

**AstroParticle Observatories and  
GEoscience Infrastructures Activities**



**A tribute to Stavros'  
encyclopedic vision**



*Véronique Van Elewyck*



*AstroParticule et Cosmologie*

# APOGEIA v1: a lockdown adventure

## PAGE 1: OBJECTIVES

*There are more things in Heaven and Earth, Horatio,  
than are dreamt of in your philosophy.*  
Hamlet, Shakespeare

*The main objective of APOGEIA is to support the recent but strong convergence between Geosciences and Astroparticle Physics, to bring together, integrate on European scale, and open up, key relevant national and regional research infrastructures to all European researchers, from both academia and industry, ensuring their optimal use and joint development.*

Earth and Astroparticle sciences share a **mutual scientific culture based on common objects of study, methods and approaches**. The Geosphere, a direct object of study of Geoscientists, is both the target and the detecting medium for Astroparticle observatories.

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 fundamental physics, chemistry, biology and computer sciences. They also use **large infrastructures** which allow for **fast and massive data manipulation** and **worldwide networking, including distribution of alerts**. [...]

- **Incredible coordination effort led by Stavros** (& his team at EGO, especially Francesca Spagnuolo) Proposal prepared in 1,5 month (April-May 2020): 70+ participants, countless zoom meetings...
- Submitted to EU Call H2020-INFRAIA-2018-2020 (Integrating and opening research infrastructures of European interest) **5 M€ requested**
- Encapsulates Stavros' credo: **Earth and Astroparticle sciences maximize their potential by cross-fertilization!**

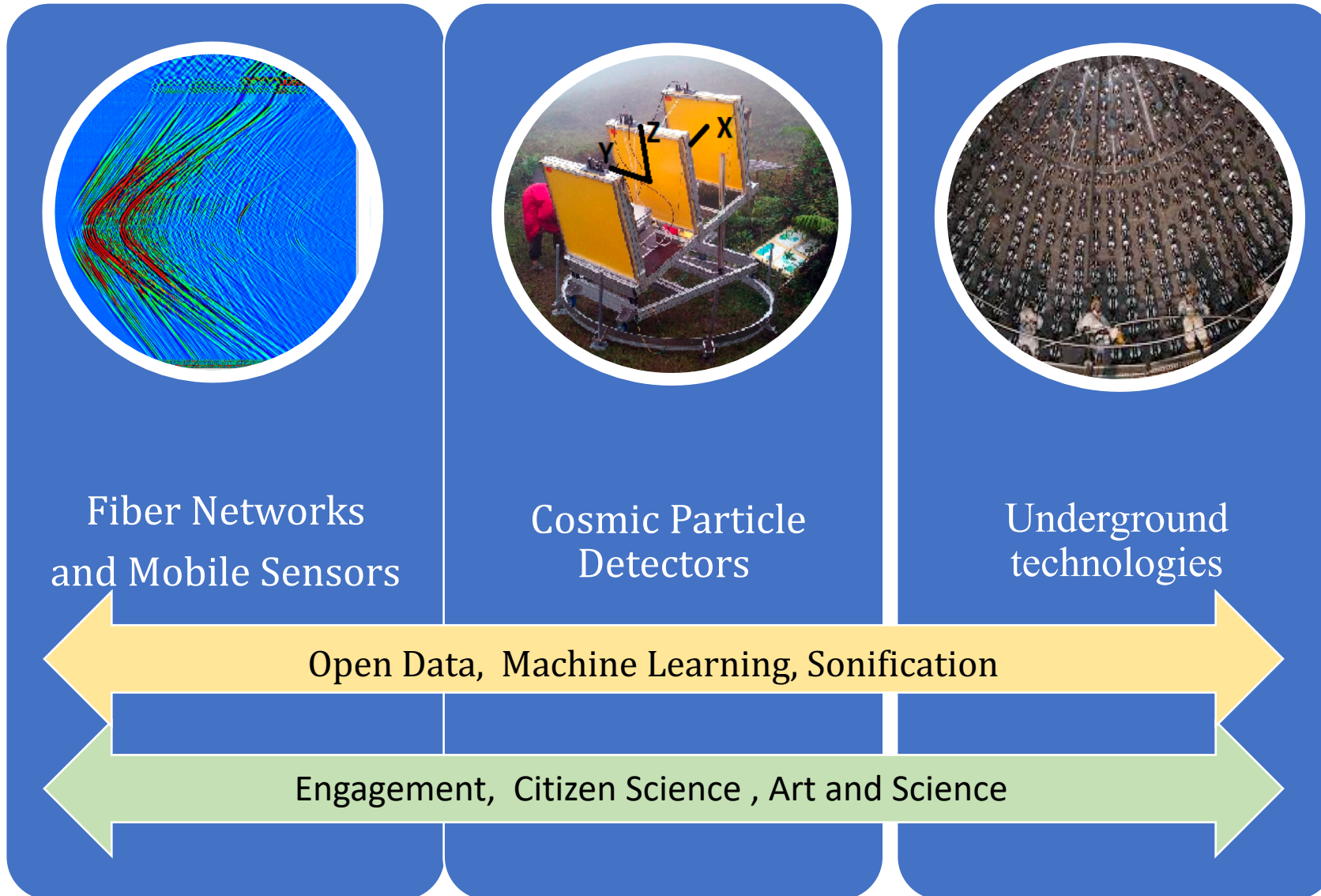
# APOGEIA v2: a broader community, new instrumental synergies

