S. Katsanevas

26 October 2021

APOGEIA 2.0 for HORIZON-INFRA-2022-TECH (closing date 20 Apr 2022, Budget 10 M€)

AIM: Ground-breaking RI technologies, including scientific instruments, tools, methods, and advanced digital solutions, *while paving the way to innovative solutions to societal challenges and new industrial applications, products and services*. New instruments and tools (advanced sensors, imaging devices, light source detectors, high-tech developments for accelerators, robots/automated solutions) and advanced digital solutions (e.g. digital twins, data analytics and AI tools, etc.) for RI upgrade.

IMPACT: set out a credible pathway to contributing to one or several of the following impacts:

1. investments into the development, of forward-looking technical instruments and tools for European RIs.
2. *co-development with industrial actors of advanced RI technologies and technology transfer;*
3. new areas of research and development of new industrial applications/products;
4. skills of RI staff aligned with the advancements of the RI technologies;
5. Transdisciplinarity, cross-fertilisation and a wider sharing of knowledge and technologies between academia and industry;
6. Wider use of AI

Prerequisites, Eligibility. A plan for the exploitation and dissemination of results including communication activities, a Gender Equality Plan (GEP). Consortia must include at least 3 different research infrastructures, each of them being an ESFRI infrastructure and/or a European Research Infrastructures Consortium (ERIC) or another research infrastructure of European interest (i.e. a research infrastructure which is able to attract users from EU or associated countries other than the country where the infrastructure is located).

APOGEIA 2.0 for HORIZON-INFRA-2022-TECH (closing date 20 Apr 2022, Budget 10 M€)

Outcome: Project results are expected to contribute to several of the following expected outcomes:

1. enhanced scientific competitiveness of European research infrastructures
2. foundations for the development of innovative companies;
3. increase of the technological level of industries through the co-development of advanced technologies for research infrastructures and creation of potential new markets;
4. integration of research infrastructures into local, regional and global innovation systems.

Aim of ***HORIZON-INFRA-2022-TECH-01-01*** The aim of this topic is to deliver innovative scientific instrumentation, tools and methods, which advance the state-of-art of European RIs, and show transformative potential in RIs operation. The related developments, which underpin the provision of improved and advanced services, should lead research infrastructures to support new areas of research and/or a wider community of users, including industrial users.

Cutting-edge technologies will also enhance the potential of RIs to contribute addressing EU policy objectives and socio-economic challenges.

Proposals should address all following aspects:

1. Research and development of new scientific instrumentation, tools and methods for research infrastructures taking into due account resource efficiency (e.g. energy consumption) and environmental (including climate-related) impacts;
2. their technology validation and prototyping;
3. training of RI staff for the operation and use of these new solutions;
4. the innovative potential for industrial exploitation of the solutions and/or for the benefits of the society.

APOGEIA 2.0 goals

APOGEIA develops new technologies in collaboration with industry to develop the technology of European RI's while at the same time addressing key issues of climate change, extreme phenomena low latency alerts, through the study of solid earth, ocean and atmosphere including outer space.

It does this through the exploitation of the technology and data produced by Astroparticle and Geoscience research infrastructures, having developed in the recent years strong synergies and links based on common objects of study, instruments and approaches.

The Geosphere, direct object of study of the Geosciences, also determines the conditions of sensitivity of Astroparticle observatories. A better understanding of the Geosphere improves the Astroparticle Physics Observatories sensitivity (e;g. Gravitational waves), while astroparticle "messengers" (e.g. cosmic rays and neutrinos) increase the explorative capabilities of Geosciences, also offering infrastructures in extraordinary locations for combined studies, beyond the State of the Art.

Both fields deal with large scale natural systems, deploy large sensor networks in sometimes extreme environments, use observations acquired over a large range of time scales, employ large data manipulation, machine learning techniques and worldwide networking, including the distribution of alerts.

