Curriculum 1

(1A) Study of the high energy cosmic radiation with space-based missions and corresponding detector design and optimization

(1B) Multi-wavelength observations of Galactic and extragalactic compact objects and transients

(1C) Galactic science with Cherenkov Telescope Array within the project CTA+ funded by the PNRR with CUP C53C22000430006

(1D) Analysis, Combination and Interpretation of Space Measurements of Galactic, Extra-Galactic and Cosmological Electro-Magnetic and Gravitational Radiation

(1E) Multi-messenger and multi-wavelength observations of Cosmic Rays accelerators

(1F) Understanding the production mechanism of light antinuclei to constraint indirect searches for dark matter annihilation in space

(1G) Constraints from space borne observations of the cosmic microwave background and of the large scale structure of the Universe

(1H) Space based observations and experiments for the detection of cosmic sources and the characterization of their physical properties

(1L) Modeling and experimental study of astrophysical processes across the electromagnetic spectrum

(1M) Multimessenger and multiwavelength signals of particle dark matter

(1N) Measurements of antimatter in space

Curriculum 2

(2A) Studies of the coupling processes of geospheres (from the lithosphere to the upper atmosphere) induced by volcanic activity

(2B) Space physics and Sun-Earth relations

(2C) Study through nanosatellites of solar drivers and Sun-Planet interaction in the context of Space Weather

(2D) Deep Learning for Time-transient phenomena in the ionosphere and correlation with seismo-induced events

Curriculum 3

(3A) Sensors and techniques for the exploration of the Solar System

(3B) Mathematical challenges in space science: theoretical and computational methods in Celestial Mechanics and Astrodynamics

(3C) Natural and synthetic analogues of the planet Mercury: mineralogical and petrological aspects

(3D) Search, characterization and exploration of exoplanets and exoplanetary systems

(3E) Analysis of planetary data acquired by remote sensing and radar instruments

Curriculum 4

(4A) Bioactive lipids and resolution of inflammation in microgravity

(4B) Molecular modifications induced by long term spaceflight in humans and in experimental biological models. Focus on innovative countermeasures to support space exploration

(4C) Astrobiology, Life Science and Space Medicine

(4D) Bioengineering approaches to neurophysiology in the space environment

(4E) Physiological adaptations and behavioral alterations in extreme environmental conditions and microgravity

Curriculum 5

(5A) Space Surveillance and Tracking with Radar Systems

(5B) Study, design and qualification of electronics and electro-optical systems for space applications

(5C) Space compliant LGAD sensors

(5D) Design and prototype characterization of innovative high energy particle detectors for space application

(5E) Photonic Integrated Sensor Systems for Space Applications

(5F) Modular observatories to study the most energetic events in the Universe

(5G) Design, simulation and test of a not-imaging space detector devoted to cosmic-rays studies

Curriculum 6

(6A) Advanced manufacturing of microwave and millimeter/sub-millimiter-wave and components for Space payloads

(6B) Model-based software engineering and formal methods for space systems

(6C) Self-antifrosting microstructured surfaces

(6D) Antennas, sensors and RF systems for satellite applications

(6E) Engineering challenges for future 'near-Earth' missions

(6F) Telecommunication systems: High frequency transceiver systems for small satellites, towards a 5G transceiver in Ka band

UNIVERSITÀ DI TRENTO

PhD SST
Space Science and Technology

Curriculum 1

- (1A) Study of the high energy cosmic radiation with space-based missions and corresponding detector design and optimization

Funding institution: Gran Sasso Science Institute - GSSI
Doctoral site: L'Aquila
Contact: Ivan De Mitri (ivan.demitri@gssi.it)

The PhD student will be fully involved in the activities of the GSSI group for the experimental study of cosmic radiation with space based detectors.
His/her research work will be focused on one (or more) activities carried on by the group, also depending on the student proposal.
These includes the study of galactic cosmic rays (CR) up to about 100 TeV through the analysis of the data of the DAMPE mission, the GSSI being part of the international collaboration, and the R&D and detector optimization activities on future space missions for the study of CRs, gammas and neutrinos, also through dedicated Monte Carlo simulations: HERD (a CR detector that would reach few PeVs in energy range thanks to its innovative design and large acceptance), NUSES (a GSSI led project aiming at the validation of new technologies and observational approaches in the studies of ultra high energy CRs and neutrinos, but also low energy phenomena and interdisciplinary applications), Crystal Eye (for the detection and study of 0.1-10MeV photons emitted by transient or steady astrophysical sources).
The activity will be carried on in the Astroparticle Physics division of GSSI (and the nearby LNGS lab) and its international atmosphere with students, researchers and faculties coming from all over the world (www.gssi.it).

- (1B) Multi-wavelength observations of Galactic and extragalactic compact objects and transients

Funding institution: Istituto Universitario di Studi Superiori - IUSS Pavia
Doctoral site: Pavia
Contact: Paolo Esposito (paolo.esposito@iusspavia.it)

This scholarship will entail working on a variety of cutting-edge research topics, investigating at all wavelengths compact objects (white dwarfs, neutron stars and black holes, with particular attention to the supermagnetic pulsars known as magnetars and the extragalactic ultraluminous X-ray sources) and astrophysical transients (including rapid localization of outbursts from compact objects, electromagnetic counterparts of gravitational wave sources, fast radio bursts, gamma-ray bursts, and tidal disruption events). The successful candidate will work on the analysis of data from space-borne and ground-based instruments, their

interpretation, and on the optimization of observing and data-mining strategies. Participation in the development of new observatories and instruments will be possible as well.

- (1C) Galactic science with Cherenkov Telescope Array within the project CTA+ funded by the PNRR with CUP C53C22000430006

Funding institution: Istituto Universitario di Studi Superiori - IUSS Pavia
Doctoral site: Pavia
Contact: Paolo Esposito (paolo.esposito@iusspavia.it)

The Cherenkov Telescope Array (CTA, https://www.cta-observatory.org/) will be the largest ground-based gamma-ray observatory in the world, with more than 100 telescopes in both hemispheres. It will be several times more sensitive than the current detectors (HESS, MAGIC and VERITAS) and its angular resolution will be unprecedented, making it possible to probe the physical processes at work in some of the most extreme environments in the Universe. CTA will be able to detect hundreds of objects in the Milky Way. These Galactic sources will include the remnants of supernova explosions, the rapidly spinning neutron stars known as pulsars, pulsar wind nebulae, black holes, microquasars and gamma-ray binary systems hosting a compact object. The CTA data will give us a picture of the conditions and physical processes occurring in and around these objects, providing new insights on particle and cosmic rays acceleration up to PeV energies and gamma-ray emission processes. In this PhD project, these phenomena will be explored on the basis of existing data and models, and the expected performances of the CTA observatory; a contribution to the optimization and development of the instrumentation will be possible as well.