*Apogeia will certainly lift-off ( θα απογειωθεί, "raise from the earth" in greek ) -- Stavros*

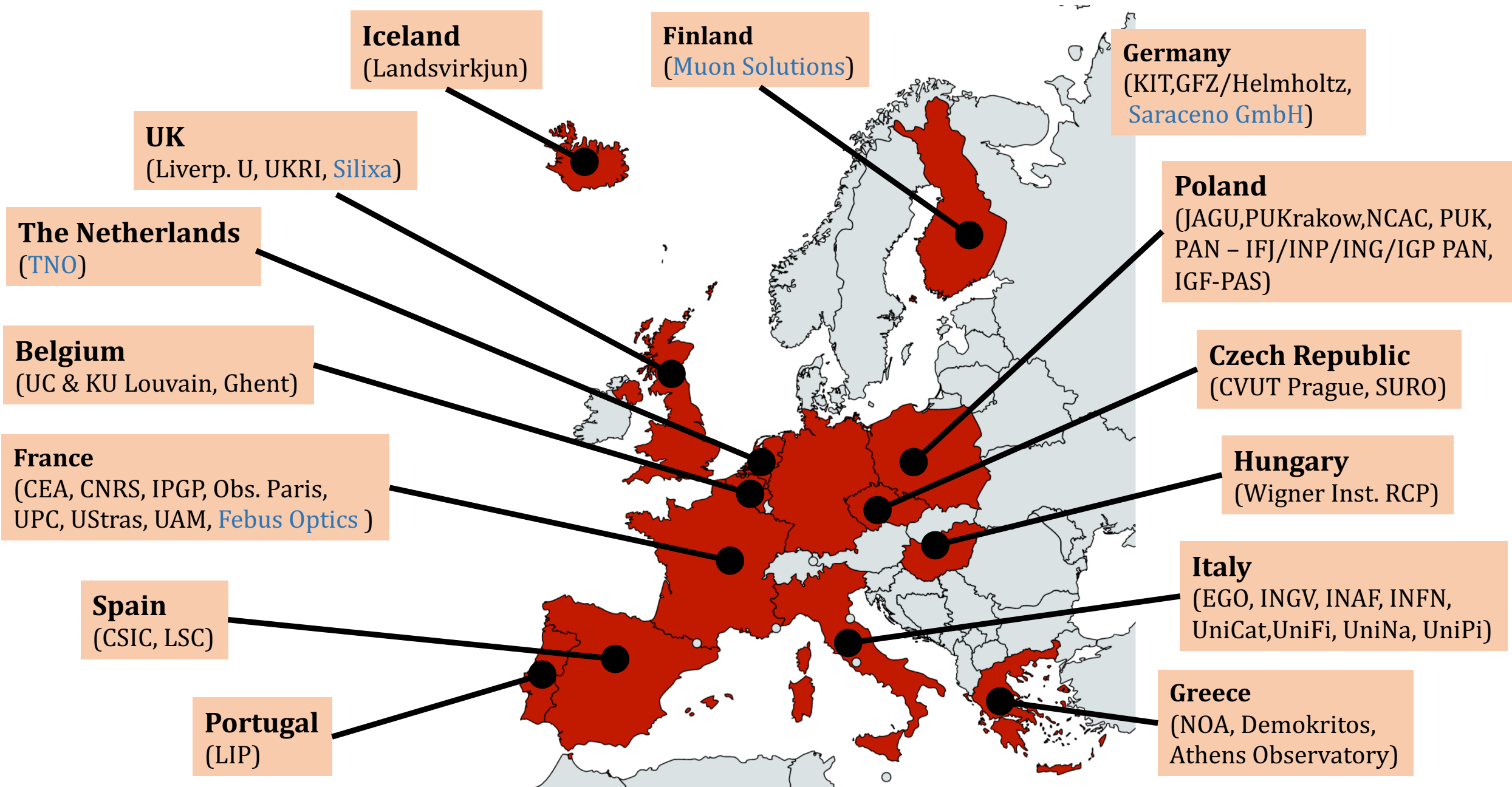
- Repurposed for EU Call HORIZON-INFRA-2022-TECH-01  
(Next generation of scientific instrumentation, tools and methods) - **11 M€ requested**
  - **broader scientific community,**
  - increased participation of **industrial/SME partners**
  - inclusion of major EU research infrastructures: **EGO, KM3NeT** (ESFRI Roadmap), **EMSO** and **EPOS** (ERICs), underground labs (**Boulby, Canfranc, Modane, Gran Sasso**)
- Stronger focus on Instrumentation: **development of interdisciplinary groundbreaking technologies to advance science in remote/extreme environments:**
  - deployment of large arrays of sensors
  - Earth & climate monitoring, natural catastrophe alert systemsbenefit from methodologies and approaches developed within astroparticle/geoscience research: **clock distribution, large-scale data processing, machine learning ...**
- **Ambitious societal agenda: open data, citizen science, art & science...**