There are many smaller or larger industries that accompany this effort and the mutual profit will be important for the European Industry a well as the forthcoming RI

APOGEIA 2.0 priorities

Astroparticle Physicists and Geoscientists both deal with complex natural large scale systems, deploy large sensor networks, sometimes in extreme environments (sea, desert, underground, space), use long series of precise observations acquired over long time scales, use discovery instruments, develop models relying on the state-of-the-art in physics and computer sciences. They also use large infrastructures (such as fibre optic cables telecommunication networks and satellites), which allow for fast and massive data manipulation and worldwide networking, including distribution of alert. Both develop techniques of monitoring, new technologies (e.g., Innovation can come through new "smart" technologies (Industry 4.0)), new deep and machine learning tools. In particular, main directions and priorities concernthe following 3 directions:

1. Large and deep scale mapping (Fiber networks, Muography, Distributed/mobile sensors, CR Atmospheric monitoring)

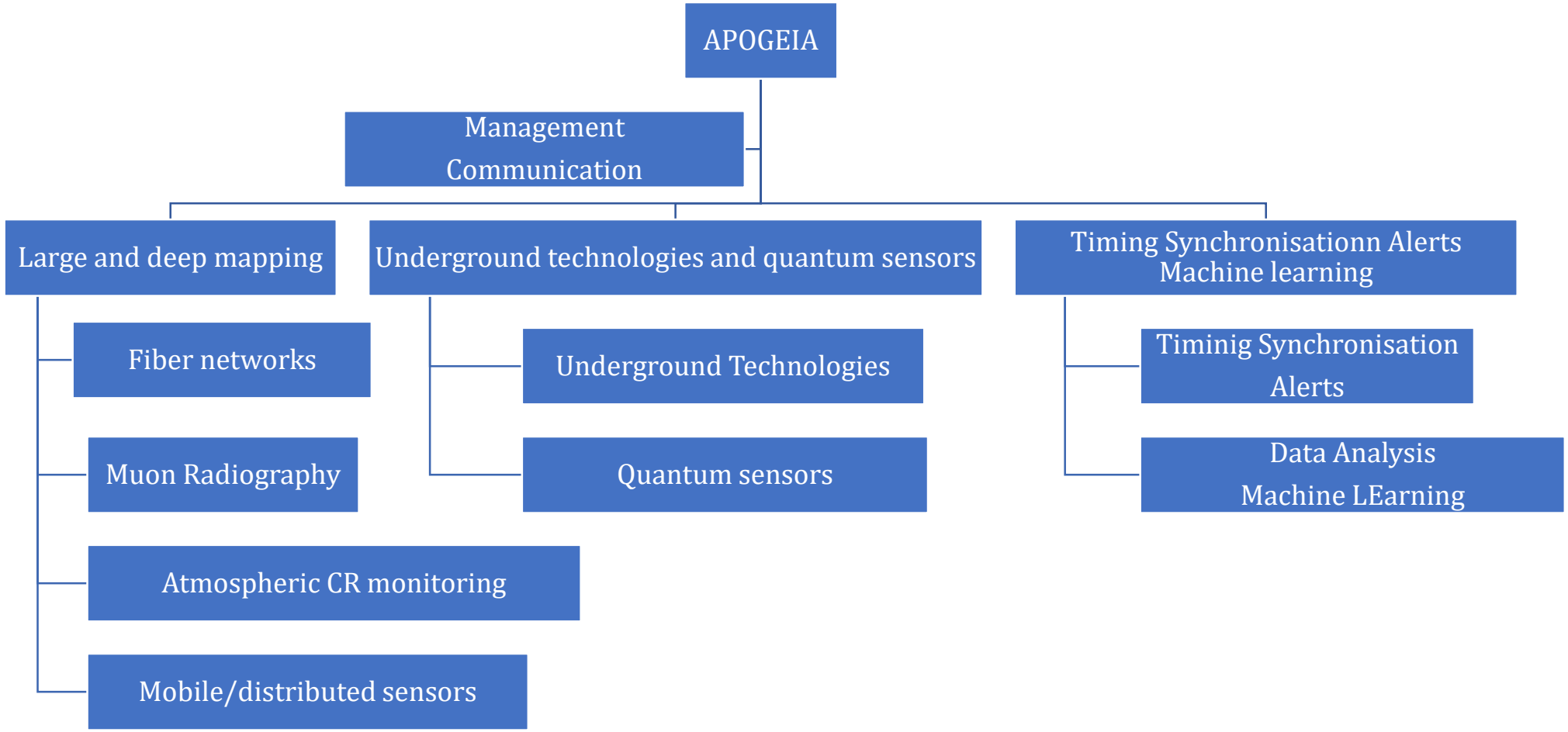
2. Underground technologies and quantum sensors (CR and Radon free environment ; New PM, stray light control and sensors for GW research)

3. Timing synchronisation and alerts, data analysis and machine learning

On what concerns Astroparticle, all connected to devpts to Virgo/ET, KM3NEt, Underground labs, CTA, Auger, in short the 7 magnificent

