies, and educational. ASI is delegated by the Italian Government to lead and support the Italian space science program, including the mandatory and optional contribution to ESA. Other relevant contributions are provided by the national research bodies and Universities proposing space programs, missions, satellites and observatories in different research fields. When the relevant peer committees approve a program, the above mentioned bodies provide staff scientists, engineers, technologists and management on contracts as well as laboratories and dedicated financial support on ground and operations in space. The majority of the Italian scientific space programs are carried out in the framework of ESA funding, via the mandatory and optional programs. Italy has also a well-consolidated partnership with NASA. In addition, it has a history of on-going programs with ROSCOSMOS, JAXA and other international space organizations via bilateral or multilateral agreements. In the last decade a broad range of programs have started with China in different scientific fields, materialized the 2nd of February 2018 with the successful launch of CSES-01, the 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 more than four years CSES is successfully 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 correlations with the occurrence of seismic events. Recently, on December 9, 2021 the IXPE (Imaging X-ray Polarimetry Explorer) satellite, a NASA-ASI astrophysical mission, has been successfully launched from the Kennedy Space Center in Florida with a Falcon 9 carrier, by the private company SpaceX.

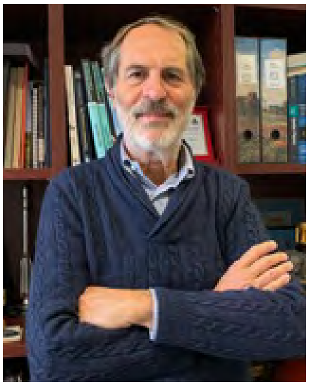
A robust national program, including dual missions, complements these international endeavours. Italy is playing a major role in the

ESA Cosmic Vision program, participating with PIs and Co-Is in the on going Large mission to Mercury, BepiColombo, Small mission for exoplanet search, CHEOPS, Medium size missions, Solar Orbiter, Euclid, PLATO, and EnVision. The Italian community is also committed to the exploitation of the ESA Large mission JUICE, to the Jupiter's icy moons, as well as ATHENA, an unprecedented sensitive X-Ray Observatory to study the hot and energetic Universe, and the forthcoming LISA, the Gravitational Wave Observatory to be realized with an important US participation. Among the ESA optional program, Italy participates to the ExoMars programs, with the first spacecraft already orbiting Mars and the second one, featuring a rover: a scientific exploration mission lead by ASI to bring a rover to Mars, a joint venture between Italy, ESA and Russia.

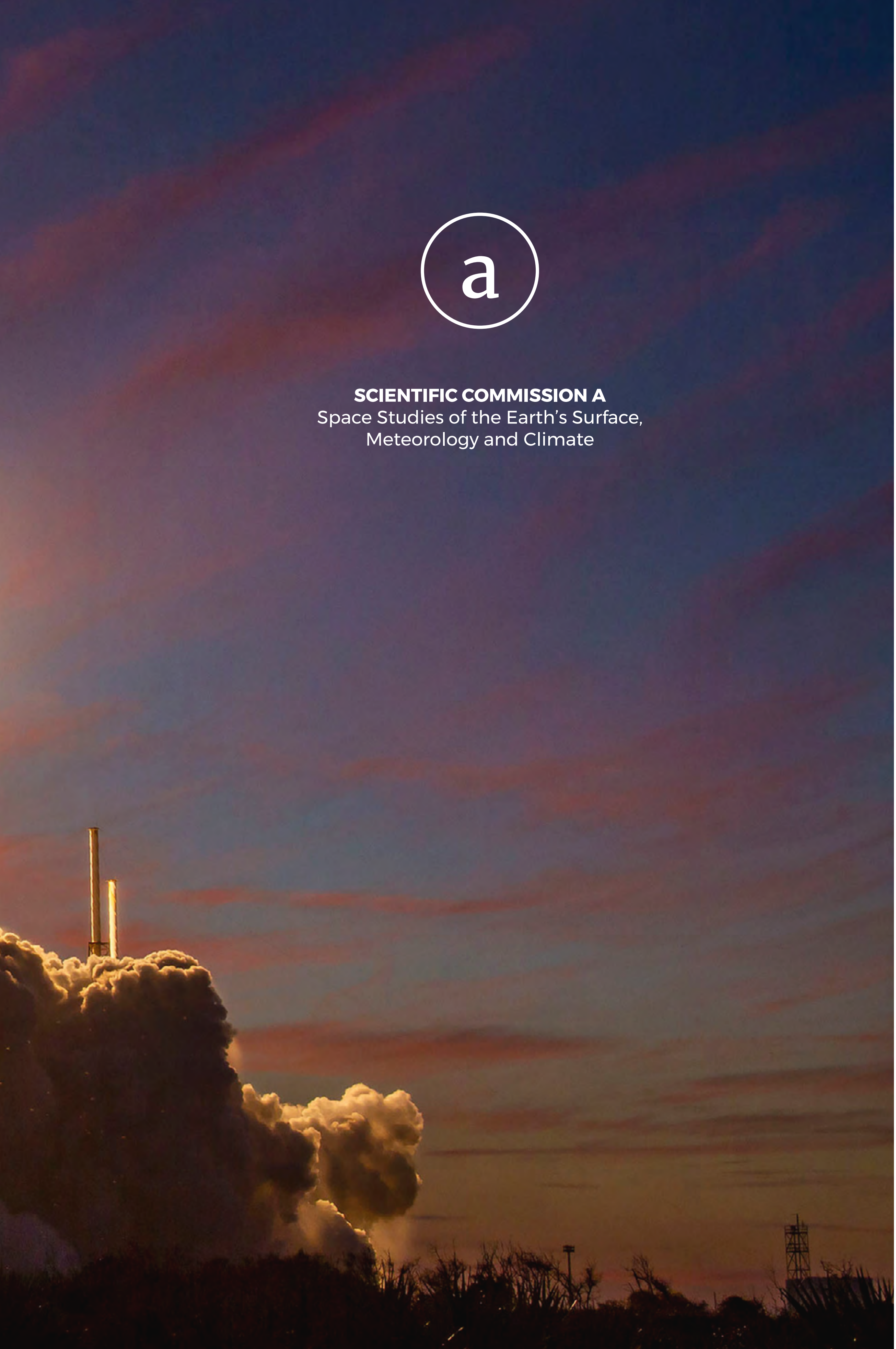
While we are publishing the Report the ESA Council, during the meeting held in Paris on 16 and 17 March, decided to suspend the ExoMars program, due to the impacts of the war in Ukraine. In summary, the measures taken are:

- Suspension of the ExoMars rover mission;
- Put on hold of all missions scheduled for launch by Soyuz from the European spaceport of Korou;
- Continuation of the International Space Station Program.

Italy also has a relevant participation to the International Space Station with more than 40% of the habitable modules delivered by the Italian space industry and an important astronaut crew, committed to the success of the Italian and international manned space programs during the years to come. The next mission will be the participation of the Italian ESA astronaut Samantha Cristoforetti to the mission Minerva as Leader of the Us orbital Segment (USOS). The NASA module Crew Dragon of SpaceX is planned to lift-off from the Launch Complex 39A at the Kennedy Space Center to bring the crew of four astronauts to the ISS. Finally, it is worth mentioning that in the past 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. A text-book result is the first, and so far unique, prompt detection of gamma-rays, contemporary by INTEGRAL and FERMI, in coincidence with the GW170817 signal from a Binary Neutron Stars system coalescing, 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



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

Previous page: The spectacular launch from Cape Canaveral just after sunset january 31th deliveres to orbit Italy’s second satellite in a new generation of COSMO-SkyMed radar remote sensing spacecraft. Credit: SpaceX.

cosmo-skymed

COSMO-SkyMed consists of a constellation of four Low Earth Orbit mid-sized satellites still operating for Earth observation, funded and managed by the ASI and the Italian Ministry of Defense.

COSMO-SkyMed (COnstellation of small Satellites for Mediterranean basin Observation) represents the largest Italian investment in space systems for Earth observation. It is a dual-use (civilian and defence) end-to-end Earth observation system aimed at establishing a worldwide service providing data, products and services compliant with well-established international standards and relevant to a wide range of applications, such as emergency and risk management, scientific, commercial and defence applications. The system consists of a constellation of four Low Earth Orbit mid-sized satellites, each equipped with a multi-mode high-resolution SAR (Synthetic Aperture Radar) operating at X-band and fitted with particularly flexible and innovative data acquisition and transmission equipment and a dedicated full featured ground infrastructures for managing the constellation and granting ad-hoc services for collection, archiving and distribution of acquired remote sensing data.
The first generation of the COSMO-SkyMed program is based on a constellation of 4 medium-size satellites, each one equipped with a high-resolution SAR operating in X-band, having ~600 km single side access ground area, orbiting in a sun-synchronous orbit at ~620 km 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 Constellation started operations in September 2008, with the deployment of the first two satellites qualified in orbit. The deployment of the complete constellation onto operations, with four satellites qualified in orbit, was completed in January 2011.
COSMO-SkyMed Mission offers today an efficient and well-established response to actual needs of Earth observation market providing an asset characterized by full global coverage, all weather, day/night acquisition capability, higher resolution, higher accuracy (geo-location, radiometry, etc.), superior image quality, fast revisit/response time, interferometric/polarimetric capabilities and quicker-and-easier ordering and delivery of data, products and services. The system is conceived to pursue a Multi-Mission approach thanks to its intrinsic interoperability with other Earth observation missions and expandability towards other possible partners with different sensors typologies to implement an integrated space-based system providing Earth observation integrated services to large user communities and partner countries (IEM capability).
These features designate COSMO-SkyMed as a system capable to provide “Institutional Awareness” in order to make proper decisions in preventing and managing world-wide crisis. In particular primary mission objective is thus to meet customer’s needs, under economical, schedule and political constraints, for a space borne Earth Observation System capable to provide:
- environmental risk and security management for both civilian institutional and defence needs, through monitoring and surveillance applications assessing exogenous, endogenous, and anthropogenic risks;
- commercial products and services (e.g. for agriculture, territory management) to world-wide civilian user community.

cosmo–skymed second generation

COnstellation of small Satellites for Mediterranean basin Observation SG are satellites planned for Earth observation with state of art technologies.

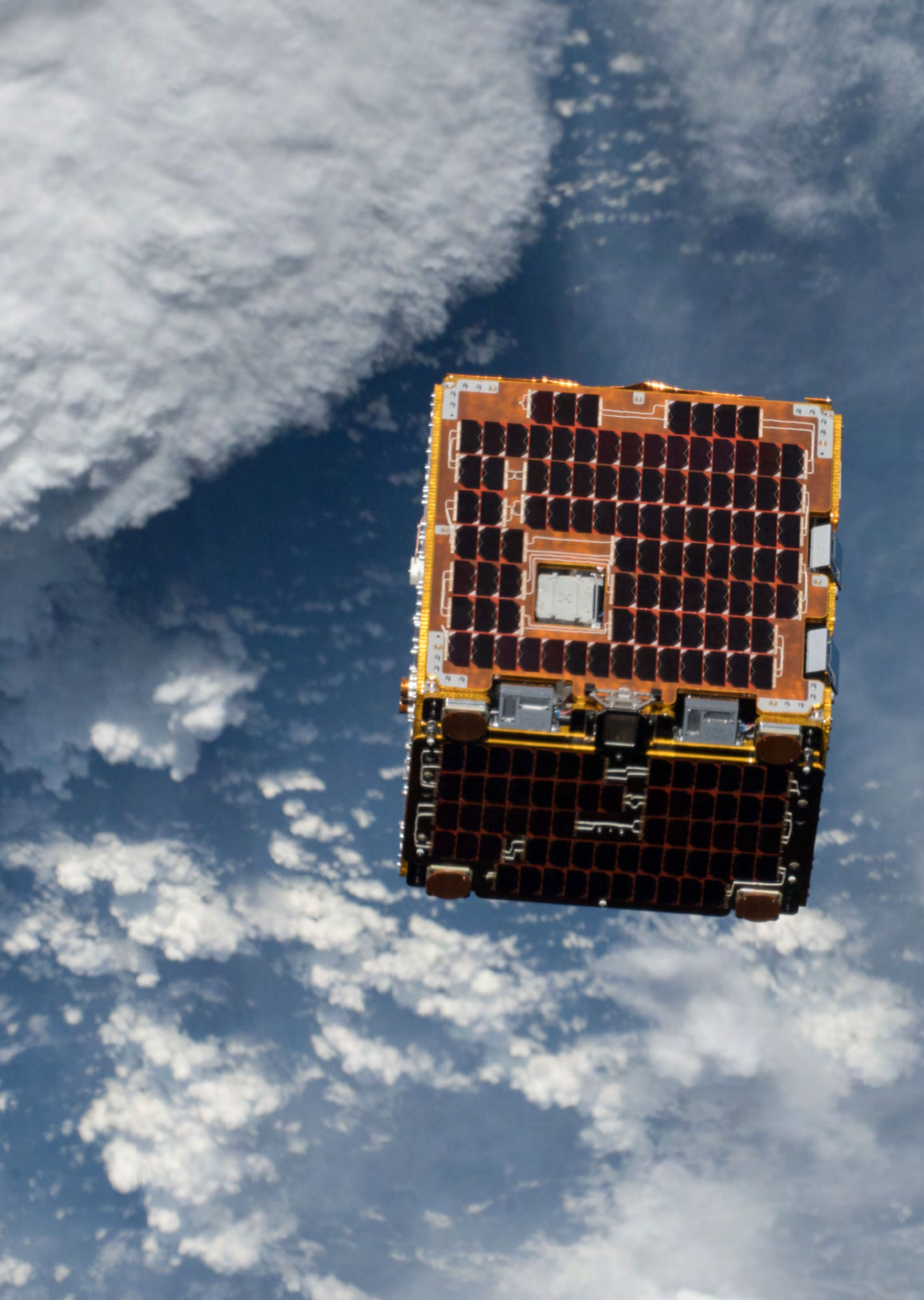
The new constellation will further improve the Italian leadership in this area of strategic observations, allows to ensure the full operational continuity of the entire COSMO-SkyMed mission. The constellation have also the aim to expand strategic partnership at international level. COSMO-SkyMed second generation will consist in four new technology satellites to be launched into a Sun-synchronous orbit at 619 km. The first Second Generation satellite was launched from the Kourou launch facility in French Guyana and was placed in orbit with a Soyuz at the end of 2019; in February 2022 was launched the second satellite from Cape Canaveral Kennedy Space Center and was placed in orbit by SpaceX's rocket, Falcon 9 Block 5.
These satellites are equipped with SAR (Synthetic Aperture Radar), in order to be able to provide detailed Earth observation in any meteorologic situation and illumination. COSMO-SkyMed is funded by ASI in partnership with the Defense Ministry.
It is the product of the best practices among the ASI and the national space industry, with Leonardo S.P.A., Thales Alenia Space and Telespazio also in collaboration with several PME.

The lava flow of the Cumbre Vieja volcano, on the island of La Palma, seen from Cosmo-SkyMed. Credit: ASI.

prisma

PRISMA is an Earth Observation System launched in 2019 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 has been launched on 22 March 2019 on board a VEGA rocket. PRISMA is a scientific and demonstrative mission lead by ASI. It will play a significant role in the upcoming international scenario of Earth observation, both for scientific community and for end users, thanks to the capability to acquire worldwide a large amount of data with a very high spectral resolution and in a wide range of spectral wavelengths. PRISMA provides the capability to acquire, downlink and archive images of all Hyperspectral/Panchromatic channels totaling 200,000 Km2 daily almost on the entire worldwide area, acquiring square Earth tiles of 30 km by 30 km. The combined hyperspectral and panchromatic products enable the capabilities of recognition of the geometric characteristics of a scene and may provide detailed information about the chemical composition of materials and objects on the Earth surface, giving enormous impacts to remote sensing applications. The PRISMA system includes ground and space segments. The PRISMA mission can operate in two modes, a primary mode and a secondary mode. The primary mode of operation is the collection of hyperspectral and panchromatic data from specific individual targets requested by the users. In the secondary mode of operation, the mission will have an established ongoing 'background' task that will acquire imagery to fill up the entire system resources availability. Daily planning should always include the user acquisition requests and enough background (systematic acquisitions) to guarantee the full usage of the entire system resources. The PRISMA payload consists in a hyperspectral/panchromatic camera with VNIR (Visible and Near-InfraRed) and SWIR (ShortWave InfraRed) detectors. This imaging spectrometer is able to acquire in a continuum of spectral bands ranging from 400 to 2505 nm (from 400 nm to 700 nm in VNIR and from 920 nm to 2505 nm in SWIR) with 30 m of spatial resolution and a medium resolution PAN (Panchromatic Camera, from 400 nm to 700 nm) with 5 m resolution. The PRISMA Hyperspectral sensor utilizes the prism to obtain the dispersion of incoming radiation on a 2-D matrix detectors in order to acquire several spectral bands of the same ground strip. The "instantaneous" spectral and spatial dimensions (across track) of the spectral cube are given directly by the 2-D detectors, while the "temporal" dimension (along track) is given by the satellite motion (push broom scanning concept). The dissemination of PRISMA data has opened the mission portal (https://prisma.asi.it/) on May 2020, releasing the products to the user community with a quasi-open and free license. At present time such community has grown to more than 1100 users exploiting an archive actually containing 146000 hyperspectral images, acquired all over the world lands. In 2022 some upgrades of the PRISMA mission are foreseen: a new data policy allowing (under some conditions) the commercial exploitation of the data, a Toolbox supporting an easy ingestion and visualization of the products and finally the enabling of the best geometric accuracy (15m CE90 on L2x products) allowed by the system.



b

SCIENTIFIC COMMISSION B

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

Previous page: The ISS deployes a small satellite for the NanoRacks-Remove Debris investigation. Credit: NASA.

abcs

ABCS is an Italian cubesat mission to be launched in 2022, hosting a mini laboratory payload for research in astrobiology, life sciences, biotechnology and pharmaceutics.

ABCS (AstroBio CubeSat) is a scientific 3U cubesat hosting a mini laboratory payload based on innovative lab-on chip technology suitable for research in astrobiology, life sciences, biotechnology and pharmaceutics. INAF/OAA with the collaboration of Roma Sapienza University have the responsibility of the project, that will be launched on May 2022 from Guiana Space Centre with the Vega C qualification maiden flight. ABCS will be deployed in an approximately circular orbit at 5900 km altitude and 70° of inclination spending a significant amount of the orbital period within the harsh internal Van Allen belt.ABCS will host a laboratory payload based on an innovative lab-on chip technology suitable for research in astrobiology. ABCS hosts a micro laboratory based on Lab-on-Chip technology able to provide a platform for performing autonomously bioanalytical experiments in space with a number of potential applications in manned and unmanned planetary exploration missions. The payload uses a microfluidic system based on chemiluminescence (CL) bioanalytical tests made of a paper substrate with an origami-like structure, on which biological reagents are deposited in a dried form. A system of pumps delivers liquid solvents and/or CL reagent solutions that dissolve the reagents on the paper, thus activating the biochemical reactions leading to light emission. The mission aims at evaluating the overall system functionality in an extremely harsh environment such as: handling of liquids in microgravity, chemicals and biomolecules stability in space, Lab-on-Chip and photo-detection characterization, readout noise evaluation, etc. The main challenge of the project is to mitigate the effects of the expected very high flux of charged particles, keeping the suitable temperature and pressure range to prevent reagents degradation. This invoked a series of technological solutions to protect the payload. The pressurized environment is ensured within an inner aluminium box, hosting both the experiment and the main subsystems (batteries, on-board data handling, telemetry, tracking and control), hermetically sealed and providing shielding from radiation and charged particles. A thermal control system, including a passive control multi-layer insulation and an active heather mounted inside the pressurized box, maintains the temperature in the desired range. The experiments will aim at evaluating the functional tests of the device (delivery of reagents, mixing of chemicals, detection of emitted photons, electronics, data storage and transmission) and the stability of chemicals and biomolecules
employed in the experiment and necessary for performing bioassays (e.g., immunoassays exploiting chemiluminescence detection) in space conditions for astrobiological investigations. In-orbit validation of the proposed technology would represent a significant breakthrough for autonomous execution of bio-analytical experiments in space with potential application in planetary exploration for biomarkers detection, astronauts' healthcare, space stations' environmental monitoring and more. INAF/OAA has the responsibility of the project with the collaboration of Sapienza University, School of Aerospace Engineer in Rome and the support of Italian Space Agency.

bepicolombo

BepiColombo is an ESA/JAXA mission devoted to the exploration of Mercury and to fundamental physics quests, with an important Italian contribution. Launched in 2018, it will arrive at Mercury in 2025.