# APOGEIA v2: a broader community, new instrumental synergies

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# Country map & institutions

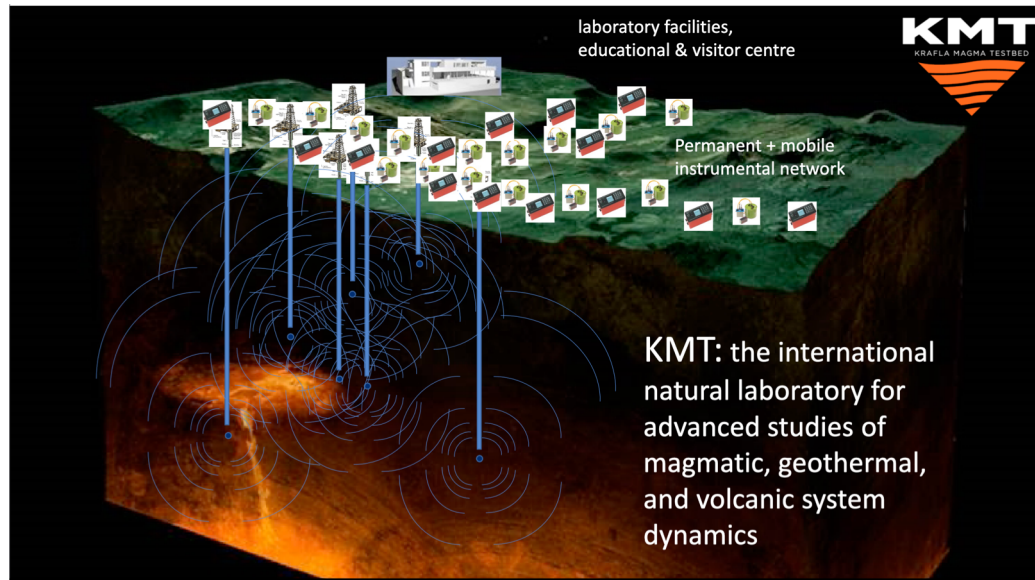


# Distributed Fiber Optic Sensing

Current optical fiber technologies and infrastructure provide high-precision time/frequency distribution & real-time data transmission

→ Coupling with adapted, mobile sensors allows for distributed temperature/acoustic/strain sensing, also in remote areas