- (1D) Analysis, Combination and Interpretation of Space Measurements of Galactic, Extra-Galactic and Cosmological Electro-Magnetic and Gravitational Radiation

Funding institution: Scuola Internazionale Superiore di Studi Avanzati
Doctoral site: Trieste
Contact: Carlo Baccigalupi (bacci@sissa.it)

SISSA (sissa.it) participates with roles of responsibility to several global programs for the investigation of fundamental physics through Space Research for the Observations of the Universe, in an integrated manner with other Institutions in the network represented by the SST PhD. The targets of these campaigns concern Cosmological and Astrophysical Gravitational Waves (CGWs, AGWs), Cosmic Microwave Background (CMB), Large Scale Structure (LSS) and Dark Marter (DM), Galaxy Formation and Evolution (GFE), High Energy Astrophysics (HEA) and Compact Objects (CO).

Space Programs at SISSA include the LiteBIRD Satellite for the observations of CGWs from CMB Polarization, as well as the Euclid Satellite for LSS, Global Astrometric Interferometer for Astrophysics (GAIA), the James Webb Space Telescope (JWST), and the preparatory work for the Interferometer Space Antenna (LISA).
In addition, SISSA leads areas of work in relation to Ground-Based observatories exploiting technology operating in Space, in particular for what concerns the combination of Ground and Space based probes, such as the Simons Observatory and CMB-Stage IV for CMB research of primordial gravitational waves, the Atacama Large Millimeter/Sub-Millimeter Array (ALMA) and the Squared Kilometer Array (SKA) for LSS and GFE, the LIGO/VIRGO and Eistein Telescope (ET) for the AGWs observations and CO investigations.
Moreover, SISSA leads the study and exploitation of innovative Data Science based methods of analysis in these contexts, with the design of the innovative Statistical and Learning algorithms which are necessary to deal with the complexity of the Datasets coming from the Probes listed above, both in the analysis and combination.

Applications are welcome on each of these research lines, characterized by diversity and balance in all respects, from motivated young scientist, to undertake a PhD Program in SST in relation to the programs above. The latter possesses an high level of integration between Italian institutions participating to the PhD and of course centers of research abroad, connected with the quoted projects. The students are expected to attend a series of courses to be specialized for the PhD Program, share the research with other Institutions within the SST PhD, and spend a minimum period of 6 months abroad.

- (1E) Multi-messenger and multi-wavelenght observations of Cosmic Rays accelerators

Funding institution: University of Bari “Aldo Moro”
Doctoral site: Bari
Contact: Domenico Capolongo (domenico.capolongo@uniba.it)
Francesco Giordano (Francesco.Giordano@ba.infn.it)

Recently many signatures about the possibility to see gamma rays emitted in hadronic processes have been discovered in different astrophysical sources. In this view, a multi wavelength approach is fundamental to disentangle the different mechanism behind the gamma rays fluxes observed emitted by both galactic and extragalactic objects. The project aims at studying the gamma rays from different sources in steady and / or flaring episodes in order to obtain further confirmation about the acceleration processes, also considering a possible multi messenger approach.

- (1F) Understanding the production mechanism of light antinuclei to constraint indirect searches for dark matter annihilation in space

Funding institution: University of Brescia
Doctoral site: Brescia
Contact: Ramona Leo (ramona.lea@unibs.it)

In the past few years there has been an increasing experimental effort to detect cosmic-ray anti-nuclei as a signature of the dark matter (DM) annihilation, which should be seen as an excess above the astrophysical background. This potential breakthrough discovery, must be compared with theoretical predictions which suffers from a severe lack of knowledge of the anti-matter production in space. The main limitations for detailed studies of anti-nuclei come from the difficulty in producing anti-nuclei beams in laboratory. To overcome this problem, the Large Hadron Collider (LHC) can be used as an efficient antimatter factory, allowing for precise study on the production mechanism of light antinuclei.

The PhD candidate will study the production of light antinuclei (anti-d and anti - 3He) in different collision systems, exploiting the unique particle identification capability and the large statistics that will be collected by the ALICE experiment at the LHC during the ongoing Run 3. Simultaneously, the size of the source from which light antinuclei are produced will be measured by means of the two-particle momentum correlation using protons. The combined measurements will be compared with the state-of-the-art theoretical models usually used to describe light nuclei production mechanism in different environments, and allowing to disentangle among them.

- (1G) Constraints from space borne observations of the cosmic microwave background and of the large scale structure of the Universe

Funding institution: University of Ferrara
Doctoral site: Ferrara
Contact: Paolo Natoli (ntlpla@unife.it)

The cosmology group at the Department of Physics and Earth Sciences, University of Ferrara (https://www.fe.infn.it/cosmologia/index.php/home/?lang=en) is active on several research aspects in cosmology, from cosmo-particle projects with a mostly-theoretical flavour to the development and validation of data analysis pipelines. The group is deeply involved in space-borne projects for the cosmic microwave background (CMB) and large scale structure (LSS), including Planck (legacy), LiteBIRD, Euclid, as well as in sub-orbital efforts complementary to space probes, including LSPE, Simons Observatory, CMB-S4.

Applications are invited from strongly motivated prospective students to join the group's activities as part of the SST National Doctorate program. Possible research topics include:

pipeline development for next generation CMB experiments, cross-correlation of CMB data with large-scale-structure surveys, likelihood analysis, cosmological model building and investigation of fundamental physics with present and upcoming cosmological datasets. Students will be required to spend at least six months abroad, visiting one or more of the several foreign acquaintances of the group. Possibilities include several countries in Europe, the US and Canada, Japan and Vietnam.

The group has access to High Performance Computing facilities and maintains close connections with the National Institute for Nuclear Physics (INFN), the National Institute for Astrophysics (INAF) and the HPC consortium CINECA. The group currently includes 5 staff, 3 postdocs and 7 PhD students.

