Strategic Plan

Update 2023

GRAN SASSO SCIENCE INSTITUTE

Introduction

2023 is a breakthrough year for GSSI, considering the full application for the Institute of the same regulations as the other Universities, both in terms of legislation regarding the recruitment possibilities (Punti organico) and in terms of limitations imposed by financial regulations. The GSSI presents indexes of economic and financial sustainability (2,57 at 31.12.2021, an improvement over 31.12.2020) and fixed allowances/ FFO ratio (30,69%) which place it at second place among Universities and Special University Institutes.

The results of VQR (Research Quality Assessment) have rewarded GSSI in terms of Ordinary Financing Funds' (FFO) rewards share (quota premiale,) which has increased from €1,7 million in 2021 to average € 4,3 million in 2022. Moreover, it is worth pointing out that GSSI has also achieved the very good result of being admitted to the Department of Excellence (Dipartimento di Eccellenza) in the Area 01 (Mathematics and Computer Science), meaning that in case the project is financed, more resources will be allocated.

With respect to the PNRR fundings, and fundings PNRR-related, GSSI participated in a number of projects and obtained important fundings (among others: Vitality, Seic). The year 2023 is expected to be crucial to significantly start and progress these projects.

The Nuses project has begun to make important progress, tender notice for the construction of the payload terzina (about € 1,9 million) was published at the end of 2022 and the executive phase is expected in the first months of 2023.

The SEIC project (€19 million) will involve important activities throughout 2023 (renovation works of the former Psychiatric Hospital of Collemaggio, building B20).
From the teaching side, an increase in the number of Ph.D. students has been observed, not only on account of the extension of the fourth-year Cohort due to Covid, but also due to the funding of additional Ph.D. scholarships.

The foundation "Ferrante D'Aragona" will be operational within the beginning of 2023: GSSI is preparing the call for tenders for the furniture of the apartments, with the goal of assigning them to the first-year students in the Academic Year 2023/2024.

Considering the complexity of the activities and projects that are expected to be managed, it is crucial to give importance to the recruitment plan of teaching staff, researchers, managers and administrative staff, but also to the planning of teaching, research and third mission activities.

The GSSI, also to cope with the considerable workloads, will try to complete the hiring of managers and administrative staff as agreed by the boards. Many selection procedures are in progress in order to reach 35 units in the Administration staff.

The number of Professors and Researchers, on the basis of the recruitment plan of the Areas and of the scientific and teaching exigencies, within the limitations imposed by hiring faculties (available Punti Organico) will be able to increase, by taking into account the fixed allowances/ FFO ratio, in order to maintain an optimal balance of the budget.

This document of annual update of the Strategic Plan and of the GSSI 2030 Programme aims to give account of the strategic plans of the scientific Areas, waiting to adopt the new directions from the Scientific Committee.

Physics

The Physics Area of the Gran Sasso Science Institute is active in the field of Astroparticle Physics, a research domain that straddles Astrophysics and Particle Physics. The research and advanced study activities of the Area are subdivided into three main sectors: Low Energy Astroparticles (LE), Gravitation and Cosmology (GC), and High Energy Astroparticles (HE). Within each sector, several research paths – both theoretical and experimental – are pursued. Below we briefly describe the ongoing activities, particularly those that will involve the greatest efforts over the next three-year period 2023-2025.

The LE research domain focuses on the study of rare processes, such as the neutrinoless double beta decay (DBD) and the direct detection of Dark Matter (DM). These topics – among the most important and compelling of fundamental physics – constitute the cornerstone of the research carried out at the Gran Sasso National Laboratories (LNGS).

Observation of DBD would allow the absolute mass scale of neutrinos to be determined, and their Dirac or Majorana nature established. GSSI groups, which play a prominent and responsible role, take part in: (i) research with germanium detectors through the LEGEND-200 experiment, currently at the installation stage in LNGS, and the design of its future upgrade to a mass of one tonne (LEGEND-1000); (ii) research using bolometric detectors through the CUORE experiment – which has been gathering data at LNGS since 2017 – and its upgrade CUPID, tasked with developing thermal sensors suitable for the experiment in terms of energy and time resolution, with characterising the new design and with studies concerning the forecast and optimisation of the experiment's background radiation. The GSSI groups are further engaged in complementary activities for CUPID, such as the ACCESS (Marie Curie) project for the study of forbidden nuclear processes and the development of innovative cryogenic sensors (PRIN 2020).