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. It is an ESA/JAXA mission devoted to the exploration of Mercury and to fundamental physics quests. The BepiColombo mission is composed of two modules: the MPO (Mercury Planetary Orbiter) and the MMO (Mercury Magnetospheric Orbiter). In MPO, 11 European instruments are integrated. BepiColombo has been launched in 2018 with an Ariane 5, and the two modules will be inserted in orbit around Mercury at the end of 2025. 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 Italian contribution, coordinated by ASI, is very important, including four PI instruments on the MPO plus minor participation on other instruments on both modules. The ISA (Italian Spring Accelerometer), with the responsibility of INAF/IAPS, will measure with high accuracy non-gravitational accelerations. The MORE (Mercury Orbiter Radio science Experiment), with the responsibility of the Roma Sapienza University, 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 (Search for Exosphere Refilling and Emitted Neutral Abundances) instrument, with the responsibility of INAF/IAPS, will monitor neutral energetic atoms and ions of the planet exosphere. Finally the suite SIMBIO-SYS (Spectrometers and Imagers for MPO BepiColombo Integrated Observatory), with the responsibility of INAF/OAPD 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.

comet interceptor

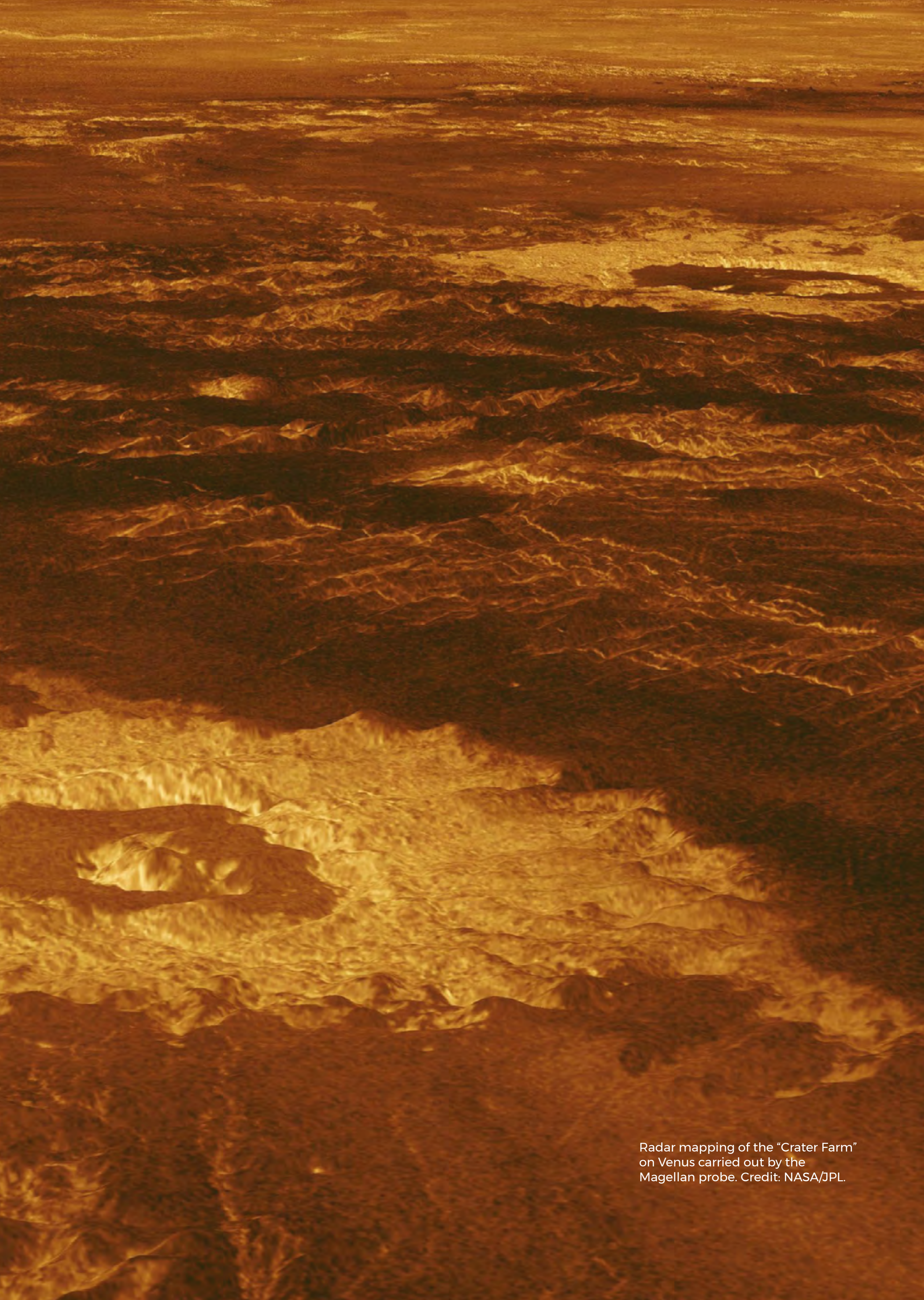
Comet Interceptor was selected in 2019 by ESA to be launched in 2029. The probe will be the first one to visit a dynamically new comet or possibly an interstellar body.

ESA selected Comet Interceptor in June 2019, the first ESA/F-class mission, which will be launched in 202 together with Ariel, an exoplanet telescope. For the first time a space probe will visit a dynamically new comet, i.e. never having approached the Sun before, or possibly an interstellar body. Such objects are difficult to target: they can only be discovered when entering the inner Solar System.
Comet Interceptor will likely be launched before its exact target is even known and an observation strategy is being organized to generate the largest catalogue of Solar System objects to date: the Vera Rubin Observatory's LSST (Legacy Survey of Space and Time). LSST is involving available ground based observational facilities and pushing at the edge the technological capabilities. The LSST Solar System Science Collaboration will actively contribute to the identification of potential targets for Comet Interceptor. In fact, after the launch, the mission will wait at the stable Lagrange point L2 for about 2 years, waiting for the discovery from ground observations of a suitable target, which will be then intercepted close to the ecliptic plane.
To ensure a low-risk interdisciplinary scientific return via multi-point measurements, which will provide unprecedented 3D information on the target, Comet Interceptor consists of 3 spacecraft: after departure from L2 the main spacecraft will stay at safe distance from the target and the two small spacecraft will separate and proceed for a closer distance. In support to spacecraft operations safe planning, numerical simulation of the dusty-gas environment of a possible target object are being developed. Since the exact target is not known in advance, the range of possible parameters and their values variation is very broad. The model is based on rather general parameters and suitable for rough description of dusty-gas environment suitable for the preliminary planning.
As for the onboard payload, Italy contributes to the DFP (Dust, Field and Plasma package) with the DISC (Dust Impact Sensor and Counter) and to the all-sky multispectral and polarimetric imager EnVisS (Entire Visible Sky).

envision

EnVision is ESA's next Venus orbiter with launch scheduled in 2032, aimed at providing a holistic view of the planet from its inner core to upper atmosphere to determine how and why Venus and Earth evolved so differently. Italy's contribution is on the Subsurface Radar Sounder.

EnVision has been selected as the fifth Medium-class missions (M5) in ESA's Cosmic vision 2015-2025 program and is planned for launch in May 2032, with arrival at Venus after a 15-month cruise, followed by a nominal science phase of 6 Venus sidereal days (4 Earth years).
The Envision payload consists of a suite of five instruments: (1) VenSAR, a reflectarray, dual polarization S-band Synthetic Aperture Radar, to provide surface images at spatial resolutions of 10 m to 30 m, altimetry, polarimetry (HV for the 1st time) and radiometry; (2) Subsurface Sounding Radar (SRS), to profile the subsurface for hundreds meters depth and search for underground layering and buried boundaries; (3) three spectrometers VenSpec-U, VenSpec-H and VenSpec-M, operating in the UV and Infrared, to map trace gases, including search for volcanic gas plumes, above and below the clouds, and map surface composition. This suite is complemented by the Radio Science Investigation exploiting the spacecraft TT&C system to map the planet's gravity field, to constrain internal structure, and to measure atmospheric properties through radio occultation. With the goal of investigating the reasons why Venus and Earth (the terrestrial planets) could have evolved so differently, EnVision will address the following overall science questions: (1) how have the surface and interior of Venus evolved? (i.e., its geological history), (2) how geologically active is Venus? and (3) how are Venus' atmosphere and climate shaped by the geological processes?
The Italian contribution to EnVision is on the payload and consists in the Subsurface Radar Sounder (SRS), which is a low frequency nadir looking radar for subsurface measurements. SRS , with the responsibility of the University of Trento, will support investigation of the geological history of the planet by investigating stratigraphic and structural patterns in the top kilometer of the subsurface, to test hypotheses related to the origin of structures at the surface and in the shallow subsurface and their relationships. EnVision is the first mission to Venus with a confirmed sounding instrument that will allow for the direct measurement of subsurface features.



Radar mapping of the "Crater Farm" on Venus carried out by the Magellan probe. Credit: NASA/JPL.

exomars

ExoMars includes two missions to Mars: the first one was launched in 2016, consisting of an Orbiter plus an Entry, Descent and Landing Demonstrator Module. The second one, including a surface platform and a rover, planned for launch in 2022 has been suspended (see ESA Press Release 9-2022).

ExoMars is an ESA/ROSCOSMOS 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 TGO (Trace Gas Orbiter) and Schiaparelli, the EDM (Entry, Descent and Landing Module), that unfortunately crashed on the surface on September 19, 2016. The TGO, with the Italian INAF/ASI participation in different instruments, including the Co-PI of NOMAD (Nadir and Occultation for Mars Discovery) and CASSIS (Colour And Stereo Surface Imaging System), is studying Mars. NOMAD is observing the gas composition of the atmosphere of Mars, looking for possible biological and geological activities. The CaSSIS camera is providing stereo colour high resolution images of Martian regions.
The second mission, expected for 2022, will have a European rover and a Russian surface platform. The rover 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, once the rover will be released, it will study the surrounding environment with a suite of instruments, including an Italian instrument (MicroMed, INAF). The other Italian instrument is Ma_MISS (INAF), 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. Italy is also responsible for the ROCC (Rover Operation Control Center) in Turin, the center from which the rover will be operated.

ExoMars 2020 will investigate the Martian soil in search of traces of past and present life. The operation control center will be in Turin, Italy. Credit: Altec.

hera

Hera is an ESA mission, planned for launch in 2024, to rendezvous and study the binary near-Earth asteroid Didymos four years after the impact of NASA's DART spacecraft.

Hera, as currently designed, is planned to launch in October 2024 and will rendezvous with the binary near- Earth asteroid (65803) Didymos and its little moon four years after the impact of NASA's DART (Double Asteroid Redirection Test) spacecraft, testified by LICIACube. Hera, named after the Greek goddess of marriage, is ESA's contribution to the international AIDA (Asteroid Impact Deflection Assessment) cooperation, the first planetary defense mission devoted tomthe deflection attempt of an hazardous near-Earth asteroid. In 2022, the NASA's DART will impact Dimorphos, the 160m diameter moon of the Near Earth Asteroid Didymos, to demonstrate the ability of kinetic impactors to change the orbit of an asteroid.

A variation of the Dimorphos revolution period around the primary body is expected and will be measured by Earth-based telescopes. However, a full picture of the collision and resulting momentum transfer will only become possible once Hera maps the mass of Dimorphos, to a high level of confidence, and the full two-body motion of the asteroid binary system. During the about six months of Hera mission, the main spacecraft and its two companion CubeSats will conduct detailed surveys of both asteroids, with particular focus on the crater left by DART's collision and a precise determination of the mass of Dimorphos. Hera's detailed post-impact investigations will substantially enhance the planetary defense knowledge gained from DART's asteroid deflection test. Hera will also demonstrate the ability to operate at close proximity around a low-gravity asteroid with some on- board autonomy. Mapping the shape of the crater will provide unique information to validate the numerical impact models necessary to design asteroid deflection missions in future. In addition, it will shed light also on the asteroid's surface properties and internal structure thanks to the first radar sounding of an asteroid. Hera will map Dimorphos' entire surface down to a size resolution of a few meters and also much of the surface of the primary Didymos, providing crucial scientific data from two asteroids in a single mission. The payload consists of two AFC (Asteroid Framing Cameras), PALT (Planetary Altimeter), TIRI (Thermal Infrared Instrument) contributed by JAXA, HyperScout (V+NIR hyperspectral imager) and two CubeSats 6U: Juventas, developed by

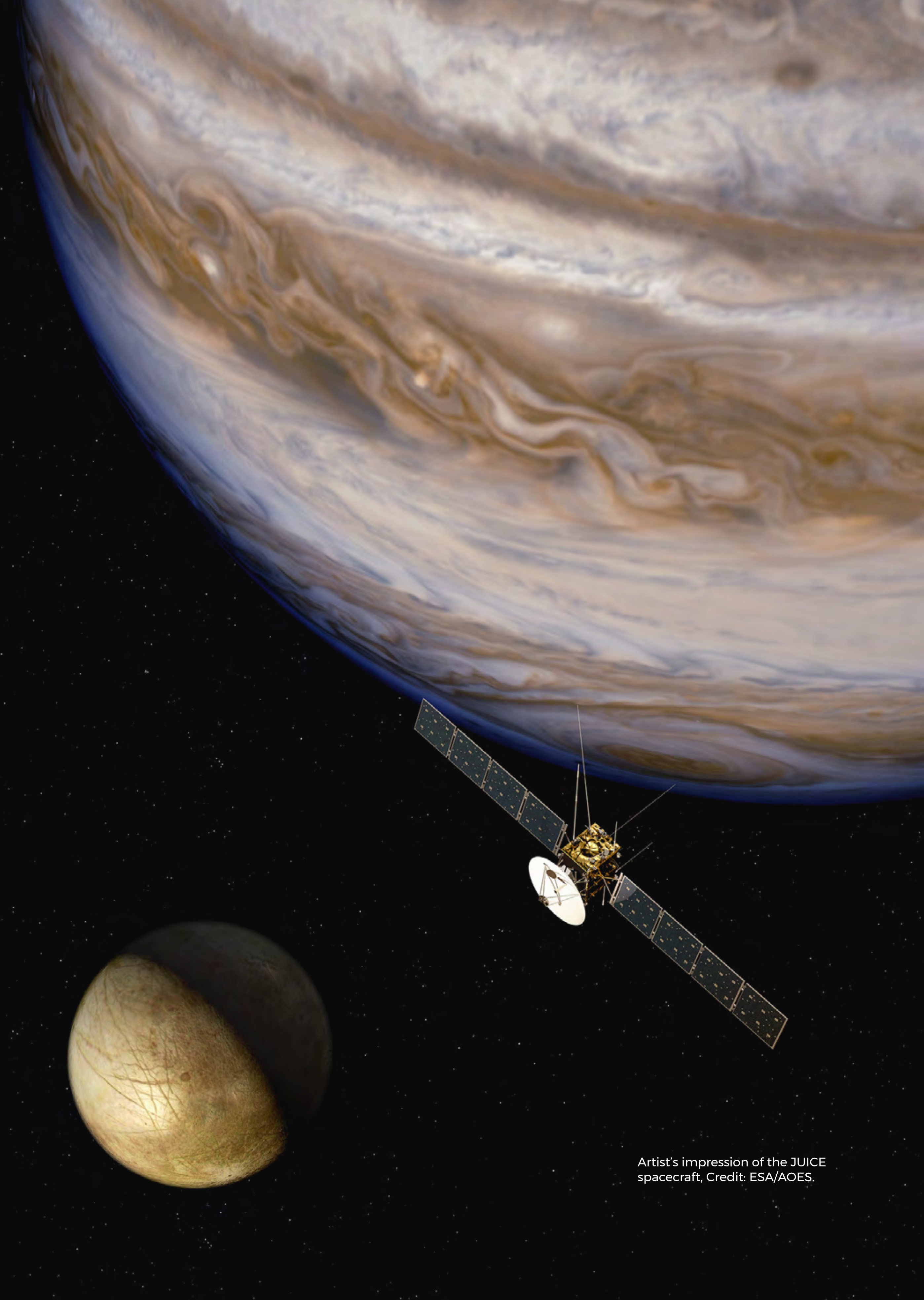
GomSpace Luxembourg; and Milani, developed by Tyvak International in Italy, with contribution from INAF-IAPS. A radio science experiment (RSE), led by the University of Bologna, will be performed including classical ground-based radiometric measurements between Hera and ground stations, images of Didymos taken by the on-board camera(s), and the Inter-satellite link (ISL) between Hera and the Cubesats. The aim of this experiment is to contribute to the determination of the binary system's mass, gravity field and rotational state and orbits. Several Italian scientists from the Universities of Bologna, Pisa, Padova, Napoli Parthenope, INAF, INFN and CNR are core members of the DART-Hera Investigation Team.

Didymos is a binary asteroid. The primary body has a diameter of around 780 meters. Credit: ESA.

juice

JUICE is a future ESA mission, planned for launch in 2023, to explore the Jupiter system and the planet's moons Ganymede, Callisto and Europa. Italy contribution is on four scientific instruments.

JUICE (JUpiter ICy moons Explorer) is the first Large-class mission in ESA's Cosmic Vision 2015-2025 program and it is planned for launch in 2023, with arrival at Jupiter in July 2031. The total mission duration is close to 12 years and with the currently envisaged launch opportunity,
the nominal mission would end in 2035.
It will spend at least three years making detailed observations of the biggest planet in the Solar System and 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 (Jovis, Amorum ac Natorum Undique Scrutator), the imaging spectrometer MAJIS (Moons And Jupiter Imaging Spectrometer), the ice-penetrating radar RIME (Radar for Icy Moons Exploration) and the radio science (3GM) experiments. The Italian contribution is funded by ASI through the main Italian industrial prime contractors: Leonardo S.P.A. (for JANUS and MAJIS) and Thales Alenia Space (for RIME and 3GM). The science responsibility for the 4 instruments are at Parthenope University, INAF-IAPS, Trento University and Sapienza University of Rome, respectively.



Artist's impression of the JUICE spacecraft, Credit: ESA/AOES.

liciacube

LICIACube is an Italian CubeSat that will be part of the NASA DART mission. It was launched in November 2021 to impact an asteroid and demonstrate the impactor method for planetary defense.

LICIACube (Light Italian Cubesat for Imaging of Asteroids) is a 6U CubeSat mission carried as a secondary spacecraft by the NASA DART (Double Asteroid Redirection Test) mission, the first aimed to demonstrate the applicability of the kinetic impactor method for planetary defense. After being launched in November 2021, in late September 2022 DART spacecraft will impact Dimorphos, the 160m-sized secondary member of the binary asteroid (65803) Didymos.
With a mass of 550 kg and an impact velocity of about 6.14 km/s, DART is expected to change the orbital period of Dimorphos around Didymos by about 10 minutes.
LICIACube will be released ten days before the DART impact, and independently navigated to achieve a fly-by of the binary system to collect several unique images of the effects of the DART impact on the asteroid. It will also obtain multiple images of the ejecta plume taken over a span of times and phase angles to investigate its nature. Collected images will be downloaded directly to Earth after the Dimorphos fly-by.
To accomplish its tasks LICIACube is equipped with two optical cameras: LEIA (Liciacube Explorer Imaging for Asteroid), a catadioptric camera designed to work in focus between 25 km and infinity, and LUKE (Liciacube Unit Key Explorer), an RGB camera designed to work in focus between 400m and infinity.
High-resolution (up to 1.38 m/px) images by LEIA, in combination with the DART-DRACO ones, will allow us to map the surface of Dimorphos, whereas the color capabilities of LUKE would give the first ever surface composition analysis of the target.
LICIACube is an Italian Space Agency (ASI) missione, developed in collaboration with Argotec (an Italian aerospace company based in Turin) which designed, manufactured, integrated, and tested the microsat.
The scientific team is led by INAF, and includes researchers of INAF/OAR, INAF/IAPS, INAF/OAA, INAF/OAPD, INAF/OATS, INAF/OAC, CNR/IFAC and Parthenope University of Napoli. The team is enriched by University of Bologna, for orbit determination and satellite navigation, and Politecnico di Milano, for mission analysis and guidance and optimization.
The mission Ground Segment, with data archiving and processing, will be managed by the Argotec Mission Control Center (MCC) and the ASI Space Science Data Center (SSDC). The acquired images will be calibrated and made available to the team and to the public using international standards for data preservation and exploitation, also thanks to SSDC distinctive scientific tools, such as MATISSE.

mars express

Mars Express is an ESA mission launched in 2003 and still exploring the planet Mars. Italy participates in five of the seven scientific experiments.

Mars Express is a space exploration mission conducted by ESA. Launched in 2003 and still exploring the planet Mars, it was the first ESA mission to enter orbit around another planet. 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 fly-bys of Phobos about every five months. Italy participates in five out of seven scientific experiments: PFS (Planetary Fourier Spectrometer), the MARSIS radar (Mars Advanced Radar for Subsurface and Ionosphere Sounding), OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) imaging spectrometer, the ASPERA (Analyser of Space Plasmas and Energetic Atoms) plasma instrument and the HRSC (High-Resolution Stereo 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. 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. MARSIS identified the presence of water-ice deposits underground and revealed the internal structure of polar deposits, detecting liquid water at the bottom of the South polar cap. The radar has also been probing the upper atmospheric layer (the ionosphere) detecting structures associated with localized magnetic fields in the Martian crust, which originates near the surface of Mars. OMEGA has provided unprecedented maps of water 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. ASPERA identified solar wind scavenging of the upper atmospheric layers as one of the main culprits of atmospheric degassing and escape. HRSC has shown very young ages for both glacial and volcanic processes, from hundreds of thousands to a few million years old, respectively, and provided evidence of a planet-wide groundwater system on Mars.

A crater on Mars acquired by the HiRISE camera on NASA's Mars Reconnaissance Orbiter. Credit: NASA/JPL-Caltech.

mro

Mars Reconnaissance Orbiter is a NASA mission launched in 2005 and still studying Mars. Italy participates with SHARAD, a low-frequency radar that probes the Martian subsurface.

Mars Reconnaissance Orbiter (MRO) is a NASA planetary mission whose key objectives are to characterize Mars' present climate and study how the climate changes seasonally on the red planet; monitor Mars' weather; study Mars' terrain and identify water related landforms; search for evidence of water and hydrothermal activity; probe underground for subsurface water and ice; scout future landing and sampling sites; and relay scientific data to Earth from Mars. The probe was launched in August 2005 and began operations at Mars in early 2006, providing more than 400 Tbits of data since then. The mission has been extended well past its original intended lifetime and it is expected to continue for several more years, as it has become a key asset in providing a communication relay between the Martian surface and the Earth. The payload consists of six scientific instruments for the study of the atmosphere, the surface and the subsurface from orbit. ASI provided the SHARAD (SHAllow RADar) 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 with a vertical resolution of 5-15 m. 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 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.