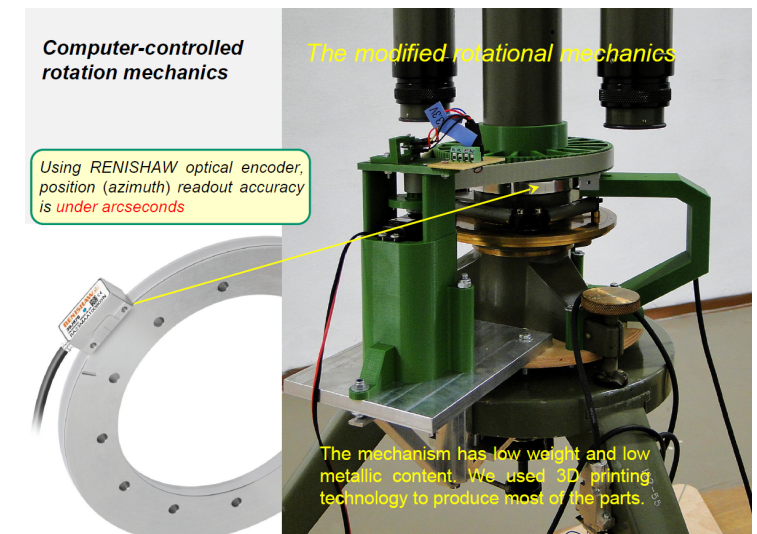
- new science perspectives for ground response characterization, near-fault observations, geohazard monitoring, bioenvironmental monitoring...



Towards fibre-optics and continuous gravity monitoring of Krafla Magma Testbed to probe T, strain and mass (Philippe Jousset, GFZ Helmholtz Centre Potsdam, DE)

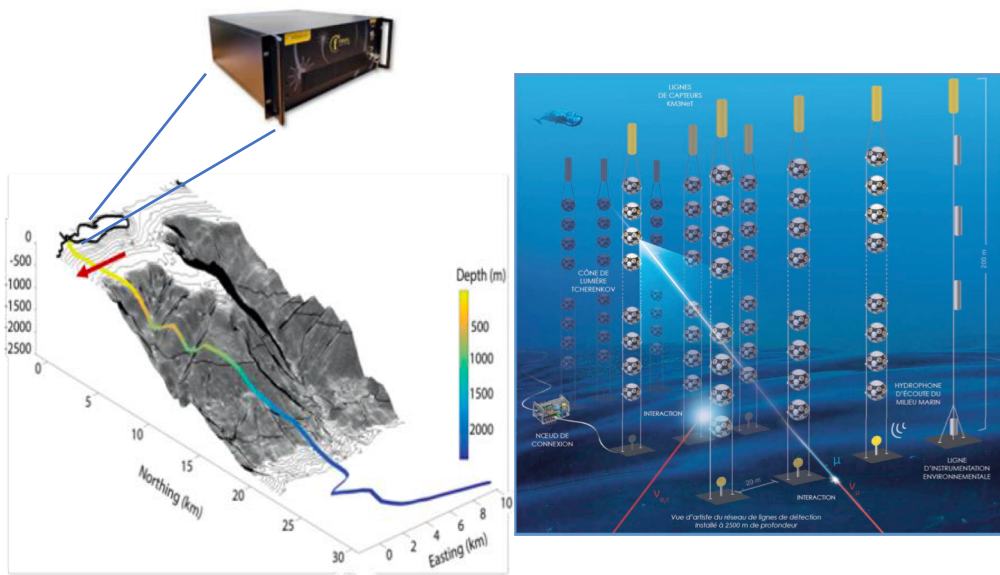


Towards a network of sensitive gravitogradiometers based on improved Eötvös-Pekár torsion balance concept (Péter Ván, Wigner-BME group of experimental gravity, HU)



# Distributed Fiber Optic Sensing

- Possibility to harness existing infrastructure to test and improve performances, develop AI algorithms for noise characterization & filtering...

