PIA3 / Appel à projets Écoles universitaires de recherche / *Call for proposals Graduate schools of research*

2017 1ère vague / *2017 1st wave*

PAGE-GS

Document de soumission / *Submission form*

Project acronym	PAGE-GS
Titre du projet en français	EUR PAGE@univ-grenoble-alpes
Project title in English	GS PAGE@univ-grenoble-alpes
Project manager	HENRI Gilles Professeur Univ. Grenoble Alpes
Requested funding	42 178 011 € TVA non récupérable incluse
Leading institution	Communauté Université Grenoble Alpes (ComUE, EPSCP)
	Is this project embedded in an IDEX / I-SITE project? X Oui UGA Université de l'innovation
Only where relevant: co-leading institution(s) **obligatoire si des UMR sont parties prenantes**	CEA - Commissariat à l'Energie Atomique et aux énergies alternatives CNRS - Centre National de la Recherche Scientifique G INP - Institut Polytechnique de Grenoble IRD - Institut de Recherche pour le Développement Irstea - Institut National de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture UGA - Univ. Grenoble Alpes USMB - Univ. Savoie Mont Blanc AMU - Aix Marseille Université IRAM - Institut de Radioastronomie Millimétrique IFSTTAR - Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux Météo France ONERA - Office National d'Etudes et de Recherches Aérospatiales
Research unit(s) involved in the Graduate school	**Research units/teams belonging to the Research Department PAGE** **LAPP** Laboratoire d'Annecy-le-Vieux de Physique des Particules **LAPTh** Laboratoire d'Annecy-le-Vieux de Physique Théorique **LPSC** Laboratoire de Physique Subatomique et Cosmologie **LSM** Laboratoire Souterrain de Modane

	IPAG Institut de Planétologie et d'Astrophysique de Grenoble **ISTerre** Institut des Sciences de la Terre **IGE** Institut des Géosciences de l'Environnement **Irstea-ETNA** Érosion Torrentielle, Neige et Avalanches **Irstea-TEGR** Territoires Environnement Grenoble **LECA** Laboratoire d'Ecologie Alpine **LEGI / MEIGE** Laboratoire des Ecoulements Géophysiques et Industriels **EDYTEM** Environnements, Dynamiques et Territoires de la Montagne **SAJF** Station Alpine J. Fourier **OSUG** Observatoire des Sciences de l'Univers de Grenoble **GIPSA-Lab / SIGMAPHY** Grenoble Images Parole Signal Automatique **PACTE / Environnements** Politiques publiques, ACtion politique, TErritoires **CNRM / CEN** Centre National de Recherches Météorologiques **Research units/teams belonging to other Research Departments of UGA** **CEA-LETI** Laboratoire d'électronique et de technologie de l'information **ESRF-FAME** French Absorption Spectroscopy Beamline in Material and Environmental Sciences **LiPhy / LAME** Laboratoire Interdisciplinaire de Physique **Institut Néel** **IMEP-LaHC** Laboratoire de Microélectronique, Electromagnétisme, Hyperfréquence, Photonique et Caractérisation **Research units/teams not belonging to UGA** **CEA-DAp / AIM** Département d'Astrophysique CEA-IRFU **ONERA - DOTA** Département Optique Théorique et Appliquée **LAM** Laboratoire d'Astrophysique de Marseille
Doctoral School(s) involved in the Graduate school	ED Physique - Physics - covering Particle Physics and Astrophysics in PAGE-GS ED TUE - Terre Univers Environnement - Earth, Universe, Environment ED CSV - Chimie et Sciences du Vivant - Chemistry and Life sciences - covering ecology and biodiversity in PAGE-GS ED I-MEP2 - Ingénierie, Matériaux, Mécanique, Energétique, Environnement Procédés, Production - covering fluid mechanics for environment and nuclear energy in PAGE-GS ED EEATS Electrical Engineering, automatics, signal processing - covering data processing and physics of detectors in PAGE-GS ED ISCE Ingénierie pour la santé la cognition et l'environnement - Health Engineering, cognition, Environment

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Scientific field(s) of the project	X Sciences de la Matière et de l'Energie X Sciences du Système Terre-Univers-Environnement ☐ Sciences de la Vie et de la Santé ☐ Sciences du Numérique et Mathématiques ☐ Sciences Sociales ☐ Humanités
Only where relevant: other EUR projects submitted by the coordinating institution	PEM-GS MSTIC-GS CBH-EUR-GS G2SI-GS HSS-L4D-GS

List of PIA projects to which this project is connected

Embedded LABEX units for which an extension of funding is requested	LABEX ENIGMASS LABEX FOCUS LABEX OSUG@2020
Embedded LABEX units for which an extension of funding is not requested	
Project links with other existing PIA entities (e.g. Equipex, etc.)	EQUIPEX **CLIMCOR** : Paleo-CLIMatic CORing: High Resolution and Innovations **CRITEX** : National Park Innovative Equipment for Study of Critical Watersheds Zones **EcoX**: Microfocus light line at the ESRF for environmental sciences **EQUIP@MESO** : Intensive computing of coordinated centers, petaflop and exascale computation **NOEMA** : Extended Millimetric Interfero-meter of the Northern Hemisphere **RESIF-CORE** : French seismological and geodesic network

List of partner institutions

Nom de l'établissement d'enseignement supérieur / *Academic institution name*	Statut / *Legal status*
Nom de l'organisme de recherche / *Research organization name*	**Statut / *Legal status***
Entreprise / *Company*	**Secteur(s) d'activité / *Field of activity***

List of acronyms

CDP	**C**ross **D**isciplinary **P**rograms of the IDEX UGA
CERN	European Organization for Nuclear Research
CNES	**C**entre **N**ational d'**E**tudes **S**patiales
ED	***E**cole **D**octorale* **- D**octoral **S**chool
EMJD	**E**rasmus **M**undus **J**oint **D**octorate
EMM	**E**rasmus **M**undus **M**aster
ESA	**E**uropean **S**pace **A**gency
ESO	**E**uropean **S**outhern **O**bservatory
ESRF	**E**uropean **S**ynchrotron **R**adiation **F**acility
GS	**G**raduate **S**chool of **R**esearch
ILL	**I**nstitut **L**aue **L**angevin
ITN	**I**nnovative **T**raining **N**etwork (H2020)
OSUG	**O**bservatoire des **S**ciences de l'**U**nivers de **G**renoble
PAGE	**P**article physics, **A**strophysics, **G**eosciences, **E**nvironment and ecology
PBO	*Organisme de recherche* - **P**ublic **R**esearch **O**rganization
UFR	***U**nité de **F**ormation et de **R**echerche* - Training and Research academic unit
UGA	**U**niv. **G**renoble **A**lpes
RD PAGE	**R**esearch **D**epartment PAGE
RI	**R**esearch **I**nfrastructure

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RESUME / *SUMMARY*

L'EUR PAGE porte l'ambition de créer de nouvelles synergies entre la recherche et la formation dans trois domaines d'excellence de la communauté académique Grenoble Alpes et de ses proches partenaires : la physique des particules et l'astrophysique, les sciences de la terre et les géosciences externes, l'écologie et l'environnement. Notre projet propose de poursuivre les projets de trois LABEX (ENIGMASS, OSUG@2020, FOCUS) dans un cadre commun et d'y adosser étroitement nos formations de master et de doctorat afin de mieux préparer nos étudiants aux métiers de demain. Les points d'articulation entre les projets des trois LABEX créeront les conditions propices à l'émergence de nouvelles synergies entre théorie, observation, innovation en instrumentation et modélisation. Beaucoup de nos recherches sont liées au développement de plateformes et de grandes infrastructures de recherche que ce soit pour l'observation de l'univers, des enveloppes superficielles de la Terre et de la biodiversité. Notre implication dans le développement et l'exploitation des données issues de ces outils et infrastructures est internationalement reconnue. Avec le soutien de l'EUR, elle sera davantage mise au service de la formation de nos étudiants. Nos recherches sont également en prise avec les grands enjeux sociétaux que sont la transition énergétique, le climat, les risques naturels, la gestion durable des ressources et l'adaptation des sociétés humaines aux changements globaux et régionaux. Notre projet contribuera à développer et à mieux transmettre les compétences, les savoir-faire et la culture scientifique transversale, ouverte à l'interdisciplinarité, qui sont nécessaires pour éclairer l'action publique sur l'ensemble de ces questions. Les principaux leviers actionnés pour transformer nos formations sont : (i) un enrichissement de l'offre de master, avec la mise en place de trois *Intensive Research Masters*, et de doctorat permettant aux étudiants les plus motivés d'approfondir et d'élargir leur champ de compétence à travers des enseignements complémentaires, des stages de longue durée, des aides à la mobilité et la participation à des écoles d'été ; (ii) un soutien à des plateformes de recherche et formation, comme le centre spatial universitaire de Grenoble, et aux partenariats avec de grands instruments (ESRF, ILL, IRAM, CERN) pour développer les enseignements de type *learning-by-doing* ; (iii) la mise en place d'une équipe pédagogique mixte dans chaque grand domaine thématique et la création d'un contrat de type *joint position* donnant davantage de cohérence, de lisibilité et de force à l'implication des personnels des organismes de recherche et des partenaires industriels dans la formation ; (iv) des moyens en faveur de l'internationalisation de nos formations en lien avec les grandes universités mondiales et avec nos partenaires du sud. L'ensemble de ces actions concourra à accroître le rayonnement de nos recherches et de nos formations et favorisera l'attractivité de Grenoble Alpes dans l'ensemble des champs de connaissance couverts par l'EUR.

The aim of the GS PAGE is to establish new synergies between research and training in three areas of academic excellence of the Grenoble Alpes community and its partners, i.e. particle physics and astrophysics, earth sciences and external geosciences, ecology and environment. Our project

proposes to pursue three LABEX projects (ENIGMASS, OSUG@2020, FOCUS) within a common framework and to reinforce the link between these projects and the curricula of our master and PhD students so that they can prepare an academic or non-academic professional project under the best conditions. The GS will strengthen cooperation among the three LABEX and this will favor new synergies between theory, observation, innovation in instrumentation and modeling. Much of our research is related to the development of research platforms and infrastructures, whether for the observation of the universe, the solid earth and the earth's critical zone and biodiversity. Our involvement in the development of these RI and in the analysis of the collected data are internationally recognized. The GS PAGE will provide support to these platforms so that they can be more closely involved in the training of our students. Our research also addresses major societal issues such as energy transition, natural hazards, management of resources and the adaptation of human societies to global and regional change. Our project will contribute to the development of a cross-disciplinary scientific culture and to the dissemination of know-how which are pivotal to address the sustainable development goals and to better inform policy makers and managers. The main levers used to transform our curricula are: (i) an enhancement of the content of master, with the setting-up of three Intensive Research Masters, and the doctoral studies allowing highly motivated students to deepen their knowledge and improve their skills and competencies with complementary courses, long-term internships, mobility aids and participation to summer schools; (ii) support for research / training platforms such as the Grenoble University Space Center and partnerships with major research centers (ESRF, ILL, IRAM, CERN) to improve our training capabilities in learning-by-doing; (iii) the establishment of mixed teaching and learning teams covering all disciplines of the GS PAGE and the setting-up of a joint position to give more coherence and strength to the involvement of Public Research Organization and industrial partners in training; (iv) incentives for the internationalization of our curricula in connection with the major universities of the world and our partners in the South. The GS PAGE will be pivotal to further ameliorate the overall level of our research and of the qualification of our master and PhD students. This will reinforce the attractiveness of Grenoble Alpes academic offer in all the fields of knowledge covered by the GS PAGE.

CADRE GENERAL DANS LEQUEL SE SITUERA L'EUR

The IDEX UGA has submitted six proposals of GS, i.e. one per Research Department (part 3.4).

1 CONTEXT AND PREVIOUS ACHIEVEMENTS

1.1 CONTEXT AND SCOPE OF THE PROJECT

PAGE-GS will develop synergies between research and training on the thematic area of the PAGE Research Department (RD) *i.e.* particle and astroparticle physics, cosmology, astrophysics,

geosciences, environmental sciences and ecology. To do this, it will rely on the **renewed scientific projects of three highly successful LABEX (ENIGMASS, OSUG@2020, FOCUS) that will be tightly connected to an enriched training program to prepare our graduate and PhD students for the careers of tomorrow.** The academic forces involved in this project (part 4.2) will continue to develop research and training at a very high level. We will build on this **critical mass of excellence** to increase the qualification and employability of our students.

