Group 2 & Group 3 activities

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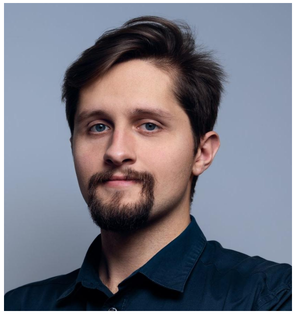
APC-Astrocent Annual meeting
Warsaw 20 December 2023

Group 3
Electronics and Data Acquisition and Processing - Members


Mariusz Suchenek (leader)


Marcin Ziembicki (postDoc)


Marek Cieślar (postDoc)


Mateusz Pietrzak (phd student)


Andrzej Rychter (technician)


Kamil Rudnicki (technician)


Edit Fenyvesi (postDoc)

Group 2 & Group 3 - Activities

Measurement campaigns:

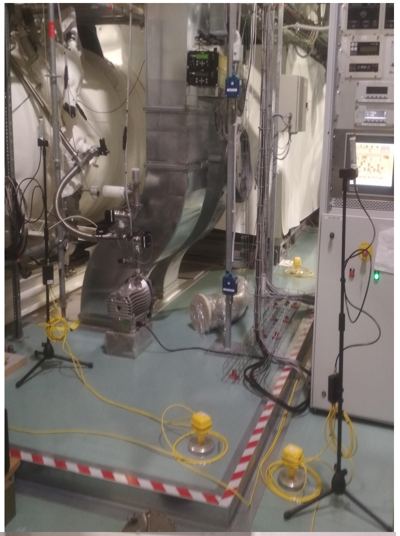
- Seismic campaign in Sardinia (ET, 2022)
- Infrasound campaign in Sardinia (ET 2022/2023)
- VIRGO seismic and infrasound sensors installation and maintenance (VIRGO)
- Maastricht ETpathfinder seismic and infrasound preparation (ET installation in 2024)
- Seismic and infrasound measurements in LNGS, Laboratori Nazionali del Gran Sasso (ET 2023)

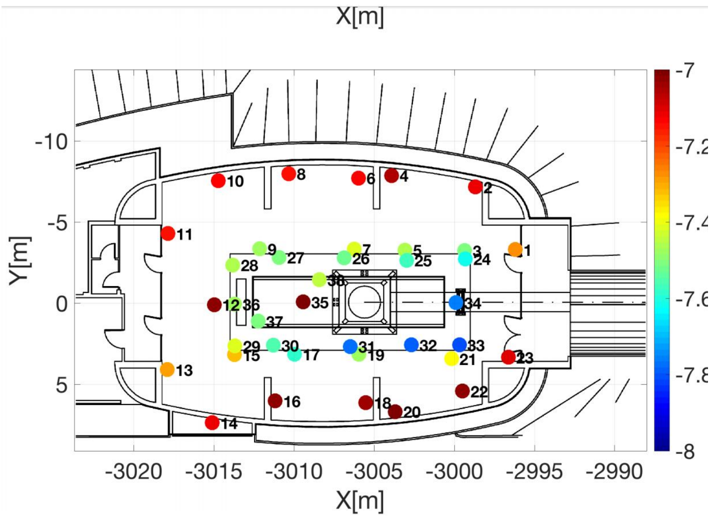
Data analysis and modeling:

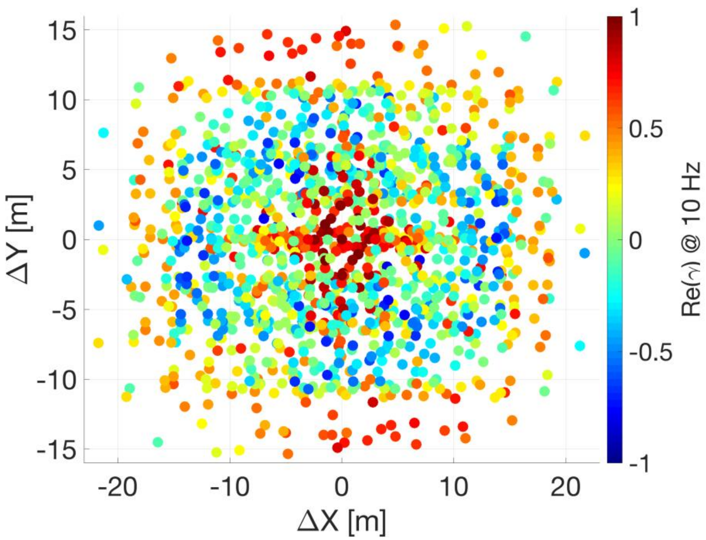
- Detection gravitational wave signals from binary black with deep learning - W. Alhassan
- Modeling quartz resonators - M. Pietrzak
- Data aqusition from a photomultipliers - M. Ziembicki

