

# SAR-GRAV: the Sardinia Underground Laboratory, a first module for the Einstein Telescope infrastructure

*Gravitational-wave Science & Technology Symposium 2018*

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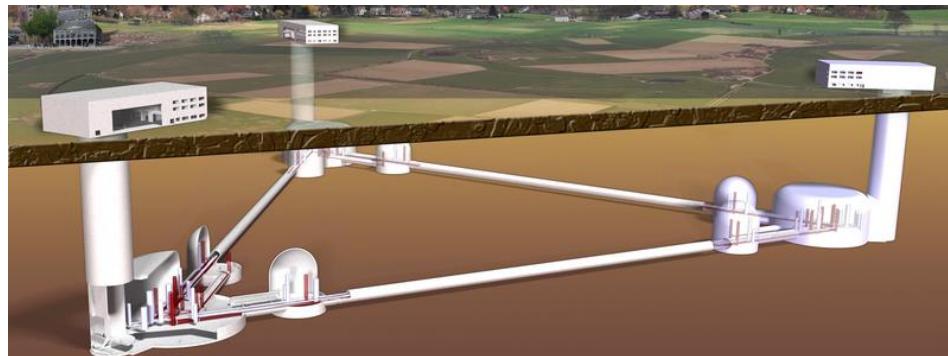
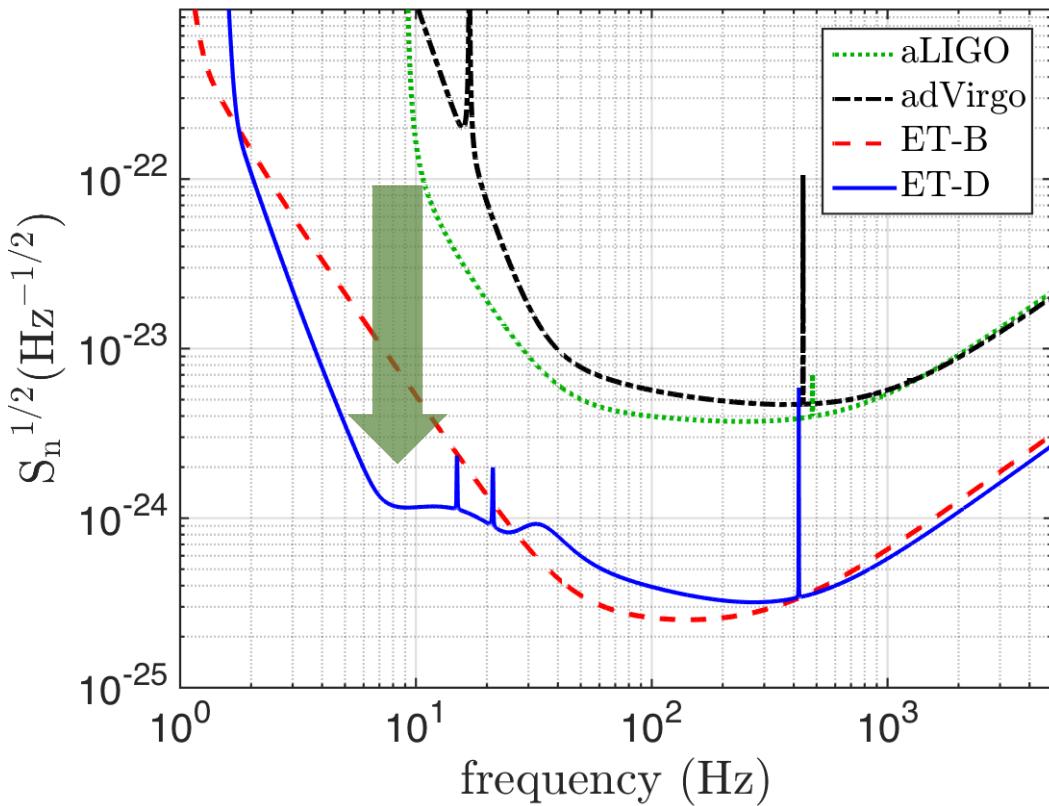
**REGIONE AUTONOMA  
DELLA SARDEGNA**



# Summary

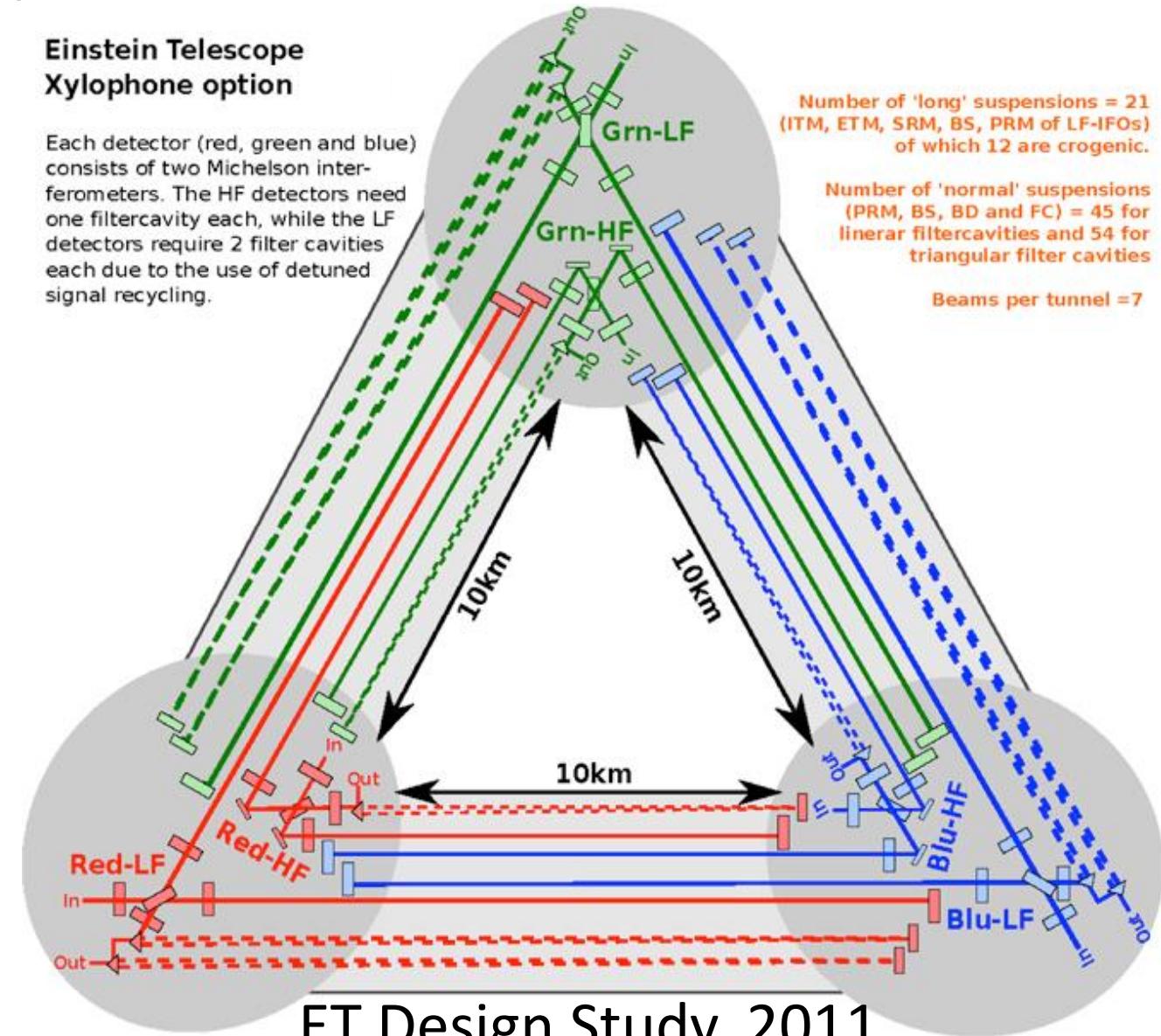
- Einstein Telescope site selection
- Sardinia: site motivation
- Sos Enattos site:
  - site *history*
  - site *characterization*
- SAR-GRAV: the future Underground Laboratory
- SAR-GRAV as a *first module* for ET

# Einstein Telescope – site selection



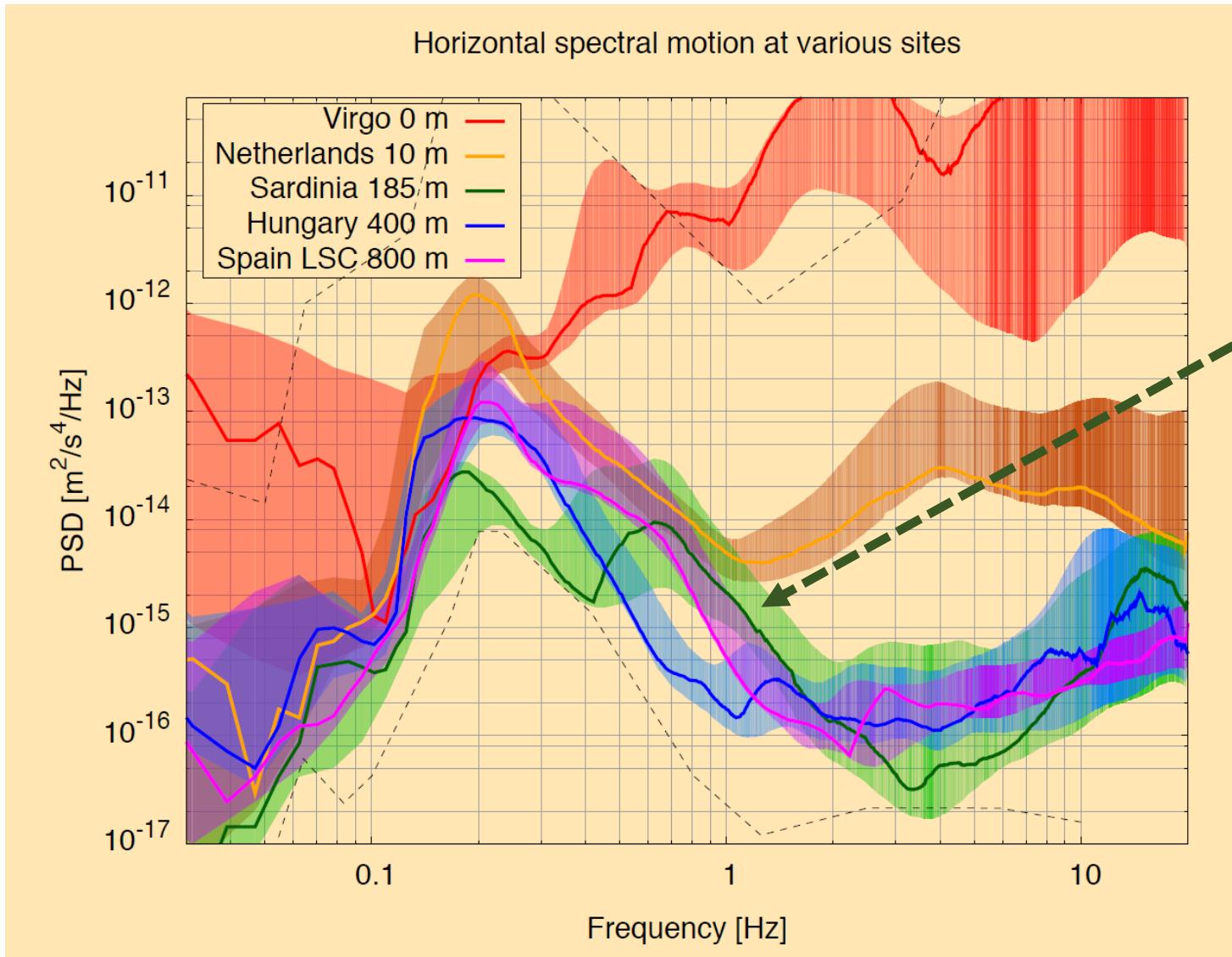
## Einstein Telescope Xylophone option

Each detector (red, green and blue) consists of two Michelson interferometers. The HF detectors need one filtercavity each, while the LF detectors require 2 filter cavities each due to the use of detuned signal recycling.



ET Design Study, 2011

# Einstein Telescope – site selection

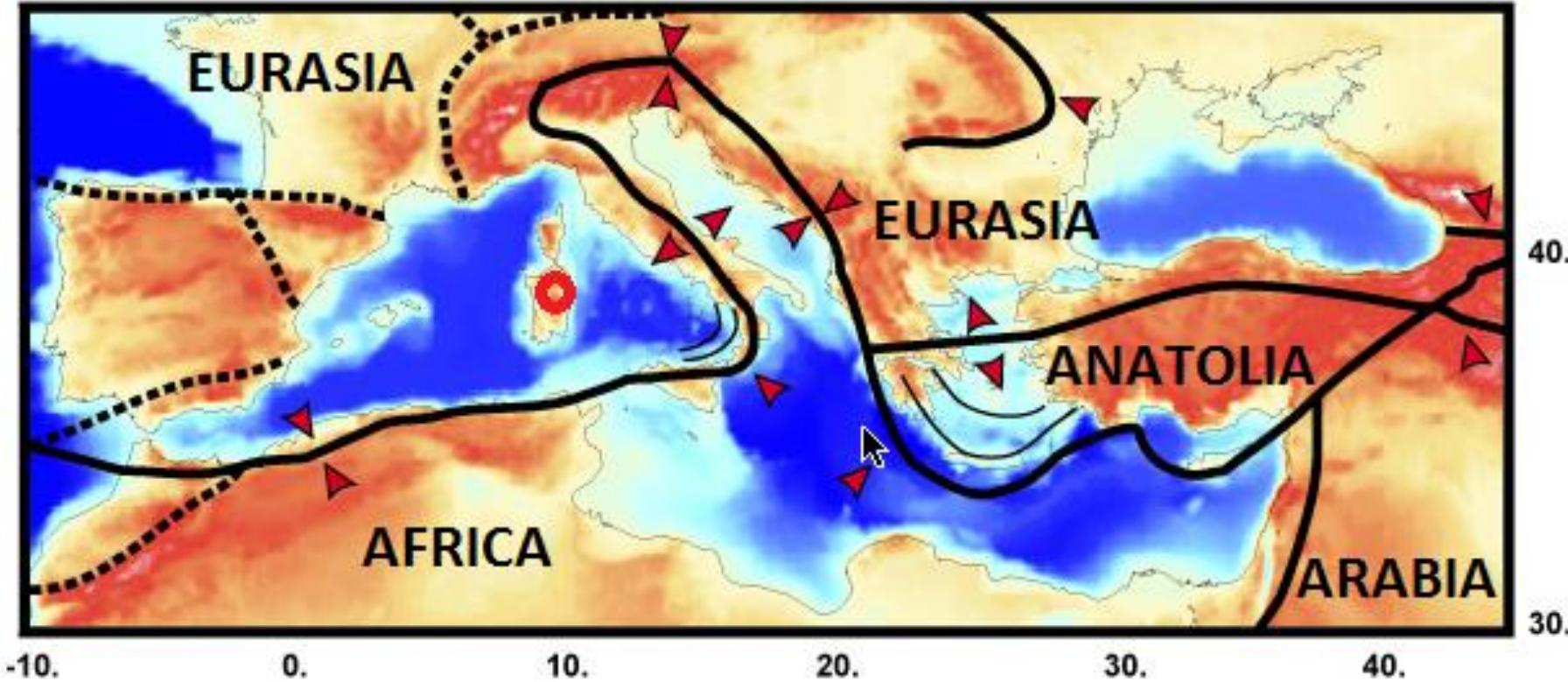


## Sos Enattos, Sardinia, Italy

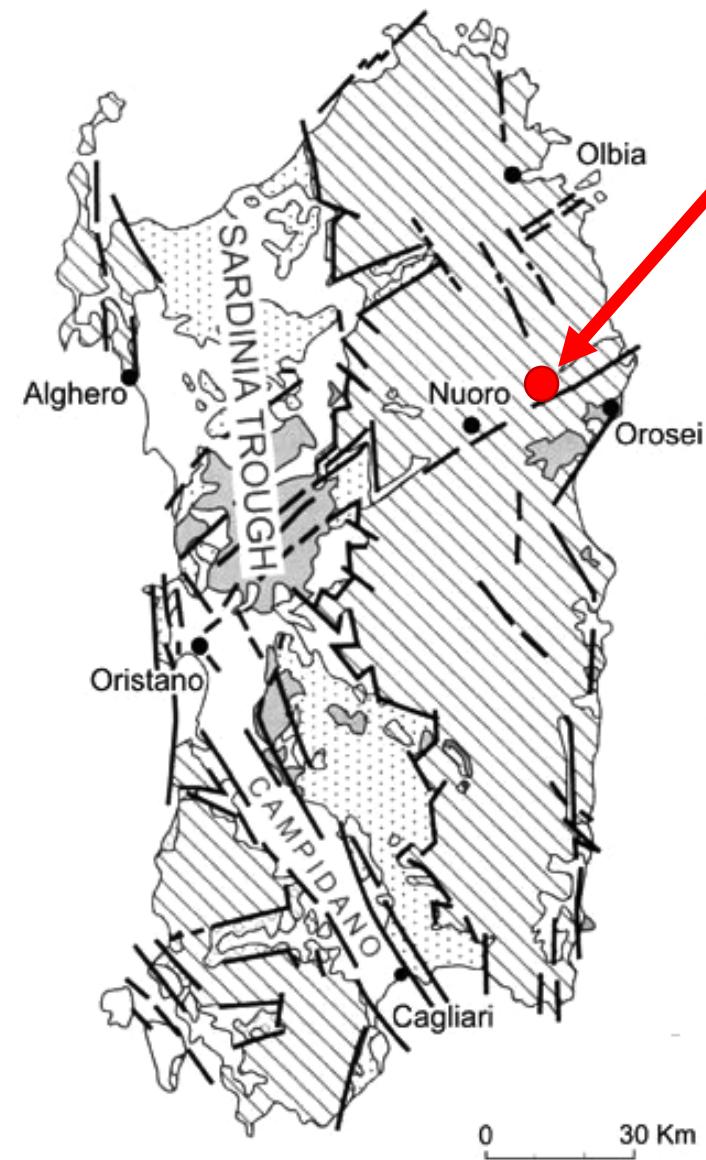
- First measurements in 2010, July (1 week of data)
- Long term site characterization from 2012, July (2 underground measurement stations + 1 surface station)