- ## (1H) Space based observations and experiments for the detection of cosmic sources and the characterization of their physical properties

Funding institution: University of Florence
Doctoral site: Florence
Contact: Alessandro Marconi (alessandro.marconi@unifi.it)

The PhD candidate will work on the analysis and physical interpretation of data from satellite or space station based observations of astrophysical sources, cosmic rays or experiments of fundamental physics.
The Department of Physics and Astronomy of the University of Florence is involved in many research projects based on data from satellites and possible research activities are related, but not limited to: the analysis of James Webb Space Telescope (JWST) observations of Galaxies and Active Galactic Nuclei from low to high redshift, the analysis of the heliospheric plasma from space based observatories, the analysis of cosmic rays detected by the CALET experiment, design of new on-orbit experiments for cosmic rays detection, precision tests of gravitational physics and general relativity with quantum sensors.

- ## (1L) Modeling and experimental study of astrophysical processes across the electromagnetic spectrum

Funding institution: University of Pisa
Doctoral site: Pisa
Contact: Luca Baldini (luca.baldini@unipi.it)

The focus of the scholarship lies at the intersection of various, diverse and yet tightly interconnected, lines of research. Possible topics related to the modeling and/or simulation of astrophysical processes include space plasmas (e.g., magnetosphere models, turbulence,

particle acceleration, magnetic reconnection), matter at extreme density (compact objects, neutron star mergers) and stellar Physics (inner structure of the Sun, helioseismology, habitability zone of exoplanets).
On the experimental side, the number and relevance of the participations of the Department in currently operating space missions (e.g. Fermi, IXPE, Solar Probe, Solar Orbiter) offer the opportunity for significant contributions in the analysis and scientific exploitation of the data being collected. Contributing to the development phase of new-generation missions such as e-XTP and LiteBird is also a possibility.
Contaminations between different lines of research are possible (and encouraged) for several specific topics.

- ## (1M) Multimessenger and multiwavelength signals of particle dark matter

Funding institution: University of Turin
Doctoral site: Turin
Contact: Nicolao Fornengo (nicolao.fornengo@unito.it)

A long-standing hypothesis on the nature of dark matter is that it is composed by a new type of elementary particle. However, up to now its evidences are of purely gravitational origin and no direct and unambiguous proof that it is composed by particles has been provided. The goal of this project is to test the particle physics interpretation of dark matter by employing in a synergic way the information originating from the possible particle physics cosmic signals of dark matter in terms of messengers, namely charged cosmic rays, neturinos, photons. In particular, for electromagnetic signals the project aims at investigatin dark matter emissions across the whole electromagnetic spectrum and plans to extend recent techniques which attempt at cross-correlating radiative dark matter emissions with gravitational tracers of the same dark matter distribution in the Universe. The activity will be of theoretical and phenomenological nature.

- ## (1N) Measurements of antimatter in space

Funding institution: University of Trento
Doctoral site: Trento
Contact: Roberto Iuppa (roberto.iuppa@unitn.it)

The PhD project aims at studying a new experimental technique to directly and effectively measure cosmic antiparticles (antinuclei, positrons) from 1 GeV to 30 TeV, extending the reach of state-of-the-art experiments and improving their sensitivity in already explored rigidity regions. The candidate will work in close contact with the AMS-02 collaboration and

his/her work will regard both Monte Carlo simulation and hardware development, based on the ALADiNO and the LAMP proposals.

Curriculum 2

- (2A) Studies of the coupling processes of geospheres (from the lithosphere to the upper atmosphere) induced by volcanic activity

Funding institution: Istituto Nazionale di Geofisica (INGV)
Doctoral site: INGV sections in Rome and Catania
Contact: Giuseppe Puglisi (giuseppe.puglisi@ingv.it)
Fabrizia Buongiorno (fabrizia.buongiorno@ingv.it)

The impact of volcanic activity in the middle and lower atmosphere is well known, as well as its effects on society (e.g., the blocking of aviation operations in the European skies due to the eruption of Eyjafjallajökull in 2010). Less well known is the impact on the upper atmosphere, although recent eruptive events (e.g. the eruption of the Hunga Tonga in 2022) have shown that volcanic activity can cause major disturbances in the ionosphere. Satellite systems and technologies make it possible to give new perspectives to ongoing researchers on these issues.

The objective of the proposed scholarship is therefore the integration of satellite and terrestrial multiparametric data for the characterization of background conditions and for the study of coupling processes of geospheres in the presence of volcanic activity. The study will be aimed at identifying precursor phenomena and/or anomalies associated with the occurrence of volcanic activity. The impact of volcanic emissions (solid and gaseous) into the atmosphere will be studied, at different distances and altitudes from the volcano; furthermore, the study will be aimed at identifying the possible presence of any pre, on-going or post event anomalies of the main physico-chemical parameters of the atmosphere .

The application of artificial intelligence methods for the analysis of multiparametric data provided by the various satellite constellations and observational systems of the ground-based networks and the development of algorithms for modeling the coupling processes of the geospheres is envisaged. The models will be developed using Italian volcanoes as test areas, but also will be validated on case studies which have had an impact on a global scale.

The training activities will therefore be aimed at providing advanced data analysis tools, algorithmic development skills and knowledge relating to the physics of the atmosphere (at various altitudes), and to the pre-eruptive, eruptive and post eruptive processes that can impact the atmosphere.

The sections of the INGV involved in the activities of the National Doctorate are located in Rome (the three sections “National Earthquake Observatory”, “Rome 1” and “Rome 2”) and Catania (Mt. Etna Observatory) (https://istituto.ingv.it/it). The location of the PhD scholarship will be defined on the basis of the approved research project.

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- (2B) Space physics and Sun-Earth relations

Funding institution: University of Calabria
Doctoral site: Cosenza
Contact: Vincenzo Carbone (vincenzo.carbone@fis.unical.it)

The Sun is the primary source of energy for our planetary system. It determines the physical conditions of the heliosphere and near Earth space, and acts as the main engine on the climate of our planet. Furthermore, the interplanetary space is permeated by a supersonic plasma flow of solar origin which is highly turbulent, so that the interplanetary space represents the main “laboratory” where spacecrafts can obtain “in situ” measurements of plasma parameters.
Fluctuations in the magnetic field within the solar atmosphere act as complex modulations of plasma conditions in the interplanetary space, the fluxes of solar energetic particles (SEP) and cosmic rays, the UV component of the solar spectrum and sudden coronal mass ejections (CME). These events are associated with the origin of magnetic storms, which have important effects on our technological society, and possibly to changes the climate conditions through complex interactions with the Earth's atmosphere. On the other hand the generation of solar magnetic field has a well known 11-years cycle, all physical properties of the Sun follow this cycle, and this influences Earth on longer time-scales. An interdisciplinary approach is urgent to face problems related to different areas of solar and heliospheric physics, and on different time-scales. Among them, we recognize the generation and evolution of the multi-scale magnetic field, the physical processes able to heat the coronal plasma and generate the turbulent solar wind, the explosive and eruptive processes that give rise to magnetic storms and events associated with energetic solar particles, the transport of plasma to the magnetosphere within the turbulent solar wind, and finally the UV radiative input on the Earth's atmosphere able to influence the climate.