PAGE-GS will **strengthen the interactions between the three LABEX to open new research frontiers**. This applies in particular to instrumental research projects with the development of new sensors for astrophysics and biogeosciences, to the implementation of integrated observation projects on the dynamics of earth combining ground measurements and space technologies, to research on interstellar chemistry and the formation of planetary systems with questions on the habitability of exoplanets. The research and training project of PAGE-GS will also contribute to key knowledge challenges such as (i) the development and learning of new numerical and algorithmic methods for big data processing in our disciplines (in connection with MSTIC-GS), (ii) the development of new synergies between theory and observation-instrumentation (link with PEM-GS), (iii) research and actions at the environmental-societal interfaces focusing on the vulnerability and adaptations to global and regional changes (link with HSS-L4D-GS). On all these issues, the challenge is **to forge a cross-cutting scientific culture that should inspire our curricula.**

A strong originality of the GS PAGE will be **the involvement of research platforms - *i.e.*** (very) large instruments dedicated to the observation of the universe and instrumented sites that are part of National and International Research Infrastructures (RI). Our community contributes to the instrumentation of the main infrastructures in particles physics at CERN and of astrophysics, as ESO and IRAM or large observatories. One of the main purposes of FOCUS addresses the technology of the detectors for the next generation of instrumentation for these infrastructures. PAGE-GS also includes LSM, the deepest site in Europe offering a low noise environment. Over the last decades, our community has also been very active in the development of RIs for the observation of the Earth including geophysical, ecological and social components and participated to their integration into National (Allenvi) and European road maps (ESFRI). We will further contribute and engage into these developing national and international initiatives and will better integrate these RI in the training of our master and PhD students.

PAGE-GS curricula will include specific actions to support our best Bachelors to pursue their studies in master and PhD. The graduate curricula will be backboned **by three intensive research masters** covering all our disciplinary fields. Intensive research masters will provide our enrolled students with new opportunities **to deepen their knowledge and improve their skills and competencies through a closer contact with researchers, engineers and the private sector**. Funded internships, scholarships and apprenticeships in France and abroad, additional training hours will allow them to prepare under

the best possible conditions an academic or non-academic professional project. The training project will be supervised and implemented by **mixed teaching and learning teams** bringing together faculties, researchers and engineers. The involvement of PBO and of non-academics in the training will be reinforced with the labelling of a **joint position**. Links with the industrial sector will be consolidated, notably in the field of clean and safe energy, instrumentation and space research, natural hazard assessment, environmental quality and monitoring, and management of resources.

1.2 MAIN PREVIOUS ACHIEVEMENTS

Bold text refers to the main achievements of the LABEX since the evaluation of 2015.

LABEX ENIGMASS

ENIGMASS aims at exploring the origin of mass, which permeates practically all aspects of fundamental physics: the dark matter and dark energy puzzles, the matter/antimatter asymmetry, the dynamics of the universe. The research program is focused on 3 priorities.

The *search for new physics and precision measurements* of the standard model (SM) are the cornerstones of the physics at colliders: the LABEX period spanned over the first two runs of the Large Hadron Collider (LHC) at CERN and the large data samples accumulated by ATLAS and LHCb allowed to often exceed the original goals. **Our ATLAS groups became leading experts in diphotons**, a key discovery channel for the Higgs boson, highlight of the first years of ENIGMASS. Our precision measurements of Higgs properties, top quark polarization, cross-sections of Z, tW or WZ as well as the CKM angles confirm the validity of the SM down to 1% level. Flavour physics and dark matter searches triggered new collaborations with theorists: important progresses were made on precision calculations for SM and new physics processes, model building, development of tools and interpretation.

We are also strongly involved in detector operations and performance studies, in computing and in upgrades. Thanks to the LABEX funding, we acquired a **new expertise in the tracking detectors**, developing a **novel ATLAS Alpine Pixel tracker** design for the High Luminosity LHC. We also made major contributions towards preparation of the upgrades of the LHCb DAQ system and ATLAS Liquid Argon calorimeter electronics.

ENIGMASS allowed the development of a rich *neutrino physics* program covering key subjects. 2016 has seen the realization of the first purified 82Se sources for the SuperNEMO demonstrator (double ß-decay search) at LSM and several analyses on NEMO-3 data were completed. The **STEREO experiment** (sterile neutrinos search) has been installed at the ILL reactor, **taking its first data**. The participation to WA105/DUNE (project for neutrino oscillations) in developing a large liquid argon TPC prototype has taken a growing place.

The *dark matter (DM)* mystery remains a key question, although the 2017 context differs from that of 2012. The LABEX teams contributed to make significant progress on questions such as: how much

(**PLANCK: accurate measurement of the DM quantity** in the universe), where (NIKA(2): detailed mapping), what (**AMS**, HESS(2): **measurement of energy spectra of several species** giving severe indirect constraints on the nature of DM, ATLAS@LHC). ENIGMASS provided an essential impetus for the preparation of future instruments to constrain, e.g. the evolution of the spatial distribution of the DM (Large Synoptic Survey Telescope) or to attempt direct detection with complementary approaches (MIMAC, NEXT). These activities are synergized by numerous phenomenological studies on dark matter and cosmic/gamma radiation.

The most remarkable result in 2016 is **the opening of a new window on the universe with the discovery of gravitational waves**, announced by the global collaboration LIGO-Virgo. More speculative, the quantum gravity applied to black holes and cosmology is also promising. In the field of gamma-ray astronomy ENIGMASS nested a new activity on very high-energy electromagnetic emissions from Active Galactic Nuclei around the HESS and Fermi experiments in the prospect of the Cherenkov Telescope Array observatory (ESFRI CTA).

In the *field of education*, ENIGMASS created two innovative schools. ESIPAP (European School of Instrumentation in Particle & Astroparticle Physics) targets mainly an international audience of master and PhD students and young professionals working in research institutes. The GraSPA Summer School, dedicated to 3rd and 4th year physics students, aims to accomplish the important mission of training young students through close interaction with researchers.

LABEX OSUG@2020

OSUG@2020 has promoted major activities of OSUG, one of the most prominent observatories among the 24 French *Observatoires des Sciences de l'Univers* (OSU). Its main missions are long-term observations of astronomical and terrestrial systems, organized at national and European levels relying on CNRS-approved observation services (SNO, ZA), large RIs, and data centers.

OSUG@2020 addresses four major objectives: (i) to enhance observation systems and improve our capacity to link and process data collected in different scientific or regional domains for a better understanding of, and ability to predict natural systems; (ii) to expand our shared expertise on environmental issues and their socio-economical impacts; (iii) to develop innovative training programs to address strategic research priorities related to environmental issues and technologies, social sciences and health; (iv) to augment industry-oriented actions through technology transfer with SMEs or larger companies and filing of patents. To these ends, OSUG@2020 has annually (co)funded more than 30 scientific projects, 3 PhD theses (increased to 13 in 2017), approximately 12 workshops and summer/winter schools, and 15 student exchanges, including 20% coming from developing and emerging countries. **In 2017, a specific call allowed us to launch six ambitious scientific projects concerning the full range of scientific domains covered by OSUG@2020**. Two of these projects received co-funding from the IDEX UGA.

For example, selected projects aim at **developing, constructing and installing innovative astronomical instruments** such as **SPHERE, GRAVITY, SPIRou and CTA** to study planet formation, to search for exoplanets, and to study high energy phenomena in the universe. Other projects concern the acquisition and exploitation of cutting-edge equipments like a **tomograph for cryospheric studies**, a network of stand-alone **seismic stations** and wireless **electric field sensors** for geophysical imaging, as well as the development of a **miniature imaging spectrometer** for the detection of greenhouse gases for nanosatellites. One of the IDEX co-funded projects concerns the **development of an integrated environmental database** of climate, land use, multitrophic biodiversity, and ecosystem multi-functionality for the French Alps. Predictive climate modeling will benefit from the **transformation of the Regional Atmospheric Model** (MAR) developed at OSUG into a community model to facilitate the simulation of the regional climate. OSUG@2020 developed the **OSUG Data Center** for the processing and distribution of data originating from monitoring activities.

The **link between geophysical observations and their impact on societies** has been addressed in a series of PhD theses and **communicated to local authorities** through several workshops and large-audience seminars. A major education action has been developed around the regular support of the platform ***Campus de l'Environnement***, which includes instruments for innovative field courses for data analysis and processing in fields ranging from solid Earth to ecology. OSUG@2020 has also regularly supported the **European Research Course on Atmospheres (ERCA)** attended by 1000 participants from some 60 countries.

In terms of technology transfer, an excellent example is the **SWIFT device**, the worldwide smallest spectrometer developed for astrophysical applications, which has been transformed into a tool to measure rock deformation, seismic events, and Earth tides with an unprecedented sensitivity and accuracy.

Concerning outreach, the last edition of ***Rencontres Montagnes et Sciences*** was attended by 6000 spectators in Grenoble and in the Auvergne Rhône-Alpes region. The **MOOC** *À la recherche d'autres planètes habitables* co-funded by FOCUS was followed by 4600 participants from more than 90 countries.

LABEX FOCUS

Substantial progresses have been achieved in each of the three axes. On the first research program (sensors for the mm and sub-mm wavelength), the research has kept on developing along two different technologies:

- Silicium-Grid bolometers *(and the ASTROBOND project).* The development of the novel bolometers has made good progresses, with a slower rate for the electronics. Bolometers are at the heart of an instrument proposed to complement the Safari Instrument of the SPICA space mission project. **The instrument has been included in the proposal sent as an answer**

to the call for mission M5 issued by ESA. SPICA is among the 10 projects which have passed the ESA technical assessment.

- *Kinetics Inductance Detectors (KIDs).* The KIDs detectors keep on developing at a very fast rate. **The NIKA2 camera at IRAM is a great success; the commissioning is almost finished and the instrument is made available to the astronomical community on a shared-risk basis**. The instrument is equipped with arrays of KIDs at 1 and 2mm (total of 3000 detectors), funded by FOCUS. For the future, developments are made to extend the wavelength coverage of the detectors, their polarimetric capacity and to use them for spectroscopic observations (Kiss project as a pathfinder of the Concerto project, a low resolution spectro-imager to map the carbon at high redshift). This technology has been chosen for the CORE proposal to ESA, a post-Planck mission to measure the polarization of the cosmic microwave background, but the project did not pass the M5 ESA technical assessment.

In relation with our second research program (sensors for the infrared wavelength range), **the development of large format (2Kx2K), low noise, near infrared detector arrays has been completed in 2016**. Given the financial support of FOCUS (1 M€) to LETI and SAp, a consortium made of SOFRADIR, LETI and SAp has answered the call from ESA to develop such arrays and has been selected (2 M€). The consortium has also been at the origin of an answer to the European Commission to develop the tools needed for the large format, which has been selected (5 M€). In a two years timeframe, FOCUS will receive one of the 2Kx2K detector arrays developed in this framework. FOCUS has issued a call for the observational use of this array. The market of this critical component may reach 200 M€ for the 15 coming years. The strong dependence to a unique US provider has been identified by ESA as a critical issue. For our industrial partner located in Grenoble even part of this market will change significantly his production

Partnerships with CNES and CEA allowed us to **develop detector arrays for the ARIEL space project under competitive phase A study (HgCdTe detectors operating at relatively high temperature in LWIR range) ending in 2017**. The first results are promising, and if ARIEL is selected, these detectors would be considered as an alternative to US detectors.

Along with the third research program (Innovative Focal Plane), good progresses have been made in the development of curved detectors, which is of major interest to simplify optical systems. This has been achieved by combining the expertise of two laboratories (LETI and LAM). An ERC was obtained in 2015. Several patents were obtained. Finally, we have also developed a new generation of arrays with spectroscopic capability, integrated in the close environment of the detector, reducing drastically the size of such devices and opening new applications, such as their use in nanosatellites. Prototypes have been build and have shown the huge potential of the technology. **FUI program (IMAGAZ with Total) has been accepted and an H2020 program (3 M€) with a big aeronautical European company has been submitted**. Such an integration of advanced optical system functions in miniaturized instruments are really promising for a wide range of application in astronomy and

biogeosciences. Particular efforts will be devoted to develop these applications in the framework of PAGE-GS.