ET Design Study, 2011  
ET-0106C-10

# Sardinia: site motivation



# Sardinia: site motivation

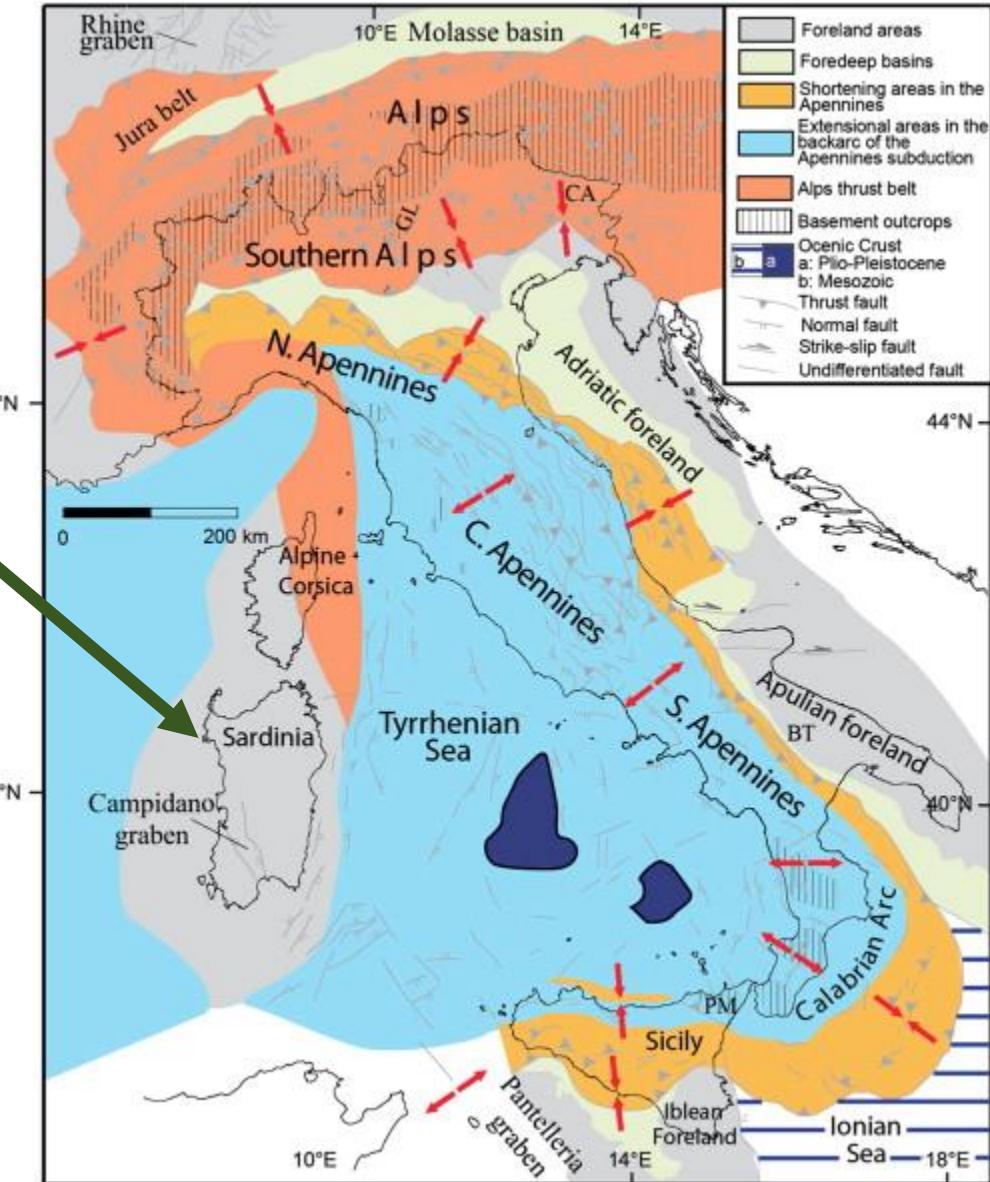


**Sos Enattos**

Tyrrhenian sea

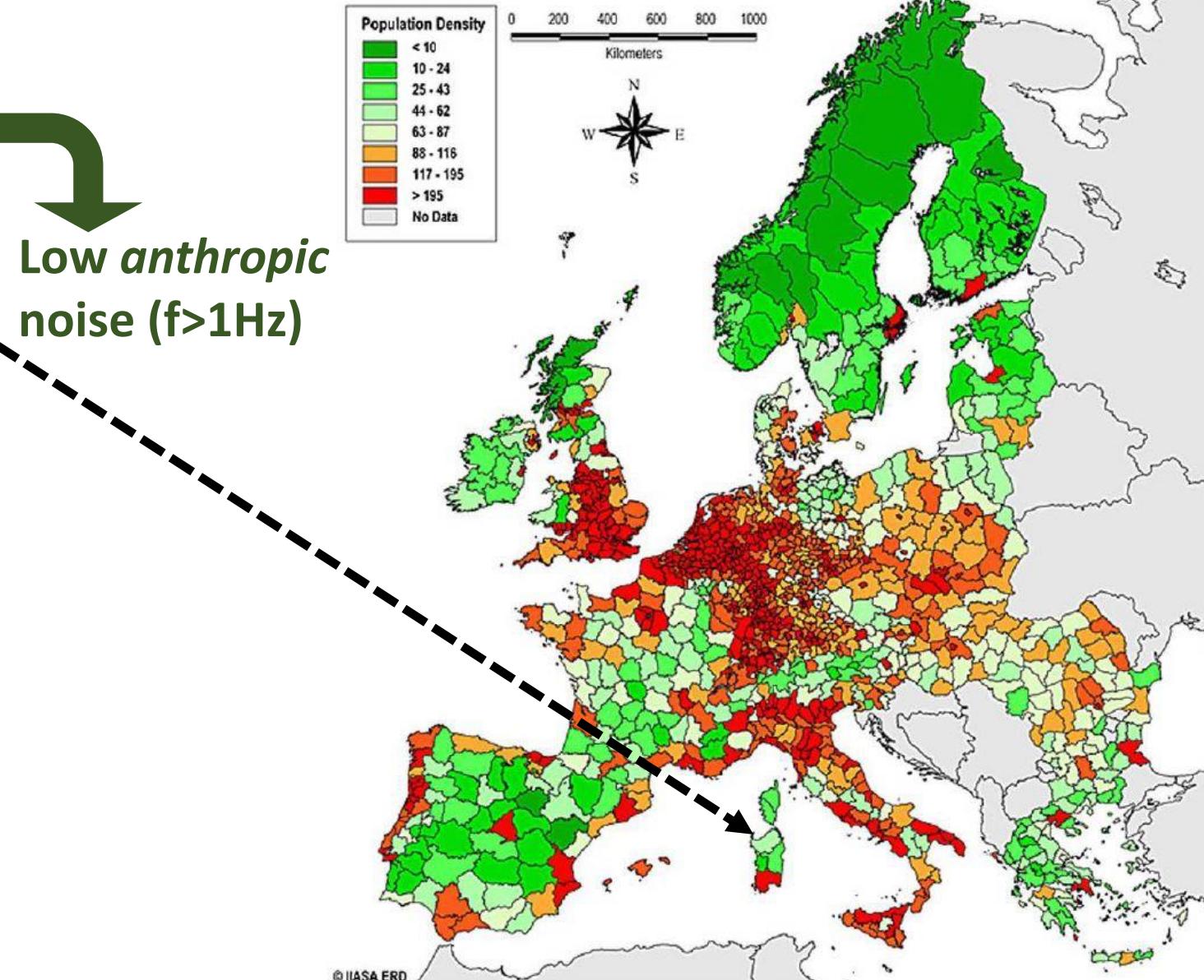
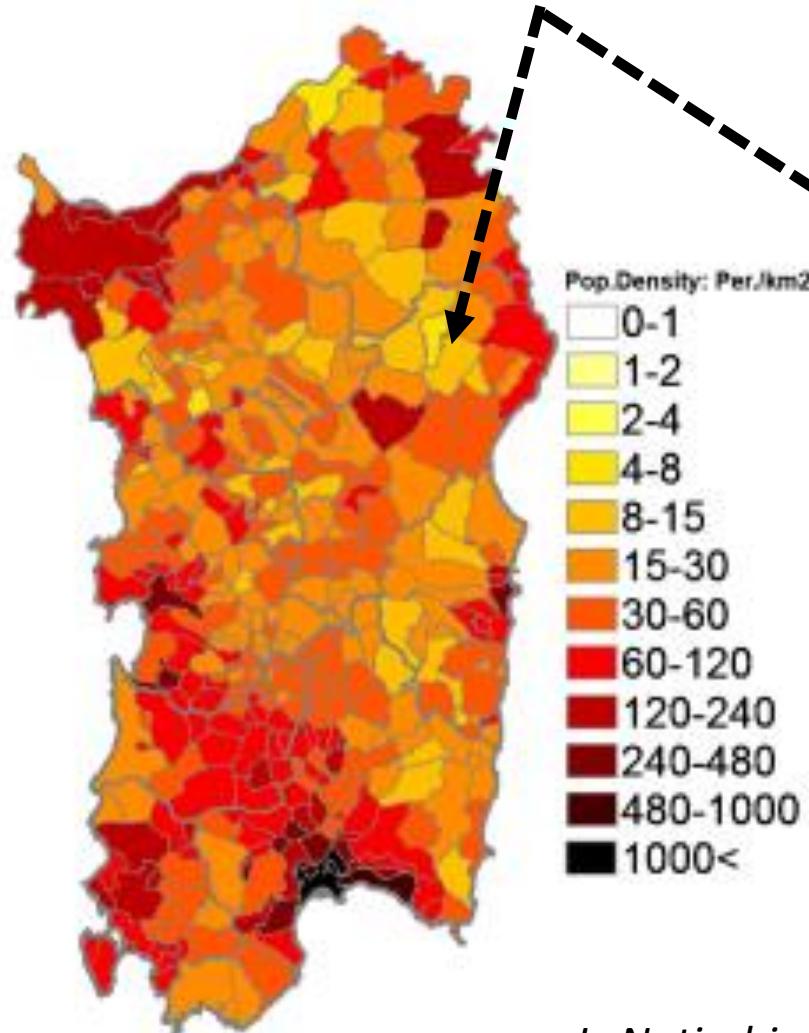
Ancient rocks, European continental landmass:  
seismically quiet

- faults
- continental deposits (Pliocene-Quaternary)
- alkaline volcanic rocks (Pliocene)
- volcanic-sedimentary deposits (Miocene)
- volcanic, pyroclastic and basaltic rocks (Oligo-Miocene)
- Cixerri conglomerates (Oligocene)
- Hercynian basement of Sardinia (Paleozoic) and superficial sedimentary rocks (Mesozoic-Eocene)