The investigation of solar and interplanetary space conditions, the understanding of the processes of interaction with Earth's magnetosphere and their observations are crucial to be able to predict and mitigate those phenomena that affect space and ground infrastructures or impair human health. For this reason, agencies and international panels include the study of Space Weather, such as the ESA with the Space Situational Awareness program, or attempt to quantify the effect of the solar radiation on the Earth's climate and its variations, such as the Intergovernamental Panel on Climate Change.

Candidates are encouraged to present PhD projects addressing some of the main issues concerning the nature of variability of solar activity and the physics of interplanetary space, including the effects on Space Weather and Earth's climate through the analysis of data obtained from observatories in space and ground-based, through the construction of theoretical models, and through direct numerical simulations of the basic physical processes.

- ## (2C) Study through nanosatellites of solar drivers and Sun-Planet interaction in the context of Space Weather

Funding institution: University of Rome Tor Vergata
Doctoral site: Rome
Contact: Francesco Berrilli (francesco.berrilli@roma2.infn.it)

Space Weather is focused on studying the physical conditions of the Sun, interplanetary space and the circumterrestrial environment. Especially, when these conditions can affect satellite operations and ground technology or put the health of astronauts at risk, especially during Extravehicular activity (EVA) or while exploring deep space. The physical processes related to the solar energy radiative emission (X and Gamma) and the interaction of the solar magnetized plasma with the circumterrestrial environment, at the origin of the Space Weather phenomena, are particularly important. The thesis project aims to improve the understanding of solar drivers (flare, CME, EPS, ..) and of the physical processes connected to them that are the basis of the coupling of solar radiation and plasma-upper earth's atmosphere through measurements with innovative instrumentation from nanosatellite, in different types of orbit, with the support of ground-based instrumentation. The data produced by the Solar Orbiter and Parker Solar Probe heliophysics missions will provide useful additional information in this context.

- ## (2D) Deep Learning for Time-transient phenomena in the ionosphere and correlation with seismo-induced events

Funding institution: Fondazione Bruno Kessler
Doctoral site: FBK- Trento; University of Trento
Contact: Marco Cristoforetti (marco.cristoforetti@fbk.eu)
Roberto Iuppa (roberto.iuppa@unitn.it)

The Limadou project gathers some Italian institutions participating in the China Seismo Electromagnetic Satellite (CSES) mission. CSES consists of a constellation of satellites, designed to pursue the deepest campaign of observation of the ionosphere. One of the most important scientific goals of the mission is to look for correlations between transient phenomena in the ionosphere and seismic events. Among payloads, a set of particle detectors is devoted to the detection of charged particles trapped in the Van Allen Belts, to monitor the solar activity and to measure galactic cosmic rays of very low energy. The APP group of the Physics Department in Trento looks for candidates to a PhD programme on the analysis of the scientific data from the payloads on board the CSES-01 and those to be launched on board the satellite CSES-02 in 2022. The student will focus on time-series analyses and participate in the development of the event reconstruction software. These studies will be carried out using the most modern machine learning techniques for clustering and anomaly detection, using full information from CSES payloads. The activity will be carried out in collaboration with INFN-TIFPA, Fondazione Bruno Kessler and the Institute of

the High Energy Physics of Beijing. Candidates familiar with the experimental techniques for the detection of charged particles in space are welcome, as well as basic knowledge of Machine Learning/Deep Learning is recommended.

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Curriculum 3

- (3A) Sensors and techniques for the exploration of the Solar System

Funding institution: Istituto Nazionale di Astrofisica - INAF
Doctoral site: One of INAF site in Italy
Contact: Francesca Esposito (francesca.esposito@inaf.it)
Fabrizio Fiore (fabrizio.fiore@inaf.it)

The range of possible fields of scientific research connected to this theme is very broad and can range from the development of innovative sensors for space missions dedicated to the exploration of the Solar System, to the planning and design of new missions, to the laboratory study of planetary analogues, to the simulation of environments and processes active in the Solar System, to the study of the characteristics of the bodies of the Solar System starting from the analysis of the data acquired by the various space missions, to the development of theoretical models that describe processes and phenomena active in the Solar System. The candidate, in agreement with the supervisor, will be able to choose the scientific theme most akin to his/her interests and training. He/she will then be able to carry out his/her research activity at one of the INAF sites where there are research groups interested or active in the identified scientific field.

- (3B) Mathematical challenges in space science: theoretical and computational methods in Celestial Mechanics and Astrodynamics

Funding institution: Istituto Nazionale di Alta Matematica - INDAM
Doctoral site: Padova, Pisa, Roma Tor Vergata o Torino
Contact: Giovanni Federico Gronchi (giovanni.federico.gronchi@unipi.it)

This grant is devoted to the study of mathematical problems arising in the field of the dynamics of celestial bodies, taking also into account their applications to astronomy and space navigation, e.g. orbit determination, the N-body problem, low-thrust orbits in space missions. The techniques employed to deal with these problems can belong to different branches of mathematics, e.g. general theory of dynamical systems, perturbation theory, calculus of variations, computational algebra, numerical analysis.