With respect to the search for direct evidence of DM, GSSI groups are at the forefront in developing a gas Time Projection Chamber (TPC) capable of determining the incoming direction of DM. This characteristic allows not only direct search beyond the Neutrino Floor limit, but also, most importantly, to have incontrovertible evidence of the DM signal through its correlation with the incoming direction of the particles. GSSI groups are in charge of CYGNO, currently at the design stage of the 0.4 m^3 detector to be installed at LNGS, and are responsible for the experiment's management, data analysis and simulation, and physics results. In addition, over the past year two new grants were obtained to optimise the same experimental technique for measuring the Migdal effect (FARE award 2020) and X-ray polarimetry (PRIN 2020). Concerning the direct search for DM, GSSI groups are also involved in the COSINUS experiment, currently being built at the LNGS, aimed at verifying the claim of the DAMA experiment concerning the annual modulation of DM using the same target and a bolometric technique. The GSSI groups handle the selection of ultrapure materials, the background modelling, the apparatus Cherenkov veto and the cryogenic measures aimed at optimising the detector prototypes. Lastly, the GSSI groups are in charge of the construction of a new generation of liquid argon detectors through the DarkSide-20k experiment, which is being constructed at the LNGS. This experiment has the best sensitivity for massive DM candidates when compared with all other detectors – whether at the design or construction stages – over the next decade.

The GC research sector focuses on such astrophysics, fundamental physics and cosmology studies as rendered possible by the nascent gravitational wave astronomy and multi-messenger astronomy.

Currently, the GSSI staff is engaged in several research tracks: (i) experimental research: the group is strongly committed, with a leadership role, to the technological development of the Virgo, Ein-

stein Telescope (ET) and Luna Gravitational Wave Antenna (LGWA) experiments. The Einstein telescope is the next-generation gravitational wave detector that has recently become a priority for ESFRI (one of the candidate sites for hosting this two-billion-euro experiment is located in Sardinia). LGWA is an experiment aimed at extending observations to the decihertz band, and it can provide valuable insights into lunar exploration. The Italian Space Agency – a partner of the Artemis programme) – has recently manifested its interest in the development of LGWA. Starting from next year, a new GEMINI experiment will be installed at LNGS within the context of PNRR; the experiment is of fundamental importance for the technological development required by ET, and has the additional capacity to characterise the cryogenic payload of LGWA. The GEMINI control aspects will benefit from another ongoing project involving GSSI and Google Deepmind, where advanced control methods using machine learning are being developed. The collaboration agreement with Google Deepmind was signed in 2021 and will be extended for another year in 2023. A third partner of this collaboration is Caltech, where students and postdocs can work on the practical implementation of algorithms using a laser interferometer prototype. Beyond the research activities of a predominantly experimental nature, GSSI groups are also involved in phenomenological and observational research tracks, consisting mainly of astrophysics studied of gravitational sources in multi-messenger contexts. In particular, activities centre on observations and data analysis to detect gravitational wave and electromagnetic signals (optical, X and gamma) from transient astrophysical events such as gamma-ray bursts, kilonovae and supernovae. For this purpose, GSSI groups have access to data from LIGO, Virgo and KAGRA, and to the best ESO and satellite telescopes through their involvement with the ENGRAVE and GRAWITA collaborations. GSSI groups are deeply involved with the development of ET, LGWA and LISA scientific cases, and with the instruments that will work in synergy with them in a multi-messenger environment (such as THESEUS, Vera Rubin Observatory, ELT, CTA). In addition to data analysis, GSSI groups are engaged in developing models for the interpretation of the observations. A third research track within GC that concentrates significant efforts on the part of GSSI groups concerns theoretical research dealing mainly with the physics of gravitational and electromagnetic wave emission, and neutrinos from astrophysical transients such as neutron stars, black holes (from stellar to supermassive) and white dwarfs. In particular, the group activities focus on modelling inspiral and post-merger gravitational signals generated by black-hole binaries in order to develop the wave forms to be used as a test of General Relativity, on modelling signals emitted by coalescent neutron star systems in order to study the properties of matter at supernuclear densities, on characterising compact objects in General Relativity and in extended gravitation theories as astrophysical sources for space- and Earth-based third-generation detectors, on the study of the emission mechanisms of gamma-ray bursts, and kilonovae and their characterisation in terms of the astrophysical source properties. In all the research tracks mentioned, GSSI staff act as international coordinators.