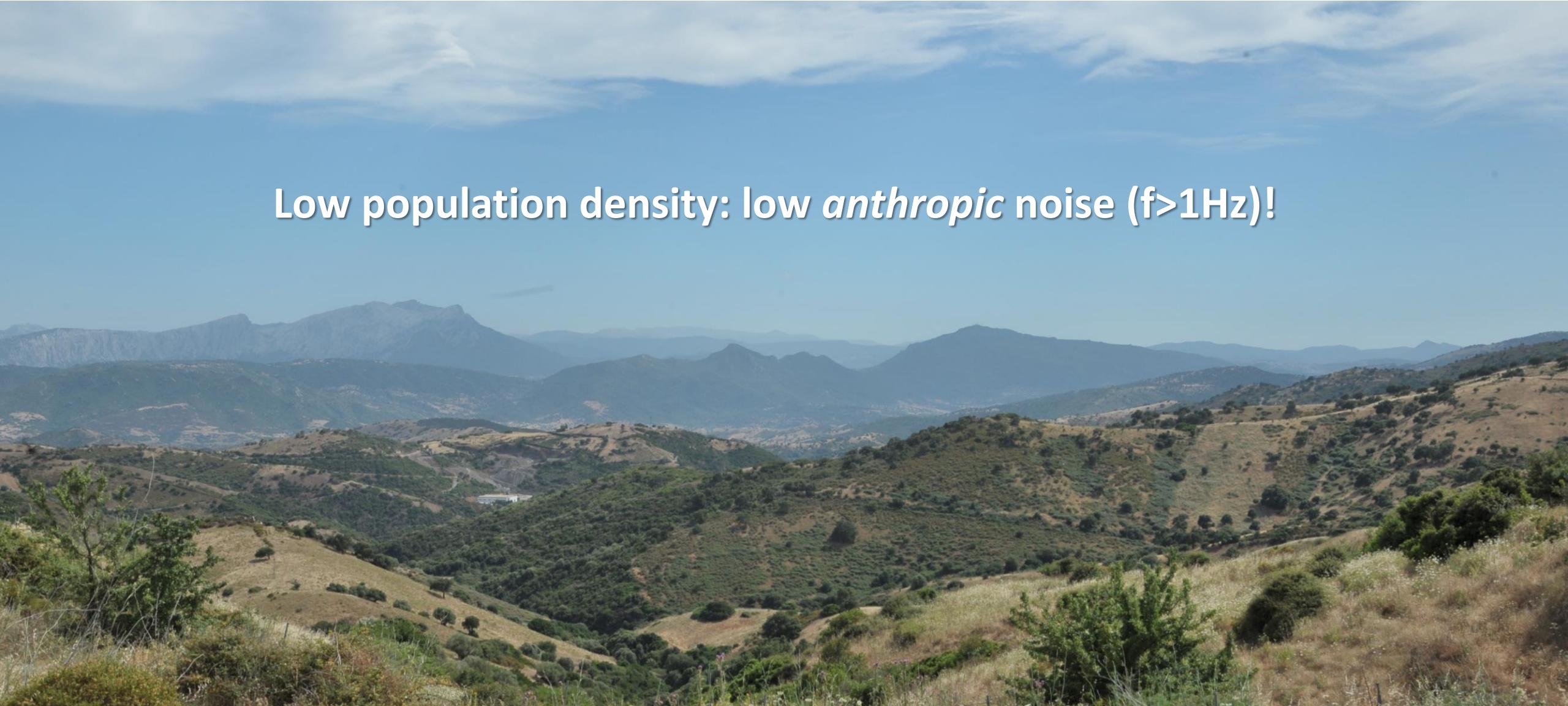
# Sardinia: site motivation

North-East Sardinia:  
Low population density



# Sardinia: site motivation

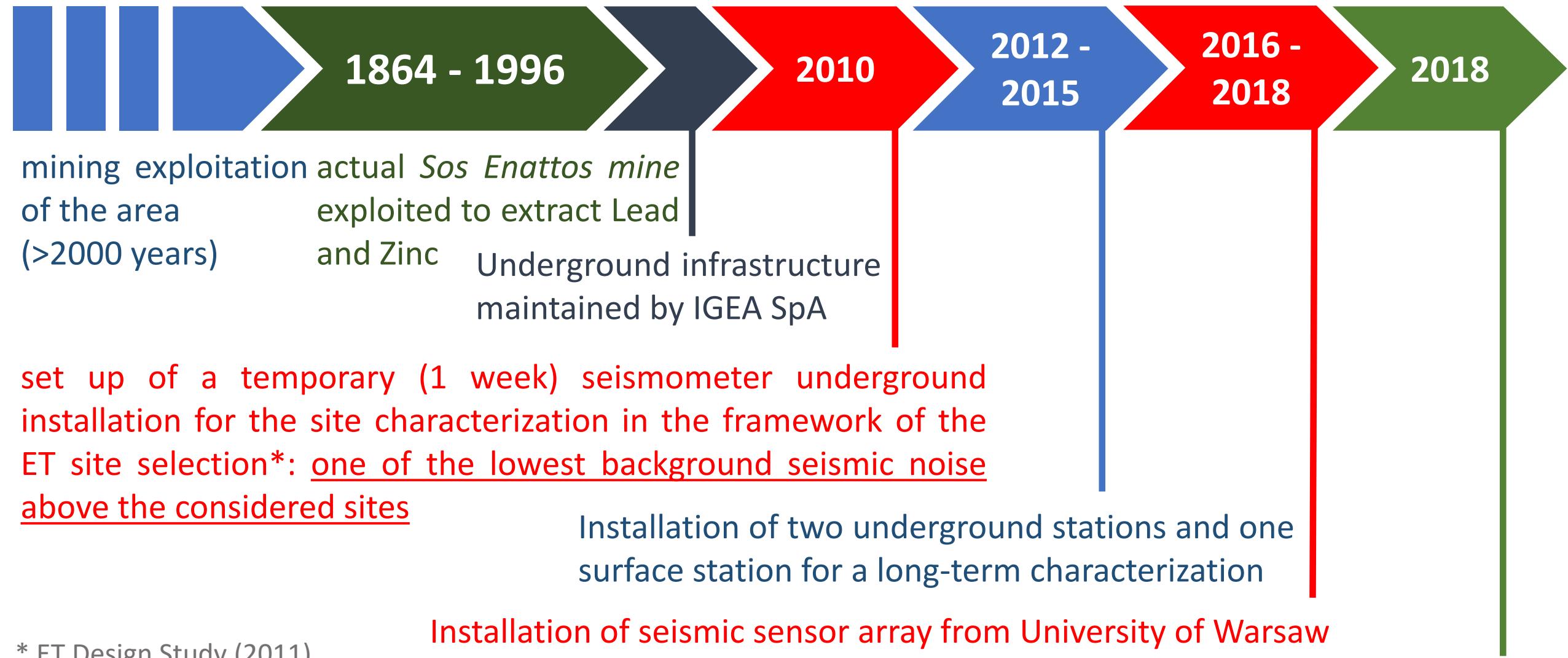
**Low population density: low *anthropic* noise ( $f > 1\text{Hz}$ )!**



# Sardinia: the Sos Enattos site



# Sos Enattos: a brief history

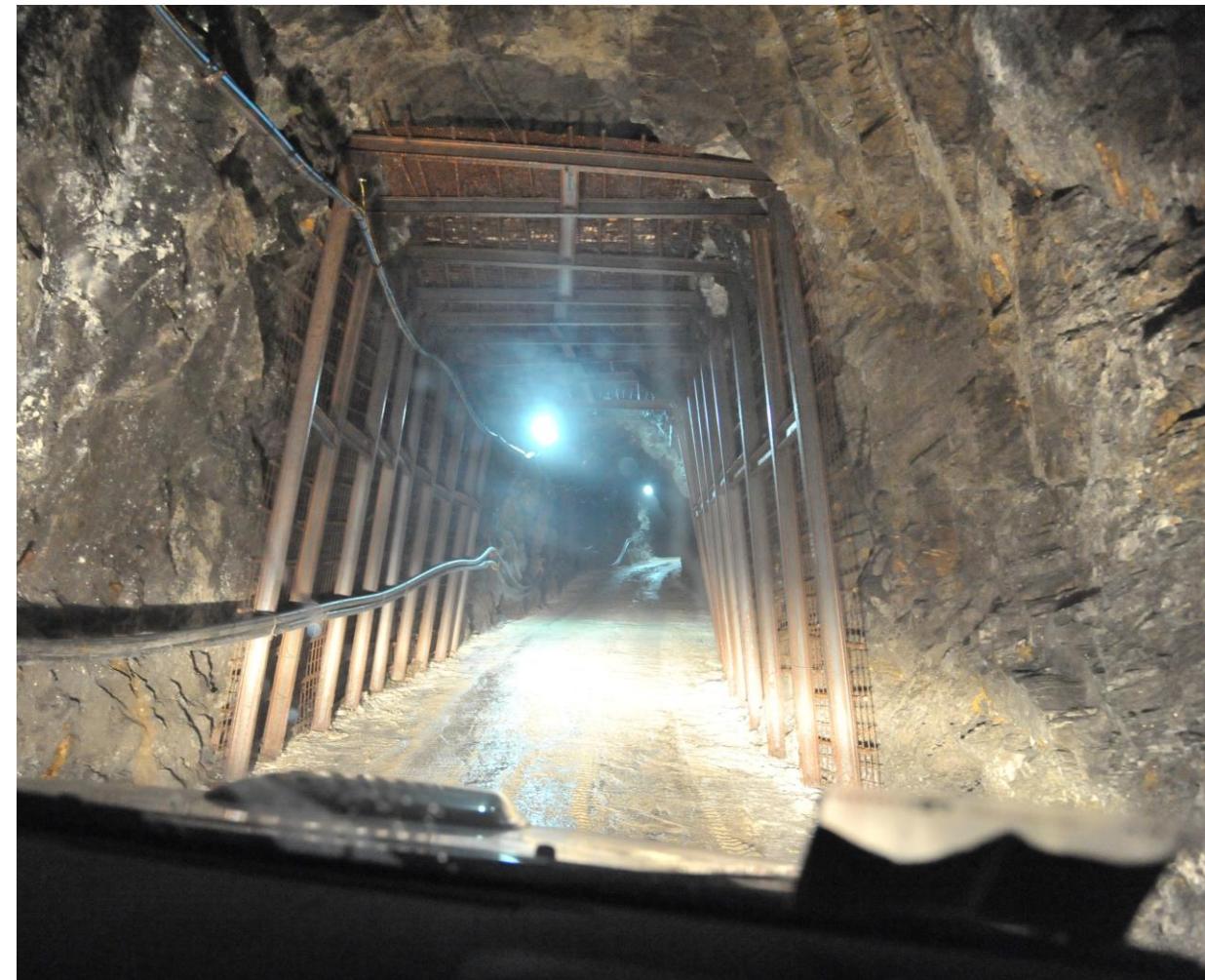
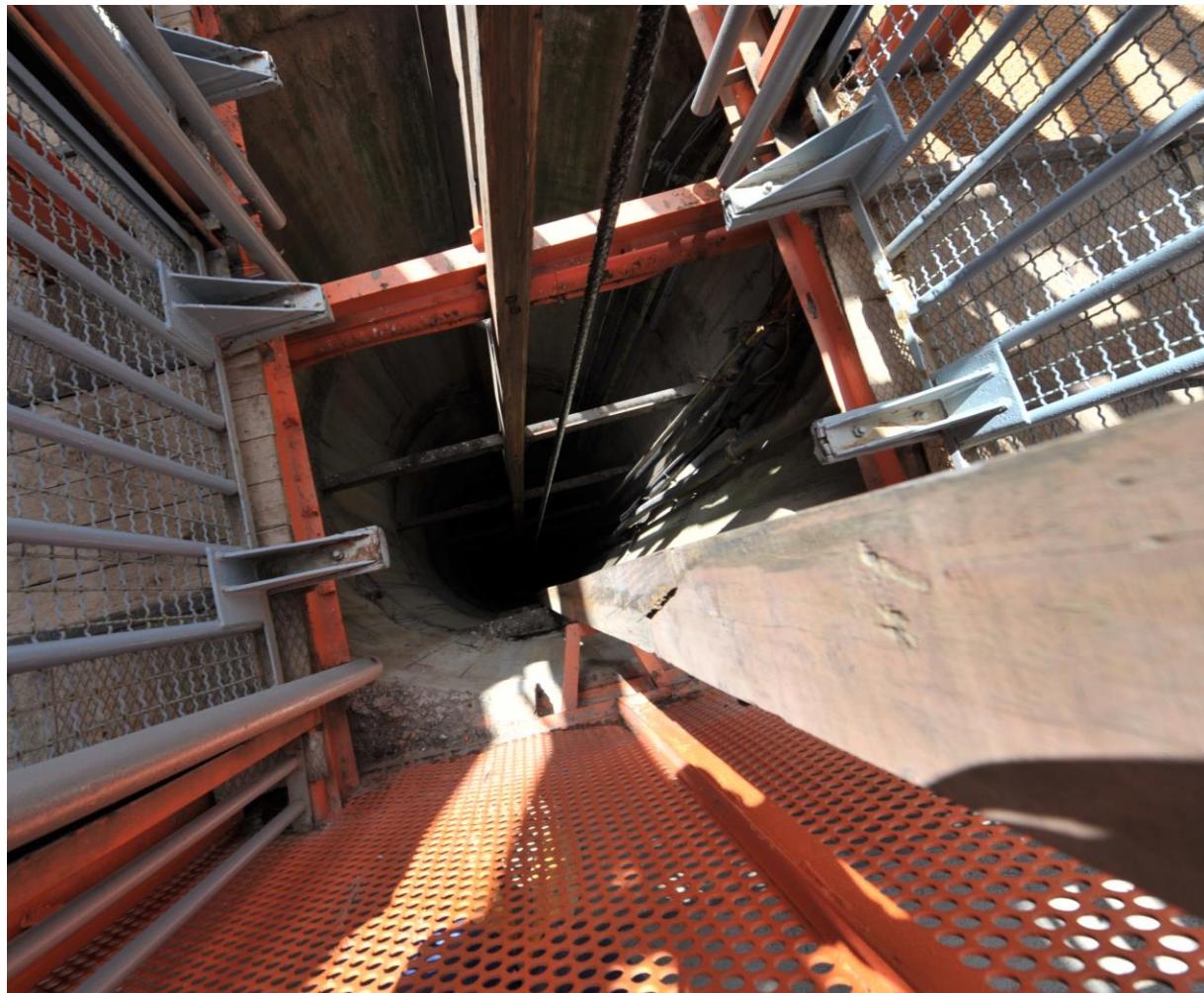