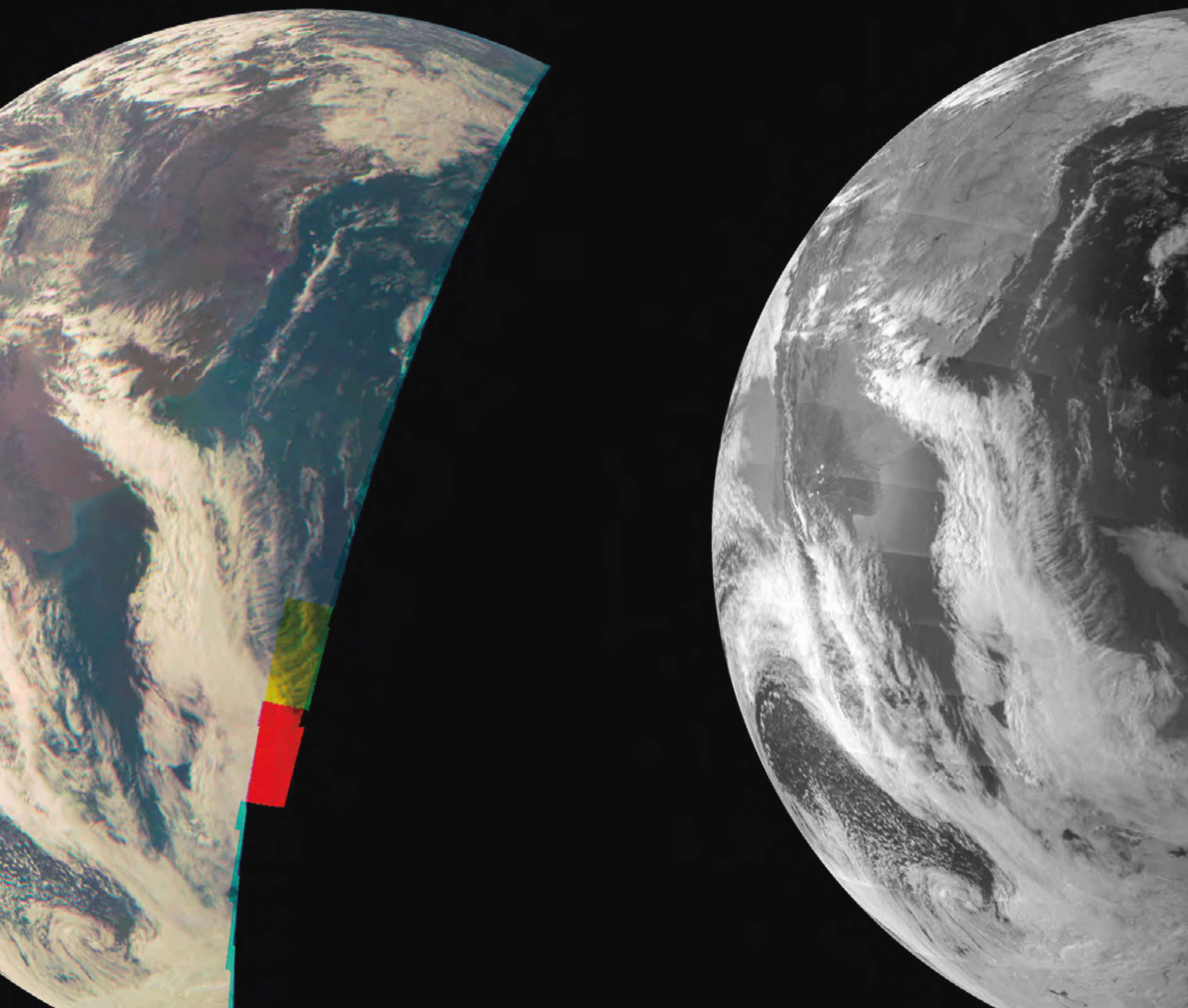
osiris-rex

2016 OSIRIS-REx, a NASA mission which collected on October 2020 fragments of the primitive carbon rich asteroid Bennu and will return them to Earth in 2023.

OSIRIS-REx (Origins, Spectral Interpretations, Resource Identification, Security - regolith EXplorer) is a New Frontiers NASA mission that traveled to the near-Earth asteroid Bennu 1999 RQ36 and it is on its way back to Earth with a load of samples (about hundreds of grams). The mission launched Sept. 8, 2016, from Cape Canaveral, reached Bennu in 2018, collected the samples on 20th October 2020 and will return a sample to Earth in 2023. The samples once curated at Johnson Space Center will be available for detailed analysis in the most advanced worldwide laboratories. The objectives of the mission are:

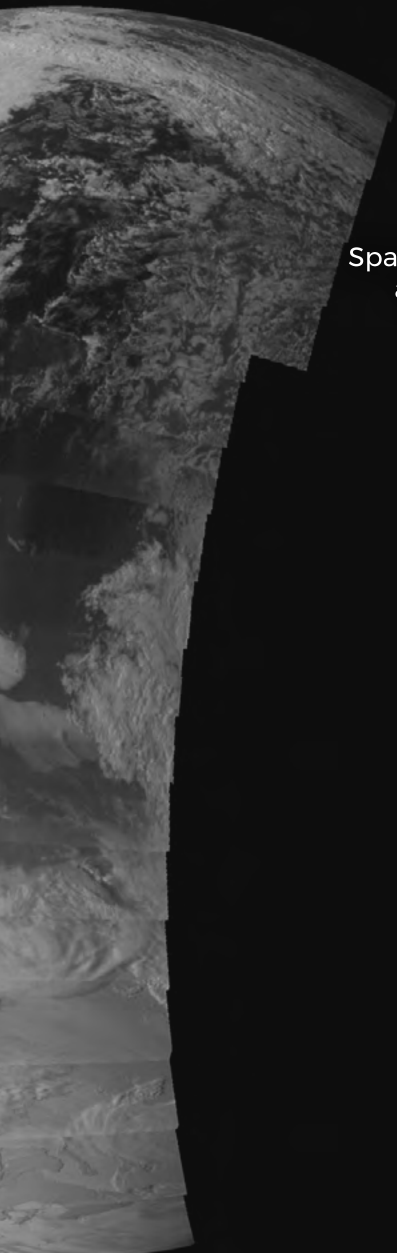
- To map the global, chemical, and mineralogical properties of the asteroid in order to characterize its geological and dynamic history and to provide the context for the collection of the sample.
- To document the structure, morphology, geochemistry and spectroscopic properties of the regolith in the sampling area at the millimeter scale.
- To measure the Yarkovsky effect - the thermal force acting on the asteroid - on an asteroid potentially dangerous for the Earth and define the properties of the asteroid that contribute to this effect.
- To characterize the integrated global properties of a carbonrich primitive asteroid to allow a direct comparison with the observations of the entire asteroid population from the ground.
- To bring to the ground and analyze a sample of carbon-rich primitive regolith in a quantity sufficient for the study of the nature, history and distribution of the minerals and the organic material of which it is composed.

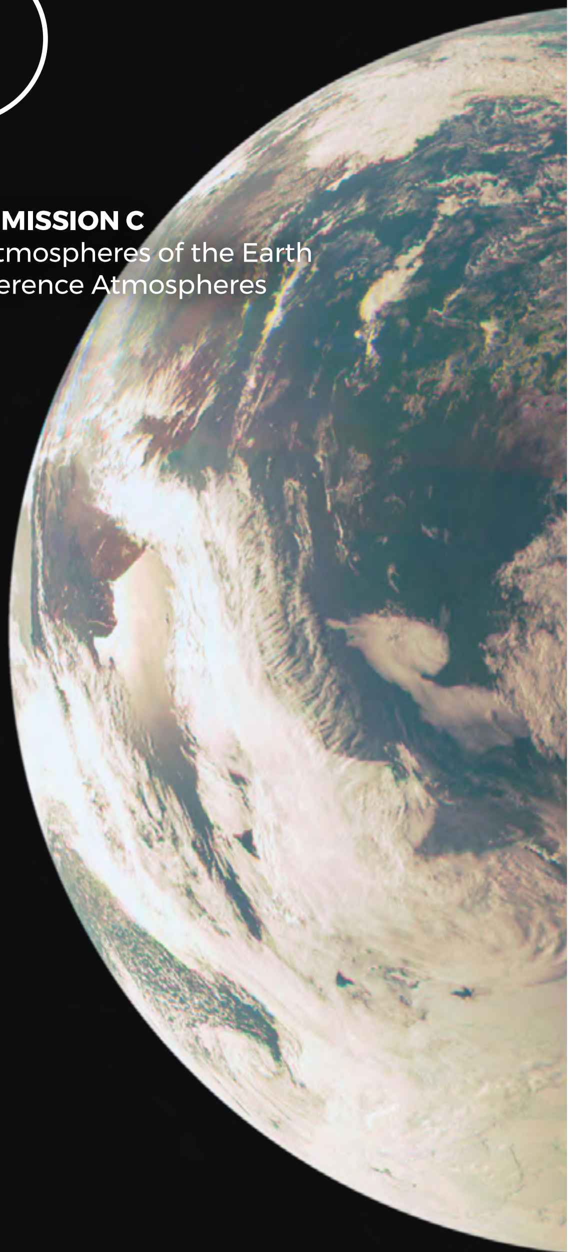
The group of INAF/OAA and INAF/OAR analyzed data of the OVIRS (OSIRIS-REx Visible and Infrared Spectrometer) and the OTES (OSIRIS-REx Thermal Emission Spectrometer) spectrometers on board of OSIRIS-REx, acquired spectroscopic data in laboratory and made comparison with laboratory measurements. The group of INAF/OAPD studied the global and local distributions of the boulders present on the surface of the asteroid Bennu, analyzing the sampling sites.



C

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





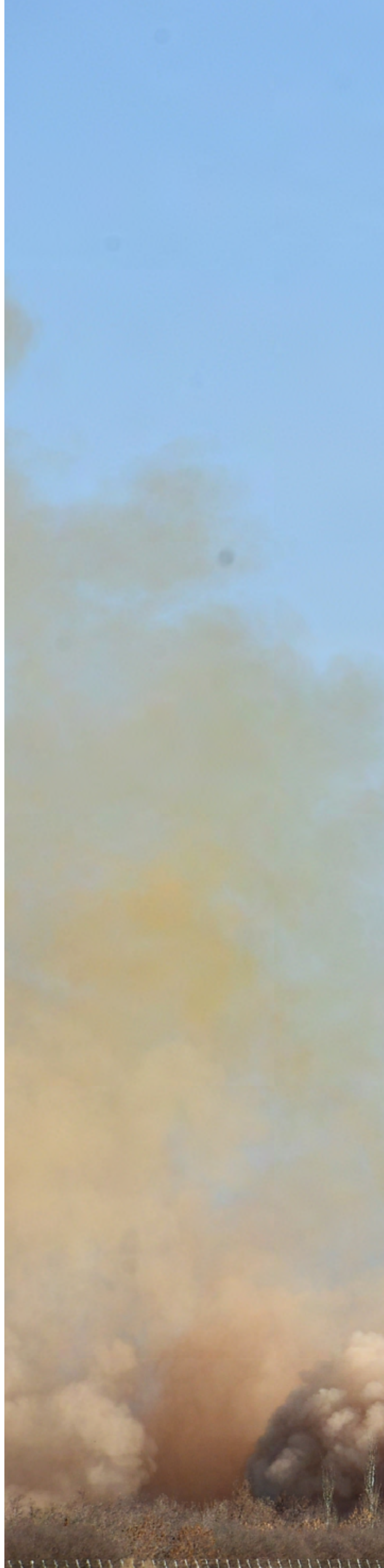
Previous page: Junocam view of Earth taken during Juno's close flyby on 9 October 2013. Credit: NASA/JPL-Caltech/MSSS.

cses

CSES (China Seismo-Electromagnetic Satellites) is a constellation programme by CNSA and ASI that cooperate for instruments development, calibration and data analysis.

CSES-01 has been successfully launched from Jiuquan Satellite Launch Center on February 2, 2018, and its expected lifetime is 5 years at least, while the launch of CSES-02 is foreseen for March 2022.
The CSES-01 satellite has 9 scientific instruments aboard, targeted at the measurement of the magnetic field (Search-Coil Magnetometer - SCM and High Precision Magnetometer - HPM), of the electric field (Electric Field Detector – EFD), of the properties of ionospheric plasma (Plasma Analyzer Package - PAP, Langmuir Probe – LP, GNSS Occultation Receiver and Tri-Band Beacon) and of the flow and spectrum of high-energy particles (High Energy Particle Detector - HEPD, High Energy Particle Package - HEPP).
The main objectives of the missions are to monitor perturbations in the ionosphere, induced from the solar forcing, through the magnetosphere and the Van Allen belts, and those possibly due to electromagnetic phenomena of natural, aiming the study of their correlation with seismic events. Furthermore, the CSES scientific program can provide a strong improvement in the comprehension of the physical of the ionospheric plasma properties at the satellite altitude, to characterize the ionosphere in quiet and disturbed conditions. The study of the effect of solar perturbations, namely CMEs (Coronal Mass Ejections), SEPs (solar flares, solar energetic particles), 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. INAF and INFN are directly involved in instrumental development and test respectively. The INFN, with its branches of Bologna, Naples, Perugia, Roma Tor Vergata, the TIFPA-Trento center and the National Laboratories in Frascati, is the

main partner of the ASI in its cooperation with the CNSA.
The INAF-IAPS of Rome, the Universities of Bologna, Perugia, Roma Tor Vergata, Trento, the International Telematic University UniNettuno (UTIU), the IFAC/CNR and the National Institute of Geophysics and Volcanology (INGV) are also involved, with their own scientific expertise as regards data analysis and development of geophysical models.
The HEPD-01 and 02 (High-Energy Particle Detector), developed by INFN and several Italian Universities, detects high energy electrons, protons and light nuclei. Their 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.
The EFD-02 (Electric Field Detectors) developed by INAF/IAPS and INFN has been specifically designed to monitor electromagnetic fields (from DC to 3.5 MHz) for the study of Space Weather and ionospheric disturbances possibly related to seismic activity and earthquake preparation mechanisms. The new design of the instrument will allow the detection of environmental irregularities in a wider range of plasma density, thus including extreme phenomena induced by transient electric fields.
The environmental plasma parameters, including ion density, temperature, drift velocity, composition and density fluctuation, are monitored by the CSES PA (Plasma Analyser) and by two LP (Langmuir probes) developed by NSSC. Their functionalities are tested at the Plasma Chamber at INAF/IAPS in order to check their sensitivity in detecting the ionospheric plasma parameters. Italian collaboration will be renewed for instrumental development and calibration, and for the data analysis.



duster

The DUSTER project is aimed at uncontaminated in-situ collection, retrieval and laboratory analysis of stratospheric solid aerosol particles from the upper stratosphere.

DUSTER (Dust in the Upper Stratosphere Tracking Experiment and Retrieval) is a multinational project aimed at collecting and retrieving solid micron-submicron dust from upper stratosphere (altitude >30km). Dust particles are collected and analyzed 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 ejected residues are more prevalent 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

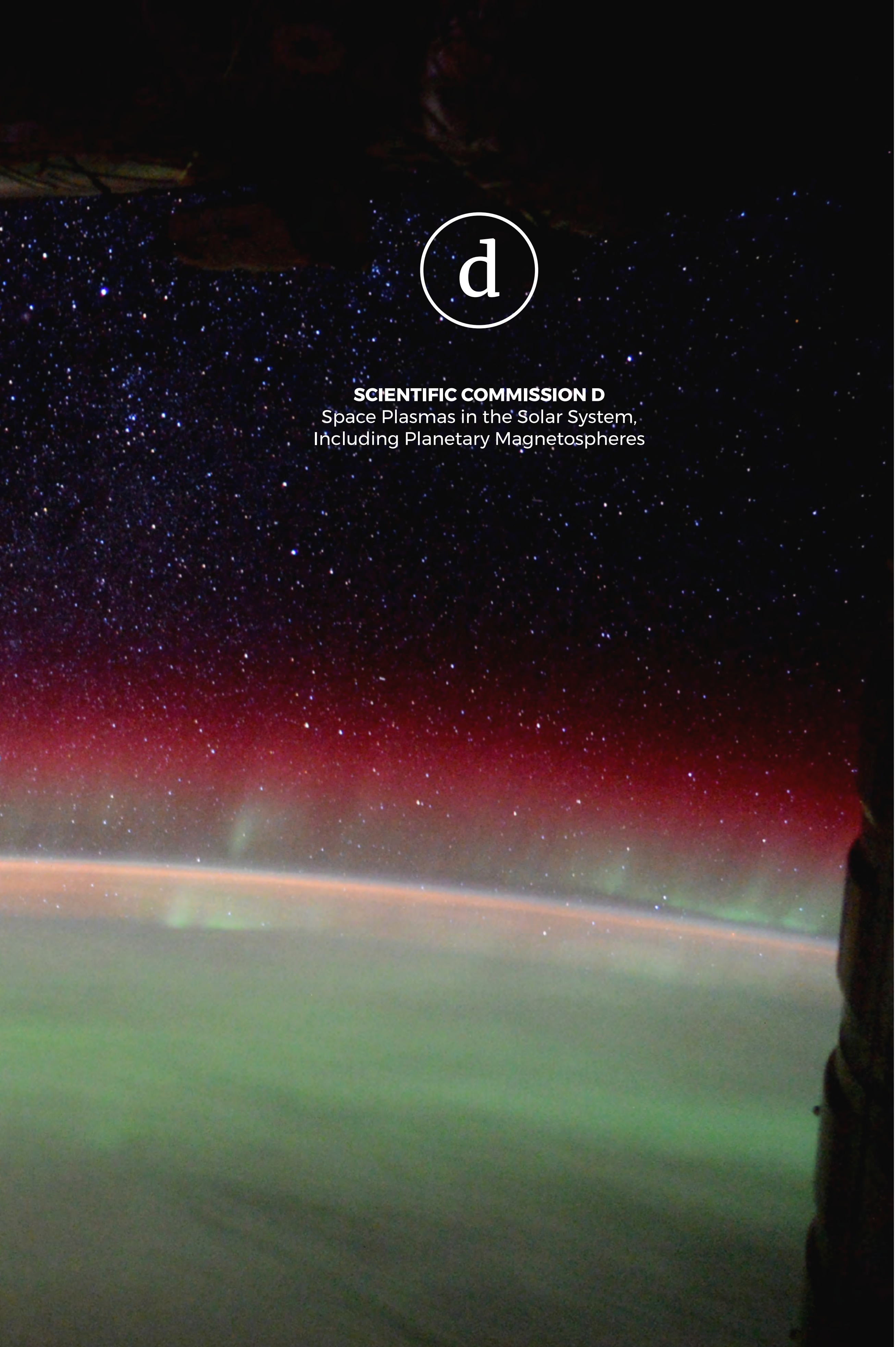
Previous page: The satellite Zhangheng 1 launched on 2 February 2018. Credit: Wang Jiangbo/Xinhua.

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 PNRA funded a DUSTER launch campaign from Antarctica, which took place at the end of 2016. Compositions, morphologies and structure of the analyzed 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.
In the frame of the HEMERA H2020 program, two flights were performed in September 2019 and 2021 from the Esrange SSC launch facility. These campaigns collected about 200 stratospheric particles each, and analysis to understand the origin are on going. Thanks to DUSTER for the first time extraterrestrial 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 extraterrestrial dust collection in the upper stratosphere. The Italian man power contribution is assured by INAF/IAPS and Parthenope University.

juno

NASA's Juno mission to Jupiter, launched in 2011, is devoted to study the planet's interior, atmosphere and magnetosphere with the goal of understanding its origin, formation and evolution.

Juno's main scientific objective is the study of the planet's formation, to better understand the history of the whole Solar System. Its scientific goals are the magnetosphere, its radiation environment and the electromagnetic fields, the auroras, the atmospheric composition and structure, the gravitational field and the planet interior. The Juno spacecraft entered the orbit of Jupiter on 4 July 2016 and, based on the prime mission plan, it should have ended its observations in mid-2021; however, it has been recently extended to mid 2025. The current mission profile includes ~70 elliptical orbits lasting up to 53.5 days each. The passages above the planet are at an altitude of about 5000-8000 km; as of March 2022, 40 orbits were performed. Among the main scientific results: the discovery of regular cyclone polygons in the Jupiter poles; the structure of the winds below the visible surface of Jupiter; the presence of the "blue dot" in its magnetic field; new volcanoes and hot spots on the moon Io; the fine morphology of the auroral restrictions in the correspondence of the footprints of the moons; a new understanding of the structure of the "core" of Jupiter. Italy participates to Juno with two scientific instruments: the KaT (Ka band Transponder) and JIRAM (Jovian InfraRed Auroral Mapper). The radio science Ka-band frequency translator KaT is the core element of the gravity experiment on Juno for mapping the gravitational field of the planet. It was developed by Thales Alenia Space and ASI, under the scientific responsibility of the Roma Sapienza University. It has a frequency stability of a few parts in 10-16 at an integration time of 1000 seconds, corresponding to a range rate accuracy of about 0.0001 mm/s. The end-to-end radio system, including the media and ground station contributions, has attained range rate accuracies of 0.0015 mm/s after all calibrations have been applied. Coherent X-and Ka-band links will enable precise measurement of spacecraft motion during close polar orbits to determine the gravity field, distribution of mass, core characteristics, and perhaps convective motion in the deep atmosphere. JIRAM has been manufactured by Leonardo S.P.A. and it's activity is under the scientific responsibility of INAF/IAPS. JIRAM includes a spectrometer and a camera in the infrared wavelength range between 2 and 5 μm. JIRAM provides maps and spectra of the auroras generated by H3+, of the thermal emission of the planet near the 5 micron spectral window and of the characterization of the planetary emission with a resolution of 9 nm. The spatial resolution of the instrument at 1 bar can vary from 10 km to 300 km depending on the position of the spacecraft with respect to the planet. The primary objectives of JIRAM are the study of the polar auroras and the Jovian atmosphere up to the depths (depending on the presence of clouds and atmospheric opacity) of 3-5 bars in terms of chemical composition related to some minority gases (water, ammonia and phosphine), microphysics (clouds) and atmospheric dynamics. JIRAM is also used to observe the moons of Jupiter Io, Europa, Ganymede and Callisto, providing information about the temperature and surface composition and, in the case of Io, the position and morphology of the "hot spots". JIRAM was built according to the specifications provided by INAF/IAPS. The JOC (JIRAM Operative Center) team is at INAF/IAPS and follows the entire operational phase of the mission from planning of the observations, to generation of the operating sequences of remote controls, to collection and calibration of data up to delivery (as foreseen for the mission) to the "Planetary Atmospheric Node" of NASA's "Planetary Data System".



d

SCIENTIFIC COMMISSION D

Space Plasmas in the Solar System,
Including Planetary Magnetospheres

Previous page: ESA astronaut
Tim Peake captures this dazzling
display of the aurora Australis from
the ISS during his mission in 2016.
Credit: ESA/NASA.

aspiics

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

ASPIICS (Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun) is a coronagraph imaging the solar corona out to 3 solar radii. With a launch foreseen in 2023, it is 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 invisible light.