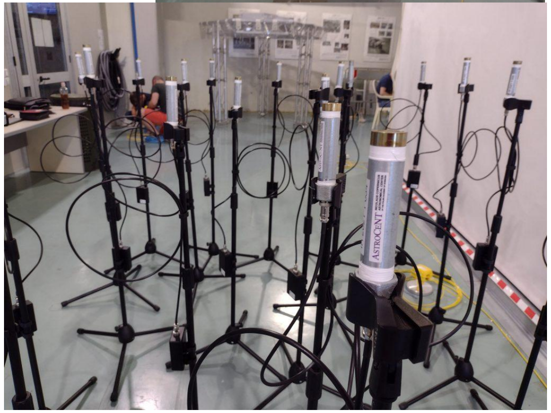
VIRGO seismic and infrasound sensors

- We are responsible for over 120 seismic and infrasound sensors installed in VIRGO buildings (North, West and Central)
- Sensors create a network which mitigates Newtonian Noise and increases sensitivity of gravitational wave detector
- We use a modified IT infrastructure, modified with sensor synchronization and power supply



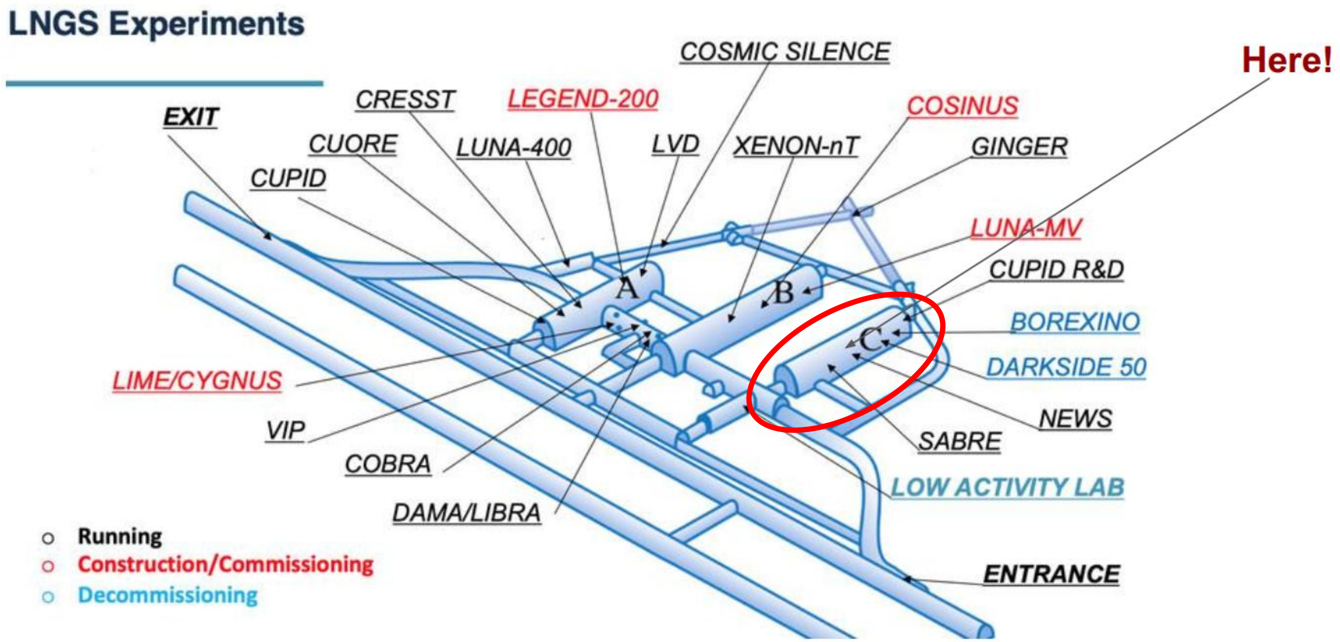