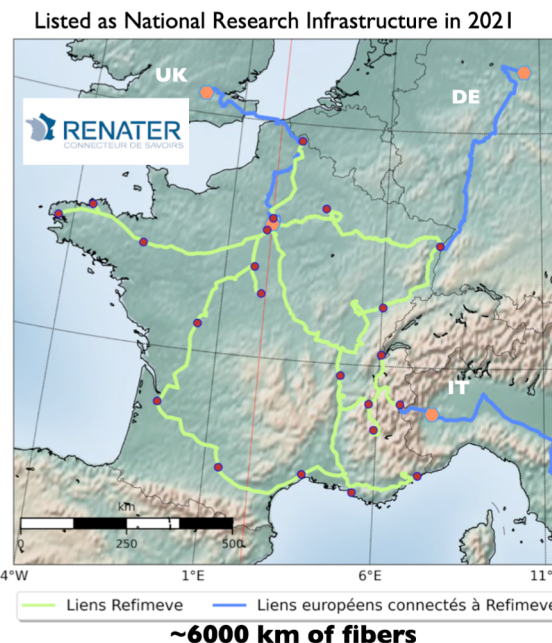


convert the KM3NeT submarine electro-optical cable into 6500 thermal, seismic and acoustic sensors using a DAS interrogator (P. Coyle, A. Sladen et al., LSPM/CNRS)

- Fruitful partnership with private companies

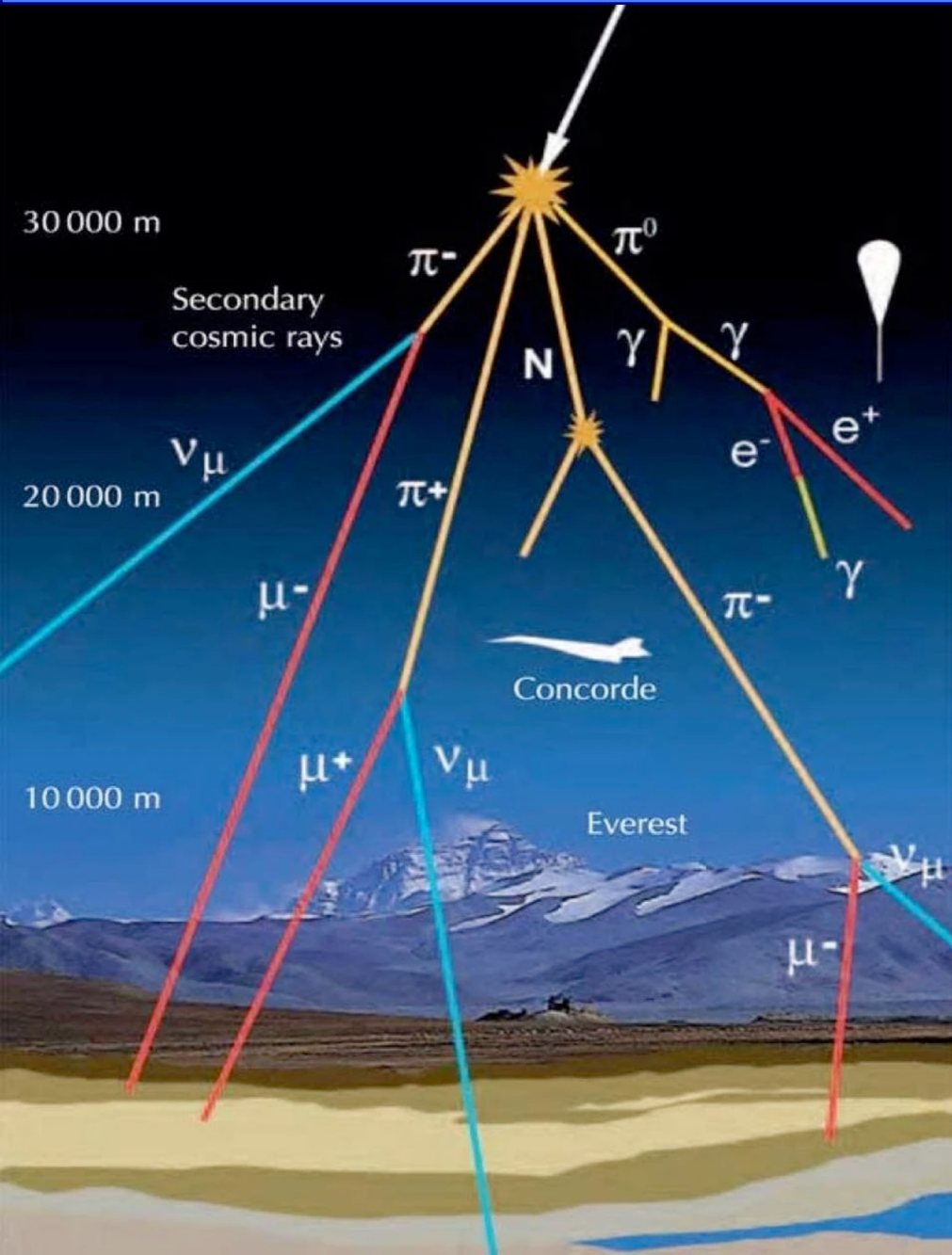


REFIMEVE Network



profit from existing national-scale fiber network to test timing performance (P. E. Pottie et al., Observatoire de Paris)