-

A possible layout of workpackages



APOGEIA 1 ➔ 2 Partners

UNIVERSITE CATHOLIQUE DE LOUVAIN	**BE**
UNIVERSITEIT GENT	**BE**
UNIVERSITE DE GENEVE	**CH**
IEAP/CTU	**CZ**
KARLSRUHER INSTITUT FUER TECHNOLOGIE	**DE**
HELMHOLTZ ZENTRUM POTSDAM DEUTSCHESGEOFORSCHUNGSZENTRUM ,GFZ	**DE**
Studio Tomás Saraceno GmbH	**DE**
ETHNIKO ASTEROSKOPEIO ATHINON	**EL**
NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	**EL**
AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS	**ES**
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	**FR**
INSTITUT DE PHYSIQUE DU GLOBE DE PARIS, IPGP	**FR**
UNIVERSITE DE PARIS	**FR**
CEA	**FR**
WIGNER FIZIKAI KUTATOKOZPONT	**HU**
LANDSVIRKJUN	**IS**
EUROPEAN GRAVITATIONAL OBSERVATORY, EGO	**IT**
LNSG, ISTITUTO NAZIONALE DI FISICA NUCLEARE, INFN	**IT**
INSTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA INGV	**IT**
STICHTING NEDERLANDSE WETENSCHAPPELIJK ONDERZOEK INSTITUTEN	**NL**
UNIVERSITEIT UTRECHT	**NL**
NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	**NL**
RadBoud University	**NL**
CENTRUM ASTRONOMICZNE IM. MIKOLAJAKOPERNIKA POLSKIEJ AKADEMII NAUK	**PL**
INSTYTUT NAUK GEOLOGICZNYCH POLSKIEJ AKADEMII NAUK	**PL**
LIP	**PT**

11 countries

In bold, the institutions that re-expressed recently their interest to participate

9 industrial partners interested:

1. TNO, Netherlands
2. Alcatel Submarine Network , France
3. Silixa, UK
4. IRIS Industries France
5. Muon Solutions Oy, Finland
6. Landvirksjun, Krafla Magma Testbed (KMT) Island
7. Techno-in Geosolutions, Italy (Naples, Sardinia)
8. Eugenides Foundation
9. Saraceno GmBH

Mails or renewal of interest

1. Fibers: (INGV, LNS, KIT, GFZ, Silixa, APC)
2. Muon Radiography (LNS, LIP, IP2I, KIT, Ghent, UCLouvain, INFN (Florence/NApoli))
3. Underground technologies/Quantum Sensors (LNGS/LSM/Camfranc, IEAP/CTU, Astrocent, Florence)
4. Distributed Sensors (IP2I, Astrocent)
5. Data analysis/ML (LIP, KIT, Ghent, IEAP/CTU
6. Outreach Citizen's Science (LIP ,KIT, Ghent, UCLouvain, IEAP/CTU
7. Astro-Geo twining (APC, AStrocent)

FDAS: Fiber Distributed Acoustic systems

1. **Seismic, Acoustic, Temperature, ... networks**
2. **Seismology and Bio-Environmental Monitoring** (deep sea, volcanoes, faults, KM3NeT, EMSO, EPOS)
3. **Acoustic Neutrino detection** of deep ocean sites: KM3NeT
4. **Characterization and monitoring of current and next generation ground and underground infrastructure sites.** (3G GW, civil infrastructures, Archeology) Additional data will be retrieved by integrating existing seismological networks (INGV network from the Italian national earthquake monitoring program, ORFEUS (Observatories & Research Facilities for European Seismology) network, Corinth (an EMSO facility) and the PANGEA infrastructure under development in Greece.
5. **Seismic, UHECR and GW acoustic detection.** Lunar deployment APC/IPGP

Muon radiography

1. **It concerns :** a) geosciences, b) geotechnics, c) industrial applications, d) hardware solutions, e) computing & methods; f) extensions (e.g. to neutrino tomography)

2. **Volcanology & Geoscience.** There are well established collaborations for muon imaging of volcanoes, which led to huge progress in the understanding of the internal structure and magma dynamics. One of these is the DIAPHANE, combining continuous muon measurements with seismic noise acquisitions and continuous gravity data to characterize the hydrothermal activity of La Soufrière de Guadeloupe volcano in France. The other is MURAVES, aiming at the imaging of Mt. Vesuvius in Italy, one of the most dangerous and scientifically interesting volcanoes in Europe. Italian volcanoes are well known key targets for muography, but they are not the only one. Secondary targets are the Soufrière of Guadeloupe (Lesser Antilles, France) and Sakurajima volcano in Japan. Although the distance of those volcanoes impedes the deployment of detectors by other teams, the teams already working on them will share their data such that they may be used for data analysis and methodology development.

