

EINSTEIN
TELESCOPE



Olbia

Nuoro

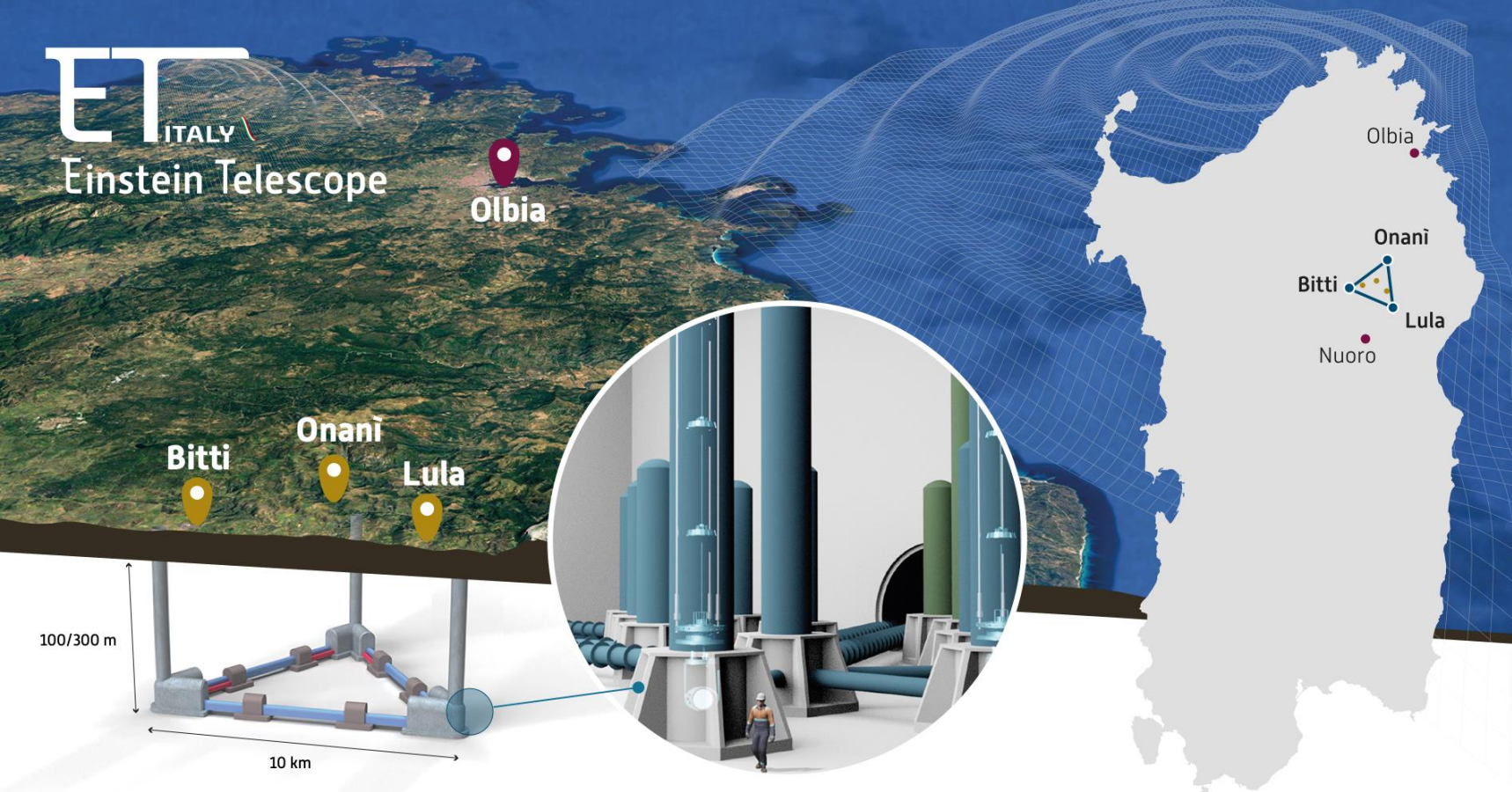
Probing the quiet site: multidisciplinary characterization at Sos Enattos for the Einstein Telescope

on behalf of the Sardinian site characterization team

Andrea Contu, INFN Cagliari

4th ET Annual Meeting, 23 Ottobre 2025





- First seismic characterization in 2010-2014
- ET full site characterization started in 2019
- Since then, activities funded by INFN ET-Italia, in collaboration with INGV



We are in the **SOS ENATTOS** former mine area, where the **SARGRAV laboratory** can host:

UNDERGROUND
EXPERIMENTS

CRYOGENIC
PAYLOADS

LOW FREQUENCY AND CRYOGENIC
SENSOR DEVELOPMENT

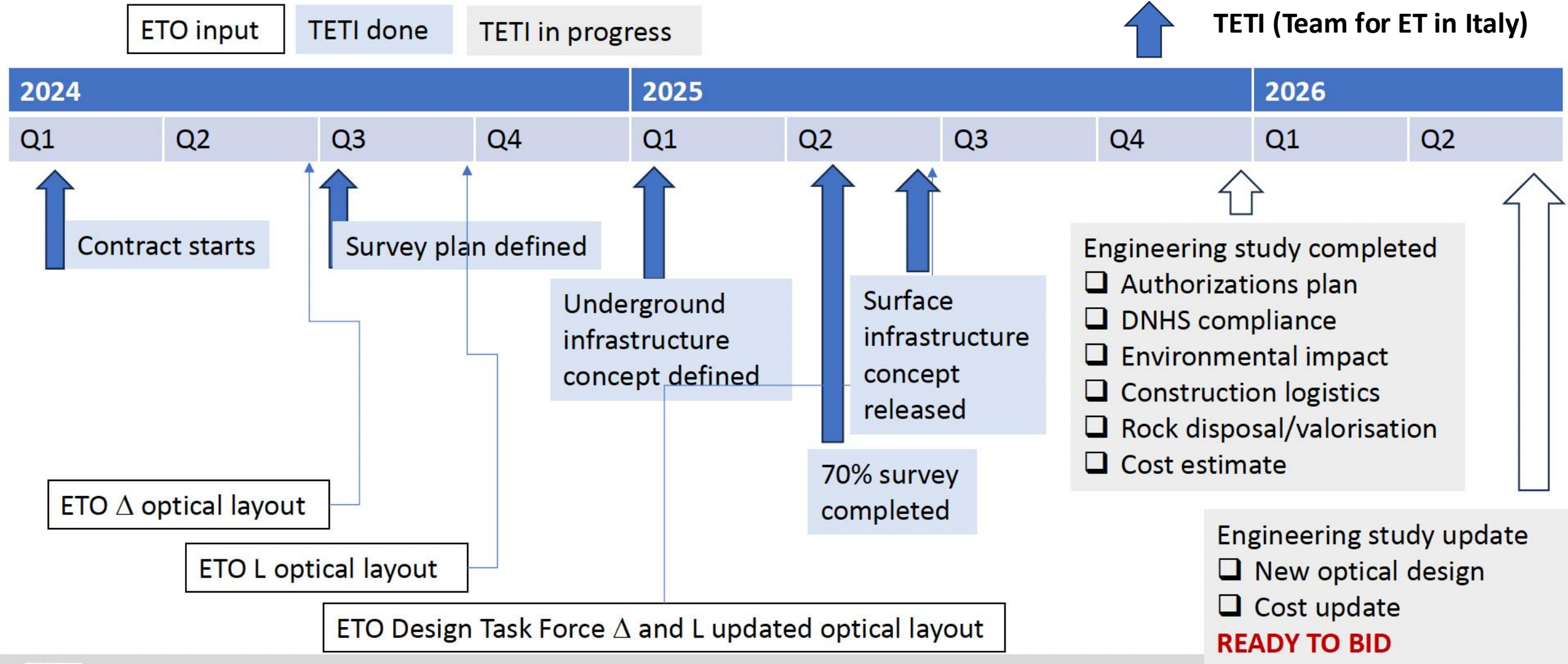
that need **LOW SEISMIC** and **ANTHROPOGENIC NOISE**