- (3C) Natural and synthetic analogues of the planet Mercury: mineralogical and petrological aspects

Funding institution: University of Florence

Doctoral site: Florence
Contact: Giovanni Pratesi (g.pratesi@unifi.it)

The Bepi-Colombo space mission is aimed at observing the planet Mercury and its surrounding environment. In particular, the study of Mercury is crucial for defining and validating models of planet formation and evolution, as well as for understanding the boundary conditions favorable for the emergence of life on our and other planets. Among the major scientific objectives of the mission, of particular interest to this Ph.D., is the study of the origin and evolution of a planet orbiting close to its star, more specifically the differentiation of a rocky planet as can be derived by the study of its surface composition and internal structure. Within the Ph.D., the candidate shall define the possible mineralogy and petrology of Mercury based on compositional and spectroscopic data, acquired by the MESSENGER mission and relative to the surface of the planet. The candidate will then proceed to define the potential terrestrial and extraterrestrial analogs of the surface of Mercury, to the synthesis of analogous products, and to their complete mineralogical, petrological, and geochemical characterization. In addition, the candidate will perform a spectroscopic characterization of the analogs in the VNIR and MidIR ranges in support of the measurements performed by the VIHI and MERTIS instruments onboard BepiColombo

- (3D) Search, characterization and exploration of exoplanets and exoplanetary systems

Funding institution: University of Padua
Doctoral site: Padua
Contact: Giampaolo Piotto (giampaolo.piotto@unipd.it)

After 27 years since the discovery of the first exoplanet, more than 5100 planets in about 3800 exoplanetary systems have been discovered. A large amount of exoplanet search and characterization projects have been developed in these years, with a huge effort dedicated by the European (ESA) and USA (NASA) agencies for development of space based observatories dedicated to this purpose. Thanks to these missions (Kepler, TESS, CHEOPS, PLATO, ARIEL) we are now able not only to find new exoplanets, but also measure their radius, mass, therefore density and estimate their bulk composition, as well as study their atmosphere basic properties and composition.
For the closest to the Earth systems, there are projects to send a cluster of microchips launched at 0.2 times the light speed for direct investigation of their planets (Breakthrough program).
The student enrolled on this theme will be inserted into one of the ESA space mission programs (CHEOPS, PLATO or ARIEL), depending on her/his expertise/interests, with a possibility to also participate in the Breakthrough project.

- (3E) Analysis of planetary data acquired by remote sensing and radar instruments

Funding institution: University of Trento
Doctoral site: Trento
Contact: Lorenzo Bruzzone (lorenzo.bruzzone@unitn.it)

Space missions for Earth observation and planetary exploration are of crucial importance for the huge scientific and technological return associated with them. Some of the most challenging science objectives of these missions require the analysis of the large amount of data acquired by the different instruments present in the mission payload. To improve the capability of extracting the information from these data (either focusing on a single instrument or on the data acquired by different instruments), it is required to develop automatic techniques based on the most recent machine learning methodologies that can enable both the definition of a new generation of data analysis systems and new capabilities of exploitation of the big data acquired by satellite missions. This PhD position is aimed at the development of novel methodologies and techniques for the analysis of data/images acquired by remote sensing and radar systems for improving the science return of planetary exploration and/or Earth observation missions. The research (which will be developed at the RSLab, Dept. of Information Engineering and Computer Science, University of Trento) will address the definition of a general framework for the development of data analysis methodologies based on artificial intelligence and deep learning that will be then applied to missions in which RSLab is involved (refer to https://rslab.disi.unitn.it for more details).

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Curriculum 4

- (4A) Bioactive lipids and resolution of inflammation in microgravity

Funding institution: University of L'Aquila
Doctoral site: L'Aquila
Contact: Mauro Maccarrone (mauro.maccarrone@univaq.it)

The research aims at studying the molecular mechanisms underlying the interaction, even under microgravity conditions, between lipid signals responsible for inflammation and its resolution: specialized resolution mediators (SPMs) and sphingosine 1-phosphate (S1F). These signals are implicated in many neuroinflammatory processes and, therefore, are both potential biomarkers of serious human diseases and primary targets for innovative drug development. The study of these bioactive lipids is critical to facilitate both Drug Discovery and Clinical Translation of experimental data.
The research topic is emerging, and it ranks among the open challenges of the major areas of innovation in applied research in neurodegenerative disorders like Alzheimer's and Parkinson's diseases, Multiple Sclerosis, and Amyotrophic Lateral Sclerosis, all of which are characterized by a common state of neuroinflammation. In addition, neuroinflammatory diseases are progressively increasing in developed societies, where they go hand in hand with an aging population and are among the most common causes of dementia, markedly contributing to worsen quality of life (including for "care givers" who assist the sick) and mortality worldwide. Of particular note is the fact that under microgravity conditions there is accelerated aging of the immune system (Immunosenescence), which makes weightlessness particularly useful for investigating this phenomenon. In this context, modulation of microglial activation, where the SPM and S1F systems play an important role, and more generally of the inflammatory state in the brain, are able to improve the symptomatology of many pathological conditions, decreasing the extent of neurodegeneration. Today, the challenge that appears most difficult is to understand the molecular mechanisms of neuroinflammation in which the SPM and S1F systems are involved. This could help to identify new specific biomarkers and therapeutic targets to combat neurodegenerative/neuroinflammatory diseases, with useful spin-offs also for countermeasures to be put in place to safeguard astronaut health and well-being during space missions.

DOCTORAL OBJECTIVES.
The objectives of this doctoral project are, therefore, as follows:

1. To identify and characterize in detail the molecular mechanisms by which elements of SPM and S1F signaling may regulate the neuroinflammatory process in the BV2 microglia cell model exposed to microgravity by RCCS
2. To identify the molecular intermediates of coordinated signaling between these two lipid systems, capable of reducing neuroinflammation in the activated microglia cell

model, by means of different methodological approaches of biochemical-molecular analysis and cellular imaging techniques
3. To analyze with computational technologies the molecular targets of SPM and S1F, for the design of novel bioactive molecules as diagnostic tools.

- (4B) Molecular modifications induced by long term spaceflight in humans and in experimental biological models. Focus on innovative countermeasures to support space exploration

Funding institution: University of Milan "La Statale"
Doctoral site: Milan
Contact: Angela Maria Rizzo (angelamaria.rizzo@unimi.it)

The future long-duration space exploration missions will predispose astronauts to the onset of chronic diseases and premature aging by strongly influencing metabolism, tissue physiology, redox processes, microbiota, immune function, as well as endotoxin and pro-inflammatory signal production. The different components of space flight such as altered gravity, space radiation, isolation and habitat adaptation, will be tested thanks to the use of different experimental models, using simulators available on earth and analyzing blood samples from astronauts on short and long duration space missions. The research will be multidisciplinary and will have the aim to develop possible countermeasures; the student will work within different research environments in Italy and abroad. The participation in current and future space missions will depend upon ongoing space projects.

