italian report

to the 45th
Cospar Scientific Assembly

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editorial

Space is a challenge and an opportunity that Italy has taken very seriously from the beginning of the so-called space race, and that has deep and firm roots. The curiosity-driven search for explaining what is observable above our heads in the sky is, in fact, the core business of the Italian National Institute for Astrophysics. The challenge is always of at least twofold: scientific and technological. The network of INAF researchers and laboratories and several other Italian and international actors, both on the institutional and industrial level, fuel the challenge to discover the nature of several celestial objects.

Our Solar System, a vast and intricate realm, presents a multitude of challenges for exploration. From the massive gaseous planets to the tiniest dust particles, from the optically thickest impenetrable clouds to the ever-changing space weather around the Sun, each element brings its unique sets of physical conditions. Even the underground is not spared, with probes equipped with cameras venturing into the depths of Mars.

With their surface, atmosphere, and exoplanetary architecture still vastly unexplored, the hosted exoplanets of stars within our Galaxy can today be counted in the dozens to a few thousand. Such figures are destined to multiply exponentially, incorporating the most modern technologies into spacecrafts and providing a completely different view of our anthropocentrism.

Today, we can observe the Universe over the entire electromagnetic spectrum or, as we like to say, in multi-wavelengths. This means that we are able to see and study objects that are “invisible” to our eyes. From the feeble radio frequencies up to the violence of the highly energetic X-ray and Gamma ray sources, along with the carriers of information that no longer belong to the descriptions offered by the Maxwell equation (the Gravitational Waves, for example).

All these factors together provide a view of the Universe on a scale comparable to the distance light travels over a period equivalent to the age of the Universe. This perspective will likely change our cosmological understanding of the genesis of everything.

This scientific hunger for knowledge can be accomplished only through highly innovative technological development that, thanks to

the higher demands on the industrial level, provides a powerful tool for technological innovation. The scientific discoveries that are sure to happen (I admit, it's an easy bet!) will likely involve a slower but not less significant challenge, leading to a possible reassessment of our philosophical and conceptual view of the cosmos.
The uniqueness and fragility of our world, and consequently its importance, will likely become more emphasized through observations of how different worlds have evolved, or failed to evolve, into states utterly different from our own. The vastness of space and its structure could change our reasoning and thinking. The reward for a fruitful, internationally collaborative effort to understand the mechanisms behind the intricate mechanism of the universe is so significant that the cost of this research is undoubtedly one of the best investments for humankind.

Roberto Ragazzoni
President of the Italian National Institute for Astrophysics

foreword

The Italian Report to the 45th COSPAR Scientific Assembly to be held in Busan, South Korea, is edited by 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. As for the past edition, this Report summarizes the last two years of space science activity in Italy and has been formulated in a similar condensed form of the previous 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 a 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

This Report aims to provide an overview of the main involvement or commitment of the Italian community to the space programs, mission by mission. We have limited the descriptions of the missions to those that are still ongoing, approved or formally proposed for selection at national and international level, at our best level of knowledge at the publication time of the present edition. The main research programs are

COSPAR Scientific Commissions

Two primary types of scientific bodies 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.

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.
The Italian Government delegates ASI 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, Universities and industries proposing space programs, missions, satellites and observatories in different research fields. When the relevant peer committees approve a program, the mentioned bodies provide staff scientists, engineers, technologists and management on contracts as well as laboratories, facilities and dedicated financial support on the 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 also has a well-consolidated partnership with NASA. In addition, it has a history of ongoing 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 in China in different scientific fields, materialized on 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. For more than six years CSES-01 is successfully monitoring electromagnetic fields and waves, plasma and particles and gamma-ray perturbations of the atmosphere, ionosphere and magnetosphere induced by natural sources and anthropocentric emitters, and to study their correlations with the occurrence of seismic and cosmic events. The second satellite of the constellation is planned to be launched by the end of 2024. A robust national program 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 unprecedentedly sensitive X-Ray Observatory to study the hot and energetic Universe, and LISA, the Gravitational Wave Observatory.
Among the ESA optional program, Italy participates to the ExoMars programs, with the first spacecraft TGO orbiting Mars since 2016 and the second mission, expected for 2028, will bring an European rover to the planet's surface. The rover combines the capability of movement to that of drilling the surface up to 2 meters in depth with the main objective to find evidence of past or present life.
Italy has entered its sixth decade of space scientific exploration: since 1964, with the successful launch of the San Marco 1 satellite, the national scientific and industrial community has continued its path toward space science and exploration building up on the achieved record of success, investing in space programs and cooperation with other Space-Faring nations pushing to the extremes our frontier of knowledge.
Italy also has a relevant participation in 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. Last but not least, the recent participation of the Italian ESA astronaut Samantha Cristoforetti to the mission Minerva as *Leader of the Us orbital Segment* (USOS).

Pietro Ubertini
COSPAR Vice President
Italian N.C. Delegate to COSPAR

a

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

Previous page: The launch from Cape Canaveral just after sunset on 2022 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 First Generation 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 first generation of the COSMO-SkyMed program is based on a constellation of 4 medium-size satellites, each one equipped with a with a multi-mode high-resolution SAR operating in X-band, orbiting in a sun-synchronous orbit at ~620 km height over the Earth's surface, with the capability to change attitude in order to acquire images at both on the right and the left side of the satellite ground track (nominal acquisition is right looking mode). The system consists of particularly flexible and innovative data acquisition and transmission equipment and a dedicated full featured ground infrastructure for managing the constellation and granting ad-hoc services for collection, archiving and distribution of acquired remote sensing data.
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 the 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 sensor 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 or providing "Institutional Awareness" in order to make proper decisions in preventing and managing world-wide crisis. In particular the 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.

They 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 has also the aim to expand strategic partnership at the international level. The new constellation 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 the second satellite was launched 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 led by ASI. It plays a significant role in the 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 totalling 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 can provide detailed information about the chemical composition of materials and objects on the Earth's 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 have an established ongoing 'background' task that will acquire imagery to fill up the entire system's resource 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 of a hyperspectral/panchromatic camera with VNIR (Visible and Near-InfraRed) and SWIR (ShortWave InfraRed) detectors. This imaging spectrometer can 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 a 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/) in 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 2350 users exploiting an archive actually containing 297000 hyperspectral images, acquired all over the world lands. Since the start of the mission operations, many upgrades of the PRISMA mission have been done: 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.

SCIENTIFIC COMMISSION B

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

Previous page: Mercury, as seen
by the joint European-Japanese
BepiColombo mission in June 2022.
Credit: ESA/BepiColombo/MTM

abcs

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

Astrobio cubesat ABCS was successfully launched on 13/07/2022, at 13:17 UTC from ESA's Centre Spatiale Guayanise CSG during the LARES2 launch campaign. ABCS was released at 15:27 UTC at an altitude of 5800 km while the launcher was flying over the Antarctic zone and therefore not in visibility of any ground station. The first signal was received from an amateur radio station in Australia and the satellite confirmed to be in nominal status. On 15/07/2022 the first run of experiments was carried out and on 18/07/2022 the second run was carried out. The last signal beacon was received on 21/07/2022, following which the satellite did not send any more signals. An analysis of the operation of the systems up to the time of the disappearance of the signal indicates the on-board radio as the likely subsystem to have failed. In any case, the estimated nominal operational life was only a few days, due to the presence of an intense radiative environment caused by orbiting through the van Allen belts; in this sense, the mission duration was in line with or even slightly exceeded the estimates. Precisely because of the risk that the mission would last even in the order of a few hours, and considering that the only dedicated ground station had been installed in Rome and the first passage was scheduled to take several hours, a communication strategy was set up involving radio amateurs scattered around the globe in downloading data packets, thanks to an ad hoc developed distributed data download protocol. This strategy, which was the only one possible in light of the mission profile, made it possible to collect and reconstruct all the mission data with the exception of a few packets, although the process took much longer. The subsequent analysis of the data and telemetry, which took place over the following months, revealed that the experiments on the 6 channels were repeated twice. All the main elements of the demonstrator functioned nominally, but in 5 out of 6 circuits the experiments were not completed; this is presumably attributable to a malfunction of the pumps, similar to a problem that had already manifested itself during the ground tests and was believed to have been resolved but instead probably reoccurred in orbit. Bearing in mind that ABCS was conceived as an initial flight test. Following the failure analysis conducted despite the fact that it was not possible to obtain scientific data on the astrobiology experiment due to an anomaly in the communication software and the anomaly in the physical properties of the tubes used interfaced with the pumps, it is considered essential to consider the benefits obtained from this world's first-ever opportunity for a lab-on-chip microfluidics experiment in space. Several lessons were learnt that are being put to use in further activities. The ABCS mission can be considered positive overall. The experience gained was significant and will limit potential failures and setbacks in future similar programs.

ariel

Adopted as ESA M4 mission to be launched in 2029, 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 2029, 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 aluminium, 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.

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 on December 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 two different orbits around Mercury at the end of 2025. The main scientific objectives are related to the surface geology 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's 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; it is composed of a stereo camera, a high resolution camera and a hyperspectral Vis-NIR imager, and will provide 50% of the data volume of the entire mission through images and spectra of the entire surface of Mercury, even in 3D.

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.

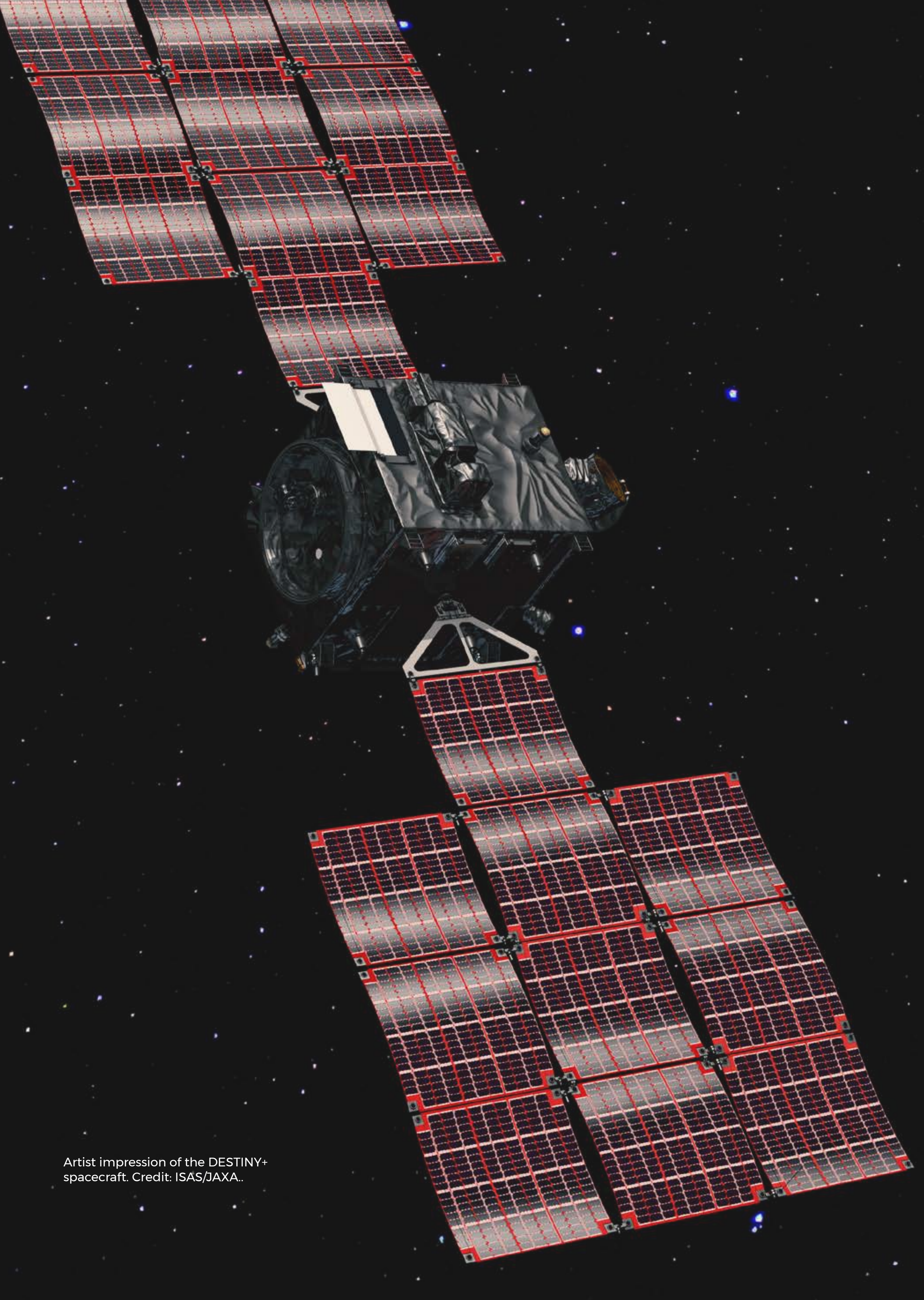
CHEOPS (CHaracterising ExOPlanet Satellite) is mainly dedicated to determining the internal structure of small-size transiting planets by means of ultrahigh precision photometry of their parent stars. It is the first small mission in ESA Cosmic Vision 2015-25 program. Launched in 2019, with its extremely precise measurements Cheops is contributing to several key discoveries in the field of exoplanets. Among them we highlight: i) the discovery of 3 new planets of TOI-178, a star slightly cooler than the Sun orbited by 6 planets. Cheops data made it possible to understand that the 5 outermost planets are in orbital resonance with each other: when a planet completes a certain number of orbits, another planet in the system completes a different number of orbits. ii) the characterisation of the shape of WASP-103b; by closely monitoring how the luminosity changes during the transit of the planet in front of the star, scientists from the CHEOPS team have observed that the planet is shaped like a rugby ball, a deformation due to the intense gravitational pull of the star. iii) the discovery of Ltt9779 b an ultra-hot planet with a mass similar to Neptun but orbiting in less than a day around a solar-like star. Reflective clouds of metal cover Ltt9779 b, and this makes it the shiniest exoplanet ever found. The puzzling aspect about Ltt9779 b is that our models predict that planets like this one cannot stay so close to their star, simply because the evaporation of their atmosphere due to the strong stellar irradiation should shrink them to rocky small size planets. Ltt9779 b is a perfect target for follow-up observation by JWST and HST. CHEOPS is providing a great amount of targets to the future ground (e.g. E-ELT) and space-based (e.g. JWST, Ariel) facilities, that will be used to characterize the exoplanet atmospheres.

CHEOPS is a joint ESA-Switzerland mission, with important contributions from Italy and other ESA member states. Funded by ASI, the Italian contribution to the payload 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 the 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. Cheops completed the nominal phase in September 2023 and has entered the extension phase, approved by the ESA SPC to 2026 with indicative extension to 2029, contingent upon ongoing commitments from national contributors and partners.

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.

Comet Interceptor ESSA mission dedicated to the exploration of a little-processed long-period comet, possibly entering the inner Solar System for the first time, or to encounter an interstellar object originating at another star. The objectives of the mission are to address the following main questions: (1) What are the Nucleus surface composition, shape, morphology, and structure of the target comet? (2) What is the composition of the gas and dust in the coma, its connection to the nucleus, and the nature of its interaction with the solar wind? The mission was proposed to the European Space Agency in 2018, and formally adopted by the agency in June 2022, for launch in 2029 together with the Ariel mission.
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, The mission can take advantage of this placement to wait for the discovery of a suitable comet reachable with its minimum ΔV capability of 600 ms−1. Comet Interceptor will encounter the target at a nominal closest approach distance of 1000 km. The target will be a comet that represents a near-pristine sample of material from the formation of the Solar System. It will also add a capability that no previous cometary mission has had, which is to deploy two sub-probes – B1, provided by the Japanese space agency, JAXA, and B2 – that will follow different trajectories through the coma. While the main probe passes at a nominal 1000 km distance, probes B1 and B2 will follow different trajectories through the coma at lower distances. This multi-point measurements configuration will provide unprecedented 3D information on the target, in support to spacecraft operations safe planning, numerical simulation of the dusty-gas environment of a possible target object is 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 a 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). The scientific teams of the two instruments are composed by people from different Italian research institutes including INAF (OACN, OATS, IAPS), CNR-IFN, University of Napoli "Parthenope".



Artist impression of the DESTINY+ spacecraft. Credit: ISAS/JAXA..

destiny⁺

2025 DESTINY⁺, an ISAS/JAXA mission. it is a science and technology demonstration mission to asteroid (3200) Phaethon, the parent body of the Geminids meteor shower.

DESTINY⁺ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) will explore the (3200) Phaethon asteroid during a flyby, and conduct scientific observations of cosmic dust, which is considered to be a source of the organic matter on Earth. This mission will demonstrate technologies that will enable future low-cost and high-frequency deep space exploration.
In-situ analysis of interplanetary and interstellar dust using the dust analyser (DESTINY⁺ Dust Analyzer (DDA)), developed under the leadership of the University of Stuttgart and supported by DLR (Deutsches Zentrum für Luft- und Raumfahrt), will be carried out during the interplanetary space till reaching the target asteroid Phaethon, as well as during the flyby of the asteroid. It will investigate the composition, mass, velocity, and direction of arrival of the dust from Phaethon. Phaethon's flyby survey will be conducted at speeds over 33 km/s with two cameras that will image the surface.

The group of INAF/IAPS is participating in the DDA team and is working on Phaethon surface thermal processing due to the very close passages from the Sun during the perihelion. These types of processes are reproduced in the laboratory by well calibrated heating cycles on carbonaceous chondrite meteorites. The release of refractory dust fragments produced as a consequence of dehydration and decomposition of phyllosilicates during thermal processes, are investigated by observing samples at SEM and XPS. This mechanism could be at the origin of the dust tails generated by Phaethon and, possibly, of the Geminid meteoroids. This project is supported by INAF.

ema

Artist's impression of the asteroid belt.

The Emirates mission is dedicated to the exploration of the main asteroid belt, with launch expected in 2028.

The Emirates Mission to the Asteroid Belt (EMA, previously known as MAX) is scheduled to launch in 2028 to explore seven primordial and water-rich asteroids. Thanks to its solar electric propulsion, the spacecraft will travel more than five billion kilometers and perform gravity-assist manoeuvres around Venus, Earth, and Mars throughout a seven-year-long cruise. The spacecraft is targeting six asteroids which will be observed during flybys: 10253 Westerwald, and 623 Chimaera in 2030; 13294 Rockox in 2031; 88055, and 23871 in 2032; and 59980 in 2033, before entering in orbit around 269 Justitia in 2034, one of the few main belt objects showing an extreme red spectral color on telescopic observations from Earth. This evidence makes 269 Justitia similar to other red-colored objects orbiting the outer Solar System among trans-Neptunian objects (TNOs) and Centaurs. The red color and low visible albedo are strong indicators of the presence of complex organic matter and hydrated minerals on its surface. A lander will be released on 269 Justitia's surface at the end of the mission to demonstrate future exploitation of resources.

The UAE government has promoted the EMA mission with the scope of inspiring new Emirati graduates to be trained in this field, establishing deep space mission ground control centers, and opening the field of

space technology to private Emirati enterprises. The EMA spacecraft, called MBR Explorer, will weigh about 2,300 kilograms at launch and will be designed, assembled, and tested at the University of Colorado's Laboratory for Atmospheric and Space Physics as "knowledge partner" of the UAE Space Agency.

The mission scientific payload consists of four remote sensing instruments provided by the US and Italy. These were selected to infer the morphology, composition, and thermal properties of the asteroids at different spatial scales.