TETI Activities Timeline

**Contract closed at
the end of October**



TETI (Team for ET in Italy)



GREEN LIGHT FROM THE CONFERENCE OF SERVICES: THE EINSTEIN TELESCOPE CAN BE BUILT IN SARDINIA. PRELIMINARY STUDY UNANIMOUSLY APPROVED

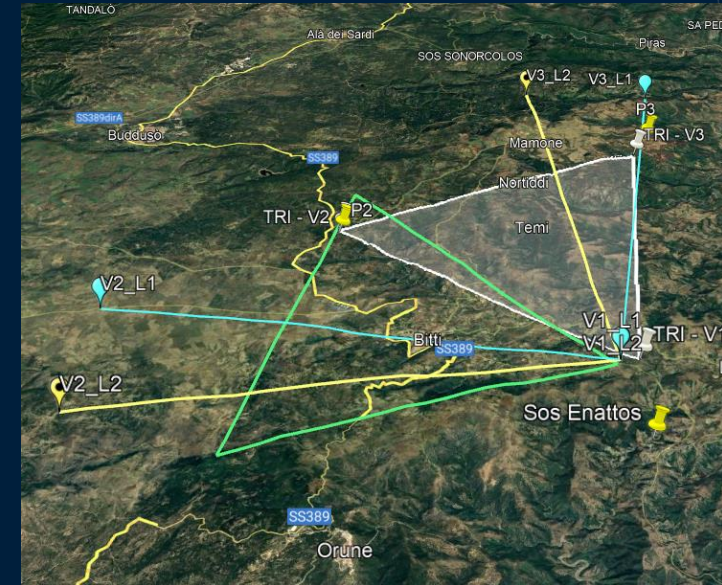
7 November 2025 · 5 min read

Green light for the possible construction of the Einstein Telescope in Sardinia, for both of the two alternative configurations — the “L” shape and the triangular one. from the preliminary Conference of Services on the preparatory study for the development of the technical, economic, and environmental feasibility project of the future gravitational wave observatory.



[Click here link for detailed info](#)

Site Monitoring



Permanent and temporary ARRAY for characterization and Newtonian noise purposes

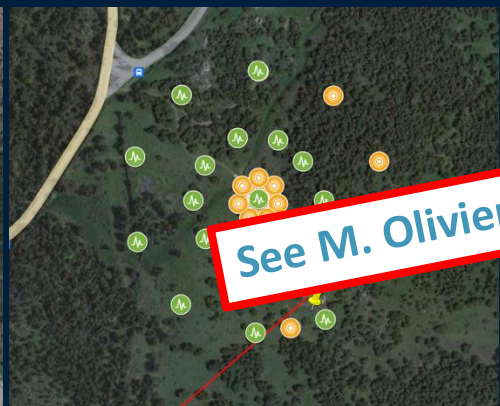
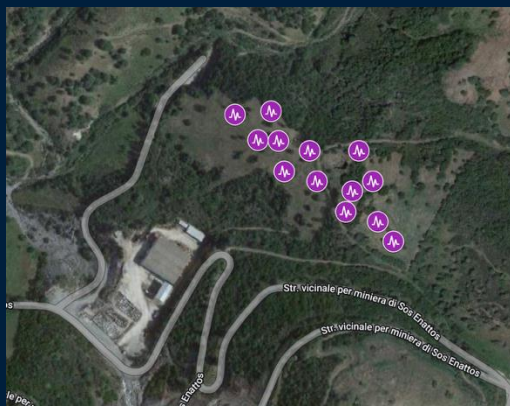
Sos Enattos broadband array
(January 2021)

P2 broadband array +
geophones (September 2021)

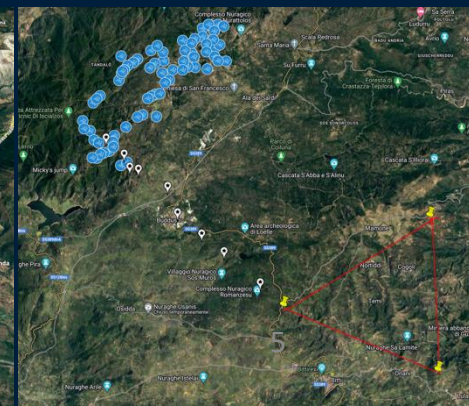
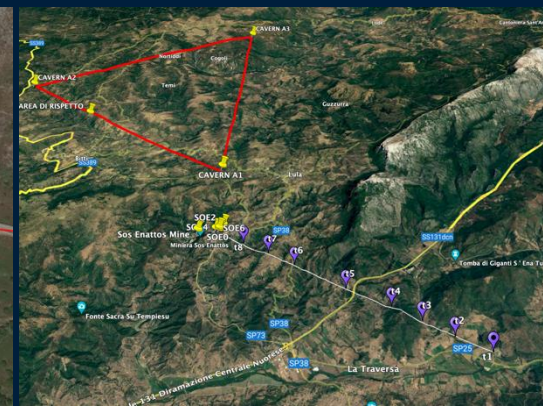
P3 broadband array +
geophones (July & Oct 2021)

Explosion broadband array
(early 2022)