# Cosmic particle detectors



Cosmic rays interacting in the atmosphere produce extensive air showers of secondary particles that can be used to probe the Geosphere:

→ measuring the particle yield on the ground informs on atmospheric parameters

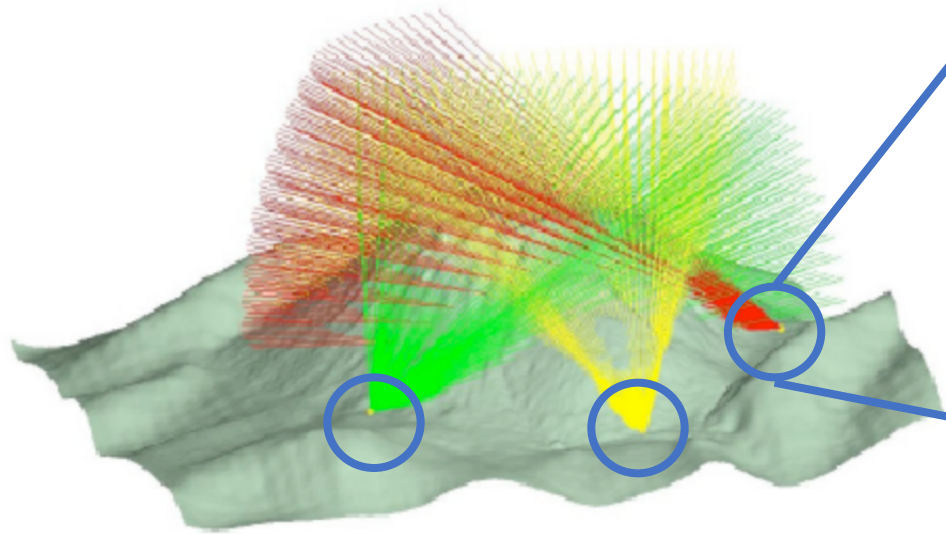
→ penetrating particles (muons, neutrinos) can be used as **imaging techniques for scanning structures opaque to standard methods** (too large, too dense, or located in inaccessible environments)

→ Also a **source of background for many (under)ground astroparticle physics experiments**



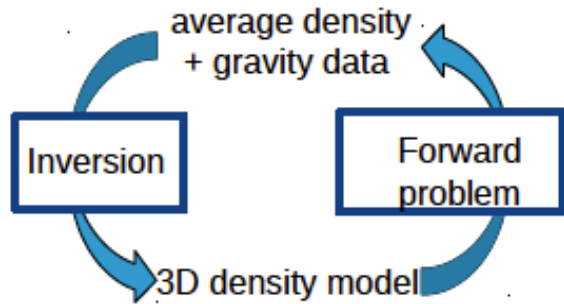
# Cosmic particle detectors: Muography

Input: atmospheric muon flux



Field detectors based on different techniques: scintillators, emulsions, Micro-megas, RPCs...

Wide range of applications:



Transmission/scattering imaging technique sensitive to density + Z/A

## Geosciences



- Volcanology
- Geology
- Hydrology
- Atmosphere physics
- CR physics
- ...

## Archaeology



- Pyramids
- Tumulus
- Anthropic structures
- Ruins
- ...