ASI and INAF, as part of a large European consortium, are responsible for coronagraphic calibrations, optimization of the occulter and for formation-flying metrology system and for contributing to the spectral filter.

cluster

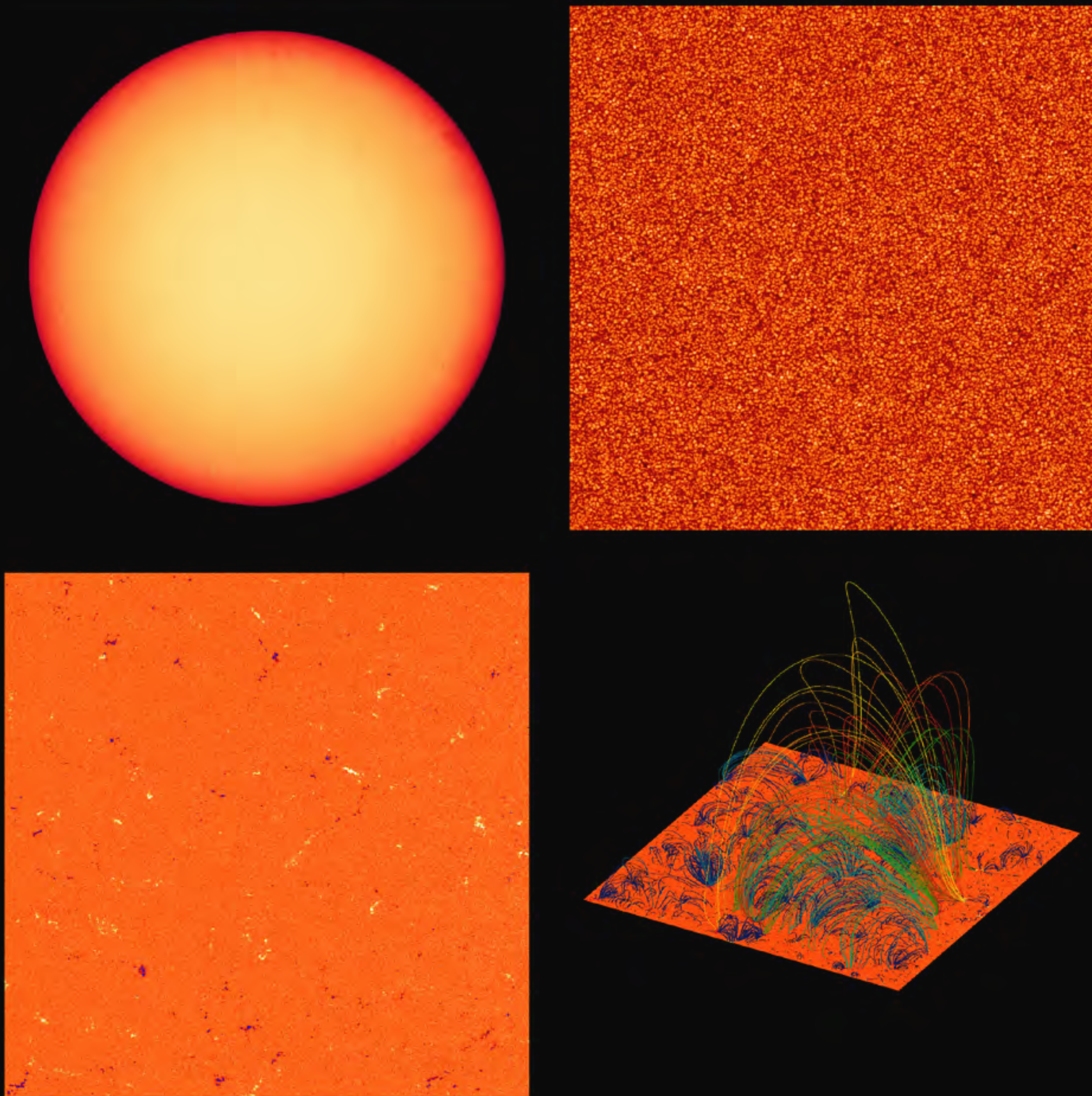
Cluster is a fleet of four spacecrafts launched in 2000, which provided in situ tridimensional measurements allowing significant advance in the knowledge of fundamental space plasma processes.

Cluster is an ESA Horizon 2000 cornerstone mission launched in 2000, extended until 31 December 2023. 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 software of the CIS (Cluster Ion Spectrometry) 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.

hinode

Hinode is a Japanese mission with USA and UK contributions, launched in 2006, observing the Sun in the optical, EUV and X-ray band.

Hinode is a JAXA solar mission (Japan) launched in 2006, devoted to the study of solar activity. A set of instruments in the optical (SOT, Solar Optical Telescope), EUV (EIS, Extreme ultraviolet Imaging Spectrometer) and X-ray bands (XRT, X-Ray Telescope) are on-board Hinode. Italy has worked on the instrument calibration and studied the magnetic photosphere, the hot and dynamic corona. INAF has been directly involved in the calibration of the XRT telescope, with its XACT/OAPA laboratories in Palermo. 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. Data from Hinode are still used to complement observations from other missions, such as Solar Dynamics Observatory.



The Sun and its magnetic properties. Credit: Solar Orbiter/ PHI Team/ESA & NASA.

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 2021.

SCORE (Sounding Rocket Coronagraphic Experiment), 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 2022 is in preparation. A third launch has been approved for 2023.
SCORE is the first multi-band coronagraph obtaining simultaneous images of the solar corona in polarized visible light, 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/OATO and by the Florence University.

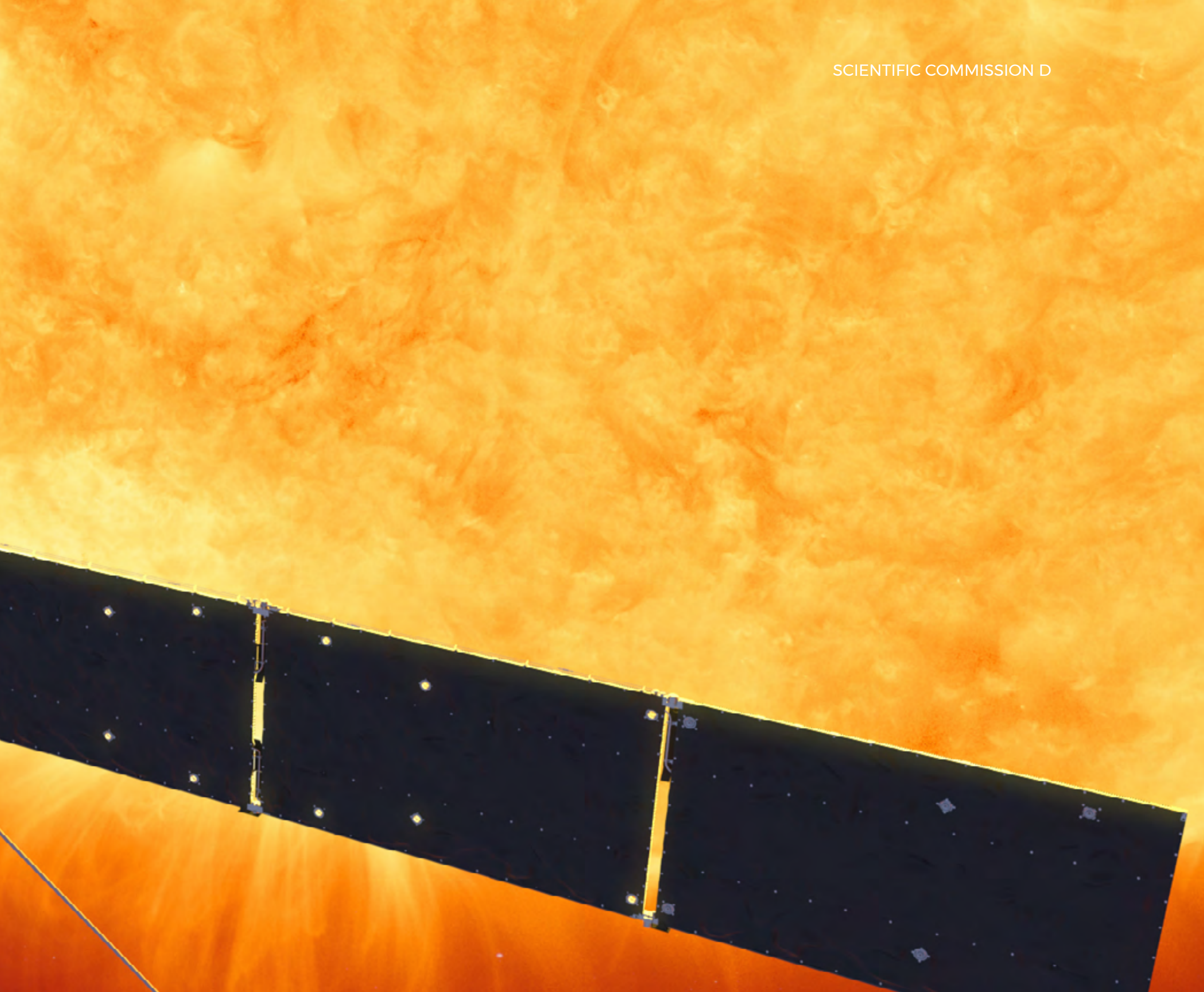
solar orbiter

Solar Orbiter is ESA's primary contribution to the ILWS (International Living With a Star) program. Launched in 2020, it will contribute to reveal how the Sun creates and drives the heliosphere.

Solar Orbiter is an ESA Cosmic Vision M1 mission launched on February 9, 2020 with nominal science phase already begun in December 2021. Solar Orbiter will provide 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.

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, 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 (Firenze University) and is realized in Italy under ASI contract, exploiting the legacy of UVCS/SOHO. Germany (MPS) and Czech Republic (CAS) provide a hardware 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 2000 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. Metis has already provided maps of the solar wind outflow velocity in the outer corona. It has also contributed to exploring the physical properties of the solar wind from its source in the corona into the inner heliosphere during the first Solar Orbiter - Parker Solar Probe quadrature. Metis has already observed several coronal mass ejections in both visible and UV light, in cooperation with other instruments on board Solar Orbiter. Moreover, it is contributing to cosmic-ray flux predictions and observations in the inner heliosphere. The scientific payload of Solar Orbiter also includes SWA (Solar Wind Analyser), a plasma analyser suite with 4 sensors and a single, common DPU (Detector Processing Unit). The DPU has an Italian Co-PIship (INAF) and has been realized in Italy with the ASI support. SWA is measuring particle velocity distribution functions of protons, helium, minor ions and electrons in different structures 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

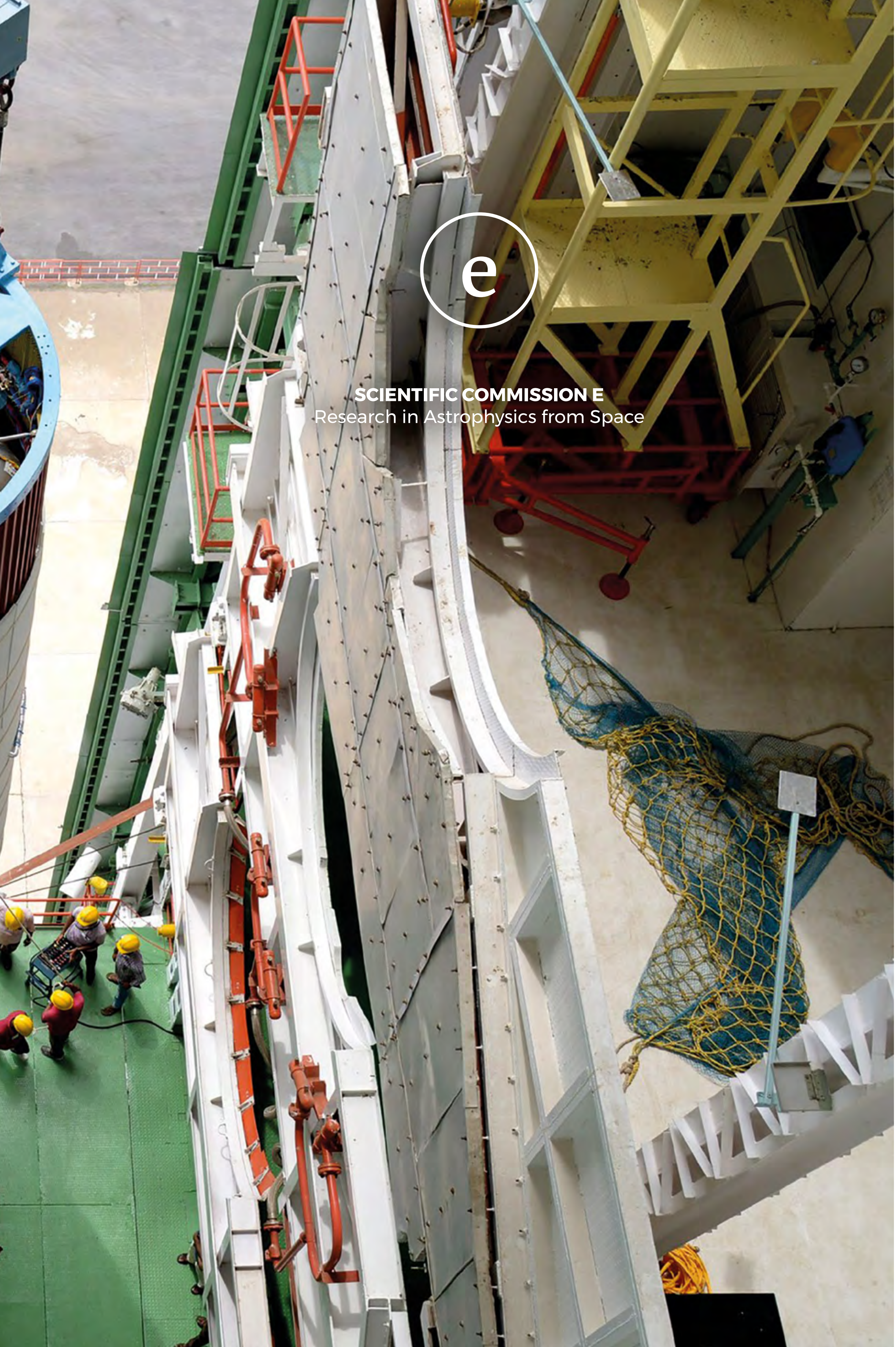
STEREO consists of two space-based observatories, one ahead of Earth in its orbit, the other trailing behind. Launched in 2006 by NASA, its goal is to study the structure and evolution of solar storms.

STEREO (Solar TErrestrial RElations Observatory) has been launched in 2006 as the third mission in NASA's STP (Solar Terrestrial Probes) program. It consisted of two space-based observatories, one ahead of Earth in its orbit, the other trailing behind. They were separated 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 were equipped with the same set of instruments for remote sensing and in-situ observations of the Sun and of the heliosphere. Contact with STEREO Behind was lost in 2014 but STEREO Ahead is still operational.

The Italian solar physics community is involved in the analysis of data from the instruments SWAVES (STEREO/Waves), IMPACT (In-situ Measurements of Particles And Cme Transients) and PLASTIC (PLAsma and SupraThermal Ion Composition), finalized to the investigation of turbulence in the solar wind and particle acceleration, and from the instruments Secchi COR2 (Outer Coronagraph) and Secchi HI (Heliospheric Imager), designed to study the solar wind acceleration with correlation tracking techniques and the physics of coronal mass ejections.

Previous page: An artistic rendering of the Solar Orbiter. Credit: ESA/ATG medialab.


PSLV
C30



SCIENTIFIC COMMISSION E
Research in Astrophysics from Space

Previous page: Hoisting of PSLV-C30 (AstroSat mission) second stage during vehicle integration. Credit: Indian Space Research Organisation.

agile

AGILE is an X-ray and gamma- ray astronomical satellite by ASI, launched in 2007.

AGILE (Astro rivelatore Gamma a Immagini LEggero) is an ASI space mission dedicated to high-energy astrophysics. The main goal is the simultaneous detection of hard X-ray and gamma-ray radiations in the 18-60 keV and 30 MeV-30 GeV energy bands, with optimal imaging and timing capability. The AGILE satellite was launched on 23 April 2007 from Sriharikota (India) in an equatorial orbit. Since then, AGILE contributed very significantly to the study of Galactic and extragalactic cosmic sources. The main scientific results are 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); the 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; the detection at the highest energies of TGFs (Terrestrial Gamma-Ray Flashes). Particular care is devoted to multi-frequency programs in synergy with radio, optical, X-ray and TeV observations. AGILE has also a great capability for prompt detection of gamma-ray counterparts of gravitational wave sources, neutrinos, FRBs (Fast Radio Bursts), and other transients.

ariel

Selected as ESA M4 mission to be launched in 2028, ARIEL will study the atmospheres of a large and diverse sample of exoplanets across the optical and infrared bands.

ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) was selected as ESA M4 mission for launch in mid-2028, to 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 ~1-8 μm spectral range and broadband photometry in the optical. Because of their high temperatures, the well-mixed atmospheres of the majority of ARIEL's planets will show limited or minimal condensation and sequestration of less volatile materials and will reveal their bulk and elemental composition (especially C, O, N, S, Si). Observations of the exo-atmospheres will allow to explore the link between the planets and their formation environments in circumstellar discs, and to understand the earliest stages of planetary and atmospheric formation and their subsequent evolution. ARIEL will thus provide a truly representative picture of the chemical nature of the exoplanets, contributing to put our own Solar System in context, and relate this directly to the characteristics and chemical environment of their host stars, exploring the interaction of stars with their planets in a large range of star-planet configurations. To address this ambitious scientific programme, ARIEL is designed as a dedicated survey mission for transit and eclipse spectroscopy, capable of observing a large and representative planetary sample within its 4-year mission lifetime. The Italian contribution to ARIEL is relevant, with two Co-PIs of the mission and important contributions for the hardware of the telescope, including the telescope responsibility and the realization of an innovative 1-m primary mirror, entirely built in aluminum, electronics, software, and ground segment, with the responsibility of the coordination of the science ground segment. In addition, Italian researchers chair some of the scientific working groups built within the international consortium for the scientific consolidation of the mission. Several Italian scientific institutes, laboratories and universities participate to ARIEL's scientific and technological activities.

astrosat

AstroSat is an Indian mission launched in 2015 to study celestial sources in X-ray, optical and UV spectral bands simultaneously. It opens a window onto X-ray fast timing, with an interactive software developed by INAF.

AstroSat is the first dedicated Indian astronomy mission aimed at studying celestial sources in X-ray, optical and UV spectral bands simultaneously. It was launched on 2015 September 28 into a LEO (Low Earth Orbit). It carries on board two 38-cm optical/UV telescopes, an array of 3 proportional counters (3-80 keV, 8000 cm2 @ 10 keV, only one of them is operating since 2019), a soft X-ray telescope (0.3-8 keV, 120 cm2 @ 1 keV), a CZTI (Cadmium-Zinc-Telluride Imager) 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. Since 2019, all observing time is open to the world through annual calls of opportunity. The Italian participation is through the software for timing analysis GHATS, developed at INAF/OAB, for the analysis of bright X-ray sources. One Italian scientist is part of an instrument team and currently collaboration projects with INAF/OAB scientists are ongoing.

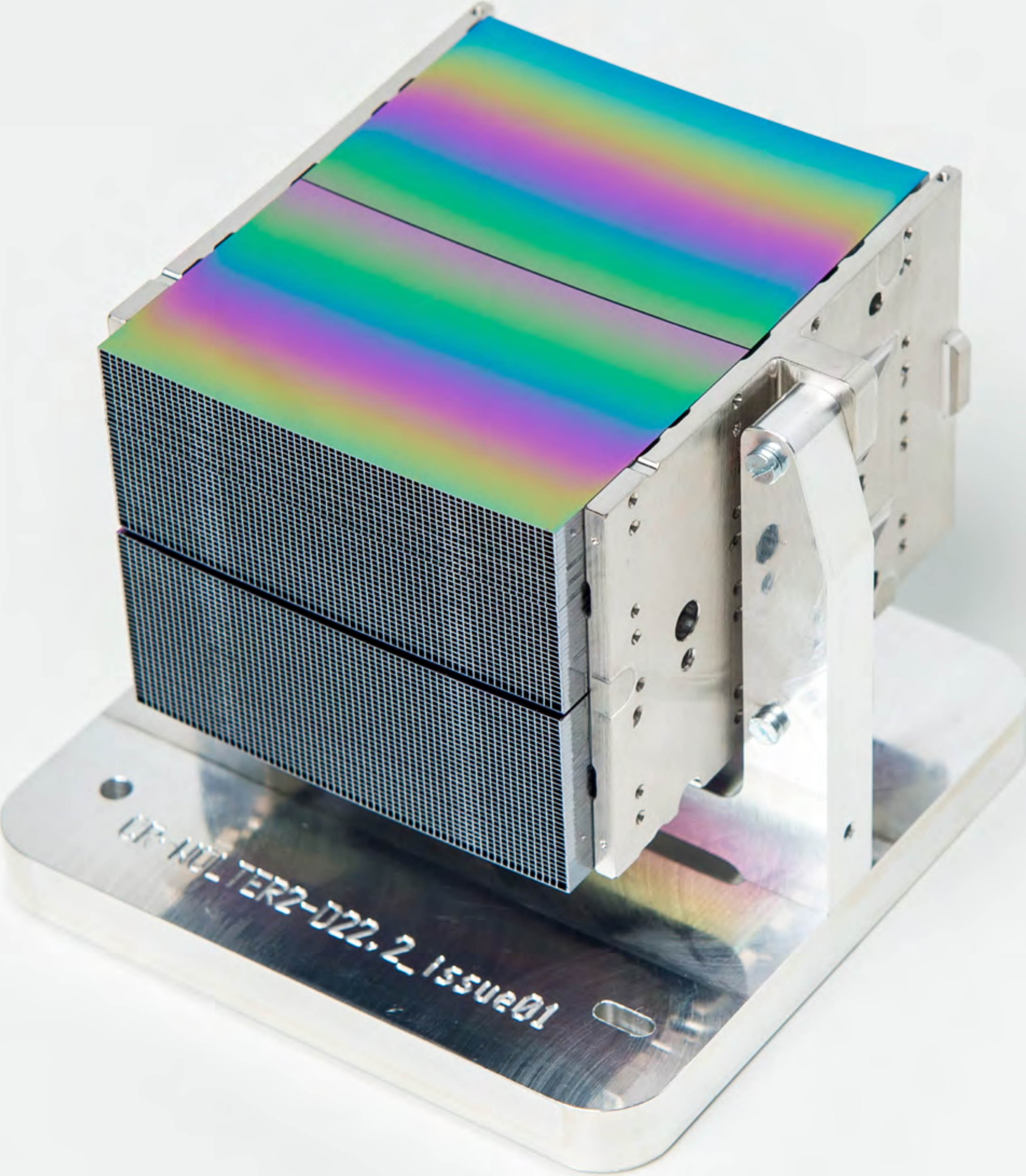
athena

ATHENA is a large ESA X-ray observatory with a launch planned for 2034 that will address the most pressing questions in astrophysics for the early 2030s.