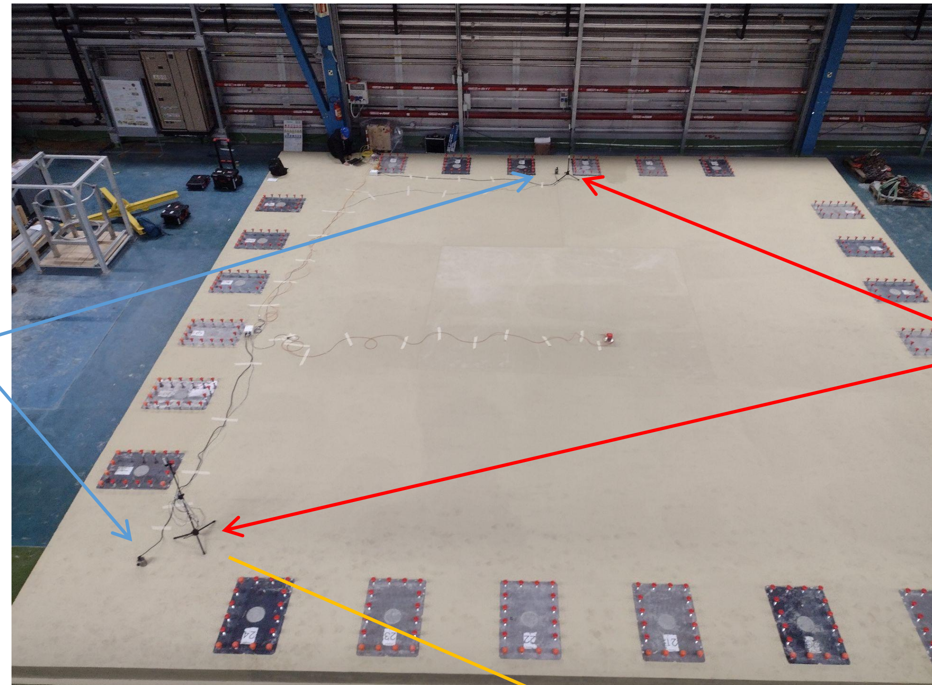
The infrasound and seismic installation

- Characterization of the infrasound and seismic field underground, a place similar to the destination site for the telescope and other experiments
- Seismic and infrasound noise are the components of the Newtonian noise
- 22 days of data, 06.03-28.03 2023
- Data stored at intra.astrocent.camk.edu.pl - available for all
- Sensors placed in Hall 1 with existing experiments

