ET ITALY
Einstein Telescope

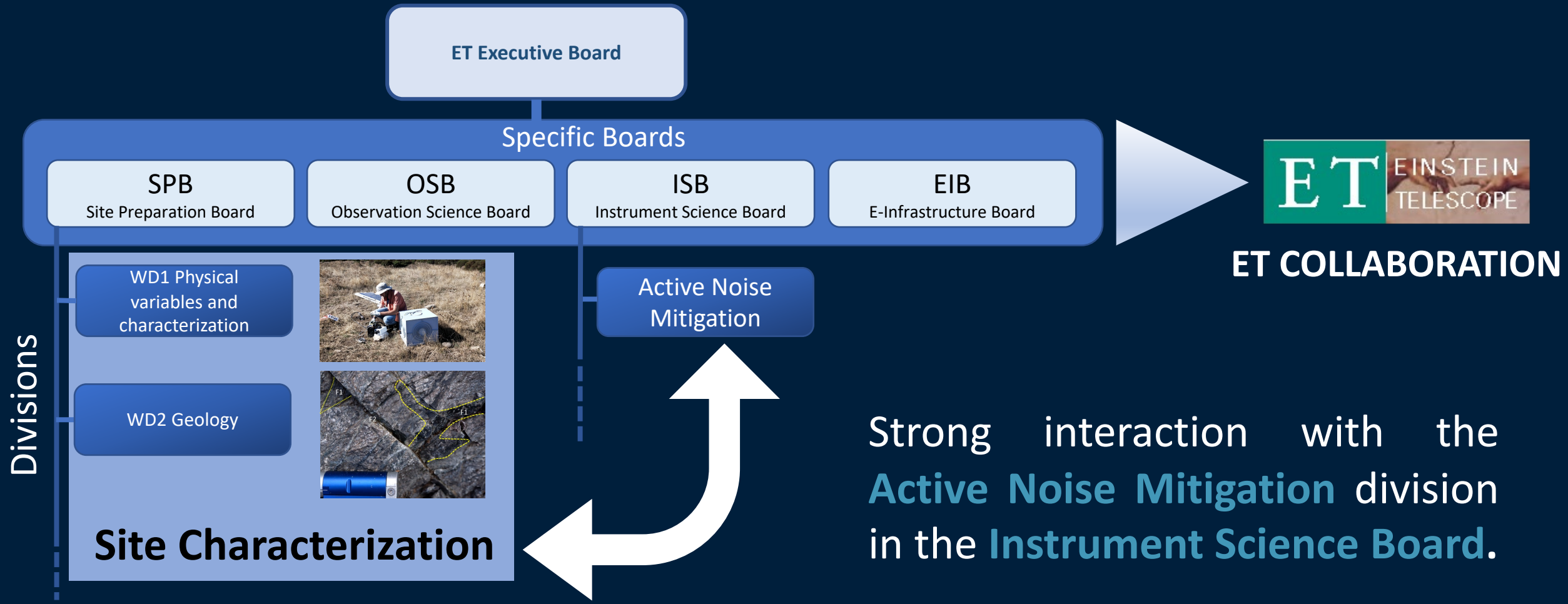
May 23rd, 2024

Status of the Sardinia site

Davide Rozza
on behalf of the Sardinian site characterization team

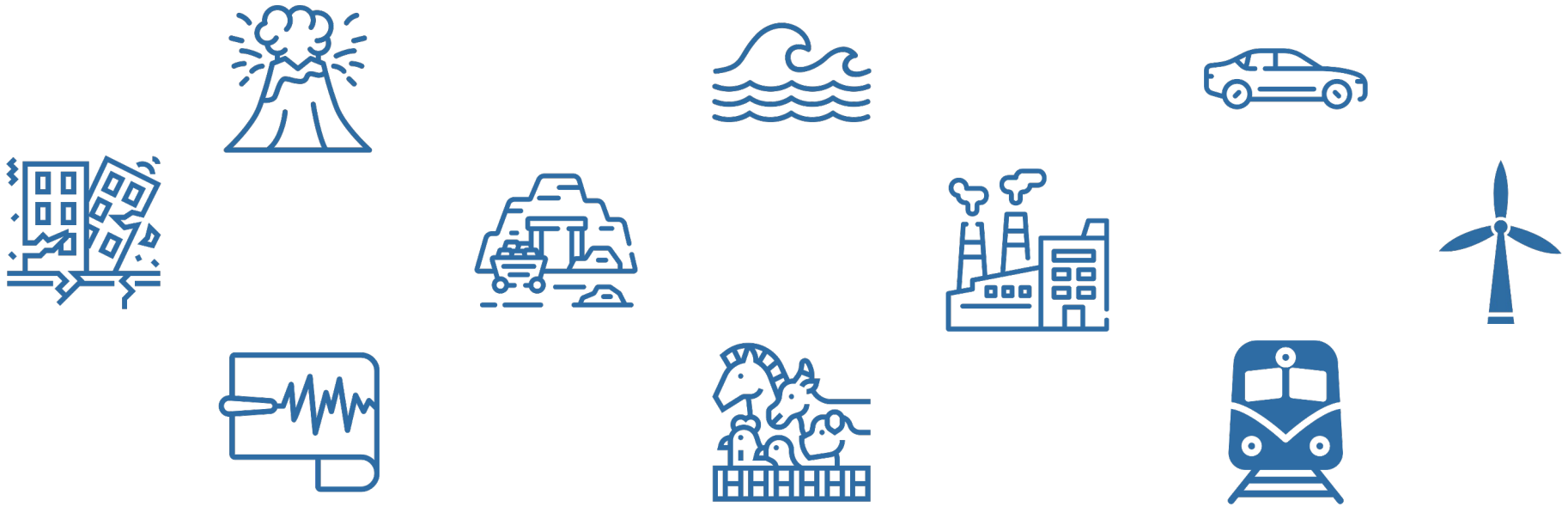
INFN
Istituto Nazionale di Fisica Nucleare

Site Characterization at the candidate sites is coordinated in the framework of the ET **Collaboration** **Site Preparation Board**.



Strong interaction with the **Active Noise Mitigation** division in the **Instrument Science Board**.

Einstein Telescope will be built underground to operate below 10 Hz.
Potential **noise sources**, both **natural** and **anthropic** origin,
Can affect the **Einstein Telescope** measurements.



WE WILL SEE THAT THE ITALIAN CANDIDATE SITE IS CHARACTERISED BY:

Geodynamic quietness

Low Anthropogenic noise

Low E.M. noise

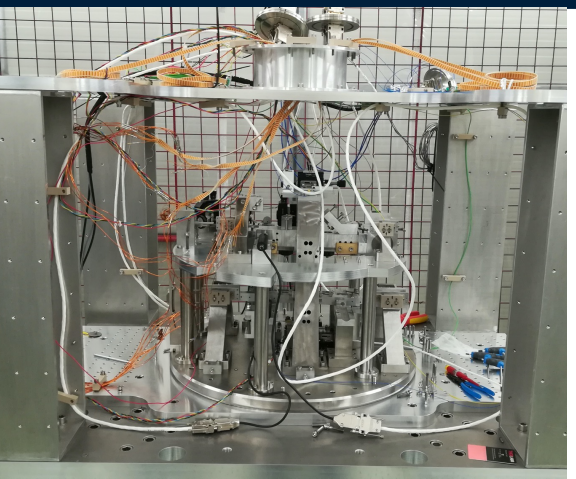
In the **SOS ENATTOS** former mine area, the **SARGRAV laboratory**, a seed of ET, can host:

- UNDERGROUND EXPERIMENTS
- CRYOGENIC PAYLOADS
- LOW FREQUENCY AND CRYOGENIC SENSOR DEVELOPMENT

that need **LOW SEISMIC** and **ANTHROPOGENIC NOISE**

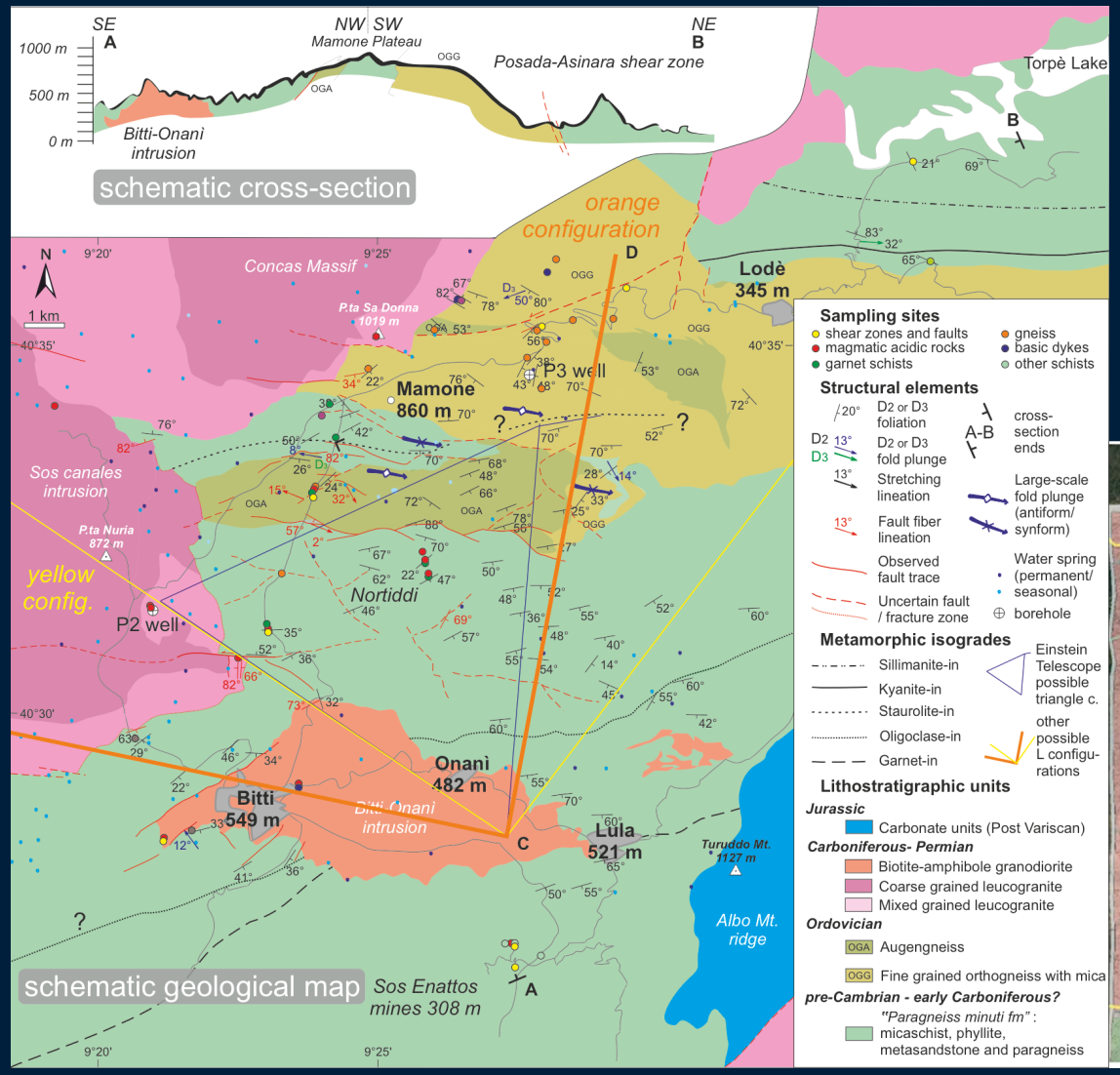
2010, first analysis was performed in the Sos Enattos mine.

The mine was not abandoned; therefore, it provided the adequate manpower, infrastructure and experience to start underground characterization studies in **2014**.



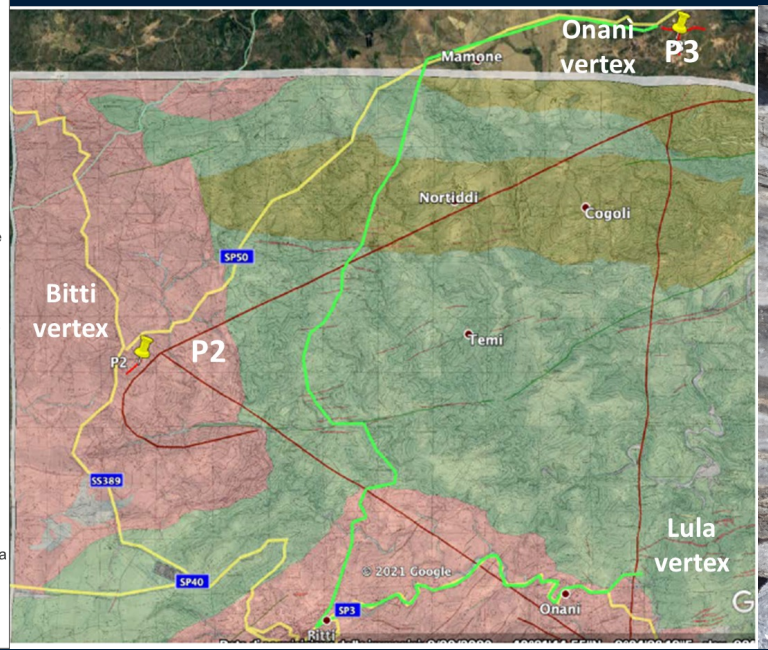
Today, the mine is considered a regional heritage site, it hosts the SARGRAV LABORATORY and the ARCHIMEDES EXPERIMENT.

The ET Italian candidate site is located in the stable **VARISCAN BASEMENT OF SARDINIA**



LITHOLOGIES: Orthogneiss, granitoids, micaschists.