1.3 ASSESSMENT OF THE AFFILIATED LABEX BY THE UNIVERSITY AND/OR RESEARCH ORGANIZATION AUTHORITIES

2 PROJECT DESCRIPTION

2.1 PROGRAMME OUTLINES, VISION, AMBITION, EDUCATIONAL STRATEGY

2.1.1. Project overview

PAGE-GS will be built around two main pillars (Fig. 1): (i) **Particles and Universe** supported by the new ENIGMASS project, on which we shall ground a training program in physics; (ii) **Earth and Planetary systems** supported by the new OSUG@2030 project, which constitutes the basis of a training program in the science of telluric planets, external geosciences, ecology and geography. Masters and PhD curricula affiliated to these two pillars are detailed below (part 2.3). In this overall scheme, new FOCUS project will be a transverse axis structuring our research and innovation in sensors and instrumentation with application in physics, astrophysics, planetology or geosciences and ecology.

The first pillar gathers five internationally recognized laboratories (IPAG, LAPP, LAPTh, LPSC, LSM) which organize the activities of internationally recognized research teams supported by significant technical teams and innovative instrumental developments, along themes ranging from particle physics to the study and observation of the cosmos. Involvement of large instruments or RIs (eg ATLAS, LHCb and ALICE at the LHC, NAOS and SPHERE on VLT, telescope networks such as HESS and CTA, IRAM/NOEMA, Virgo, LSST, etc.) and spatial instrumentation (eg Concert on Rosetta, AMS) are characteristic of this axis. **With the proximity of CERN and the presence on the site of two major international institutes (ILL and IRAM), the research-training ecosystem is exceptional**.

The second pillar brings together the laboratories (IPAG, ISTerre, IGE, LECA, LEGI, Irstea-TEGR, Irstea-ETNA, SAJF) and associated research teams (CEN, Environnements, FAME, LAME, SIGMAPHY) of OSUG and EDYTEM. This community has developed a common scientific culture favoring **an integrated approach to the study of the Earth system around probing, monitoring, and predictive modeling** and **open to the challenges of interdisciplinarity with the social sciences**. The research teams are involved in the structuring or animation of major national and international RI for Earth observation (deep earth and critical zones): RESIF associated with ESFRI EPOS, European RI ACTRIS, the OZCAR and Réseau des Zones Ateliers with the European mirror project eLTER, ANAEE-France and Europe with SAJF, the national data center Theia which brings together (satellite and *in situ*)

observation data from continental surfaces.

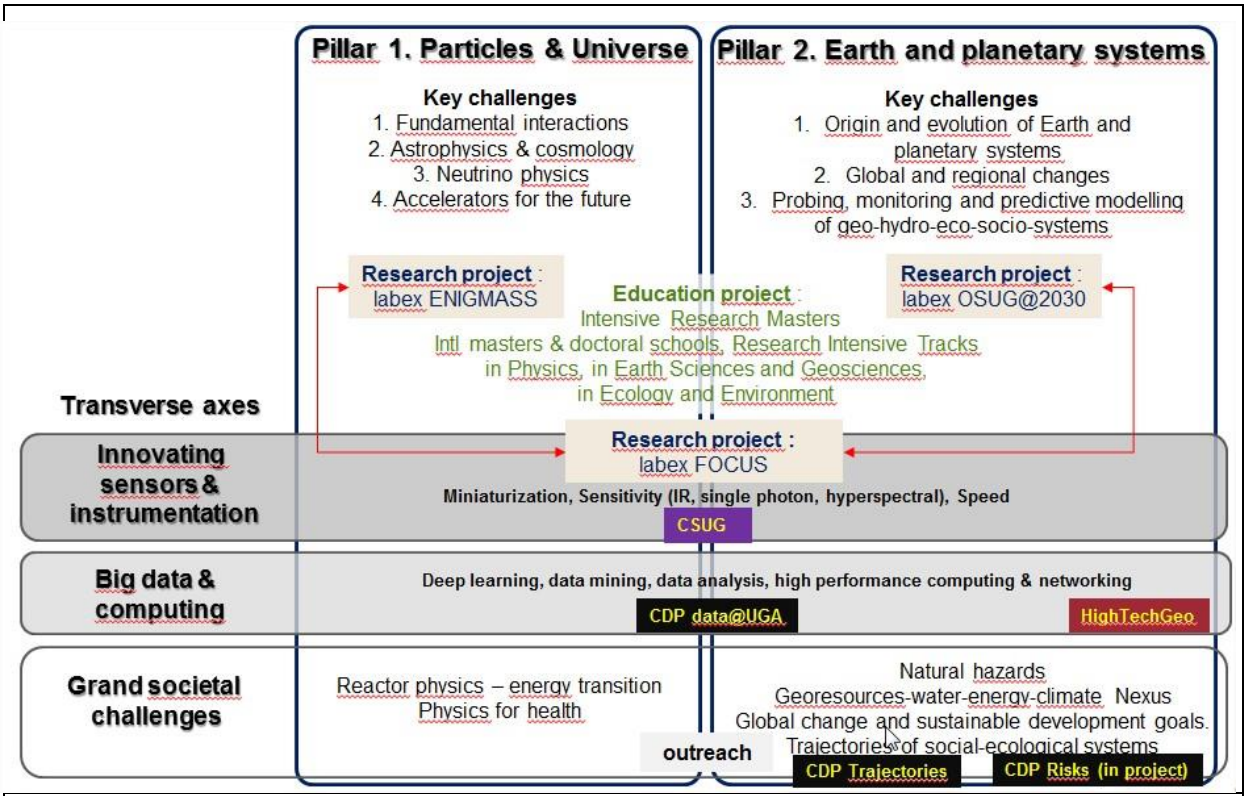


Figure 1: Project overview

2.1.2 Socio-economic impacts

Our project will be in line with the grand societal challenges identified by the National Research Strategy and the IDEX UGA:

- **secure, clean and efficient energy** with a training program in nuclear engineering, georesources and energy transition;
- **resource-saving management and adaptation to climate change** with internationally recognized research on climate, georesources, natural hazards, closely linked to three master programs and two EDs. Our works on the socio-ecosystems at the interfaces between social sciences and humanities, and geosciences provide elements of aid to public decision-making for a sustainable management of territories;
- **health and well-being** with the development of particle sources for therapeutic applications and research on air quality;
- **information and communication society**, with open access to large data volumes in the research domains of the RD PAGE, and digital developments in order to help the scientific

users and citizens in their exploitation.

2.1.3 Structuring effect

The PAGE-GS project will have a strong structuring effect for our community:

- it will accompany the determination of the renewed ENIGMASS project to enlarge its scope;
- it will enhance the development of research linked to pillar 2 and OSUG@2030 by supporting cross-disciplinary initiatives on mountain territories, natural hazards, georesources and environmental quality;
- it will expand the partnership between the RD PAGE and UFRs over a wider area now covering research, training, development and dissemination of knowledge;
- it will create new synergies between LABEX by encouraging cross-cutting research actions;
- it will catalyze tighter partnership between researchers and faculties to enhance our training programs and improve the employability of our students.

2.1.4 Towards a French model of Graduate School of Research

PAGE-GS will contribute to a French model of GS by proposing:

- the development of **intensive research masters** covering all our thematic fields of excellence (Physics-Astro, Earth Sciences and external geosciences, Ecology and environment);
- a stronger and more readable involvement of PBO and industrial sector in education through the setting up of **mixed teaching and learning teams and joint position offers**;
- **a labelling of summer/winter schools** that will be part of the curricula;
- a strong support to develop **learning-by-doing projects on research platforms**;
- **mobility incentives for master and PhD students** with high potential to attract or retain the best French or foreign students;
- **the internationalization of our training programs**, with the continuation and / or emergence of Research Intensive Track, Erasmus+ Master and International Doctoral School programs.

Contributions from the three LABEX and from the GS budget will be managed in a concerted way to support these actions. **The annual financial effort amounts 2.7 M€.**

2.2 SCIENTIFIC SCOPE AND CONTENTS OF THE PROJECT

2.2.1 First pillar "Particles and Universe"

The success of the LHC, as admirable as the triumph of the Standard Model (SM) of the fundamental interactions, confirms the existence of a scalar particle which looks like the Higgs boson. Yet, the lack of understanding of the electroweak phase transition below 1TeV, leave the picture obscure. Besides, the matter/antimatter asymmetry of the universe remains unexplained, motivating the search for CP violation at the intensity frontier (flavor and neutrino physics, ultracold neutrons). The recent results of numerous independent observations of the Cosmos establish firmly the standard model of cosmology where the composition of the universe today is dominated by dark matter and

dark energy. These facts strongly hint at the presence of some new phenomena beyond the SM. The successful experimental discovery of gravitational waves and the measurement of very high-energy gamma rays in the recent years opened new windows in astronomy and in the exploration of the non-thermal Universe. Our teams cover all these aspects in a complementary approach in particle physics, astrophysics and cosmology, starting from theoretical and mathematical aspects to instrumentation, data analysis and interpretations.

On the **collider side** (ATLAS, LHCb, ALICE), the search for new phenomena and new particles, both directly and indirectly through precision measurements, will take full advantage of the future high luminosity and high energy phases of the LHC. We have established a rich program which covers a wide variety of final states, complemented by work at the theoretical level on higher-order calculations and development of computational tools, and by phenomenological studies of effects beyond the SM. Key examples cover searches for dark matter, measurements by the ATLAS groups of the Higgs boson couplings and of vector boson scattering cross-sections. The precise measurement at LHCb of the baryon CP-violating gamma-phase, crucially entering in many observables, is expected by 2023. The strong interaction will be probed with unprecedented precision via studies of the Quark-Gluon plasma produced in heavy ions collisions at LHC: ALICE team carries out analysis of the in-medium parton energy-loss using signatures such as high-pT jets, photons and heavy flavor particles. These searches are complemented by precision measurements at low energy, using ultracold neutrons, to measure the neutron electric dipole moment at PSI and to search for new short-range forces affecting their quantum states when trapped in the Earth gravitational field at ILL.

On the **astrophysics and cosmology** side, the challenges remain multifold. ENIGMASS is ideally positioned to significantly contribute to several subjects and to strengthen synergies between multi-wavelength and multi-messenger approaches.

The origin of cosmic rays and the nature of cosmic-ray accelerators in the Universe are questions addressed by CTA thanks to its ability to perform spectral and morphological studies of sources of gamma rays and by Auger-Prime sensitive to ultra-high energy cosmic rays. More generally, we want to address the question of the sources of high energy phenomena in the universe.

The LIGO/Virgo consortium has opened the time of gravitational-wave astronomy; with future observations of black holes and neutron stars coalescence, the discipline will enter the measurement era and the next generation of detectors such as Einstein Telescope is already framed.

Determining the nature of dark matter and measuring its distribution in the universe requires several completing methods: direct detection with the approaches of the MIMAC, Cygnus and future NEXT experiments, indirect detection with CTA, detailed study of large-scale structures with NIKA2, Euclid and LSST.

Planck made cosmology enter the precision era and future projects such as E4, LSST, Euclid, Advirgo and CTA will contribute to highlight signatures of the primordial inflation, to determine the nature of the dark energy and to test the laws of gravitation at the greatest scales. These efforts are sustained

by theoretical work on loop quantum gravity.

On the **neutrino sector**, the ENIGMASS experimental program is performed using in-site and close infrastructures (CERN, ILL, LSM). We play a key role in the STEREO experiment searching for the existence of light sterile neutrinos, and are strongly involved into the SuperNEMO demonstrator, dealing with the search for double beta decays to explore the Majorana nature of the neutrino. Further, we are strengthening our participation to the future long baseline project DUNE (2026) aiming to unfold the mass hierarchy and discover the neutrino sector CP violation. In addition to double beta decay searches with Xenon, the development of innovative technology (e.g. a spherical TPC) could be used for the investigation of neutrino nucleus coherent scattering and the detection of supernovae neutrinos.

Particle and nuclear physics rely heavily on advances in **accelerator physics and technology**. Pushing forward the energy and luminosity frontiers, mandatory for exploring for new physics, requires sustainable worldwide R&D effort over many years. Smaller accelerator centers are also operated by national communities to serve the nuclear physics programs or provide particles for testing new detectors, serving as probes to other sciences or industrial and medical applications.

ENIGMASS partners developed a long experience in several fields and a national facility is operated; they run the GENEPI2 platform, unique in France, producing a high flux of 14 MeV neutrons covering a large spectrum of applications (detector characterization, microelectronics behavior under radiation). We are a main partner of the MYRRHA project, aiming at controlling a nuclear reactor with a linear accelerator, and are developing since many years the techniques to produce ion sources to generate intense ion beams (SPIRAL2). Our teams are the world leader today on nanometer control and stabilization techniques through active feedback mechanisms of magnets and other accelerator beam components.