The HE research sector focuses on the study of high-energy cosmic radiation: cosmic rays (CR), neutrinos and gamma rays and, in general, phenomena that involve particle physics in astrophysical environments. The research activities of the HE sector currently involve GSSI groups in several research tracks: (i) experimental research, observation of cosmic and gamma rays both from space (DAMPE experiment) and from Earth (Auger experiment), development of new space detectors for CR, neutrinos and gamma rays (HERD, NuSES and CrystalEye experiments, and PNRR ASTRA and SEIC projects); (ii) phenomenology research, study of astrophysical sources of high-energy radiation, physics of propagation, including in cosmological contexts, models relevant to high-energy physical phenomena Beyond the Standard Model, with close links to the experimental activities concerning the analysis of observations (Auger) and the design of new detectors (NuSES); (iii) purely theoretical research, mainly devoted to studying the physics underlying the mechanisms re-

sponsible for the acceleration and propagation of astrophysical particles and, in general, the dynamics of particle-plasma interactions in astrophysical environments.

Research activities of GSSI groups within the HE sector find themselves at a stage of significant development, with several projects where GSSI plays a leading role in important international collaborations. The NuSES satellite, currently under construction, is a collaboration project under the leadership of GSSI that also involves the participation of groups from INFN (LNGS, Bari, Lecce, Naples, Rome Tor Vergata, Padua, Turin and Trento), the University of Geneva (CH) and the Italian Space Agency in collaboration with important aerospace companies such as Thales Alenia Space Italia. NuSES is a scientific mission in space that pursues two distinct objectives: on the one hand, it is intended to carry out basic research into particle physics, astrophysics and geophysics; on the other hand, NuSES acts as a demonstration of new technologies that have not yet been developed in the context of space, with important repercussions not only for basic research, but also for a wider range of applications. In December 2022 the Italian Space Agency recognised the NuSES satellite as a mission of interest and it will finance both the satellite launch – scheduled for the second half of 2025 – and the related ground-based operations. In the context of the NuSES project, GSSI in collaboration with INFN is building a new permanent infrastructure for space research and engineering, setting up dedicated laboratories within the LNGS complex of Assergi (L'Aquila). Another important mission under the leadership of GSSI groups is Crystal Eye, aimed at space detection of astrophysical X and gamma photons with energy between 10 keV and 10 MeV. The mission was approved by ESA for the first Space Ryder flight, scheduled for 2024, that will house a technological pathfinder for the Crystal Eye detector. Furthermore, in relation to PNRR-MUR funding for the Central Italy Innovation Ecosystem (Abruzzo, Marche, Umbria), GSSI in its capacity as head of the ecosystem's ASTRA spoke has obtained funds for building the detector (payload) of the satellite Crystal Eye in its final configuration, thus opening the door to the possibility of conducting a new space mission of great interest to the search for signals from the deep universe, including correlation with gravitational wav emission and astrophysical structure collapse events.

Research carried out by the Physics Area of GSSI, in each of its components, carries out important experimental activities, typically linked to the development of new technologies with significant industrial repercussions. This characteristic has led to the SEIC (Space and Earth Innovation Campus) project which, with funding from the territorial cohesion Agency within the PNRR context, consists in the construction of an experimental research infrastructure capable of fulfilling the demands of the Area, in particular in the field of satellite integration. The resources obtained following the approval of the SEIC project will enable GSSI to acquire, renovate and equip with laboratories, halls, offices and co-working spaces a 3000 m2 building within the GSSI campus.

Mathematics

The main development paths considered are:

1. Thermodynamic properties of out-of-equilibrium quantum systems; mathematical development of effective theories for quantum systems interacting with thermostats and external quantum fields; analysis of heat transfer phenomena and processes leading to thermal equilibrium; study of models for describing synchronisation behaviours in quantum systems; study of diffusive behaviour in classical and quantum integrable systems.

Impact: development of mathematical models to describe phenomena that are typical of open quantum systems (decoherence, entanglement, tendency to thermal equilibrium, thermal conductivity properties) whose applications include: description of radiation-matter interactions in quan-

tum optics circuits; study of the interaction between qubits and environmental noise in quantum information and computation systems; environment-induced transfer phenomena.