\* ET Design Study (2011),  
ET-0106C-10

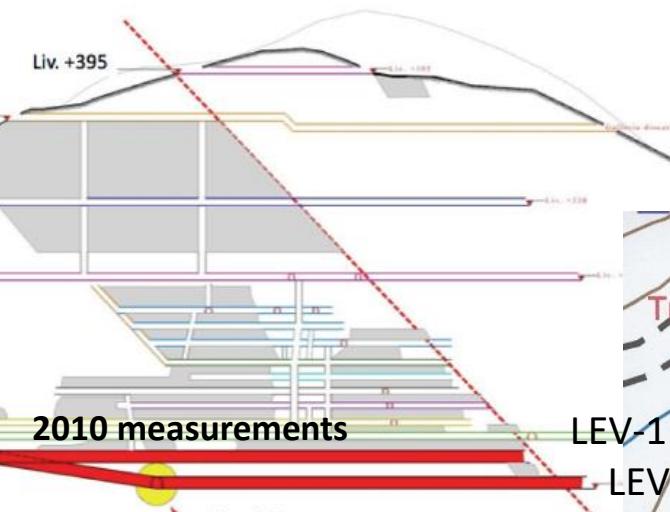
# Sos Enattos former mine



# Sos Enattos former mine

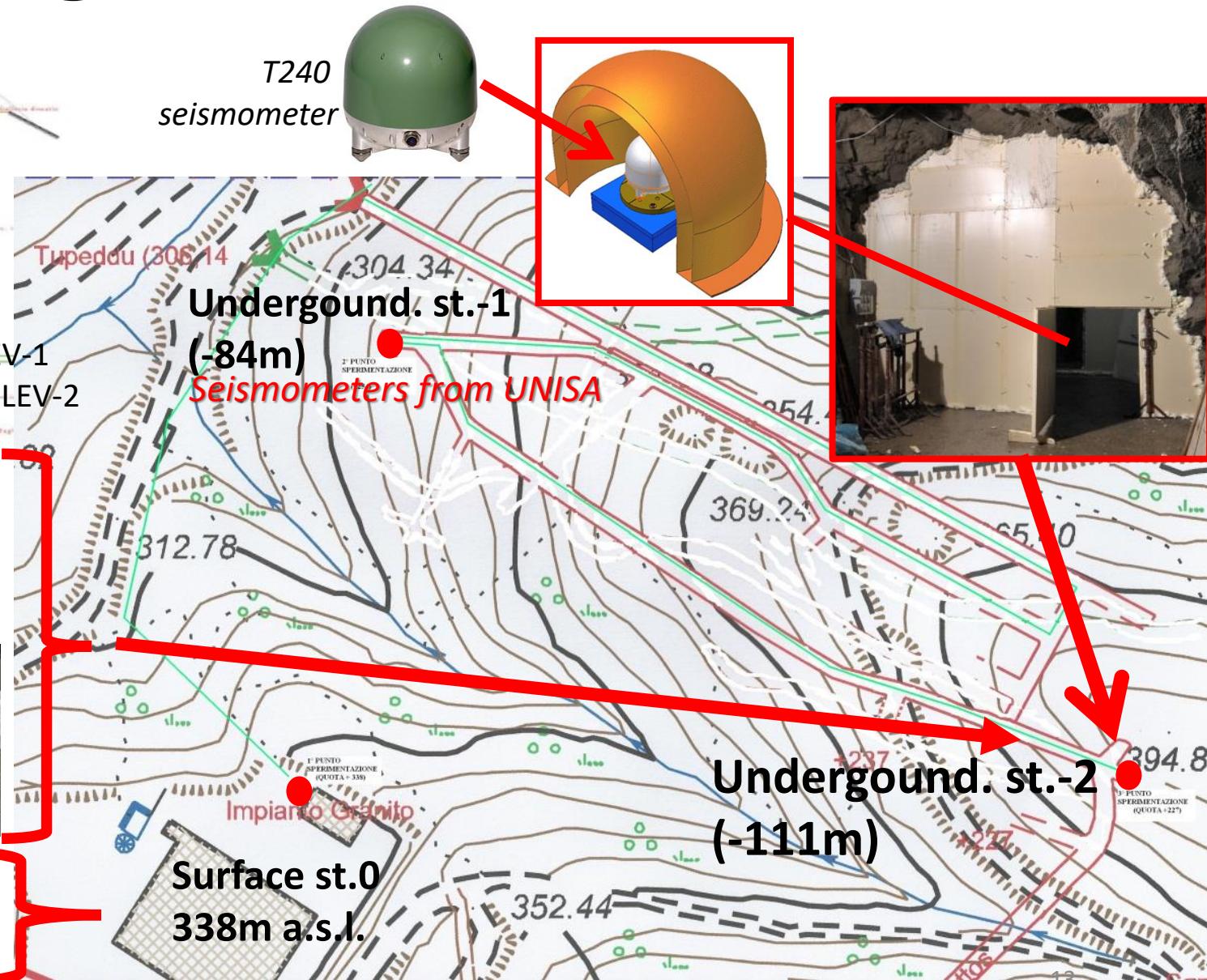


# Sos Enattos – long term characterization

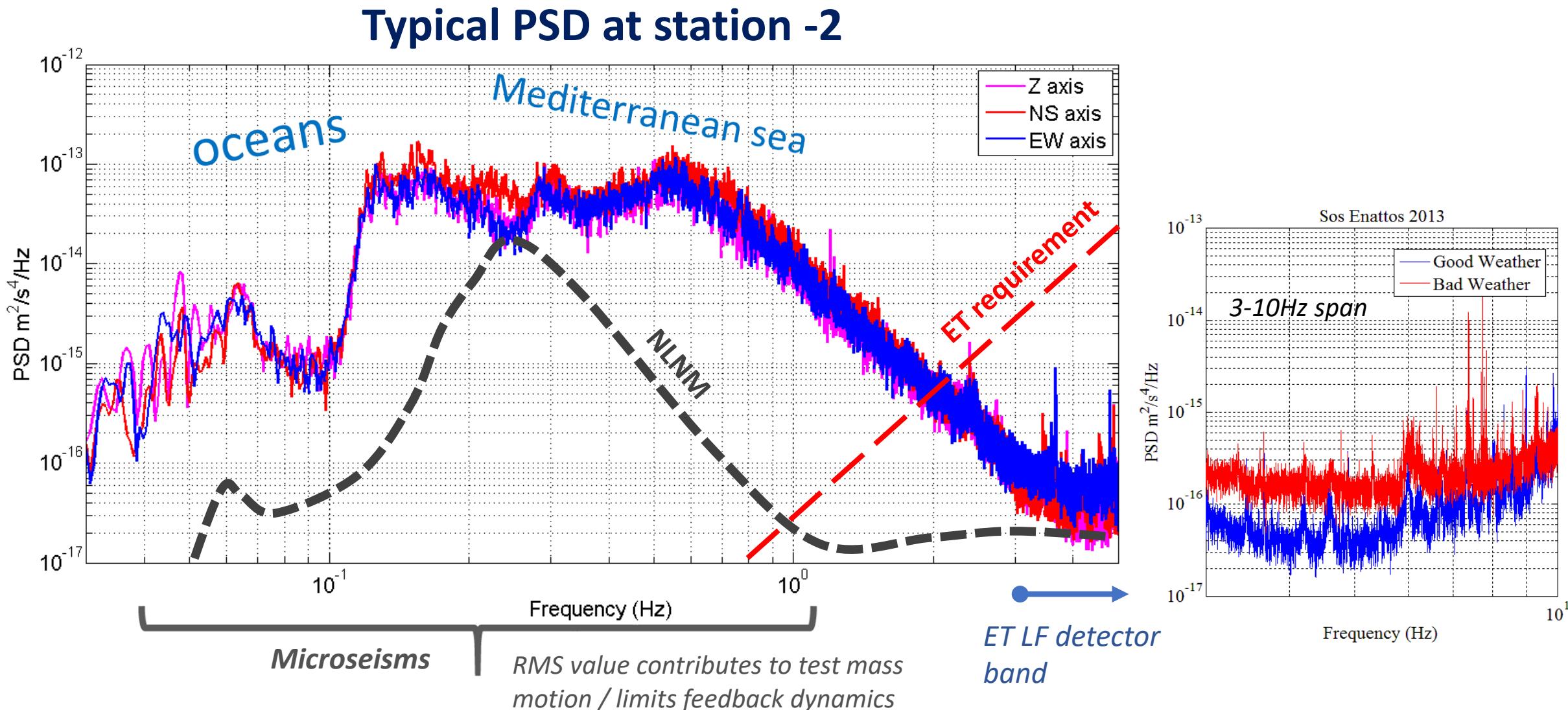


## 2012-2015 setup:

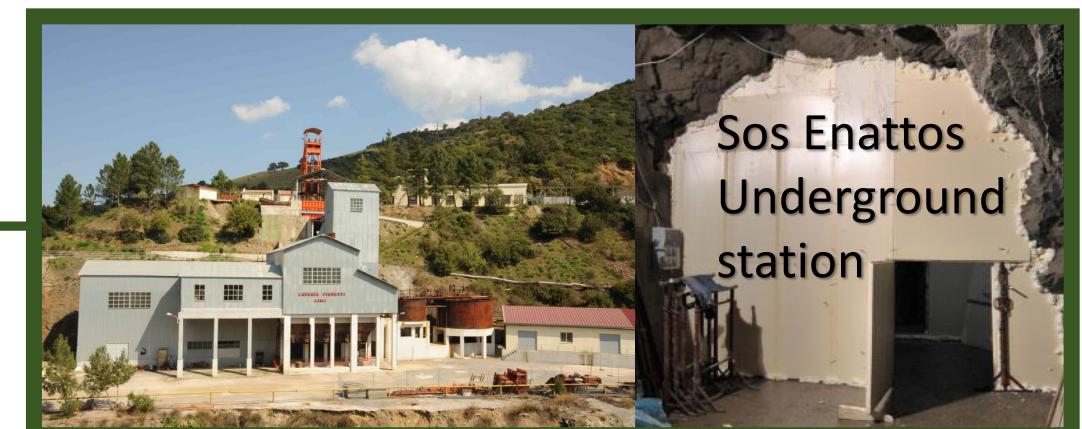
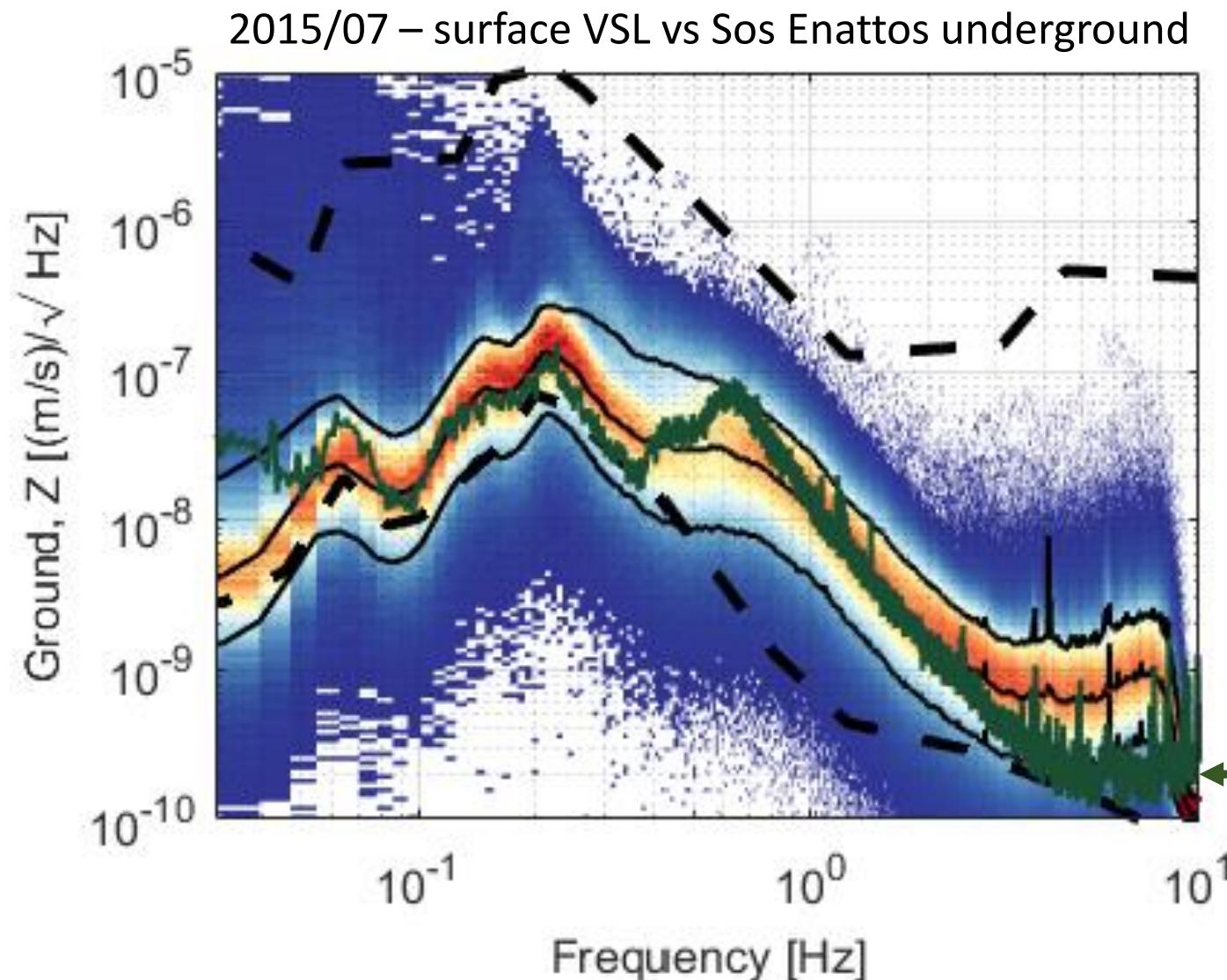
- TRILLIUM 240 - 3 axis seismometer
- TAURUS - seismograph and DAQ
- Temperature & humidity sensors (environmental and inside insulation boxes)
- DAQ computer
- Ethernet - optical fiber connection to surface (lev. 0)
- **Seismometers from UNISA**
- Davis Weather Station (temperature, humidity, barometric pressure, wind speed, rainfall)
- DAQ computer + opt/ethernet switch to underground levels



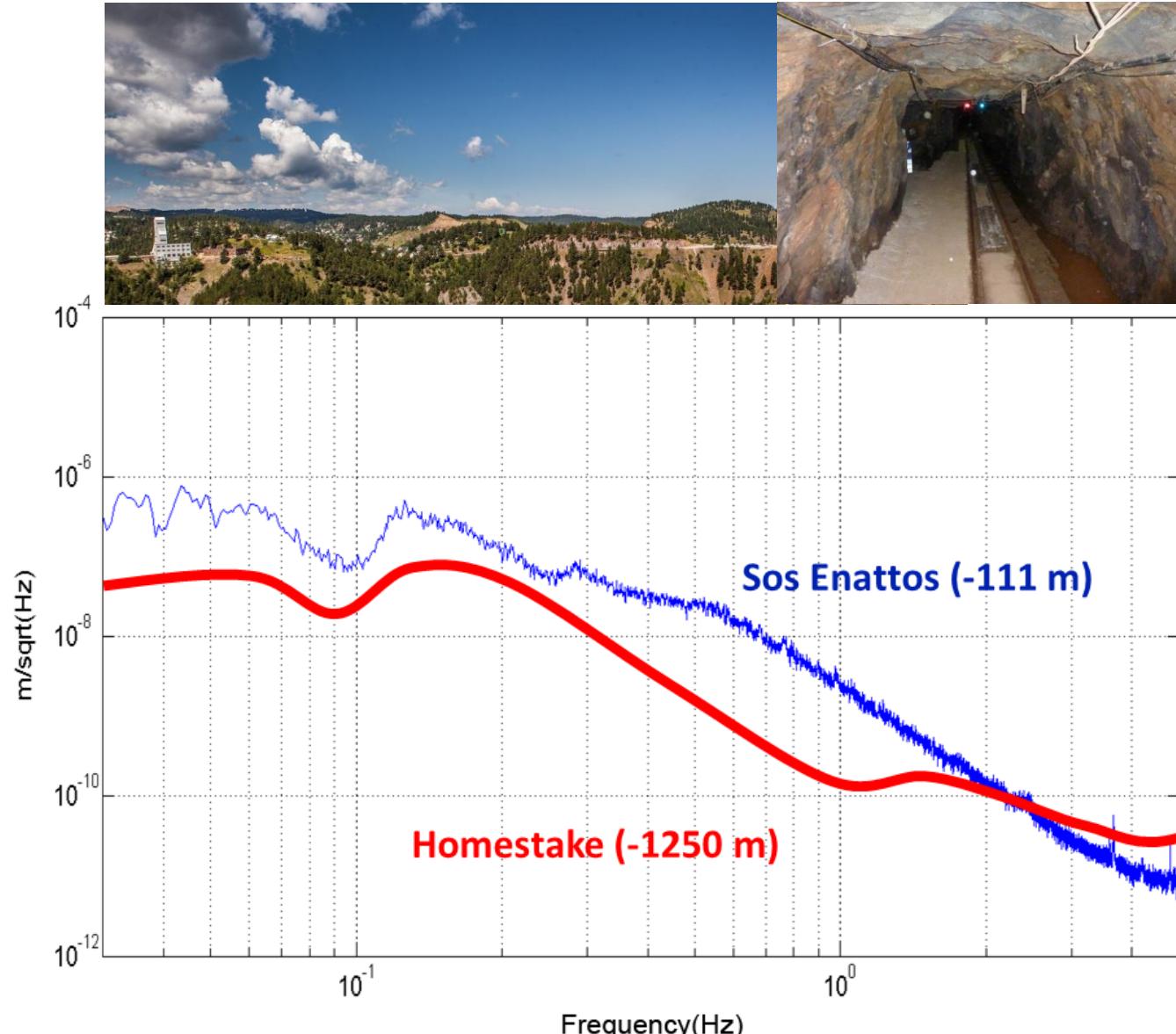
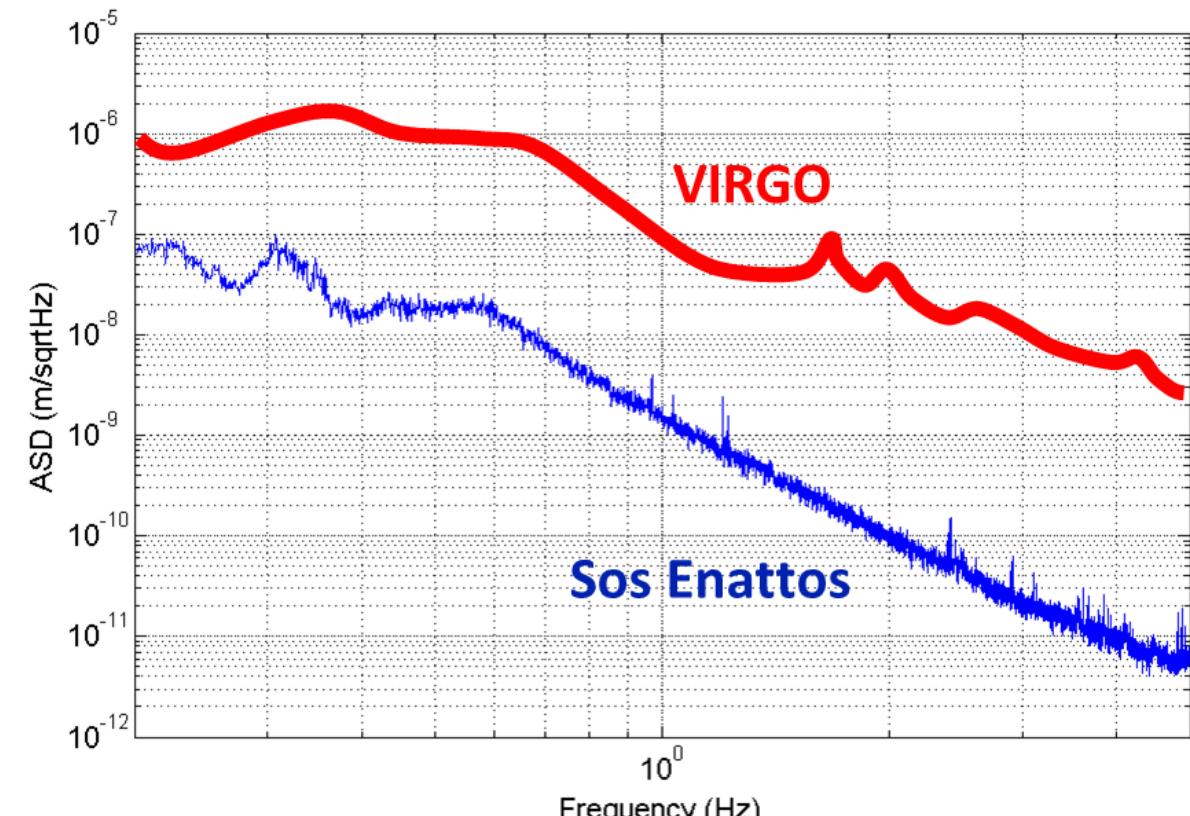
# Sos Enattos – long term characterization