- (4C) Astrobiology, Life Science and Space Medicine

Funding institution: University of Pisa
Doctoral site: Pisa
Contact: Enrica Laura Santarcangelo (enrica.santarcangelo@unipi.it)

Microbiological, immunological, behavioral, psychological and neurophysiological research is conducted in our labs. Our topics are highly relevant to space flight adaptation and to life in special environments. Our aim is to develop countermeasures to contrast the effects of microgravity on health during flights, i.e., alteration of microbiota, integrity of the intestinal barrier, sleep, immune, sensorimotor and cognitive functions. The development of sensors for neurophysiological variables and biomarkers recognition will assist in this research. The requested approach is multidisciplinary. The studies in these fields include experiments conducted before, during and after space flights, and are greatly relevant to the scientific and clinical advancement of knowledge.

- ## (4D) Bioengineering approaches to neurophysiology in the space environment

Funding institution: University of Rome Tor Vergata
Doctoral site: Roma
Contact: Myrka Zago (myrka.zago@uniroma2.it)

The PhD in Space Sciences and Technology offered by the University of Rome Tor Vergata on the topic of Bioengineering approaches to space neurophysiology aims at providing students with the theoretical background and methodological skills for carrying out cutting-edge research in the following fields: Bioengineering modelling of Human Motor Control, Space Biomedical and Life Support Sciences, Human Factors for the Design of Space Habitats, Biomechanics and Control of Movement in Hypogravity, Neurovestibular, Sensory and Cognitive Deconditioning, Musculoskeletal Deconditioning in Hypogravity. Students will work in the exciting international environment of the Center of Space Biomedicine, with tight interconnections with the Agenzia Spaziale Italiana and ESRIN - ESA in the Tor Vergata Campus, the Engineering Departments and the Medical Faculty of the University of Rome Tor Vergata. They will also benefit from the teaching facilities of UNIVERSEH, the European Space University for Earth and Humanity of which our University has recently become a member.

- ## (4E) Physiological adaptations and behavioral alterations in extreme environmental conditions and microgravity

Funding institution: University of Trento
Doctoral site: Trento
CIMeC, Rovereto (TN)
Contact: Stefania Pighin (stefania.pighin@unitn.it)

Growing interest in space travel increases the urgency of experimental research on the risks of extreme environments and microgravity conditions for mental and brain functioning. Abnormal environmental and social settings expose people to unusual and stressful conditions, making it crucial to be able to model, understand and predict human behavior. Although great strides have been made in the understanding of the importance of physiological brain alterations and cognitive functions for space performance, there remains a wide range of aspects that deserve to be explored to enable a safe presence in space. This PhD project will explore physiological alterations and behavioral modifications under psychophysical stress conditions, by means of a behavioral and/or a neuroimaging approach. The PhD research project will focus on one or more of the following topics: a) higher-order cognitive functions (specifically, reasoning and decision making); b) multisensory perception (specifically, body perception and food perception); c) sensorimotor integration in voluntary movements and actions; d) navigation in physical and abstract spaces; e) microstructural changes in cerebral tissue and reorganization of intrinsic functional brain networks.

Supervision of the PhD candidate will be a collaboration among several PIs at the Center for Mind/Brain Sciences of the University of Trento. The ideal candidate would have strong experimental and analytical skills, and top candidates would have learned or used these skills in a neurocognitive context.

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PhD SST
Space Science and Technology

Curriculum 5

- (5A) Space Surveillance and Tracking with Radar Systems

Funding institution: Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT)
Doctoral site: CNIT RASS laboratory in Pisa
Contact: Marco Martorella (marco.martorella@unipi.it)

Resident Space Objects (RSOs) are fast increasing in number and need to be monitored to safely preserve space assets, which critical services are based on (e.g. GNSS, Satellite Comms, Earth Observation and Surveillance from Space). Sensors of various types are continuously employed to detect, track and classify such objects. Among such sensors, radar systems are widely and consistently used to perform such tasks. Nevertheless, the current technology is not sufficient to perform these tasks effectively as many objects are still not catalogued, and those that are present in catalogues need continuous updates.
Modern radar systems and, more specifically, radar networks are needed to respond to the increasing demand for highly performing sensors.
This PhD work will concentrate on the study of a radar-based sensor network that is able to accurately detect, track and classify space objects. More specifically, the candidate will work on innovative system architectures and the signal processing that is necessary to perform optimal detection, tracking and imaging of RSOs. Performance predictions will be derived that will allow to optimize the radar system architecture. Several different scenarios will be considered including surveillance of LEO and GEO belts.

- (5B) Study, design and qualification of electronics and electro-optical systems for space applications

Funding institution: Consiglio Nazionale delle Ricerche (CNR)
Doctoral site: IFAC-CNR Sesto Fiorentino
Contact: Sergio Bruno Ricciarini (s.ricciarini@ifac.cnr.it)
Valentina Raimondi (v.raimondi@ifac.cnr.it)

Technologies for space applications require an extensive study and accurate design in order to provide cutting edge performances and compliance with environmental conditions expected during both launch and in-orbit operation (mechanical stresses, thermal and vacuum conditions, radiation environment, electromagnetic compatibility). This in turn implies the execution of qualification tests that require specific expertise to be carried out.
Within the PhD the candidate will work on one or more of the following themes:
(a) design, implementation and laboratory characterization of electronics dedicated to analog signal read-out and/or digital data processing for a specific space application (e.g. charged

particle or photon detector, optical system);
(b) system modelling, data simulations and analysis of technologies for the development of optical payloads for Earth Observation, with an emphasis on the study of very compact instrumentation; (c) planning, execution and data analysis for mechanical / thermal / vacuum / irradiation / electromagnetic qualification tests performed on electronics or electro-optical systems.

- (5C) Space compliant LGAD sensors

Funding institution: Fondazione Bruno Kessler
Doctoral site: FBK- Trento; University of Trento
Contact: Matteo Centis Vignali (mcentisvignali@fbk.eu)
Paolo Zuccon (paolo.zuccon@unitn.it)

Low Gain Avalanche Diodes (LGADs) are silicon sensors that feature internal charge gain.
These sensors were initially developed to provide the time information of tracks at high luminosity colliders, with performances reaching single hit time resolutions of a few tens of picoseconds for minimum ionizing particles.
These timing capabilities can find applications in spaceborne experiments like: particle identification through time of flight, distinction between incoming and outgoing particles, identification of splash back and punch through of showers in the calorimeter systems, identification of electromagnetic and hadronic showers by observation of the splash back and punch through from calorimeters.
A first production of LGADs dedicated to space applications was completed at Fondazione Bruno Kessler (FBK) and is currently being characterized.
The activities of this position will be focused on completing the characterization of this first batch, and on the qualification tests to determine whether the LGAD sensors are flight-ready.
The sensor characterization will be mainly performed in the laboratories of University of Trento and FBK.
The lessons learned in the sensor characterization and qualification will be reflected in the design of future sensors dedicated to spaceborne experiments.
Within the timeframe of this position, a second batch of LGADs for space will be produced and characterized.