Groups involved: Statistical Mechanics (thermal and transfer properties in classical systems, derivation of effective equations, open quantum systems, thermodynamic properties of quantum devices), applied PDE (dispersive equations and quantum synchronisation phenomena), Numerical Analysis and Algorithms (quantum computing).

2. Rigorous treatment of stability/instability phenomena in non-linear waves and vortices in the context of quantum fluids.

Study of fundamental problems in quantum fluid mechanics, in particular the dynamics of quantised vortices: properties, stability, creation and re-connexion of vortices, analysis of boundary layers in the proximity of an obstacle; statistical treatment of non-linear, weakly-interacting waves; understanding turbulence phenomena in quantum systems on kinetic timescales; derivation and rigorous justification of diffusive equations from the Gross-Pitaevskii model.

Impact: development of rigorous methods for describing fundamental properties of quantum fluids.

Groups involved: Statistical Mechanics (derivation of diffusion equations in classical systems, kinetic equations), applied PDE (non-linear stochastic and deterministic Schrödinger equations, solitary waves), Fluid Mechanics (numerical and asymptotic methods for the study the stability and instability of particular solutions).

3. Rigorous understanding and control of symmetry breaking and pattern formation for models of local/non-local interaction in physical regimes.

Development of solid methodologies to identify the mechanisms that lead to the formation of patterns in physical models (e.g. through Coulomb- or dipole-type interactions), thanks to the synergy of analytic, probabilistic and computational approaches. Identification of parametric/external-field control systems in order to facilitate their formation.

Impact: Collaboration between the various areas will enable consideration of the physical setting (so far unexplored) at positive temperatures, building upon the results obtained in a zero-temperature setting. Such results will be at the basis of the development of control systems to facilitate self-assembly, fundamental for applications.

Groups involved: Applied PDE (rigidity and stability estimates, integral representation formulae, control, fingering in Bose-Einstein condensates); Statistical Mechanics (large deviations, surface fluctuations between equilibrium or non-equilibrium phases); Numerical Analysis and Fluid Mechanics (simulation and comparison of quasi-optimal configurations and phase transitions; control).

4. Development of strategies for passive control of coherent vortex structures in aerodynamics.

Impact: Improved energy consumption of aerial vehicles (UAVs, drones) and reduced structural vibration and mechanical fatigue. Possible applications in the energy harvesting sector, e.g. optimisation of devices based on fluid-structure interaction (wind/hydroelectric turbines or piezoelectric plates/flapping).

Groups involved: Fluid Mechanics (fluid-structure interactions), applied PDE (control via the adjoint method), Numerical Analysis and Software Engineering (reduced-order models and high-performance computation).

5. Characterisation of emergent collective behaviour in technological and social distributed systems. Characterisation of global regularities and behaviours that manifest in modern distributed systems and their impact in areas such as: performance of globally distributed tasks, service usage, communications, social influence, dissemination of information or technology, and social justice.

We intend to improve upon known results and explore complementary directions both from the methodological point of view and the context assumptions. For example, scenarios will be considered in which the state of the system, the type of user and preferences are not fully known, but must be ascertained, revealed over time or reconstructed through distributed communication. In addition, we intend to characterise the structure and estimate the level of bub-optimality of solutions and equilibria, and delimit the convergence timeframes for the interaction dynamics of the entities involved.

Impact: Understanding and prediction of emergent phenomena in social networks and digital platforms, such as the formation of communities, the spread of misinformation, and resource congestion.

Groups involved: Algorithms (optimisation and approximation, graph theory, algorithmic game theory, distributed computation theory); Numerical Analysis and Statistical Mechanics (linear algebra, probability, spectral analysis and high-performance computation, machine learning).

Social Sciences

Disciplinary areas

The main disciplinary area consists of the Scientific Disciplinary Sector SECS-P06 "**Applied Economics**" within Area 13 (Economics and Statistics Sciences), complemented by the disciplinary area that refers to the Scientific Disciplinary Sector M-GGR/02 "**Economic and Political Geography**" within Area 11 (History, Philosophy, Education and Psychology Sciences). The relative weight of this complementarity may be surmised from the ministerial accreditation forms for our PhD programme in "Regional Science and Economic Geography", where we have so far declared a percentage weight of the Applied Economics teaching staff between 70 and 80%. Our "figure" stems from "applied" research and education, rather than from purely theoretical approaches; that is to say, they require the use and analysis of data, both quantitatively (econometric analysis of large *secondary* databases) and qualitatively (analysis of case studies from *primary* data, gathering through questionnaires, including national-scale ones.