Using our expertise, taking advantage of the CERN proximity and the PAGE-GS training program (JUAS), our strategy is to develop the existing activities and to invest for the medium and long-term future. For the post LHC era, a new generation of e+e- colliders (innovative linear collider CLIC or new 97 km circular collider FCC) are under study also in our labs. ENIGMASS will provide the necessary support to contribute to these programs through a series of R&D actions in cooperation with CERN. There is indeed a unique opportunity in supporting research activities working on innovative accelerator techniques, as the current technology reaches its limits.

2.2.2 Second pillar “Earth and planetary systems”

Due to the monitoring activities at OSUG, we are a leading actor for interdisciplinary and integrating research of natural systems. OSUG@2030 aims to sustain and facilitate the renewal of observational equipment and the development of innovative sensors as well as strategies. We will develop integrated projects, observation systems, joint platforms, as well as conceptual and numerical models to improve our understanding of complex natural and/or anthropic systems and their

interaction with the socio-economic environment. With this new knowledge we will address three key challenges:

1. Origin and evolution of Earth and planetary systems.

This challenge includes the study of the origins of the Solar System (via the study of Mars, Titan, Small Bodies, Pluto), of planetary systems (exoplanets, proto-planetary and debris disks), and stars (interstellar medium and collapse). We will address questions related to (i) the interstellar heritage in the solar system, in star formation, proto-planetary disks and exoplanets; (ii) the search of conditions for the emergence of life via the molecular complexity, organic chemistry, habitability criteria (Mars, exoplanets), and the spectroscopy of exoplanets; (iii) the physical and chemical studies of the dynamic Earth and planets, especially by coupling observations of natural objects with the experimentation of related processes. We will study the physical mechanisms behind the Earth magnetic field and the dynamo effect, which is at work in most natural objects such as planets, stars or galaxies. Studies of the terrestrial system will be a major focus by advancing our understanding of the coupling and feedback between tectonics (on a crustal and lithospheric scale), climate, erosion and biodiversity. We will address questions like: How is the surface of the Earth shaped by interactions between deep (orogenic dynamics) and surface processes (climate, relief erosion, deposition)? Can we identify precursors to great geophysical events that are affecting our planet? The identification of precursory signals for disasters will be crucial to improve our predicting capabilities. Moreover, we will develop evolutionary biology approaches that bridge the gap between micro- and macro-evolutionary processes taking into account geophysical processes and parameters. This will enable us to better understand the origin of biodiversity and the diversification of ecological niches.

2. Global, regional, local changes.

We will implement integrated approaches addressing the complexity of the compartments (atmosphere, ocean, lithosphere, cryosphere, biosphere) of the Earth System and their evolution under global change at different temporal and spatial scales. This concerns the multi-scale functioning of the climate system, natural physical, chemical and biological processes, the water cycle as well as anthropogenic impacts. Global changes will be downscaled to address local and regional impacts (eg concerning water resources) in mountain ranges and intertropical or polar regions recognized as hot spots undergoing drastic changes. Another focus will be on feedback mechanisms within and at the interface of the compartments of the Earth System. For example, we will couple ecological and evolutionary approaches for estimating the impact of global and regional changes including the effect of anthropogenic forcing such as pollution or land use changes on biodiversity (distribution, adaptation) and ecosystem functioning (resistance and resilience). New concerns about environmental safety will be addressed related to the distribution of trace compounds impacting air and water quality (e.g. heavy metals, pesticides, drugs) in highly vulnerable regions (e.g. Andes, Himalaya, Arctic, West Africa, East Asia). Past changes will be reconstructed using a full variety of methods and tools for different matrices (CLIMCOR and Ice Memory). On this

topic, our community has a great international renown and our research is pivotal to IPCC reports. Mitigation strategies to reduce the impact of global changes will be addressed. We will contribute to new approaches for the use and distribution of natural resources in hotspot regions (eg Alps, Arctic, intertropical regions) as well as the sustainable use of georesources required for the energy transition.

3. Probing, monitoring and predictive modeling of geo-hydro-eco-socio-systems.

Developing innovative observational techniques to probe earth and ecosystems and innovative data processing techniques constitute a major activity. For example, physical processes that govern earthquakes, ground and fluid motions, volcanic eruptions and changes in the Earth magnetic field can be tackled by combining and optimizing *in-situ* (eg electromagnetic, acoustic, optic) and satellite observations. Quantitative, high-resolution imaging of our environment will be derived to determine processes at unprecedented spatial and temporal scales for a better understanding of physical parameters controlling the reshaping of the Earth topography. The development of new multidisciplinary observatory networks (for monitoring biodiversity, land use changes, biogeochemical cycles, etc.) and *in-situ* and *ex-situ* experiments will be pursued. These unique and high quality observations aim at improving our understanding of the functioning of the Earth System undergoing local, regional and global changes, thus, leading to fully integrated models. For example, we will contribute to the state-of-the-art components of integrated high resolution climate models by further developing advanced regional climate, ice sheet, snow, ocean, and distributed hydrological models. Within the international framework of IPBES, we will contribute to the modeling and prediction of the evolution of biodiversity distribution and ecosystem multifunctionality. The *Maison Climat Planète*, under construction on the university campus, will gather modeling experts to implement more reliable scenarios of climate change and its impact at regional scale. OSUG@2030 aims to transform this group into a major hub for the integrated modeling of geo-hydro-eco-socio-systems.

2.2.3 Transverse Axis “Innovating sensors and detectors - LABEX FOCUS” (TA1)

The new FOCUS project will pave the way for the **development of sensors and instruments** with a clear commitment to enlarge their use for the research of the two pillars via spin-off technologies and training. Our three main research programs will be expanded: space applications of detectors and readouts will be reinforced by increasing their Technology Readiness Level and working collaborations with CSUG. A priority is to address the main challenges of the forthcoming generation of instruments for large observation infrastructures (IRAM, ESO ELT and VLT) and for space missions.

*1. M**illimeter arrays***

FOCUS deals with two main technology solutions : (i) MIS which offers a fully integrated readout system but is heavy to produce with a long-time turnover - examples are the inheritance of Herschel/PACS, APEX/Artemis, and Pilot CNES balloon project; (ii) KIDs which can be customized

more easily but requires developments of a custom readout system - an example is NIKA2 operated at the telescope of IRAM in Spain. The astrophysical motivation lies in the future ground-based, balloon-borne and satellite experiments aiming at the 3K Cosmic Microwave Background polarization B-modes, the spectral distortion of the 3K background, the reionization epoch, and finally the magnetic field and star formation in our own galaxy. Here, links to pillar 1 will be reinforced as spectroscopy-enabled KID detectors could provide a key element in new generation instruments dedicated to mapping the large-scale structures of the high-redshift Universe. For **KIDs and MIS focal-plane arrays**, the main areas in the instrumental research will be: (i) the extension to other wavelengths (above 3 mm and below 1 mm), (ii) the space qualification (low background sensitivity, cosmic ray impacts, readout hardening and power consumption) in partnership with CNES and ESA, (iii) the addition of new functions close to the detectors such as polarization-enabling technology and spectroscopic capabilities. On the long term, the same detectors will be tested in other parts of the electromagnetic spectrum and in a photon-counting mode.

2. IR detectors

We envision the **development and procurement of low-noise large-format focal plane arrays**. The motivation is to equip upcoming Extremely Large Telescopes (including the European 39m dish) and existing 10m class telescopes (VLT, Keck, Subaru, Gemini) with state-of-the-art arrays, knowing that scientific requirements drive towards longer wavelengths (cosmology, exoplanets, disk formation). The requirements imply mapping and spectroscopic capabilities for ground-based instruments on ELTs, in the near infrared domain. A key challenge is to perform *refined tunings and calibrations* of these numerous new arrays. In particular, the assessment of the new large format, low noise 2k.2k focal plane array (from Sofradir) will start shortly. These developments are promising (i) for the characterization of exoplanets, protoplanetary disks, and young stellar objects, (ii) for new applications in geosciences and environmental studies with the compactness and simplification of the assemblies. An example is the airborne (drone, nanosatellites) monitoring of the greenhouse gases in the Earth's atmosphere on a daily basis.

Another critical investigation, which is strategic for FOCUS, addresses the fine characterization of focal plane arrays, including **very fast behaviours of low-noise IR detectors**, that are required for adaptive optics, mandatory for ELTs, and interferometry, and **accurate pixel-to-pixel responses**.

3. Innovating detectors

The emphasis will be put on fully integrated instruments, especially for spectroscopic measurements, associated with large-format arrays (visible, IR and mm). The challenges are twofold: (i) the **miniaturization** (mini-series, low-cost, low weight and volume, low consumption compatible with drones, nanosatellites and planetary probes) geared towards space exploration and earth surface monitoring and (ii) the race towards **very large spectral resolutions** within a reasonably compact instrument. Applications involve widely deployable field instrumentation and environment sensing that could open larger domains. A very high performance spectrograph, with a much compact design

involving VIPA, can be obtained. Interferometry could produce even larger angular resolution with the maturing of new techniques involving photon-counting devices associated with frequency-comb lasers. **Forthcoming projects in planetary sciences, exoplanet science, geosciences could benefit from these new detectors**: a combination of innovative *in situ* techniques and remote sensing technologies with increased resolution, accuracy and coverage allows a more systematic observation of the Earth system.

We will investigate new upcoming technologies that allow considering a **photon-by-photon detection** (HgCdTe-APD, Kids), opening new fields of science, including time resolved spectroscopy or quantum imaging. Among these developments, LETI HgCdTe-APDs address deep space telecommunication and 3D lidar imagers, which are of crucial importance to assist the landing of modules on planets and asteroids. Advances in interferometry could produce even larger angular resolution with the maturing of new techniques involving photon-counting devices associated with frequency-comb lasers. Investigation of new generation Silicon Photomultipliers (SiPM), with specific properties, will take part in reinforcing links to ENIGMASS: SiPM qualification campaign and read-out microelectronics developments have been recently conducted by ENIGMASS partners for application in next generation cameras of CTA telescopes and for application in neutrinos and particle physics experiments.

Finally, we will also continue to explore the possibility of **curved detectors**, which represent a major disruptive technology for imaging systems. By directly correcting the field curvature in the focal plane of wide field instruments, telescopes and optical designs, the use of curved detectors allows a drastic reduction of the optical systems complexity and also increases the transmitted flux and consequently reduces the constraints in exposure time and optical quality. Prototypes already exist in CMOS technology. These technologies are clearly identified in the technical roadmaps of the ESA and the ESO for the next image sensor generation applications.

2.2.4 Transverse Axis “Big data and computing” (TA2)

Our research is based on the acquisition and interpretation of ever more numerous and heterogeneous data. The most common interpretive approaches, based on physical or statistical models, focus a high level of expertise. For example, experiments in particle physics, astrophysics or cosmology challenge the scientific community in exploring frontier solutions for the Peta-to-Exascale big-data management, processing, mining and preservation.

The extreme large database innovative solutions, the exploration of heterogeneous computing architectures for faster and more sensitive data processing are now combined together with the new challenge for **high performing scientific software programming**. The actual data volume and nature and the precision targeted by the experiments make the use of sophisticated analysis framework and advanced statistical tools (machine learning, multivariate methods) mandatory in order to understand systematic biases and minimise their impact on the measurements. The advent of deep

learning of large databases and inference (bayesian networks) are critical for data mining and reproducibility. Addressing these algorithmic problems requires new approaches that can draw on the expertise from various disciplines. In geosciences, environment and ecology these problems are furthermore preceded by essential homogenization steps before the data are ready to use. The challenges are to reinforce the synergy between *in situ* data and (space) observations to improve data interoperability and to feed multi-scale and multi-disciplinary environmental monitoring.

We aim to support some of our training courses on these new technologies, in particular to enable our students to acquire skills transferable to other disciplines and other trades, thus promoting their capacity for adaptation and innovation. This dynamics, initiated in Earth Science with the project HighTechGeo supported by IDEX, will be transposed into other disciplinary fields of the PAGE-GS. We are also committed to R&D actions proposing solutions for the scientific big-data paradigm supported by international schools for PhD students and postdoc fellows. Our expertise in operating distributed high performance computing and data center - GriCAD (Grenoble Alpes Research Intensive Data and Data Infrastructure), OSUG-DC with support from EQUIPEX equip@meso, the mesocenter MUST (Annecy) and the new environment created by the CDP Data@UGA - open up important opportunities for educational, societal and industrial innovation.