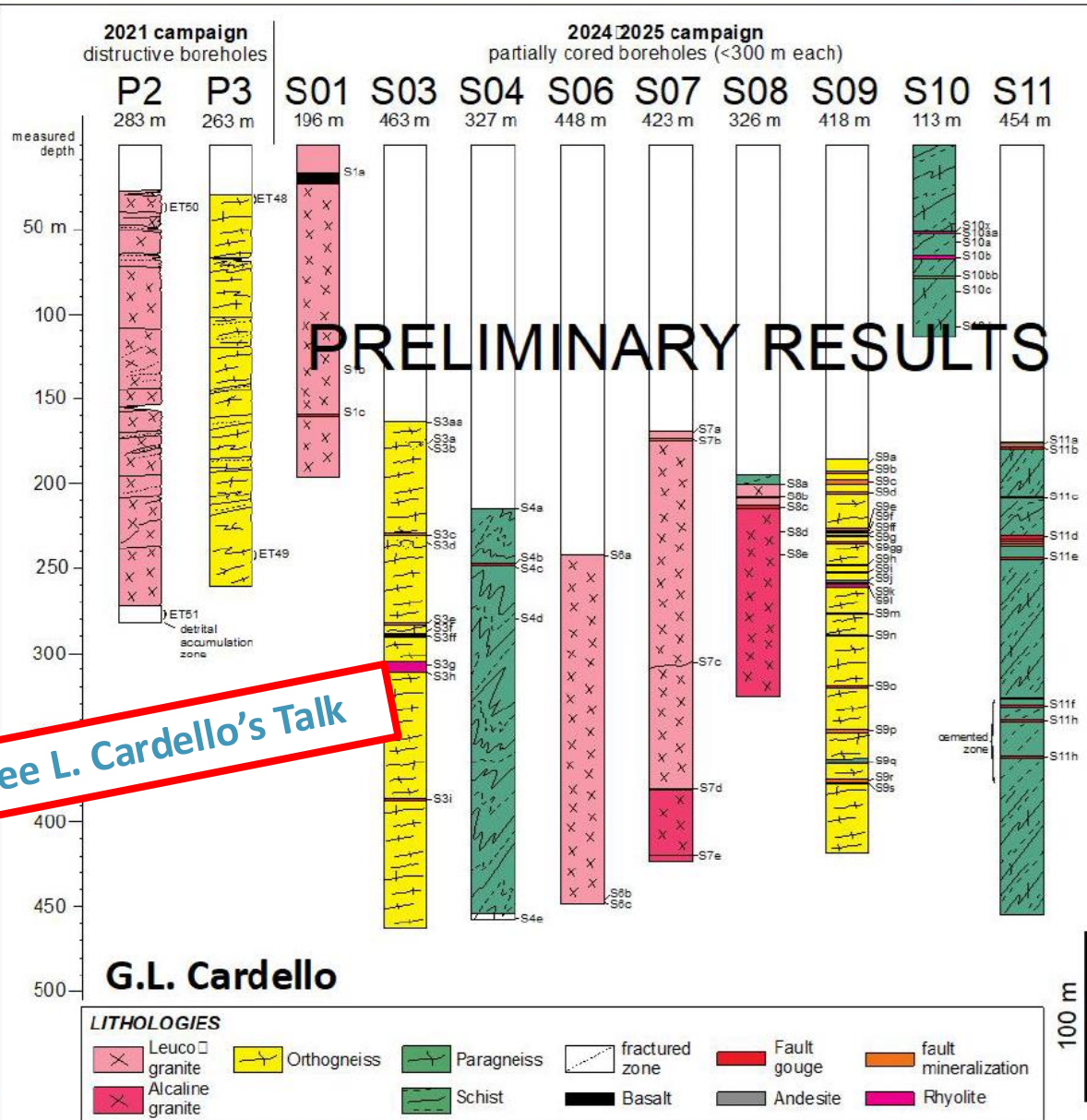
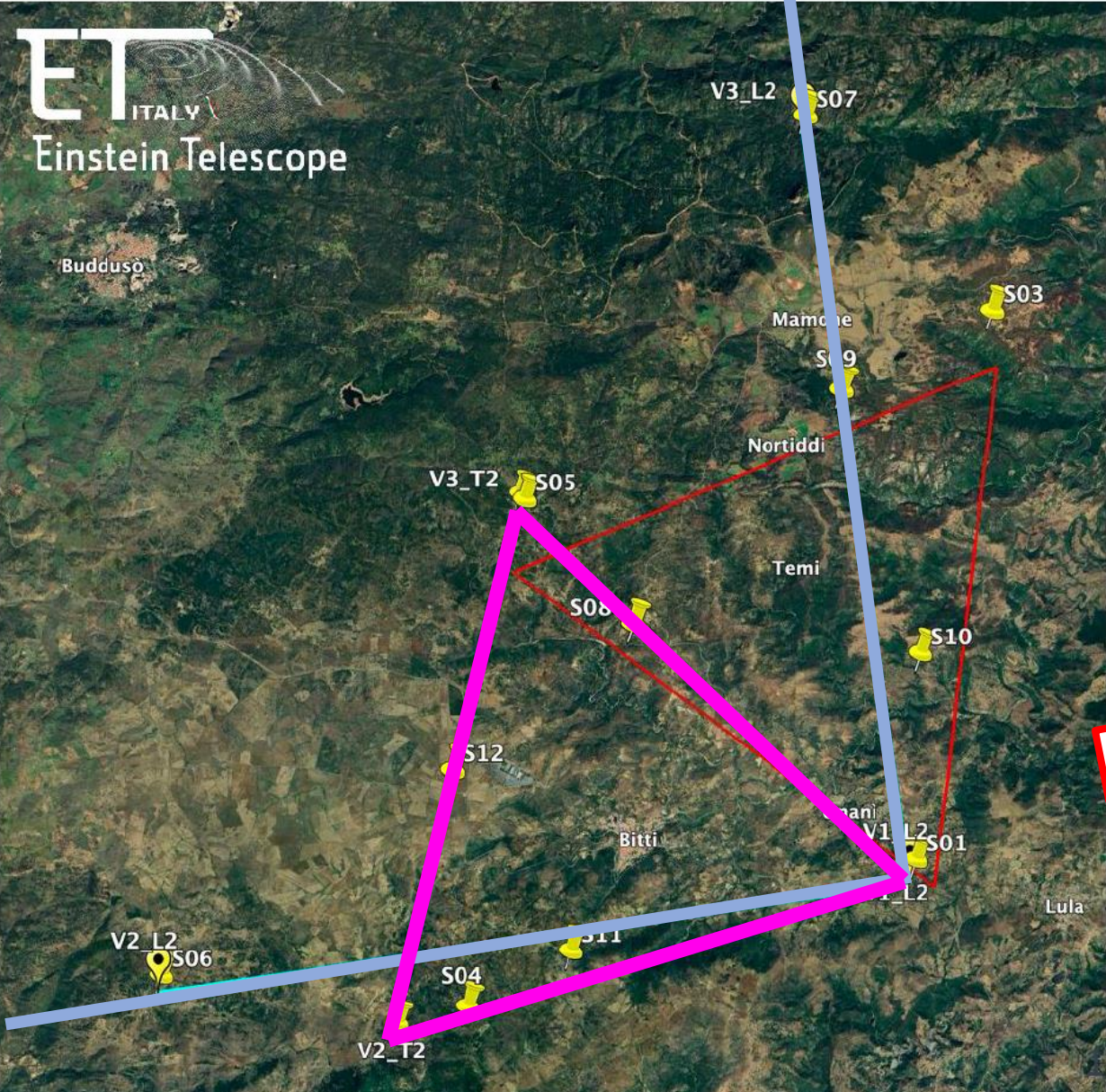
Wind Park broadband array
(early 2023)



See M. Olivieri and C. Giunchi talks



GEOLOGICAL EXPLORATION AND NEW CONFIGURATION



Electromagnetic noise measurements

Magnetometers installed in the Sos Enattos area:

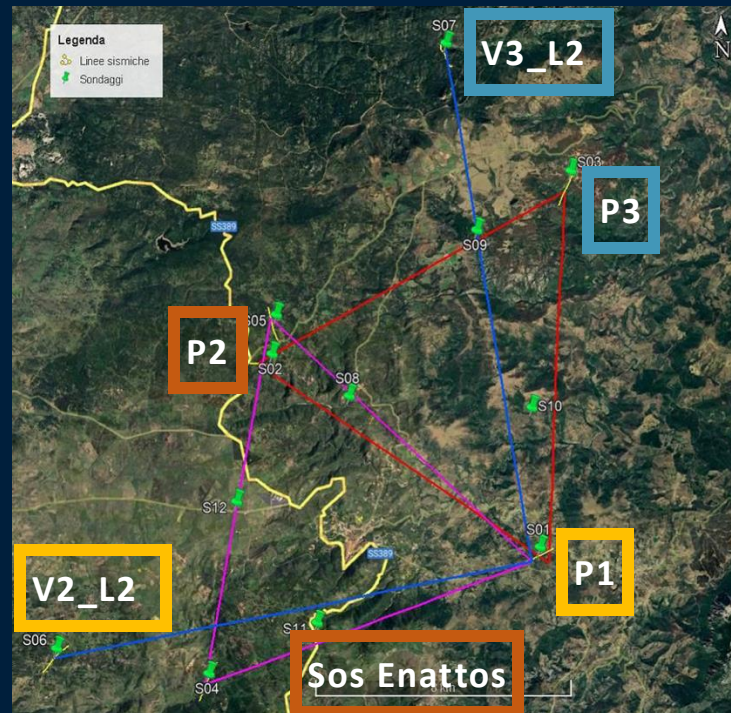
- 1 mag probe (N-S dir.) in surface at Sos Enattos (SOE0)
- 2 mag probes (N-S and E-W dir.) at -111 m underground at Sos Enattos (SOE2)
- 3 mag probes (N-S, E-W, Z dir.) in surface at Bitti (P2)

Ready to be installed:

- 3 mag probes at P3
- 3 mag probes at V3_L2

To be purchased and installed:

- 3 mag probes for V2_L2
- 3 mag probes for P1



Acoustic measurements

Davide's Setup

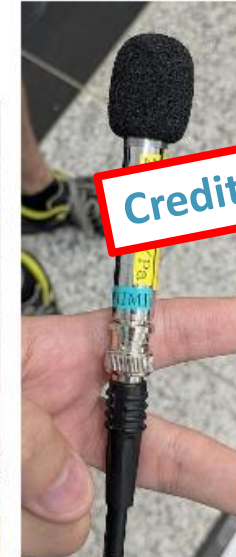


- * Data Logger : National Instruments cRIO-9053
- * File Format : tdms file
- * Power Supply : NI-9230
- * Amp Gain : 0 dB
- * Sensors
 - * CH1 : GRAS 46AZ (52.62 mV/Pa)
 - * CH3 : ACO 4152N (20.80 mV/Pa)

Washimi's Setup



- * Data Logger : GRAPHTEC GL980
- * File Format : GBD file
- * Power Supply : ACO TYPE5006/4 Low Frequency
- * Amp Gain : 20dB
- * Sensors
 - * CH1 : ACO 4152N (20.99 mV/Pa)
 - * CH2 : ACO 4152N (22.80 mV/Pa)



Credits W. Tatzuki & D. Rozza



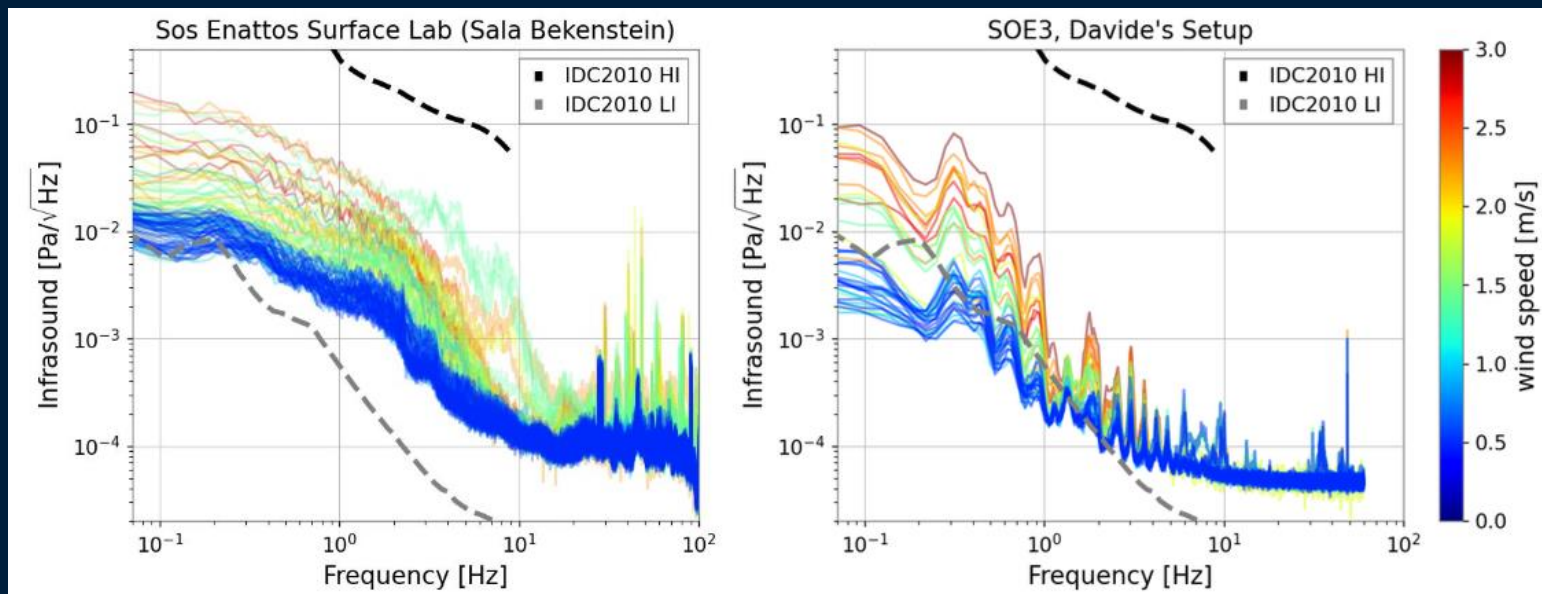
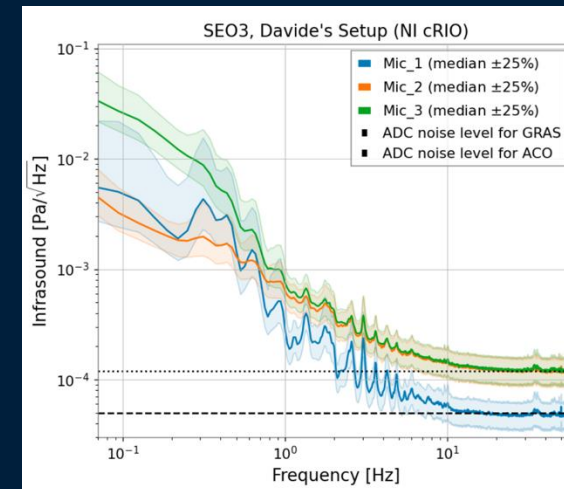
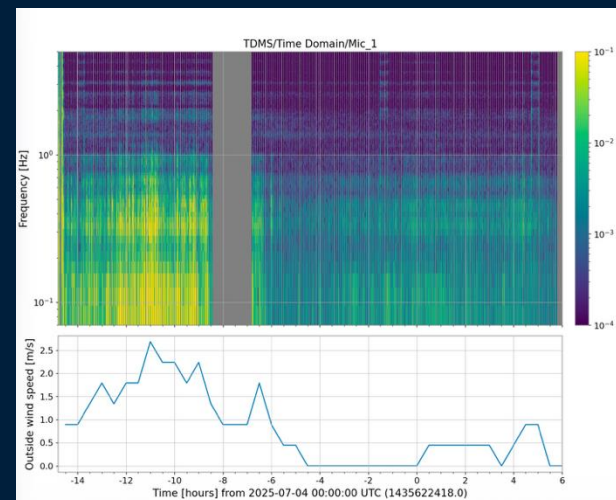
Measurements performed on surface, SOE1 (-111m) and SOE3 (-160m)