Area denomination and characterisation

The name of the "Social Sciences" area is a legacy from past choices, whereby a certain institutional and reputation path-dependency developed. Nevertheless, it is a "problematic" denomination that refers to a far wider scope than the other three GSSI areas, being equivalent to their generic indication of "STEM" areas. Obviously, our **dimensions** preclude us from coherently and exhaustively covering the "social sciences", which should, as a matter of principle, also include sociology and anthropology, for example.

In order to confront this problem, a choice was made to characterise the area by focusing on "**regional**" **sciences** which indeed bring together, for the most part, applied economists and, to a lesser extent, economic geographers. In regional sciences we also find a minority of *territorial planners* (Scientific Disciplinary Sectors ICAR9/10, within Area 8, Civil Engineering and Architecture), but in this respect we resort to external collaborations with complementary research

groups, such as the University of Camerino with which we have built the REDI consortium, and more recently with the University of L'Aquila, with which we have recovered a relationship that had become strained under the previous area leadership.

Contents, research tracks and resource requirements

Introduction

Area 13°4 "Applied Economics" is in itself very wide, comprising several sub-disciplines such as, by way of example: **regional economics**, economics of **innovation**, of **energy** and the **environment**, of **healthcare**, of **tourism**, of **culture**, of **natural disasters**.

Something that is not always clear to non-economists is that these sub-disciplines are strongly specialised and are characterised by different networks, conferences and international journals. Some of these sub-disciplines overlap and collaborate in some research fields: for example, the "GeoInno" international conference gathers both experts in regional and geographical economics, and scholars of innovation economics, and collaborations emerge. Nevertheless, discipline specialisation remains strong, even in those cases.

As the latest VQR2015-2019 study showed, the Social Sciences area of GSSI represents one of the "poles" of applied economics with the best performances in scientific production within the Italian university system. Furthermore, and even more importantly, the area enjoys a high degree of recognition and repute among the main international associations in the field of regional sciences (the most important of which are the Regional Science Association International, *RSAI*, and Regional Studies, *RSA*) and of geographical economics. As witness to the above, area members have been granted several prizes by the regional sciences associations of Europe (ERSA), America (NARSC) and the world (RSAI), and have been invited as keynote speakers on several occasions, including annual conferences and discussion meetings with international policy makers (e.g. Cohesion Policy of the European Commission, on the same panel as the European Commissioner for Cohesion). In addition, the Area takes pride in having several editors of leading international journals, both in the field of regional sciences (e.g. Journal of Regional Science and Industry & Innovation) and in the field of geographical economics (e.g. Dialogues in Human Geography). Further recognition is the appointment of our area as the venue for the Regional Studies Association Summer College over the next three years.

The scientific-disciplinary sector of Economic-Political Geography of the area, on its part, deals with similar subject matter as applied economics, but with a specific theoretical approach (following a critical-social orientation) and analytic methodology (both qualitative and quantitative, but with a more qualitative outlook). It is further characterised by its particular attention towards the global planetary dimension of economic-political processes and the analysis of geographical contexts different from those of the West, the global South in particular. As z discipline, it is open to discussion with other social sciences (currently defined as a "post-disciplinary" discipline), cultural anthropology and sociology in particular, but also with political science and economics of heterodox orientations. The sector was not included in the previous VQR evaluation, since the staff at the time consisted of a single member.

Research tracks

Currently, research is organised around "keywords". Keywords have been identified for communication purposes, in order to render our research more readily understood by the various stakeholders that may potentially be interested. They are not meant to be isolated containers, since the

various research subgroups are strongly interacting and interconnected. The keywords identified are:

1. EDUCATION, SKILLS AND HUMAN CAPITAL
2. MIGRATION
3. DISASTERS AND RESILIENCE
4. ENVIRONMENT AND CLIMATE CHANGE
5. INNOVATION AND GLOBAL FUTURES
6. TOURISM AND CULTURE
7. PERIPHERIES
8. CITIES

Resources for the three-year period

The results mentioned above are the fruit of intense research activities carried out by the Area during the years 2017-2022 within its "characteristic" tracks, and of the recruitment choices made in order to achieve them. Such results, therefore, encourage us to adopt a research programme along the same lines according to a **rationale of extension and in-depth analysis**, rather than re-thinking or, worse, abandoning them.