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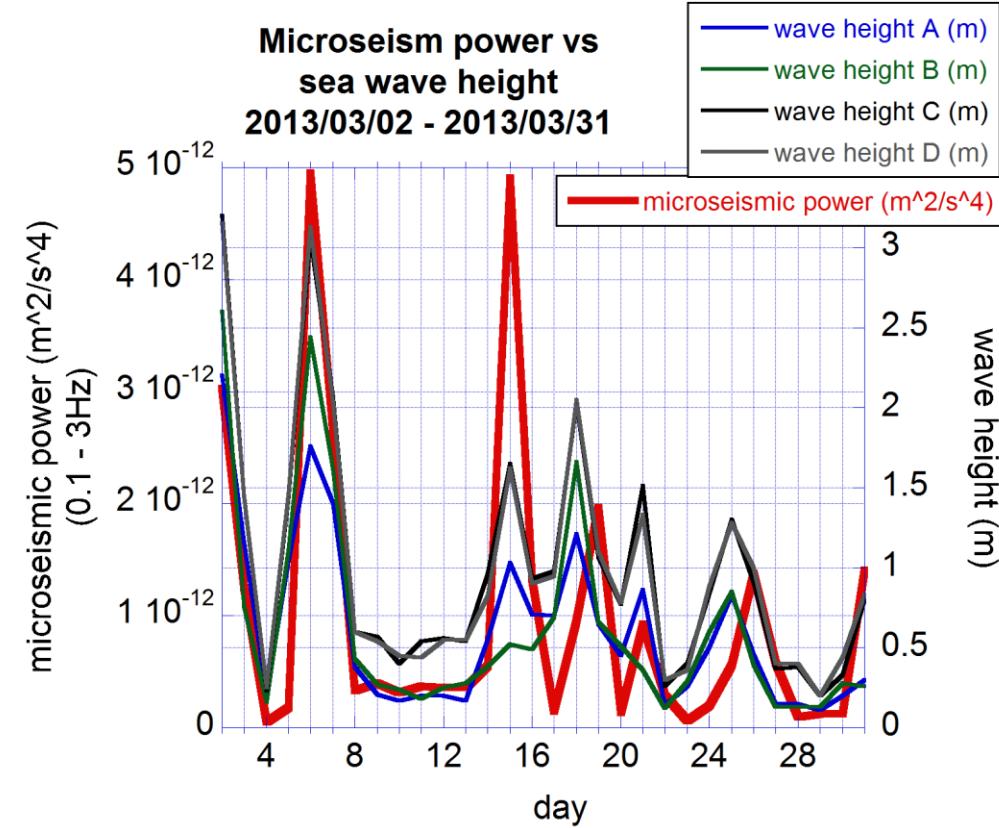
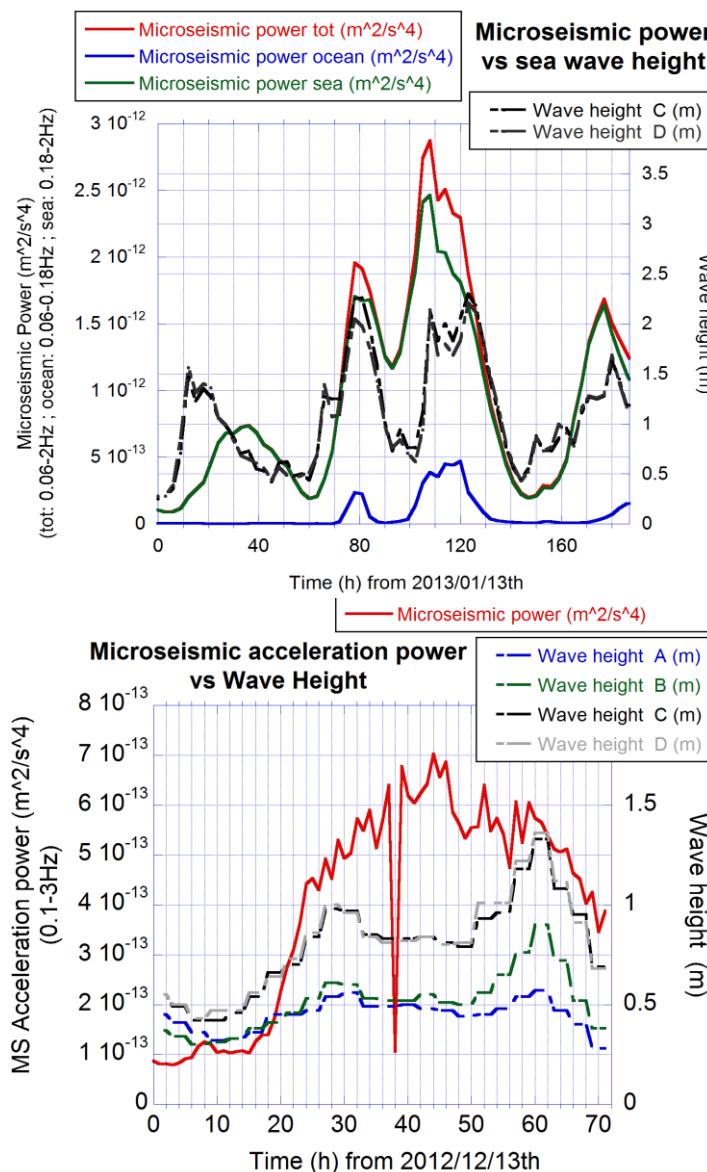
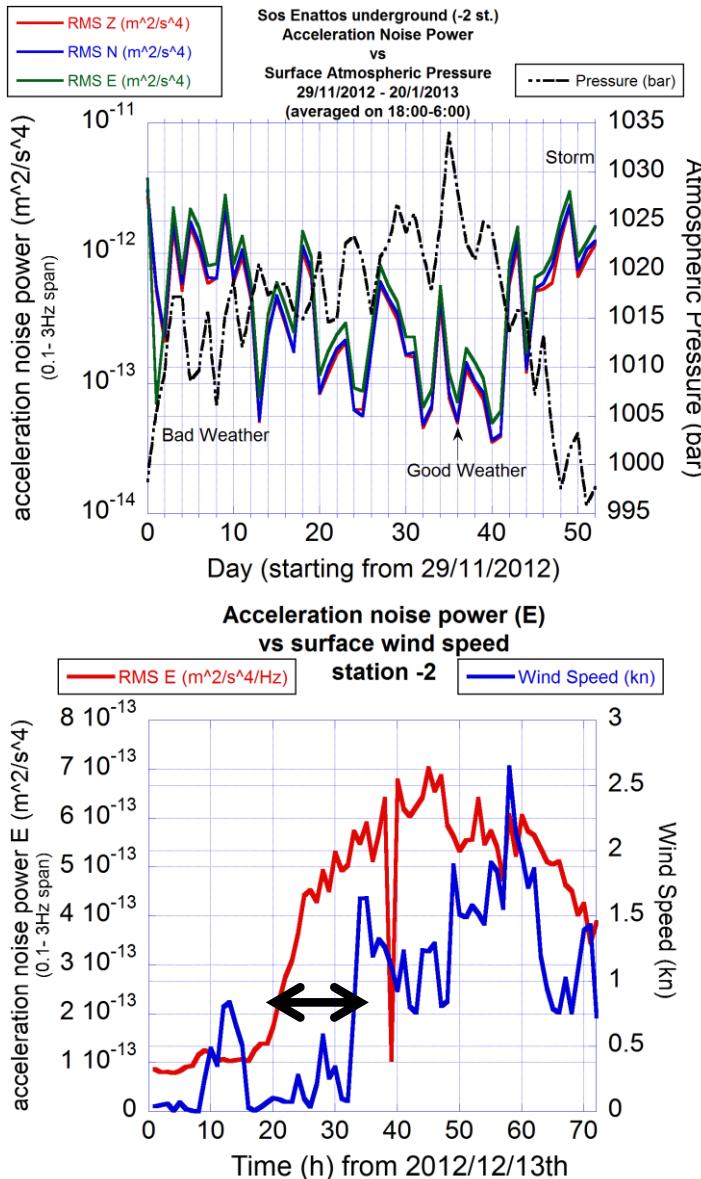
# Sos Enattos – long term characterization

Point	Coordinates (latitude and longitude)	Depth [m]	Distance [m] (from Sos Enattos)
A	40°32'60.00"N 9°48'00.00"E	< 10	31308
B	40°27'00.00"N 9°48'00.00"E	< 10	29112
C	40°32'60.00"N 9°56'60.00"E	155	43416
D	40°27'00.00"N 9°56'60.00"E	134	41840



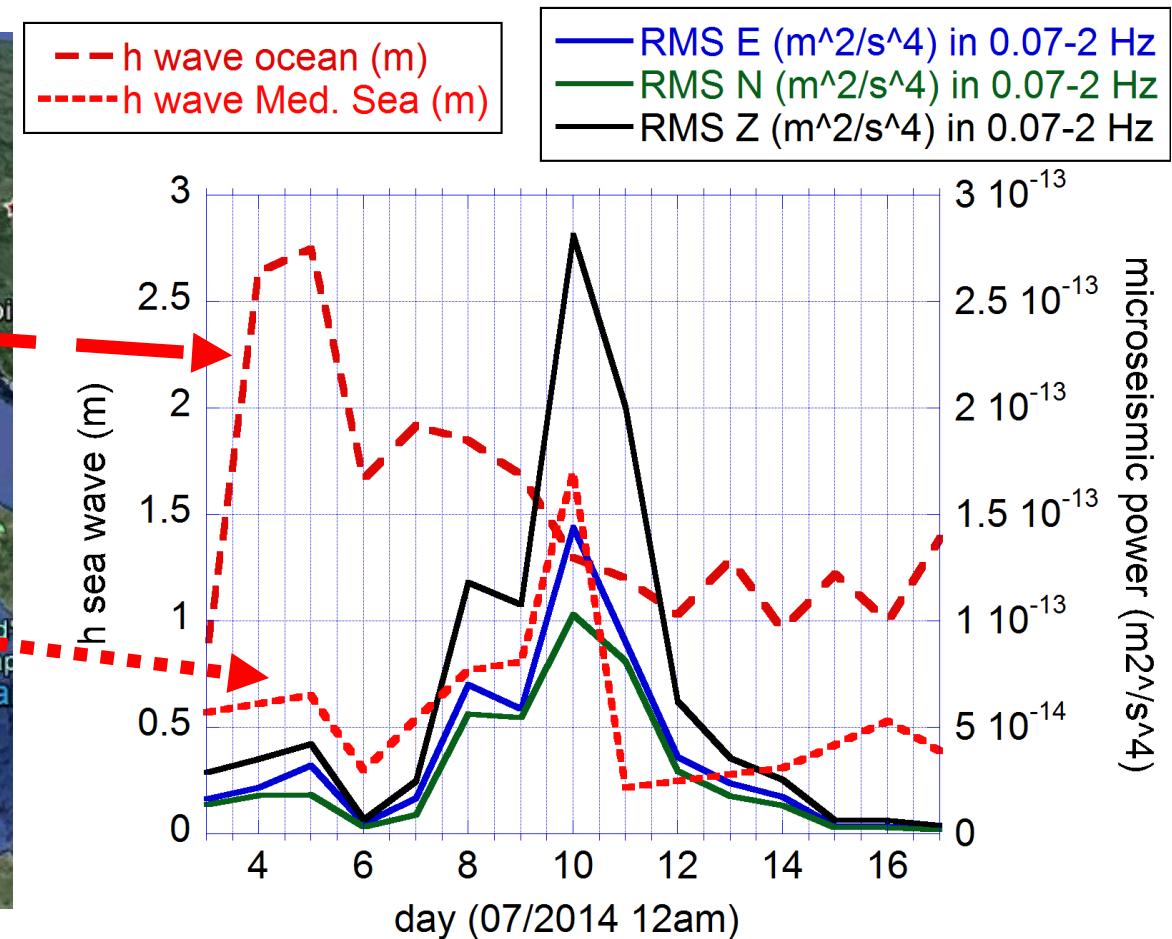
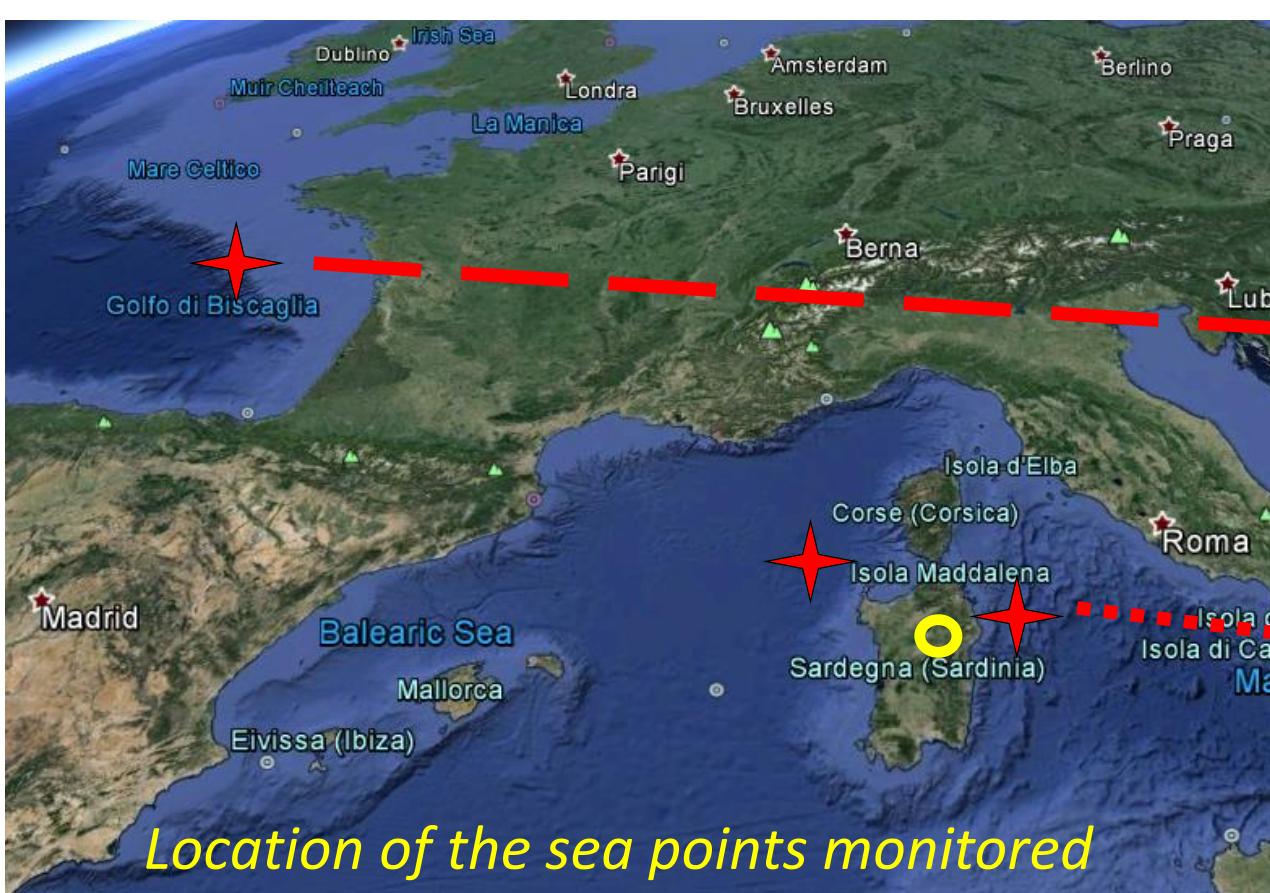
Significant height of combined wind waves and swell [m]
Mean wave direction [deg]
Mean value of the wave frequency [Hz]
Wind speed [ $ms^{-1}$ ] (10 m space resolution)
Wind direction [deg] (10 m space resolution)
Wave frequency of the highest peak in one-dimensional spectrum [Hz]
Coefficient of drag with waves
Mean sea level $u$ component of wind [ $ms^{-1}$ ]
Mean sea level $v$ component of wind [ $ms^{-1}$ ]