2.2.5 Transverse Axis “Grand societal challenges” (TA3)

We hold a robust and multidisciplinary expertise on several key societal issues related to energy, health, natural hazards, resources and environmental issues. We shall create the leverage to better include them into curricula.

Reactor Physics. Research at LPSC spans three axes: transmutation with investigations on an Accelerator Driven System, a nuclear reactor dedicated to minor actinide incineration; conceptual design of a Molten Salt Fast Reactor, a next generation design-by-safety nuclear reactor that has been retained by the international Generation IV Forum; evaluation of modified versions of a Pressurized Water Reactor in terms of fuel cycle and safety using multi-physics and multi-scale simulation tools. All studies are carried out in the framework of national, European and international collaborations involving both academic and industrial partners (e.g. AREVA).

Physics for health. The treatment of tumors is one of the major challenges in medical science. The LPSC is developing innovative radiotherapies (MRT, SSRT, HT, AB-NCT) in partnership with ILL, providing the most intense source of neutrons for research in the world, ESRF with a medical experimental line and the University Hospital (CHU). This network of research laboratories working on nuclear physics, material physics, biology and chemistry provides a unique environment for major advances in research and training of future experts in the domain.

Natural hazards. Interdisciplinary research projects will address natural hazards caused by active mountain belts, faults, rock falls, landslides, snow avalanches, ice floes and floods. Studies will combine multi-scalar observations, cataloging and analyzing of *in situ*, remote sensing, and satellite

data with laboratory experiments and modeling to assess the impacts on human societies. They will contribute to international, national or local monitoring networks with the objective to improve and develop mitigation strategies and disaster prediction.

Georesources-water-energy nexus. While the energy transition will generate increasing demands on existing or new georesources and renewable energy, freshwater resources face increasing stresses related to population growth, climate change, food security, agriculture and mining. We will develop new strategies, technologies and tools to promote a sustainable use of georesources, water and energy for anthropogenic activities. For example, subsurface systems play critical roles in water and energy extraction and disposal, yet we currently lack knowledge of the responses of the exploitation of these systems. Moreover, the transient storage of groundwater, the storage of gases as energy and fuels, the re-use or disposal of fluids with contaminants require new understanding of geochemical and biological reactions.

Global Change and Sustainable Development goals (SDG). Finding new development pathways based on scientific knowledge in a world under heavy pressure is a key responsibility for our community. We will focus on key regions, where extensive experience has been developed over the past 20 years: West Africa, the Amazonian-Andes transition, the Mekong delta. Building on long term observing systems deployed in these regions since the early 90's, our research will examine the impact of climate intensification and land use changes on the water cycle and its associated resources as well as on interactions with life and health issues (nexus between SDGs # 2, 3, 6, 13, 15 in these regions).

Trajectories of mountain social-ecological systems. The integration of diverse knowledge sources from biogeosciences, social sciences and non-academic stakeholders is pivotal to address complex environmental changes and its impact on societies. We are engaged in cross-cutting research projects focusing on the interactions between human societies and environment. A particular emphasis is put on **mountain environments**. This research is part of national (Réseau des Zones Ateliers, OZCAR, EQUIPEX CRITEX) and European (eLTER) research networks and initiatives. It is supported by IDEX (CDP Trajectories) and shared with the HSS-L4D-GS.

2.3 DESCRIPTION OF THE LEARNING CURRICULUM

2.3.1. Existing courses at the GS PAGE

The master curricula of the GS PAGE includes six programs ("*mentions de master*") steered by several departments (UFRs) at UGA (Table 1), and is completed by three engineer courses led by G-INP (Table 2). Number and origin of students are summarized in Tables 1 and 2.

In relation with the pillar "Particles and Universe"

- ***Master of Physics:*** includes 8 tracks; only Subatomic Physics and Cosmology, Astrophysics,

Medical Physics are relevant for PAGE-GS. The program in first year (M1) is mainly common in the first semester and gradually specializes in the second semester. The second year (M2) is more specialized but mixed cursus are also possible. Although few courses are taught in English, it welcomes a significant number of foreign students including ERASMUS ones, and it offers a double diploma with Karlsruhe University. The SPC track can be completed by attending the European Schools JUAS (physics of accelerators) or ESIPAP (instrumentation in particle physics). Around 30% of M1 students and 30% of M2 students come from outside.

- ***Master in Nuclear Engineering*.** The track Nuclear Energetics is led by G-INP (it will merge in the future with one track of the Master of Physics devoted to renewable energies, more in the field of PEM-GS). It has also international collaborations with the KTH in Sweden. Three other tracks (taught in UGA-Valence) deal with nuclear plant decommissioning, management of nuclear wastes, nuclear safety. They have strong interaction with the French nuclear industry and offer an excellent employability. They do not aim at forming researchers, although they benefit from the existence of experimental platforms in research laboratories (LPSC).

In relation with the pillar "Earth and planetary systems"

- ***Master in Earth and Planetary Sciences and Environment (STPE):*** include seven tracks spanning the whole range of Earth sciences from solid Earth sciences (Geophysics, Geodynamics, Georesources, Georisks, and the EMM in Earthquake Engineering and Engineering Seismology) to fluid envelopes (Atmosphere, climate and continental surfaces; Hydro-resources). All the tracks can be taught in English following the audience. Some tracks are more devoted to research and some have stronger links with the industry, although they all can prepare to all kinds of careers.
- ***Master of Mechanics:*** harbors an international track, Environmental Fluid Mechanics. It is mainly followed by foreign students with a strong research component.
- ***Master of Biodiversity, Ecology, Environment (BEE):*** comprises two tracks, Dynamics and modeling of biodiversity, and Management of Environment. The former is partly taught in English and could benefit from a better internationalization.
- ***Master of Geography, Environment, and territory development (GAED).*** Only two tracks are relevant to PAGE-GS: GEOSPHERES, common with other institutions (Univ. St-Etienne, USMB, Engineers schools of mining in St-Etienne and in Alès), and GEOIDES. Learning curricula pertains to social-ecological systems confronted to changes in climate, biodiversity, and the reduction and mitigation of risks (GEOSPHERES) and acquisition, processing and representation of data (GEOIDES).

					Origin of M1 students					Origin of M2 students				
Mention	Dept	Tracks	Nbr of M1 students	Foreign M1 students	Bachelor from UGA	M1 from UGA	Students from outside	Nbr of M2 students	Foreign M2 students	Same mention	Other M1 from UGA	Students from outside	% pursuing as PHD students	% PhD @ Grenoble
Biodiversity Ecology Environment	Chemistry-Biology	All tracks	54	3	31	5	18	25	0	18	2	5	60	30
Physics	PhITEM	common M1; Astrophysics; Subatomic Physics and Cosmology; Medical Physics	51	5 (+ 15 Erasmus)	13	11	17	30	12	18	1	11	60	30
Nuclear Engineering	PhITEM/ Valence	common M1; ADIN; GEDERA; SN	35	2	13	9	13	46	2	28	2	16	0	0
Earth Sciences Planets Environment	PhITEM	All tracks	55	14	22	4	29	75	27	45	1	30	35	20
Mechanics	PhITEM	Environmental Fluid Mechanics (M2)						11	9		2	9	60	30
Geography, environ., territory devel.	IGA	GEOIDES, GEOSPHERES	27	3	15	0	12	43	6	33	2	8	15	7

Table 1. Overview of student enrolment for the master programs of the GS PAGE

- **Engineer courses**

G-INP offers some engineer courses covering the PAGE-GS project. Two of them are devoted to nuclear energy: *Reactor Physics and Nuclear engineering* is steered by Phelma school and shares most of its lectures with the corresponding master; *Nuclear Energy Engineering* is led by ENSE3 school. Finally, *Hydraulics, Buildings, Environment* is devoted to hydraulics and civil engineering.

Engineer programm	# students /yr	# double cursus master /yr	# PhD /yr	% foreign students
Hydraulics, Buildings, Environment (ENSE3)	50	2	2	50
Engineering for Nuclear Energy (ENSE3)	20	0	2	10
Nuclear Engeneering (PHELMA)	50	20	10	10

Table 2. Overview of student enrolment in Engineer programs of the GS PAGE

The master programs of Mechanics, Physics, Nuclear Engineering and Earth sciences are co-accredited between UGA and G-INP, meaning that they can be followed indifferently by students from both institutes. Engineer and master courses benefit from numerous cross mutualization of lectures and professors. Some students can follow both courses (double diploma).

The yearly average number of students entering a PhD in the GS PAGE approximates 125. Details for the six EDs (pp 1, 2) are provided in Table 3.

Doctoral School	# PhD /yr	# PAGE PhD /yr	# PAGE foreign PhD students/yr	UGA Master or Engineer diplom	Other French Master or Engineer Diplom	Foreign Master	Main laboratories
Physics	100	20	10	6	7	7	LPSC, IPAG, LAPP
Earth Sciences, Universe (TUE)	50	50	20	15	20	15	IsTerre, IGE, PACTE
Chemistry, Life Sciences (CSV)	80	8	3	3	4	1	LECA, Irstea
Electrical Engineering, Signal(EEATS)	150	6	2	3	1	2	Gipsa Lab
Engineering,Materials,Mechanics,Environment, Energetics,Process,Production (I-MEP2)	130	10	4	4	3	3	LEGI, LPSC
Health Engineering, Cognition, Environment (ISCE)	220	30	10	10	10	10	IsTerre

Table 3. Statistics of PhD students in the GS PAGE

2.3.2. Development of a specific training program

The GS offers to supplement this training program with **specific actions** aiming at a tighter match between research, technological innovation and training, an increased visibility and international influence of our curricula.

The main mechanism that will be set up is the deployment of **two complementary courses: an *Intensive Research Master* (IRM) in Physics-Astro, STPE and BEE, primarily intended for bright national students, and a *Research Intensive Track* (RIT) for foreign students who have a good theoretical knowledge of the field.** We describe here the IRM, the IRT being developed in part 2.3.4.

Intensive research master will align on the curricula of the "magistere" in physics which awards a University Diploma. **It will offer additional theoretical and practical training to highly motivated L3 and master students having a strong willingness to deepen their knowledge and improve their competencies.** Enrolled Students will participate in international summer schools labeled by the GS (part 2.4). They will preferably benefit from GS (including abroad) internship grants, offering the opportunity to spend 6-months immersion in a laboratory. They will be able also to benefit from specific PhD scholarships, ahead of the original schedule. **Our target is to have 30% of M1 students enrolled in IRM at the beginning and 50% after 3 years.**

To implement this transformation, the actions planned as soon as the project starts include:

- **Orientation at the bachelor level**. The recruitment of high-potential master students also involves **specific courses at the bachelor level for those who intend to do high-level scientific studies** awarded by a doctorate. PAGE-GS aims at being associated with the project "LIMPIde", proposed as a part of the NCU call for projects at the bachelor level, by supporting certain courses and by identifying and following the best elements likely to benefit from a research course at the master level. These courses of excellence at the L1-L2 level will constitute an entry point for students eager to follow the IRM. We also intend to support the Bachelor Summer Program introducing students to research with large facilities.

- **A fellowship program for extended laboratory or platform internships** (part 2.4). 40 scholarships per year for 6-months internships from the end of Master 1 will be offered to students enrolled in IRM, for a **total amount of 1.3 M€ over the ten years**. Specific support to encourage the **outgoing and incoming mobility** of master students will also be financed (**20 scholarships / 160 k€ per year**). The same fellowship opportunities will be offered to foreign students enrolled in RIT.

- **New courses** will be progressively proposed in accordance with the key programs of the GS. A first example is a **training course in the detectors and instrumentation domains**, led by researchers involved in FOCUS, is under consideration. It will have the objective of enhancing direct links between students, researchers and employers through regular classes or training sessions supervised by industry engineers and researchers. This should increase the capabilities of our students to handle with new technologies and measurement devices and be prepared to find job opportunities in **companies specializing in innovative technologies**. A second example is **a training course dedicated to mining activities in Europe**: including field trips and practical activities in world-class ore deposits currently mined in Europe, workshops animated by international experts, policy-makers, mining engineers, economists, and ore geologists. This will provide a platform for students and experts from academic, economic and industrial domains to meet and discuss today's and tomorrow's needs and opportunities in mineral exploration in Europe.