ATHENA (Advanced Telescope for High-Energy Astrophysics) is a large X-ray observatory and the second large-class ESA mission (L2), with a launch planned for the beginning of 2034 and currently in B phase. Its adoption is planned for 2024 with C phase starting in 2023. 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 early 2030s 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, 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.

The Italian community has a key role as regards both the scientific part and the instruments of the mission, supported by ASI.



The sophisticated mirror module destined to form part of the optical system of ESA's Athena X-ray observatory. Credit: ESA.

The Japanese Experiment Module with the Earth in the background. Expedition 55 crew. Credit: NASA.

calet

CALET experiment is in operation on the ISS since 2015 to search for possible signatures of dark matter in the spectra of electrons and gamma rays and measure the spectra of CR elements up to iron and beyond.

CALET (CALorimetric Electron Telescope) is a mission by JAXA in collaboration with ASI and NASA, that reached the ISS in August 2015 starting an initial 5 year period of data taking on the JEM-EF exposure facility. Thanks to its success, CALET experiment operative life has been extended up to the end of 2024 at least. 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. CALET explored the all-electron spectrum from 11 GeV to 4.8 TeV and is now chasing rare electron events at higher energies up to 20 TeV. Deviation from a simple power-law in proton and He spectra were measured with high precision in the region of a few hundred GeV and an unexpected spectral softening of both elements has been recently observed above 10 TeV/n. Cosmic-ray nuclei from proton to iron are being studied as well as the abundances of trans-iron elements up to Z=40. The spectrum of nickel has been measured for the first time with unprecedented precision. CALET gamma-ray observations are complemented by the detection of several gamma-ray transients with the dedicated GBM (Gamma-ray Burst Monitor). Continuous observations of solar modulation, Space Weather phenomena and a search of e.m. counterparts of GW events are ongoing.

chandra

Chandra is a high angular resolution X-ray telescope launched in 1999 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 inclose 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, and actually is, 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. Chandra combines the mirrors with four science instruments to capture and probe the X-rays from astronomical sources. The incoming X-rays are focused by the mirrors to a tiny spot (about half as wide as a human hair) on the focal plane, about 30 feet away. The focal plane science instruments, ACIS (Advanced CCD Imaging Spectrometer) and HRC (High Resolution Camera), are well matched to capture the sharp images formed by the mirrors and to provide information about the incoming X-rays: their number, position, energy and time of arrival. ACIS is one of two focal plane instruments and it is an array of CCDs, which are sophisticated versions of the crude CCD's used in camcorders. This instrument is especially useful because it can make X-ray images, and at the same time, measures the energy of each incoming X-ray. ACIS is the instrument of choice for studying temperature variations across X-ray sources such as vast clouds of hot gas in intergalactic space, or chemical variations across clouds left by supernova explosions. The primary components of the HRC are two MCP (Micro-Channel Plates). They each consist of a 10 cm square cluster of 69 million tiny lead-oxide glass tubes that are about 10 micrometers in diameter (1/8 the thickness of a human hair) and 1.2 millimeters long. HRC is especially useful for imaging hot matter in remnants of exploded stars, and in distant galaxies and clusters of galaxies, and for identifying very faint sources. Two additional science instruments provide detailed information about the X-ray energy, the LETG (Low Energy Transmission Grating Spectrometer) and HETG (High Energy Transmission Grating Spectrometer) spectrometers. The LETG gratings are designed to cover an energy range of 0.08 to 2 keV, while the HETG gratings a 0.4 to 10 keV energy range. These are grating arrays which can be flipped into the path of the X-rays just behind the mirrors, where they redirect (diffract) the X-rays according to their energy. The X-ray position is measured by HRC or ACIS, so that the exact energy can be determined. The science instruments have complementary capabilities to record and analyse X-ray images of celestial objects and probe their physical conditions with unprecedented accuracy. The INAF/OAPA 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. It was launched in 2019 to study the internal structure of small-size transiting planets.

CHEOPS (CHaracterising ExOPlanet Satellite) is mainly dedicated to the determination of the internal structure of small-size transiting planets by means of ultrahigh precision photometry of their parent stars. It is the first small mission in ESA Cosmic Vision 2015-25 program. Launched in 2019, it is providing data of quality even better than expected, useful to constrain the formation of planetary systems and to further explore their diversity. Cheops moreover provides the targets to the future ground (e.g. E-ELT) and space-based (e.g. JWST, Ariel) facilities, that will be used to study 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 was the integration and testing of its 32 cm telescope, whose optical parts were designed by INAF and produced by the TJV made by Leonardo S.P.A., Thales Alenia Space and Media Lario SrL. INAF and ASI contributed before launch to the preparation of the scientific program and the realization of the mirror archive for the scientific data. Italian members of the Core Science Team are leading the studies of multiplanetary systems via the TTV technique, and the CHEOPS Ancillary Science. CHEOPS in Italy is made by a collaborative efforts of INAF (INAF/OACT and INAF/OAPD), Padua University, and ASI.

dampe

DAMPE is a Chinese space telescope for high energy gamma-rays, electrons and cosmic rays detection, in a sun-synchronous orbit at the altitude of 500 km since 2015.

DAMPE (Dark Matter Particle Explorer, also known as Wukong), is a Chinese CAS satellite launched on December 17, 2015, with main scientific objective to measure electrons and photons with much higher energy resolution than currently achievable, in order to identify possible Dark Matter signatures. DAMPE is composed by a double layer plastic scintillator, a STK (silicon-tungsten tracker-converter), made of 6 tracking double layers of silicon strip detectors with three layers of Tungsten plates for photon conversion, and an imaging calorimeter (BGO, Bismuth Germanium Oxide) of about 31 radiation lengths thickness, made up of 14 layers of Bismuth Germanium Oxide bars in a hodoscopic arrangement.
On the hardware the the Italian contribution, under the leadership of INFN - Perugia, has been in the design and construction of the STK. Currently the science team is working on the data analysis and contributed to the study of charged cosmic rays flux with direct measurements of protons and helium up to energies of O(100 TeV) and energy up to 4.6 TeV for electrons+positrons.and ASI.

Following page: The Euclid's instrument-carrying payload module and its supporting service module.. Credit: ESA.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euclid

Euclid, to be launched in 2023, will investigate the distance-redshift relationship and the evolution of cosmic structures, galaxies and clusters of galaxies.

Euclid, to be launched in 2022 to an L2 orbit, will observe more than 15000 square degrees of extragalactic sky in a 6 year long mission. 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 3D 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: VIS (visible panoramic camera) and NISP (Near-IR Spectro-Photometer). 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.
The Euclid Consortium is composed of more than 250 institutes from 16 European countries, with the participation of NASA. Italy is leading the Science Ground Segment and delivered the Detector Control and Data Processing Units, along with their On-Board softwares, for both instruments, and the NISP Grism Wheel. Italian scientists have key roles in all scientific areas in the consortium and in the ESA Euclid Science Team.

euso-spb2

The Extreme Universe Space Observatory - Super Pressure Balloon is a second generation stratospheric balloon instrument for the detection of UHECRs with a Fluorescence telescope and VHE neutrinos through Cherenkov emission.

EUSO-SPB2 is a cosmic ray detector onboard a NASA Super Pressure Balloon that will be launched in Spring 2023 from Wanaka, New Zealand. It will take a long duration flight of about 100 days at a nominal altitude of 33 km, with an average observation time per night of about 5 hours. EUSO-SPB2 is designed with two Schmidt telescopes, each optimized for their respective observational goals. The EUSO-SPB2 Fluorescence detector (FT) points to nadir and will allow the first observation of extensive air showers using the fluorescence technique from suborbital space. Such a measurement would prove the feasibility of measuring UHECRs with this technique, proposed also for the POEMMA mission. It is the third mission developed by the JEM-EUSO collaboration on balloons and the instrument has been improved. The FT camera has a modular design with 3 Photo Detection Modules (PDM), each consisting of 2034 pixels capable of single photoelectron counting in the wavelength bandwidth 290-430 nm and with a time resolution of less than 1 μs. The optical system is a Schmidt system consisting of 6 mirror segments with a diameter of 1 m and an effective focal length of 860 nm. A Schmidt corrector plate at the aperture will be placed providing a field of view of roughly 12° x 37°. The EUSO-SPB2 Cherenkov Telescope (CT) has a Schmidt system with 4 mirror segments and a field of view of 6.4° x 12.8°. The mirror segments are aligned in such a way that a parallel light pulse from outside the telescope produces two spots in the camera. This bi-focal alignment allows to distinguish triggers of interest from single spot events caused by low-energy cosmic rays striking the SiPM camera directly. The CT will change its orientation to observe a volume of 10° above and below the limb for the first time. Above the limb, the CT will record direct Cherenkov light from PeV cosmic rays during the flight to verify the functionality of the instrument. Below the limb, the CT will search for signals corresponding to the upward τ-induced EAS. In case an astrophysical event alert is issued during the mission, the zenith and azimuth pointing capability of the CT will allow for a follow-up search. CT proves also a measurement of the ambient background photon fields, known as Night-Sky-Background, fundamental for the prediction of VHE-neutrino observations.

fermi

Launched in 2008, Fermi observes the cosmos using the highest-energy form of light, providing an important window into the most extreme phenomena of the Universe and playing a crucial role in the newly born multi messenger astronomy.

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. Thanks to the detection of gamma-rays from a neutrino emitting AGN and from a Gravitational Waves event produced by a NS-NS merger, in the summer of 2017 Fermi contributed to the birth of multi-messenger astronomy. Thanks to its capabilities, Fermi has collected 4 Bruno Rossi prizes, the most prestigious acknowledgment in the high energy astrophysics.

The scientific payload is composed of the LAT (Large Area Telescope), operating in the 20 MeV-300 GeV energy range, and the GBM (Gamma-ray Burst Monitor), 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. After more than 14 years of successful operations, the Fermi LAT half Source Catalog exceeds 5,000 entries. While more than 3,000 sources have been identified or associated with active galactic nuclei, pulsars are the second most numerous source class with about 280 objects a third of which were not known before Fermi LAT, notably we now know 72 young Geminga-like plus 6 msec radioquiet neutron stars.

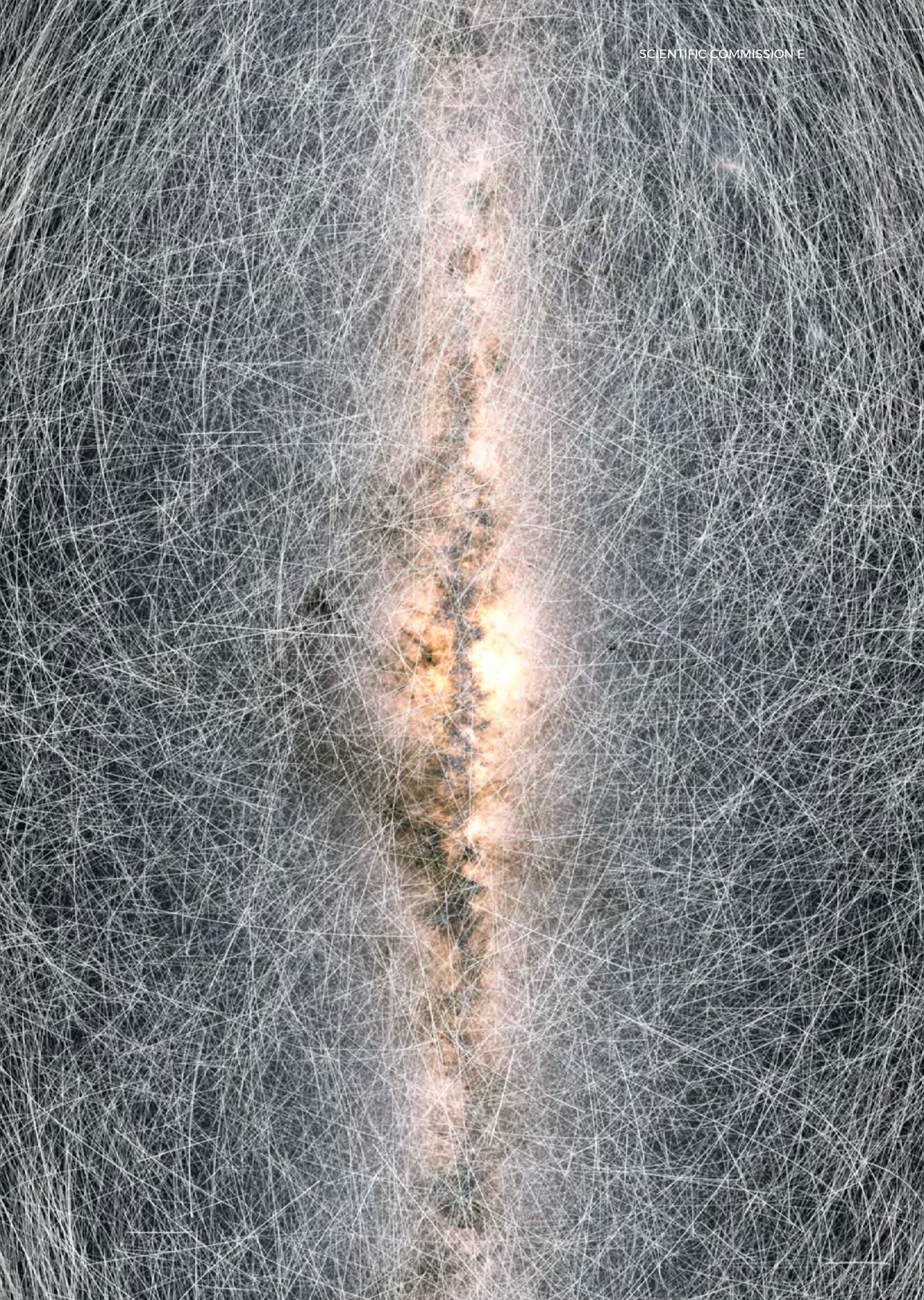
The Italian participation encompasses several contributions starting with the design, construction and calibration of the LAT tracker, performed by INFN under ASI responsibility, and the exploitation of the data by INAF, INFN and Italian universities. Additional tasks such as software development, management of the Italian data archive mirror as well as scientific data analysis are jointly performed by INFN and ASI/SSDC.

Following page: How 40.000 stars will move across the sky in the next 400 thousand years. Credit: Gaia Early Data Release 3 (Gaia EDR3).

gaia

Launched in 2013, ESA mission Gaia is providing a whole-sky census of over 1.5 billion objects, mostly stars in our Galaxy and its immediate surroundings, unraveling the chemical and dynamical history of the Milky Way and, therefore, of its place in cosmology.

Gaia is a major project for the European astronomical community that is revolutionizing our view of the Galaxy, with a precise and detailed entire-sky survey of all detectable celestial objects down to the G(aia) magnitude 20.7 (close to R). Gaia, launched in December 2013, commenced science operations in the Summer of 2014. The onboard fuel reserve is expected to keep Gaia operational until 2025. For this reason, ESA has already officially extended the Gaia mission until the end of 2022. Gaia's high-accuracy global astrometry measures the 3D position of a star and its movement across the sky. In addition, thanks to its multi-function focal plane, Gaia gathers also spectroscopic and spectrophotometric data, yielding quality radial velocities and multi-band photometry for the determination of astrophysical properties (luminosity, surface gravity, temperature and chemical composition).
The predicted end-of-mission parallax standard errors, i.e. after global processing the totality of data acquired over the mission lifetime, is anticipated at 9-25 µas at R =15 depending on star color, providing a 10% error up to individual distances of 10 kpc.
The GDR2 (Gaia Data Release 2) catalog was released in 2018 with the astrometry for more than 1.5 billions sources and partial spectrophotometry. GDR2 processed together the first 22 months of satellite data. Gaia Data Release 3 will be published on Monday 13 June 2022; at least one full release will follow.
The scientific data processing is the responsibility of the DPAC (Gaia Data Processing and Analysis Consortium), a pan-European effort of ~430 scientists and engineers.
Italy's strategic involvement in DPAC activities, the second largest, includes: Gaia Initial Catalog, the catalog of SPSS (Spectro-Photometric Standard Stars), daily and cyclic pipeline astrometric verification, spectrophotometric data reduction and absolute calibration, variable and special object treatment (with primary responsibility on Cepheids, RR-Lyrae, moving objects, e.g. known and new asteroids, and extrasolar planets), source classification and cross-match to external catalogs. To support the astrometric verifications, Italy has contributed a dedicated data processing center, the DPCT (jointly participated by ASI and INAF with ALTEC Inc as industrial contractor), one of the six across Europe. The DPCT receives all of the Gaia observations including the raw pixels of the astrometric focal plane, requiring a 1.5 PBy DBMS, the largest ever in Italy dedicated to astronomy, and a direct connection to the Italian supercomputing center at CINECA to operate its global astrometric pipeline. Italy also provides one of the four partner data centers (the ASI/SSDC at ASI Hq) for the access and distribution of Gaia's released catalogs, thus supporting the National scientific data exploitation.



gaps

GAPS is stratospheric Antarctic balloon mission to be operated in 2023 for the study and search of the rare antimatter components in cosmic rays.

GAPS (the General AntiParticle Spectrometer) is an experiment designed to study the rare antimatter component in cosmic rays with a specific focus on low energy (<0.25 GeV/n) anti-proton, anti-deuteron and low-energy anti-helium nuclei. Anti-deuteron and anti-helium nuclei have never been detected in cosmic rays, and their identification would provide unprecedented information on the understanding of the Universe, revealing unique details on the nature of Dark Matter and on the origin of cosmic rays. The GAPS detector is now starting its integration phase and will be operating on a stratospheric long duration (30 days) balloon flight in Antarctica from the McMurdo base during austral summer 2022.

The GAPS antiparticle identification approach is an innovative technique based on the measurement of the features of the decay of exotic atoms produced after capture of anti-nuclei by the atoms of the detector materials. A plastic time of flight system tags the particle and measures its velocity and energy deposits. The particle then slows down and form an excited exotic atom in the Si(Li) tracker which de-excites and releases X-rays and a "star" of pion and protons from the nuclear annihilation. The simultaneous measurements of the X-ray energy deposits, with 4 keV energy resolution of the Si(Li) detector, the pion and proton multiplicities, and the stopping depth, velocity and energy deposition of the primary precisely determine the type of primary particle. This provides the required rejection of protons and other nuclei for an anti-nuclei search, and discrimination between the different anti-nuclei species. The data collected during the first flight will provide enough statistics to investigate the properties of low energy anti-protons, while two additional flights will be required to achieve the scientific objectives for anti-deuteron and anti-helium physics.

GAPS is an experiment led by University of Columbia with participation of scientists from other American, Japanese and Italian institutions. Italian researchers from INFN departments and Firenze, Pavia, Bergamo, Napoli, Torino, Roma Tor Vergata and Trieste Universities participate to GAPS since 2017 and with support from ASI since 2018.