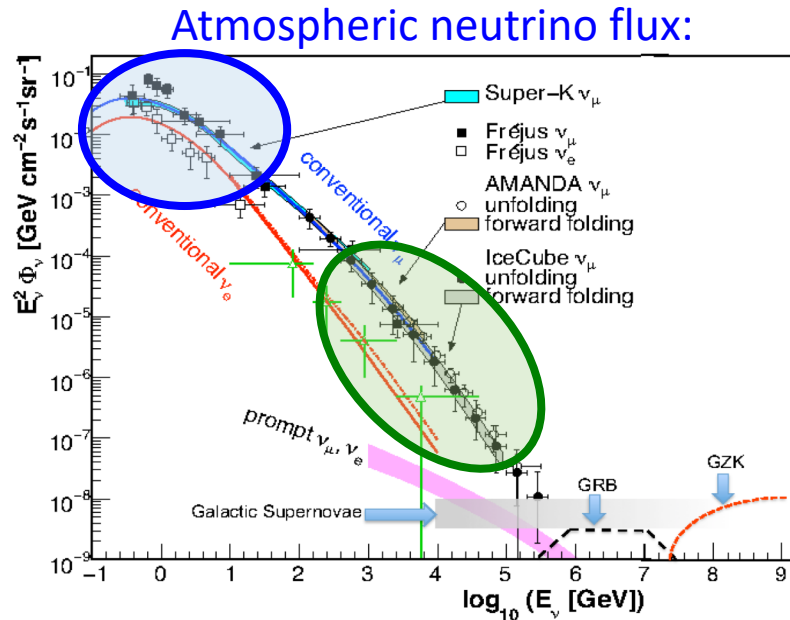
## Industrial controls



- Non invasive controls
- Nuclear cycle production
- Civil engineering
- Tunnel boring machines
- Prospection & mining
- ...

# Cosmic particle detectors: Earth tomography with neutrinos

Neutrinos are even more penetrating than muons; they can cross the whole Earth!



At GeV energies:  
neutrino oscillation  
tomography

At TeV-PeV energies:  
neutrino absorption  
tomography

$$N_e = \frac{N_A}{m_n} \times \frac{Z}{A} \times \rho_{matter}$$

electron density

matter density

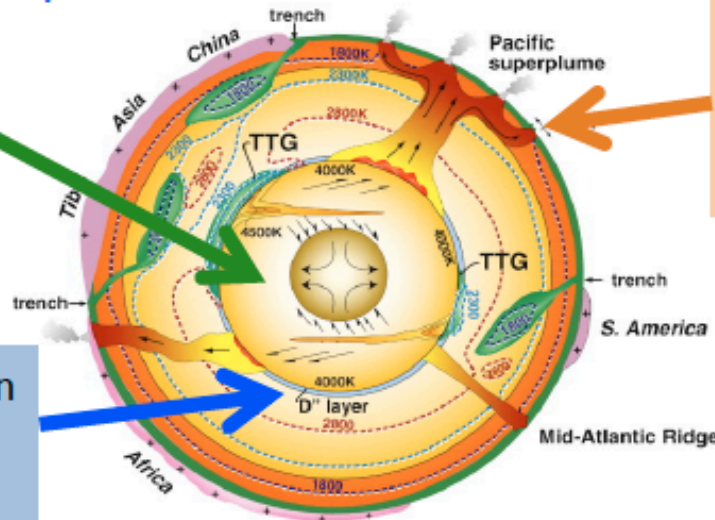
related to composition  
of the medium

Investigate geophysics open questions:

Presence of light elements (e.g. hydrogen) in the outer core ?

Nature and composition of large-scale inhomogeneities in the mantle ?

Nature and composition of D'' layer ? (water reservoir ?)



2d workshop on Multi-Messenger  
Tomography of the Earth

APC, July 4- 7, 2023

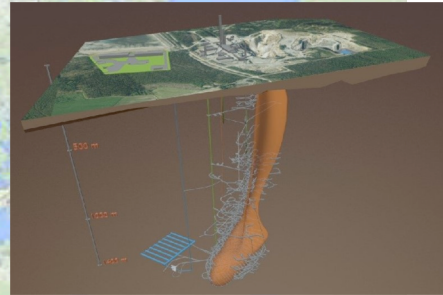
<https://indico.in2p3.fr/event/30001/>

## European Facilities (>1km w.e.)

Main science case:

- Direct dark matter search
- Neutrinoless double beta decay
- Neutrino physics
- Nuclear astrophysics
- Technology for radio-purity assay & low-background environments