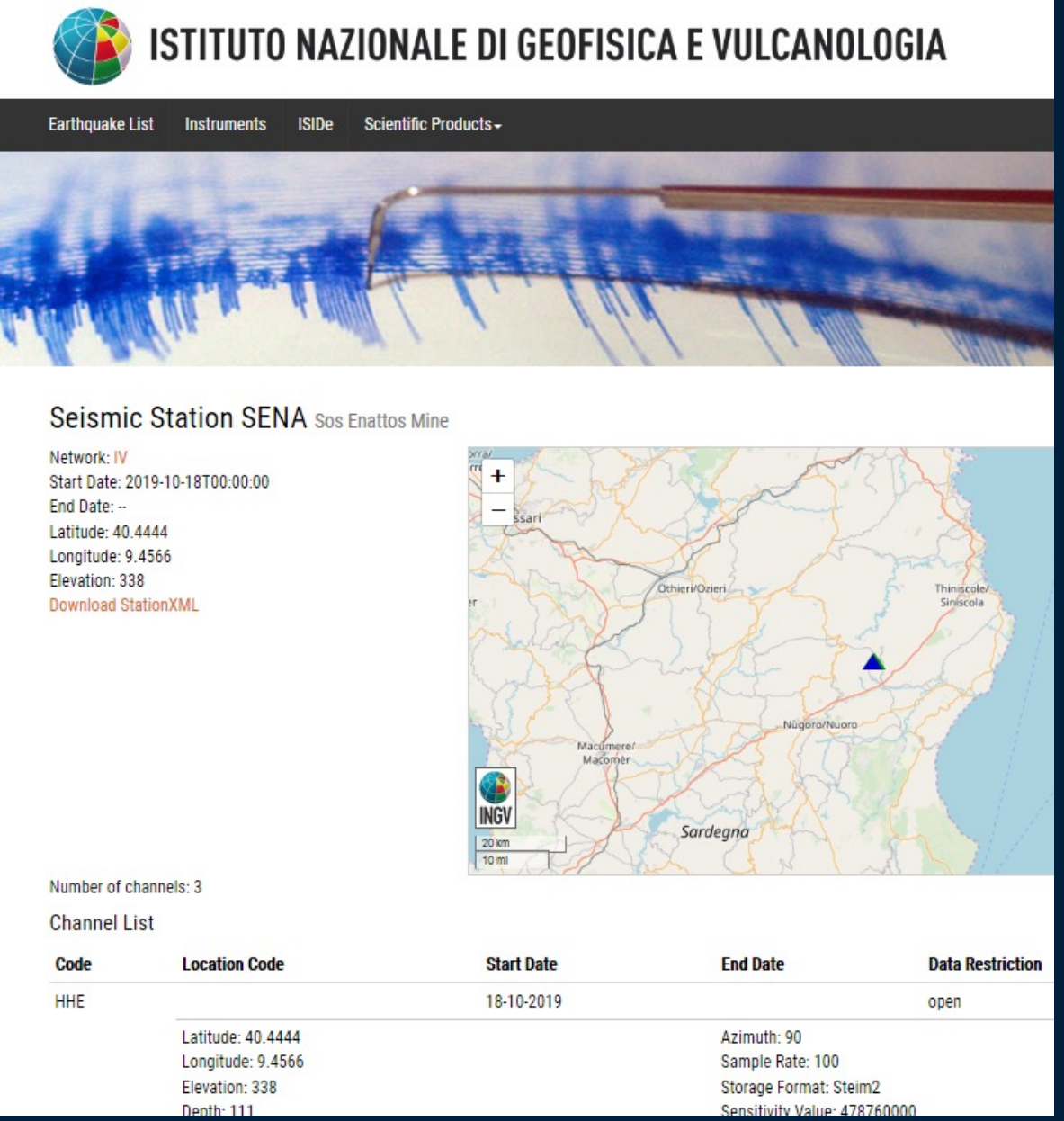
P2 and P3 are the borehole locations optimization is ongoing.



PERMANENT ARRAY since 2019

Since 2019, in Sos Enattos there are:

- 4 permanent seismic stations for long term studies (Trillium 240, 360 and 120 Horizon, Guralp 360)
- 1 weather station
- 1 microbarometer
- 3 magnetometers (MF6-06)
- 2 microphones
- 1 high precision tiltmeter (Archimedes prototype)



SOE2 station is integrated into the Italian national seismometer **network of INGV**. Station: **SENA**, network:

- IV (Italian National Seismic Network - INSN), 2019-2022/01
- MN (*Mediterranean Very Broadband Seismographic Network*) since 2022/02

http://cnt.rm.ingv.it/en/instruments/station/SENA

PERMANENT ARRAY since 2021

Since 2021, more permanent sensors have been installed at 2 of the proposed vertices (P2, P3)