The Italian contribution concentrates on the development and construction of electronics components of the detector and on the development of data analysis pipelines and simulations and data interpretation models.

hst

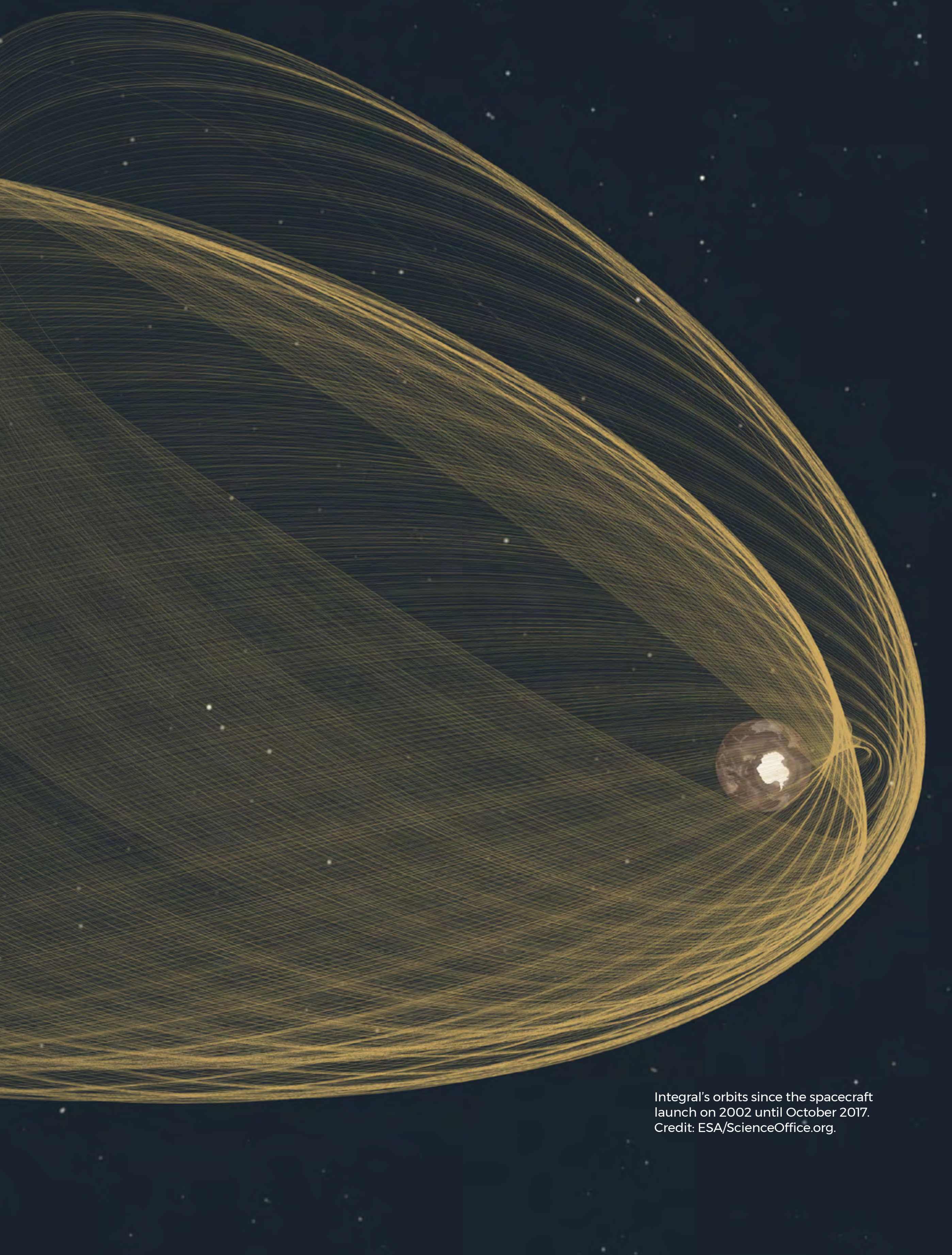
HST is the most popular NASA/ESA joint mission. It has recently celebrated 30 years of achievements and the most dramatic discoveries in the history of astronomy. It will soon be partner with the James Webb Space Telescope, launched in 2021, to give us more astounding images and ground-breaking science.

Launched in 1990, HST (Hubble Space Telescope) has provided the most spectacular images of the Universe.
With its spectroscopic and imaging instruments that cover from the Ultraviolet through the Infrared bands, it has provided unprecedented insight into many astrophysical questions, from the Solar System to the early stages of the Universe. After having been serviced several times by the Space Shuttle, allowing repair and substitution of its instruments, it is still working at its best. It is expected to continue operation for several more years, with significant overlap with the JWST mission.
HST has three types of instruments that analyze light from the universe: cameras, spectrographs and interferometers. It has two primary camera systems to capture images of the cosmos. Called the ACS (Advanced Camera for Surveys) and the WFC3 (Wide Field Camera 3), these two systems work together to provide superb wide-field imaging over a broad range of wavelengths. While ACS is primarily used for visible-light imaging, WFC3 probes deeper into infrared and ultraviolet wavelengths, providing a more complete view of the cosmos. The current two spectrographs are: the COS (Cosmic Origins Spectrograph) and the STIS (Space Telescope Imaging Spectrograph). COS and STIS are complementary instruments that provide scientists with detailed spectral data for a variety of celestial objects. Working together, the two spectrographs provide a full set of spectroscopic tools for astrophysical research. The three interferometers aboard Hubble are the FGS (Fine Guidance Sensors). The FGS measure the relative positions and brightness of stars and are very sensitive instruments. They seek out stable point sources of light (known as “guide stars”) and then lock onto them to keep the telescope pointing steadily.
Italy has 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 that played a crucial role in discovering the first prompt electromagnetic radiation in coincidence with a Gravitational Wave event, opening the Multi-Messenger astrophysics era.

The INTEGRAL (INTernational Gamma-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 (Imager on Board of the INTEGRAL Satellite) giving the sharpest gamma-ray images yet seen from astronomical targets; and the spectrometer SPI (SPectrometer on INTEGRAL) which precisely measures Gamma-ray energies. 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, detection and location of all the sources. After almost 20 years of operation, INTEGRAL has detected more than 1000 high-energy emitters of all types, most of which are new detections 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 up to the end of 2022, with an ongoing extension request till 2025. 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. It still continues to contribute to this key topic linking the new non-electromagnetic astronomies with the high- energy electromagnetic Universe in the poorly-covered 10 keV to 10 MeV domain. This is mainly due to the unique capabilities: highly efficient coverage of the whole sky and rapid reaction for Target of Opportunity observations. No mission, neither in operation, nor planned in the coming years, offers INTEGRAL's combination of capabilities in the hard X/γ-ray parts of the electromagnetic spectrum.
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 (INAF/IAPS, INAF/IASF Milano, IASF-Palermo and INAF/OAS) 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.



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

ixpe

IXPE: launched on December 9 2021 with a Space-X Falcon 9 launcher. The first year oberving plan comprises about 30 sources X-ray source from almost of the classes.

IXPE (Imaging X-ray Polarimetry Explorer) is a SMEX (Small Explorers) mission was launched on 9th December 2021. The mission, led by NASA/MSFC is devoted to make time-spectrally-spatially resolved X-ray polarimetry. It comprises three GPDs (Gas Pixel Detectors) provided by ASI and three X-ray optics developed at NASA/MSFC. The first year observing plan comprises about 30 X-raysources chosen among almost all the classes. The main contractor for the spacecraft is Ball Aerospace. IXPE reaches a focal length of 4 meters by means of an extendable boom provided by Northrop Grumman Space System. X-ray polarimetry allows to study black holes and neutron stars binaries in their variable physical conditions for the unstable presence of jets, coronae and 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 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 Nebula for mapping magnetic fields, determining its uniformity for studying the acceleration mechanisms at the emission site. The Italian contribution comprises the unique focal plane instrument: the Detector Units, with the Gas Pixel Detectors, have been provided by INFN; INFN, also, designed the back-end electronics manufactured by OHB-Italia. OHB-Italia designed and built the Filter and Calibration Wheel, the High Voltage power supply and the Detector Service Unit. INAF lead the project, designed and built the flight calibration sources, included a polarized one, to monitor the detector performances during flight and the UV-ion filters. INAF accomplished the acceptance test and the ground calibration of all the Detector Units and performed the electrical and functional integration and test of the instrument. INFN also performed the Thermo-Vacuum test at INAF-IAPS. ASI provided the Malindi primary IXPE Ground Station and contributes to the development of the flight pipeline with ASI/SSDC.

A SpaceX Falcon 9 rocket launches with NASA's Imaging X-ray Polarimetry Explorer. Credit: NASA.

MINI-EURO is hosted in the ISS Russian Service Module, Zvezda. Credit: NASA.

jem–euso

JEM-EUSO is a program that includes several missions to explore the origin of the extreme energy cosmic rays and cosmogenic neutrinos.

JEM-EUSO (Joint Experiment Missions for Extreme Universe Space Observatory) is a program that aims at exploring the origin of the extreme energy cosmic rays and cosmogenic neutrinos by looking downward at Earth from space, and detecting the fluorescence light of extensive air-showers that they generate in the Earth's atmosphere. The origin and nature of UHECRs (Ultra-High Energy Cosmic Rays) and cosmogenic neutrinos remain unsolved in contemporary astroparticle physics. Give an answer to these questions is rather challenging because of the extremely low flux at extreme energies (i.e. E > 5x1019 eV). The main objective of JEM-EUSO is the realization of an ambitious space-based mission devoted to UHECR science. The JEM-EUSO program includes several missions: on ground, EUSO-TA, in operation at the Telescope Array site in Utah since 2013; on board stratospheric balloon, EUSO-Balloon, that flew in August 2014, EUSO-SPB1, launched in April 2017 on a super pressure balloon, EUSO-SPB2, in construction phase for a long duration flight in 2023; in space, TUS, a Russian mission that has been flying for a year on board the Lomonosov Satellite since April 2016; MINI-EUSO, in operation since August 2019 inside the ISS, looking down the atmosphere from the UV transparent window in the Russian Module; and the large size mission K-EUSO, in phase of realization, to be installed outside the ISS. The final goal of the JEM-EUSO program is to send in orbit a super-wide-field telescope that will look down from space onto the night sky to detect UV photons emitted from air showers generated by UHECRs in the atmosphere, with a year time exposure more than one order of magnitude of Auger. This is the context of the POEMMA mission (Probe Of Extreme Multi-Messenger Astrophysics) at present in a study phase. 16 countries and about 300 researchers are collaborating in JEM-EUSO. MINI-EUSO and EUSO-SPB2, in the context of the JEM-EUSO program, in Italy are presently funded by ASI and INFN.

jwst

JWST is the largest telescope ever conceived to work in space, and has been launched on December 25th 2021. It will be the premier observatory of the next decade, serving thousands of astronomers worldwide.

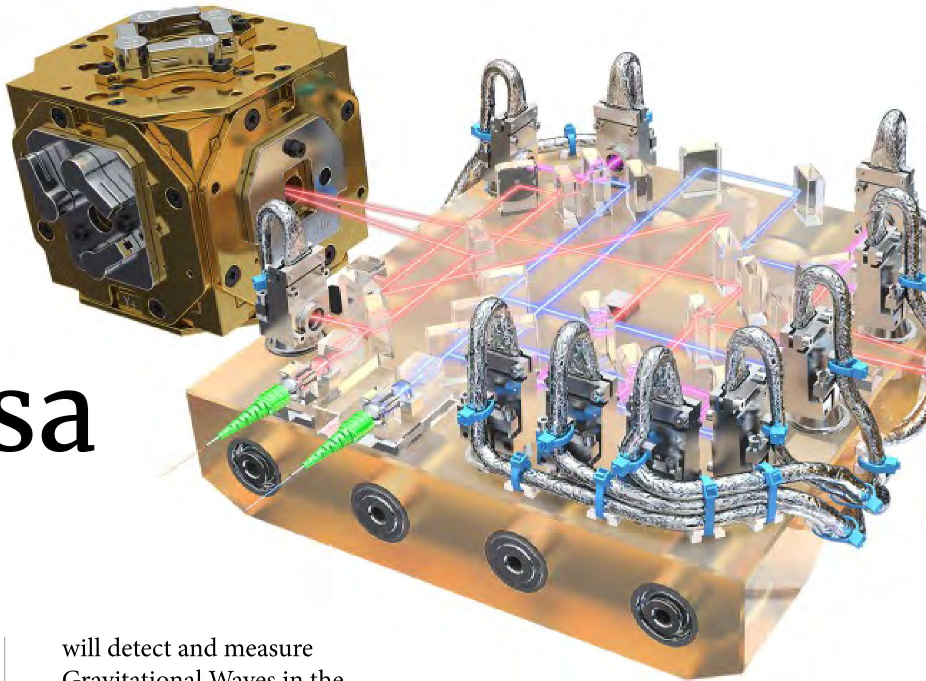
JWST (James Webb Space Telescope) is an infrared telescope with a 6.5-meter primary mirror, the result of the fruitful collaboration of NASA, ESA and CSA, the space Agencies of the US, Europe and Canada. It has been successfully launched from French Guiana by an Ariane 5 rocket, and has reahed its final destination in the Lagrangian point L2 30 days after launch.
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.

Several innovative technologies have been developed for JWST, which include the primary mirror made of 18 separate segments, made of ultra-lightweight beryllium covered by a thin gold layer, successfully unfolded after launch, and the impressive tennis-court-sized five-layer sunshield that attenuates light and heat from the Sun and has also been successfully deployed a few days after launch.
JWST is equipped with 4 instruments: NIRCam (Near-InfraRed Camera), built by the Arizona University, NIRSpec (Near InfraRed Spectrograph), provided by ESA with components by NASA/ GSFC, MIRI (Mid-InfraRed Instrument), provided by a European Consortium including ESA and by NASA/ JPL and FGS/NIRISS (Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph), provided by CSA. NIRCam is JWST's primary imager and will cover the infrared wavelength renge of 0.6-5 microns. NIRCam will detect light from the earliest stars and galaxies in the process of formation, the population of stars in nearby galaxies, as

well as newly born stars in the Milky Way and Kuiper Belt objects. NIRCam is equipped with coronagraphs, instruments that allow astronomers to take pictures of very faint objects around a central bright object, like exoplanets around their star. NIRSpec will operate over a wavelength range of 0.6-5 microns to study thousands of galaxies during its 5 year mission and is designed to observe 100 objects simultaneously, the first spectrograph in space that has this remarkable multi-object capability. MIRI has both a camera and a spectrograph that sees light in the mid-infrared region of the electromagnetic spectrum, with wavelengths in the 5-28 microns range. Its sensitive detectors will allow it to see the redshifted light of distant galaxies, newly forming stars still embedded in their dusty cocoons, and faint comets and objects in the Kuiper Belt. FGS allows JWST to point precisely, so that it can obtain high-quality images. FGS/NIRISS will be used to investigate, in a wavelength range of 0.8-5.0 microns, the following science objectives: first light detection, exoplanet detection and characterization, and exoplanet transit spectroscopy.

Italians are participating to the mission, either as ESA members or because of their individual role in international consortia and committees. The TAC (Time Allocation Committee) had several members from Italy (including the Chair) and met in early 2021 to select, on the basis of scientific excellence, the best projects that will exploit JWST during its first observing cycle. Oversubscription was obviously very high, with proposals arriving from 44 different countries, and Italians performed very well, either as Principal or as co-Investigators: 10% of the approved programs are led by Italian scientists (9 of whom affiliated to Italian Institutions). Italian astronomers are also co-Investigators of GTO (Guaranteed Time Observations allocated to the consortia that built the instruments) and ERS (Early Release Science) programs, that will be executed as soon as the telescope and its optics are well calibrated.

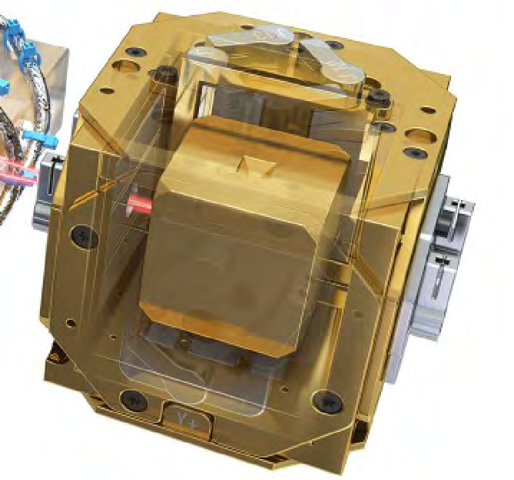
Following page: the core of LISA Pathfinder, two 46mm cubes of gold-platinum. Credit: ESA/Medialab.



lisa

LISA is a Gravitational Waves observatory made of a constellation of 3 spacecrafts millions of km apart, currently under study by ESA (phase B1) in preparation for a launch in 2037.

The gravitational Universe is the theme of the ESA L3 Mission (third Large mission of the ESA Cosmic Vision program).. ESA has selected the LISA (Laser Interferometer Space Antenna) gravitational wave observatory for L3 and is currently developing the mission for a 2035 launch. LISA will consist of a constellation of three spacecrafts, with a 2.5 million km separation, each containing Test Masses in free fall, whose relative motions are measured by laser interferometry. LISA will detect and measure Gravitational Waves in the 100 microHz to 1 Hz band (optional extended band down to 20 microHz), 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. Most of the “enabling technologies” have been tested by LISA Pathfinder. Based on its role in LISA Pathfinder, Italy leads the development of the Gravitational Reference Sensors (GRS) which contain the free-falling test masses.



lspe

LSPE is an ASI and INFN stratospheric balloon mission that will measure the polarization of the CMB radiation at large angular scales. The first flight is planned for December 2023.

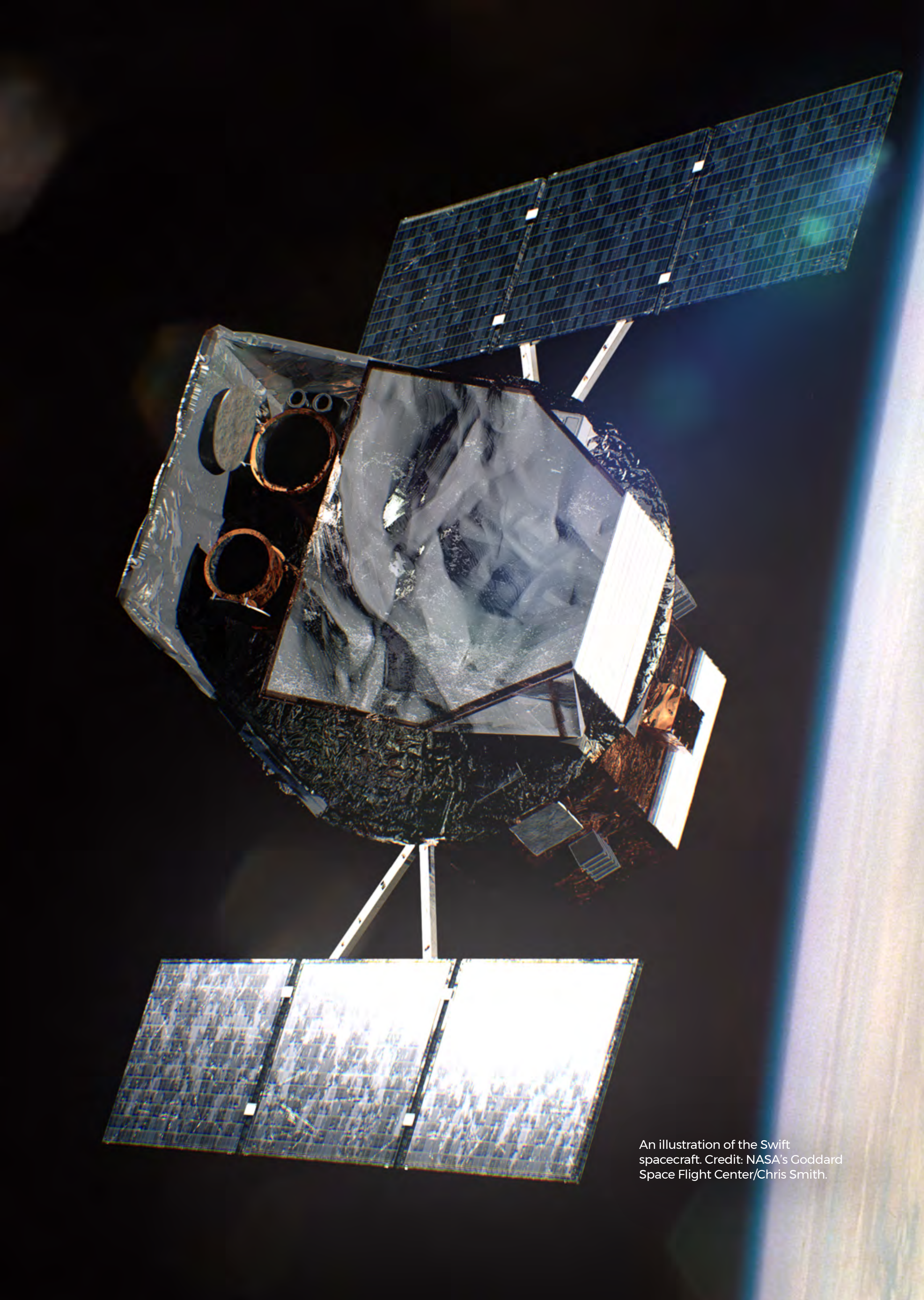
LSPE (Large Scale Polarization Explorer) is a stratospheric balloon mission funded by ASI and INFN, with a first flight planned for 2021. LSPE will measure the polarization of the CMB (Cosmic Microwave Background) radiation at large angular scales, during a long duration stratospheric flight in the Arctic Winter.
Gravitational Waves produced during cosmic inflation, a split-second after the big-bang, induce linear polarization in the CMB (with both gradient modes E-modes and curl modes B-modes). The signal from B-modes is extremely small, <0.1 microK rms, and is mainly at large angular scales. LSPE targets are the reionization and recombination bumps in the angular power spectrum of B-modes. The LSPE program features two polarimeters: the SWIPE (Short Wavelength Instrument for the Polarization Explorer) balloon-borne polarimeter, with cryogenic multi-mode bolometers and a spinning HWP modulator (Half Wave Plates), and the STRIP (Survey TeneRIfe Polarimeter) ground-based polarimeter with low-frequency coherent radiometers, aimed at foreground monitoring. The 40-250 GHz frequency range is covered with 5 channels, with an angular resolution of 0.5-1.3 deg FWHM and a combined sensitivity of 20 microK arcmin.

mini–euso

Mini-EUSO is a next-generation telescope for the study and monitoring of terrestrial, atmospheric and cosmic emissions in Ultraviolet (UV) that operates in the ISS since 2019.