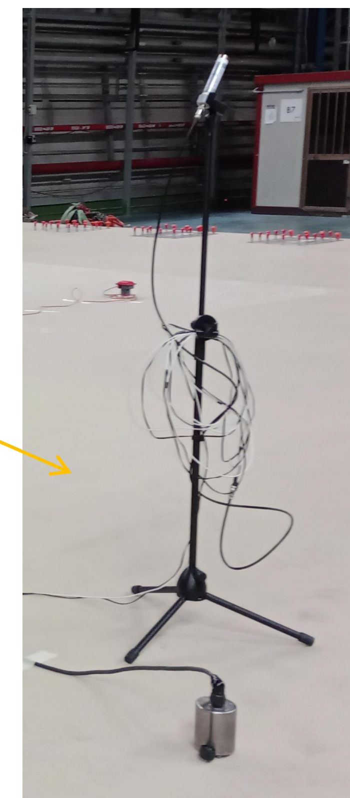


The infrasound and seismic installation

2x seismometers



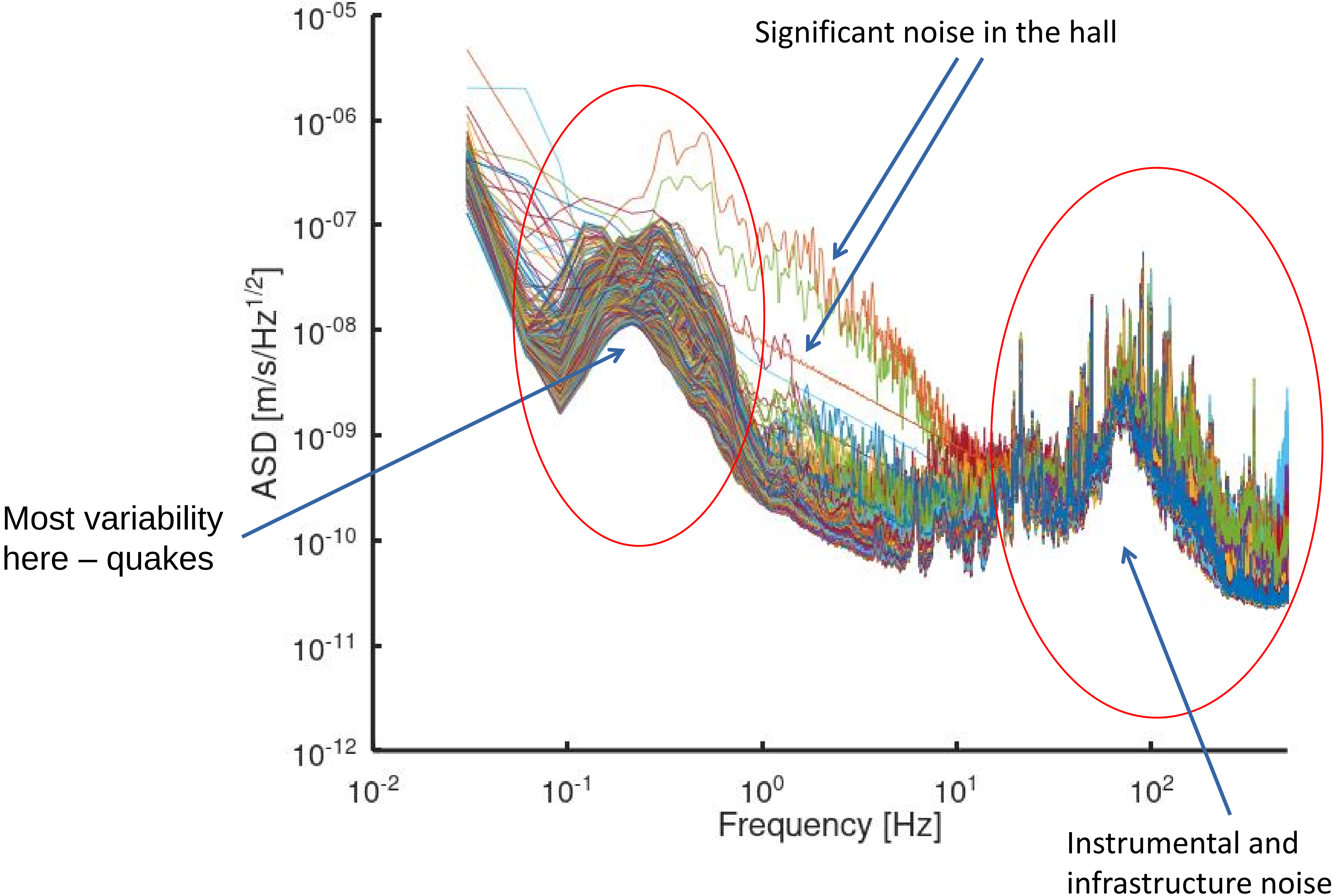
2x microphones



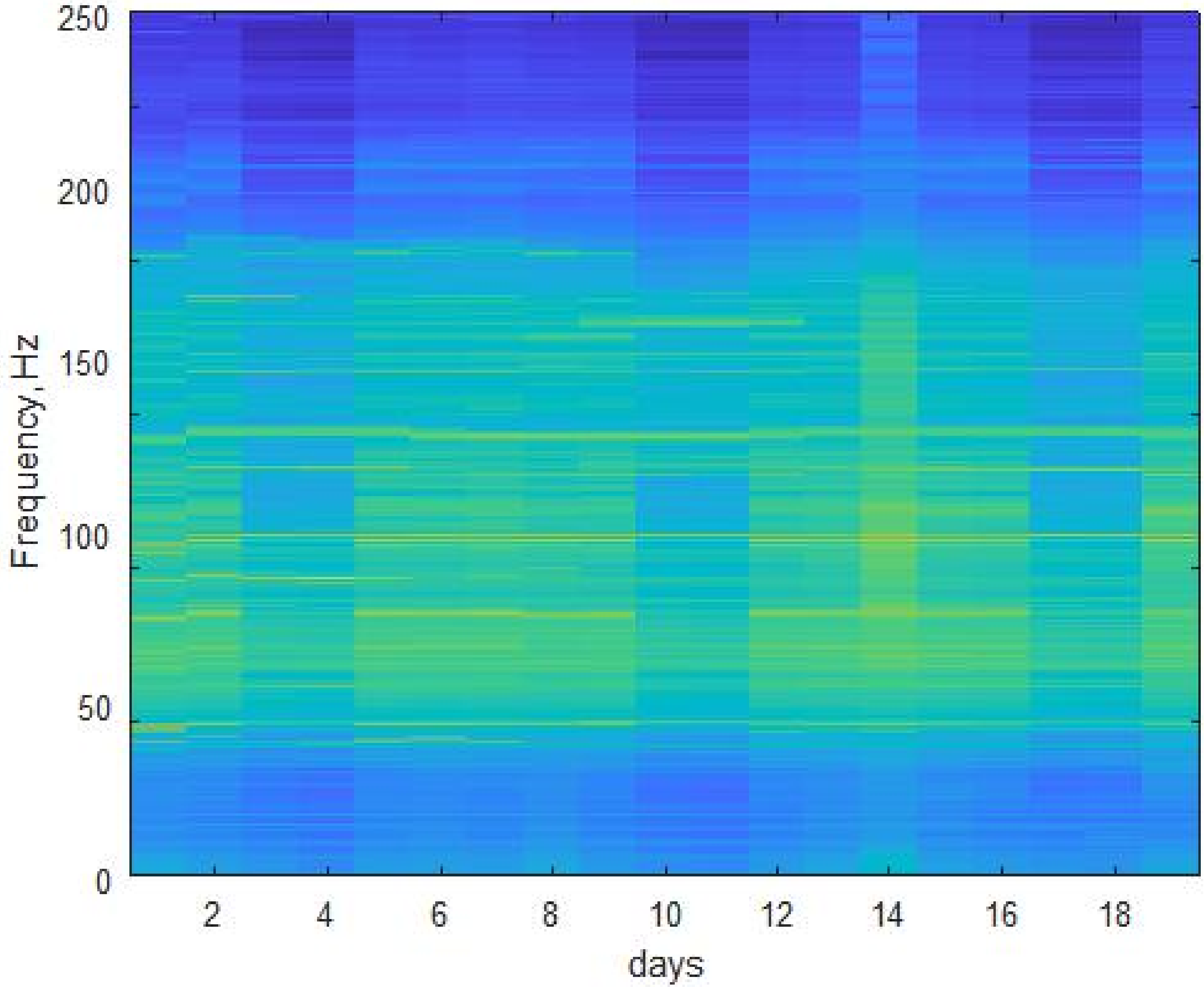
- sensors placed on a concrete foundation

