Sardinia Site Characterisation Activities
Luca Naticchioni (INFN Roma)
on behalf of the ET Sardegna site characterisation team
Summary

- **Introduction: The Sos Enattos site in Sardinia**
- **Characterisation of the Sos Enattos corner**
- **First results at Sos Enattos**
- **Characterisation of the other two corners**
- **Conclusions**
The Sos Enattos site in Sardinia

Site access: 50’ (85km) drive from Olbia airport (SS 131 highway)
SarGrav underground laboratory

Sardinia Radio Telescope

“ARIA” project (for Gran Sasso Dark Side DM det.)

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The Sos Enattos site in Sardinia

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The Sos Enattos site in Sardinia

Sos Enattos former mine

- Maintained (by IGEA SpA) underground access via tunnels and shaft;
- Site studied in 2010-2014. **Long-term sensors deployment since March 2019**;
- Hosts the **SarGrav Laboratory** (→ talk by D. D’Urso).
The Sos Enattos site in Sardinia
Site Characterisation

- Seismic noise at the triangle corners (Sos Enattos, Bitti and Onanì);
- Other environmental noises in the area (magnetic, acoustic...);
- Local geology (rocks, groundwater...);
- Seismic field and Newtonian noise modelling at the site.

- ET requirements check;
- Site qualification;
- Possible site-dependent choices for the detector design.

Talks by:
- G. Saccorotti & E. Calloni
- R. De Rosa
- G. Oggiano
- J. Harms & T. Andric

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Characterisation of Sos Enattos

Measurement stations at the Sos Enattos site:

- SarGrav surface Lab + Control Room;
- SOE0 (surface);
- SOE1, SOE2, SOE3 (86m, 111m, 160m underground).

Sensors currently installed:

- 4 broadband triaxial seismometers (Nanometrics Trillium 240 and 120horizon);
- 2 magnetometers (MF6-06);
- 3 short-period triaxial seismometers (Nanometrics Trillium 20PH, first seed of a surface array);
- High Precision Tiltmeter (part of the Archimedes experiment @ SarGrav → talk by L. Errico)
- Weather station (@ SarGrav Lab).

Work in progress: new sensors (seismometers and geophones, magnetometers, microphones) will be added to the network in the next months
Sos Enattos measurement stations (2019-2020)

Rampa Tupeddu entrance

SarGray Control Room (340 m asl)

SOE1 (-84 m)

SOE2 (-111 m)

SOE0 (400 m asl)

Control Room + Surface Lab
Sos Enattos measurement stations (since Aug. 2020)
Characterisation of Sos Enattos

SARGRAV surface lab & control room

MFS06 Magnetometer buried at surface close to the SarGrav control room

DAQs, Network connections, weather stations, Archimedes tiltmeter

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Characterisation of Sos Enattos

SARGRAV surface lab & control room

New (large) experimental area in preparation

DAQs, Network connections, weather stations, Archimedes tiltmeter

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Characterisation of Sos Enattos

SOE0 station (since December 2019)

TRILLIUM 240s + Taurus DAQ
Characterisation of Sos Enattos

**SOE1 station** (84m underground, *Mar. 2019 – June 2020*)

**TRILLIUM 240s + Taurus DAQ**

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**SOE1 station** (84m underground, *since June 2020*)

**TRILLIUM 120 Horizon + Centaur6 DAQ**

DAQ input range reduced to 4Vpp (WRT 40Vpp standard settings);

→ Effective reduction of DAQ self noise in the few Hz band;

→ Measured noise floor hits the Earth Person’s Low Noise Model.

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Characterisation of Sos Enattos

SOE2 station (111m underground, since March 2019)

Double wall + insulation box + *pasta-pot* insulation

*TRILLIUM 240s + Centaur6 DAQ*
Characterisation of Sos Enattos

**SOE2 station** (111m underground, *since March 2019*)

Double wall + insulation box + *pasta-pot* insulation

Magnetometer MFS-06
Characterisation of Sos Enattos SOE2 station (111m underground, since March 2019)

SOE2 station is integrated into the Italian national seismometer network of INGV (SENA station)

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

Public data access

NB: standard DAQ input range (40Vpp)
Characterisation of Sos Enattos SOE3 station (160m underground, since Aug. 2020)

TRILLIUM 240 + Taurus DAQ
DAQ input range reduced to 4Vpp as in SOE1
Characterisation of Sos Enattos

Local noise sources and Newtonian Noise modelization

Surface Seismometers Array

A surface array made of tens of seismometers and geophones (provided by INFN+INGV) is planned to be installed at Sos Enattos ({delayed due to COVID-19 emergency}).