Acoustic measurements: Surface vs SOE3

tunnel resonance peaks (< 10 Hz)

wind induced sound (< 1 Hz)

Credits W. Tatzuki & D. Rozza

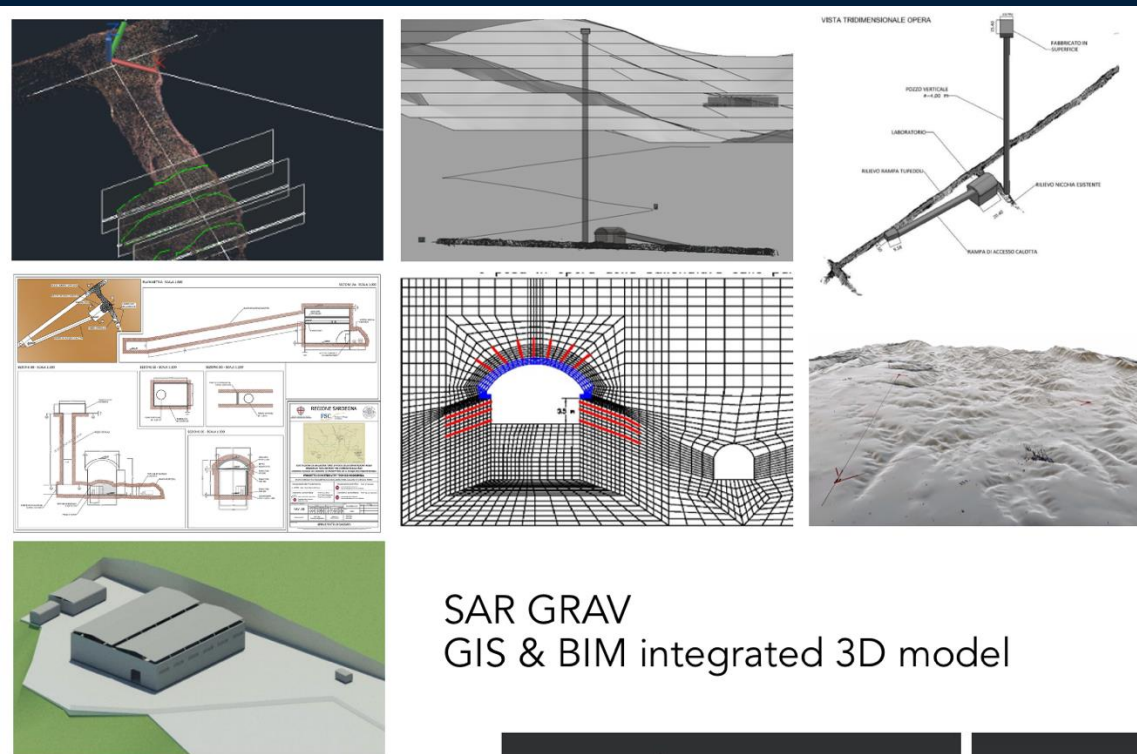


Wind-induced infrasound

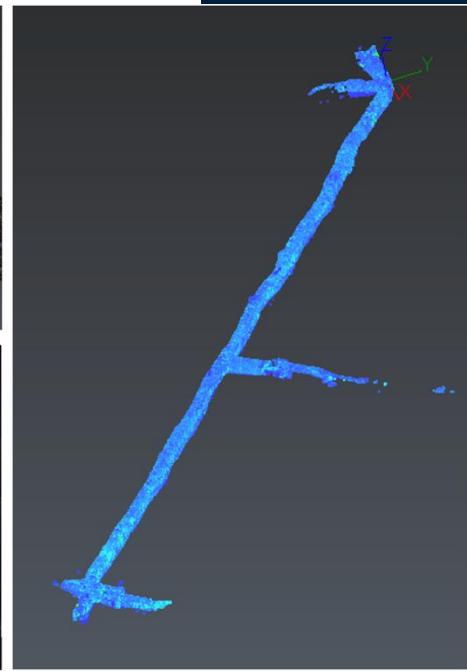
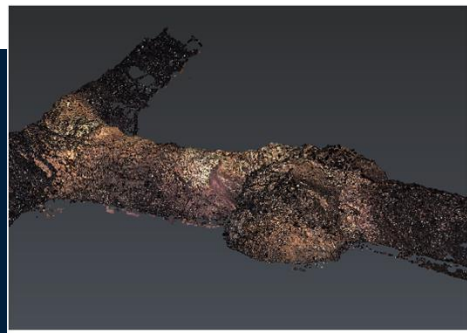
- Surface Lab : Smooth (shoulder-shape) spectrum, wind direction dependence?
- SOE3 : Tunnel resonance peaks grow due to the surface wind.
- At weak wind time, the infrasound at SOE3 was lower than the IDC2010 low noise model (Brown et. al. 2012).
- Limited by the ADC noise ($\sim 5 \times 10^{-5}$ Pa/√Hz)