prepared for the darkwave experiment

Seismic spectra



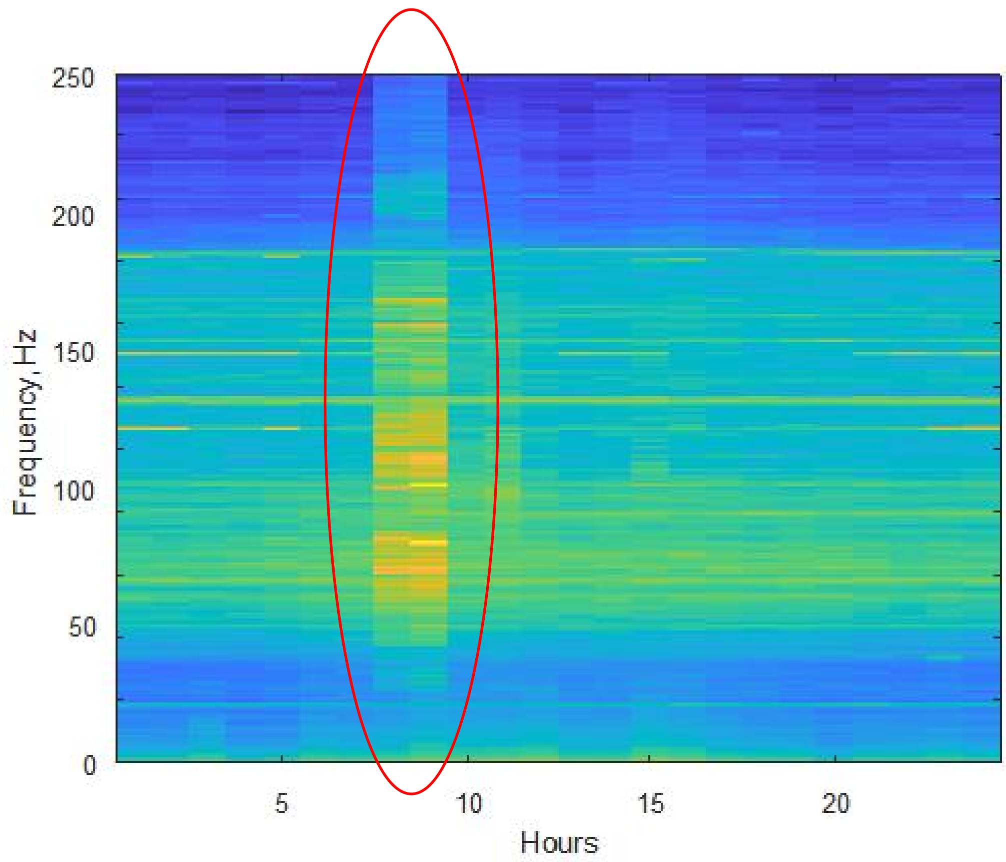
Seismic spectra - 22 days

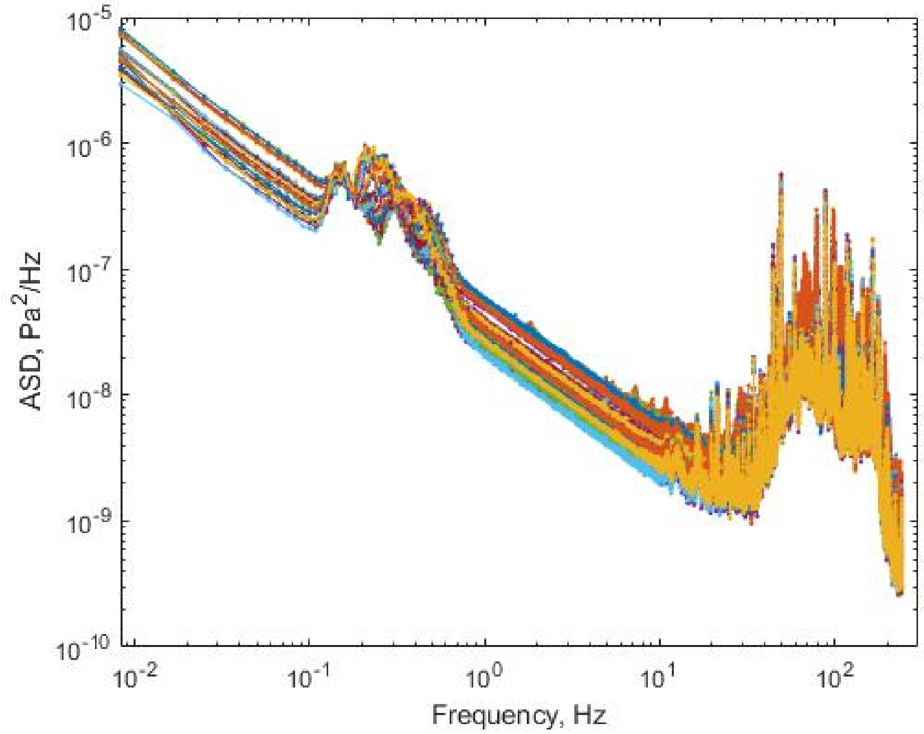


Seismic spectra - 10.03.2023 (24 hours)