The Italian contribution to the EMA mission is the MWIR Imaging Spectrometer for Target-Asteroids (MIST-A), an instrument designed to acquire hyperspectral images of the seven asteroids and characterize their composition and thermal properties. MIST-A is designed to operate in the 2-5 μm spectral range where it can identify and map the distribution of various classes of relevant compounds for primitive targets, such as aromatic and aliphatic organics, carbonates, phyllosilicates, ammonium salts, and water ice. Moreover, the instrument is capable to measure the surface thermal emission longward of 3 μm from which diurnal temperature can be inferred. The imaging capabilities of MIST-A will permit to reach spatial resolution better than 20 m/px at 269 Justitia.

The MIST-A science and operations responsibility are in INAF/IAPS, Rome. The Italian Space Agency (ASI) is managing the program as the leading funding agency. Leonardo S.p.A. (Campi Bisenzio, Florence) is the prime industrial contractor.

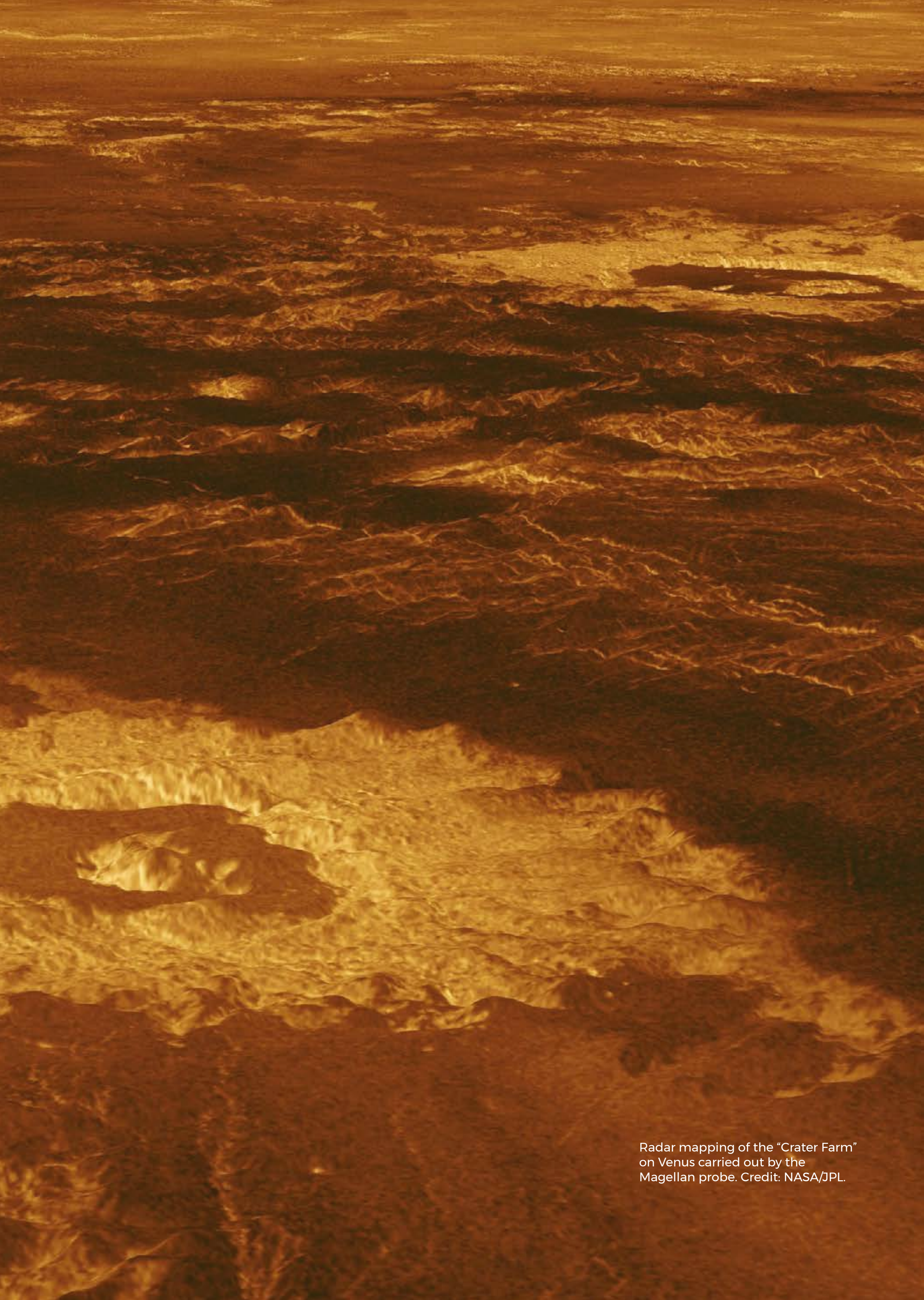
envision

EnVision is ESA's next Venus orbiter with launch scheduled in 2031, aimed at providing a holistic view of the planet from its inner core to the upper atmosphere to determine how and why have Venus and Earth evolved so differently. Italy's contribution is to the Subsurface Radar Sounder.

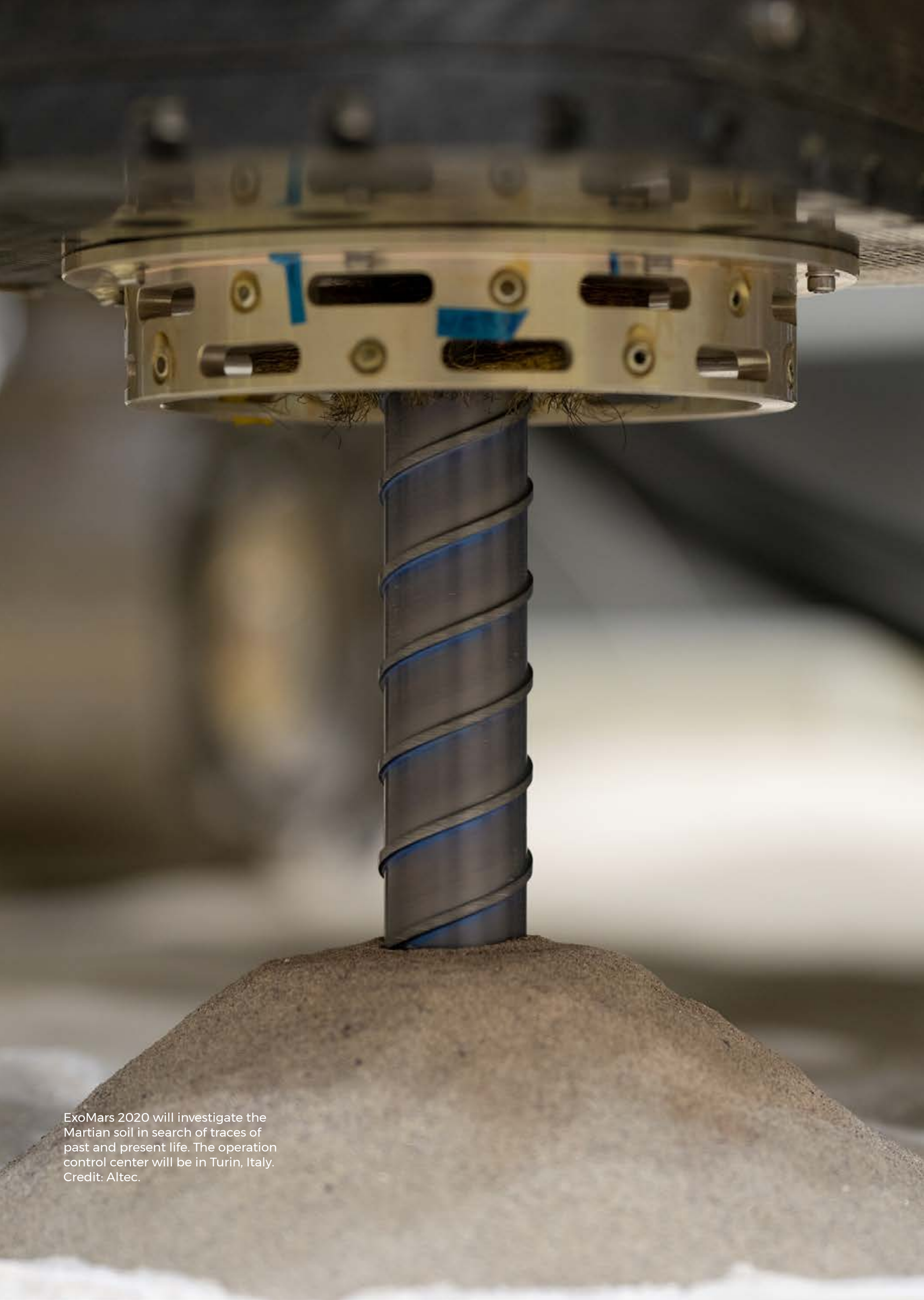
EnVision has been selected as the fifth Medium-class mission (M5) in ESA's Cosmic vision 2015-2025 program and is planned for launch in November 2031, with arrival at Venus after an 18-month cruise. Following orbit insertion, orbit circularization will be achieved by aerobraking over a period of about 16 months, followed by a nominal science phase of 4 Earth years.

The Envision payload consists of a suite of five instruments: (1) VenSAR, a reflect array, dual polarization S-band Synthetic Aperture Radar, to provide surface images at spatial resolutions of 10 m to 30 m, altimetry, dual polarimetry and radiometry; (2) Subsurface Sounding Radar (SRS), to profile the subsurface for hundreds of meters in 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) History - how have the surface and interior of Venus evolved? (2) Activity - how geologically active is Venus? (3) Climate - 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 will support the 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. A goal of the mission is to use the sounder also for detecting lightning.



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



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.

exomars

ExoMars consists of two missions to Mars: the orbiter (TGO) is collecting data from Mars and the Rosalink Franklin rover that is planned for launch in 2028.

ExoMars is an ESA programme. Divided into 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 2028, will bring a European rover to the surface of Mars. The rover combines the capability of movement whit 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 Italian instrument is Ma_MISS (INAF), a spectrometer inside the rover's drill (also an Italian development), 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.

hayabusa2

2014 HAYABUSA2 is a JAXA mission which collected on 2019 fragments of the primitive carbon rich asteroid Ryugu and returned them to Earth in 2020.

Hayabusa2 is a Japanese Space Agency (JAXA) mission designed to rendezvous with asteroid 162173 Ryugu and return a sample. The mission is similar in design to the first Hayabusa mission, but this carried an impactor which has been used to create a crater and expose fresh material that have been collected and returned to Earth for analysis. The mission was launched on 3 December 2014, arrived at Ryugu on June 27, 2018, collected samples from the asteroid during two touchdowns in 2019, and delivered the sample capsule back to the Earth on December 6, 2020. After delivering the capsule, the spacecraft continued on to a new mission. This new phase is referred to as the "Extended Mission", with as new target destination the small asteroid 1998 KY26.

This is a long-term mission whose duration exceeds 10 years, over which there is an itinerary of events followed by the rendezvous with the rapidly rotating 1998 KY26.

Hayabusa2 examined asteroid (162173) Ryugu, which is a type C asteroid and it is believed that the composition of such asteroids still includes organic matter and water from when the Solar System was forming, roughly 4.6 billion years ago. The second goal of the Hayabusa2 mission is to investigate questions regarding the origin of the Earth's water and where the organic matter that forms life originally came from. Another aspect of the mission is to examine how the planets formed through the collision, destruction, and combination of planetesimals, which are thought to have been formed early in the Solar System.

INAF/IAPS is leading this program and it will analyse NIRS3 (Near-Infrared Spectrometer) and ONC (Optical Navigation Camera) data to understand possible latitudinal compositional differentiation making comparison with laboratory measurements of asteroid analogues with the support of the University of Florence. In preparation of the extended mission, INAF/OAR have planned telescopic observations to characterize the Hayabusa 2 targets , 2001 CC21 and 1998 KY26 as well as those of other similar near-Earth asteroids.

As a side project, INAF/IAPS has been selected to obtain some Ryugu returned grains to perform analysis with the objective to understand the role of space weathering in changing chemistry/mineralogy and morphology of the grains. This program is supported both by INAF and by the Italian Space Agency.

hera

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

Hera, named after the Greek goddess of marriage, is a mission in development within the ESA Space Safety Program, due to launch in October 2024, will arrive at the Near-Earth Asteroid (65803) Didymos binary system around late 2026. Hera payloads consist of two AFCs (Asteroid Framing Cameras), PALT (Planetary ALTimeter), TIRI (Thermal Infrared Instrument) contributed by JAXA, HyperScout (VIS+NIR hyperspectral imager) and two 6U CubeSats: Juventas, developed by GomSpace Luxembourg; and Milani, developed by Tyvak International in Italy. They will be the first CubeSats to orbit in close proximity to a small celestial body and to perform scientific and technological operations around a binary asteroid. A Radio Science Experiment (RSE), led by the University of Bologna, will contribute to the determination of the binary system's mass, gravity field and rotational state and orbits. On Sept. 26 2022, the NASA's DART (Double Asteroid Redirection Test) spacecraft impacted Dimorphos, the 160m diameter moon of the Didymos, at a speed of 6.6 km/s, changing its orbital period. One of Hera's main objectives is the validation of the kinetic impactor as a planetary defense technology against potentially dangerous Near-Earth Objects (NEOs). In this context, Hera will provide a detailed analysis of the Didymos binary system in the post-impact phase, characterizing the evolution of the orbital parameters of the two asteroids as a consequence of the impact. During the six months of the mission, the main spacecraft and its two CubeSats will conduct detailed surveys of both asteroids allowing the characterization of the mass, dimensions, and morphology of Didymos and Dimorphos, the determination of the superficial and sub-superficial properties of the asteroids and the characterization of the impact crater and the materials ejected during the impact. The data collected by the mission will provide unique information for the validation and improvement of numerical models and evolutionary theories.

The main Italian scientific contribution to the Hera mission will come from INAF. In particular, INAF-IAPS will identify calibration and data analysis methods of the VISTA payload, through laboratory analysis of Didymos analogues samples, and they will also support the calibration and analysis pipeline of both the ASPECT and the TIRI data. Furthermore, they will obtain spectroscopic and photometric observation of the asteroids. INAF-OAPD and the University of Padova main contribute is the characterization of surface geomorphology and mechanical properties of the asteroids, and also to support the definition of observing strategies of the high-resolution cameras (Asteroid Framing Camera, AFC) and the Hyperscout spectrometer on board the mother probe. INAF-OAR will study the dynamics and the physical properties of the dust ejecta after the impact and the analysis of up-close data of DART. Other Italian members of the Hera investigation Team are scientists from the Universities of Bologna, Pisa, Napoli (Parthenope), Firenze, INFN and CNR.

This project is supported by The Italian Space Agency.

juice

JUICE is an ESA mission launched on April 14 2023, to explore the Jupiter system and the icy 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 was launched on April 14 2023, with arrival at Jupiter in July 2031. The total mission duration is close to 12 years and with the current plan 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 icy moons of Jupiter 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 focus on investigating its structure, dynamics, and composition. The focus on the Jovian magnetosphere will include an investigation of the three-dimensional properties of the magnetodisc and an in-depth study of the coupling processes within the magnetosphere, ionosphere, and thermosphere. Within 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, including cameras and spectrometers, a laser altimeter, an ice-penetrating radar, a magnetometer, plasma and particle monitors, and 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. ASI funds the Italian contribution 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 is at INAF-IAPS (for JANUS and MAJIS), University of Trento (for RIME), and University of Rome La Sapienza (for 3GM).

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 witness the DART impact of 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, DART impacted Dimorphos, the 160m-sized secondary member of the binary asteroid (65803) Didymos, on 26th September 2022 , at a distance of more than 12 million km from Earth, and changed its orbital period around Didymos of about 33 minutes.

LICIACube was released fifteen days before DART's impact and performed orbital manoeuvres to fly-by the binary system at about 58 km. The more than 420 images of the effects of the DART impact, collected over a span of times and phase angles, allowed to obtain an accurate investigation of the asteroids' nature. To accomplish its tasks LICIACube was equipped with two optical cameras: LEIA (Liciacube Explorer Imaging for Asteroid), a panchromatic 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.

LICIACube is an Italian Space Agency (ASI) mission, developed in collaboration with Argotec (an Italian aerospace company based in Turin) which designed, manufactured, integrated, and tested the microsatellite.

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 the University of Bologna, for orbit determination and satellite navigation, and the Politecnico di Milano, for mission analysis and guidance and optimization.

The mission Ground Segment, with data archiving and processing, was managed by the Argotec Mission Control Center (MCC) and the ASI Space Science Data Center (SSDC). The acquired images were 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.
The mission is still considered as a relay for deep space activities.

milani

Milani is a CubeSat developed by Tyvak International, on board the Hera spacecraft and devoted to the visual and spectral inspection and dust detection of Didymos asteroids following DART impact.

Hera will be launched in October 2024 and will arrive at Didymos binary asteroid in late 2026. Hera will deploy two CubeSats, Juventas and Milani, in the proximity of the binary system to enhance the scientific return of the mission. Milani is a 6U CubeSat created for the European Space Agency by Tyvak International in Torino, together with a consortium of partner companies, universities, and research institutes from Italy, Finland, and the Czech Republic. Milani was named after the Italian mathematician and astronomer Andrea Milani, a leading figure in Europe's space science community, and a pioneer of asteroid risk analysis. After its deployment, Milani will carry independent detailed characterization of Didymos asteroids at distances ranging from 5 to 10 km supporting Hera observations. Milani mission objectives are i) Map the global composition of the Didymos asteroids, ii) Characterize the surface of the Didymos asteroids, iii) Evaluate DART impacts effects on Didymos asteroids and support gravity field determination, iv) Characterize dust clouds around the Didymos asteroids.
The scientific payloads on board of Milani are ASPECT, a visible - near-infrared imaging spectrometer, a Navigation Camera, and VISTA, a micro-thermogravimeter that will study the dust environment around the Didymos system after DART impact. The Navigation Camera, delevoped by Tyvak and PoliMi, will allow the shape reconstruction of Didymos and Dimorphos, their surface characterization and the evaluation of DART impact effects. The heart of the VISTA is a piezoelectric crystal microbalance capable of detecting and characterizing organic compounds and volatiles of astrobiological interest, by means of Thermo-Gravimetric Analysis (TGA). VISTA will accomplish the following scientific goals: 1) detect the presence of dust particles smaller than 5-10 μm; 2) volatiles (e.g., water) and light organics characterization (e.g., carboxylic acids with low carbon chain); 3) contamination monitoring in support of other instruments (e.g., ASPECT Spectrometer). The instrument has been developed by an entirely Italian Consortium composed by INAF-IAPS (Prime), CNR-IIA and Politecnico di Milano, which has a strong heritage in the design, development and testing of microbalance-based instrumentation for space and laboratory applications. In addition, two miniature laser retroreflectors are onboard Milani, to be observed by Hera's LIDAR, developed by INFN.

m-matisse

The M-MATISSE mission is an ESA Medium class (M7) candidate currently in Phase A study. It is dedicated to study the Magnetosphere-Ionosphere-Thermosphere (MIT) coupling, which results from the interaction between Mars and solar wind.