Other specific actions will be set up to encourage the doctoral studies of the most deserving students and the acquisition of dual competences in doctoral studies:

- Setting up of a **predoctoral year** open to students with a master's degree but whose application for a PhD grant is premature, either that the student wishes a complementary training in laboratory, or that the hosting team wishes to evaluate the student's ability to fit into a research project. This tools is especially important for students from developing countries. The year (open as a university degree) will combine a long-term internship with courses taken in addition. **10 predoctoral fellowships / 80 k€ are forecast per year**.

- Setting up of an **early session (Feb.-March) for the allocation of the GS PhD scholarships**. **An important part (4.6 M€ or 30%) of the specific budget of the GS corresponding to 5 specific PhD scholarships per year** will be allocated by the ED. Part of the LABEX PhD grants may also enter this scheme. A selection criterion will be the research experience of the candidates acquired through long internships. This session may concern national candidates (especially those enrolled in the IRM) or foreigners (especially those who have benefited from the predoctoral fellowship).

- Setting up of a post-thesis fellowship program to enable our PhD students to acquire a **dual competence** making them more attractive in the labor market. This will include accelerated training in numerical methods (part 2.2.4) in relation to MSTIC-GS. This may also include complementary training in economics, law, management, social sciences, etc. A total of **65 fellowships / 520 k€ over the ten years** will be devoted to this action.

2.3.3 Strengthening our links with the industrial sector

PAGE-GS will support knowledge transfer between public research organizations and the private sector. Some courses are already firmly anchored to the business sector, e.g. the nuclear industry, in strong interaction with partners such as EDF, AREVA. In the field of earth and environmental sciences, the aim is to develop synergies between academia, industry and the environmental stakeholders. The European project “OpenYourMine” in georesources submitted to the EIT RawMaterial (with the objective of an Erasmus+ Master), has the ambition to create a major training center for geologists, able to answer to the challenges of energy transition and the risks on the raw materials supply.

Specific training courses for enhancing collaboration with social sciences, support to case-study projects in link with professional structures, improvement of lifelong or vocational training in relation with research platforms (part 2.4.1) constitute other action items. The fields of instrumentation and mechatronics could be privileged targets for strengthening the links with industry and to foster innovation (cf. FOCUS partners, links with CERN) through networking of university-business platforms. CSUG, supported by UGA foundation, constitutes a strong partnership with several industrial actors (Airliquide, STMicroelectronics).

2.3.4 Internationalization of the training

Based on existing international training courses (e.g. EMM MEEES giving rise to a joint degree, EMJD International Relativistic Astrophysics PhD, both highly selective, double master program between UGA and KIT (Germany) within the framework of the French-German University), the main markers of internationalization will be:

- Development of **Research Intensive Tracks** (RIT) open to international students with an

already solid theoretical knowledge through their previous studies. A long-term 6-months laboratory internship, complemented by specialization courses taken in existing master or doctoral programs, constitutes the RIT year. It naturally leads to the M2 specialty year. The emergence of new RITs will be integrated into the think-tank devoted to the new GS training programs.

- **Involvement in training in and dedicated to the South**, in close partnership with IRD. It concerns earth sciences (seismic risks in South America and the Middle East), hydrology (intensification of the water cycle and use of water resources in vulnerable regions) and in glaciology-nivology (impacts of global change on the snow and glaciers in the Himalayas and Andes). The objectives here are to strengthen the capacities of researchers from the South, to train students from the South by research, to participate in the setting up of master courses in the South (joint degrees or Erasmus+ labels), involving universities of inter-tropical countries. A host mechanism for researchers from the South will be created and strengthened for students from the South through master or pre-doctoral internships.

The 5-year objectives concern joint master's degree (e.g. Natural hazards in civil engineering with Lebanon, Hydrohazards in relation to the nexus climate-water-energy with Greece), support for new Erasmus+ labeled masters (e.g. Water / Agriculture in partnership with the Sahelian zones, collaboration with Bolivia and Ecuador, CARE laboratory courses in Vietnam). The GS will also ensure the sustainability of the strategic EMM-MEEES and will support the internationalization of the forthcoming training project related to mining activities (part 2.3.2)

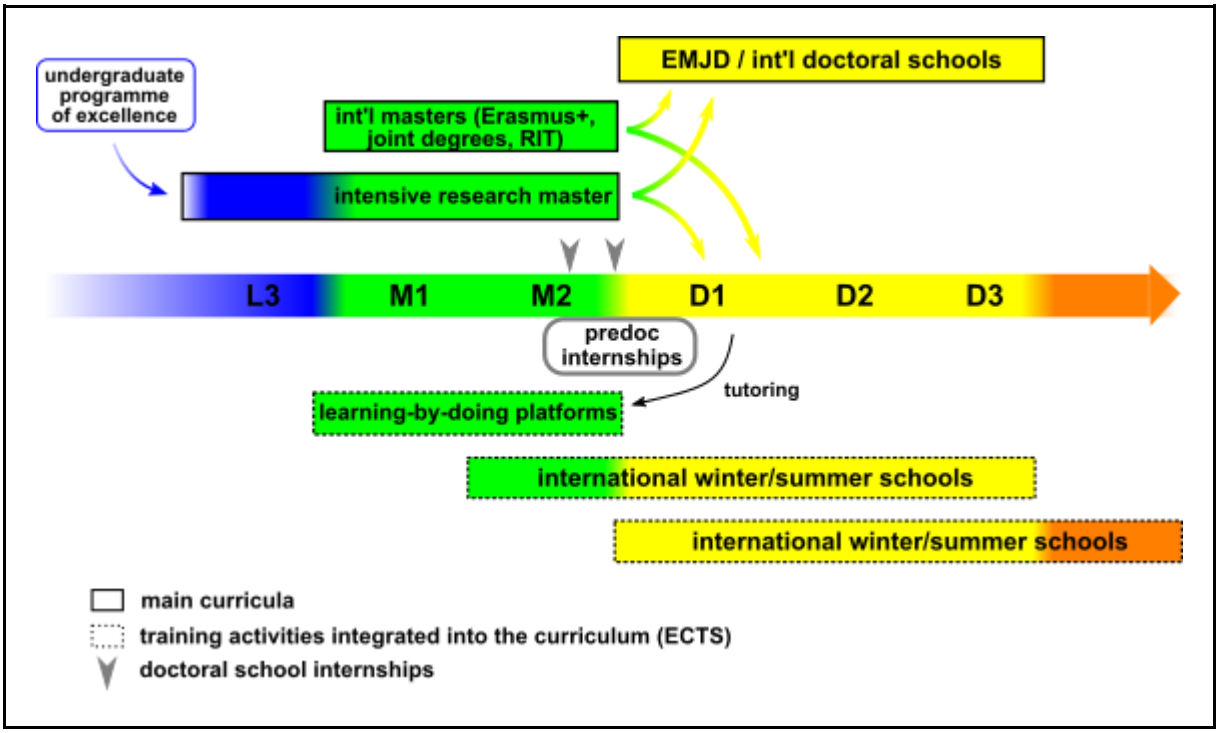
At the PhD level, the creation of a French-Russian **international doctoral school** in fundamental physics is in progress. The target is to set up a joint doctoral training corpus, to increase mobility for teachers and students. Specific PhD scholarship may be associated. The initiative also wishes to register as an international PhD model by adopting standards recommended by the European Commission. In agreement with Torino and Hamburg universities, we will present a **Capacity Building project** in the field of higher education in partnership with Russian Federation and Kazakhstan.

We will share doctoral training programs among European partners by capitalizing on existing ITNs. They will strengthen quality through mobility and cross-border cooperation, build international strategies and encourage more flexible governance using good practices.

In order to strengthen the visibility and attractiveness of PAGE-GS, **event actions such as graduation ceremony, awards, integration days** (especially for international students), conference events will be organized. A particular attention will be put on **involving alumni** in these events**.** 500 k€ will be devoted to these actions.

2.3.5 Outreach teaching actions

Our research contributes to the awareness and understanding of societal issues. A portfolio of actions will be sustained to reach different audiences as teaching Sciences of the Universe to primary school and high school teachers, organization of Astronomical observation sessions for the general public on OSUG telescope, development of the Europe-funded Geopsy project (SESARRAY software suite, for the analysis and processing of seismic data), and the creation of new MOOCs (eg Natural Hazards, Planetary Systems). The project of a **L-TP** platform (part 2.4.1) will be complemented with a permanent exposition entitled "from the infinitesimally small to the unbelievably big". Such an outreach exposition will integrate a journey from particle physics to cosmology together with an immersion in the research expertise with equipment in the domain of mechatronics, detector instrumentation and Big Data management.



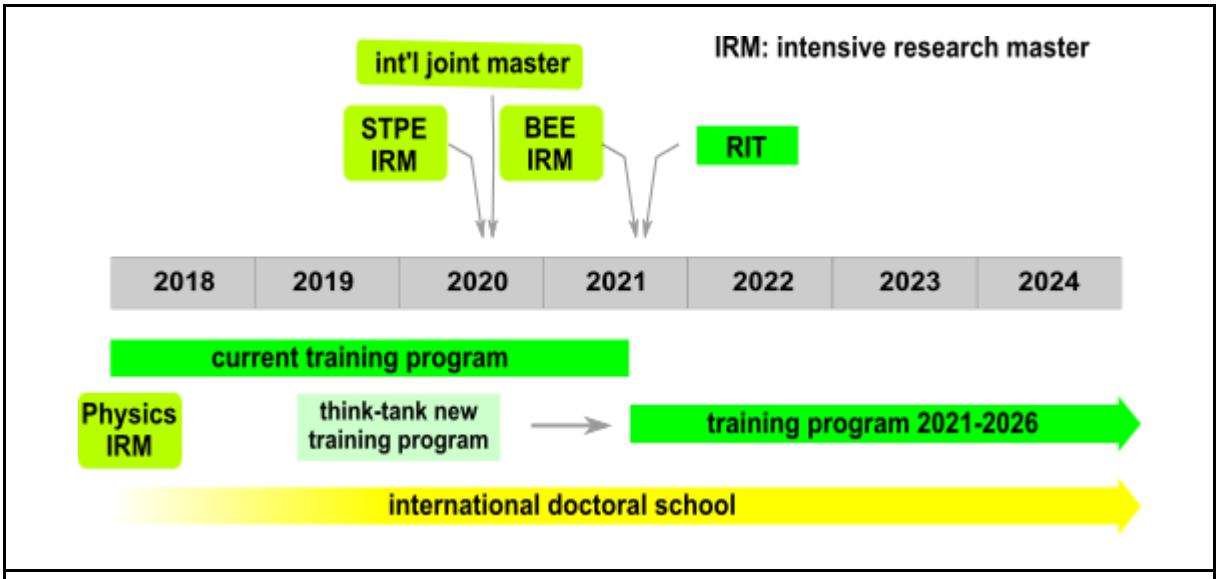


Figure 2: (*top*) Overview of curricula showing the set of specific training actions, with a particular emphasis on intensive research master. (*down*) Timeline showing the progressive set up of the specific trainings.

2.4 RESEARCH-LEARNING INTERFACE

Research-learning interfaces will be strengthened through three key actions.

2.4.1 Involvement of research platforms in learning-by-doing

Learning-by-doing features are enabling students to run experiments for one or several days with advanced instruments and to develop their skills by confronting them to the difficulties of real life problems and to directly participate to the R&D process. **The development of platforms to improve learning-by-doing training programs will be supported by the GS PAGE with a total amount of 2.5 M€ over the 10 years.** Below is a non-exhaustive list of platforms that will be part of the GS.

The Grenoble University Space Center (CSUG), created in 2015, unites a large number of PAGE stakeholders with a high potential of technology transfers to local or non-local industries. CSUG is specialized in space miniaturized instrumentation for cubesats and in small satellites space data uses, in close coordination with FOCUS and OSUG@2020. Students with different background or academic levels are involved in interdisciplinary projects. Around 100 students per year are supervised by researchers, faculties and partners from the private sector. The CSUG has been labelled as an IDEX training action. **The CSUG and the GS PAGE signed the CNRS-INSU *quality chart* on GS actions in the small satellites domain.**

The instrumentation and experimentation platform in subatomic physics, recently renovated with

the support from universities and the ENIGMASS LABEX, consists of more than 15 experimental installations and welcomes around 500 students (master and engineers) per year for practical teaching in basic physics, medical physics and nuclear energy. Faculties, researchers and engineers are heavily involved to expand the training offer through new experimental installations, profiting from the most recent instrumental developments for research.