With respect to the research tracks themselves, the Area finds itself at the turning point from an as it were "start-up" phase to a **consolidation phase** where **more ambitious objectives** may be pursued, such as:

i. to raise the fifth-place standing granted by the last VQR evaluation in the Applied Economic sector and attain a place within the first three, at least, including in the Economic-Political Geography sector:
ii. to continue to obtain funds, as we have done in the past, not only for national projects, but also, and particularly, for international ones, with special emphasis on H2020 projects, but also from other sources, such as COST and Doctoral Networks, with the aim to reach ERC and Marie Curie;
iii. to consolidate, and possibly increase, the Area's visibility, widening the geographical sphere of that recognition it already enjoys in the European and American contexts (especially to South America, but also parts of North America, including Canada and Mexico), extending it into the United States and Asia (though this year we had our very first Asian student), which have been pushing to move the boundaries of research into regional and geographical sciences.

As mentioned above, the desired results should be obtained by extending, deepening and developing the Area's characteristic research tracks. Since we are dealing with **sub-tracks that enhance** the characteristic research tracks of the Area, their completion requires further resources, over and above the existing ones, to be allocated to the recruitment specified below, sorted by **temporal priority**:

Table 1: Research tracks, requirements and time frame

Research track	**Requirements**	**Time frame**

1. Internal areas, twin (green & digital) transition and territorial cohesion - The aim is to develop a new research sub-track within that devoted to internal areas which, through new studies of mixed-method type, i.e. combining qualitative and quantitative methods, in order to analyse the so -called twin transition (green and digital) in more peripheral areas, paying attention to their feasibility and sustainability, as well as to the possible long-term effect on local development and territorial cohesion. - This research track has a great potential for collaboration with the computer science area.	RTDB SECS-P06	ASAP
2. Geographies of globalisation and of urban and regional development - The aim is to enhance the research track dealing with the study of regional and urban development, integrating quantitative analysis – where the area is already competent – with qualitative analysis and case studies through field research intended to gather empirical evidence based on the direct observation of phenomena and on paying attention to their geographical diversity in the current scenario of an increasingly multi-centric globalisation. - This research track offers great potential for enriching the quantitative research track and enhancing the supervision of PhD candidates with an interest in qualitative methodologies.	RTDB M-MGR/02	2022
3. Local labour markets, human capital, education and migration - The aim is to develop a new research sub-track that, following the frontier of studies on the subject matter, integrates the analyses completed to date with a study concerning the matching of the skills and competences offered by migrant workers and those required by employers. - This research track, which typically requires building and using LEED (Linked Employer-Employee Datasets), has great potential for enhancing the area's available data sources both for researchers and PhD candidates.	RTT SECS-P06	2023
4. Multi-scalar geographies of public policy - The aim is to enhance the quantitative research track dealing with monitoring and evaluating the socio-	RTT M-MGR/02	2023

economic impact of local projects and policies through qualitative analyses intended to probe deeply – considering multi-scalar relationships (local, national, supranational, global) – into the effects of policies and projects, including in terms of access to essential services (education, healthcare, transport, accommodation) and social infrastructure. These topics have acquired great relevance within the PNRR and, in general, within the EU policy making. - This research track has great potential to fill a gap in the use of evaluation methodologies at the boundaries that go beyond the cost-benefit analysis and other standard methods employed in the field of consultancy.		
5. Climate change and environmental economics - The aim is to develop a new research sub-track intended to analyse, with quantitative methods applied to large databases – including satellite data (e.g. emissions, air quality, waste) – the evolution of problems related to climate change at the local level, analysing the socio-economic and sanitary consequences, and policies of mitigation and adaptation. - This research track has great potential to complement the Open-type databases of GSSI.	RTT SECS-P06 o P02	2024
6. Regional economics and territorial/spatial analysis of economic phenomena - The aim is to enhance the scientific prominence of "general" research carried out in the area and its international network by engaging a high-profile scholar that might complement the high-level staff already present in some areas (e.g. labour and education economics) and attract research tracks that currently lack a scholar of solid academic weight (e.g. tourism and culture economics). - Such an enhancement has obvious positive effects in terms of complementarity for the development of the area as a whole.	PO SECS-P06	2024