3. **Underground targets and site characterization.** This task will perform cosmic muon imaging for several objectives: 1. to extract density distribution from underground targets with an array of muon sensors in order to characterize underground dynamics; 2. to monitor underground civil works and also archaeology; 3. to understand the impact of cosmic rays (e.g. via extended air showers effects on the mirrors) in the next-generation, buried gravitational wave telescope Einstein.

4. **Muon radiography and Machine Learning.** Analyse the data from the MURAVES experiment, applying for the first time ML to a muon radiography problem involving the imaging of a large target.

Atmospheric monitoring

1. **Use CR frequencies as an atmospheric probe (in association with portable lidars and other environmental sensors), including the monitoring of Ozone with CR.**
2. **GEO3BCN-CSIC** (Jordi Diaz) **Monitoring solar magnetic storms** using permanent and portable broad-band seismometers. Last years were published some contributions on that subject (3 new publications added)
3. **GFZ** (Yuri Shprits) **Development of the infrastructure for monitoring and now-casting particle environment in the near-Earth space.** This effort is also directly relevant to climate and we can add the development of the infrastructure related to the precipitation of particles into the atmosphere where they affect the Ozone and climate. Installing a neutral monitor on a ship. That could help track GCRs and how they propagate through the atmosphere. We can of course look at other particles such as inner magnetospheric electrons, ions, etc.
4. Offer by Evgenides Foundation to provide globe navigating ships for deployment of CR detectors and other atmospheric instrments

Distributed sensors, including mobile sensors

1. **DIstributed networks for characterisation, monitoring, alerts**
2. **Mobile sensor networks** Mobile sensor and/or distributed networks. The partners will design and test a mobile platform for various sensors able to include seismic and infrasound acoustic sensors (Astrocent, EGO,NIKHEF, ...). several sensors offset, distant, and movable with a common link (vibration, and/or, same interrogation beam). This with independent linked radio and/or gravi.
3. **Early warning systems**. This task could also develop earthquake and GW early warning/low latency systems.
4. **Lunar rovers**

Underground technologies

1. **Radiation free environment , Radon suppression, for research and strorage**
2. **New SiPM , pixel detectors, scintillating detectors, and quantum sensors for imaging technologies**
3. Ultra sensitive HPGe spectroscopy for detection of radioactivity,
4. Radon suppression (antiradon device and clean room with "zero dose" environment),
5. Biological studies in zero dose environment....
6. Sensors: it could be extended into R&D of progressive detection techniques, such as pixel detectors (allowing precise spatial and time resolution, distinguishing of different particles by tracks and energies), strip detectors or scintillating detectors. We have several pixel detectors on satellites (even in outer space) and we plan to develop new generation of pixel detectors for space. Pixel detectors are in our institute used also for imaging in biology, medicine and material studies (X-ray and neutron tomography, 3D scan).
7. In this field we have close contact with industrial partners (ADVACAM - pixel detectors, NUVIA as a branch of French company Soletanche Freyssinet with nuclear power engineering, laboratory technology, software development, industrial automation and systems for ionizing radiation detection, and CRYTUR - special types of scintillating detectors

- Interested underground labs
  - Laboratori Nazionali del Gran Sasso (LNGS) Italy
  - LSM Laboratoire Souterrain de Modane France
  - CANFRANC/GEODYN geophysical observatory at LSC Spain

Quantum Sensors

1. **Gravimetry and Gradiometry sensors.** Accurate gravity measurements with quasi-continuous atom gravimeter and study innovative quantum sensors for ultra-sensitive gravitational gradient measurements to be employed in Fundamental Physics tests and in the study of phenomena of interest in Earth Physics.
2. **New SiPM good for PET**
3. (OBSM, Pottie): Participation in gravimeter with our atomic gravimeter and in gradiometry with our atomic gradiometer (vertical).
4. **Stray light control** Controlling stray light with baffles, detectors and the afferent simulations is a necessary condition for X and γ ray satelites, gravitational wave detectors and preservation of entanglement in view of quantum computing.