CallioLab



Boulby



LSM

LSC

LNGS

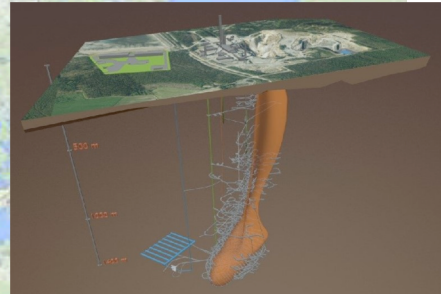


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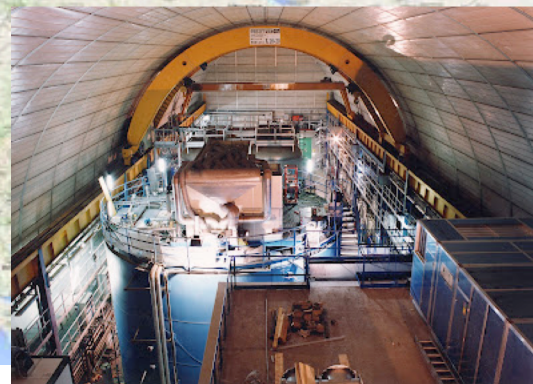
Boulby



LSM

LSC

LNGS



Within APOGEIA:

- silicon-based photodetectors
- Cryogenic detectors for gravimetry & rare events searches
- Devices for quantum computing
- radon-free environments
- underground biology

## Open Science

AGOSC:

a European-based Astroparticle and Geoscience Open Science Centre

data platform and website providing access to the data produced by APOGEIA and to large parts of observational data produced by Geoscience and Astroparticle communities

building on existing platforms:

**ORFEUS** Observatories & Research Facilities for European Seismology



## Citizen science (...and not only)

Sonification of astronomical, seismic and environmental data

→ increase accessibility of data, eg. to visually impaired citizens and scientists

→ augment the discovery potential of research by the inclusion of new sensorial data

strong synergy with REINFORCE project



# Art & Science

Art as a vector of transmission of the new paradigms of science and of promotion of human values associated to world-wide, interdisciplinary and inter-cultural collaboration

Continued collaboration with **Tomás Saraceno**



**TOMÁS SARACENO**  
**CONURBAZIONI NEBULOSE /**  
**CONURBAÇÕES NEFELIBATAS**

Tomás Saraceno dialoga con  
Stavros Katsanevas

con la partecipazione di  
Luciano Migliaccio, Giselle Beiguelman,  
Lucia Tongiorgi Tomasi, Alessandro Tosi

**mercoledì 9 giugno ore 15:00**



<https://www.youtube.com/watch?v=JayMgVvEDmA>

**Tim Otto Roth**

aiskju:b]

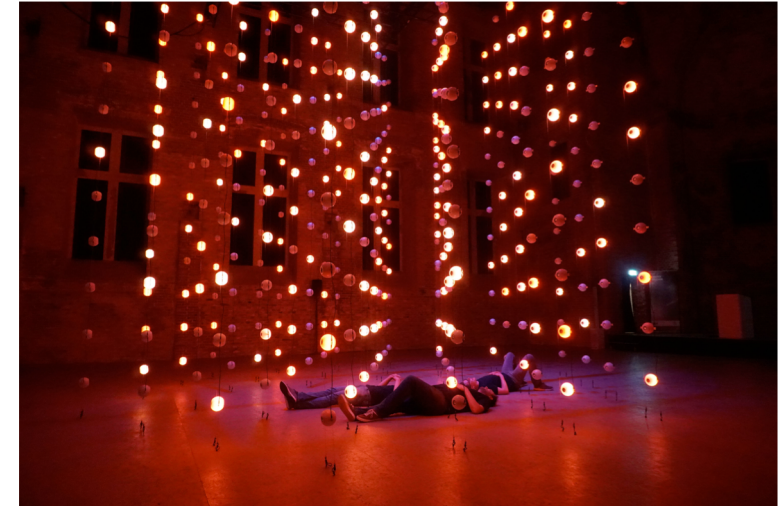
a sound laboratorium



**Donald Fortescue**

Bathysphere

(for KM3NeT)



# APOGEIA behind the scenes



A visit of the Silixa team to EGO  
under 5-day Covid travel restrictions  
-- with Mahmoud Farhadiroushan &  
the late Sergey Shatalin (Chief Scientist)  
July 2021



discussing astrophysical plans for APOGEIA  
over coffee in Sarzana (Liguria, Italy)  
– with Elena Pian and Paolo Mazzali,  
May 28th, 2022

# A tribute to Stavros from APOGEIA participants