# Sos Enattos – long term characterization

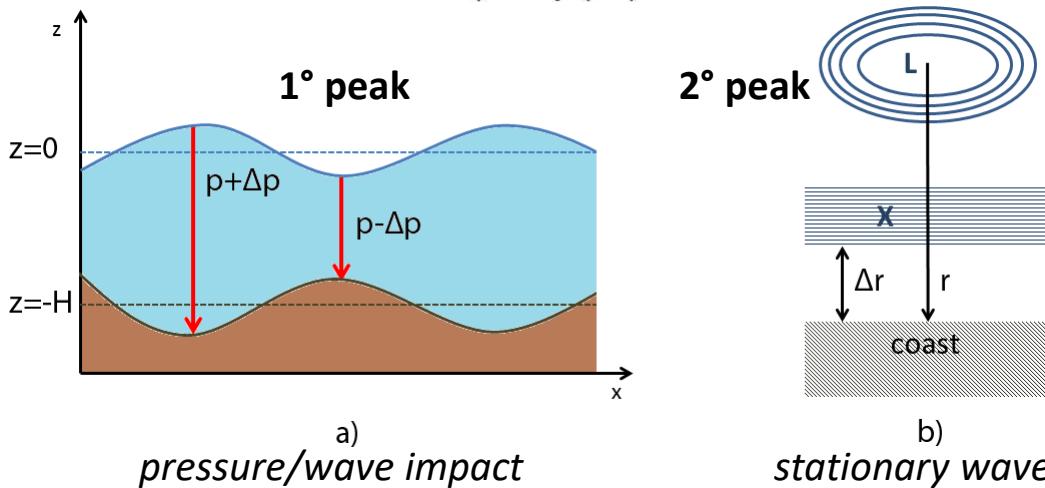
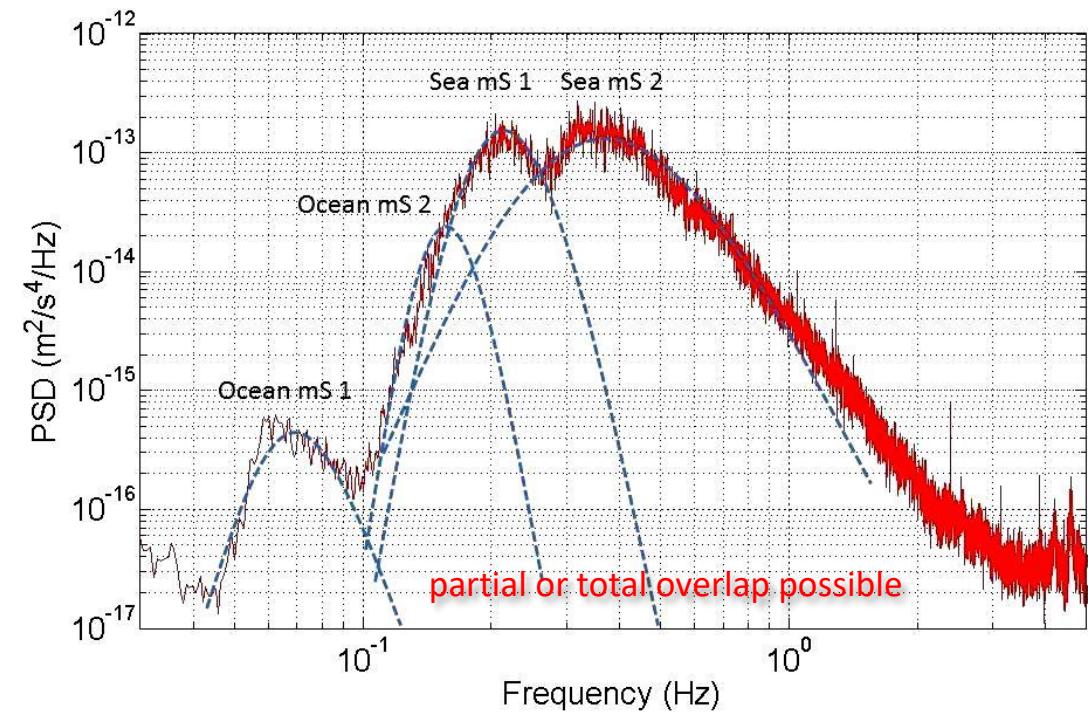
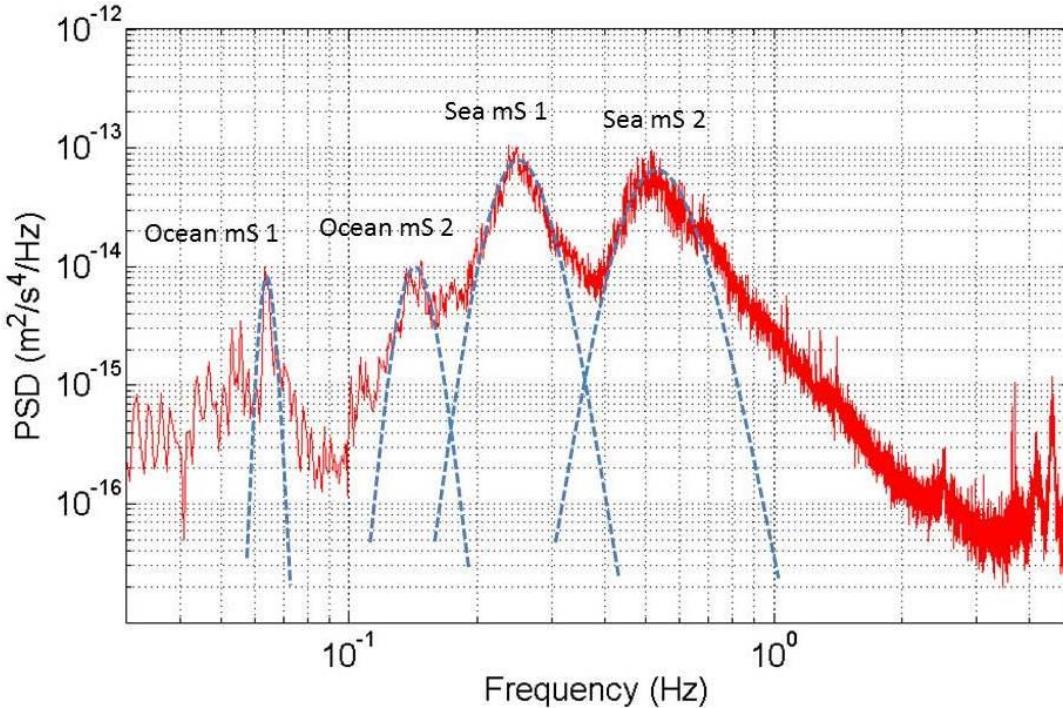


L Naticchioni, M Perciballi, F Ricci, E Coccia, V Malvezzi, F Acernese, F Barone, G Giordano, R Romano and M Punturo, 2014, *Class. Quantum Grav.* **31** (10)

# Sos Enattos – long term characterization



# Sos Enattos – long term characterization



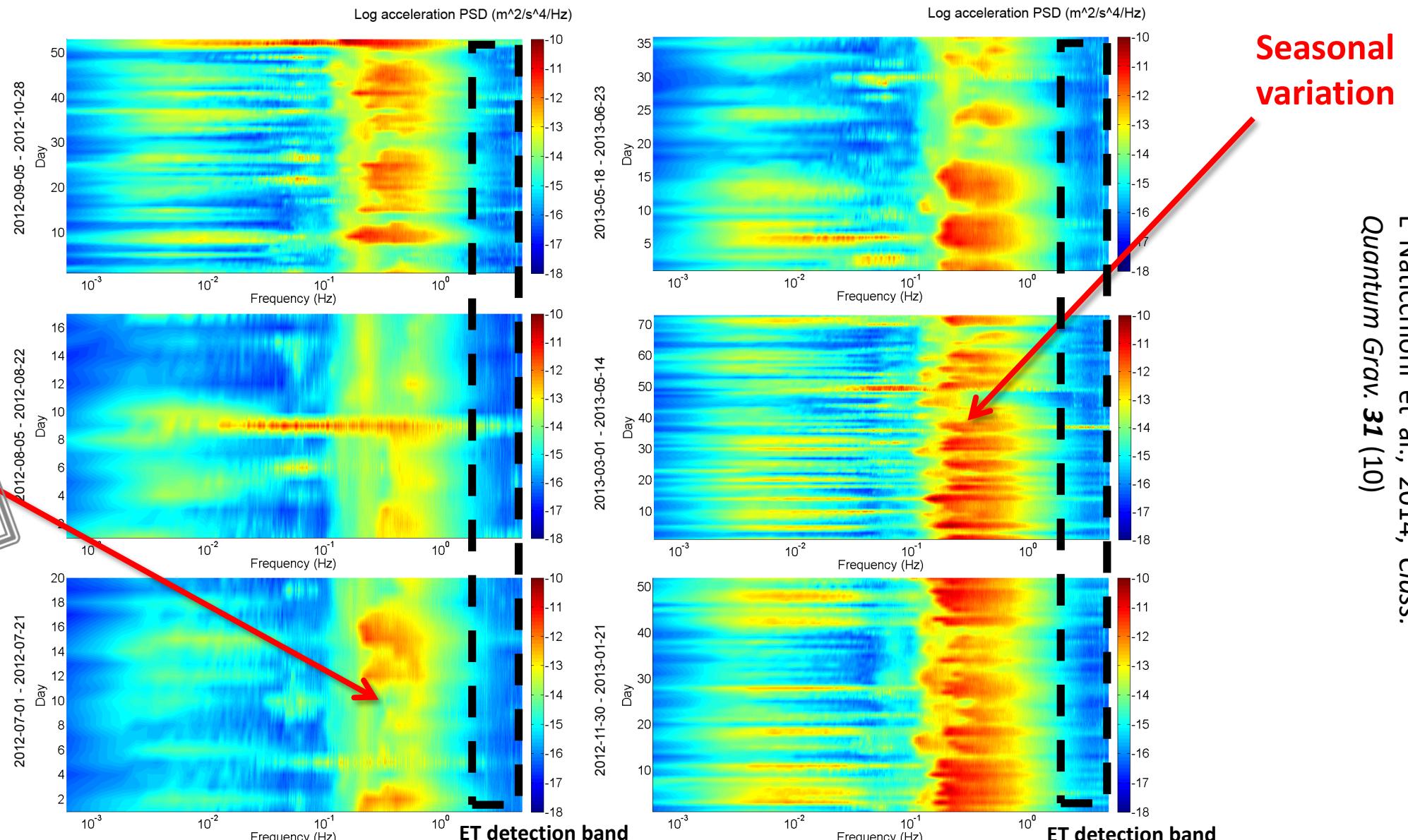
Peak	Source	Mechanism	Frequency [Hz]
Primary	Oceans	Pressure variations, wave impact on shores	$6 - 9 \times 10^{-2}$
Secondary	Oceans	standing wave	$0.12 - 0.20$
Primary	Tyrrhenian sea	Pressure variations, wave impact on shores	$0.08 - 0.23$
Secondary	Tyrrhenian sea	standing wave	$0.16 - 0.46$
Tertiary	Mediterranean (?)	standing wave or local resonance	$0.27 - 0.63$

# Sos Enattos – long term characterization

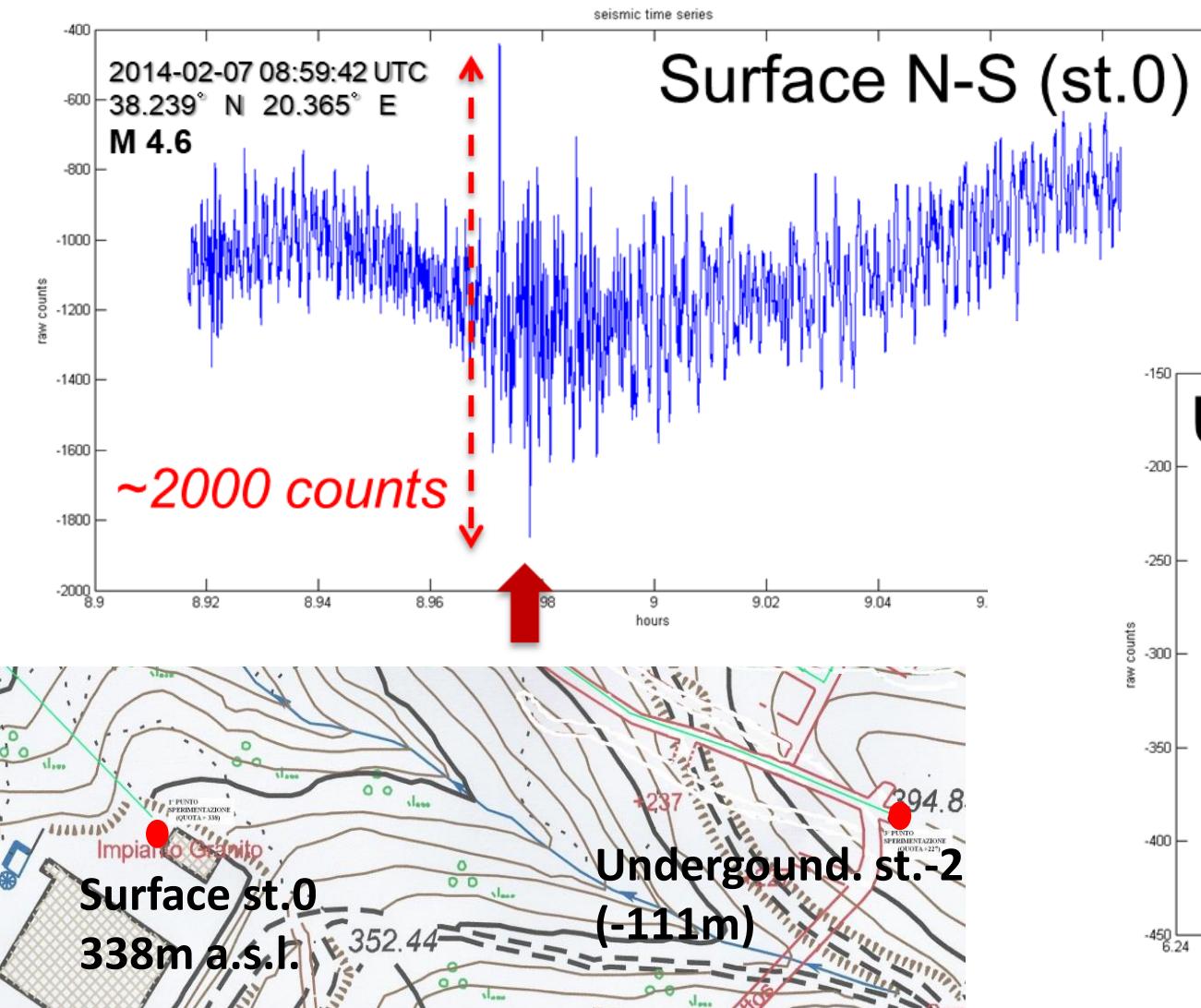
1 year data

Microseismic  
Peak  $< 10^{-10} \text{ m}^2 \text{s}^4 \text{Hz}^{-1}$

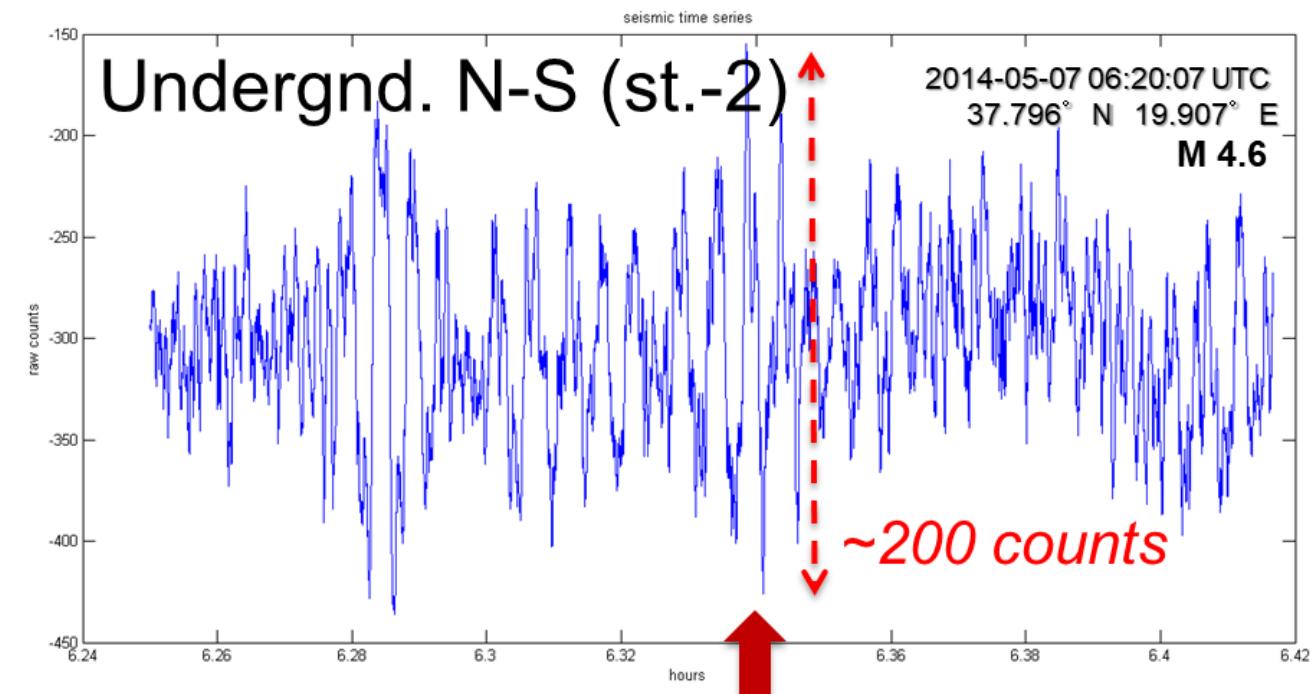
compliant with the  
ET-LF requirement



# Sos Enattos – long term characterization



Earthquake:  
Surface vs Underground



# SAR-GRAV

A pilot Underground Laboratory that will host experiments requiring a low seismic environment, allowing *in-situ* R&D for 3<sup>rd</sup> generation GW detectors.