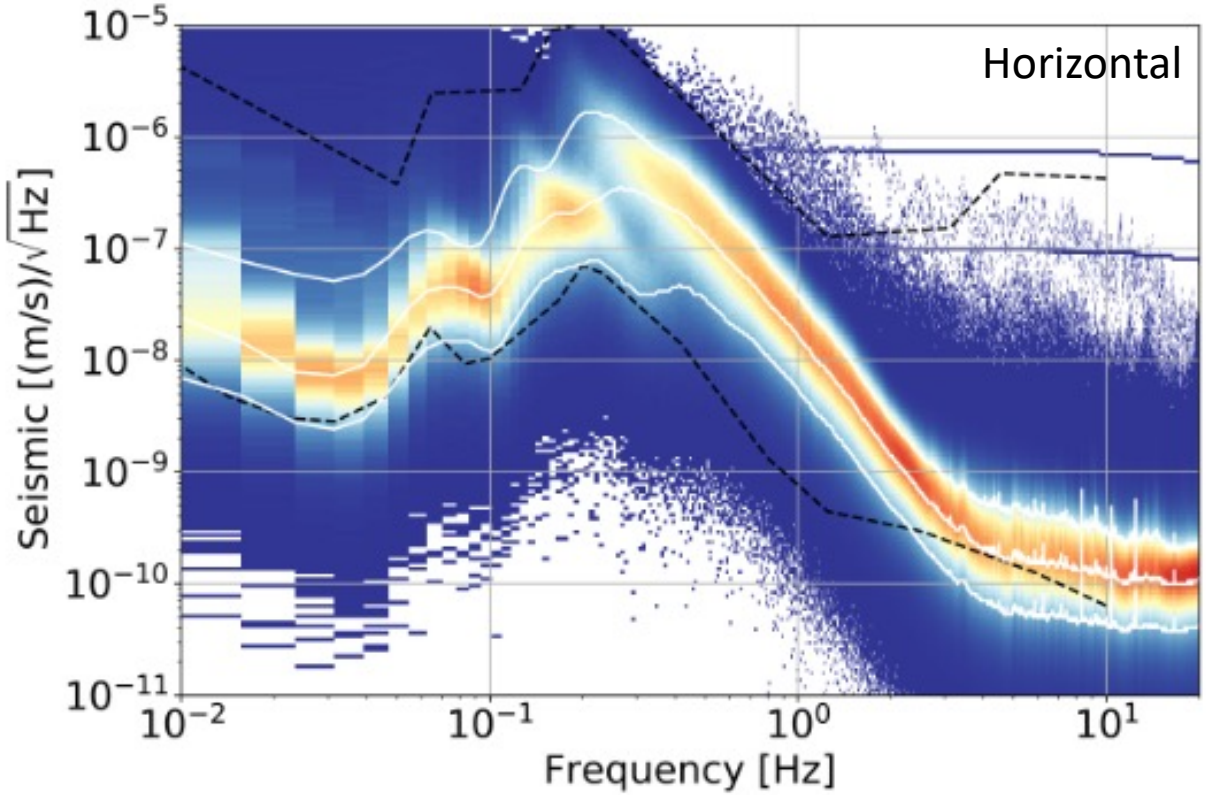
2 broadband seismometers on surface

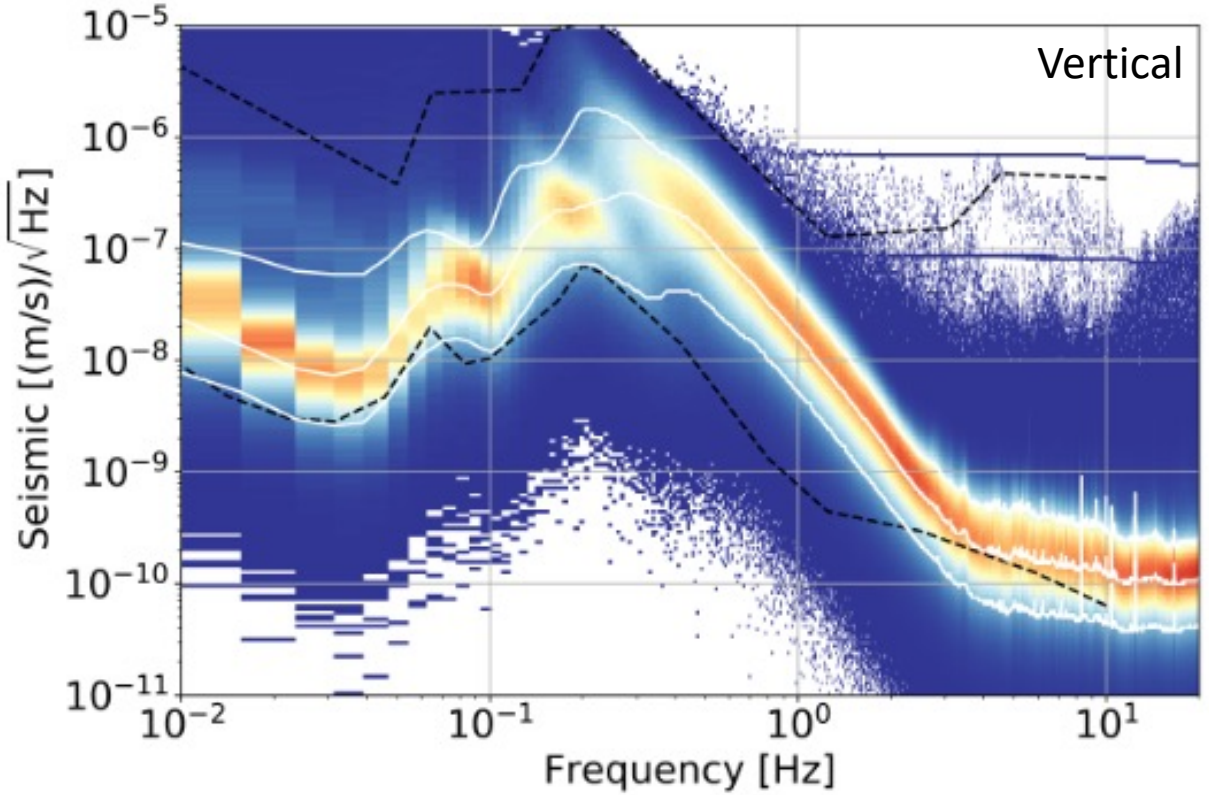
2 broadband seismometers in borehole

2 magnetometers at P2

Collaboration with Germain group (KIT)

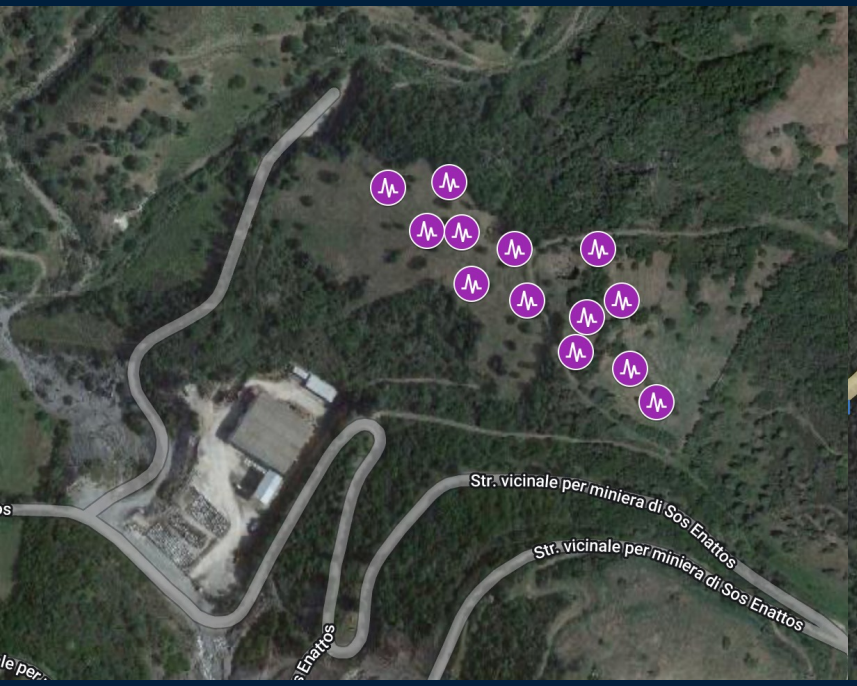
PPSD - P2 borehole seismometer



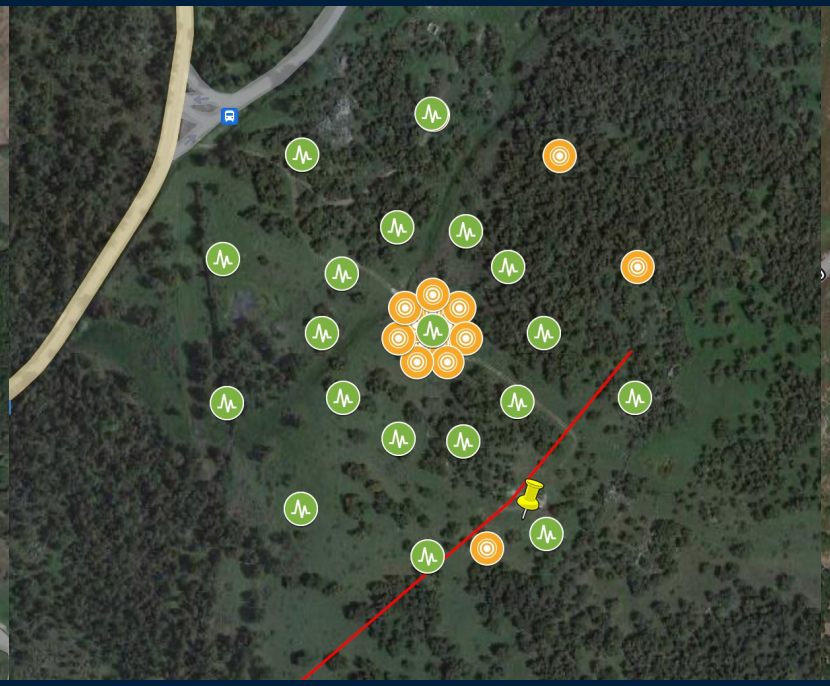


Very low noise background in the **2-10 Hz** band, sometimes even **below** the Peterson's **New Low Noise Model**!

