GRAN SASSO G S S SCHOOL OF ADVANCED STUDIES Scuola Universitaria Superiore

Ambient noise studies in Sardinia for the Einstein Telescope

MATTEO DI GIOVANNI ET SYMPOSIUM 2023





ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA





Outline

- Introduction;
- The Sardinia site and its instrument network;
- Potential ambient noise sources;
- Summary of long term ambient noise studies (2019 2023);
 - noise levels;
 - ambient noise variations by natural sources;
 - ambient noise variations by anthropogenic sources;
- Conclusions and open questions.



Introduction

The paper Temporal variations of the ambient seismic field at the Sardinia candidate site of the **Einstein Telescope** (**DOI** 10.1093/gji/ggad178) has finally been accepted for publication on Geophysical Journal international on 20/04/2023.

Sardinia candidate site:

- Naticchioni et al. (2014) **DOI** 10.1088/0264-9381/31/10/105016
- Naticchioni et al. (2020) **DOI** 10.1088/1742-6596/1468/1/012242
- Di Giovanni et al. (2021) **DOI** 10.1785/0220200186
- **DOI** 10.1140/epjp/s13360-021-01450-8 • Allocca et al. (2021)

This paper completes, for now, the set of publications devoted to the ambient noise characterization of the

JOURNAL ARTICLE ACCEPTED MANUSCRIP

Temporal variations of the ambient seismic field at the Sardinia candidate site of the Einstein Telescope

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Summary

Einstein Telescope (ET) is a proposed underground infrastructure in Europe to host future generations of gravitational-wave (GW) detectors. One of its design goals is to extend the observation band of terrestrial GW detectors from currently about 20 Hz down to 3 Hz. The coupling of a detector to its environment becomes stronger at lower frequencies, which makes it important to carefully analyze environmental disturbances at ET candidate sites. Seismic disturbances pose the greatest challenge since there are several important mechanisms for seismic vibrations to produce noise in ET, e.g., through gravitational coupling, stray light, or through harmful constraints on the design of ET's control system. In this paper, we present an analysis of the timevariant properties of the seismic field at the Sardinia candidate site of ET connected to anthropogenic as well as natural phenomena. We find that temporal variations of source distributions and of the noise spectra generally follow predictable trends in the form of diurnal, weekly, or seasonal cycles. Specific seismic sources were identified such as road bridges, which produce observable disturbances underground. This information can be used to adapt a detector's seismic isolation and control system.

Keywords: Einstein Telescope, Gravitational waves, Time series analysis, Seismic noise, Seismic instruments

Issue Section: Research Paper





Introduction

- 3rd generation gravitational wave (GW) detector Einstein Telescope (ET);
- detectors at the same location (triangle configuration) make ET extremely susceptible to ambient noise sources;
- Properties of seismic noise are influenced by local activities (natural and anthropogenic);
- Investigation of noise sources of human origin is particularly important for future decisions about exclusion zones;
- Gather useful information to adapt the detector seismic isolation and control system.



The proposed ET Triangle foresees three nested interferometers. Being all at the same location, ambient noise plays a crucial role in the correction operation of the detector.

At the beginning of the previous decade, the area surrounding the Sos Enattos mine (Sardinia) was selected as one of the potential sites to host the future

The extension of the observable bandwidth down to 3 Hz, the increased sensitivity with respect to 2nd generation detectors and the presence of three





Proposed ET triangle orientation at the Sardinia Site.



The Sardinia site

- hosts the SarGrav laboratory and the Archimedes experiment;



Main well

Former mineral processing unit

• Sos Enattos is a former lead and zinc mine active from the Roman age until the late 1990s;

• Today it is not abandoned and is still maintained for environmental safety and guided tours and









SarGrav laboratory





The Sardinia site

vertices of the interferometer have also been identified



The Onani corner

According to the current proposed orientation for the ET Triangle, the sites to host the actual



The Bitti corner







Permanent Instrument Network

Since 2019, in Sos Enattos there are:

- 4 permanent seismic stations for long term studies:
 - Surface: SOE0;
 - Underground: SOE1, SOE2, SOE3;
- 1 weather station;
- 1 microphone (SOE2)
- 2 magnetometers;
 - Surface: control room;
 - Underground: SOE2;
- All permanent seismic stations are provided with broadband seismometers (Trillium 240, 360 and 120 Horizon, Guralp 360);





Permanent Instrument Network



Permanent Instrument Network

In 2021, more permanent sensors have been installed at 2 of the proposed vertices (P2/3):

- 2 broadband seismometers on surface;
- 2 broadband seismometers in borehole;
- 1 magnetometer at P2

In the near future, more sensors will be installed also at P1.







Potential noise sources

We identified some potential noise sources, both of natural and anthropic origin. Some of them have been clearly identified and characterized. Other are still being investigated to assess their contribution to the overall background noise in Sos Enattos.

- Natural:
 - microseisms;
 - wind;
- Anthropic:
 - day/night cycle from human activities (mainly farming activities);
 - two road bridges in the neighborhood of the mine;
 - wind farms;







Noise levels

- Noise level in Sardinia are very low and hits the self noise of the seismometers;
- The seismic stations have an excellent raking when compared against other quiet seismic stations all around the world;
- For more details see Naticchioni et al. (2014, 2020) and Di Giovanni et al. (2021, 2023) 10^{-6}







Ambient noise variations (natural sources)







Ambient noise variations (natural sources)







Wind effects

Natural to anthropogenic transition



Ambient noise variations (anthropic sources)



Day/night - weekdays/weekend variations



Noise level variation during the 2020 COVID lockdown

Noise level variation during the 2019 summer holidays

Identification of a noise source in Sos Enattos

• At the beginning of 2021, the deployment of a seismic array by INGV at Sos Enattos, revealed the presence of spectral peaks that seemed compatible with the presence of two road bridges nearby;

Identification of a noise source in Sos Enattos

• At the end of 2021, GSSI deployed 5 geophones for five days to confirm the origin of those peaks.

Identification of a noise source in Sos Enattos

- Spectral correlation confirmed the origin of those peaks;
- The distance of the bridges from the site is no more than 1.5 km;
- Those peaks also have a seasonal frequency drift with different rates;
- This may be caused by temperature variations that change the vibrational properties of the structures;
- Engineers observe drift to lower frequencies as the temperature increases and vice-versa as the temperature decreases;

Identification of a noise source at P3

Right - spectral cross correlation between the two seismometers closest to the tower (about 20m each)

Wind turbines

- Some small wind turbines are located in the area close to P2 and P3;
- According to Westwood et αl. 2015, noise from small low-power turbines exhibits a significant attenuation already at 200m;
- Up to now, data from P2 and P3 do not show peaks of seismic origin that can be related to wind turbines;
- The lack of a weather station at P2 and P3 still prevents a more detailed study;
- At the moment, the our attention is devoted to the Buddusò wind park, 15 km away;
- According to studies for the Virgo site (Saccorotti et al.) 2011), big wind parks can produce peaks at less than 2.5 Hz and visible up to 10 km.

Conclusions

- The Sardinia site is the object of a thorough site characterization campaign (see also other presentation of this session);
- Noise levels generally very low in the frequency band of interest for ET;
- Seismic ambient noise studies revealed which are the dominant noise sources at the site;
- Up to now, besides the day night cycle of normal human activities, the only clear source of noise of anthropic origin at the site are the two bridges at Sos Enattos;
- Studies to asses the contribution of the wind turbines are still underway.