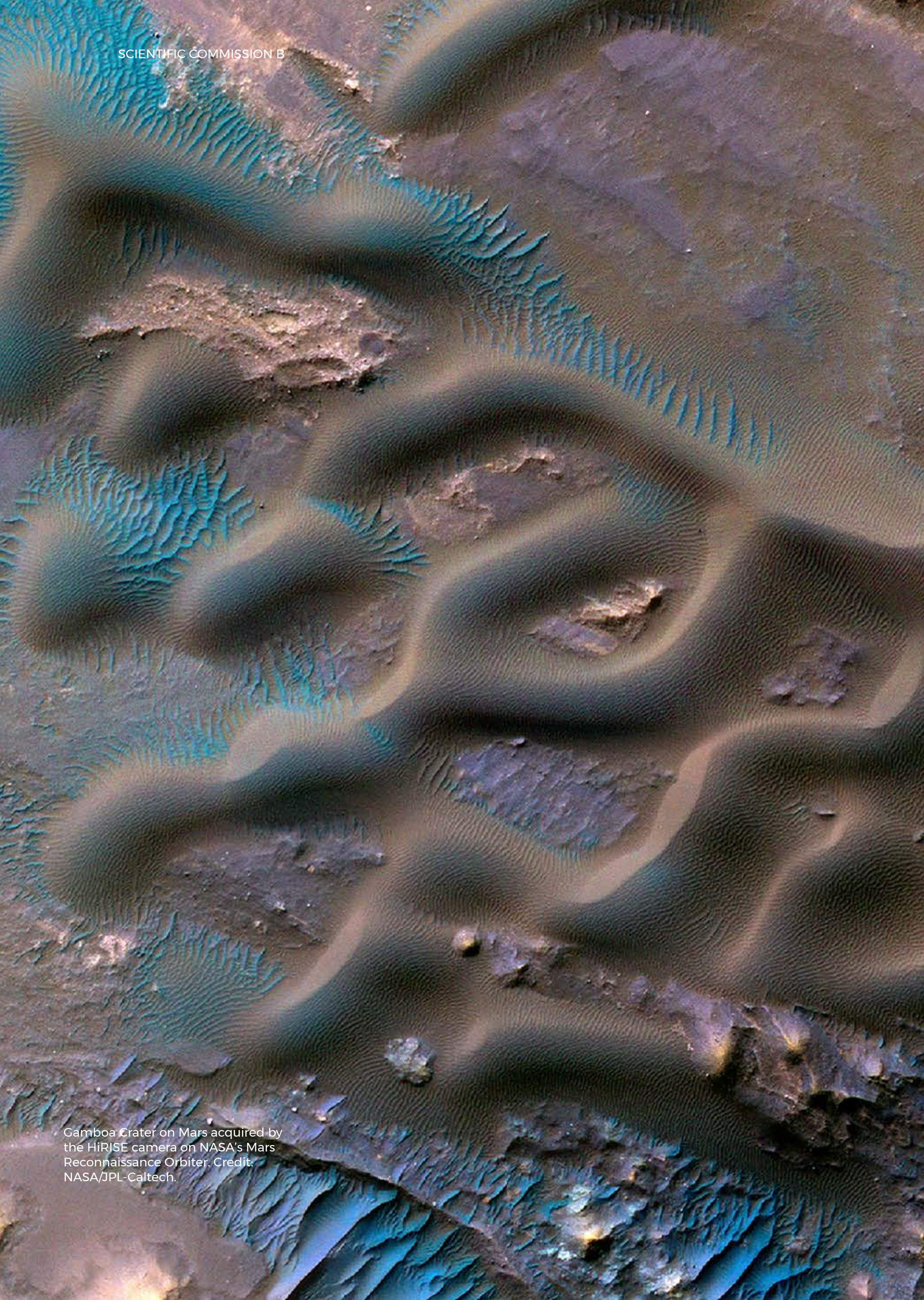
The Mars Magnetosphere ATmosphere Ionosphere and Space-weather SciencE (M-MATISSE) will exploit simultaneous observations from two orbiters, carrying an identical set of instruments. The fathership, also called Henri, has a periapsis of ~250 km and an apoapsis of ~3000 km with an inclination of 60°, mainly dedicated to study the Martian plasma system. The daughtership, also called Marguerite, also has an inclination of 60°, a periapsis of ~250 km and an apoapsis of ~10,000 km, and it is intended to spend most of its time in the solar wind and/or far tail of Mars.

The particular mission profile will allow us to identify the physical processes that govern the dynamics of the MIT system. This represents a focal point to understand the evolution of Mars' atmosphere and climate, as well as the radiative environment, and it is essential to prevent hazardous situations for spacecraft and humans and for accurate Space Weather forecast.

Being equipped with 6 scientific instruments, the payload also includes the Mars Ensemble of Particle Instruments (M-EPI) which is a set of three particle sensors, such as the Mars Electron Analyser System (EAS), the Mars-Ion and Neutral Energy Analyser (M-INEA), and the Solar Particle at Mars (SP@M), combined in a single unit with a common Data Processing Unit (M-EPI DPU), the only interface with the spacecraft.

M-EPI will characterise the Martian particle environment at different energies, with particular reference to atmospheric neutral particles, ionospheric ions, electrons and negative ions, magnetospheric ions and electrons, solar wind ions and electrons, and solar energetic particles.

M-EPI has an Italian Co-PIship and the PIship (INAF) of the M-EPI DPU. The latter will be provided by Italy with the ASI support. Italy is also involved as Deputy PI of the M-EPI DPU, and also with several co-Is of the M-EPI DPU and co-Is of M-INEA (INAF).



Gamboa 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 is 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

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

The NASA OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security - Regolith Explorer) spacecraft launched from Cape Canaveral on September 8, 2016, and reached near-Earth asteroid Bennu in 2018. The mission team mapped the asteroid's global, chemical, and mineralogical properties, characterized the regolith at the sampling area, and measured the Yarkovsky effect - a thermal force affecting asteroids' orbits, particularly those posing a threat to Earth.

In October 2020, the spacecraft collected samples from Bennu's surface, with the goal of returning at least 60 grams of asteroid samples for analysis in advanced laboratories worldwide. It delivered a sample from the primitive carbon-rich asteroid Bennu to Earth on September 24, 2023.

The mission returned 121.6 grams of pristine carbonaceous asteroid regolith, now curated at Johnson Space Center. Furthermore, through sample analysis the OSIRIS-REx team seeks to characterize a carbon-rich primitive asteroid for comparison with others, and analyze its regolith to study its mineral and organic composition, providing insights into these materials' nature and distribution.

After the delivery of the sample to the Earth, the OSIRIS-REx mission was renamed OSIRIS-APEX (OSIRIS-APophis EXplorer). The spacecraft was redirected to the stony asteroid Apophis. Scientists will study the near-Earth asteroid Apophis for 18 months after the asteroid's close approach to Earth on April 13, 2029.

Regolith is dispersed as the OSIRIS-REx spacecraft attempts to take a sample of the surface of asteroid Bennu.Credit: NASA.

plato

PLATO will catalog transiting planets of close stars, including earth like planets, providing measurements with unprecedented accuracy of planetary density and age.

PLATO (PLAnet Transit and stellar Oscillations), to be launched in 2026 by ESA, 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. The main purpose is the search for exoplanets, including rocky Earths and SuperEarths, and obtain seismic measurements 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 handling 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 that spread throughout Italy.

prospect

The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is an ESA/NASA mission to study Moon resources whose launch is planned in 2026.

The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is a package to access and assess potential resources on the Moon and prepare technologies that may be used to extract these resources in the future. PROSPECT's drill (ProSEED) will drill beneath the surface in the South Pole region of the Moon and extract samples, expected to contain water ice and other trapped chemicals. Samples taken by the drill will then be passed to a chemical laboratory (ProSPA) where they will be heated to extract these cold-trapped volatiles.
The Italian scientific community (INAF and Politecnico di Milano) is part of the Science team, evaluating the performances and defining the operations. Moreover, the team is involved in the selection of the landing site and its characterization in terms of geology and thermophysical properties. Prospect will be onboard of the lunar mission CLPS-22.

tianwen2

Tianwen-2 is a Chinese asteroid sample return and comet exploration mission (target for sample return mission is the asteroid Kamo'oalewa), planned for launch in 2025.

Tianwen-2 is scheduled to be launched in May 2025. It will use solar electric propulsion to explore the co-orbital near-Earth asteroid 469219 Kamo'oalewa and the main-belt comet 311P/PANSTARRS. The spacecraft will rendezvous with Kamo'oalewa and conduct remote sensing observations in orbit, before landing on the asteroid to collect a sample of regolith.
Tianwen-2 will then return to Earth to drop off a return capsule containing the sample and conduct a gravity assist manoeuvre to propel the spacecraft toward 311P/PANSTARRS. Remote sensing and in-situ measurements will be conducted at 311P/PANSTARRS. The spacecraft will host several types of instruments, including wide/narrow angle multispectral and color cameras, a thermal emission spectrometer, a visible/near-infrared imaging spectrometer, a detection radar, a mass spectrometer, a charged/neutral particle and dust analyzer, a magnetometer and an Ejecta Analyzer.
The Italian contribution to TianWen2 is the DIANA (Dust In-situ ANAlyzer) microbalance system, that is located inside the Ejecta Analyzer payload. DIANA consists of two sensor heads (SH1 and SH2) and the related Proximity Electronics (PE). The developed sensor heads are based on a new concept of microbalances, maximizing quartz piezoelectric properties and adapting thermo-mechanical structure consequently. The interface between DIANA and the Main Electronics of the Ejecta Analyzer will be obtained through a collaboration between INAF and the Shanghai Institute of Technical Physics (SITP), Chinese Academy of Science.
While DIANA-SH1 is a microbalance sensor designed to measure the dust flux and the abundance of low-volatility compounds in the dust, DIANA-SH2 has the objective of characterizing cometary dust through Thermo-Gravimetric Analysis (TGA) up to high temperatures (up to 230°C) in order to detect organics.
The Italian consortium leaded by INAF/IAPS includes CNR and Politecnico di Milano is part of the Tianwen-2 Team and responsible for the DIANA instrument on board the Ejecta Analyzer. This project is supported by The Italian Space Agency.

C

SCIENTIFIC COMMISSION C

Space Studies of the Upper Atmospheres of the Earth and Planets Including Reference Atmospheres

Previous page: The Jupiter’s southern hemisphere view captured by the JunoCam imager aboard Juno spacecraft. Credit: NASA/JPL-Caltech/SwRI/MSSSImage.

cses

CSES (China Seismo-Electromagnetic Satellites) is a constellation programme by CNSA and ASI that cooperate for instrument development, calibration and data analysis. The satellites, 3-axis attitude stabilized, are based on the Chinese CAST2000 platform designed to operate in a 98° Sun-synchronous circular orbit at an altitude of 500 km. CSES-01 has been successfully launched from Jiuquan Satellite Launch Center on February 2, 2018, and its expected lifetime is more than 6 years at least, while the launch of CSES-02 is foreseen for December 2024.

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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). For the CSES-02 payload, the HEPP has been replaced by the Coherent Population Trap (CPT). The other instruments have been confirmed even if in updated versions.
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 nature, 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 variations are other relevant topics that can be covered by the mission as well.
Italy participates in several universities and research institutes. INAF and INFN are directly involved in instrumental development and test respectively. The INFN, with its branches of Bologna, Napoli, Torino, Roma Tor Vergata, the TIFPA-Trento center and the National Laboratories in Frascati, are the main partner of the ASI in its cooperation with the CNSA.
The INAF-IAPS of Rome, the Universities of Bologna, Roma Tor Vergata, Trento, the IFAC/CNR and the National Institute

of Geophysics and Volcanology (INGV) are also involved, with their 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, detect 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 have 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 the upper stratosphere (altitude >30km). Dust particles are collected and analyzed in the laboratory by state of the art analytical techniques for a physico-chemical characterization and disentanglement of the terrestrial and extra-terrestrial components.
DUSTER results are related to 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 currently sample the upper stratosphere. DUSTER provides a record of the amount of solid aerosols, their size distribution, shapes and chemical properties in the upper stratosphere, for particles down to about 0.5 micron in size. Two fully successful DUSTER flights were performed from the Stratospheric Base in Svalbard Islands, Norway in June 2008 and July 2009, supported by ASI and a third flight was performed in 2011 from Kiruna, Sweden, thanks to CNES. The 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's 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 ongoing. The whole collection of these 2 flights will be analyzed in the frame of a new research program funded by the Italian Ministry of Instruction, Research and University with the aim to understand the composition of the dust complex in the inner Solar System (the zodiacal cloud) through the integration of the micrometeorite and IDP collected by DUSTER. 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 manpower contribution is assured by INAF-OACN and Parthenope University Naples.

juno

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

Juno is a NASA New Frontiers mission devoted to an in-depth study of Jupiter, launched in 2011. 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's 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 recently been extended to mid-2025. The current mission profile includes ~70 elliptical orbits lasting between ~30 to ~50 days each. The passages above the planet are at an altitude of about 5000-8000 km; as of February 2024, 58 orbits were performed. Currently in its extended mission phase, Juno is focusing its investigations on the Galilean moons of Jupiter, and to Io in particular. A couple of close fly-bys of Io have been performed at the very beginning of 2024. 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.

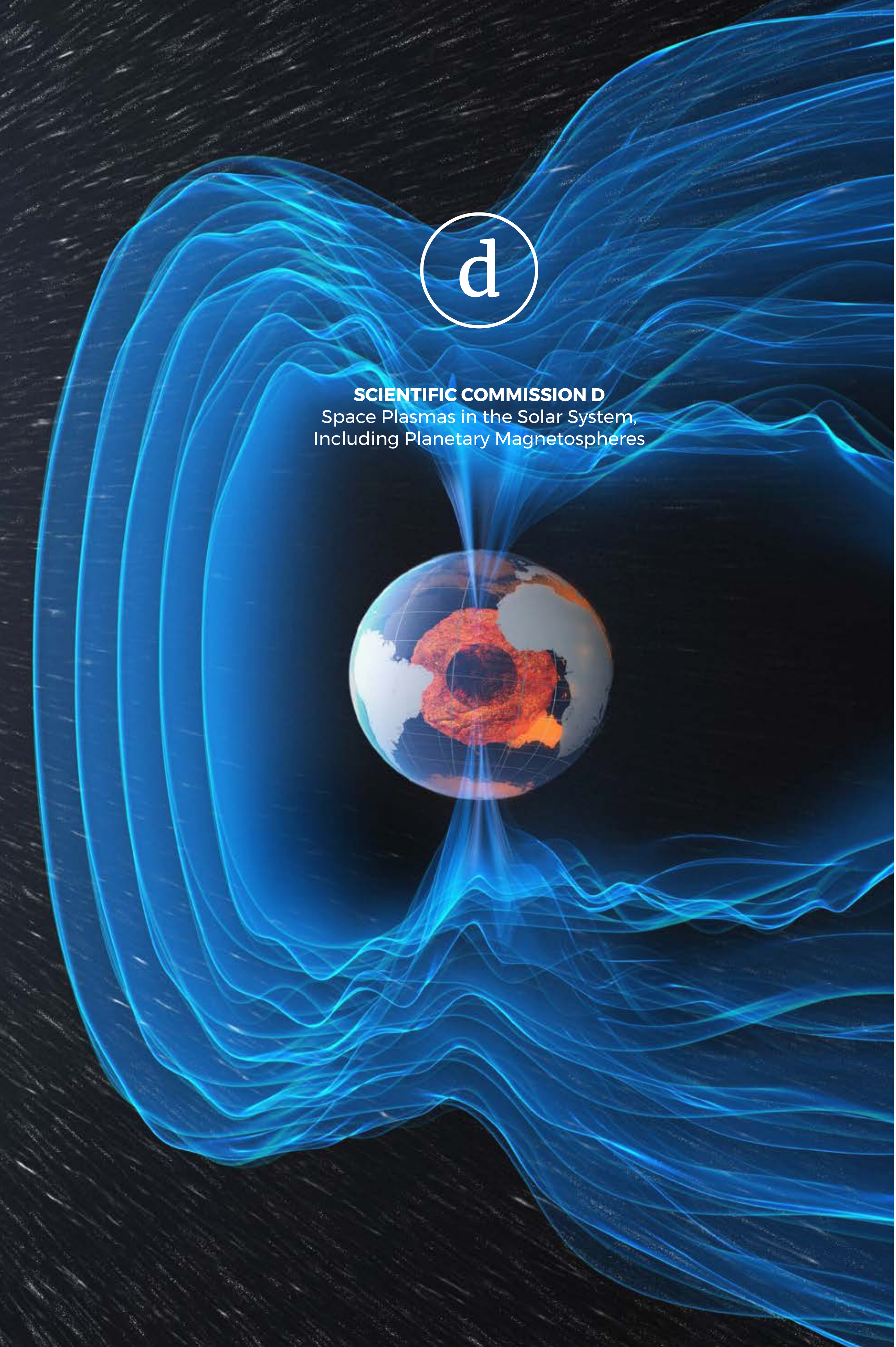
Italy participates in Juno with two scientific instruments: the KaT (Ka band Transponder) and JIRAM (Jovian InfraRed Auroral Mapper). The radio science Ka-band frequency translator KaT is the core element of the gravity experiment on Juno for mapping the planet's gravitational field. It was developed 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 applying all calibrations. 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 its 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 5m 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 the generation of the operating sequences of remote controls, to the collection and calibration of data up to the delivery (as foreseen for the mission) to the “Planetary Atmospheric Node” of NASA’s “Planetary Data System”.

plasma observatory

Plasma Observatory will unveil plasma energization and energy transport in the near-Earth plasma environment through the first multiscale observations in the Eart's Magnetospheric System.

Plasma Observatory is one of the three ESA M7 candidate missions undergoing the competitive Phase A study with the final selection in 2026. Coupling across large, fluid and small, kinetic plasma scales has a fundamental role in particle energization and energy transport in the Earth's Magnetospheric System. The Plasma Observatory (PO) multi-scale mission concept is tailored to ultimately understand such processes through simultaneous measurements at both fluid and ion scales. In particular, PO scientific questions are: how are particles energized in near-Earth space plasmas, in particular at shocks, during magnetic reconnection, by waves and turbulent fluctuations, in plasma jets and by a combination of processes, and which processes dominate energy transport and drive coupling between different regions of magnetospheric system, implying the understanding of how plasma jets interact with Earth's dipole field, how field-aligned currents connect different regions of the magnetospheric system, which are the key plasma instabilities involved in energy transport and how energy flux is partitioned in different energy transport processes. PO baseline mission includes one mothercraft (MSC) and six identical smallsat daughtercraft (DSC) in two nested tetrahedra formations with MSC at the common vertex for both tetrahedra. The PO baseline orbit is an HEO 8x18 RE, covering all the key regions of the Magnetospheric System including the foreshock, the bow shock, the magnetosheath, the magnetopause, the magnetotail current sheet, and the transition region. The MSC payload provides a complete characterization of electromagnetic fields and particles with sufficient time resolution to resolve kinetic physics at sub-ion scales (for both protons and heavy ions). The DSCs are equipped with more straightforward identical payloads giving a full characterization of the plasma at the ion and fluid scales.
PO will allow us to resolve for the first time scale coupling in the Earth's Magnetospheric System, leading to transformative advances in the field of space plasma physics. PO is one of the three ESA M7 candidate missions that were selected in November 2023 for a competitive Phase A with a mission selection planned for 2026 and launch in 2037.
Italy is the Plasma Observatory Lead Proposer with France as Co-lead Proposer. Moreover, the Italian contribution at the payload level foresees the responsibility of the Particle Processing Unit-M (the unique interface between the particle instruments and the MSC) and of the Ion Mass Spectrometer-M (providing the three-dimensional velocity distribution function of H^+, He^{++}, and O^+ at very high time resolution) on board the mothercraft. More detail about the IMS-M will be provided in the framework of a consortium with France, the United States, Belgium, Hungary and Switzerland. Italy will also be actively contributing to the Plasma Observatory giving support to the mission design using the exploitation of advanced numerical simulations. Moreover, the Italian community is actively involved in the scientific studies related to the objectives of Plasma Observatory.