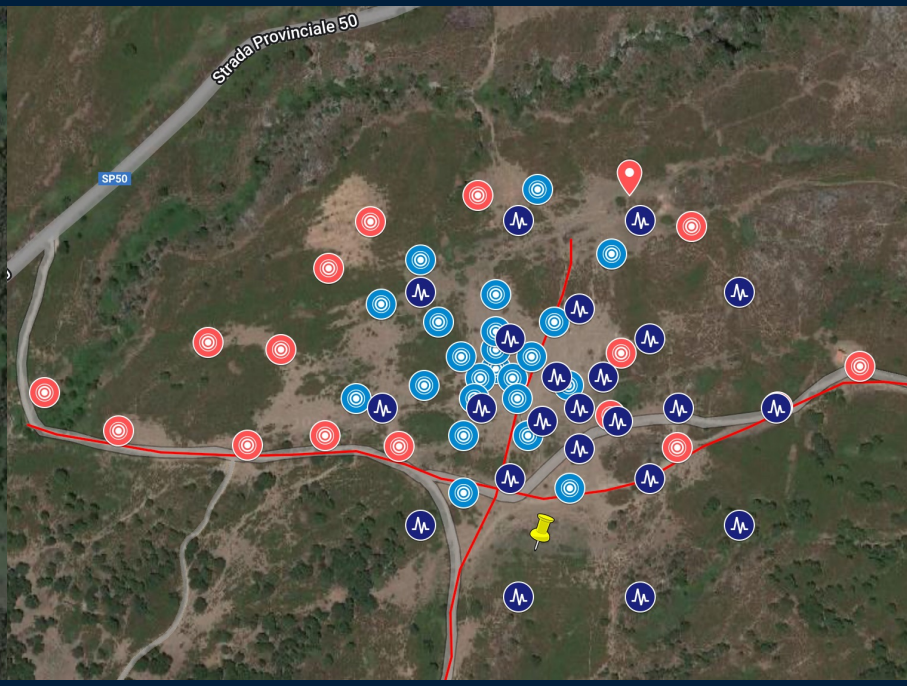
TEMPORARY ARRAY for seismic properties and Newtonian noise purposes



Sos Enattos broadband array (January 2021)

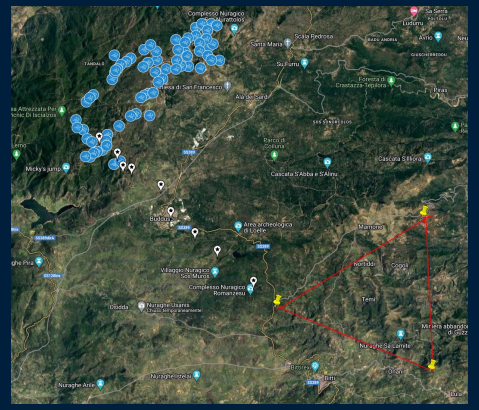


P2 broadband array + geophones (September 2021)



P3 broadband array + geophones (July & Oct 2021)

Explosion broadband array (early 2022)

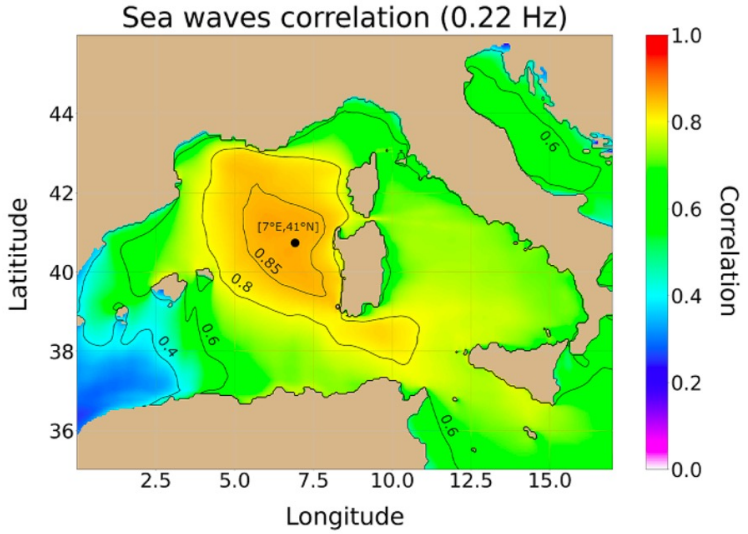


Wind Park broadband array (early 2023)


ET ITALY
Einstein Telescope
IDENTIFICATION of some potential noise sources, both of natural and anthropic origin

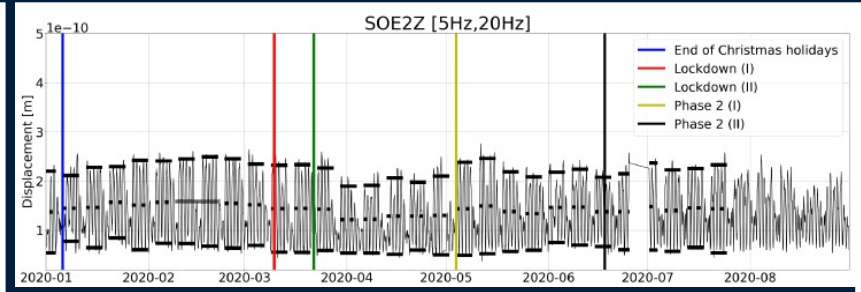
Hunting the noise sources

Sea waves

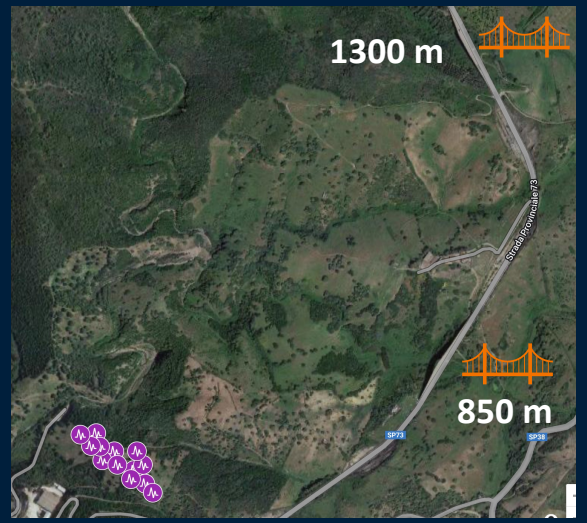


Microseismic (0.05-1Hz) coming from **waves** in the Gulf of Lion (~0.22Hz,NW Mediterranean sea) and Atlantic ocean depending on weather conditions and season.

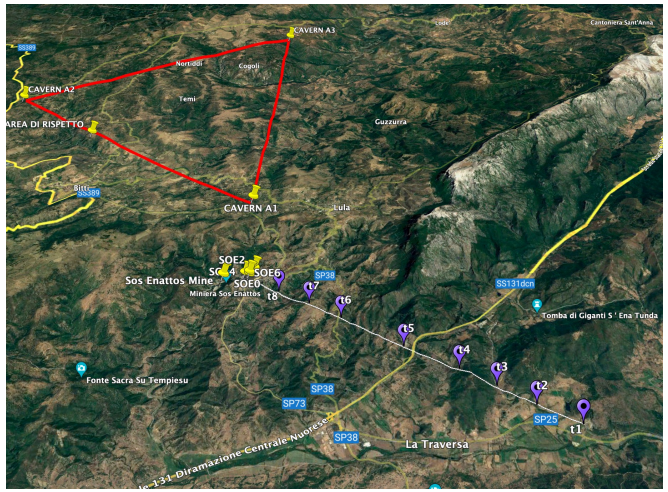
Human activities



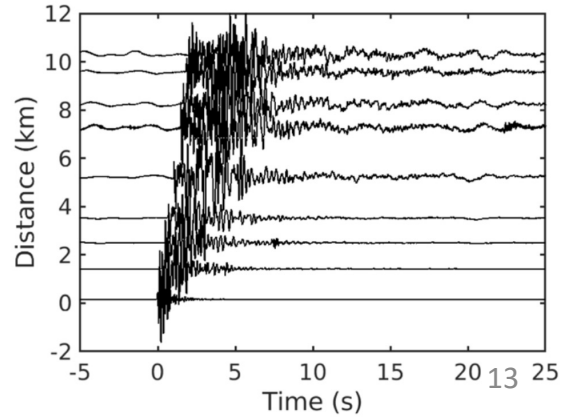
At higher frequencies, **anthropic noise** pattern observed.