Mini-EUSO (Multiwavelength Imaging New Instrument for the Extreme Universe Space Observatory) is a telescope designed to perform observations from the ISS, of UV light emission in the atmosphere of the Earth. On August 2019 it was launched to the ISS with an uncrewed Soyuz spacecraft. Since October 2019, it is observing the Earth looking nadir through a UV-transparent window in the Russian Zvezda module. The main optics of the telescope is composed by two, 25cm diameter Fresnel lenses, with a focal surface composed by an array of 36 Hamamatsu 64 channel multi-anode photomultiplier tubes, for a total of 2304 pixels. Additional detectors are two ancillary cameras in the visible and NIR range, and an 8x8 array of Multi-Pixel Photon Counter SiPMs. The field of view on the ground is 40 degrees, corresponding to about 320x320 km2 on the surface of our planet. The acquisition is performed with a 2.5 μs sampling speed, with triggered acquisitions taking place at this time scale and at 320 μs, and continuous acquisition being performed at 40ms. The scientific objectives include: Realization of the first UV night map of the Earth with a resolution of a few km; Detection and study of meteorites (more than 10,000 detected so far); Search for interstellar meteorites; Search for quark strange matter; Monitoring and tracking of space debris for the realization of future laser-based removal methods; Search for ultra-high-energy cosmic rays (E>1e21 eV); Study of marine bioluminescence and of the 'milky sea' phenomenon, generated by plankton. Technological goals include the first use of a refractive telescope based on Fresnel lenses in space and the first use of a high sensitivity focal surface, capable of single-photon detection; development and test of the related electronics capable of working in the space environment. These technologies and techniques have applications ranging from the creation of new and larger spatial telescopes for the study of fundamental physics phenomena in space to practical applications related to the new type of optics and detectors in space (solar energy concentrators, removal of space debris, monitoring of land and pollution).

Mini-EUSO was developed under an agreement between ASI and ROSCOSMOS with a wide international collaboration led by the University of Rome Tor Vergata and INFN in Italy and MSU in Russia. The Italian contribution also involved other scientific realities and Italian academics.



An illustration of the Swift spacecraft. Credit: NASA's Goddard Space Flight Center/Chris Smith.

neil gehrels swift observatory

The Neil Gehrels Swift Observatory (previously named Swift) is a NASA mission with a strong contribution from Italy and UK. It was launched in 2004 to solve the mystery of the origin of Gamma Ray Bursts.

The Neil Gehrels Swift Observatory was launched on November 2004. It was previously named Swift and renamed in memory of Neil Gehrels, who served as its principal investigator until his death on Feb. 6, 2017. The Neil Gehrels Swift Observatory is a collaborative MIDEX (Medium-Class Explorers) NASA Mission with a strong contribution from Italy and UK for the observation of the GRB (Gamma Ray Bursts). It has onboard three instruments: the BAT (Burst Alert Telescope), the XRT (X-Ray Telescope) and the UVOT (Ultraviolet/Optical Telescope). 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, more than five 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 and neutrino sources. Italy provides the ASI ground station in Malindi for the uplink/downlink of the data, the Mirror Module of the XRT developed by the INAF/OAB under an ASI contract, the XRT data analysis software developed by the ASI/SSDC. Furthermore, the Italian team participates to the scientific management of the mission, funded by ASI.

nustar

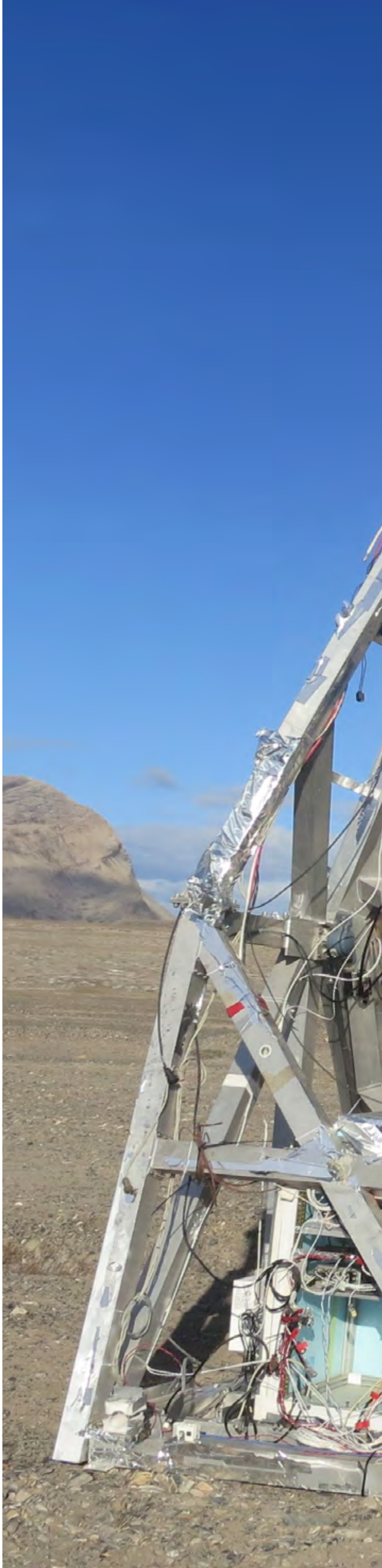
The NuSTAR mission is a NASA Explorer launched in 2012: it is the first hard X-ray focusing satellite.

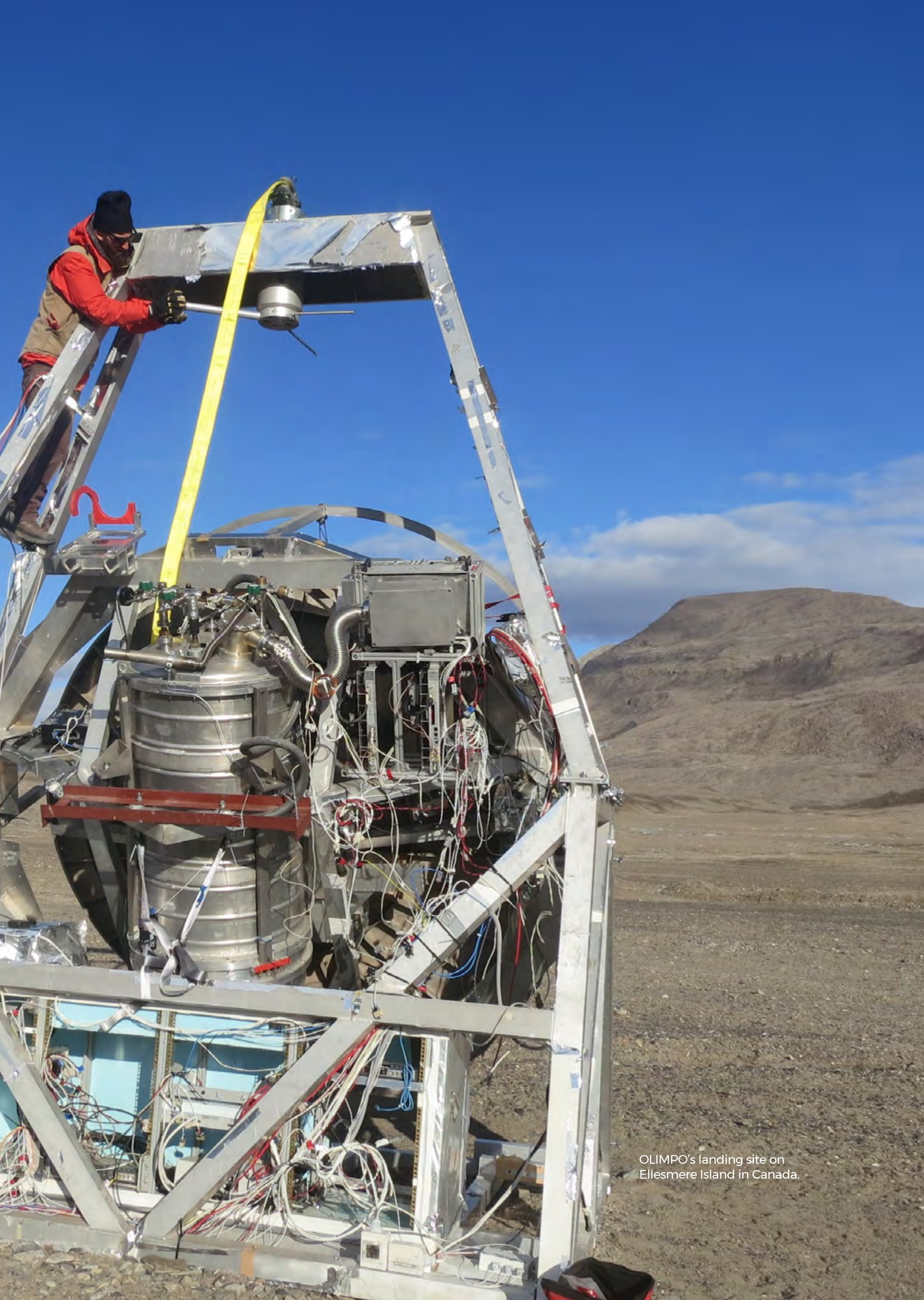
NuSTAR (Nuclear Spectroscopic Telescope Array) mission is a NASA Explorer launched in 2012: it is the first orbiting telescopes to focus light in the high energy X-ray (6-79 keV) region of the electromagnetic spectrum.
Main results include a census of black holes and stellar compact objects at different scales; the measurements of their spins and of the properties of their outflows; shedding light on acceleration processes in various sites; the mapping of the radioactive debris of the CasA supernova remnant; the study of the Galactic Center with unprecedented resolution at hard X-rays and the properties of ultraluminous sources with the discovery of an ultraluminous pulsar and, more recently, the observation of microflaring active regions of the Sun.
NuSTAR works efficiently in coordinated programs with other X/Gamma-ray missions.
The Italian contribution includes: the provision of ASI ground station in Malindi (Kenya), data reduction software support and archival storage at the ASI/SSDC, contribution to the project with a team of INAF scientists that collaborates to the primary scientific mission goals.

olimpo

OLIMPO is a balloon mm-wave telescope for spectroscopic measurements of the Sunyaev-Zeldovich effect in clusters of galaxies. It was flown in a first flight in 2018, with a long duration Arctic flight.

OLIMPO is a balloon-borne 2.6 m aperture mm-wave telescope coupled to a DFTS (Differential Fourier Transform Spectrometer) with 4 cryogenic detector arrays, covering spectroscopically 4 wide bands centered at 140, 220, 340, 480 GHz. The DFTS rejects the common-mode signal with high efficiency, extracting tiny spectral anisotropies from an overwhelming instrumental and atmospheric background. In the first long-duration flight from Svalbard islands, in july 2018, the instrument and its new kinetic inductance detector arrays were successfully validated. The instrument has been recovered and is being prepared for a second circumpolar flight, aimed at obtaining data-cubes from about hundred deep sky areas, including Sunyaev-Zeldovich targets, as well as blank reference areas, to measure the spectral-spatial anisotropy of the diffuse mm and sub-mm cosmic background. The experiment is funded by ASI.





OLIMPO's landing site on Ellesmere Island in Canada.

plato

PLATO, to be launched in 2026 by ESA, will catalog transiting planets of closeby stars, including earth like planets, providing measurements with unprecedented accuracy of planetary density and age.

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 2026. It 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.

Made by a set of 24 telescopes, mounted on the satellite in 4 slightly misaligned groups, it provides a field of view of almost 2400 square degrees and an equivalent aperture comparable to a 0.9 m telescope. Two more telescopes are optimized to observe very bright stars (magnitude 4-8), each of which specializes in blue and red light, respectively. Italy, through ASI, is providing the 26 Telescope Optical Units, made in collaboration with Bern University, based on an optical design by INAF, tested and delivered by Leonardo S.P.A., Thales Alenia Space and Media Lario SrL. Italy, through ASI, is also providing the Instrument Control Unit (made in collaboration with IWF, Graz, Austria, designed at INAF, produced, tested and delivered by Kayser Italia), the segment of the ground centre devoted to the handling of the PLATO Input Catalog (ASI/SSDC). Moreover, ASI and INAF are leading the coordination of the PLATO Camera System, and together with Padua University, the preparation of the PLATO Input Catalog. The preparation of the PLATO scientific program involves researchers from INAF and universities spread overall Italy.

theseus

M-class mission concept, studied by ESA in 2018-2021, to open a new window on the early Universe and the multi-messenger transient sky.

THESEUS (Transient High-Energy Sky and Early Universe Surveyor) is one of the three mission concepts selected by ESA in 2018 for a 3-years Phase A study as candidate M5 mission. Based on the heritage of this assessment study and the great support by the scientific community, the THESEUS mission concept is being further developed and proposed again to ESA in response to the recent call for a M-class mission to be launched in 2037. THESEUS aims to explore the early (first billion years) Universe through high-redshift GRBs (Gamma-Ray Bursts), the most extreme explosions in the cosmos, and to provide detection, accurate location and redshift of the electromagnetic 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. THESEUS will provide a fundamental contribution to the time-domain and multi-messenger astrophysics and to several fields of astrophysics, cosmology and fundamental physics. It will operate in beautiful synergy with the large worldwide facilities planned for the next decade devoted to the study of the Cosmos, such as LSST, ELT/ TMT, Ska, CTA, Athena, Ligo, aVirgo, Kagra, Et and Km3NeT.
The THESEUS mission concept was proposed and is supported by an European consortium led by Italy and with main contributions by UK, France, Germany and Switzerland. Further relevant contribution come from Spain, Denmark, Poland, Belgium, Czech Rep., with additional minor contributions from other European countries like, e.g. Slovenia. A possible international contribution by NASA will be explored.
The Italian participation is led by INAF/OAS and funded by ASI and it includes the development of one of three instruments on board, the XGIS (X/Gamma-ray Imaging Spectrometer), the development of the TBU (Trigger Broadcast Unit), the contribution to ground segment (Malindi Antenna) and the general coordination of the international consortium.

xmm–newton

Since 1999, XMM-Newton is detailing 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. The mission shall operate up to at least 2022 with possible extension to 2025. Taking advantage of its high throughput, 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 the mechanisms acting for the production of X-rays in the magnetosphere of planets.

The XMM-Newton spacecraft is carrying a set of three X-ray CCD cameras, comprising the EPIC camera (European Photon Imaging Camera). Two of the cameras are MOS (Metal Oxide Semi-conductor) CCD arrays. They are installed behind the X-ray telescopes that are equipped with the gratings of the RGS (Reflection Grating Spectrometers). The EPIC CCDs are designed to exploit the full design range of the X-ray mirrors, 0.1-15 keV. They provide energy resolution at 6.5 keV of E/dE~50, and their positional resolution is sufficient to resolve the mirror performance of 6 arc seconds FWHM (15 arc seconds HEW). The MOS CCDs are front illuminated 600x600 pixel devices. The physical size of each pixel is 40μm, corresponding to 1.1 arc seconds on the sky. There are seven CCD chips with one in the center of the field of view with the other six surrounding it. The CCDs are offset from one another to match the curvature of the focal plane. RGS consist of RGAs (Reflection Grating Assemblies) and RFCs (RGS Focal Cameras). The RGS provides high spectral resolution (E/dE from 200 to 800) X-ray spectroscopy over the energy range 0.35-2.5 keV (5-35 Å). The RGAs intercept about 50% of the X-rays passing through the mirrors. The reflected X-rays are directed onto linear arrays of 9 MOS chips forming the RFC. The OM (Optical Monitor) is co-aligned with the X-ray telescopes, providing simultaneous UV/optical/X-ray observations. The instrument consists of a 30 cm Ritchey-Chretien telescope feeding a compact image-intensified photon-counting detector. The detector operates in the UV and the blue region of the optical spectrum. Since the majority of X-ray sources are variable, the optical monitor allows the observer to know the optical state of the X-ray object they are viewing. Thanks to the coordinated involvement of its research structures INAF/IASF, INAF/OAS and INAF/OAPD, INAF is contributing to the realization of the three EPIC (European Photon Imaging Camera) cameras. Moreover, INAF/OAB did significantly contribute, together with the Media Lario SrL, to the realization of the large area mirror modules. The INAF/OAPA has been involved in the development and calibration of the EPIC optical filters.


AFT

SCIENTIFIC COMMISSION F
Life Sciences as Related to Space

Previous page: Luca Parmitano performs a European experiment called GRIP that studies astronauts' perception of mass and movement in microgravity. Credit: ESA/NASA.

vita, beyond and the asi experiments

VITA and BEYOND are two Italian missions conducted onboard the ISS by astronauts Paolo Nespoli and Luca Parmitano including a large number of experiments in different research fields.

Thanks to the agreement with NASA signed in 1997 (Memorandum of Understanding between NASA and ASI - MoU), ASI has a privileged access to the ISS. In fact, according to the MoU, in exchange for the supply of the three MPLMs (Multi Purpose Logistic Module), ASI is entitled - among other things - to long-lasting astronaut flights every 5 years and to the exploitation of part of NASA's on-board resources (0.85% of NASA ISS resources, which corresponds to 0.6% of the total station resources).
In 2017, ESA and ASI jointly selected the astronaut Paolo Nespoli for the long-lasting flight mission called VITA.
In order to complement the VITA mission, ASI coordinated a pool of scientists, industry leaders in innovative technological fields and academic researchers who worked on the design and implementation of payloads, experiments and scientific protocols in the fields of human physiology, cell biology, countermeasures, physical sciences, technological demonstrations and educational activities.
Following a call for research opportunities, as well as promoting public-private partnership, ASI appointed for the VITA mission a total of 11 investigations, involving 29 different institutions and about 40 investigators.
The return of the ESA astronaut with Italian passport Luca Parmitano on board the Soyuz MS-13, on February 6th, 2020, is the event that signed the successful completion of the ESA mission BEYOND.
One of the mission goals was to carry out six experiments sponsored by ASI. Three investigations (Acoustic Diagnostics, Amyloid Aggregation and NutrISS) were integrated on board and operated via a specific agreement between ESA and ASI, two (XenoGRISS and LIDAL) were launched through the ASI-NASA MoU for the MPLM/PMM modules, one (Mini-EUSO) stemmed by an international cooperation led by Italy and Russia, which required a specific agreement between ASI and ROSCOSMOS.
Based on the resources available from the start of the program until the completion of the mission BEYOND, ASI has conducted 73 experiments, in all the different research fields foreseen for the ISS science.

ESA astronaut Samantha Cristoforetti exercising on the ISS during her Futura mission in 2015. Credit: ESA/NASA.

in situ bioanalysis

The IN SITU Bioanalysis project allows to perform on board the ISS chemical-clinical analysis of biological samples obtained in a non-invasive way.

The scientific objective of the IN SITU Bioanalysis project was the design and development of a portable analytical device, suitable for the quantitative measurement of biomarkers of interest in the oral fluid of astronauts during their mission onboard the ISS. In particular, the project was focused on the measurement of salivary levels of cortisol, as a stress biomarker, but in the future, it can be easily adapted for the analysis of other biomarkers of interest in different biological samples. The entire analysis was conducted during the VITA mission on board the ISS, without the need to send samples to Earth, offering the astronaut the opportunity to monitor his health in real time. The system is based on the LFIA (Lateral Flow Immunoassay) technique, widely known in the diagnostic field (e.g. pregnancy test), which exploits the high specificity of antibodies to recognize the biomarker of interest and the capillary forces to promote the movement of reagents; the coupling with the chemiluminescence detection (CL-LFIA) allows to obtain accurate quantitative information.
Currently, biological samples taken by crewmembers on board the ISS are normally frozen and kept on board until they can be sent to Earth and analyzed in the laboratory. This makes the operation extremely complex and expensive, and it also significantly lengthens response times. Furthermore, this scenario is not conceivable for long-range future missions. The peculiarity of the IN SITU Bioanalysis is that the chemical-clinical analysis is carried out directly within the ISS, allowing a timely diagnosis and therefore a rapid intervention in case of problematic situations. This device, designed for space, can then also be used in other critical situations on Earth, for example for POCT (point-of-care testing) applications at the patient's bed, in the doctor's office or in an ambulance, in emergency medicine, in cases of bioterrorism or for diagnostics in developing countries or in remote or isolated communities.

acoustic diagnostic

The Acoustic Diagnostics experiment aims at evaluating possible hearing damage on astronauts by performing tests before and after their missions and on board the ISS with an innovative system.

Microgravity and environmental noise are potential risk factors for the astronauts' hearing, particularly in case of very long-term missions that are foreseen for the exploration of the Solar System. The Acoustic Diagnostics experiment aims at evaluating possible hearing damage by comparing the outcome of several audiological tests performed on the astronauts before and after their mission, and by performing accurate OAE (Oto-Acoustic Emission) tests on a monthly base while on board the ISS. OAEs are acoustic signals generated in the hearing sensory organ (the cochlea), as a response to acoustic stimuli, and measured in the ear canal. Their amplitude is strictly correlated to hearing sensitivity, so they represent an objective, fast, non-invasive hearing diagnostic tool. An innovative system for measuring DPOAE (Distortion Product of OAE) was designed, guaranteeing high reproducibility of the test results, exploiting a particular technique for the stimulus calibration in the ear canal, and a high frequency-resolution.
A customized probe, inserted in the ear canal, houses the loudspeakers delivering the stimulus and the microphone recording the OAE response. Periodic DPOAE measurement session were performed on two astronauts during the mission BEYOND on board the ISS. The astronauts set up and operated the experiment, guided by a user-friendly acquisition software. Both ears were tested in each session.
The test results will allow us to demonstrate or to exclude hearing damage, even mild or transitory, statistically associated to residence on board the ISS in conditions of noise and microgravity, with obvious implications for the design of future longer-term missions, dedicated, e.g. to the exploration of Mars.
Some additional sessions are going to be performed by one astronaut during the mission COSMIC KISS and by another one during the mission MINERVA, on board the ISS. Such sessions will enhance the statistic value of the obtained data.
Such a compact and performing device will find interesting applications in clinical audiology and health at work, allowing performing accurate audiological tests in a noisy environment.


ELC2

SCIENTIFIC COMMISSION H
Fundamental Physics in Space

Previous page: The second Alpha Magnetic Spectrometer (AMS-02) on the ISS. Credit: NASA.

ams-02

AMS-02 is a particle physics detector operating on the ISS since 2011 performing precision measurements of cosmic ray composition and fluxes and studying the Universe and its origin by searching for antimatter and dark matter in cosmic rays.