Computer Science

In 2022 GSSI participated for the first time in the Ministry of University and Research call of ANVUR (Italian National Agency for the Evaluation of Universities and Research Institutes)[1] to evaluate universities in Italy. The Evaluation of Research Quality (VQR) report presented by ANVUR analyses the research outcomes and third mission of public universities and research institutes, as well as those of private institutions that voluntarily submit their research outcomes for evaluation.
The evaluation is the instrument to promote the improvement of research quality in the assessed institutions and to allocate the performance-based share of the Fondo di Finanziamento Ordinario (FFO) – the Ordinary Financing Fund for the Italian university system.

In its first participation in the evaluation (2015-2019 research activity evaluation), the computer science area (sector INF01) has been evaluated as the **first computer science department in Italy**.
After this excellent achievement, GSSI and specifically the 01 area, which includes both computer science and mathematics, was invited to present a project. The Gran Sasso Science Institute is one of the 180 Italian **"Departments of excellence"**, obtaining more than 7.3 million Euros in additional funding (MUR is still evaluating the exact amount of additional funding)[2]. Overall, 180 Italian departments will be financed with a budget of 270 million euros. With prestigious recognition, this will bring additional permanent positions and significant funds for building autonomous systems, IoT, and algorithms engineering laboratories.
Moreover, the GSSI project scored **first place in the specific disciplinary sector**[3] among the 11 financed projects, with only three of them (including GSSI) concerning computer science. The first place is shared with the Scuola Normale Superiore of Pisa and the University of Pisa, two other prestigious Italian institutions.
The project of the department of excellence identifies the research directions and ambitions of the computer science area. This project proposes to face some significant challenges posed by science and society. All activities will be carried on with a multidisciplinary approach, in a multi-direction analysis of critical subjects such as applied analysis, probability, numerical analysis, network analysis, machine learning, algorithmics, formal methods, software engineering, and computational mathematics, among others. The project will identify and shape coherent structures in highly complex socio-technical, economic and cyber-physical systems, inspired by biology, medicine, neural networks, quantum systems, turbulent fluid dynamics and short- and long-range interaction systems. In particular, the computer science area will focus on the following directions, interconnected and at the same time complementary to each other, specifically in the A2-A4 directions:
● A1. Identifying, deriving, and analyzing effective models and fundamental qualities that describe the most relevant characteristics of the aforementioned systems at different scales or levels of abstraction, from micro to macro or from local to global;
● A2. Studying patterns and structures that emerge within the proposed models;
● A3. Studying control techniques and identifying suitable parameters within systems in order to obtain predefined coherent structures;
● A4. Engineering software-intensive systems that permit to obtain specific structures or prescribed global behaviours.
Our overall ambition is to become the reference centre in Italy on the topic of analysis and engineering of patterns and coherent structures by reducing the gap between theoretical and computational knowledge of physical, social, and digital phenomena.
We can identify the following research directions on which the CS area will focus:

[1] ANVUR website: https://www.anvur.it/en/agency/mission/
[2] https://www.anvur.it/attivita/dipartimenti/
[3] https://www.anvur.it/wp-content/uploads/2022/12/ALLEGATO-NOTA-ANVUR_esito-180.pdf