- for 2 hours (8.00-10.00) significantly higher

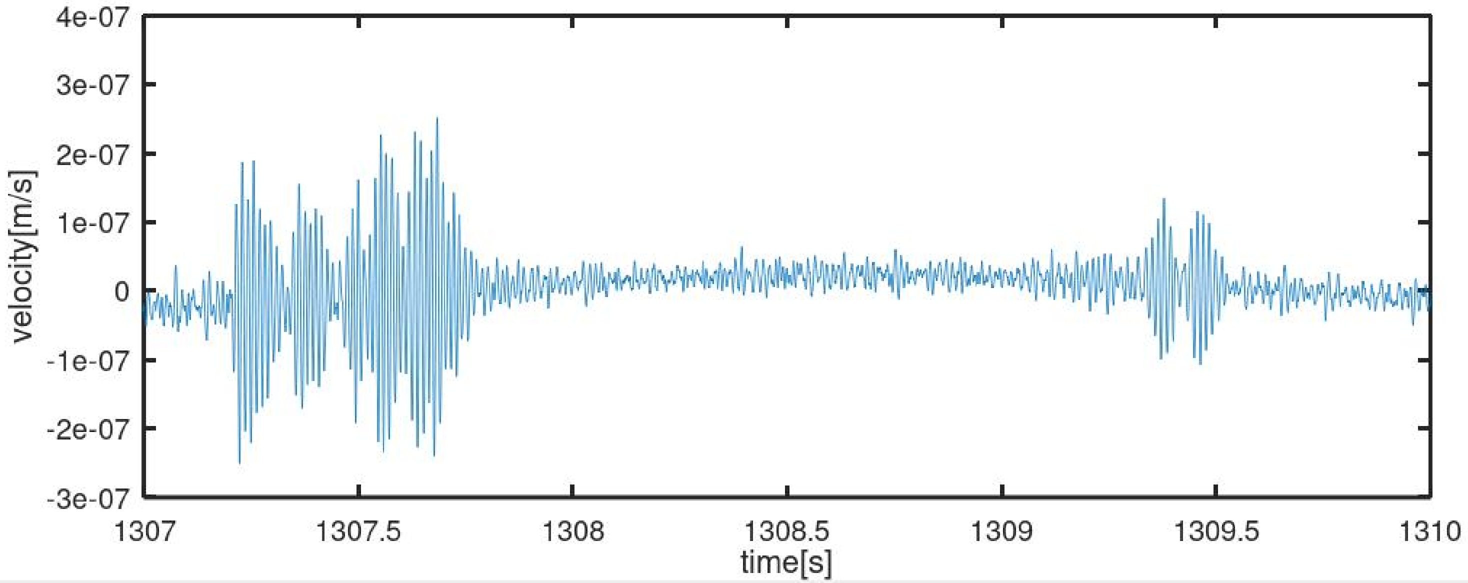
seismic noise, inflates the average