Identification of the noise contribution from **two bridges** (peaks at ~4.2 Hz, 4.6 Hz, 6 Hz).



Updates and improves of the resolution of the dispersion curves for **compressional and shear wave velocities**.



Hunting the noise sources

The **Budussò Wind Park**: one of the largest wind parks in Italy.

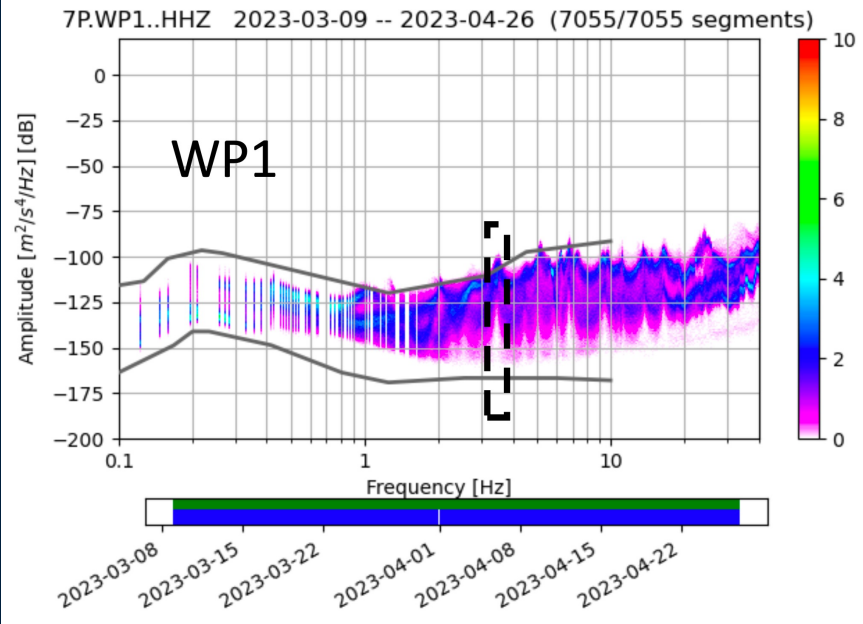
69 turbines (~2 MW each).

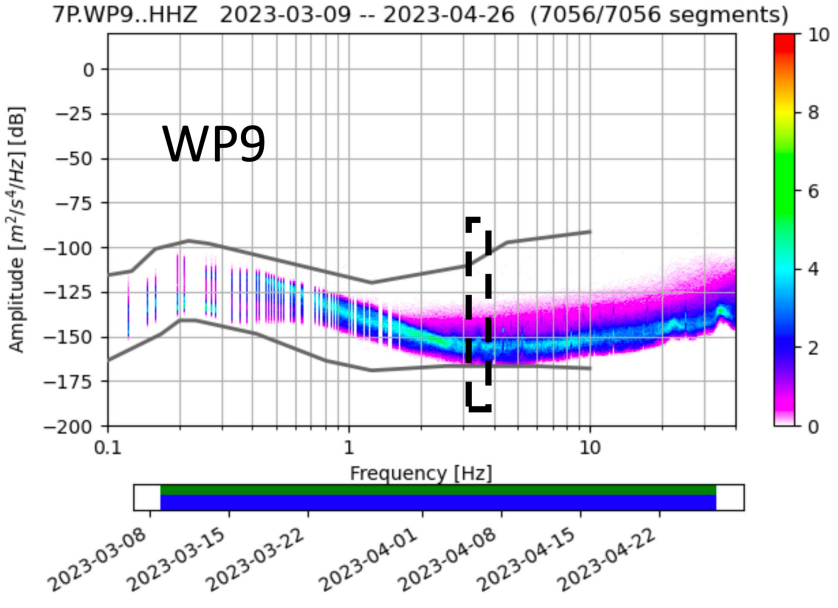
A total of **130 MW installed**.

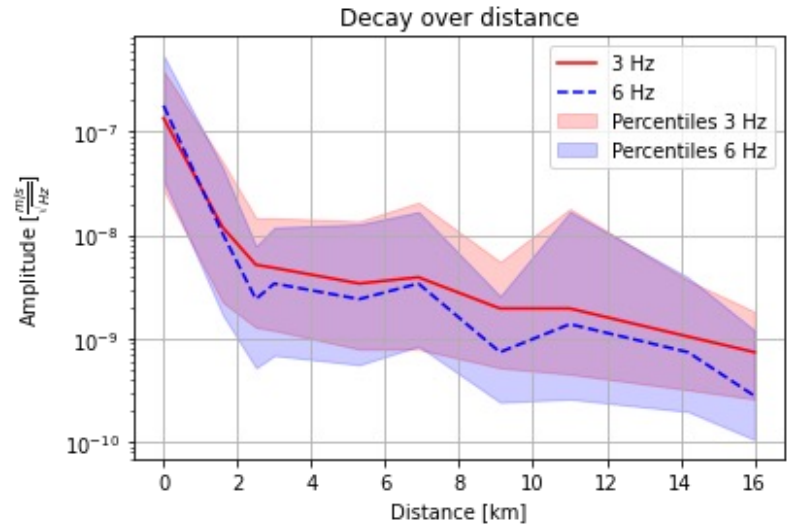
Blades motion is **transferred** to tower and to the ground.

Seismic noise propagates as **surface waves**

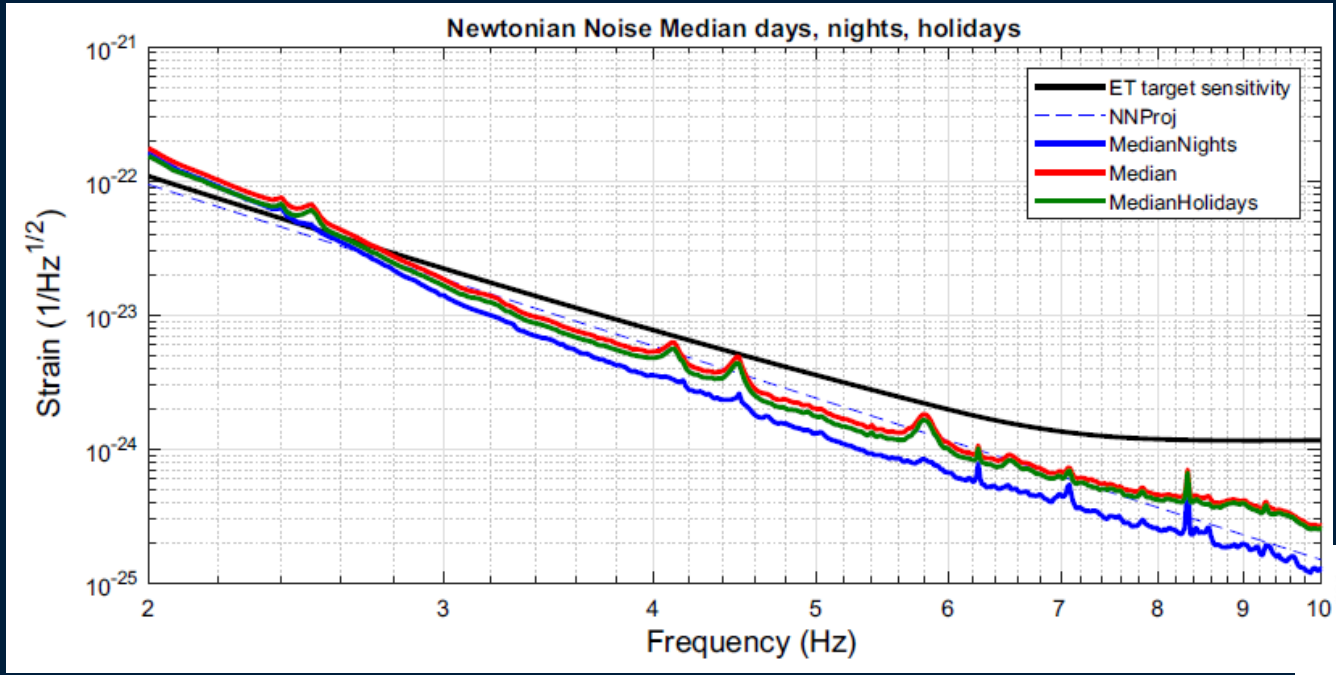
Generated noise is found in the **1-10 Hz** frequency band.