**Collaboration of Regione Sardegna, IGEA SpA, University of Sassari, INFN and INGV**

# SAR-GRAV

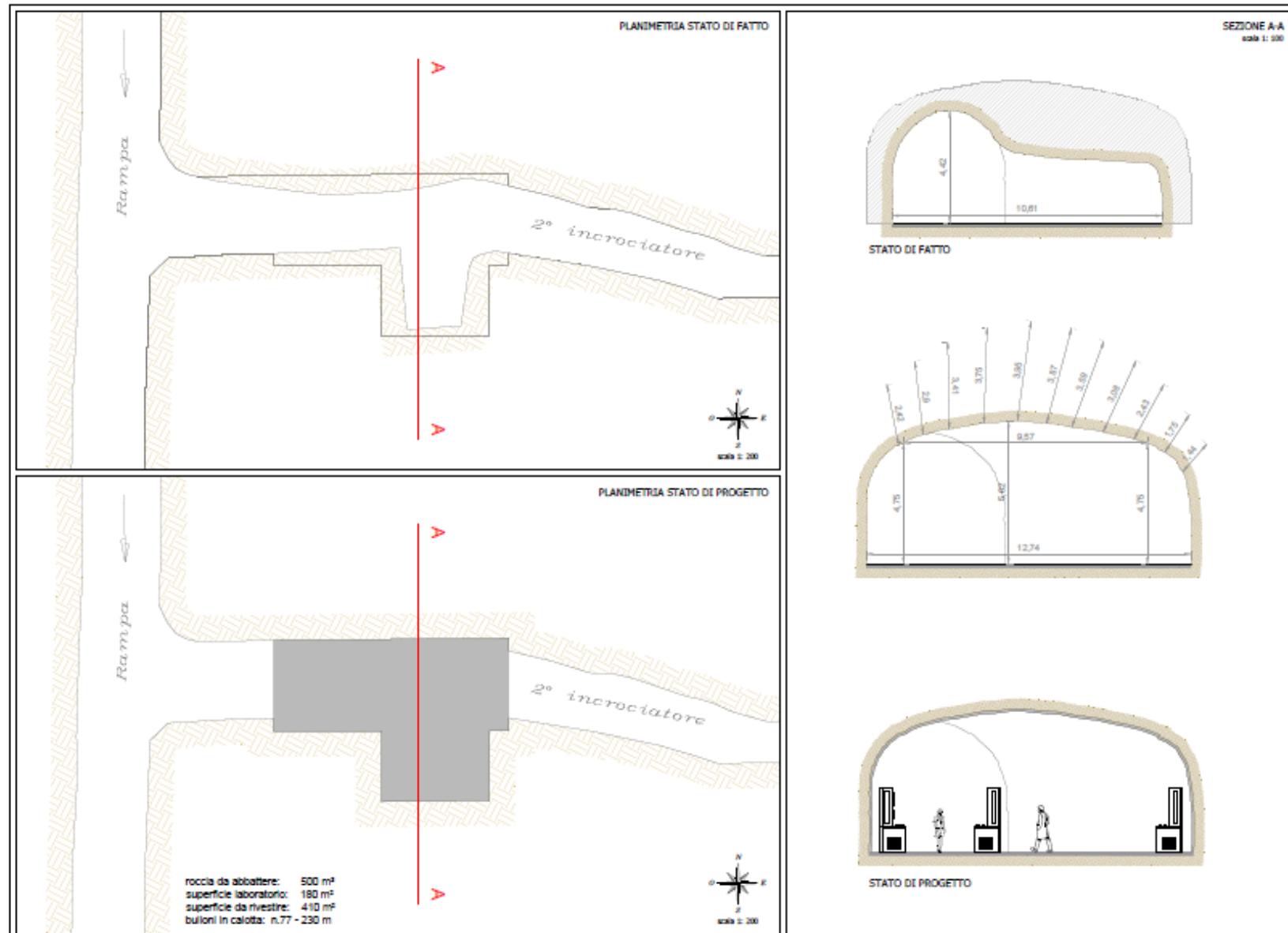
New underground facility:

Surface: 120 m<sup>2</sup>

Height: 4.75 m

Depth: 110 m

*Concrete base anchored to  
the bedrock*

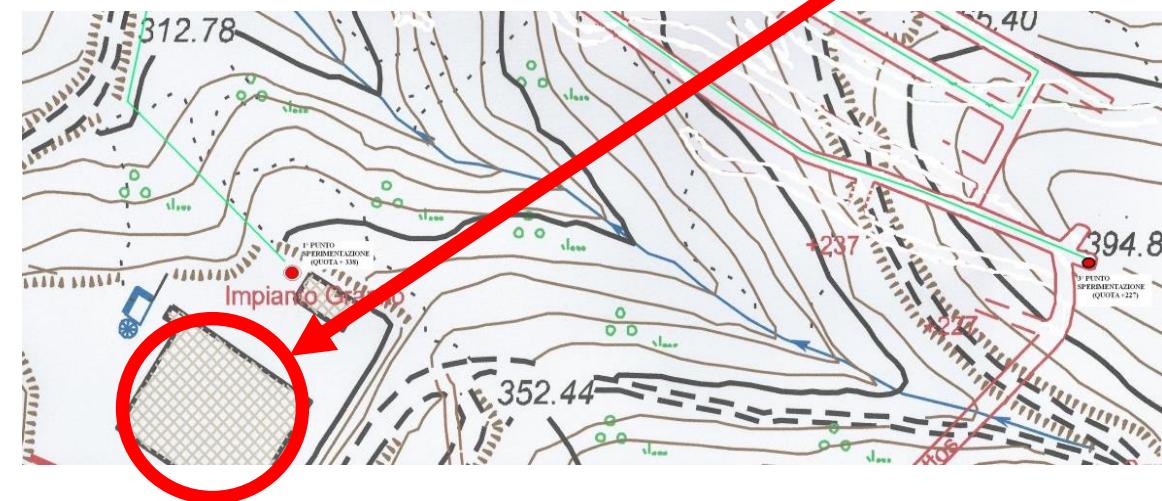


# SAR-GRAV

## Surface building:

Surface: 200 m<sup>2</sup>

- *Control room*
- *Offices*
- *Services*
- *Electronic and mechanical workshops*



Area for the Surface Lab

# Archimedes @ SAR-GRAV

**Archimedes**, funded by INFN-CSN2, will be one of the first experiments hosted in the new underground laboratory of SAR-GRAV.

It will study the **interaction** between **vacuum fluctuations** (Casimir effect) and **gravity**

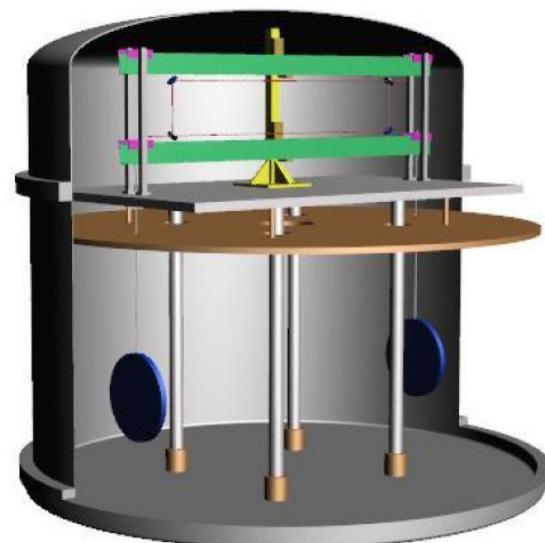
- INFN Napoli – Univ. Federico II
- INFN Roma1 – Univ. La Sapienza Roma
- INO-CNR Napoli
- Université de Aix-Marseille, Centre de Physique Théorique de Luminy
- Institut Universitaire de France



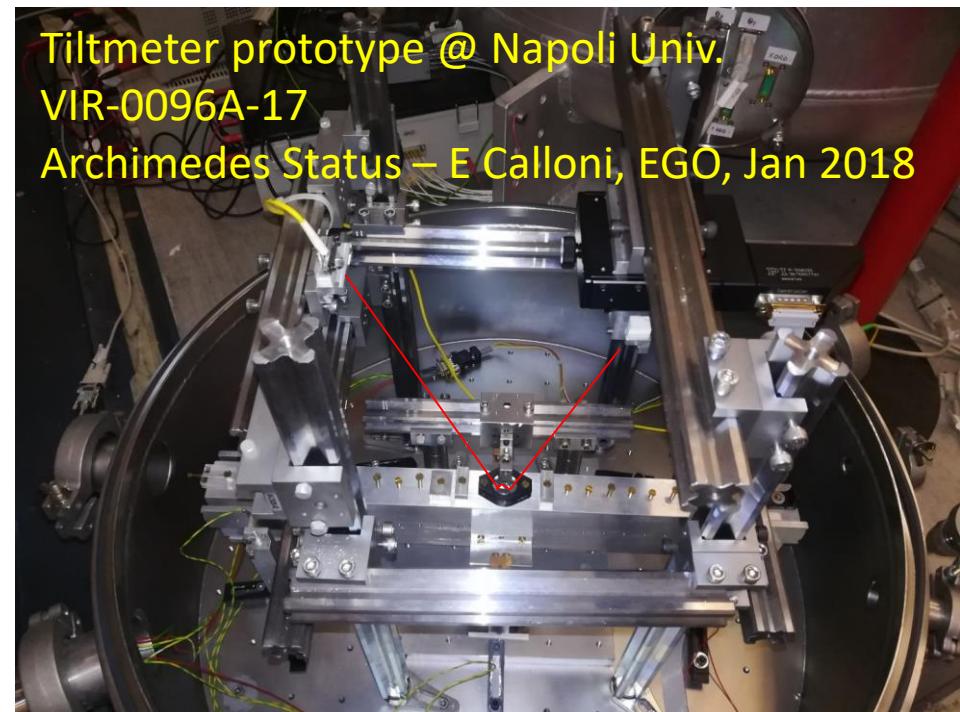
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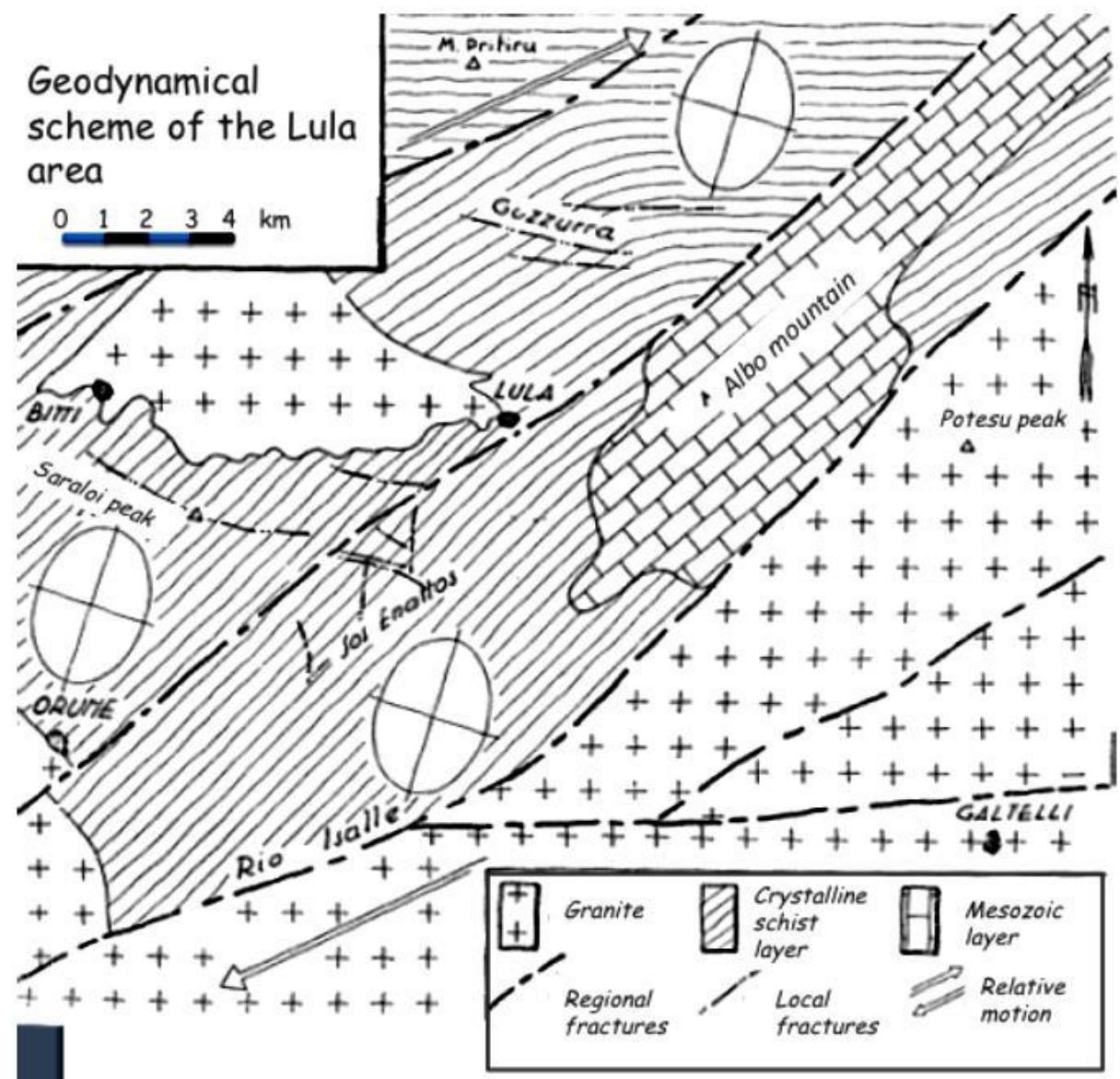
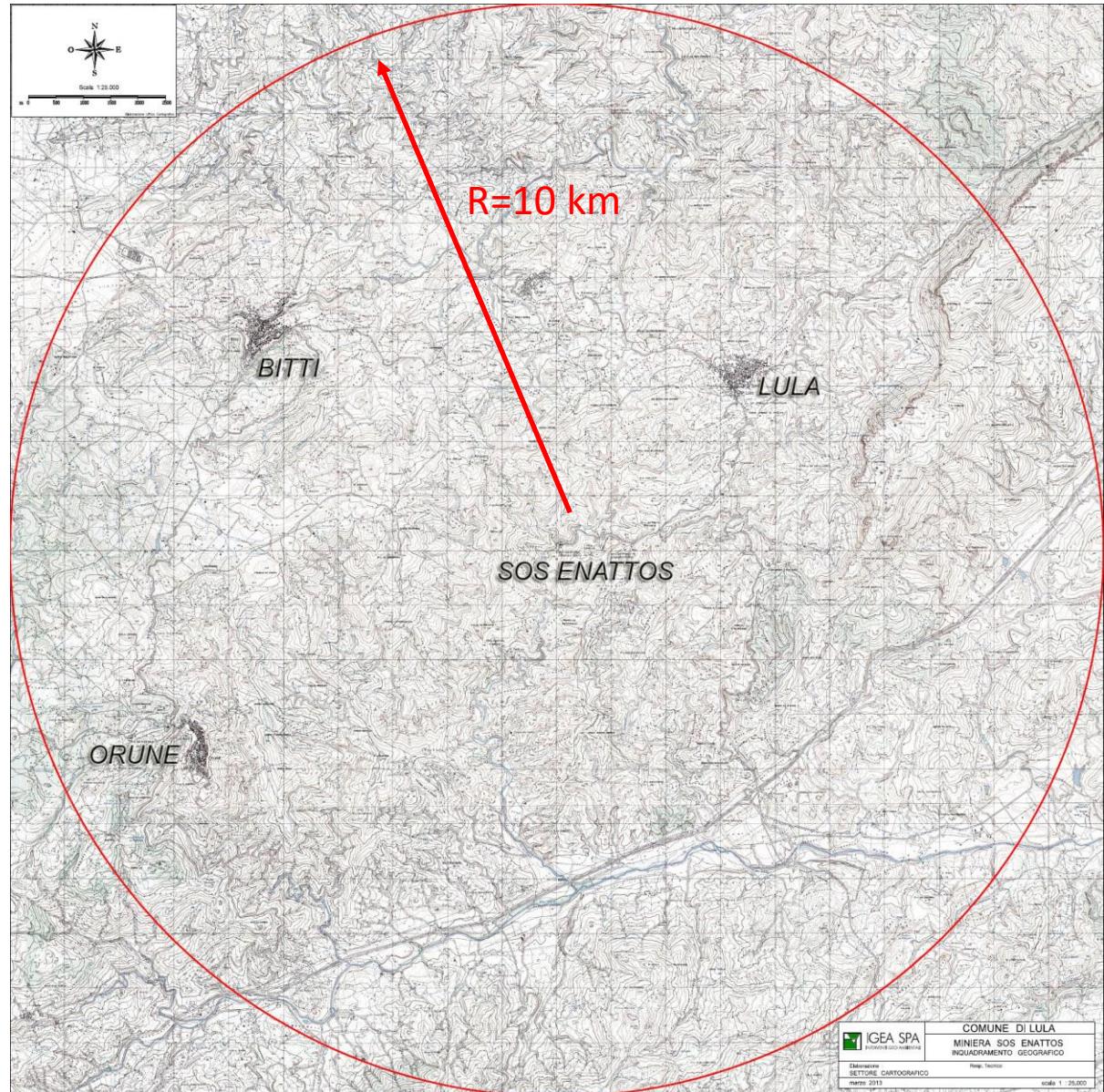
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→M. De Laurentis' talk!