3D Survey and characterisation of the rocks in the Sos Enattos mine

Credits M. Marsella & P. Valentino
Faculty of Engineering & INFN Sapienza



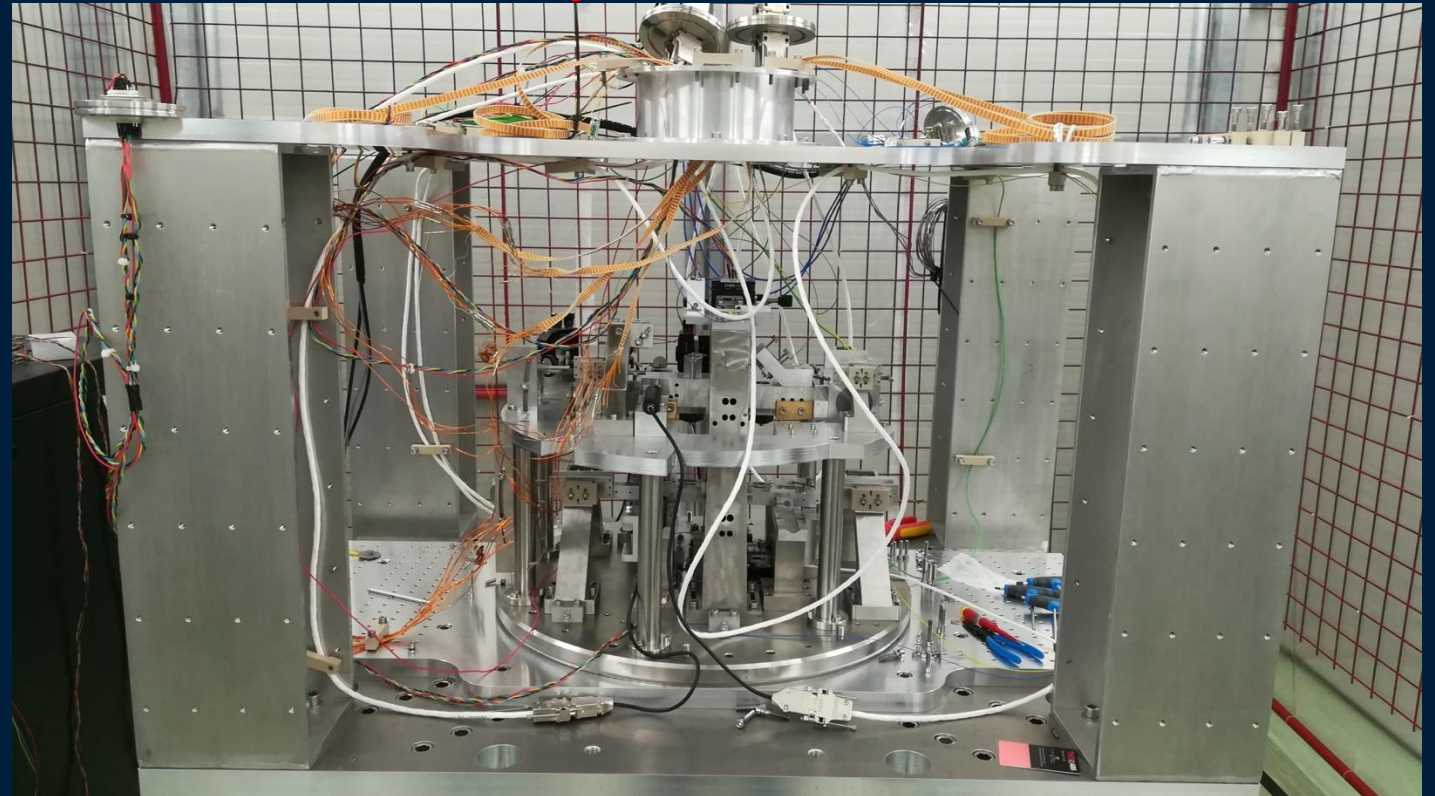
SAR GRAV
GIS & BIM integrated 3D model



Archimedes experiment

Double-arm suspended interferometric balance at
Sos Enattos.

See E.Calloni's talk



Gravimeter installation

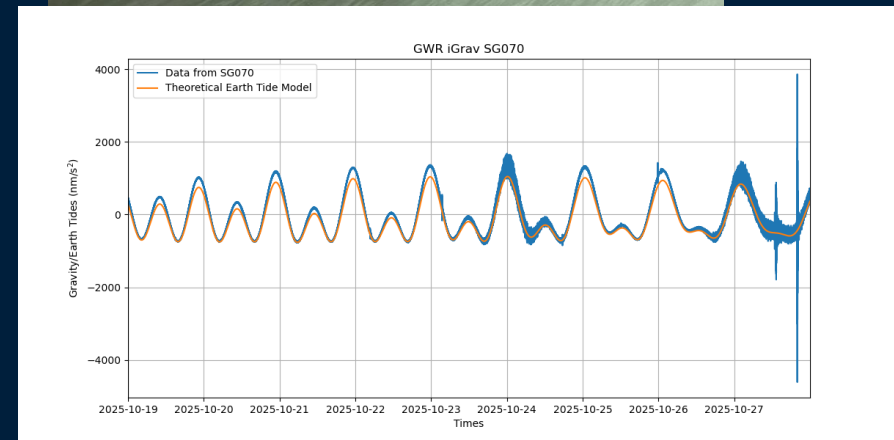
- Superconducting gravimeter GWR iGrav SG070 currently operating in Sos Enattos
- In test run since mid'October 2025
- Final installation close to the mine entrance in the coming months

Credits C. Giunchi

SPECIFICATIONS

iGrav® Gravity Sensor (single-sphere Niobium-based transducer):

Noise:	3 nm/s ² /(Hz) ^{1/2}
Frequency domain:	Sub-nanoGal (< 10 ⁻² nm/s ²) signals observed
Time domain:	1 to 3 nm/s ² signals observed, 1-minute filtering
Scale factor:	Stable to better than 1 part in 10 ⁴ for decades
Linearity:	Linear to 1 part in 10 ⁷
Insensitivity:	Cryogenic environment insensitive to temperature, pressure and humidity

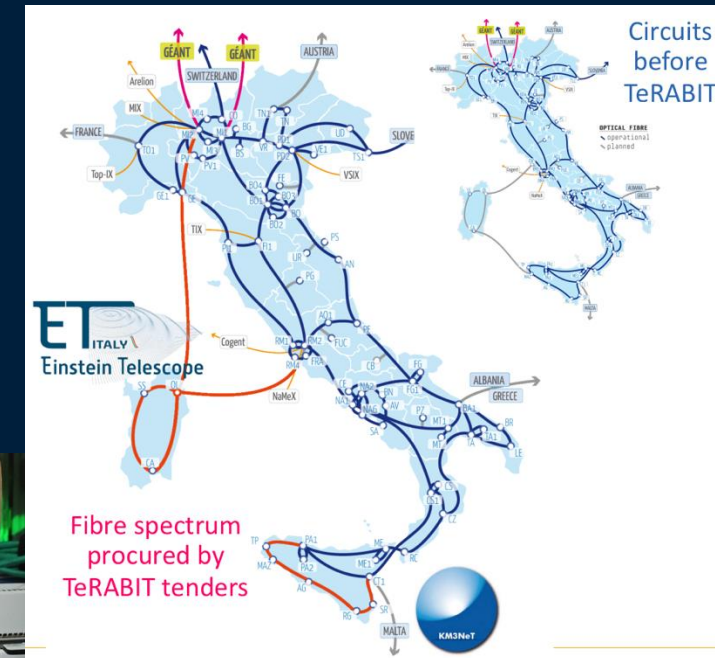
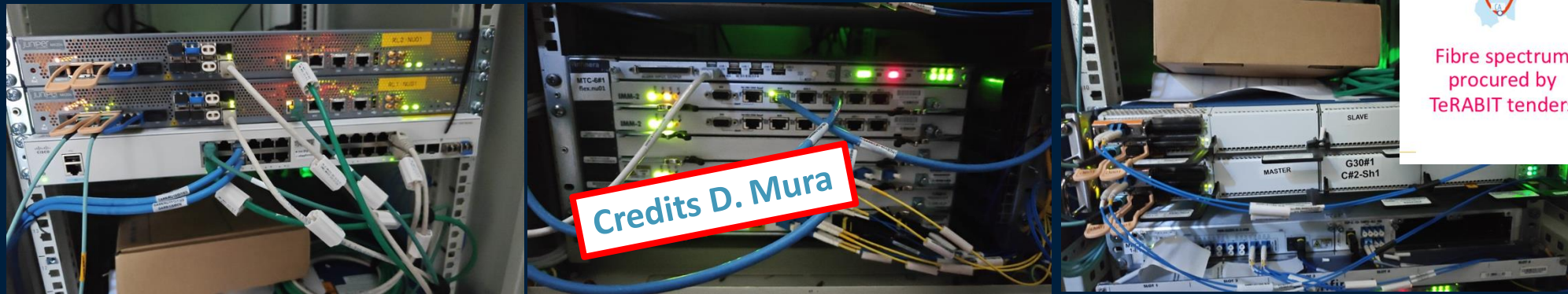