PAGE-GS gathers several **(inter)national observation platforms (OP)** to study the water cycle. They provide water and mass balances for multi-scale basin sizes, and address the hydrological impacts in West Africa, in glacier regions (Alps, Andes, Himalayas, Antarctica) and in Mediterranean region. These OPs are part of the RI OZCAR and its European target (eLTER). They welcome many field works included in the STPE curricula and in our international partnerships (e.g. Benin, Ivory Coast, Bolivia). They are also used in professional education programs covering hydrology (France, Benin, Niger) and hydro-geophysics (Bolivia, Vietnam).

Alpine Field Station J. Fourier is part of the "Réseau National des Stations d'Écologie Expérimentale" (RenSEE) and of the European RI AnaEE. It is a master site of the Long Term Social-Ecological Research Network - Zone Atelier Alpes and provides unique facilities for learning-by-doing projects dedicated to snow and mountain climate science (STPE) and ecology and environment (BEE).

Links with other existing PIA entities will concern (i) the **EQUIPEX NOEMA** (Northern Extended Millimeter Array), a project that will increase the capacity of the IRAM Plateau de Bure (Devoluy, France). IRAM organizes every year an international school on millimeter astronomy and interferometry. (ii) **the EQUIPEX EcoX** is a partnership between ISTerre and ESRF that provides increased facilities for X-ray adsorption fine structure spectroscopy, and is linked with EnviroSynch a project of Erasmus Mundus Joint Master Program dedicated to environmental research using synchrotron radiation; (iii) the **EQUIPEX RESIF-CORE** for the monitoring and understanding of the solid Earth. We host the national seismic data center and manage the national set of mobile seismic instruments. The GS will build on this expertise to propose learning-by-doing projects dedicated to seismic instruments, data acquisition and processing.

Finally, the project **L-TP** aims at providing research opportunities for students in Physics and Engineering through a set of experimental facilities inspired by or closely related to some of the RI at the heart of pillar 1, some of which being the result of collaborations with the industrial sector, also exposing students to situations where innovation is part of experimental research.

2.4.2 GS labeling of summer/winter schools

Our community is strongly involved in several international schools of very high level. These schools are an effective lever to favor the emergence of new tools in a given field, the dissemination of local expertise, and interdisciplinarity.

PAGE-GS will label summer schools to cover all its thematic fields as well as links with other GS of UGA (Table 4). Labeling will depend on the adequacy between the scope of the school and the curricula and the capacity of the school to open up to master or PhD students. Participation in

labeled schools will be recognized as an integral part of the curricula. Co-funding of labeled schools will be for 5 years. **A total amount of 70 k€/yr is budgeted for this action**.

School	*Pillar or transv. axis & Labex*	*Number of participants*	*Duration (weeks)*	*open to master students*	*open to PhD students*	*Master/PhD program*
ESIPAP (European School in Instrumentation for Particle and Astroparticle Physics)	1 / ENIGMASS	24	8	x	x	Physics
Les Houches PhysTeV Series	1 / ENIGMASS	140	3		x	Physics
ASTERICS-H2020	1 / ENIGMASS	80	1		x	Physics
GraSPA	1 / ENIGMASS	30	1	x		Physics
ERCA (European Research Course on Atmospheres)	2 / OSUG@2020	35	4		x	STPE / TUE
Doctoral Training on internal Earth	2 / OSUG@2020		2	x	x	STPE / TUE
International Field Course	2 / OSUG@2020	20	1,5	x	x	STPE / TUE
FOCUS training sessions	TA1 / FOCUS	15	1	x	x	Physics
Stat4Astro / SOS	TA2 / OSUG@2020	50	1	x	x	Physics
	TA2 / ENIGMASS	60	1		x	
Summer School in Ambient Noise Imaging & Monitoring	TA2		1	x	x	
School in Statistical Methods in Population Genomics	TA2	50	1		x	BEE/CSV
Spring school in DNA metabarcoding	TA2	50	1		x	
Around 2°C	TA3	45	1	x	x	STPE/TUE
Water & Society	TA3	20	1	x	x	STPE
School in social-ecological science This will be a joint action with the GSR PSH (see TA 3)	TA3	to be launched	1	x	x	BEE/CSV

Table 4. A **provisional list** of schools likely to be labeled by the GS

2.4.3 Involvement of Public Research Organizations (PBO)

For each thematic field, we will set up a **mixed teaching and learning team** bringing together faculties and staff from PBO including researchers and engineers. The commitment of PBO staff will be based on a **3 year-long joint position including 64 hours of teaching per year**. This will go far beyond the existing framework of one-off interventions in masters and PhD curricula. People benefitting from a joint position will be involved in defining the curricula, coaching and evaluating students. They will be encouraged to take pedagogical responsibility.

Eligible actions to a joint position are training of masters and PhD students, participation to labeled summer/winter schools (part 2.4.2), supervision of internships or apprenticeships, development of research-training projects in relation with platforms (part 2.4.1). This will be recognized by a number of hours of teaching according to a referential to be defined at the beginning of the project. **1200 additional teaching hours (i.e. ≈580 k€) per year are budgeted for this action. This corresponds to a 30% increase of the current participation of PBO** (Table 6)**.**

Each year, the relevant committee of the GS will review the new applications for joint position and will recommend or not their funding to the GS steering committee (part 4.2). An annual report will be sent to PBO on the pedagogical involvement of their staff benefiting from the joint position.

Program	Track	UGA	Other Univ	CNRS	% CNRS	CEA	IRD	Other Public	Private
Physics	L3	1055		34	3%	15			
	M1	1800	27	91	5%				33
	M2 (PAGE tracks)	509	90	50	7%				26
Earth Science	L3	881		97	10%		6		
	M1	1566	61	128	6%		153	20	75
	M2	2170	50	314	11%		77	24	155
Biodiversity, Ecology, Environment									
	M1	714		115	12%	37		80	23
	M2	366		48	10%			10	70

Table 6. Amount of teaching hours taught by faculties and researchers from various PBO in the Intensive Research Master curricula.

3 PROJECT ORGANIZATION AND MANAGEMENT

3.1 PROJECT MANAGER

The GS PAGE will be led by the director of the RD PAGE and the director of an UFR (part 3.3). The Project Manager (G. Henri) has been chosen among the three project coordinators: Ph. Choler (director of the RD PAGE), L. Frappat (director of the LAPTh) & G. Henri (director of the UFR PhITEM).

Pr. Gilles Henri teaches astrophysics at UGA. He is a specialist in high energy astrophysics. He is a member of HESS and CTA gamma-ray telescopes collaborations, chairing the HESS extragalactic working group during two years. He is the co-author of more 140 publications with an h-index of 45. He is a former junior member of Institut Universitaire de France. He has a large experience in management of teaching, having been the head of astrophysics track and then the whole master of physics program during several years. He has been deputy vice-president for teaching at the Univ. Joseph Fourier before the creation of UGA and has steered the preparation of the master program contract. He has been also in charge of the budget of departments at UJF and knows very well the economics of university courses. He is presently the head of the UFR PhITEM (steering the teaching of physics, mechanics, earth sciences, electrical and civil engineering from bachelors to masters).

3.2 ORGANIZATION OF THE STAKEHOLDER ENTITIES

PAGE-GS has a permanent academic staff of **320 researchers, 240 faculties, 455 engineers and technicians** (Fig. 3). Its research activity translates into high QS ranking of Grenoble Alpes in *Physics & Astronomy*, *Earth and Marine Sciences* and *Environmental Sciences*. In these three fields **UGA was within the top 150 (or even the top 100 in Earth sciences) world universities in 2016.** The level of our research can be summarized by the following key numbers:

- an average of **1580 papers per year** published in peer-reviewed journals over the last 6 years (Web of Science™). 4% of these papers were published in the top centile journals and 21% in the top decile (Incites™ Journal Citation Report).
- **4 highly cited researchers** in 2016 according to Clarivate Analytics™ methodology: 3 in Environment/Ecology (LECA) and 1 in Geosciences (IGE)
- **8 ERC projects from 2012 onwards**: 3 starting grants, 3 consolidators, 3 advanced and 1 Proof of Concept spread throughout physics (1), earth sciences (1), geosciences (2), planetary science and astrophysics (5), environment/ecology (1)
- **15 members elected at the prestigious Institut Universitaire de France from 2005 onwards:** 4 in geosciences (IGE), 7 in earth sciences (ISterre), 5 in planetary science and astrophysics (IPAG), 1 in particle physics (LPSC), 2 in theoretical physics (LAPTh)
- **14 recipients of CNRS medals since 2011** : 7 bronze, 6 silver and 1 cristal
- from 2011 onwards, **107 funded projects by the French National Agency (ANR) and 55 European projects** for which the PI belonged to the RD PAGE
- 34 **registered patented technologies** over the last 5 years

Our research and curricula benefit from a set of research infrastructures that have been developed over the past years. Our academic environment includes world-class infrastructures and research entities (CERN, ILL, IRAM) that will be associated to the GS project through the funding of master and PhD scholarships.

Partners of the GS PAGE have a long experience of collaboration in research and teaching. UGA and G-INP faculties are working in the same laboratories and 7000 hours of teaching are exchanged yearly between G-INP and UGA. Many engineer students are engaged in double cursus and follow also a master program, even in fundamental domains such as astrophysics and particle physics. On the other hand, master programs can include courses delivered to engineers students. Public research organizations take already a significant part in the formation of students, and this part is planned to increase (part 2.4.3).

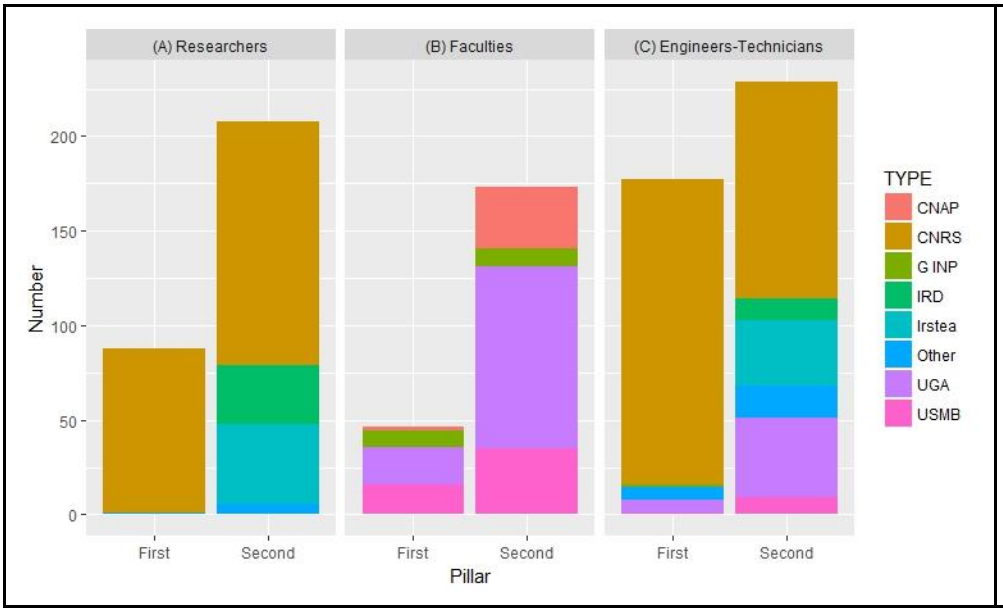


Figure 3. Permanent academic staff involved in PAGE-GS. Data are presented per research institute / university and for each pillar.

3.3 COORDINATION FRAMEWORK

3.3.1. Role of the IDEX

The core partners of the GS PAGE are members of the IDEX Univ. Grenoble Alpes. The strategy, objectives and role of the IDEX are explained below (part 3.4). Its governance is designed to ensure rapid decision-making capacity, constant focus on key objectives and effective implementation of IDEX actions. It is based on three levels: strategic, executive and operational, all of them in place since January 2016. Concerning the strategic governance, it is taken in charge by the steering committee of the IDEX, chaired by the PI. Its missions include:

- Steering the IDEX strategy and ensuring that commitments and objectives are fulfilled.
- Supervising the implementation of the actions and trajectory of the IDEX.
- Supervising partner's adherence to the IDEX contract.