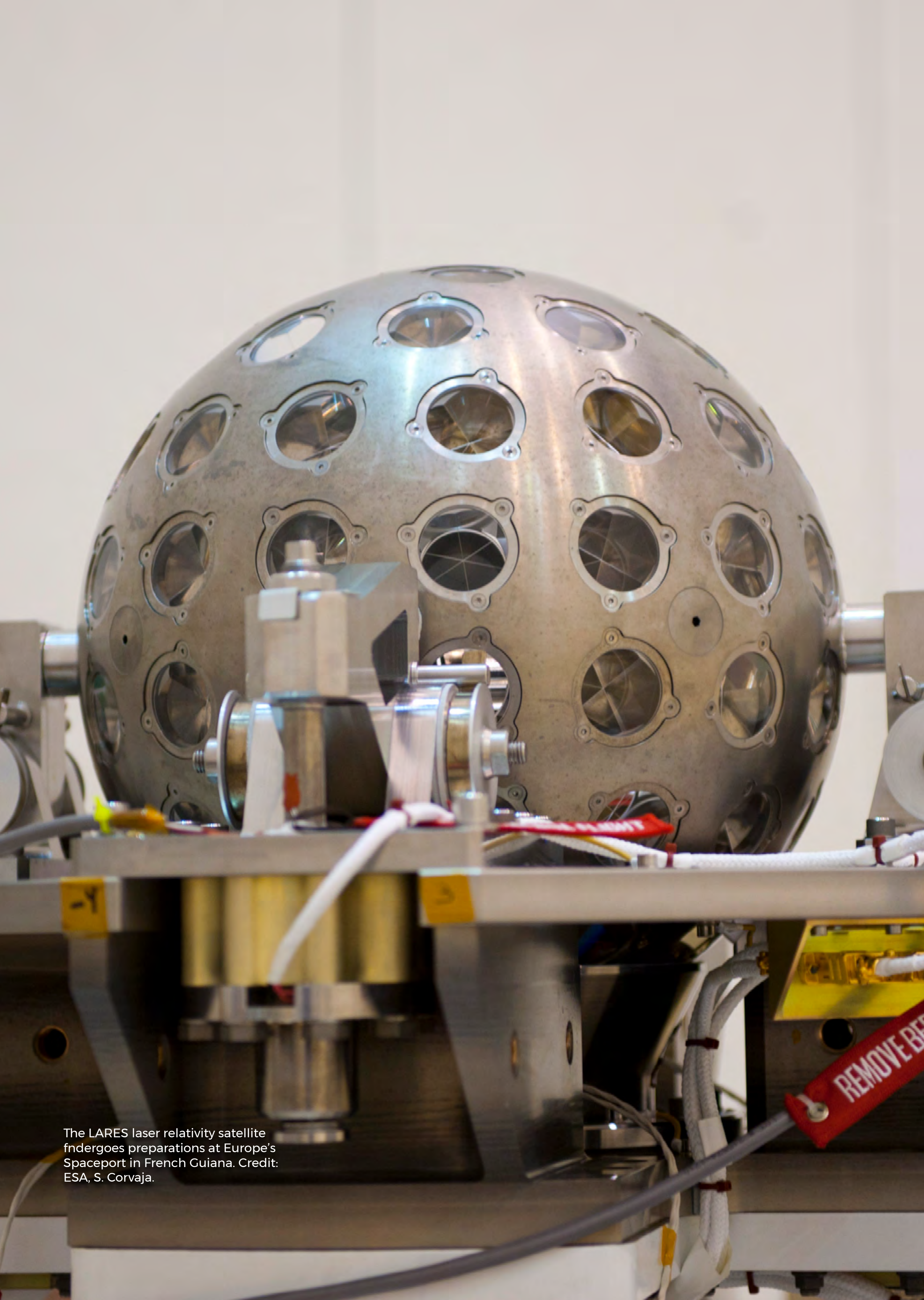
The Alpha Magnetic Spectrometer (AMS-02) is a particle physics spectrometer operating on the ISS since 2011. It uses the unique environment of space to study the Universe and its origin by searching for the rare antimatter components and for dark matter signatures in cosmic rays while performing precision measurements of cosmic ray composition, fluxes and time dependences.

AMS-02 is the only magnetic spectrometer operating on the ISS. It measures the particle rigidity and sign of the charge with its permanent magnet, separating matter from antimatter in cosmic rays. Additional subdetectors provide complimentary and redundant information on the particle charge, velocity and energy to precisely identify the nature and properties of each cosmic ray particle crossing the detector.
AMS-02 has been launched onboard the Space Shuttle Endeavour in 2011 and has been operating on the ISS ever since. The recent upgrade of the AMS-02 Tracker Thermal Control System, which required four successful Extra Vehicular Activities completed in January 2020, allowed to extend the expected AMS-02 lifetime up to at least 2030. In more than 10 years of operations, AMS-02 has collected approximately 200 billion cosmic rays. The results from the analysis of the AMS-02 data have been published in several papers and are providing unprecedented advances in the understanding of the mechanisms of cosmic ray origin, acceleration and propagation, of the origin of the rare components of cosmic rays and of solar physics.
AMS is an international collaboration of 44 institutions from America, Europe and Asia. Italy has a prominent role in the collaboration thanks to the funding of INFN and ASI. Scientists from INFN branches and from Universities of Bologna, Milano Bicocca, Perugia, Pisa, Roma La Sapienza, Roma Tor Vergata, Trento and from ASI contribute to the detector operations and data analysis.
The ASI Space Science Data Center (ASI-SSDC) hosts the Cosmic Ray Database (CRDB) that provides access to the AMS published data.

lares

LARES is an ASI laser-ranged satellite launched in 2012 aiming at performing tests of General Relativity and measurements for space geodesy and Earth science.

LARES (LAser Relativity Satellite) is an ASI laser-ranged spherical passive satellite launched in 2012 with VEGA. It is made up of a single high-density Tungsten alloy to minimize the non-gravitational orbital perturbations acting on it. Its area-to-mass ratio is by far the smallest among all artificial satellites, making LARES the densest known orbiting object in the Solar System. An high-precision determination of its orbit is achieved thanks to the very precise range measurements provided by Satellite Laser Ranging (SLR), the satellite being covered with 92 retroreflectors distributed on its surface. Its main purpose is enable precise tests of Einstein's theory of General Relativity, in particular of frame-dragging. Frame-dragging is an intriguing phenomenon of General Relativity: in Einstein's gravitational theory the inertial frames, which can only be defined locally according to the Equivalence Principle, have no fixed direction with respect to the distant stars but are instead dragged by the currents of mass-energy such as the rotation of a body, e.g., the rotation of the Earth (the axes of local inertial frames are determined in General Relativity by local test gyroscopes). The worldwide SLR measurements of LARES are coordinated by the International Laser Ranging Service (ILRS). Through the analysis of the SLR data, combined with the ones of LAGEOS (NASA) and LAGEOS-2 (ASI-NASA) satellites, the LARES science mission provided in 2019 a measurement of frame-dragging with an approximately 2% accuracy. Independent analyses performed at INAF-IAPS confirmed and strengthened this result. The LARES data are exploited also for other fundamental physics tests, such as verifying the Weak Equivalence Principle, or uniqueness of free fall, and for space geodesy and Earth science. The LARES science mission is a collaboration between ASI, Centro Fermi Roma, the Universities of Lecce, Roma Sapienza, Maryland, Texas at Austin, Yerevan State, Oxford, and Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences.



The LARES laser relativity satellite fndergoes preparations at Europe's Spaceport in French Guiana. Credit: ESA, S. Corvaja.

lares-2

LARES-2 is an ASI new generation high-altitude laser-ranged satellite to be launched in 2022, aiming at highly accurate measurements for General Relativity and fundamental physics tests and Earth Science.

LARES-2 (LAser Relativity Satellite-2) is an ASI new generation high-altitude laser-ranged satellite to be launched with VEGA C in May 2022 at about 12270 km of altitude. Its main purpose is enable highly accurate tests of General Relativity and fundamental physics, in particular of frame-dragging with an accuracy of approximately 2 parts in one thousand. Frame-dragging has intriguing astrophysical implications for spinning black holes, active galactic nuclei and quasars. The detections of Gravitational Waves by the LIGO-Virgo-KAGRA Collaboration have benefited from computer calculations of the collision of spinning black holes and spinning neutron stars to form a spinning black hole. In such astrophysical processes, frame-dragging plays a key role. LARES-2 is made of high-density material to minimize the non-gravitational orbital perturbations acting on it. An high precision determination of its orbit is achieved thanks to the very precise range measurements provided by the International Laser Ranging Service (ILRS). The satellite is endowed with 303 retroreflectors for laser-ranging, distributed on its surface. The LARES-2 data will also be exploited for other tests and measurements in fundamental physics, space geodesy and Earth science. The LARES-2 science mission is a collaboration between ASI, Centro Fermi Roma, the Universities of Lecce, Roma Sapienza, Maryland, Texas at Austin, Yerevan State, Oxford and Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences.

ACRONYMS

acronyms

ASI - Italian Space Agency

ASI/SSDC - ASI Space Science Data Center

CAS - Chinese Academy of Science

CNES - Centre National d'études Spatiales

CNR/IFAC - CNR Nello Carrara" Institute of Applied Physics

CNR/SPIN - SuPerconducting and other INnovative materials and devices institute

CNSA - China National Space Administration

CSA - Canadian Space Agency

ESA - European Space Agency

INAF - National Institute for Astrophysics

INAF/IASF - INAF Institute for Space Astrophysics and cosmic Physics of Milano

INAF/IAPS - INAF Institute for Space Astrophysics and Planetology

INAF/OAA - INAF Astronomical Observ. of Firenze

INAF/OAB - INAF Astronomical Observ. of Brera

INAF/OACT - INAF Astronomical Observ. of Catania

INAF/OATO - INAF Astronomical Observ. of Torino

INAF/OAPA - INAF Astronomical Observ. of Palermo

INAF/OAPD - INAF Astronomical Observ. of Padova

INAF/OAR - INAF Astronomical Observ. of Roma

INAF/OAS - INAF Astrophysics and Space Science Observatory of Bologna

INAF/OATS - INAF Astronomical Observ. of Trieste

INFN - Italian National Institute for Nuclear Physics

ISS - International Space Station

IWF - Institut für WeltraumForschung

JAXA - Japan Aerospace Exploration Agency

MPS - Max Planck Society

NASA - National Aeronautics and Space Administration

NASA/GSFC - NASA Goddard Space Flight Center

NASA/JPL - NASA Jet Propulsion Laboratory

NASA/MSFC - NASA Marshall Space Flight Center

NSSC - National Space Science Center, CAS

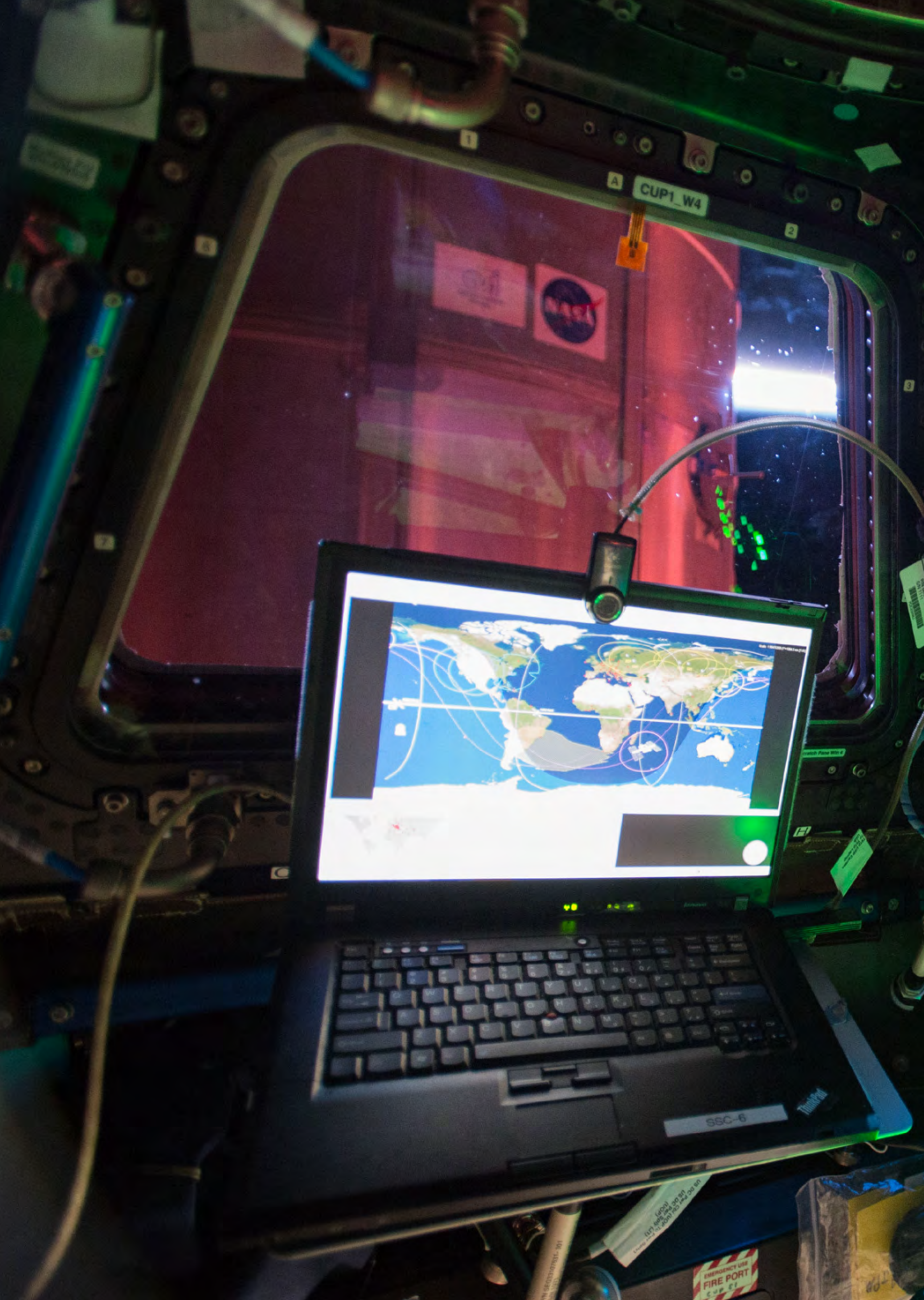
PNRA - National Antarctic Research Program

ROSCOSMOS - Russian State Space Corporation

SRON - Netherlands Institute for Space Research

SSC - Swedish Space Corporation

XACT/OAPA - X-ray Astronomy Calibration and Testing laboratory in INAF/OAPA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SSC-6
ThinkPad
EMERGENCY USE
FIRE PORT

SITOGRAPHY

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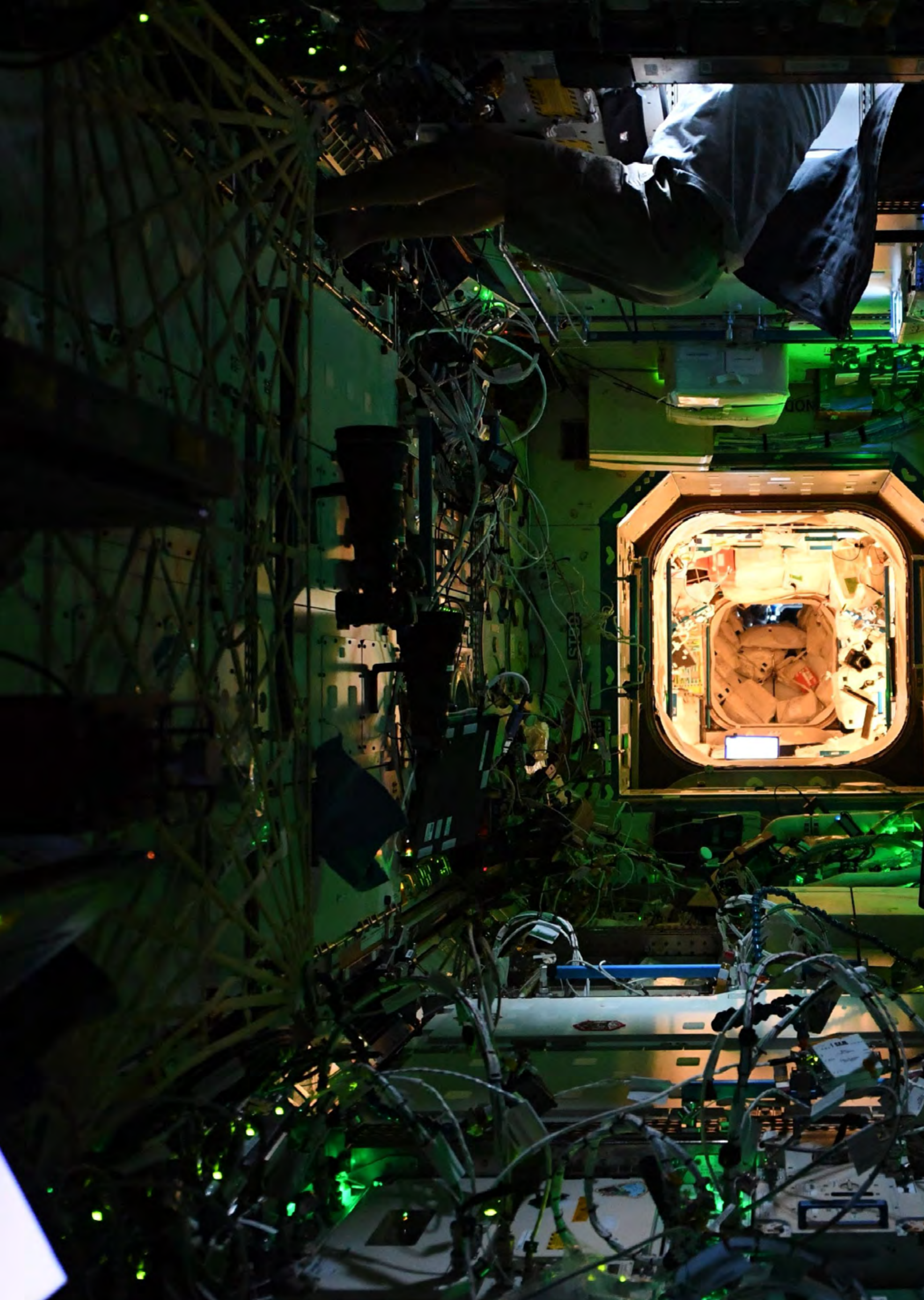

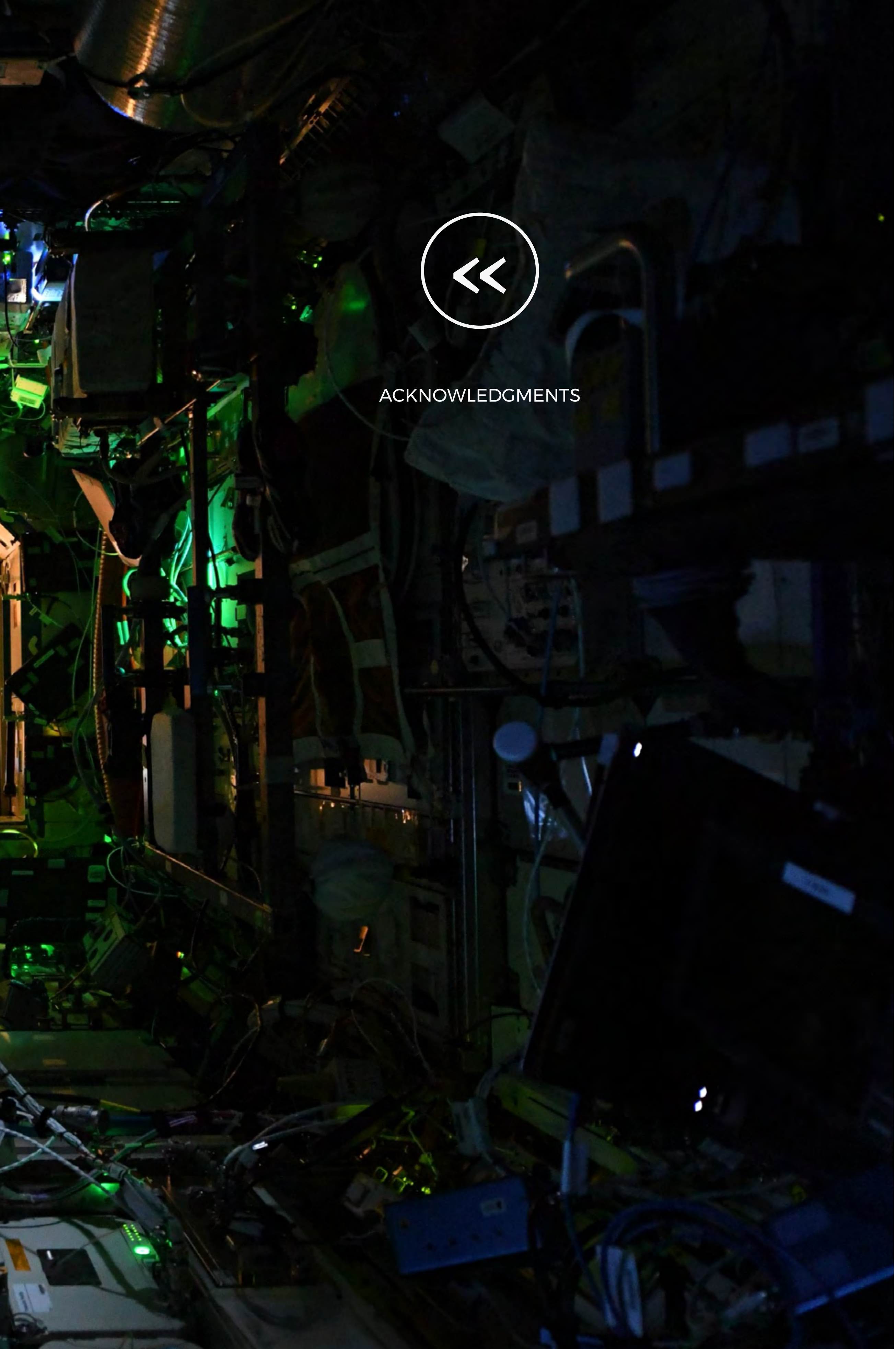

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Italy presents the candidacy
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