- (5D) Design and prototype characterization of innovative high energy particle detectors for space application

Funding institution: Istituto Nazionale di Fisica Nucleare (INFN)
Doctoral site: INFN- Bari
INFN- Rome Tor Vergata
Contact: Fabio Gargano (fabio.gargano@ba.infn.it)
Roberta Sparvoli (roberta.sparvoli@roma2.infn.it)

The next generation of space missions, aimed at studying the charged and neutral cosmic radiation, will require highly innovative high-energy particle detectors.
The research activity of this PhD will be focused on a detector design based on scintillators, readout by Silicon Photomultipliers, to detect gamma-rays and charged particles from the MeV up to the GeV/TeV energy region.
The doctoral work will be organized in a first phase, dedicated to simulations of the detector geometry and its expected performance. In this phase it will be essential to use Montecarlo packages typical in high energy physics (Geant4, Fluka ...).
The work will continue in a second phase in which the detector prototype will be produced, assembled and tested.
The PhD activity will fit the space projects supported by INFN.

- (5E) Photonic Integrated Sensor Systems for Space Applications

Funding institution: Scuola Superiore Sant'Anna
Doctoral site: Scuola Superiore Sant'Anna (Pisa)
Contact: Claudio Oton (c.oton@santannapisa.it)
Fabrizio Di Pasquale (f.dipasquale@santannapisa.it)

Silicon photonics (SiPh) provides a disruptive technology for reducing the size, weight, cost and energy consumption of optical fiber telecommunication and photonic sensor systems. SiPh ensures in fact low-cost and high-volume production, complimentary metal-oxide-semiconductor (CMOS) compatibility and potential for monolithic integration with electronics. The most widely developed platform utilizes Si-on-Insulator (SOI) nanowire waveguides and has been extended to include integrated active components such as modulators and photodetectors.
SOI based photonic integrated circuits (PICs) are particularly attracting for industrial sectors requiring mass production such as automotive, sensing, computing and datacom markets.
Addressing the design and development of radiation-hard PICs for sensing in space applications will be the main subject of this PhD. Although preliminary results have recently pointed out the SiPh potential for operation in harsh environment characterized by large ionizing radiation, further studies are required to fully validate and qualify the technology for space missions and particle accelerators.

- (5F) Modular observatories to study the most energetic events in the Universe

Funding institution: University of Palermo
Doctoral site: Palermo
Contact: Alessandro Busacca (alessandro.busacca@unipa.it)
Giovanni Marsella (giovanni.marsella@unipa.it)

Fabio Reale (fabio.reale@unipa.it)

This project regards the study of high-energy astrophysics phenomena, the most energetic events in the Universe. In particular the observation in the X-ray-Gamma-ray band of systems containing a compact object, i.e. a black hole or a neutron star, such as X-ray binaries, Gamma-ray Bursts, etc. and the search for the electromagnetic counterparts of Gravitational-Wave events, produced by the merging of two compact objects. This study will be performed through dedicated observations obtained with the available to date X-ray and Gamma-ray observatories. Furthermore, a part of this project will regard the study of the performances of an all-sky monitor for high energy astrophysics (hard X-ray/soft gamma-ray) made up of several small satellites (CubeSats for instance) equipped with off-the-shelf instruments and able to locate impulsive events with a triangulation technique very similar to that used by the gravitational antennae, such as the HERMES (High-Energy Rapid Modular Ensemble of Satellite) constellation. This was financed by the Italian Space Agency (ASI) and the European Community (through a H2020 project) in order to build a technological and scientific pathfinder made up of six nano-satellites in Low Earth Orbit. The HERMES Pathfinder should be launched and start operations by the end of 2023, demonstrating the feasibility to build a high-energy all-sky monitor in a few years from the mission concept to the operative phase. This PhD project will contribute to the HERMES project through simulations, in order to address its capabilities, and possibly analyzing the first data from the constellations as soon as it will start operation.

- (5G) Design, simulation and test of a not-imaging space detector devoted to cosmic-rays studies

Funding institution: University of Salento
Doctoral site: Lecce
Contact: Francesco De Palma (francesco.depalma@unisalento.it)

Space detectors are fundamental instruments for the understanding of cosmic ray (CR) origin and composition. Several detectors have already taken data on orbit and our knowledge of cosmic radiation has improved significantly in the last decades. A new CR space detector to be relevant to the field will need to precisely measure CR spectra and mass composition in a large energy range and to have large acceptance and sensitivity for gamma-rays. Those goals require the design, the simulation and the test of new and challenging sub-detectors.

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Curriculum 6

- (6A) Advanced manufacturing of microwave and millimeter/sub-millimiter-wave and components for Space payloads

Funding institution: Consiglio Nazionale delle Ricerche (CNR)
Doctoral site: CNR IEIIT (Turin) or CNR STIIMA (Milan)
Contact: Oscar Pevereni (oscar.peverini@ieiit.cnr.it)
Irene Fassi (Irene.Fassi@stiima.cnr.it)

Within this Ph.D., the candidate will investigate the application of advanced manufacturing technologies, such as additive manufacturing and 3D printing, and micro-manufacturing, to the development of radiofrequency breadboards for Space applications. Indeed, next-generation payloads will consist of hundreds of multi-band and multi-polarization radio frequency chains operating from the Ka/Q/V bands (30-50 GHz) up to sub-millimeter frequencies (200-600 GHz). As a few examples:
• Future Earth Observation missions aimed at climate-change monitoring and at atmosphere/ meteorological-events studies require the use of passive multi-beam radiometric architectures operating at frequency channels > 200 GHz embarked on constellations of small satellite platforms (<150 kg) or on stratospheric platforms.
• Next generation VHTS (Very High Throughput Satellite) satellite telecommunication networks will be more integrated with terrestrial ones (5G, 6G and beyond), offering an aggregate channel capacity of the order of Terabit/s. These networks will be based on cellular architectures, similar to current terrestrial telecommunication networks, in which the required channel capacity will be guaranteed thanks to multiplexing in space and the use of transmission channels at higher frequencies (Q, V, W and D bands, i.e. up to 140 GHz).
• In the field of Cosmology, some of the radiometric channels of potential interest are 385-500 GHz, and 602-720 GHz, 787-950 GHz.
These applications require manufacturing technologies able to fabricate high precision components with complex geometry and accurate micro-features, with high throughput, zero waste and sustainable footprint. In this context, advanced manufacturing technologies play an enabling role for the development of innovative payloads in terms of performance and compatibility with platforms. This multi-disciplinary study will be carried out at the two institutes STIIMA (https://www.stiima.cnr.it) and IEIIT (https://www.ieiit.cnr.it) of the CNR in synergy with the research activities that the CNR carries out within the GSTP and ARTES programmes of the European Space Agency.