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

Previous page: Curiously named bursty bulk flows are directly connected to abrupt changes in the magnetic field near Earth's surface. Credit: ESA/Cluster.

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 2024, 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 tri-dimensional measurements allowing significant advance in the knowledge of fundamental space plasma processes and magnetospheric physics.

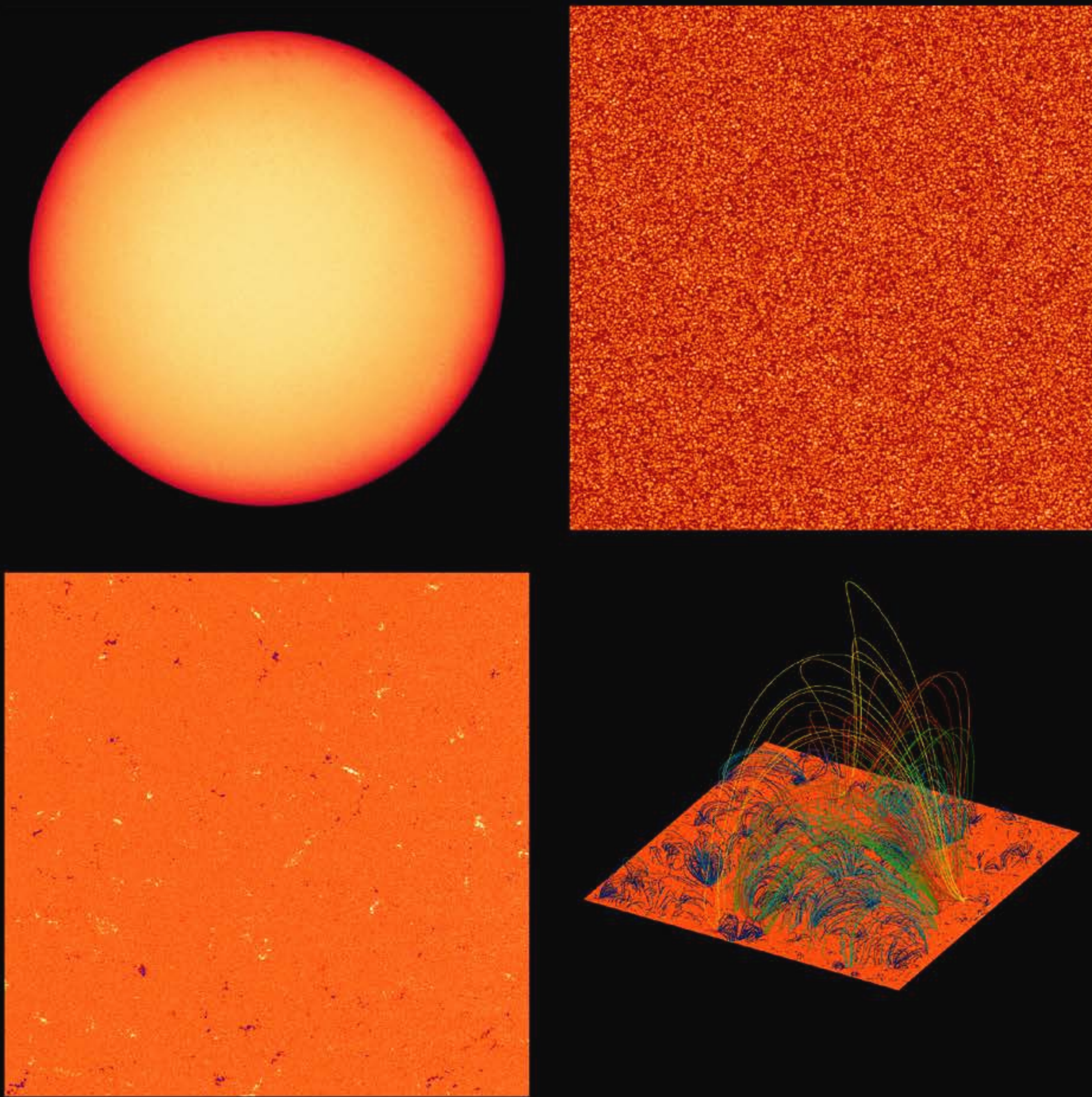
Cluster is an ESA Horizon 2000 cornerstone mission launched in 2000. Cluster comprises four spacecrafts, flying in a tetrahedral formation, which carry an identical set of instruments for the in situ measurements of charged particle and fields. Cluster operations have been extended until September 2024, when the re-entry of the first one of the four spacecraft is planned. Even if Cluster operations will come to an end, the Cluster data made available to the scientific community through the Cluster science archive will continue to enable scientific progress for long time.

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.

henon

The HENON mission aims to demonstrate that a significant improvement in the forecasting capabilities of the most relevant Space Weather hazards can be achieved by exploiting for the first time ever the Distant Retrograde Orbit (DRO) of the Sun-Earth system that permit HENON to stay for a long period upstream of the Earth ~ 0.1 AU (well beyond L1).

The HENON mission aims to pave the way towards a significant improvement in the forecasting capabilities of the most relevant Space Weather hazards as SEPs events and geoeffective interplanetary perturbations. HENON foresees one 12U CubeSat orbiting for the first time ever a Distant Retrograde Orbit (DRO) of the Sun-Earth system. The chosen DRO is such that HENON will stay for a long period upstream of the Earth ~ 0.1 AU (well beyond L1). The payload under consideration for HENON comprises a state of the art radiation monitor for the high-resolution measurements of energetic particle spectra, a Faraday Cup for the measurements of the solar wind parameters (density, velocity and temperature) and a miniaturized magnetoresistive sensor for the measurement of the Interplanetary Magnetic Field. The HENON peculiar orbit and payload, tailored to SWE observations, makes HENON the first mission ever monitoring in near real time the particle radiation environment in the deep space and measuring the interplanetary structures with such a time advance with respect to spacecraft located at L1 that the forecasting horizons of geo-effective phenomena are considerably enhanced (several hours). HENON also has the capability to provide new data for the study of the fundamental phenomena at the base of Space Weather. The HENON CubeSat will undertake important technological challenges implying that unique resources are needed in terms of lifetime, manoeuvring capabilities and operability. The realization of HENON will enable a future fleet of CubeSats, which could provide continuous near real-time measurements for space weather forecasting.
The HENON Phase A and B, developed under ESA's General Support Technology Programme Fly Element, studies have been successfully completed. HENON is part of the ALCOR program of the Italian Space Agency.
The Italian industry and scientific community is giving an important contribution to HENON being the Consortium Prime and the Scientific PI of the mission. HENON consortium includes Finland, Czech Republic and United Kingdom.



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

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, flaring and non-flaring corona (EIS, XRT). Data from Hinode are currently used in the Italian community to study flares (Vasantharaju et al. 2023) and active regions (Mihailescu et al. 2023) as a component of multiband observations, including other missions and telescopes, such as IBIS (Ermolli et al. 2022) and Solar Dynamics Observatory.

muse

MUSE is a NASA MIDEX mission to be launched in 2027 for high resolution EUV spectroscopy of the solar corona.

The MUSE NASA mission, with significant ASI-INAF contribution, will use EUV spectroscopy in 3 single-line bands (FeIX 171A, FeXV 284A, FeXIX 108A) to probe basic magnetic and heating processes in the solar corona. The lines are sensitive to plasma emission at about 1, 2.5 and >8 MK, respectively. Resolving the lines will allow to obtain information about non-thermal processes and plasma dynamics, and the 35 slits will allow to have this information at a good time and space resolution (DePontieu et al. 2022, The Astrophysical Journal, 926:52).
Italy is contributing through an ASI-INAF agreement which includes scientific modeling and diagnostics (University of Palermo, University of Calabria, INAF/OACN and OACt), and technological instrumentation, in particular, filters with CNT technology (University of Palermo, INAF/Astronomical Observatory of Palermo), mirrors (INAF/Astronomical Observatory of Brera) and coating tests (CNR/IFN Padua).

score

Prototype of the Solar Orbiter coronagraph Metis, SCORE was successfully launched in 2009 as part of the NASA suborbital flight program HERSCHEL, resulting in the first measurements of the helium absolute abundance in the solar corona.

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. After a second flight in 2022, NASA has approved. A third launch has been approved for 2024.
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.

solar-c euvst

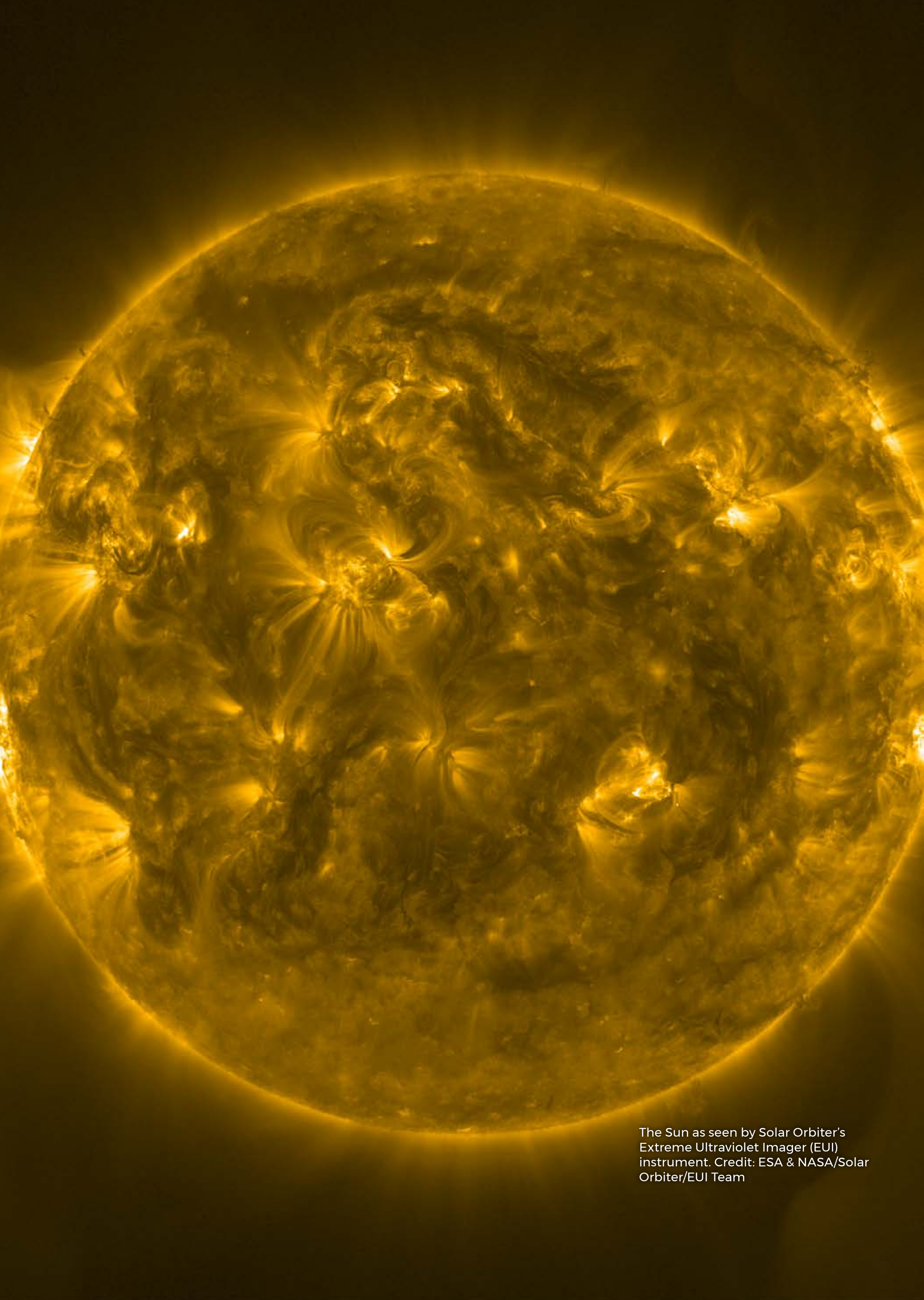
SOLAR-C is the next Japanese solar physics mission, carrying onboard as its main mission payload an EUV imaging spectrometer, called EUVST (EUV High-Throughput Spectroscopic Telescope), operating in the 17-130 nm range and equipped with a context imaging system.

The mission was down-selected in April 2020 by ISAS (Institute of Space and Astronautical Science) of JAXA (Japan Aerospace Exploration Agency) as the 4th in the series of competitively chosen M-class missions to be launched with an Epsilon launch vehicle in the late 2020s. The current launch date is scheduled for the end of 2028. The primary scientific objectives of the SOLAR-C mission are: (1) understand how fundamental plasma processes lead to the formation of the solar atmosphere and wind, and (2) understand how the solar atmosphere becomes unstable, eventually releasing the energy that drives solar flares and eruptions.

The EUVST telescope onboard SOLAR-C will address these scientific objectives by carrying out the most accurate and complete spectroscopic observations obtained to date, combining simultaneous measurements of the properties of the solar atmosphere over an unprecedented range of temperatures (5x10^4 - 2x10^7 K) at very high resolution, both spatial (0.4 arcsec, or 300 km on the Sun) and temporal (down to 0.5 s cadence). These spectroscopic measurements will be obtained together with context imaging in the UV at similar resolution.

SOLAR-C is a mission of international cooperation between Japan, USA (NASA), and Europe (with contributions from ESA, Italy, France, Germany, and Switzerland).

The Italian contribution to the mission consists of the spectrograph's slit assembly, as well as in the participation to the definition of the mission science and operating modes.



The Sun as seen by Solar Orbiter's Extreme Ultraviolet Imager (EUI) instrument. Credit: ESA & NASA/Solar Orbiter/EUI Team

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 the 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's 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 of 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 an 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 explore 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. In particular, important information has been obtained concerning the role of turbulence in the heating and acceleration of the solar wind plasma. Metis has already observed several coronal mass ejections in both visible and UV light, in cooperation with other instruments on board Solar Orbiter. It has also observed periodic density perturbations propagating outward in the corona, which can give a significant contribution to the slow solar wind plasma flow. Moreover, it is contributing to cosmic-ray flux predictions and observations in the inner heliosphere. 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 of 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 spacecraft 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.

SCIENTIFIC COMMISSION E
Research in Astrophysics from Space

Previous page: A picture of the EUSO-SPB2 fully assembled instrument before launch. Credit: NASA/Bill Rodman.

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. AGILE re-entered the atmosphere, thus ending its intense activity as a hunter of some of the most energetic cosmic sources in the Universe that emit gamma-rays.

astrosat

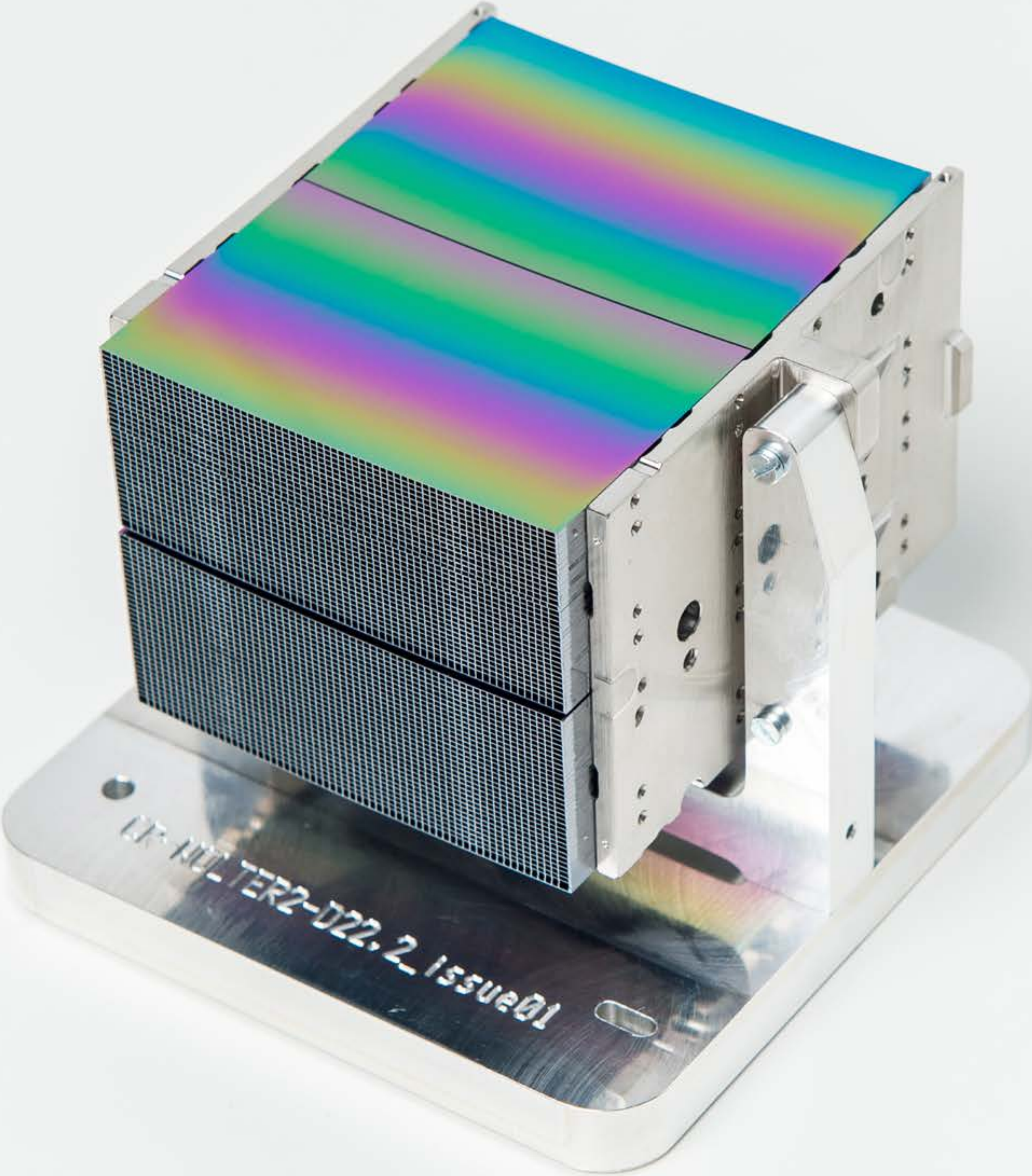
AstroSat is an Indian mission launched in 2015 to study celestial sources in X-ray, optical and UV spectral bands simultaneously. It opens a window onto X-ray fast timing, with an interactive software developed by INAF.

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 (Advanced Telescope for High-Energy Astrophysics) is a large ESA X-ray observatory with a launch planned for 2037 that will address the most pressing questions in astrophysics for the late 2030s.

ATHENA is a large X-ray observatory and the second large-class ESA mission (L2), with a launch planned for 2037 and currently in A/B1 phase. Its adoption is planned for mid 2027 with C phase starting 2028. It will continue the series of large X-ray observatories inaugurated by Chandra and XMM-Newton, offering transformational capabilities in several key areas. It is conceived to answer some of the most pressing questions in astrophysics for the late 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.

calet

The CALET experiment, in operation on the ISS since 2015, measures the spectra of cosmic-ray elements up to iron and beyond and carries out searches for possible signatures of dark matter in the spectra of electrons and gamma rays.