The steering committee is composed of the partners' representatives and meets monthly. An International Scientific Committee (ISC) provides informed guidance to the steering committee. The IDEX GS reports to the steering committee.

Concerning the global organization of the diplomas in the IDEX, the governing principle is that (i) there is a single IDEX partner in charge of operating each curriculum and (ii) education teams bringing together faculties and researchers from different partners are in charge of defining the curricula, their objectives and of delivering the courses.

IDEX, LABEX and GS actions for socio-economic transfer will be combined to increase synergy and efficiency and guarantee coherence and compliance to the IDEX objectives.

As PAGE-GS will be part of the IDEX, we will apply the same IP (Intellectual Property) rules as in the consortium agreement of the IDEX.

3.3.2 Governance of the GS PAGE

The core partners of the GS PAGE are similar to those of the RD PAGE set up in autumn 2014 (part 3.4) and are used to working together. The steering of the GS will capitalize on the governance of the RD with some adjustments to ensure coordination among LABEX and between faculties and researchers. Overall there will be a simplification as several actions will be conducted at the level of the GS (rather than at the LABEX level).

A framework document will be written at the start of the GS. The main lines of the decision-making process will be as follows:

Research projects. A single call will be organized with different themes covering all funding needs of the LABEX. This simplified schedule will foster research proposals between LABEX and will meet a strong demand of our community. The call will fund emerging exploratory projects, support for newcomers, PhD scholarships and postdoctoral positions, observation and equipment projects. It will be financed by the contribution of the three LABEX and by the contribution of the RD PAGE. Allocation of resources will be in proportion to each partner's contribution. Funding from the RD PAGE will mainly focus on cross-cutting initiatives and the support of young researchers. The RD PAGE and OSUG@2020 already co-organized a common project call in 2017. Project evaluation will be led by the competent committees of each LABEX. The recommendation will be examined by the GS steering committee who will take a decision based on scientific excellence, adequacy to the scientific strategy of the GS and balance between the main research themes.

Training and valorization projects. The contributions of the LABEX, the GS PAGE and the IDEX will be combined to organize one or two calls per year. All the funding requirements for affiliated and specific training of the GS, the dissemination of knowledge, and the valorization actions will be covered by these calls. Representatives of the competent committees of the LABEX and the UFRs will be responsible for reviewing the proposals and formulating recommendations for funding to the GS steering committee.

Governance. The GS will be co-led by a director in charge of research and a director in charge of training. The direction will represent the GS to academic and non-academic audiences.

The **steering committee** will be chaired by the two co-directors and will also include PIs of LABEX, a representative of the UFRs, a representative of the EDs and one qualified personality nominated by the direction. The steering committee will replace the LABEX steering committees. It will implement the shared research-training strategy. On the basis of recommendation by committees, it will take the final decision for the allocation of funding.

The **directors' committee** will be an expanded version of the directors' committee of the RD PAGE and will include persons in charge of masters and research platforms. It will discuss the strategy of

the GS and the allocation of funding and HR and will make recommendations to the steering committee.

The **elected council** will be the representative body of the academic communities. Composed of elected members of the RD PAGE and UFR councils, it will play the role of a "supervisory board" making recommendations on the functioning and trajectory of the GS. External qualified personalities of the PAGE council who represent the socio-economic sector will also be part of the GS council.

The **strategic steering committee** already in place for the RD PAGE will also be seized with questions related to the GS. Its members will represent all co-leading institutions. It will ensure agreement between the actions of the GS and the policies of the institutions. It will deliver recommendations on the main orientations of the GS and will be consulted before any change in the GS membership.

The **International Scientific Council** will be identical to the one put in place for the IDEX UGA. It will provide an external perspective on the main achievements and trajectory of the GS and its adequacy with the strategy of the IDEX.

This governance scheme does not entail any additional complexity. All persons involved in the governance of the GS governance will have been elected or appointed to other functions or mandates. As a consequence, the composition of GS committees will change according to the elections or appointments in the RD PAGE, the LABEX, the UFRs and the EDs.

For the governance support of the GS, an administrative coordinator (senior level) is planned for the whole duration of the project (400 k€). The running operational costs will be pooled by the LABEX budgets that will contribute to the corresponding budget line.

3.4 INSTITUTIONAL STRATEGY

The creation of GS PAGE is a key step towards our aim of becoming a World Class University. As we wrote in our IDEX proposal: "*Our IDEX project is focused clearly and exclusively on creating a single world-class university: University Grenoble Alpes (Univ. Grenoble Alpes). This university will reinforce our capacity to attract leading scholars and students, develop ground-breaking research and competitive curricula and promote a specific identity focused on innovation. Univ. Grenoble Alpes will be a fully integrated institution with single research and education strategies and clear decision-making processes."*

Univ. Grenoble Alpes is highly competitive:

- It was the most successful site after Paris during the recent *Investissements d'Avenir* calls, with 77 selected projects, including 1 IRT, 1 SATT and 21 LABEX, of which 14 are managed by UGA. We have more than 9 "highly cited" researchers and 102 IUF members, have won 67 ERCs (2007-2017) and our share of French scientific production is over 10% in 14 Web of Science categories.

- It is at the heart of a city ranked in the top 5 of the world's innovation centres, with exceptionally high rates of patents per inhabitant and a unique endogenous innovation ecosystem.
- It is at the forefront of pedagogical innovations, with flipped classrooms since 2006, MOOCs and shared interdisciplinary modules in critical thinking.
- Student Life is rated in the top 3 in France, with a beautiful campus adjoining the city, excellent services and ski slopes half an hour away.

Despite these strengths, the IDEX international jury correctly pointed out that "*Univ. Grenoble Alpes's visibility is not in par with its scientific excellence*". In order to improve our visibility, we organized our research in six research departments:

- 1. Mathematics, information and communication sciences, technologies
- 2. Chemistry, biology, health sciences
- 3. Particle physics, astrophysics, geosciences, environment, ecology
- 4. Physics, engineering, materials
- 5. Legal, political and territorial sciences, economics, sociology, management
- 6. Arts, literature, languages, humanities, cognitive and social sciences

These research departments integrate both basic and applied research, contribute to the definition of UGA's research strategy and coordinate existing laboratories and LABEX. They thus ensure that research policy is fully integrated between IDEX partners and help create a shared identity amongst our 5,500 scholars. This organization of research enables us to optimize UGA's scientific strategy and strengthen our synergies with national research organizations.
Reaching the same level of integration and synergy in education and training and improving our attractiveness and visibility are essential for achieving our IDEX objective of creating a world-class university. This is why we recently created a comprehensive IDEX graduate School (IDEX GS) that provides potential students with all necessary information on a single portal and supports Ph.D. students' mobility and UGA's attractiveness. In order, to further increase international visibility and attractiveness, and to better integrate research and education, we need to structure our education offer into thematic graduate schools that will promote research-based programs and interdisciplinary approaches, implement measures to attract the best students, achieve a higher level of internationalization and provide services to students (job-fairs, internships, fellowships, exchange programs).

In coherence with our overall strategy, UGA has therefore submitted six proposals for thematic GS that mirror the six research departments and their strengths. This will allow us to increase cross-fertilization between research and education. The choice of submitting a limited number of EUR is also motivated by our aim of ensuring critical mass in excellence and a concern for efficiency and coherence. Furthermore, grouping thematically coherent LABEX in the same thematic graduate

schools will allow us to improve the level of synergy and collaboration between them. Finally, the IDEX GS will be a privileged tool to develop cross-GS activities and offers us an opportunity to efficiently pool and share resources.

The partners commit to actively support the GS and to provide the necessary means and funding. More precisely, with accordance with their commitment in the IDEX, they commit to multiply by five the obtained funding. The GS will also actively contribute to the HR policy of the IDEX in close collaboration with the RDs.

4 FUNDING JUSTIFICATION

The total aid requested is € 42,178,011, of which € 14,679,451 is specific to the GS action. The LABEX part is broadly in line with the previous budgets; still necessary updates have been implemented.

For ENIGMASS, as far as large-scale international experiments are concerned, emphasis is still put on human resources in order to maintain an attractive scientific environment: PhD scholarships and post-doctoral fellowships constitute 2/3 of the aid requested (5M€). An equipment part (500k€), devoted to the emergence of new innovative R&D projects, has been added. The rest is supporting an ambitious visiting scientists program, incl. for training actions, as well as of schools, conferences and HR environment costs.

For OSUG@2030, 2/3 of the budget will be devoted to capital expenditure and running costs, the remaining part to personnel costs. It can also be decomposed into equipment, operational costs, PhD scholarships and some technical staff expenses (≈2/3 of the budget), and pooling of technical resources (engineer time, shared equipment) (≈1/3 of the budget). Long-term project-engineer time will be required to provide the international community with high-quality observations.

For both LABEX, the research part is about 50% of the budget while the educational part corresponds to about 40%, leaving 10% for valorization and communication actions.

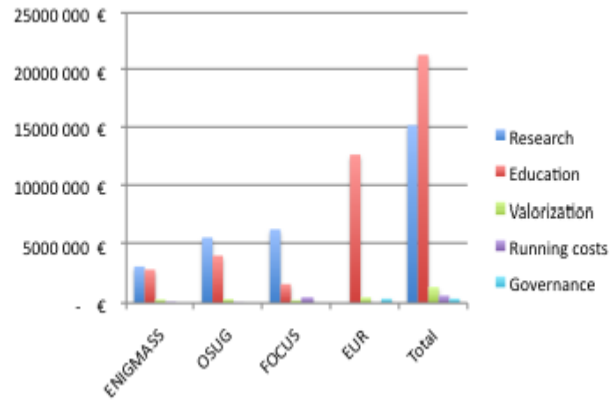
The nature of the LABEX FOCUS implies a particular strength on technology developments corresponding to production under cleanroom conditions (3.2M€), through internal invoicing. PhD scholarships, post-doctoral fellowships and high level research engineer positions constitute the major human resources demand (3M€). Altogether, the research part is about 70% of the budget.

The budget for the specific actions of the GS PAGE is summarized below (see also parts 2.3 and 2.4).

Action	Type	Category	Amount
PhD scholarships	Human resources	Education	4 560 084 €
Long-term master internships	Human resources	Education	1 440 000 €
Mobility scholarships	HR / running costs	Education	1 600 000 €
Pre-doctoral scholarships	HR / running costs	Education	800 000 €
Post-thesis scholarships	HR / running costs	Education	520 000 €
Equipment for platforms	Equipment	Education	2 500 000 €
Additional teaching hours	Running costs	Education	576 000 €
Labelling of summer/winter schools	Running costs	Education	700 000 €
Event actions	Running costs	Valorization	500 000 €
Administrative support	Human resources	Governance	396 000 €
TOTAL			13 592 084 €
Overhead			1 087 367 €
GRAND TOTAL			14 679 451 €

The budget breakdown by category for the GS action looks as follows:

Category	ENIGMASS	OSUG	FOCUS	EUR	Total
Research	3 172 498 €	5 684 000 €	6 391 784 €		15 248 282 €
Education	2 899 256 €	4 109 684 €	1 641 252 €	12 696 084 €	21 346 276 €
Valorization	309 636 €	341 280 €	250 000 €	500 000 €	1 400 916 €
Running costs	100 000 €	50 000 €	512 240 €		662 240 €
Governance				396 000 €	396 000 €
Overhead	518 511 €	814 797 €	703 622 €	1 087 367 €	3 124 297 €
Total	6 999 901 €	10 999 761 €	9 498 898 €	14 679 451 €	42 178 011 €



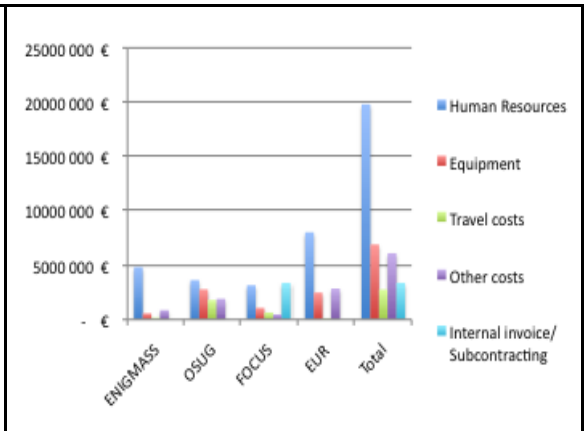


Figure 4. Budget breakdown of the GS PAGE