● Characterization of collective and emergent behaviour in distributed systems, both technological and social. Characterization of patterns and global behaviours that arise in modern distributed systems and their impact in various areas, e.g., execution of computational global execution tasks, services fruition, communication, social influence, information spreading or technology and social justice. We will improve existing results and explore complementary directions both on the methodology and assumptions on the context in which systems operate. For instance, we will consider scenarios where the state of the system is not completely new but needs to be understood or reconstructed from collected data and distributed communication.
The impact of this work concerns the comprehension and prediction of emergent phenomena in social networks and on digital platforms like communities' formation, the spread of information and the congestion of resources.
● Efficient coordination of distributed systems in environments with a high level of uncertainty and potentially hostile agents. We aim at developing strategies, rules or mechanisms to promote or incentivize cooperation or to mediate the interactions in order to achieve global objectives in various contexts, e.g. social networks, Future Internet, traffic networks, swarm or teams of robots, digital markets, Internet communities, etc.
The impact of this work concerns the control of fairness constraints in markets or digital platforms, prevention of congestions in traffic networks, pricing of goods or resources, avoidance of disinformation and manipulation of voting systems, coordination of vehicles, robots, or humans (via devices) in the case of unforeseen scenarios (e.g., disasters).
● Engineering of systems that respect privacy and ethical values as well as other human and social values. We aim at developing techniques and instruments of software engineering and formal methods, and advanced algorithms that are conceived and architected around humans. The goal here is to involve subsystems with a certain degree of autonomy that need to be coordinated and that collaborate among them to achieve global objectives while both showing an ethical behaviour and informing humans of systems' behaviour.
The impact of this work concerns making Italy and Europe the scientific and technical leaders in the development of human-centric systems while stimulating new industrial activities. An additional impact concerns Industry 4.0 thanks to the engineering of autonomous systems (e.g. robotics), the democratization of the use and programming of digital systems, and an ethical and value-centred integration with humans. This integration will clarify the responsibility of humans in the use of autonomous systems, and, consequently will help to solve problems of civil responsibility.

Achieving the above-mentioned scientific goals will require careful and timely recruitment of permanent and tenure-track faculty in the areas of specific interest for the computer science area.
Despite the positive responses to our calls for "expressions of interest" for a variety of positions, attracting top-class, computer-science faculty to the GSSI has proven to be a difficult task over the last years and will most likely remain so in the foreseeable future. Indeed, the vast majority of Computer Science departments in the world is hiring at all academic levels in response to the growing number of students who wish to enrol in computer-science degrees. The competition for talent will be fierce and building an aura of scientific excellence in our selected research areas will be crucial in attracting a good number of high-class computer scientists to the GSSI. The recent success of computer-science researchers in the National evaluation, in the department of excellence, and in grant-winning (both Italian and EU projects) on topics related to the aforementioned scientific challenges, the publications by group members in very selective and coveted outlets, the successful international conferences and other scientific events we organized at the GSSI, and the awards and honours bestowed on our students, postdocs and faculty have put our research in the spotlight and have contributed to increase the visibility of the GSSI within the computer-science community. Since achieving critical mass and visibility are important for future successful hires, we plan to considerably increase the size of the group, also

exploiting the additional funding we will receive because of the department of excellence, and to continue attracting top-class visiting researchers to the GSSI.
The computer-science area is taking great advantage of the interdisciplinary opportunities arising from the presence of the different areas at the GSSI and will be the hub of many cross-disciplinary research projects. Besides the Department of excellence project that will be developed in tight collaboration with mathematics, we are closely working with the physics area in two ambitious PNRR projects concerning space software development and cultural heritage and with the social science area in an EU project also concerning cultural heritage.
We also collaborate with the Municipality of L'Aquila on topics such as real-time tracking and travel planning in public transport, and with "Protezione Civile" in the handling of environmental disasters. This range of collaborations contributes to connecting our international outlook in research and graduate-student education with the development of the local community that hosts the GSSI. Having said so, as stated in the Vienna Manifesto for Digital Humanism[4], while digitalization provides unprecedented opportunities for growth, it also challenges scientists and technologists to use the power of computing for the common good: "Technological innovation demands social innovation, and social innovation requires broad societal engagement." Even though achieving social innovation and justice are tasks that are far beyond what an institute like the GSSI can do, we will strive to ask ourselves the question "cui prodest?" ("who benefits?") when our research can impact society and to disseminate the basic knowledge needed to appreciate the benefits and pitfalls of digitalization for society at large, starting from L'Aquila and Abruzzo as a whole. To this end, we will organize a variety of events in which our best communicators will present research results to the general public, to the whole of the GSSI and to policymakers in an accessible way, highlighting both opportunities they offer and dangers they may pose.
In particular, during the COVID-19 emergency, we started the joint ICE-TCS @ Reykjavik / GSSI virtual seminars, which brought together world-renowned scholars from different corners of the globe and are continuing even after the abolition of the restrictive measures. Interdisciplinary talks were given by renowned scientists such as Moshe Vardi, concerning the ethical crisis of computing, and Edward Lee, in his celebrated book on the coevolution of humans
and machines.

[4] https://www.informatik.tuwien.ac.at/dighum/wp-content/uploads/2019/05/manifesto.pdf