CALET (CALorimetric Electron Telescope) is a mission by JAXA in collaboration with ASI and NASA, that was deployed on the external exposure facility JEM-EF of the ISS in August 2015, starting an initial 5-year period of data taking. Thanks to its success, the CALET experiment's operative lifetime has been extended to the end of 2024 with a possible further extension to 2027, at least. CALET's main scientific objective is measuring the electron spectrum above 1 TeV to search for signatures of nearby acceleration sources at kpc distance from Earth. With excellent energy resolution, proton rejection capability and low background contamination, CALET is also 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 7.5 TeV and is now chasing rare electron events at higher energies up to 20 TeV. Furthermore, fluxes of cosmic-ray nuclei from proton to iron, and the abundances of trans-Iron elements up to Z=40 are being studied. Deviations from a simple power-law behavior in proton and He spectra were consistently measured with a unique instrument with high precision from below 40 GeV/n up to above 50 TeV/n, and an unexpected spectral softening of both elements has been observed above 10 TeV/n.

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 electromagnetic 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 detail AGN eclipses due to gas and dust clouds in close AGN. Chandra was also used to study galaxy clusters and in particular the interactions between the central giant galaxy and the intra-cluster medium. Chandra was, and actually is, fundamental to study celestial objects in the crowded fields of the Milky Way. In particular, Chandra gave a fundamental contribution to 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.

Next page: the CHEOPS satellite during preparations for EMC testing in the ESA's Maxwell test facility. Credit: ESA–G. Porter.


SMOS–A05 PART B
SN01 MASS 86 kg
SWL 450 kg
APCO

COSI

COSI is a NASA “SMEX” mission dedicated to Compton regime gamma-ray astrophysics planned to be launched in 2027.

COSI is a soft gamma-ray survey mission approved for the NASA SMEX program with launch in 2027. The core of COSI is a germanium Compton telescope sensitive in the still unexplored energy range 0.2-5 MeV matured over decades through technology development with scientific balloon flights. COSI’s sensitivity and energy resolution will allow groundbreaking advances in several fundamental topics. In particular, the mission is designed to probe the origin of the mysterious Galactic positrons, uncover the sites of nucleosynthesis in the Galaxy and find counterparts to multi-messenger (gravitational waves, neutrino) sources. Moreover, COSI will have polarization capabilities, allowing to explore the polarization of the radiation emitted by active galactic nuclei, gamma-ray bursts and pulsars. The large field of view (25% of the sky), together with the scanning observational mode, offers a great opportunity for the detection of transients.
INAF is part of the science exploitation program, instrument simulations and data analysis SW.

dampe

DAMPE is a China led international collaboration with Italy and Switzerland. It is a space telescope for high energy gamma-rays, electrons and cosmic ray detection. It was launched in 2015 in a sun-synchronous orbit at the altitude of 500 km.

DAMPE (Dark Matter Particle Explorer, also known as Wukong), is a Chinese CAS satellite launched on December 17, 2015, resulting from a collaboration with Italy and Switzerland.
The main scientific objectives include the study of cosmic electrons and photons up to few TeV and the spectral measurements of protons and nuclei up to hundreds TeV.
DAMPE is composed of a double layer plastic scintillator (PSD), 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. The Italian contribution comes from INFN and University groups in Perugia, Bari, Lecce and the Gran Sasso Science Institute.
Currently the science team is focusing on the data analysis and contributed to the study of charged cosmic rays flux spectra measurements of several species from protons up to iron, pushing towards the sub-PeV energy region.

euclid

Euclid, launched on July 1st 2023, will map 1.5 billion galaxies to investigate the properties of dark matter and dark energy on universal scale.

Euclid was launched on July 1st 2023 to an L2 orbit. Commissionig and Performance Verification Phases have been completed successfully and the Euclid survey mapping will start in February 2024. Euclid will observe more than 14000 square degrees of extragalactic sky in a 6 year long mission and it 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 the 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's 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 Euclid Consortium 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.

1000 galaxies belonging to the Perseus Cluster, and more than 100 000 additional galaxies further away as seen by Euclid. Credit: ESA/Euclid/Euclid Consortium/NASA.

euso–spb2

EUSO-SPB2 is an experiment that has flown onboard a super pressure balloon to pave the way to the measurement of neutrinos and ultra-high-energy cosmic rays from space.

Developed in the context of the JEM-EUSO programme, the EUSO-SPB2 mission had the objective of testing a new type of space detector dedicated to the observation of neutrinos and of ultra-high-energy cosmic rays through the operations of an instrument based on the synergistic and independent operations of two telescopes with a balloon flight launched in May 2023 from the NASA base in Wānaka in New Zealand. EUSO-SPB2 is also a demonstrator experiment for the POEMMA space mission, a multi-messenger astrophysics program for the study of the most extreme regions of the Universe through the observation of ultra-high-energy cosmic rays and of astrophysical and cosmogenic neutrinos with the technique explored by EUSO-SPB2. Scientists from INFN and Italian Universities with financial support from the Italian Space Agency (ASI) and in collaboration with the University of Chicago (PI institution) have been participating in this experiment since 2021, developing and realizing the data acquisition system, the trigger system and the control software of the EUSO-SPB2 Fluorescence Telescope. EUSO-SPB2 has been the second mission of the NASA balloon launch campaign from New Zealand in the year 2023. The flight, that has lasted 35 hours, was performed on a Super Pressure Balloon, a state-of-the-art stratospheric balloon experimental platform used by NASA for a few years to operate large and heavy scientific payloads in the atmosphere. The EUSO-SPB2 instrument has observed the night sky with two independent telescopes which have separately measured the component of Fluorescence and Cherenkov light produced by atmospheric showers potentially generated by ultra-high-energy cosmic rays coming from outside the atmosphere, and generated by the decay of tau neutrinos coming from below the horizon line. The successful operations of the EUSO-SPB2 telescopes have demonstrated the achievement of the technological objectives of the mission, have verified the possibility of observing atmospheric showers from Space by measuring both light components in a synergistic way, thus representing a further step towards the realization of an extremely ambitious and revolutionary program such as POEMMA. The analysis of the data collected during the operations of the EUSO-SPB2 is currently ongoing to extrapolate scientific results from the data collected by both telescopes.

extp

eXTP is a flagship X-ray observatory of the Chinese Academy of Sciences with a large European participation, planned for a launch in 2029 to study the matter under the most extreme conditions in the Universe.

The enhanced X-ray Timing Polarimetry mission (eXTP), currently in its B phase, is a large mission for Astronomy and Astrophysics that will lead the spectral-timing-polarimetry studies of the X-ray Universe in the late 20s and early 30s. The mission is being developed by a large international Consortium, which includes institutions from China, and from Italy, Spain, Austria, Czech Republic, Denmark, France, Germany, Netherlands, Poland, Switzerland and Turkey. eXTP will address key open questions of fundamental physics: the physical nature of cold ultra-dense matter; the behaviour of matter and light in space-time shaped by strong-field gravity; the astrophysics and physics of the strongest magnetic fields in nature. The matter inside neutron stars (NS), the space-time in the vicinity of the Black Hole (BH) horizon and the extremely magnetized vacuum close to magnetars and accreting pulsars are uncharted territories of fundamental physics. NSs and BHs provide a unique arena for their exploration. Thanks to its unprecedented throughput, the eXTP mission will revolutionize these fundamental areas of today's research by high precision X-ray observations of NSs across the magnetic field scale and BHs across the mass scale. In addition to investigating questions of fundamental physics, eXTP will enable excellent observatory science opportunities, providing observations of unprecedented quality on a variety of galactic and extragalactic objects. eXTP's wide field monitoring capabilities will also be crucial in the context of multi-messenger astronomy by detecting and monitoring the electro-magnetic counterparts of gravitational waves and neutrino cosmic sources. eXTP will operate at the time of operation of major facilities in multi-messenger astronomy.

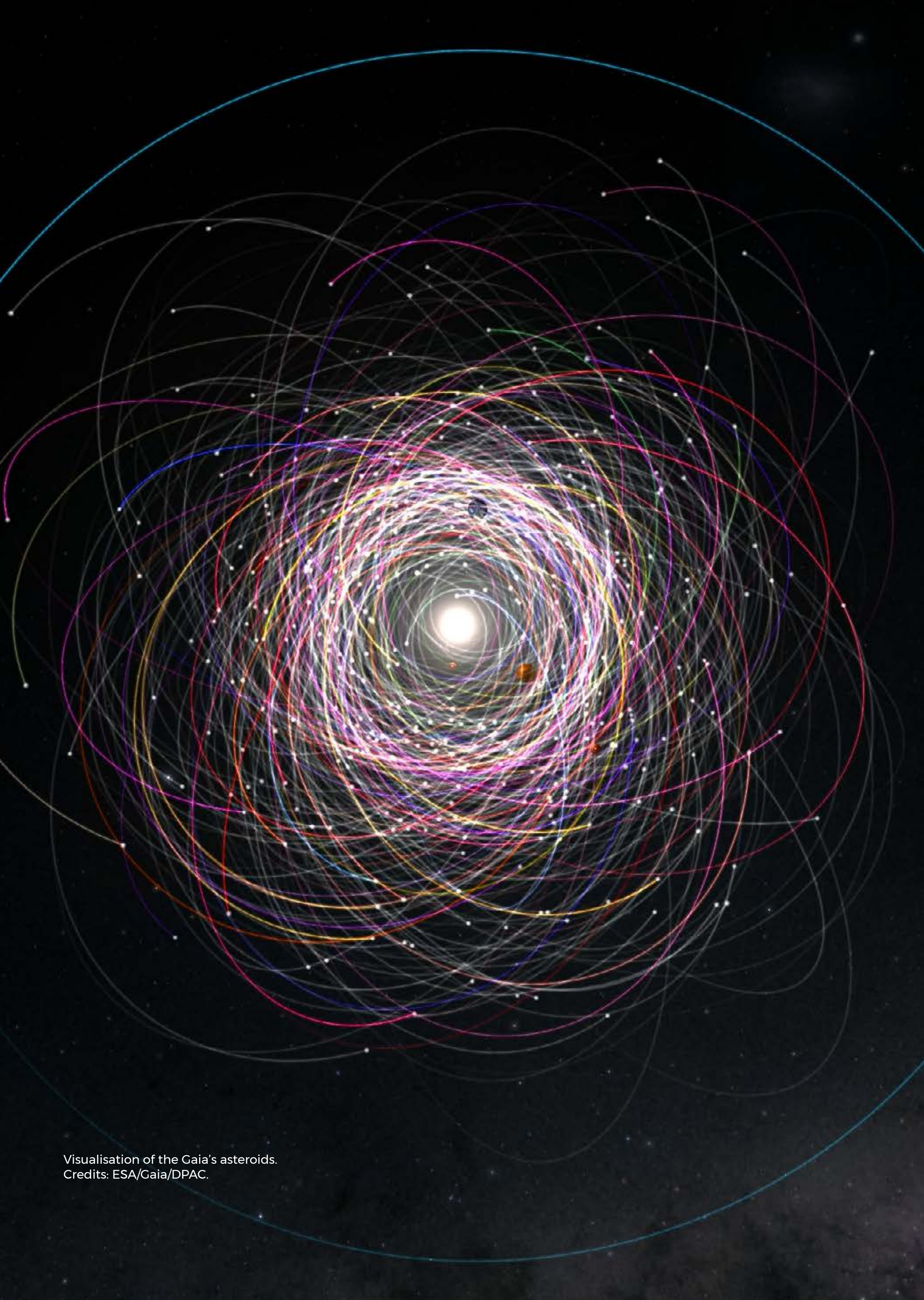
The Italian community, supported by the Italian Space Agency, leads the largest of the four payload instruments, the Large Area Detector, and contributes to the other European instrument, the Wide Field Monitor. For both instruments Italy also provides the enabling technology, the large area Silicon Drift Detectors.

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 16 years of successful operations, the most recent release (DR4) of the 4th Fermi LAT 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. The 3rd Fermi pulsar catalog (3PC) lists 294 pulsating neutron stars about half of which are msec pulsars while the remaining ones are young neutron stars, both radio loud and radio quiet, We note that half of the entries in the 3PC were not known before Fermi LAT. Notably, 78 msec pulsars were discovered searching for counterparts of unidentified sources while 70 young Geminga-like, plus 6 msec radio quiet neutron stars were found in the Fermi data using blind folding techniques.

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.



Visualisation of the Gaia's asteroids.
Credits: ESA/Gaia/DPAC.

gaia

Gaia is providing a whole-sky census of around 1.8 billion objects, mostly stars in our Galaxy and its immediate surroundings, unravelling the chemical and dynamical history of the Milky Way and, therefore, of its place in cosmology.

Launched in 2013, ESA mission Gaia is a major project for the European astronomical community that in these 10 years has obtained results that have far exceeded the initial objectives of the mission, proving to be a crucial tool for studying the formation of our galaxy and 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 operational mission until the first half of 2025. 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 also gathers 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 billion sources and partial spectrophotometry. GDR2 processed the first 22 months of satellite data together. Gaia Data Release 3 was released on Monday 13 June 2022 spanning a period of 34 months of data collection; at least one full release will follow. For the great results achieved in the astrophysics field, in 2023 the Gaia Collaboration was awarded the Lancelot M. Berkeley Prize. The scientific data processing is the responsibility of the DPAC (Gaia Data Processing and Analysis Consortium), a pan-European effort of ~450scientists 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 for 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 SpA as an 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 2.5 PB 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 partners 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 a stratospheric Antarctic balloon mission to be flown from Antarctica to study and search for the rare antimatter components in cosmic rays.

GAPS (General AntiParticle Spectrometer) is an experiment designed to study the rare antimatter component in cosmic rays, specifically low-energy antiprotons, anti-deuterons, and 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 the matter-antimatter asymmetry. The integrated GAPS detector will be shipped to the McMurdo base in Antarctica in 2024, to be launched on a NASA stratospheric long duration (30 days) balloon flight during the balloon campaign of austral summer 2024-25. The GAPS antiparticle identification approach is an innovative technique based on measuring the features of the decay of exotic atoms produced after the 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 forms an excited exotic atom in the Si(Li) tracker, which de-excites and releases X-rays and a "star" of pions 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 particle precisely determine the type of primary particle and discriminates between the different anti-nuclei species. The data collected during the first flight will provide enough statistics to investigate the properties of low-energy antiprotons. Two additional flights will achieve the scientific objectives for anti-deuteron and anti-helium physics. GAPS is an experiment led by Columbia University with the participation of scientists from other American, Japanese, and Italian institutions. Italian researchers from INFN departments and Italian Universities have participated in GAPS since 2017 and with support from ASI since 2018. The Italian groups led the development and construction of the electronic components of the Si(Li) tracker and are contributing to the data analysis, simulation, and data interpretation modelling.

grass

The GRASS instrument (Gamma-Ray Astronomy Small Sensor), is a low mass payload for the stratospheric flights of the European (Horizon 2020) program HEMERA. The instrument is based on a low energy (~0.1 – 10 MeV) gamma ray scintillation detector which has as its baseline the use of a GAGG scintillator and a readout system with the latest generation solid state sensors (SiPM).

In the latest decades, instruments on astronomical space missions have revolutionised our view of the cosmos and in particular, deepened our knowledge of the high energy phenomena at all scales and up to the most remote regions of the cosmos. In the recent era of time domain astronomy, soft gamma-ray instruments on board satellites (such as those on board Fermi, INTEGRAL and Swift) have shown their capability to detect extreme transient events, like those associated with black holes at all scales and compact star mergers, witnessing important processes e.g. the violent death of stars and the formation of the heaviest chemical elements.
Stratospheric flights on balloons offer a real opportunity to test spaceborne payloads, which is also an effective tool to support their development and raise their Technology Readiness Level. The GRASS (Gamma-Ray Astronomical Small Sensor) instrument is a low mass, position sensitive compact detector based on a GAGG (Gadolinium Aluminium Gallium Garnet) scintillator array and a readout system with the latest generation solid state sensors (SiPM). It is an advanced prototype conceived as the basic element of a larger area modular detector for time domain soft gamma-ray astronomy. GRASS has been flown two times, in two different versions in 2021 and 2022 on board stratospheric balloon gondolas provided by the European (Horizon 2020) program HEMERA. The prototypes were fully tested and calibrated on ground before the flight. The latest version also included a coded mask for imaging with a field of view of 3 steradians. Both flights have successfully tested the payload at altitudes characterised by severe and highly variable radiation environments and extreme temperature conditions, similar to those found in a Low Earth orbit.

hermes pathfinder

HERMES (High Energy Rapid Modular Ensemble of Satellites) -Technologic and Scientific pathfinder (HERMES Pathfinder) is an in-orbit demonstration consisting of a constellation of six 3U cubesat hosting simple but innovative X-ray/gamma-ray detectors for the monitoring of cosmic high-energy transients.

The main objective of HERMES Pathfinder is to prove that high energy cosmic transients such as Gamma Ray Bursts can be detected by miniatured hardware and localized using triangulation techniques.
The HERMES Pathfinder X-ray/gamma-ray detector is made by 60 GAGG scintillator crystals and 12 10x10 silicon drift detector mosaics, used to detect cosmic X-rays and to detect optical photons produced by gamma-rays in the scintillator crystals. This innovative design provides a unique broad band from a few keV to a few MeV, with an effective area of about 55 cm2.
The transient position is obtained by studying the delay time of arrival of the signal to different detectors on low Earth orbits. For this purpose, particular attention is placed on reaching the best time resolution and time accuracy, reaching an overall accuracy of a few hundreds of nano-seconds.
Two different lines of financing have allowed the realization of the HERMES Pathfinder project, in particular: (1) the HERMES-TP project is funded by the Italian Ministry for Education, University and Research, and the Italian Space Agency. (2) the HERMES-SP project is funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 821896.
Seven payload Flight Models have been integrated, tested and calibrated from 2021 to 2023 at INAF IAPS and Fondazione Bruno Kessler labs. On board softwares have been developed and realized by the team at IAAT University of Tubingen. The HERMES Pathfinder complete Proto Flight Model has been integrated and tested at the end of 2023. It passed mechanical tests in February 2024 and it will start TVAC test at the beginning of March 2024. A second complete Flight Model has been integrated and tested in January/February 2024 and it will start environmental tests in March 2023. The other four Flight Models will be integrated and tested from March to June 2024. ASI issued a contract for the launch services to D-Orbit. The constellation should launched between Q4 2024 and Q1 2025 on SSO through Falcon 9 transporter services.
An X-ray/gamma-ray payload identical to those of HERMES Pathfinder is hosted by the Australian 6U cubesat SpIRIT, managed by University of Melbourne. SpIRIT has been launched as SSO on December 1st 2023. Since then it is operating nominally. The X-ray/gamma-ray payload was switched on in January 2023 and acquired its first X-ray/gamma-ray spectra in February 2024. It is working nominally in space and it has therefore reached TRL9.

hst

Hubble Space Telescope is the most popular NASA/ESA joint mission. It has already celebrated 30 years of achievements and the most dramatic discoveries in the history of astronomy. It is now partnered 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 complimentary 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. Given 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 21 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. In view of the high quality scientific results, the operative life of the mission has been extended up to the end of 2024, with an ongoing request foran extension request till 2027. 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 continues to contribute to this key topic by 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.

This new image of supernova remnant SN 1006 combines data from NASA's Imaging X-ray Polarimetry Explorer and Chandra X-ray Observatory. Credit: NASA.

ixpe

IXPE: Now in its third year of operation. The first two year observing plan comprises about 60 sources X-ray source from almost of the classes.