TeRABIT

Terabit network for Research and Academic Big data in Italy

Provide data transfers, up to Terabits per second, between the site in Sardinia and other centers and laboratories in Sardinia, in Italy and Europe.

Necessary hardware installed already in Sos Enattos, connection speed will gradually increase in the coming months



Muon Tomography

Two device types to detect & track cosmic muons to produce Sos Enattos density map:

- Scintillators (J. Marteau et al, IN2P3 - France)
- MWPC (D. Varga, G. Surda et al, HUN-REN Wigner, Hungary)

Data acquisition started in June 2024 and will end in Dec 2025.

Devices moved in Oct 24 as two points are needed to triangulate

Results need a detailed surface map as input(already made available) will follow soon



Activities with students

Regular activities with UniCAàs physics master students:

- Cosmic rays flux with plastic scintillators at different depths and surface (for calibration). Aim at comparing flux prediction from simulations based on rock overhead
- Radon measurements through gamma spectroscopy of carbon samples exposed for 6 days to the mine atmosphere. Radon in the air is absorbed by the carbon through umidity and it is subsequently analysed with a NaI scintillator based gamma spectrometer.

Credits C. Cicalò (INFN)

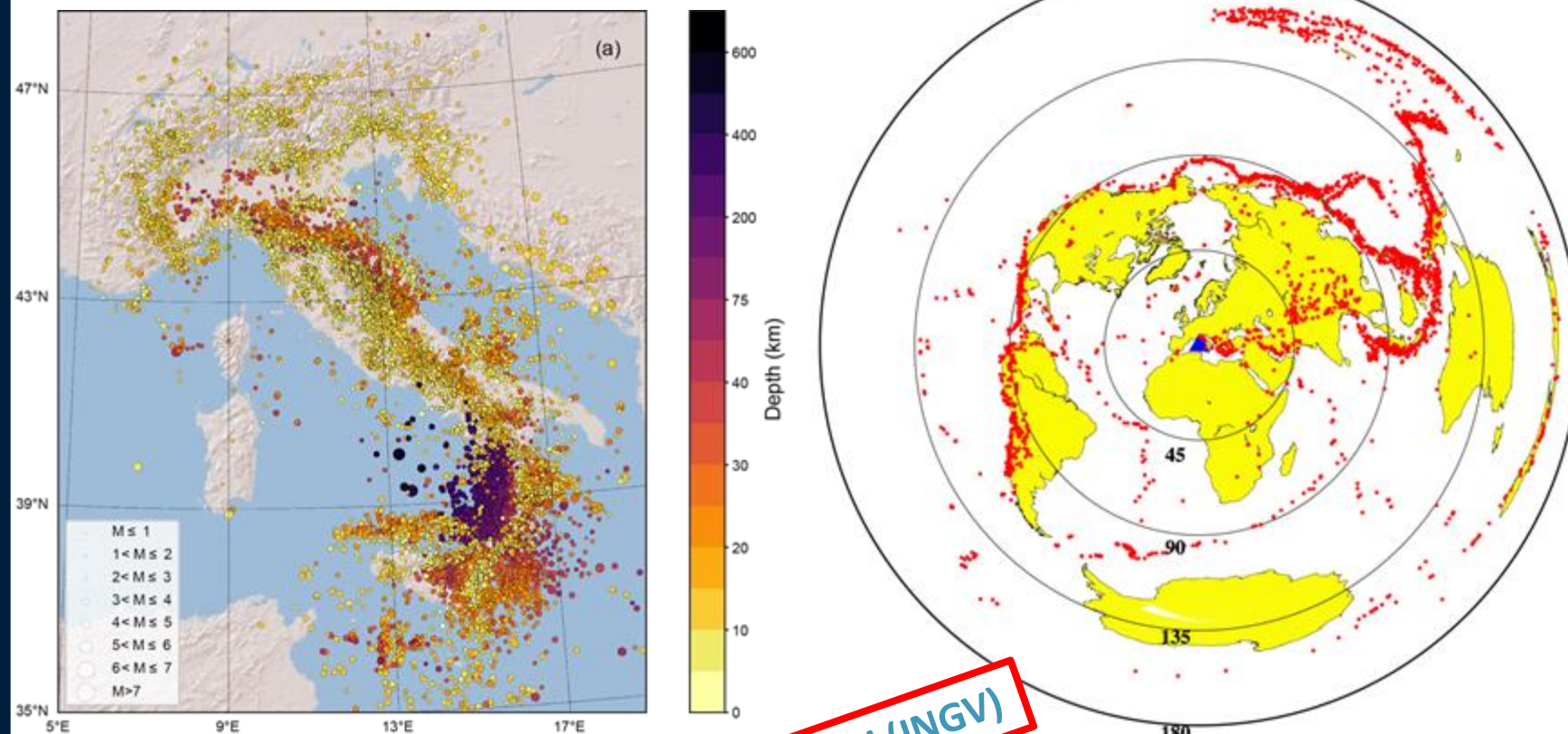




FABER (INGV)



Seismic events 1985-2022



Credits C. Giunchi (INGV)