Timing, Synchronisation, Alerts

1. **Network Synchronisation and time distribution.** This task will study how high-performance synchronization and syntonization methods could contribute to strengthen the detection capacities of interferometers, Astrophysics observation and Geophysics experiments. The benefit of the White Rabbit protocol to short or long-distance timing signal distribution will be estimated.
2. **Optical clock sensors.** Some of the partners have obtained pioneering results in chronometric geodesy with synthetic optical clock measurements and their contribution to the determination of the geopotential. This task will develop these measurements further.
3. **Develop the fiber network sensing approach**, investigating the contribution fiber network may have for seism monitoring and gravitational wave detection, increasing the scientific impact of fiber network by developing scientific collaboration. Developing the integration of REFIMEVE as a Research Infrastructure into the ESFRI landscape. SYRTE
4. **Early warning systems**. This task will develop earthquake and GW early warning/low latency systems.
5. **UHECR detectors** are having significant issues with wireless data acquisition and triggering communication in a grid of a (very) large number of detector stations, such as currently in Auger and in the future in e.g. GRAND. One big problem is to do sub-nanosecond timing synchronisation over wireless communication. In princple it should be possible, but it is far from being realised. If realised, it would probably also have important applications in industry and society. Sijisbrand deJong

Data Analysis and Machine Learning

1. **Early warning and Machine Learning**. Develop ML tools for the rapid detection and classification of seismic signals. This will connect to the work on site selection on ET sites.
2. **Characterization Classification of noise and signals sources in seismic and infrasound sensors networks.** Study the environment monitored by an infra-sound or seismic sensors network in order to identify and classify with ML techniques signal and noise sources and patterns appearing in the environment.
3. **Activities identification from seismic signals.** Perform supervised classification of records of natural or anthropogenic seismic sources generated by the human activity (people walking, cars, etc) in cities and elsewhere.
4. **Newtonian Noise and Deep Learning.** Use ML to implement a method to cancel out the Newtotnian noise of a GW interferometer by means of a suitable correction signal fed to the test masses actuators with Wiener filters optimization to follow the time evolution of the ambient noise.

Astro-Geo Twinning

1. **Earth tomography with neutrinos and seismic data. P**erform combined analyses of seismic data and neutrino data in order to gain new insights on open questions concerning the structure and composition of the deep Earth.
2. **Fluid-kinetic dynamics in astrophysical plasmas and geoscience.** Apply innovative methods to the study of volcanic and other geophysical flows that can dramatically improve our understanding of the inner workings of our planet Earth.
3. **Astro-Seismology of Compact Objects: Modelling and Data Analysis Methods. P**erform modeling and data analysis targeting the investigations of a variety of neutron star excitations which have not yet been observed in the GW channel.

Engagement strategies, dissemination, communication, art and science.

- Provide the means to disseminate the most exciting and combined results from both Astrophysics/Geoscience fields to different types of public, organising on a regular basis initiative as exhibitions, schools at visitor centres and open days, with attention to inclusiveness and synergies with other domains (arts, humanities).
- Increase the relationships with industry
- Produce multimedia material to attract the general public (e.g. apps, videos, virtual visits).
- A particular emphasis will be given to Citizen's Science
- Art and Science program under the leadership of world-renowned artist sensitive to Art and Science issues, including environmental issues: Tomas Saraceno and his laboratory.
- Increase inclusion, with sonification

Next steps

- New remote meeting 12 November
- Presential+ remote meeting on the synergy themes w.r.t the sustainable goals from 1-3 Deecember (funded by AHEAD2020)
- One on R&D in Astroparticle is also possible inside AHEAD2020

APOGEIA 2.0 in sync with the goals of International Year Basic Sciences for Sustainable development
(to be decided by end of November)

Basic sciences are the sine qua non for sustainable development

Agenda 2030 for Sustainable Development is the ambitious program that the Member States of the United Nations have agreed on to ensure a balanced, sustainable and inclusive development of the planet.

Basic sciences have an important contribution to make to the implementation of this program. They provide the essential means to meet crucial challenges such as universal access to food, energy, health coverage and communication technologies, depletion of the ozone layer, climate change, depletion of natural resources, extinction of living species.

Applications of technology are easy to recognize. On the other hand, contributions of basic, curiosity-based, sciences are not well appreciated. They are nonetheless at the basis of major technological advances that stimulate innovation, as well as essential for training future professionals and for developing capacity of populations who can take part in decisions that affect their future.

The International Year of Basic Sciences for Sustainable Development, that we will organize in 2022, will focus on these links between basic sciences and the Sustainable Development Goals. M. Spiro

https://www.iybssd2022.org/en/home/