IXPE (Imaging X-ray Polarimetry Explorer) is a SMEX (Small Explorers) mission, 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 polarizations sensitive detectors devised, fabricated and calibrated by INAF and INFN with OHB-Italia as industrial contractor and provided by ASI and three X-ray optics developed at NASA/MSFC. The Italian contribution comprises the unique focal plane instrument by INAF and INFN with the industrial contribution of OHB-Italia. ASI provided the Malindi primary IXPE Ground Station and contributes to the development of the flight pipeline with ASI/SSDC. The first two nominal mission observing plans comprise of about 60 X-ray celestial sources chosen among almost all the classes. The main contractor for the spacecraft is Ball Aerospace. IXPE reaches a focal length of 4 meters using an extendable boom provided by Northrop Grumman Space System. X-ray polarimetry allowed to study black holes and neutron star 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 imaging capabilities allow polarimetry of extended sources and dim sources such as AGNs.

Here we report on the main results of IXPE after the first two years: (1) In Pulsar Wind Nebulae the magnetic field is very ordered also at large distance from the pulsar; (2) Some supernovae show a magnetic field mostly radially directed unexpectedly even in the vicinity of the shock. In some others the magnetic field is found to be perpendicular to the radius (3) Accreting black-hole polarimetry excludes a lamppost model for the corona and urge for a more complex accretion disk. (4) In binary pulsar unexpectedly the polarization is quite small while the rotation-vector model from radio observation holds. (5) Polarimetry of different magnetars shows different behaviour of polarization degree with energy related to very different surface emission regions. (6) Radio-Quiet AGN polarimetry, again, excludes the lamp-post model and it is consistent with Unification Models. IXPE further it showed that 200 years ago our galactic centre was 10E6 times brighter than today. (7) Blazars polarimetry determines that shock is the mechanism of acceleration.

IXPE operation are extended until September 2025. Since February 2024 IXPE entered into the General Observer phase (GO1) with observing plan decided on a competitive base by the scientific community. Data are generally publicly distributed soon after the observation is accomplished. The next call deadline for GO2 will be 29th September.

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. Giving an answer to these questions is rather challenging because of the low flux intensity at extreme energies (i.e. E > 5x1019 eV). The main objective of JEM-EUSO is to establish the conditions and program for the realization of an ambitious space-based mission devoted to UHECR science. The JEM-EUSO program has been conducting several missions and experiments on ground, stratospheric balloons and space to enhance the level of technology and observational approaches towards the realization of its goal. On ground: EUSO-TA, in operation at the Telescope Array site in Utah since 2013; on board stratospheric balloon: EUSO-Balloon (August 2014); on board super pressure balloons: EUSO-SPB1 (April 2017) and EUSO-SPB2 (May 2023); in space: TUS, a Russian mission on board the Lomonosov Satellite (2016-2017), Mini-EUSO, in operation since August 2019, looking down the atmosphere from the UV transparent window in the Russian Module inside the ISS, and the large size mission K-EUSO, in phase of study, to be installed outside the ISS. POEMMA (Probe Of Extreme Multi-Messenger Astrophysics), a space observatory looking towards the Earth's atmosphere for the detection of UHECRs and neutrinos from space, is the most ambitious mission that will exploit the technological and scientific results of the JEM-EUSO programs. POEMMA is currently in a study phase, while in the following years the PBR mission (Poemma Balloon Radio) onboard a super pressure balloon will further improve the required technological readiness level for its realization. 16 countries and about 300 researchers are collaborating in JEM-EUSO. Italy participates with INFN, ASI and Italian universities to the EUSO-SPB2 and Mini-EUSO operations and data analysis. INFN and italian Universities have been also contributing since 2023 to the scientific activities for the design, integration and tests of the PBR mission.

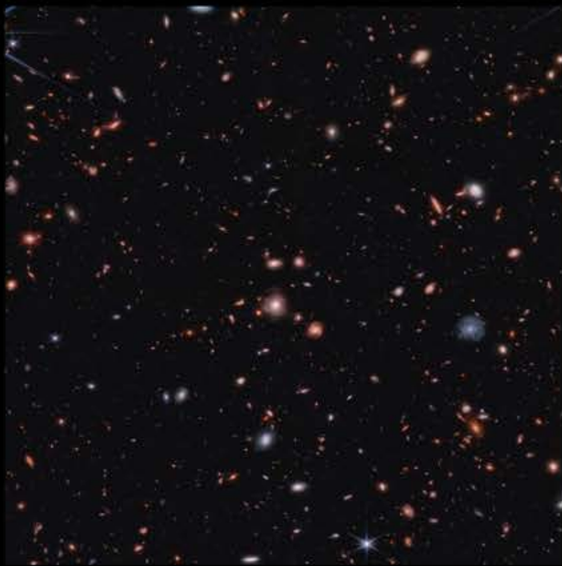
jwst

JWST is the largest telescope ever conceived to work in space. Launched on December 25th 2021, it is the flagship mission of NASA, ESA and CSA, and the premier observatory of the decade, serving thousands of astronomers worldwide. Since the very start of operations, it has demonstrated outstanding performances and transformational impact on astrophysics.

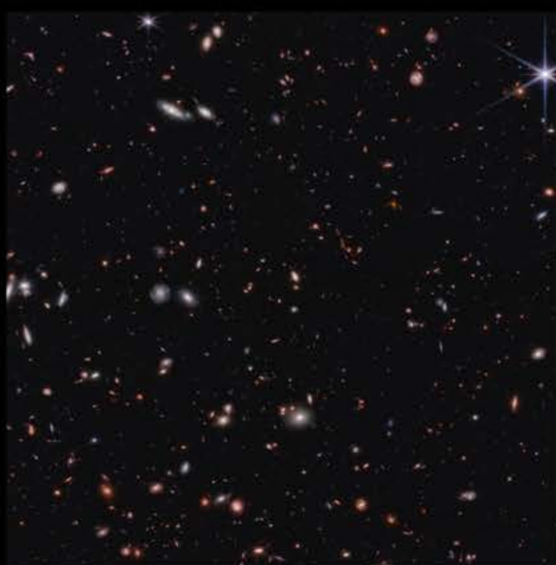
JWST (James Webb Space Telescope) is an infrared telescope with a 6.5-meter primary mirror, the result of the collaboration of NASA, ESA and CSA, the space Agencies of the US, Europe and Canada. Allowing, for the first time ever, to observe in the near- and mid-infrared at high resolution and with unprecedented power, JWST is able to look through dust and to study any dusty environment. As such, it has been conceived with four main science themes, addressing every phase in the history of the Universe: 1) first light and reionization, 2) assembly of galaxies, 3) birth of stars and proto-planetary systems, 4) planets and origins of life. In all these fields it has already allowed for astounding discoveries.
Several innovative technologies have been developed to let JWST reach these ambitious goals, including the primary mirror, composed of 18 separate segments, made of ultra-lightweight beryllium covered by a thin gold layer, and the impressive tennis-court-sized five-layer sunshield that attenuates light and heat from the Sun. 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 covers the infrared wavelength range of 0.6-5 microns. It detects 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 operates 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. NIRSpec has been the most requested and used instrument so far.

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 allow us 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 is 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 roles in international consortia and committees. In the first two years of operations, JWST's observing time has been allocated to: 1) ERS (Early Release Science) programs, selected ahead of launch to be performed in the first few months after commissioning, to let the science community quickly learn instruments use and capabilities, 2) GTO (Guaranteed Time Observations) programs assigned to the consortia that built the instruments, and 3) GO (General Observer) programs selected by the Time Allocation Committee on the basis of scientific merit.
Oversubscription is extremely high, and increasing each time (9.1 in Cycle 3), with proposals arriving from 56 different countries. Ground-breaking results, sometimes confirming and sometimes challenging current theories of stars, planets and galaxy formation have been obtained from these programs.

Following page: an image stitched together from multiple images captured by the NASA/ESA/CSA James Webb Space Telescope in near-infrared light.








lisa

LISA is an observatory for gravitational waves in the milliHertz band, made of 3 spacecraft orbiting in a triangular configuration with a 2.5 million km sidelength. It has recently been adopted as a mission by ESA and is entering the implementation phase, with a target launch date in 2035.

LISA (Laser Interferometer Space Antenna) has been adopted by ESA as the second "Large Mission" of the Cosmic Vision program, for a 2035 launch. LISA has been under study – to explore the "Gravitational Universe" – since 2017 by ESA and, for the elements of the payload, by the European member state agencies and NASA. Mission adoption, following a series of successful engineering and scientific reviews, represents the beginning of the "implementation phase" of the mission, with selection of a single industrial mission prime by ESA and formal "kickoff" expected over the next year.

LISA will consist of a constellation of free-falling test masses inside three orbiting spacecraft separated by 2.5 million km. The relative motion between pairs of distant test masses, caused by the gravitational wave "tidal deformation", is measured by laser interferometry. LISA will detect and measure Gravitational Waves in the 100 microHz to 1 Hz band (extended to lower frequencies as allowed by the in-orbit performance) for a 4.5 year nominal science life (extendable to 10 years). It will perform precise measurements of astrophysical phenomena like merging 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 a glimpse of the early Universe after the Big Bang. Most of the "enabling technologies", most critically free-falling test masses tracked by laser interferometry, have been tested by LISA Pathfinder.

litebird

LiteBIRD (Light satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection) is a JAXA Flagship Large Mission with important contributions from Europe, US and Canada, down-selected in 2019 for a launch in the second half of 2032.

The scientific objective of the project is the accurate mapping of the polarized anisotropies of the cosmic microwave background (CMB), revealing the fingerprints of the primordial gravitational waves, generated during the cosmic inflation era, the "B-modes". The measurement of the B-modes will represent a turning point for the study of fundamental physics through inflation and through extensions of the standard cosmological model such as, for example, cosmic birefringence and cosmic magnetism. LiteBIRD will also provide important data for the study of the reionization epoch and of the origin of large-scale anomalies in the Universe with unprecedented accuracy, unveiling a unique image of the dust emission in our galaxy. LiteBIRD will produce full-sky maps with an angular resolution up to 20' and a frequency coverage in fifteen channels over the wide 34 - 448 GHz range that will allow an unprecedented control of the contamination due to the polarized emission of the synchrotron and the dust from our Galaxy. To probe the very feeble CMB signal in presence of diffuse Galactic foregrounds, the payload module is based on the dual-reflector Low Frequency Telescope (LFT, 34–161 GHz) and two refractive dual-lens systems, the Medium & High Frequency Telescope (MHFT, 89–448 GHz), enclosed in an efficient radiative shielding system. Both telescopes, provided with a polarization modulator to minimize instrumental systematic effects, feed two focal planes populated with transition-edge sensor (TES) bolometric arrays. High-sensitivity CMB observations require to cool telescopes and detectors down to cryogenic temperatures, below 5 K and 100 mK respectively, by means of a complex cryochain based on passive (VGroove-type radiators) and active cooling systems.

The LFT and MHFT were developed by Japan and Europe. The Italian scientific and technological contribution, organized within the framework of the European activities, is funded by the Italian Space Agency (ASI) and the National Institute of Nuclear Physics (INFN). Italian scientists play key roles in the activities of the working groups that prepare the scientific exploitation of the mission data especially for what concerns the implications for inflationary models, reionization and fundamental physics, the study of the foregrounds, the component separation, the analysis of systematics and instrumental effects at large. The national technological contribution is based on the development of sub-systems of the MHFT (cryogenic rotator, optical absorbers), on the development of the SQUID-based readout and control electronic, on important responsibilities in the calibration activities at component and telescope level. In addition, the Italian team is one of the major candidates for the implementation and coordination of the Science Ground Segment at European level.

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 test flight is planned for september 2025.

LSPE (Large Scale Polarization Explorer) is a stratospheric balloon mission funded by ASI and INFN, with a first flight planned for 2025. 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 multimode bolometers and a spinning HWP modulator (Half Wave Plates), and the STRIP (Survey TeneRIfe Polarimeter) groundbased 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: a ISS-based next-generation telescope for studying and monitoring terrestrial, atmospheric and cosmic emissions in ultraviolet (UV) band.

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 emissions in the atmosphere of the Earth. It was launched in August 2019 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. At the time of writing, Mini-EUSO has performed more than 100 data acquisition sessions. The telescope's main optics is composed of 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.

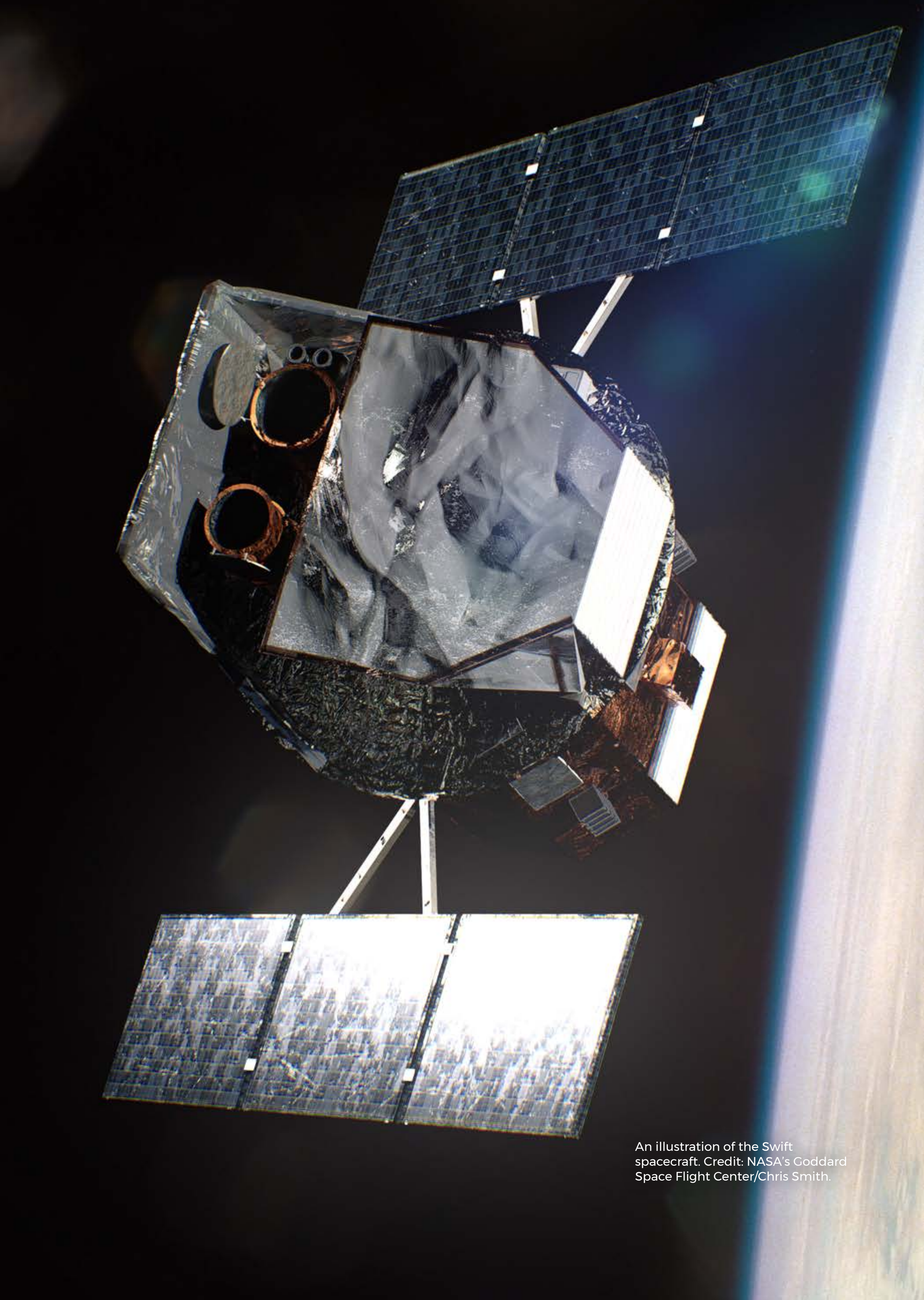
Mini-EUSO data have provided the first UV night maps of the Earth with a resolution of a few km and has measured more than 50'000 meteorites from space. Other scientific objectives of Mini-EUSO include the search from space for interstellar meteorites, of strange quark matter, and of ultra-high-energy cosmic-rays ($E>10^{21}$eV), as well as the measurement from above the atmosphere of atmospheric transients such as Transient Luminous Events and ELVES (Emission of Light and Very low frequency perturbations due to Electromagnetic pulse Sources). Mini-EUSO has also achieved technological goals such as the first use of a refractive telescope based on Fresnel lenses in space and the first operation of a high sensitivity focal surface, capable of single-photon detection. These technologies and techniques have applications ranging from the creation of new and larger space-borne telescopes for the study of fundamental physics phenomena in space to practical applications related to the new type of optics and detectors in space (e.g., 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 involves various Italian Universities and Research Institutes.

neil gehrels swift observatory

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

The Neil Gehrels Swift Observatory was launched in 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 in the scientific management of the mission, funded by ASI.



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

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 carries the first orbiting telescopes to focus light on 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 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 with 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, 2.6m aperture telescope, coupled to a cryogenic receiver hosting 4 arrays of cryogenic kinetic inductance detectors. OLIMPO covers the 145, 250, 365, 460 GHz bands with diffraction-limited resolution and is devoted to the observation of comptonized CMB photons in the direction of selected galaxy clusters and LSS filaments. OLIMPO will probe the dynamics of large-scale structure formation and evolution via direct kinetic energy measurements of the ICM gas on Mpc scales, combining its maps with new X-ray and radio data; moreover will unveil the properties of the WHIM Baryons by robustly mapping the spatial structure of the temperature, density, and velocity of the gas residing in bridges between clusters. OLIMPO was flown in the first technological flight funded by ASI in the Arctic in 2018, and validated the innovative KID arrays and the instrument. The payload was recovered and an international collaboration, including scientists from Italy, USA, UK, Germany, has now applied for a scientific Antarctic LDB flight of the instrument.

theseus

THESEUS is M-class mission concept under study by ESA 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 of the scientific community, the THESEUS mission concept was further developed and proposed again to ESA in response to the call for the M7 mission to be launched in 2037. In November 2023 THESEUS was selected by ESA for a new Phase-A study (Jan. 2024 - Jun. 2026) as one of the three M7 candidates. 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. By flying in the second half of the '30s, 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 a European consortium led by Italy and with main contributions by the UK, France, Germany and Switzerland. Further relevant contributions come from Spain, Denmark, Poland, Belgium, Czech Rep., Norway, The Netherlands, Ireland, with additional minor contributions from other European countries such as Slovenia. The Italian participation is led by INAF/OAS and funded by ASI and it includes the development of one of the two high-energy sky monitors, the XGIS (X/Gamma-ray Imaging Spectrometer), the development of the optical system of the on-board Infra-Red Telscope (IRT), the contribution to ground segment (Malindi Antenna) and the general coordination of the international consortium.

Preparing OLIMPO for the flight.
Credits: Arctic Planning.

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, after 25 years of successful operation, it is still operating perfectly. The mission shall operate up to at least 2025 with foresaw further extensions.

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 particularly 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 in the sky. There are seven CCD chips, one in the center of the field of view and 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 significantly contributed, together with the Media Lario SrL, to the realization of the large area mirror modules. The INAF/OAPA has been involved in developing and calibrating the EPIC optical filters.


PORTABLE
BREATHING
APPARATUS
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TOCA

SCIENTIFIC COMMISSION F
Life Sciences as Related to Space

Previous page: ESA astronaut Samantha Cristoforetti exercising on the International Space Station during her Futura mission in 2015. Credit: ESA/NASA.

asi human spaceflight experiments

The ASI's Human Spaceflight Program started over 20 years ago, in 2000, and it is nurtured by intense collaboration with both NASA and ESA. In the framework of its national mission of promoting and fostering the culture of space across the Country, ASI promotes national research aimed at mitigating the health risk from long-duration spaceflight and supporting the development of new skills.