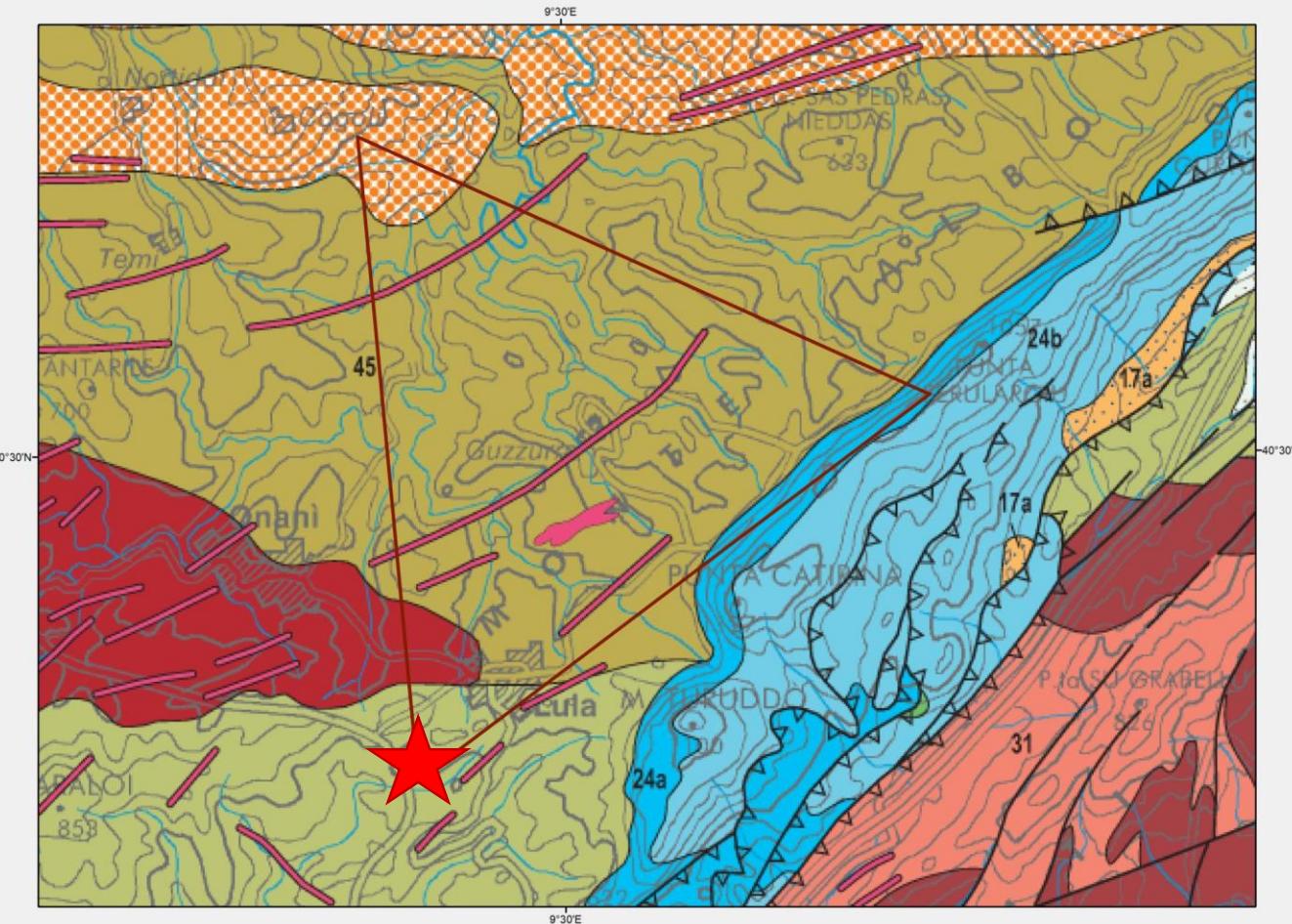
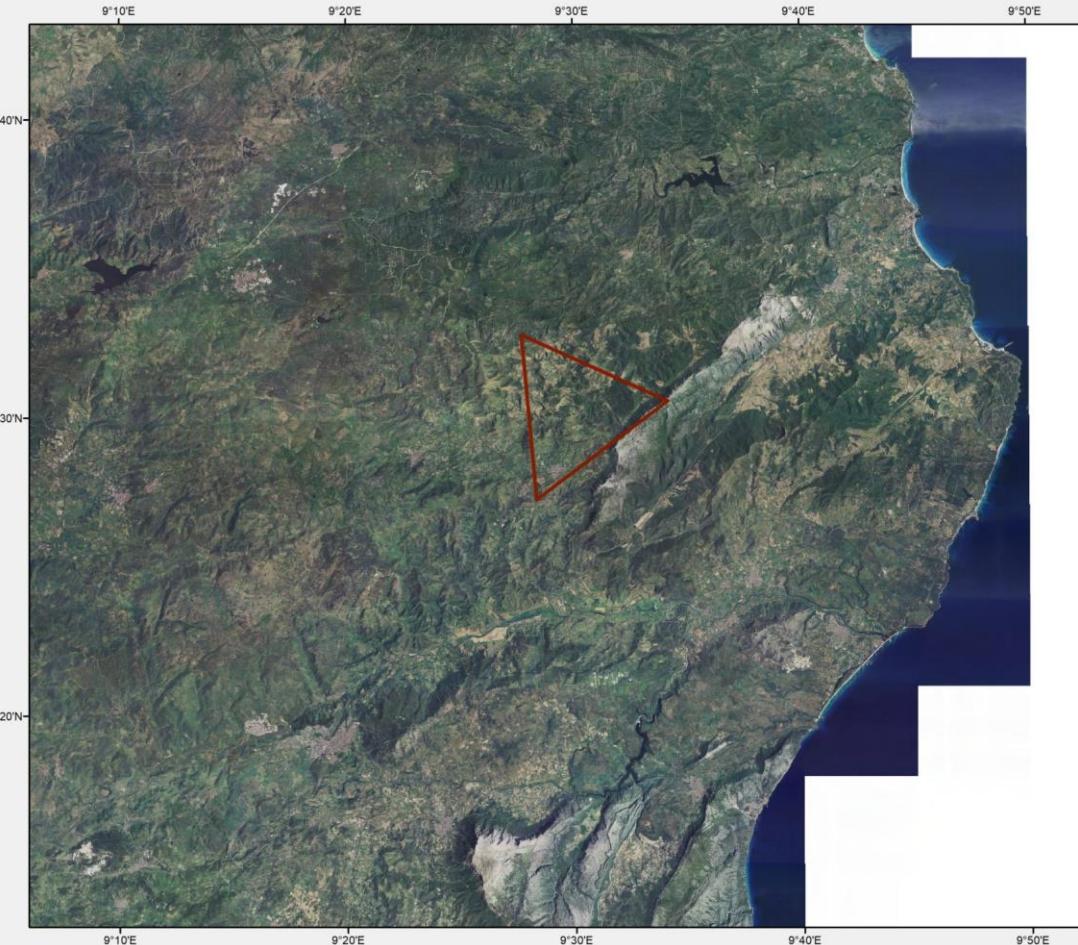


# SAR-GRAV: a first module for ET



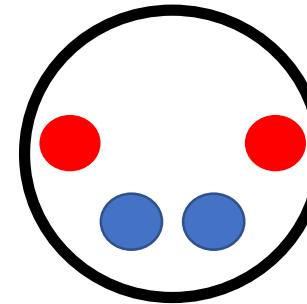
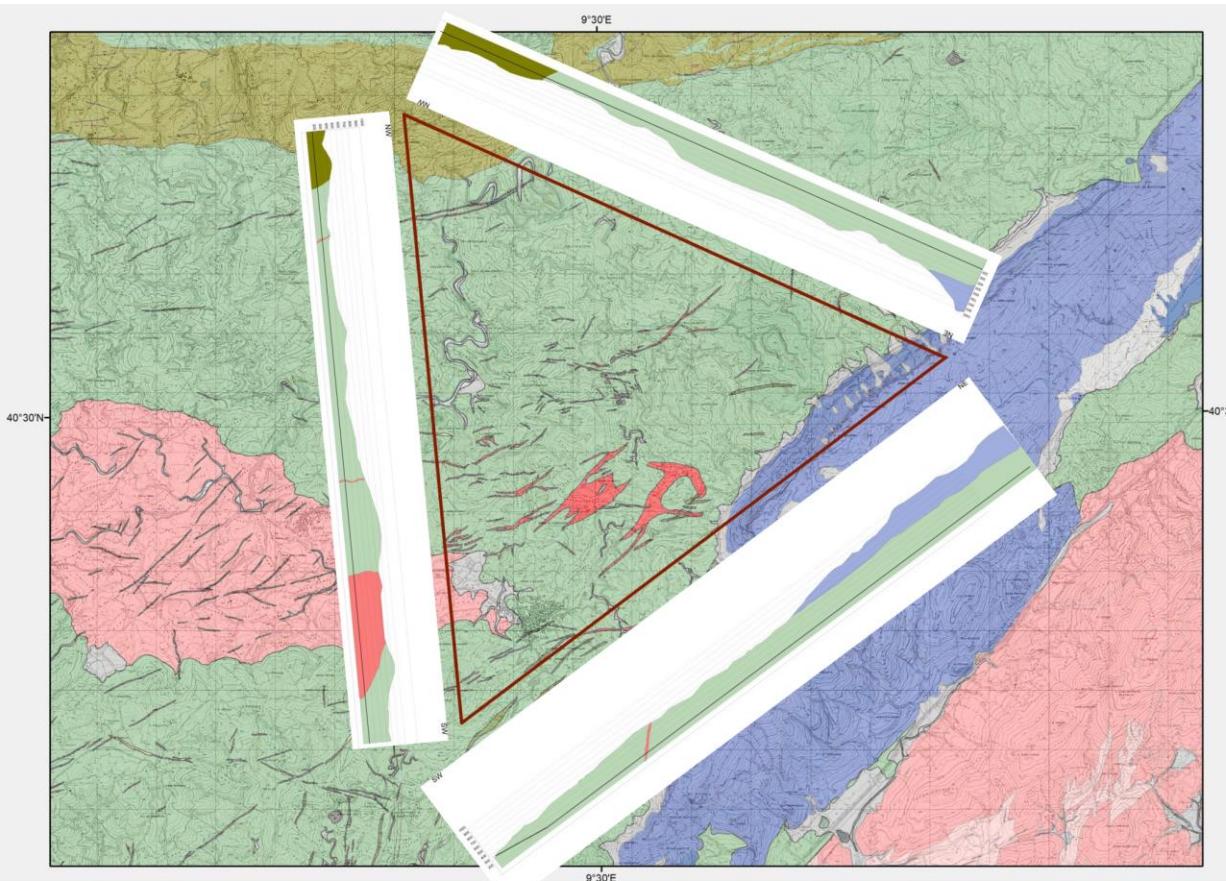
# SAR-GRAV: a first module for ET

- Underground infrastructures of Sos Enattos can be exploited as a first module for ET: first vertex station
- Xilophone orientation must be chosen according to local geological features and topography

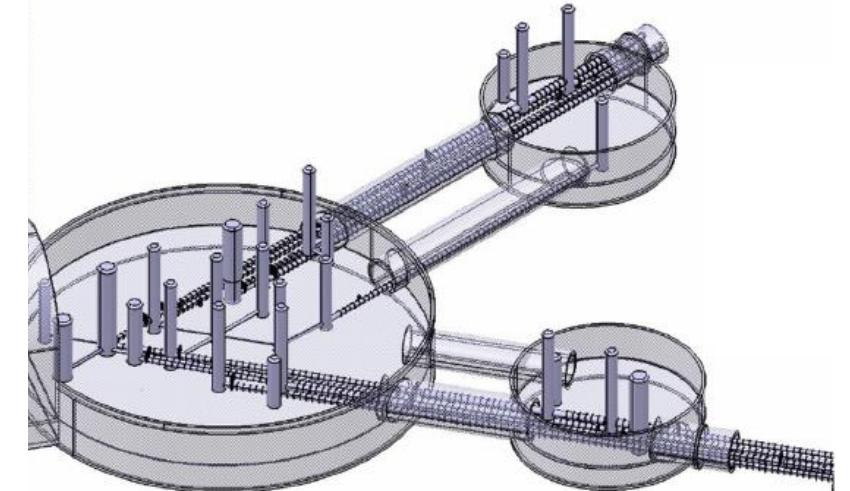


# SAR-GRAV: a first module for ET

- Underground infrastructures of Sos Enattos can be exploited as a first module for ET: first vertex station
- Xilophone orientation must be chosen according to local geological features and topography



- Reasonable tunnel diameter: 7 to 10m
- Main caves size and shape should be optimized



# SAR-GRAV: a first module for ET

More details in the next ET symposium!



*9<sup>th</sup> Einstein Telescope Symposium, 19-20 April 2018  
@ European Gravitational Observatory (EGO)*

# Conclusions

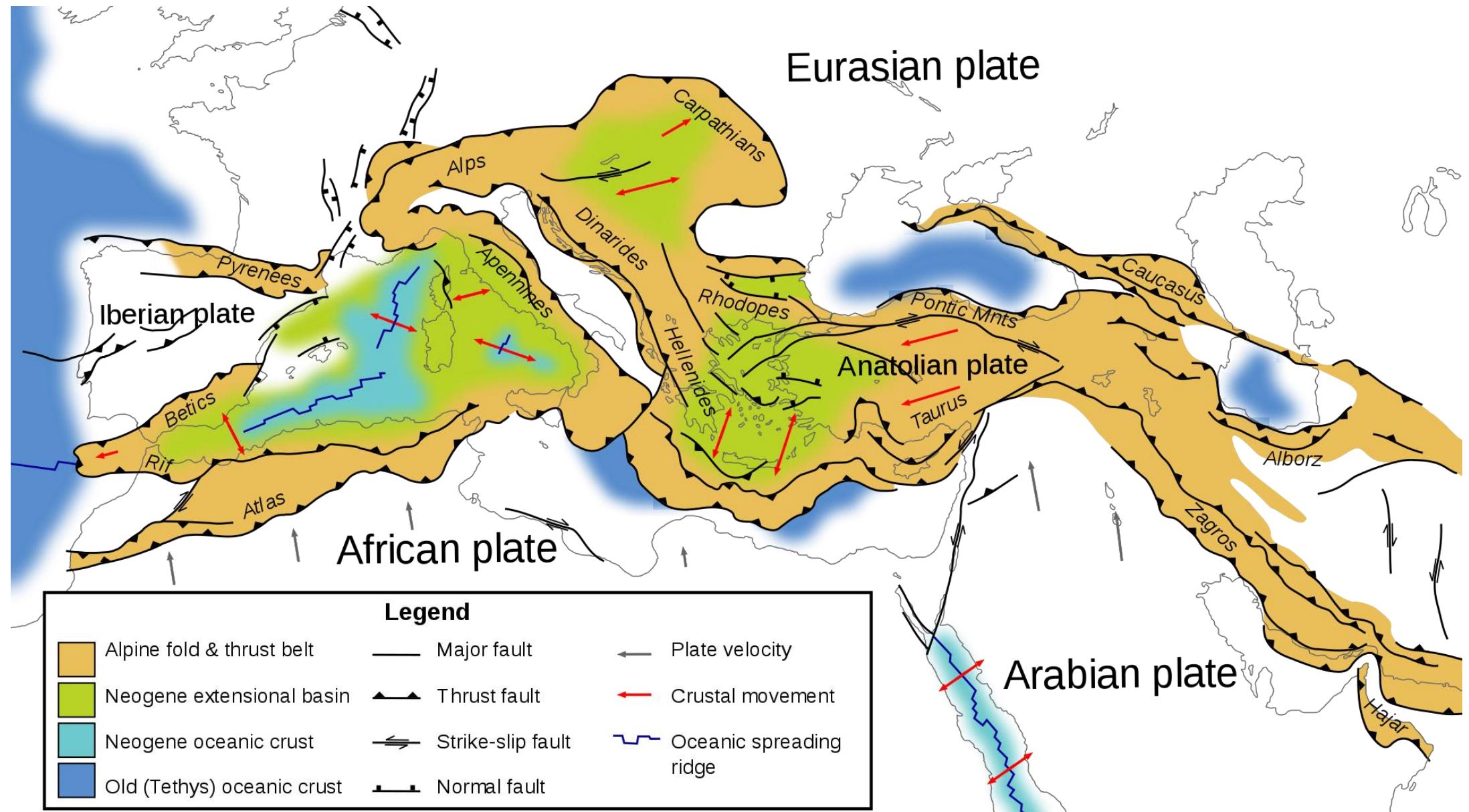
- **Sos Enattos** demonstrated to be a stable underground site with a low seismic background;
- Long term site characterization has been performed in the last years: the main microseismic peaks are related to Mediterranean sea waves, between 1 and 10Hz the seismic spectrum is close to the NLNM → one of the best European sites for ET;
- **SAR-GRAV** laboratory will be built in Sos Enattos in the next months: the underground laboratory hall ( $120\text{ m}^2 \times 4.75\text{ m}$ ) will be excavated 110 m underground, while a surface laboratory of  $200\text{ m}^2$  will be obtained from an existing building;
- **SAR-GRAV** will host experiments requiring low noise and controlled environment, providing an ideal site for the R&D of technologies for 3° generation GW detectors;
- **SAR-GRAV** can be the first module for the Einstein Telescope.

# Thanks for your attention...



# ...and see you in Sos Enattos!

# Sardinia in Mediterranean tectonics



# Peterson NLNM reference