Hunting the noise sources



NEWTONIAN NOISE and seismic glitches (based on 2020 data at SOE1)

Defining the Newtonian Noise ASD as:

$$\tilde{h}_{NN}(f) = \frac{4\pi}{3} G\rho_0 \frac{2\sqrt{2}}{L} \frac{1}{(2\pi f)^2} \tilde{x}(f)$$

Defining the Noise-to-Target Ratio of the Newtonian Noise in 1 minute window (~IMBH duration in ET band)

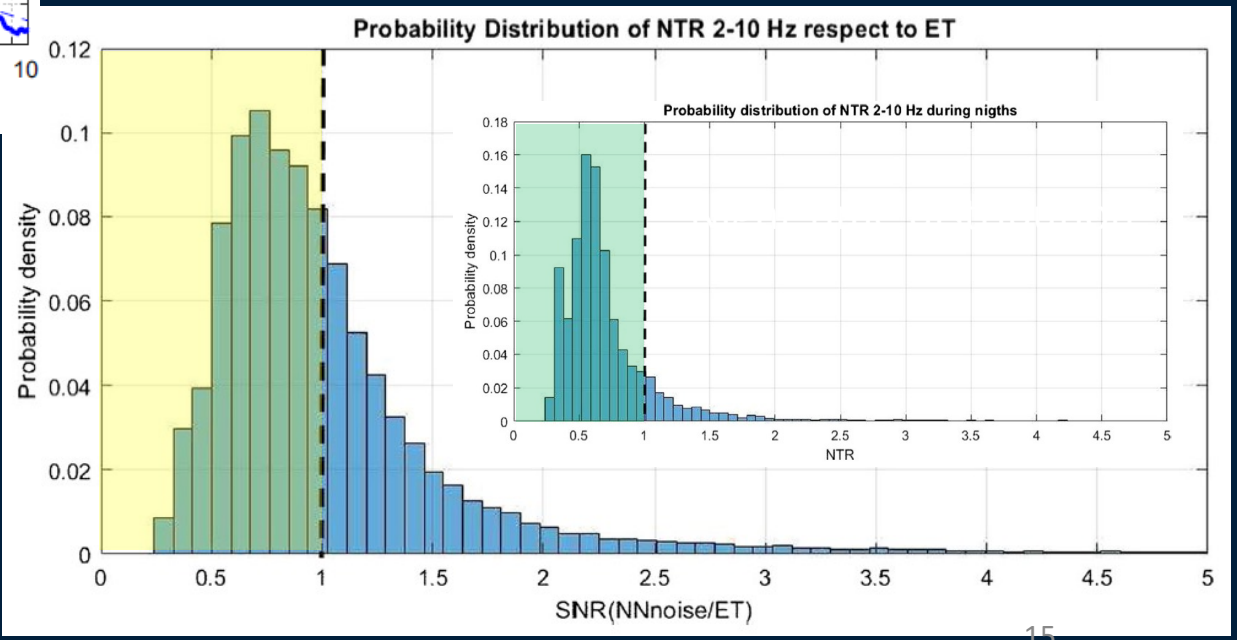
$$\mathrm{NTR} = \sqrt{\frac{1}{\Delta f} \int df \frac{\tilde{N} * \tilde{N}}{S_h}}$$

PSD of NN

PSD of ET sensitivity

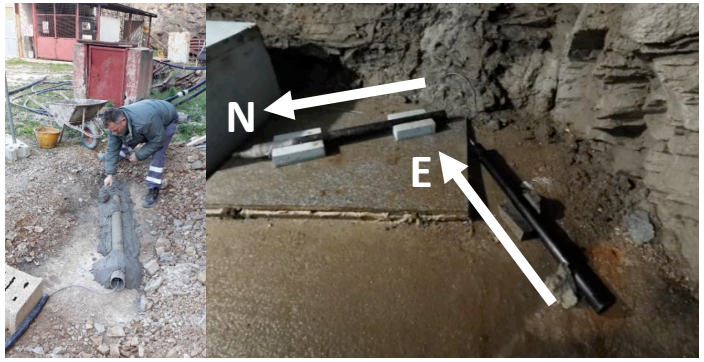
P(NRT<1)=0.6 , during nights: $P(NRT<1)_n$=0.86

Need for moderate NN subtraction only for a limited time



Hunting the noise sources

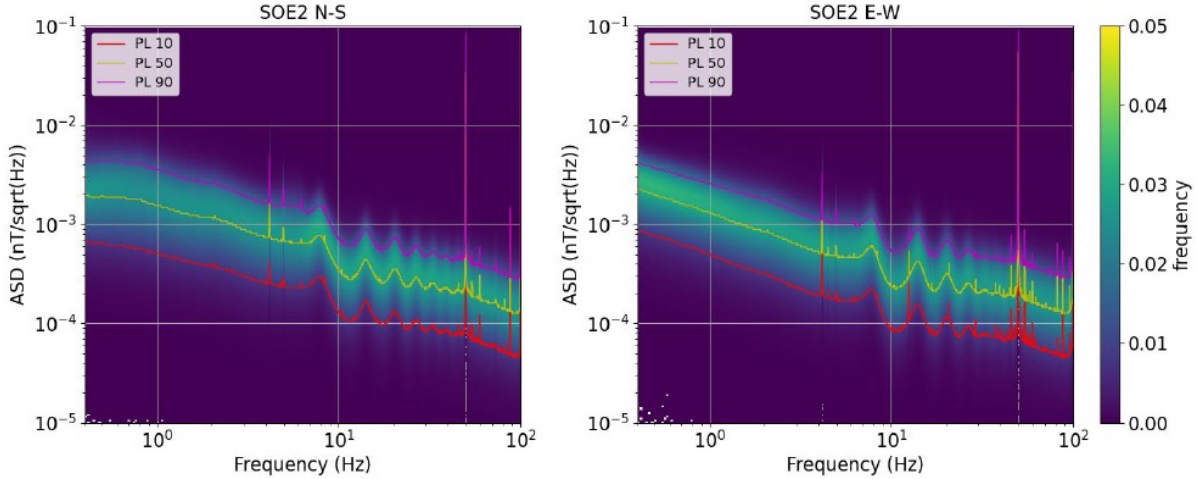
MAGNETIC NOISE



Most important mechanism in ET-LF:

- **Geomagnetic pulsations Pc1** (0.2-5Hz);
- **Schumann resonances** (5-100Hz)

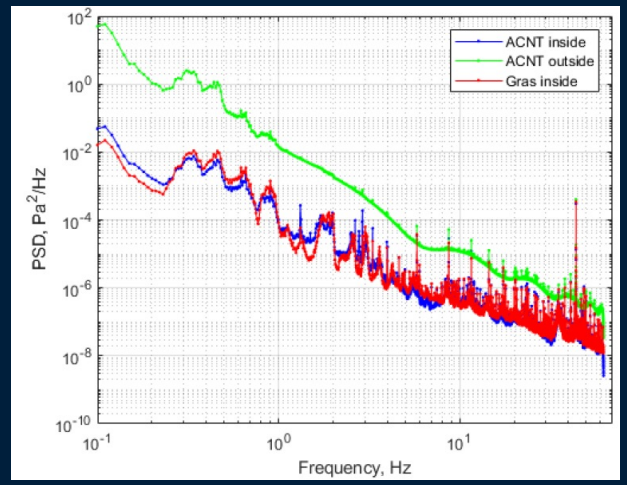
Artificial LF sources (e.g. 50-60Hz powerlines)



credits: R. De Rosa, R. Romero

INFRASOUND MEASUREMENTS

4 microphones installed along the underground tunnels for long term characterization in a joint Italian-Polish-Hungarian collaboration (*PolGrav-AstroCeNT, Wigner Research Centre*)



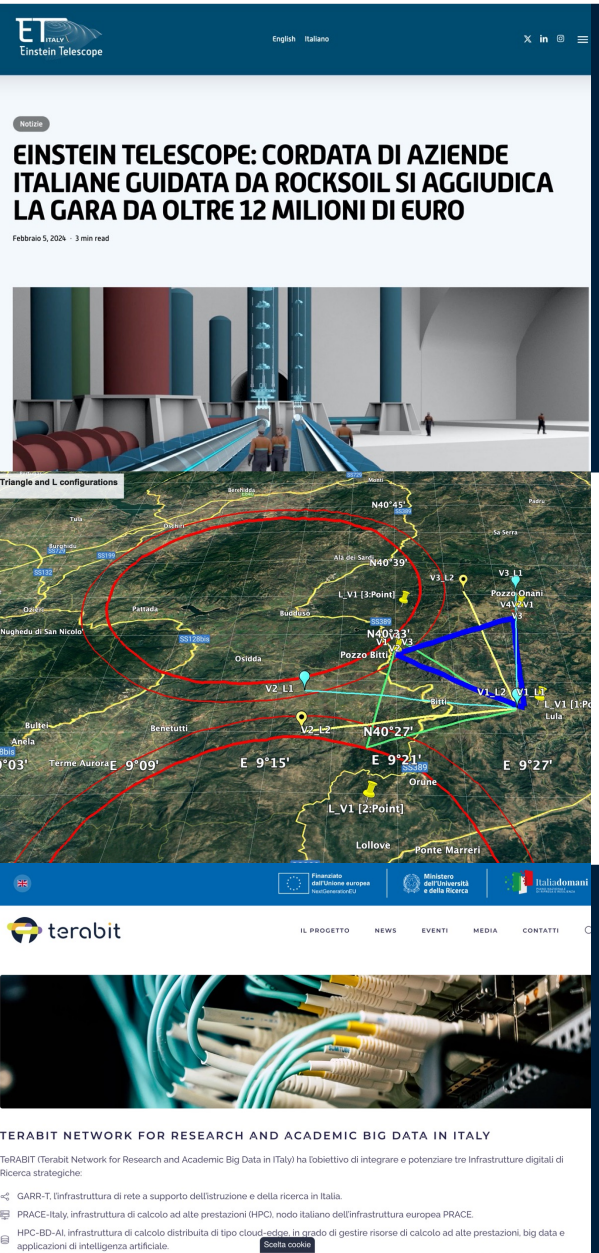
credit: T. Bulik

PUBLICATIONS:

- L. Naticchioni et al., ***Microseismic studies of an underground site for a new interferometric gravitational wave detector***, **CQG**, 2014, https://doi.org/10.1088/0264-9381/31/10/105016
- L. Naticchioni et al., ***Characterization of the Sos Enattos site for the Einstein Telescope***, **JPCS** 1468, 2020, https://doi.org/10.1088/1742-6596/1468/1/012242
- M. Di Giovanni et al., ***A seismological study of the Sos Enattos Area – the Sardinia Candidate Site for the Einstein Telescope***, **SRL**, 2020 https://doi.org/10.1785/0220200186
- A. Allocca et al., ***Seismic glitchness at Sos Enattos site: impact on intermediate black hole binaries detection efficiency***, **EPJP**, 2021 https://doi.org/10.1140/epjp/s13360-021-01450-8
- Allocca *et al.* **Picoradiant tiltmeter and direct ground tilt measurements at the Sos Enattos site**, *Eur. Phys. J. Plus* **136**, 1069 (2021). https://doi.org/10.1140/epjp/s13360-021-01993-w
- M. Di Giovanni et al., ***Temporal variations of the ambient seismic field at the Sardinia candidate site of the Einstein Telescope***, **Geophysical Journal International**, 2023, https://doi.org/10.1093/gji/ggad178
- G. Saccorotti et al., ***Array analysis of seismic noise at the Sos Enattos mine, the Italian candidate site for the Einstein Telescope***, 2023, https://doi.org/10.1140/epjp/s13360-023-04395-2.
- L .Naticchioni et al., **Results of the site characterization in Sardinia for the Einstein Telescope**, **PoS Proc. Sci.**, 2023, *accepted for publication*.

+ several internal notes, reports and talks

NEWS and UPDATES



Preliminary **feasibility study** for ET in Sardinia on going (both Δ and L).

Preliminary **cost estimation** (excavation).

Management and strategy of excavated lands & rocks.

End of activity: June 2025
Bidbook to end 2025

Optimization of ET localization

Sos Enattos area will be reached at 1 TB/s (**TeraBit project**)

Acoustic campaign at P2 & P3 borehole areas

Gravimetric campaign

Conclusions

The **geo-physical site characterization** is a task coordinated by SPB of the ET collaboration.

Site characterization is strictly related to the **noise mitigation strategy and detector design**.

LF sources of noise (2-10Hz) affected by **seismic** (→ **Newtonian**) and **magnetic** noise.

Sardinia is **geologically very quiet**, far from active fault lines, and characterized by low anthropic noise.

Since 2019 (and before in 2010-2014), we installed **permanent and temporary arrays** of sensors and **two instrumented boreholes** (operative since 2021).

Measurements show a peculiar **very low level of seismic noise** in the ET-LF band (2-10Hz), where:

Seismic noise match or goes even below the Peterson's NLNM	The projected (seismic) Newtonian noise is also compatible with ET_d	Electromagnetic noise is very low	Acoustic noise measuremement ongoing (also very quite)

Possible **local sources** of noise (e.g. wind farms) are under study.

From the geological and physical point of view, Sardinia is an optimal candidate to host the Einstein Telescope, either in Δ or in L (→ 2 sites) configuration!

A fruitful collaboration!

The geophysical characterization is a great and fruitful example of **collaboration** between Italian Research Institutes (INFN & INGV), that have brought together **different and complementary skills and expertise** to demonstrate the **extraordinary quality** of the Sardinia candidate site to host ET.