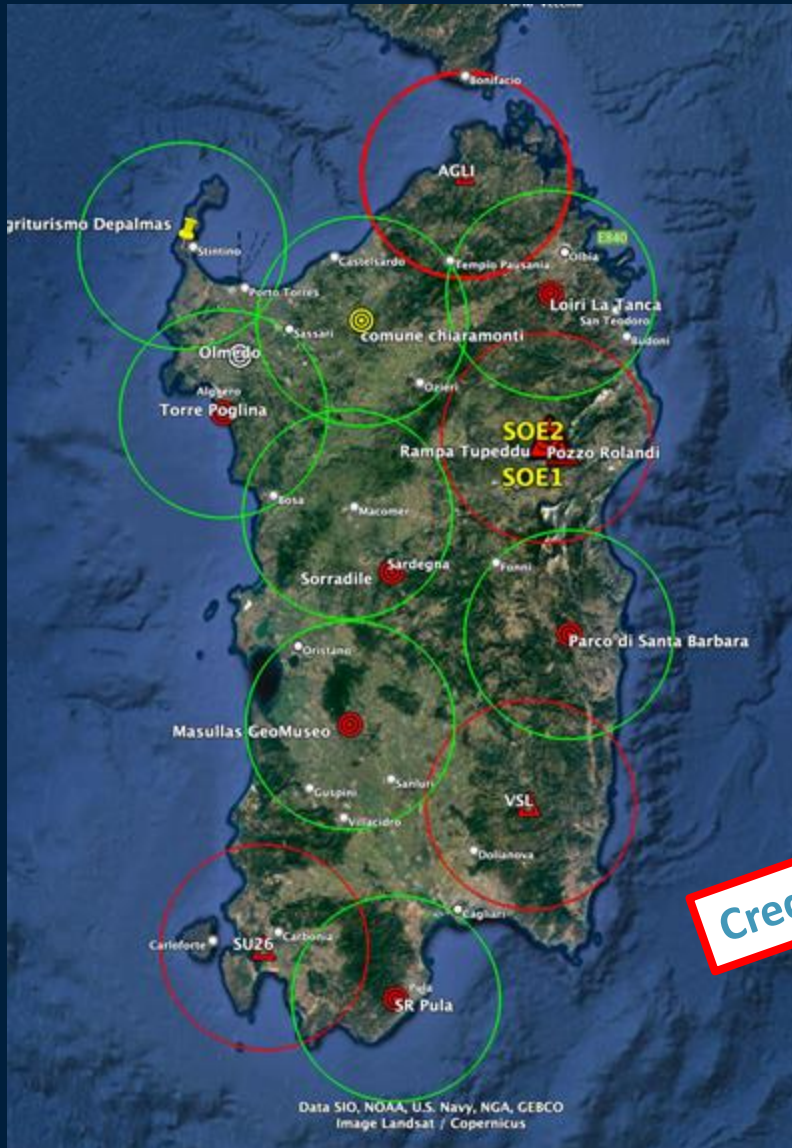
Adria Array (INGV)

- 8 broadband seismic stations
- 2 years

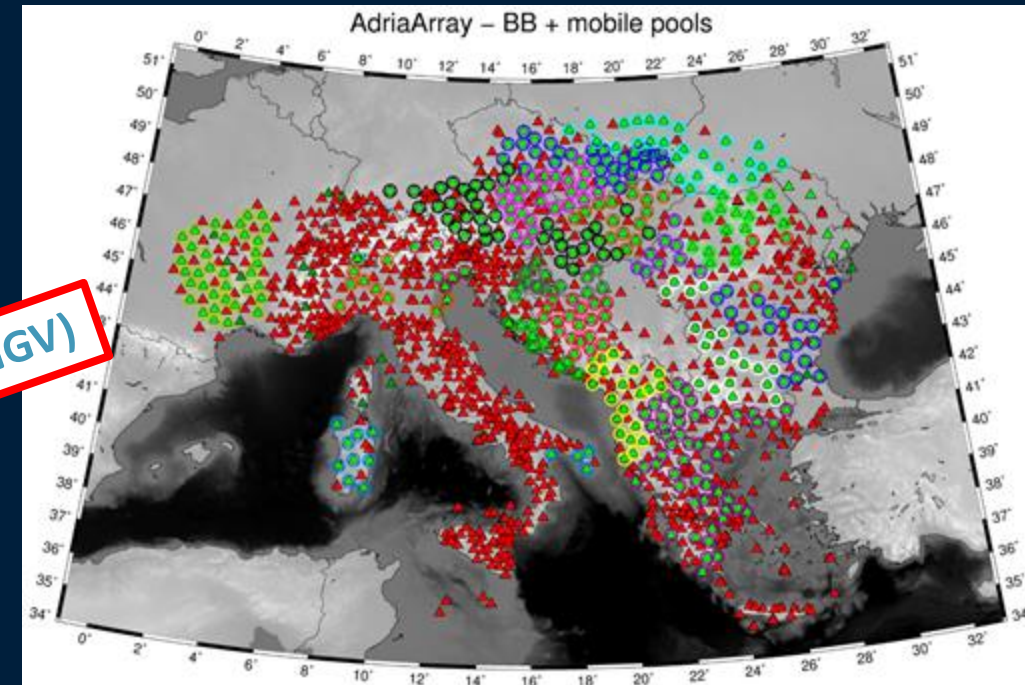


GOALS

- Improve capability to record earthquakes and quarry explosions in Sardinia
- Improving the crustal velocity model
- Contribute to the AdriaArray project to better understand the Adria plate



Credits M. Olivieri (INGV)





ET – SUNLab (INFN + INGV + INAF)



SarGrav will evolve into the new **SUNLab** Research center. Research institutes will coexist to work on enabling ET technologies but also other areas of scientific research

Next year, daily data at the mine will be affected by **working activities**, only data outside working time will be used.

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*, EPJP 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>.

[...]

PUBLICATIONS:

- ❑ L .Naticchioni et al., *Results of the site characterization in Sardinia for the Einstein Telescope*, PoS Proc. Sci., 2023, <https://doi.org/10.22323/1.441.0110>.
- ❑ A. Allocca et al., *Thermal noise-limited beam balance as prototype of the Archimedes vacuum weight experiment and B-L dark photon search*, EPJP 139:158, 2024, <https://doi.org/10.1140/epjp/s13360-024-04920-x>.
- ❑ G. Diaferia et al., *Seismic noise characterisation for the Buddusò – Ala dei Sardi wind park (Sardinia, Italy) and its impact on the Einstein Telescope candidate site*, Solid Earth 16 441–456, 2025, <https://doi.org/10.5194/se-16-441-2025>.
- ❑ F. Villani et al., *Subsurface characterization of crystalline rocks at the Einstein Telescope candidate site (Italy): Insights from seismic tomography, geoelectrical and morphostructural surveys*, Tectonophysics 911, 230830, 2025, <https://doi.org/10.1016/j.tecto.2025.230830>
- ❑ M. Di Giovanni et al., *Impact on signal SNR of local ambient noise recorded at the ET candidate sites*, CQG 42 155001, 2025, <https://doi.org/10.1088/1361-6382/aded67>.
- ❑ R. De Rosa et al., *Magnetic noise characterization of the ET candidate site in Sardinia*, in preparation (2025)

+ several internal notes, reports and talks

Conclusions

The Sos Enattos mine is the center of the Sardinian site characterisation activities and the number of activities keeps growing

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

Besides characterisation activities, the Sos Enattos site with its **SarGrav lab** attracts interests from different communities and it is becoming a place to train students

ET-SUnLab will keep building on the SarGrav success and act as a seed for ET, but also for a deeper cooperation among italian and international research institutes

These results are achieved thanks to the great **collaboration** between Italian and International Research Institutes that have brought together **different and complementary skills and expertise**.