- (6B) Model-based software engineering and formal methods for space systems

Funding institution: Fondazione Bruno Kessler (FBK)
Doctoral site: FBK - Trento

Contact: Stefano Tonetta (tonettas@fbk.eu)

The PhD will investigate new techniques for model-based system and software engineering and formal methods to support the design, mission preparation and operations of space systems. The potential research directions include faul detection, isolation, and recovery for satellites; system level diagnosis and diagnosability based on telemetry; digital twins for satellites.

- (6C) Self-antifrosting microstructured surfaces

Funding institution: Fondazione Bruno Kessler (FBK)
Doctoral site: FBK- Trento; University of Trento
Contact: Damiano Giubertoni (giuberto@fbk.eu)
Nicola Pugno (nicola.pugno@unitn.it)

Water phase changes (evaporation, condensation, freezing) are ubiquitous phenomena of great importance for living beings and in engineering applications. The structure (micro and nano) and chemistry of surfaces control the kinetics and dynamics of these transitions. Plants, for example, offer numerous examples of self-cleaning, antifreeze and water-collecting[1] properties developed over millions of years of evolution. Engineered anti-frosting surfaces find applications in aerospace (ice accretion on aircrafts), heat exchangers (refrigerators), wind turbines and power lines. Structured surfaces that increase evaporation and condensation efficiency are a challenge for Loop Heat Pipes (LHP) and Vapour Chambers that cool electronics on space stations (in microgravity conditions) or in the electronic devices we use on a daily basis. Surfaces that can efficiently collect dew and fog provide a source of water in arid environments and can improve the water recovery system of space stations.

This project will extend the studies carried out during the previous PhD scholarship (within cycle 34, in collaboration with FBK) which focused on anti-frosting and water-harvesting surfaces. The research activity will concern the theoretical study, fabrication, characterisation and experimentation of micro- and nanostructured surfaces with applications in aerospace and energy efficiency. In particular, phenomena of spontaneous jumps of condensation droplets on hydrophobic surfaces, distant coalescence on hydrophilic surfaces and freezing of droplets will be studied. Fabrication techniques may range from micro- and nanolithography, focused ion beam, etching, chemical deposition processes, and polymer moulding. The expected outputs are patents and publications on high impact journals in the field.

References

(1) Kundanati, L.; Di Novo, N. G.; Greco, G.; Siboni, S.; Della Volpe, C.; Bagolini, A.; Pugno, N. M. Multifunctional Roles of Hairs and Spines in Old Man of the Andes Cactus: Droplet Distant Coalescence and Mechanical Strength. *Phys. Fluids* **2022**, *34* (1). https://doi.org/10.1063/5.0066153.

- (6D) Antennas, sensors and RF systems for satellite applications

Funding institution: University of Cagliari
Doctoral site: Cagliari
Contact: Giuseppe Mazzarella (mazzarella@unica.it)

The PhD candidate activity will be focused on the design of some of the microwave and radiofrequency parts (telecommunication, radar and radiometer antennas, transmitters and receivers subsystems, sensors) of a satellite platform. The unique combination of different, and usually very challenging, requirements and of very harsh and strongly constrained environments (constraints on size, weight, electric consumption and operating temperature range, requirement of a very high reliability and need to take into account the electromagnetic compatibility between subsystems) requires beyond-state-of-the-art approaches and design techniques. Candidates with a background on telecommunications, electromagnetic engineering and microwave will face this task more easily.

- (6E) Engineering challenges for future 'near-Earth' missions

Funding institution: University of Pisa
Doctoral site: Pisa
Contact: Luca Fanucci (luca.fanucci@unipi.it)

The PhD grant aims to promote a technological push enabling future “near-earth” missions for the protection and the sustainable development of the planet.
PhD candidate are encouraged to submit research proposal addressing one or more of the following engineering challenges: methodologies for mission analysis, advanced materials for space, innovative and green propulsion, advanced on-board power generation and thermal control systems, methods, models and technologies for sustainability of the space environment, precision systems for Guidance, Navigation and Control, systems for distributed platforms and for micro- and nano-satellites, artificial intelligence and robotics on board, radiation robust platforms for avionics signal processing on board satellites and for efficient satellite-to-ground and inter-satellite communications.

- (6F) Telecommunication systems: High frequency transceiver systems for small satellites, towards a 5G transceiver in Ka band

Funding institution: University of Trieste
Doctoral site: Trieste
Contact: Anna Gregorio (anna.gregorio@ts.infn.it)

The PICOSATS company is industrialising its first product, RADIOSAT, a Ka-band transceiver of low mass and volume, characterised by low power consumption; the system is integrated with a modem. RADIOSAT is the first element of the complete system that PICOSATS is devising to serve constellations of small telecommunications satellites; one of the next steps concerns the evolution towards a system compatible with the 5G standard.
The system to be developed consists of a transceiver (consisting of four modules) and two antennas to be integrated into a CubeSat platform.
The current transceiver must then be adapted to the requirements of a 5G mission. The front-end of the system needs to be redesigned to couple with patch array antennas, possibly with beam-forming capabilities.
Such a product is unique, it would be the first on the market and characterised by multiple innovations, concerning both performance in absolute terms, miniaturisation and low power consumption, modularity that makes it suitable for customisation, and the use of commercial components.
The PhD activity is framed in a field at the frontier of electronics and telecommunications and is part of a line of research and development that has been launched, also in collaboration with the University of Perugia, and has already produced technical reports and scientific publications, including in international journals.