To date, the Italian Space Agency (ASI) has performed over 80 experiments on the International Space Station (ISS), which advanced our knowledge in Space Life Sciences and beyond.

In 2022, ASI sponsored six experiments in different research areas during the ESA MINERVA mission, part of which were selected and operated in collaboration with ESA (NutrISS, Acoustic Diagnostics, EVOOS), others launched through the ASI-NASA Memorandum of Understanding (LIDAL, PROMETEO, OVOSPACE).

The MINERVA mission was the second long-duration spaceflight mission on the ISS by the ESA astronaut Samantha Cristoforetti. She launched on 27 April 2022 on board a SpaceX Crew Dragon spacecraft and returned to Earth on 14 October 2022. During the flight to and from the Station, Samantha served as a mission specialist. On Station, she was USOS Lead, responsible for all activities within the US, European, Japanese, and Canadian modules and components of the Station for the duration of her mission. She also became the fifth European and the first European female commander of the ISS.

In January 2024, ASI took part to Ax-3, Axiom Space's third commercial spaceflight mission on the ISS, leveraging the participation of Italian Air Force Col. Walter Villadei as Ax-3 Pilot. This opened up to a new paradigm where private operators can provide additional opportunities to carry out experiments on the ISS and contribute to further strengthen Italian competences in the field.

Thanks to the joint effort between ASI, the leading Italian universities, research centers, and private companies, a research portfolio of experiments (PROMETEO II, Beta-Amyloid Aggregation, LIDAL, astRNAuts, NUT, EMSi) was realized to advance our knowledge on the physiological effects of spaceflight on humans and their mitigation strategies, with

strong potential to translate benefits to Earth.
ASI is currently working on the implementation of three new experiments in human physiology to be launched between 2024 and 2025.

Drain Brain 2.0 (2024) aims to validate a cervical plethysmography system as a portable, non-invasive, and easy-to-use instrument for the systematic monitoring of cardiovascular parameters of ISS crew members. This project is follow-on research of the Drain Brain experiment, which was performed on the ISS in 2015. The results will contribute to understanding the phenomena of physiological adaptation to the microgravity-induced shift of body fluids and to identifying possible thrombosis due to physical stress in microgravity.

IRIS (2025) foresees the implementation of crew personal dosimeters to be worn 24/7 and to monitor in real-time radiation impinging from 360°. Continuous radiation monitoring will be key to reducing the biological risks due to excessive radiation exposure during long missions (Mars) and long-term stays in space stations (ISS, Lunar Gateway, Mars).

APHRODITE (2025) is a follow-on project of the IN SITU Bioanalysis experiment performed on the ISS during the VITA mission in 2017. APHRODITE aims to develop a compact and versatile analytical device to measure biomarkers of immune system dysfunction from saliva samples on board the ISS. This can provide an autonomous in-flight medical diagnostic device and support a telemedicine approach to maintaining astronauts' health.

ASI experiments during the MINERVA and Ax-3 missions:

NUTRISS
Maintaining a correct body energy balance to preserve astronauts' wellness.
The NutrISS experiment was conducted on 3 astronauts during the BEYOND, COSMIC KISS and MINERVA missions. Astronauts body composition was monitored during spaceflight to inform effective nutritional interventions to counteract the detrimental effect of microgravity over skeletal muscle mass and metabolism. The results could also contribute to the clinical management of bedridden patients on Earth.

ACOUSTIC DIAGNOSTICS
Hearing monitoring as a tool to estimate intracranial pressure.
Exposure to high ambient noise (55-60 dBA) could affect astronauts' hearing during long-term missions on the ISS. The Acoustic Diagnostics experiment (2019-2023) measured Distortion Product Otoacoustic Emissions (DPOAE) complex spectra from five astronauts pre-flight, in-flight, and post-flight, which was also used to

obtain an indirect estimate of the astronauts' intracranial pressure.

PROMETEO
Developing effective and safe therapeutic tools to protect the central nervous system from the harmful effects of spaceflight-induced oxidative stress.
Oxidative stress underlies many deleterious effects of exposure to harsh environmental conditions during spaceflight, and it is strictly connected to senescence and to the onset of several diseases. The Prometeo/ Antioxidant protection project (Minerva mission, 2022) investigated the protective effect of polydopamine nanoparticles on neuronal cells. The following experiment Prometeo II/ Nanoneuroprotection (Ax-3 mission, 2024) used cerium oxide nanoparticles as a neuroprotective agent to compare the effect of the two different molecules. Innovative antioxidant nanomaterials can enormously benefit human permanence in space and may lay the ground to identify potential therapies for the mitigation of aging-related diseases on Earth, with potential relevance also to Parkinson's disease treatment. ESA has kindly provided KUBIK utilization.

OVOSPACE
Investigating the impact of the space environment on the maturation and development of ovarian cells.
Gravity absence / reduction could compromise the fertility of astronauts living for a long time in this condition. The OVOSPACE project investigated the effect of microgravity exposure on the endocrine function of mammalian (bovine) ovarian cells, focusing in particular on the structural interaction of different cell types in the ovarian follicle and on the potential protective role of myo-Inositol on their key cellular functions. The results will contribute to improving treatments for female infertility on Earth.

EVOOS
A food countermeasure to the deleterious effects of spaceflight.
Extra-virgin olive oil could represent a food mitigation measure against the effects of prolonged space environment exposure, thanks to the beneficial effects on human health of its high content of phenols, tocopherols, and essential fats. The EVOOS project is studying the effect of the space environment on the physiochemical, sensorial, and nutritional characteristics of selected samples of extra virgin olive oil. Samples were uploaded on the ISS on July 2022 and have been downloaded every six months until December 2023 for sensorial and physiochemical analysis.

LIDAL
Characterizing the radiation environment to enable health risk assessment.
LIDAL is an advanced detector system that continuously

measures harmful cosmic radiation since January 2020. It is conceived to provide for the first time all the parameters needed for a real-time radiation risk-meter on the ISS, that would also inform the crew about risks from radiation and space weather events.

Beta-Amyloid Aggregation
Advancing our understanding of Alzheimer's disease.
The Beta-Amyloid Aggregation experiment was performed twice onboard the ISS, during the VOLARE mission in 2019 and the Ax-3 mission in 2024. It aims at investigating the effect of spaceflight on neurodegeneration by assessing how microgravity affects the aggregation of amyloid beta (Aβ) proteins, which are implicated in Alzheimer's disease.

AstRNAuts and NUT
Investigating new molecular signatures of the space environment effect on human organisms.
These experiments analyse astronauts' biological samples collected at different times before and after the Ax-3 mission. AstRNAuts aims to characterize distinctively molecular signatures of circulating biomarkers that are altered upon space environment exposure. By comparing astronauts and submariners, NUT aims to distinguish the alterations induced by microgravity and cosmic rays, stressors peculiar to the space environment, from those induced by isolation and confinement, common to the ISS and submarines. Together, the results may contribute to improve astronauts' health status monitoring and to developing point-of-care devices for diagnosis and prognosis of diseases on Earth.

EMSi
Monitoring mobility functions to inform real-time countermeasures to muscle loss. EMSi is a joint experiment between ItAF and ASI. It is an intra-vehicular suit measuring muscle activity during astronauts' daily activities while applying compression to counteract shifts in body fluid distribution. It will be upgraded with electrostimulation properties to prevent microgravity-induced muscle loss. EMSi can improve astronaut health during future space missions, besides supporting muscle rehabilitation therapy or muscle strengthening on Earth.

asi activities in astrobiology

The search for life beyond Earth is one of the scientific topics that in recent years has been attracting growing interest nationally and internationally.

ASI decided to invest in this research area with a national announcement of opportunity in 2017, following which a group of 11 research teams belonging to the leading Italian universities and research institutions was supported to increase knowledge in the field. Hence the project "Life in Space: Origin, Presence and Persistence of Life in Space, from molecules to extremophiles" (2019 – 2023), which embraces the four most important topics in astrobiological research, where the Italian contribution is relevant. "Life in Space" included the study of prebiotic organic compounds formation on ice and gas for conditions expected on Pluto, icy moons, and comets, and explores the possible synthesis of prebiotic compounds in non-aqueous solvents such as liquid methane/ethane as is present on Titan. The study of origins of life investigated the formamide as a precursor to more complex organic substances, such as nucleic acids. The project focuses also on "Limits of Life" which investigates the biology and limits of adaptation of extremophiles, specifically Archaea from extreme solfataric environments, microfungi from polar regions, and cyanobacteria from hot and cold deserts. In addition, cyanobacteria and microfungi were investigated under simulated Mars and icy-moon conditions and M-star simulated irradiation, with the scope of elucidating the limits of life and adaptability under non-Earth conditions, as well as the permanence of their biomarkers. Finally, the project contributed to our understanding of Life Detection beyond Earth for future exploration missions, by investigating biomolecule interactions with mineral surfaces, and the identification of atmospheric and reflectance spectroscopic biomarkers of gases and pigments, respectively, from oxygenic photosynthetic extremophiles. Remote biosignatures were also studied, by modelling approaches, in exoplanets that could accommodate a biosphere.

Inspired by the successful initiative of "Life in Space" of bringing together different expertise in astrobiology, between 2020 and 2022 ASI promoted the definition of a national long-term astrobiology roadmap, which identifies specific areas of interest for the community, including analogue environments and extremophiles to understand processes underlying habitability; the development of more effective proxies for life detection (biosignatures); macromolecule synthesis, stability, and function in the context of plausible prebiotic conditions and environments; development of activities, including space missions, scientific experiments and theoretical modelling, devoted to the detection of life as well as to the determination of habitable conditions within worlds beyond the planet Earth. For each of these areas, the roadmap specifies several key scientific objectives with associated priorities and suggests ways to achieve them. The roadmap will drive the Italian astrobiology communities to overcome the major ongoing challenges that astrobiologists will tackle over the coming decade and to prepare the future exploration programs.

In this framework, in 2023 ASI selected and financed seven research projects in two main areas: (1) identification and development of prototypes/demonstrators/technologies for data analysis and modeling to support future space missions aimed, in particular, at the study of the origin of life and human and robotic space exploration (four projects); (2) identification of elements for human and robotic space exploration, using Terrestrial Analogue sites for scientific experimentation (three projects). Within the first area, the projects:

VENOM proposes to develop a lab-on-a-chip able to provide a highly-integrated multiparametric in situ platform utilizing immuno- and enzyme-assay for the assessment of biogenic compounds from icy samples extracted from the surface of Europa or from the plume of Enceladus.

BESIDES aims to develop a lab-on-chip technology for the search of past and present life in robotic and human space exploration missions, based on the recognition of organic molecules and molecular biosignatures correlated with life processes.

MIGLIORA aims to define an highly innovative astrochemical, chemical-prebiotic and biomolecular experimental models capable of predicting and analyzing the mechanisms that regulate molecular complexity evolution and the Origins of Life.

CASPR proposes studies on how solar UV irradiation and ferromagnetic fields induces homochirality due to interactions between the electron spin and the chiral molecular structure.

Within the second area, the three selected projects **A**STERIA, CRYPTOMARS and HELENA share the goal of exploring the origin of life, evolution, and habitability in Planetary Field Analogue by combining planetary science, geology, and microbiology.

ASTERIA aims to investigate the UVR adaptability of cyanobacteria capable of far-red photosynthesis to define surface habitability of Archean Earth, Noachian Mars and exoplanets around M stars.

CRYPTOMARS aims at characterizing Antarctic Cryptoendolithic communities, in terms of genetic and functional diversity, to understand how life originated, spread and perpetuated on Mars or other planets Mars-like.

In the project **HELENA**, the Bagno dell'Acqua lake, located at the border of a volcanic caldera with hydrothermal activity, will be characterized from an astrobiological perspective and compared with Martian paleolakes, such as the one that was presumably hosted into the Mars' Gale Crater.

on-ground asi activities

Space agencies are taking steps to begin the next era of exploration, to push the boundaries of human exploration forward to the Moon and on to Mars.

The first steps aim towards establishing a permanent human presence around the Moon. The Lunar Gateway and the lunar missions will be the testbed for new tools and equipment that could be used on the 55 million km trip to Mars, including technologies required to build self-sustaining outposts away from Earth using in situ resources. Many questions are still open and there are unique biological and biomedical challenges to be solved. The increased distance from the Earth is itself a challenge, for self-sufficiency and medical emergencies. In addition, the Space environment is characterized by altered gravity and large doses of Space radiation, which affect biological systems at both physiological and cellular levels. Other challenges arise instead from the environmental limitations of habitats in Space, being it a spacecraft or a planetary base. Life in an isolated and confined closed environment can have detrimental effects on the wellbeing of the crew and on their health. Confinement represents a risk if habitat conditions are not properly and safely set, and pathogens are not kept under control. This is also true for those organisms that could be brought by the crew, like plants and beneficial microorganisms.
Owing to limited access to spaceflight platforms, scientists rely on on-ground experiments in simulated space conditions to further our understanding of the effects of the space

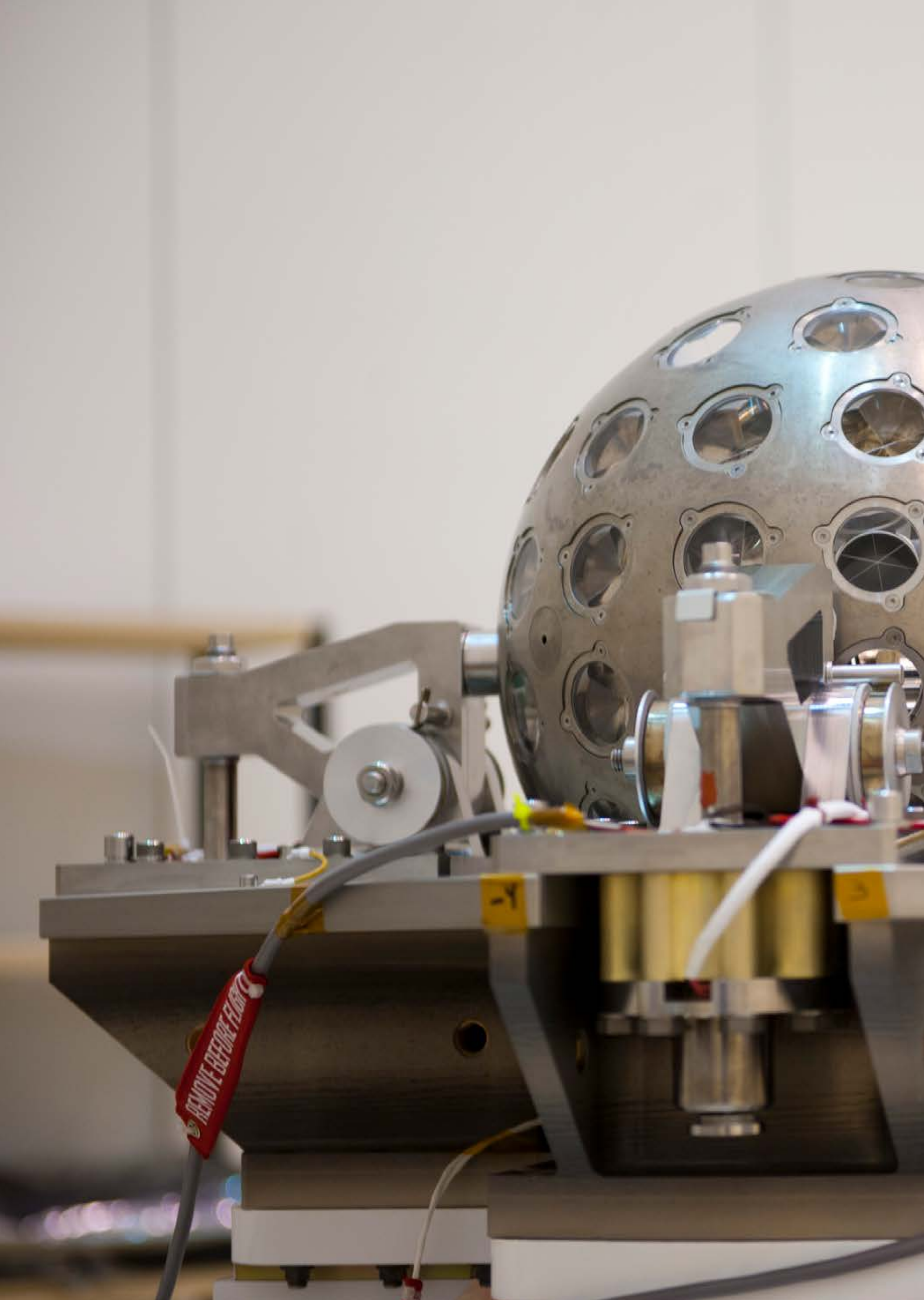
environment on living organisms. In this context, ASI has invested in the progress of Space Life Science research to advance the technologies and biotechnologies necessary for a successful human presence in Space. The Mars-Pre (2019-2022) and ReBUS (2019-2023) projects address the physiopathological response to altered gravity and bioregenerative life support systems, respectively.

MARS-Pre

The "MARS-Pre, BioMARkers for aStronautic Precision biomedicine" project was devoted to the identification of functional biomarkers for characterizing alterations of body functions induced by altered gravity conditions. Human presence in Space has uncovered several health concerns related to the Space environment that need to be addressed for future space missions. The MARS-Pre project undertook an integrated physiology approach in simulated space conditions to monitor early adaptations of living organisms to micro- and hypo-gravity. To this aim, several on-ground models were used, such as hindlimb unloading (HU) in mice, unilateral lower limb suspension (ULLS) and bed rest (6° head-down bed rest), immersive multisensory virtual reality and weight relief in humans. Each experimental condition was used to conduct a wide spectrum of analysis, such as biochemical analysis of body fluids (blood, urine, and saliva) and muscle biopsies; structural analysis of tissues through imaging technologies; functional and sensorimotor tests. This ambitious project involved 21 different operating units, involving 116 researchers from many areas of the national territory, allowing the identification of innovative early biomarkers of the main dysfunctions induced by altered gravity, including muscle atrophy, osteoporosis, alterations of the cardiovascular, pulmonary and renal systems, metabolic system, immune system, nervous system and behavior modifications. These results may contribute to the development of appropriate countermeasures and point-of-care diagnostic systems, enabling elements for future deep space exploration missions.