→ Talk by Gilberto Saccorotti

Locations of 15 Reftek seismometers
Characterisation of Sos Enattos

Local noise sources and Newtonian Noise modelization

Surface Seismometers Array

First deployment of 3 Trillium 20 seismometers in the Sos Enattos area in November!
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First results at Sos Enattos

The results of the first year of seismic characterisation at the Sos Enattos corner have been published in:

- L. Naticchioni et al., *Characterization of the Sos Enattos site for the Einstein Telescope*, JPCS 1468, 2020

- M. Di Giovanni et al., *A seismological study of the Sos Enattos Area – the Sardinia Candidate Site for the Einstein Telescope*, SRL, https://doi.org/10.1785/0220200186

**A Seismological Study of the Sos Enattos Area—the Sardinia Candidate Site for the Einstein Telescope**

Matteo Di Giovanni¹,²,³, Carlo Giunchi⁴, Gilberto Saccorotti⁴, Andrea Berbellini⁴, Lapo Boschi⁴,⁵,⁶, Marco Olivieri⁴, Rosario De Rosa⁷,³, Luca Naticchioni⁵,⁶, Giacomo Oggiano⁸,⁹, Massimo Carpinelli¹,¹², Domenico D’Urso¹¹,¹², Stefano Cuccurù¹¹,¹², Valeria Sipala¹¹,¹², Enrico Calloni¹,³,⁸, Luciano Di Fiore¹, Aniello Grado¹, Carlo Migoni¹⁴, Alessandro Cardini¹⁵, Federico Paololetti¹⁶, Irene Fiori¹⁰, Jan Harris¹,²,³, Etienne Mainfray⁷,³,⁸, Pierre Ravegnani⁸,¹⁰, Fulvio Bicc¹⁰,¹⁰, and Michele Butillo¹⁰

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First results at Sos Enattos

Low anthropic noise, no significant amplification effects

In the 1-10Hz band Sos Enattos is among the quietest sites in the world

Microseisms correlation with NW 4.5s Med Sea waves

\[ \text{Talk by G. Saccorotti} \]
First results at Sos Enattos

Reduced input range $\rightarrow$ reduced DAQ self noise $\rightarrow$ environmental seismic noise floor below the standard seismometer settings in few Hz band, close to NLNM (here SOE1, 84m depth)

SOE01 Old installation

SOE01 New installation

May to June 2020

June to August 2020

Talk by G. Saccorotti
First results at Sos Enattos

Vertical ASD 2020 June-October

Input range 4Vpp
Input range 40Vpp

SOE2 ranking among 445 stations of IRIS network

PSD at 4.1 Hz

PSD at 4.9 Hz

→ Talk by G. Saccorotti
First results at Sos Enattos

Very low electromagnetic noise observed at the site!

SOE2 (underground) magnetometer.

More details in the talk by R. De Rosa!
First results at Sos Enattos

More details & results in the these talks:

- G. Saccorotti (*seismic noise measures and analysis*)
- E. Calloni (*seismic glitch analysis and implications*)
- R. De Rosa (*environmental noise measures and analysis*)
- L. Errico (*Archimedes tiltmeter measures at Sos Enattos*)
- T. Andric (*NN cancellation & numerical simulations in Sardinia*)
- G. Oggiano (*local geology*)
- D. D’Urso (*SarGrav Laboratory status*)
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Characterisation of the corners

Surface and underground seismic and environmental measurements are planned in 2021 in the other two corners (named Bitti and Onanì).

Lula Corner
Sos Enattos

Onanì Corner

: area for boreholes and surface arrays
: proposed locations for ET main caverns

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Characterisation of the corners

Bitti corner, borehole area

Onanì corner, borehole area

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Characterisation of the corners

250m-deep boreholes at the two corners (P2, P3):
- Ongoing call for tenders, **excavation start in January 2021**;
- Borehole sensor: **Nanometrics Trillium 120 BH Slim**;
- Surface sensor: **Nanometrics Trillium 120 Horizon**;

**Surface measurements at P2, P3:**
- **Active seismic**: vibroseis truck + seismometer array;
- **Passive seismic**: 2-weeks long surface seismometer array (10x T20, 40x geophones);
- **Environmental**: magnetometer and microphones;
- **Georesistivimetric** (groundwater) survey of the surrounding area.
Conclusions

- Long-term site characterisation is ongoing at the Sardinia site: seismic and environmental monitoring at Sos Enattos, planned at the two corners (surface and boreholes, beginning 2021);
- Sinergy with SarGrav Lab activities;
- Public data (SOE2/SENA) + ET Repository (full data + analysis routines);
- First results: the seismic noise is very low (close to NLNM), even at surface, due to no involvement in active tectonics (→low crustal velocity and crustal deformation) and to low population density (→low anthropic noise for $f > 1Hz$, at few Hz one of the quietest sites in the world);
- Low environmental noise: EM noise in underground stations is extremely low;
- Good geomechanical properties of rocks, few groundwater, easy access from existing airports/highway…

The Sos Enattos area is an optimal site for the Einstein Telescope!

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Thank you for your attention!

...few km from the site!