ReBUS

The 'In-Situ Resource Bio-Utilization For Life Support System (ReBUS)' project is aimed at creating bioregenerative life support systems to support human exploration of space. It is now accepted that man can survive in Space, but the challenge we face today is to guarantee the sustainability of long-term missions. As mission objectives move away from Low Earth Orbit, the development of bioregenerative life support systems becomes essential: these systems must be able to regenerate the resources, providing adequate living conditions and minimizing the need for supplies from Earth. Bioregenerative life support systems represent real closed ecosystems, where higher plants, algae and cyanobacteria are the autotrophic producers, astronauts are the consumers, and bacteria and fungi are the decomposers. Systems of this type should perform the following tasks: regeneration of the atmosphere (production of oxygen and absorption of carbon dioxide), recovery and purification of water, production of fresh food, recycling of waste materials (i.e. residues from plant cultivation, wastewater of the crew). By integrating different organisms, the ReBUS project aims at answering many of the open questions regarding the creation of an integrated Bioregenerative Life Support Systems in space. The principles of the ReBUS project are: minimizing the use of exogenous resources; maximizing the recycling of the organic matter produced in the system itself (e.g. crop residues, crew physiological waste); exploiting the use of the in-situ resources (i.e. Lunar and Martian soils, water, and gas present in the atmosphere). This has been achieved through an integrated network of organisms: higher plants, fungi, bacteria, cyanobacteria, insects. The topic of bioregenerative environmental control and life support systems is strongly connected to the more traditional sectors of agriculture and civil engineering There's therefore high potential to transfer knowledge and technologies developed for Space, with significant impacts in area of environmental sustainability, optimization of resource use and energy efficiency.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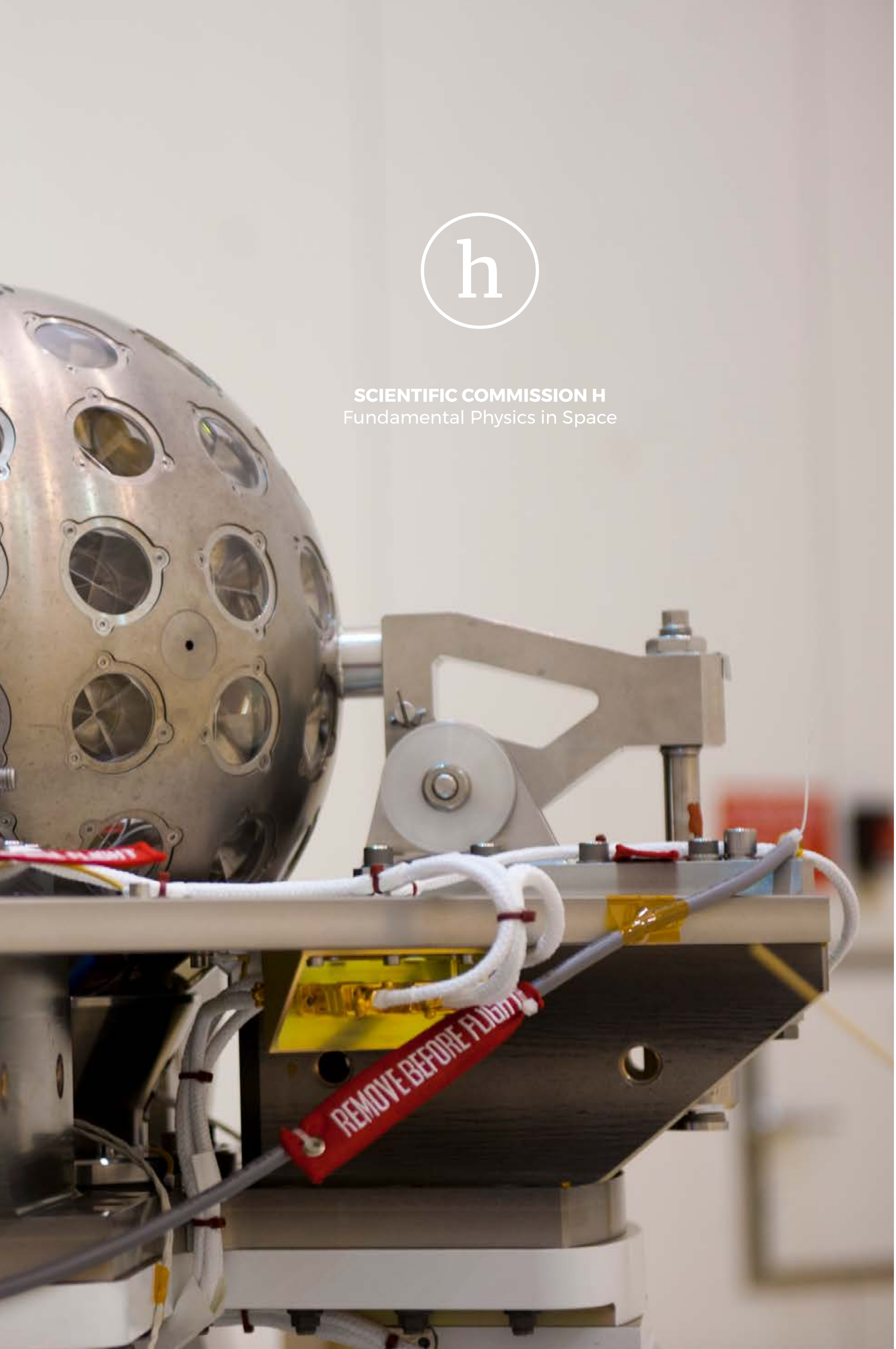


SCIENTIFIC COMMISSION H
Fundamental Physics in Space

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

ams-02

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

The Alpha Magnetic Spectrometer (AMS-02) is a high-energy particle physics spectrometer launched onboard the Space Shuttle Endeavour and installed on the ISS in 2011. AMS-02 has been collecting an unprecedented statistic of more than 230 billion cosmic rays in 12 years of continuous operations. AMS-02 is expected to collect data up to the end of the ISS lifetime, thanks to the upgrade performed in 2020 with the successful installation of the Upgraded Tracker Thermal Control System, which required a series of four challenging extra vehicular activities outside the ISS.

AMS-02 is the only detector able to separate matter from anti-matter on the ISS. Positive and negative particles are bent differently by the AMS-02 high-intensity permanent magnet. The particle sign and momentum are derived by measuring the curvature of the trajectory with a tracking system. Additional subdetectors provide complementary and redundant information on the particle that allows for precise identification of each cosmic ray. With the large statistics of measured cosmic ray species such as electrons, positrons, protons, antiprotons, helium, and nuclei with $Z>2$ up to iron, AMS-02 is being revealing many unexpected signatures in the cosmic ray spectra that have driven a profound revision of the standard models of cosmic ray origin, acceleration, and propagation. A deeper knowledge of cosmic ray physics in turn allows looking for tiny deviations in the cosmic ray spectra that Dark Matter annihilations can cause.

AMS-02 collected data over an entire 11-year solar cycle, measuring precisely daily variations of spectra of particles. The study of short-term and long-term variations of cosmic ray fluxes can be used to deepen the knowledge of the ever-changing conditions of the heliosphere.

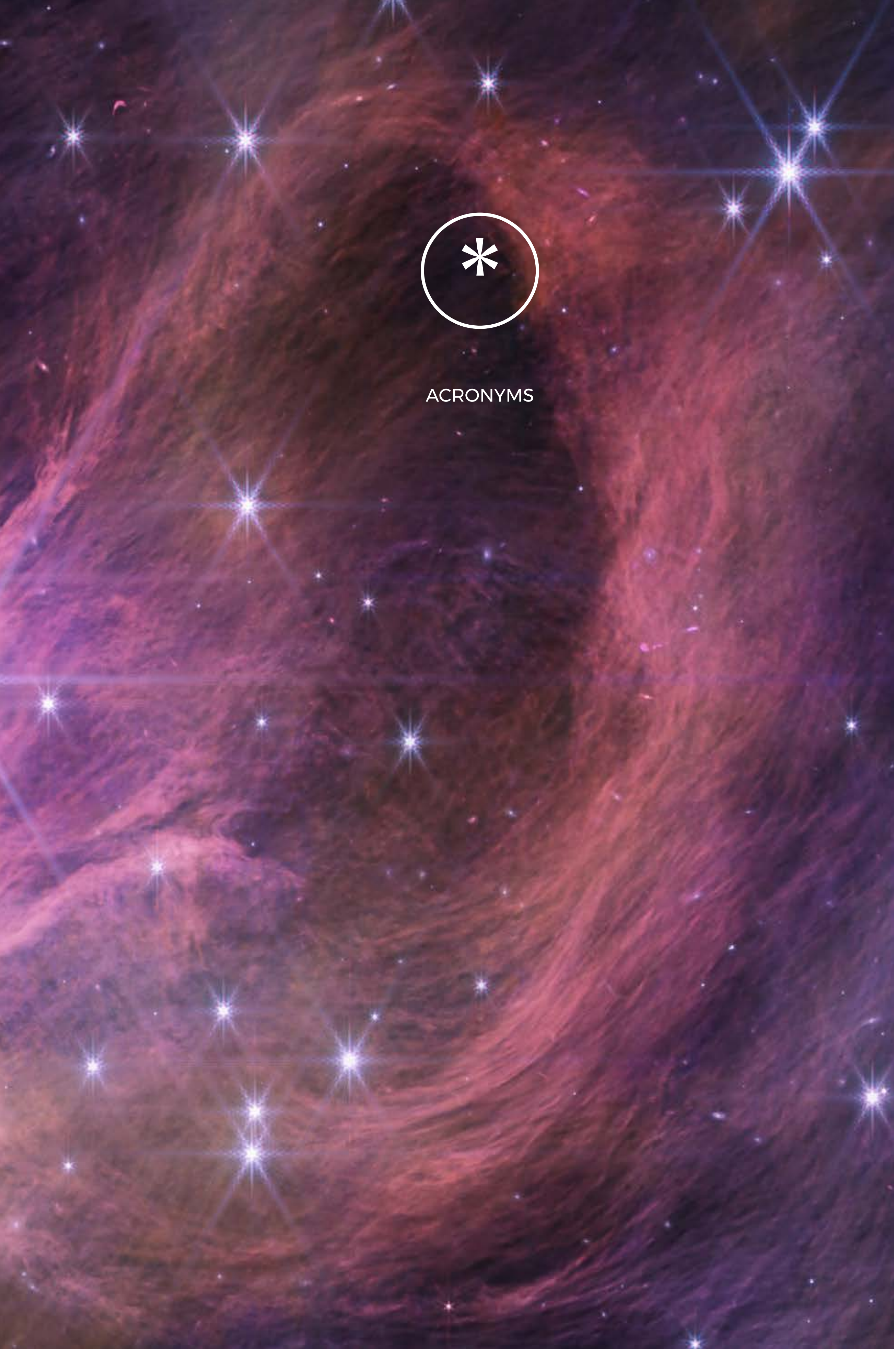
The AMS collaboration proposed an upgrade of the instrument that NASA has recently approved. The upgrade consists in the installation of an additional tracking layer on the top of the existing instrument. This will extend the instrument acceptance by a factor of 3, maximizing the scientific prospects of the remaining data taking time on the ISS.

AMS is an international collaboration of 44 institutions from America, Europe, and Asia. Scientists from INFN, ASI, and Italian Universities contribute to the detector operations, upgrade construction and testing, 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 and LARES-2 are two ASI laser-ranged satellites, launched respectively in 2012 and 2022, aiming at highly accurate 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. It is covered with 92 retroreflectors distributed on its surface. LARES-2 (LAser Relativity Satellite-2) is an ASI new generation high-altitude laser-ranged satellite launched with VEGA C in 2022 at about 12270 km of altitude. LARES-2 is made of high-density material to minimize the non-gravitational orbital perturbations acting on it. It is covered with 303 retroreflectors distributed on its surface. An high-precision determination of their orbits is achieved thanks to the very precise Satellite Laser Ranging (SLR) measurements, provided by a worldwide network of stations coordinated by the International Laser Ranging Service (ILRS). The main purpose of the two satellites is to enable highly accurate verifications of General Relativity theory and perform other fundamental physics tests. Of particular interest is the verification of frame-dragging, which is an intriguing phenomenon predicted by General Relativity: in Einstein's gravitational theory of 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). 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. Through the analysis of the LARES and LARES-2 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 a 2% accuracy. Independent analyses performed at INAF-IAPS confirmed and strengthened this result. The LARES and LARES-2 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-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

Previous page: This image from the NIRCam instrument on JWST shows the central portion of the star cluster IC 348. Credit: NASA/ESA/CSA/STScI.

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

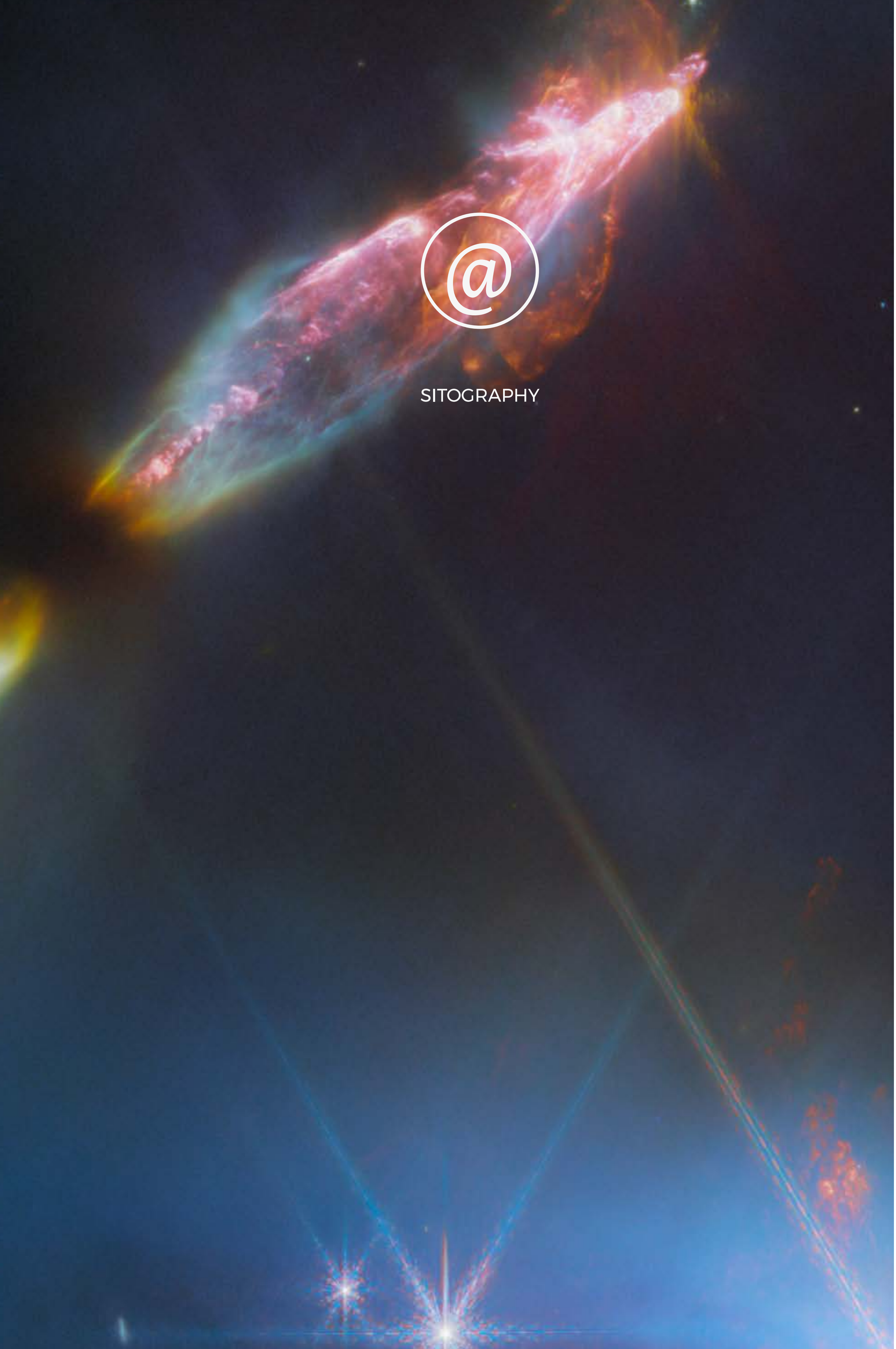
PNRA - National Antarctic Research Program

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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Previous page: JWST's high resolution, near-infrared look at Herbig-Haro 211.
Credit: ESA/Webb, NASA, CSA.

sitography

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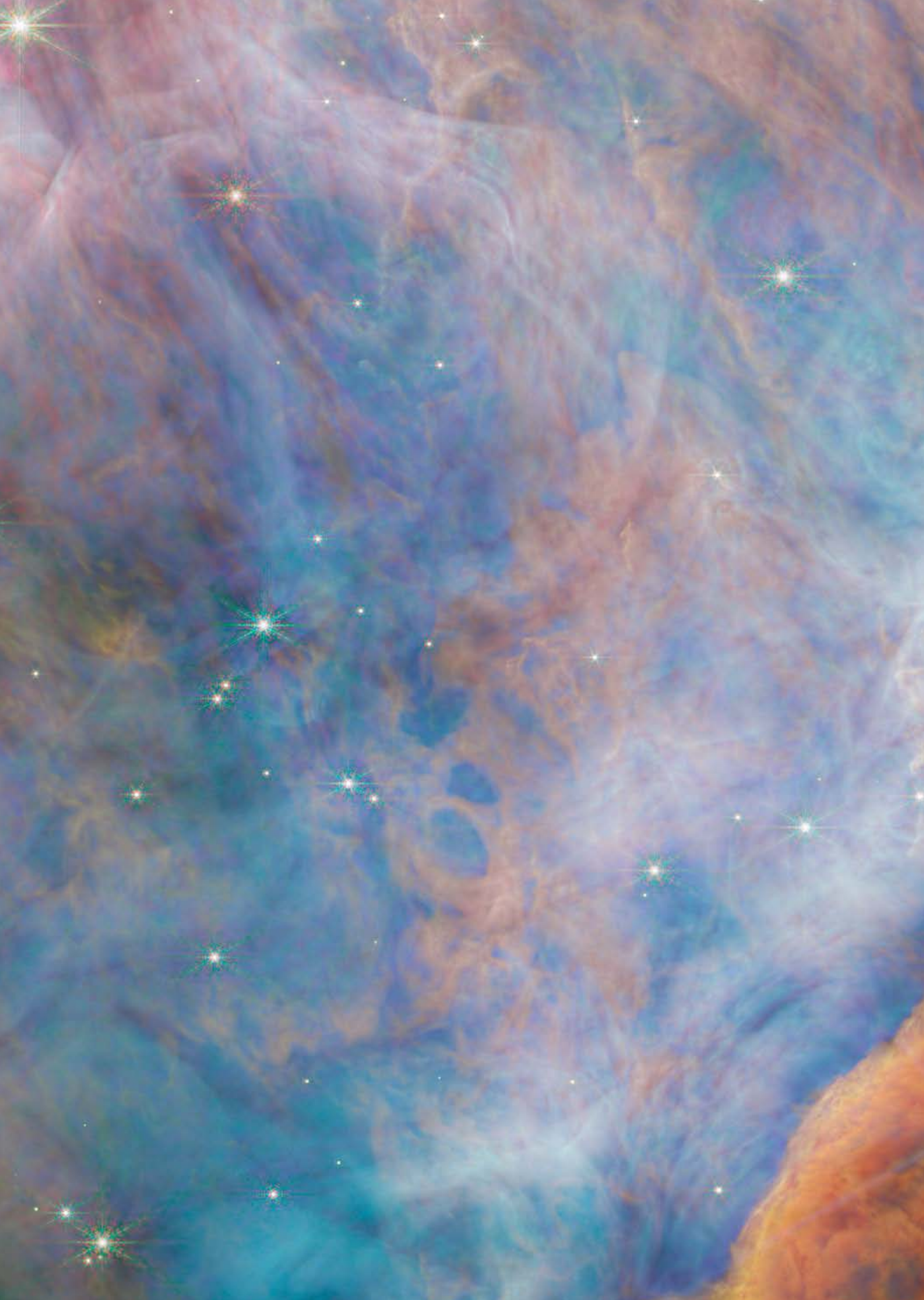

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Previous page: This image taken by Webb's NIRCam shows a part of the Orion Nebula known as the Orion Bar. Credit: ESA/Webb/NASA/CSA, Mahdi Zamani, PDRs4ALL ERS Team.

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