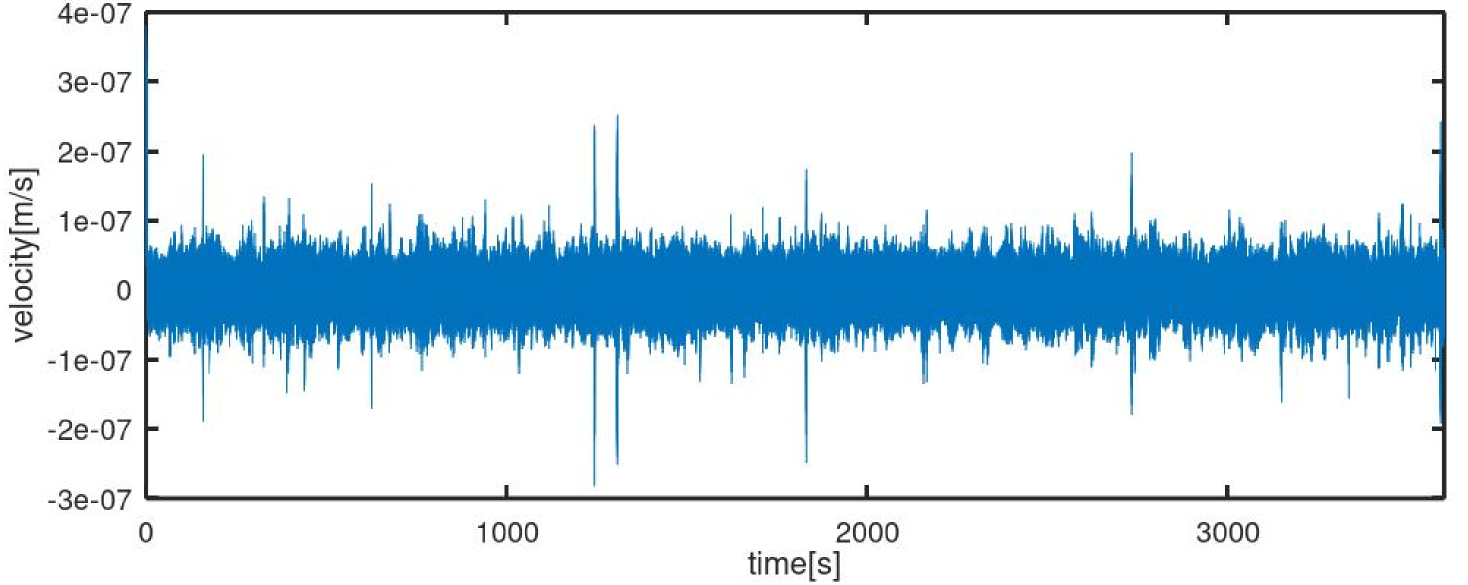


Typical microquake

- RAW data, velocity

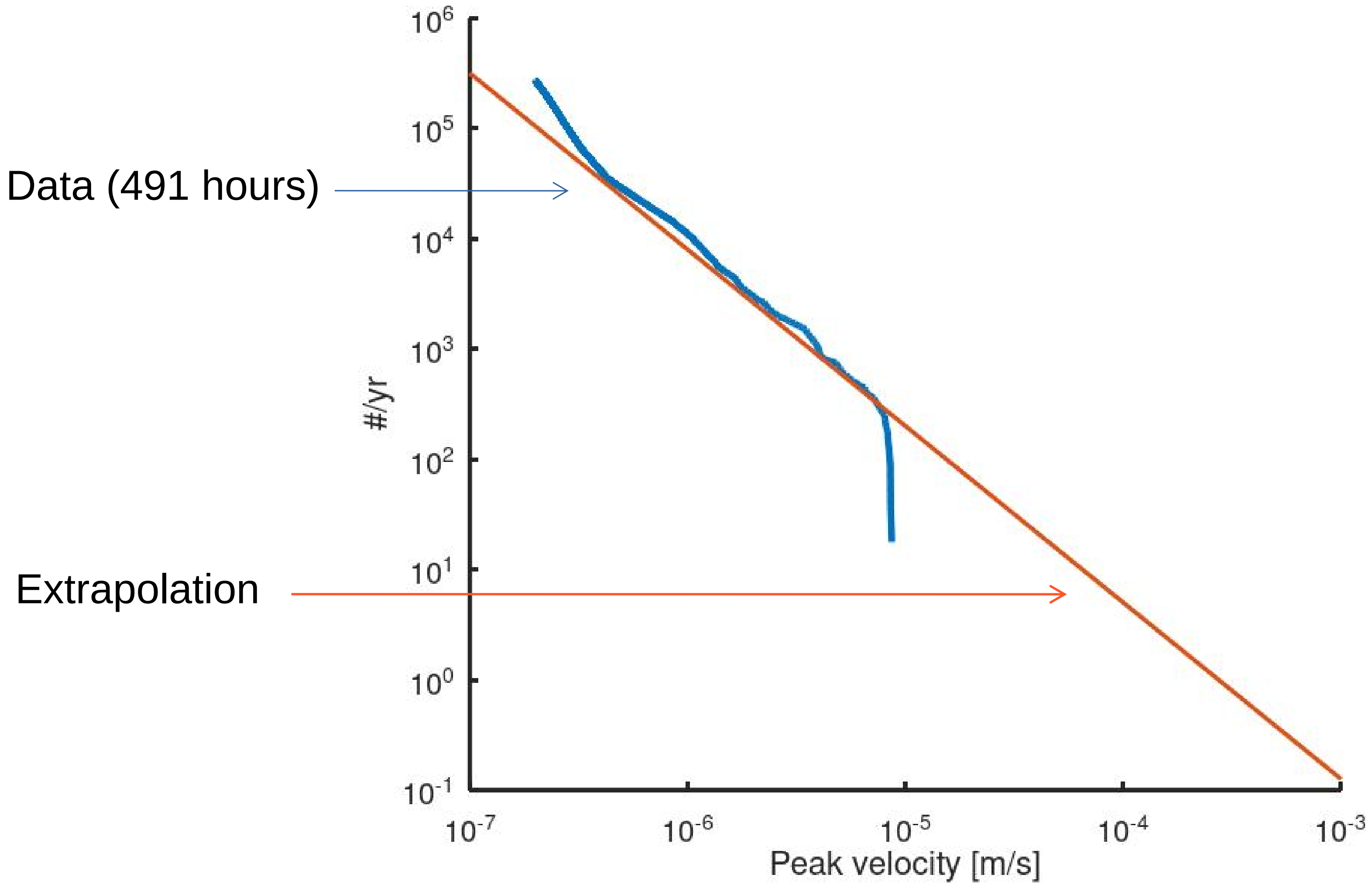


- Typical data (high pass filtered)

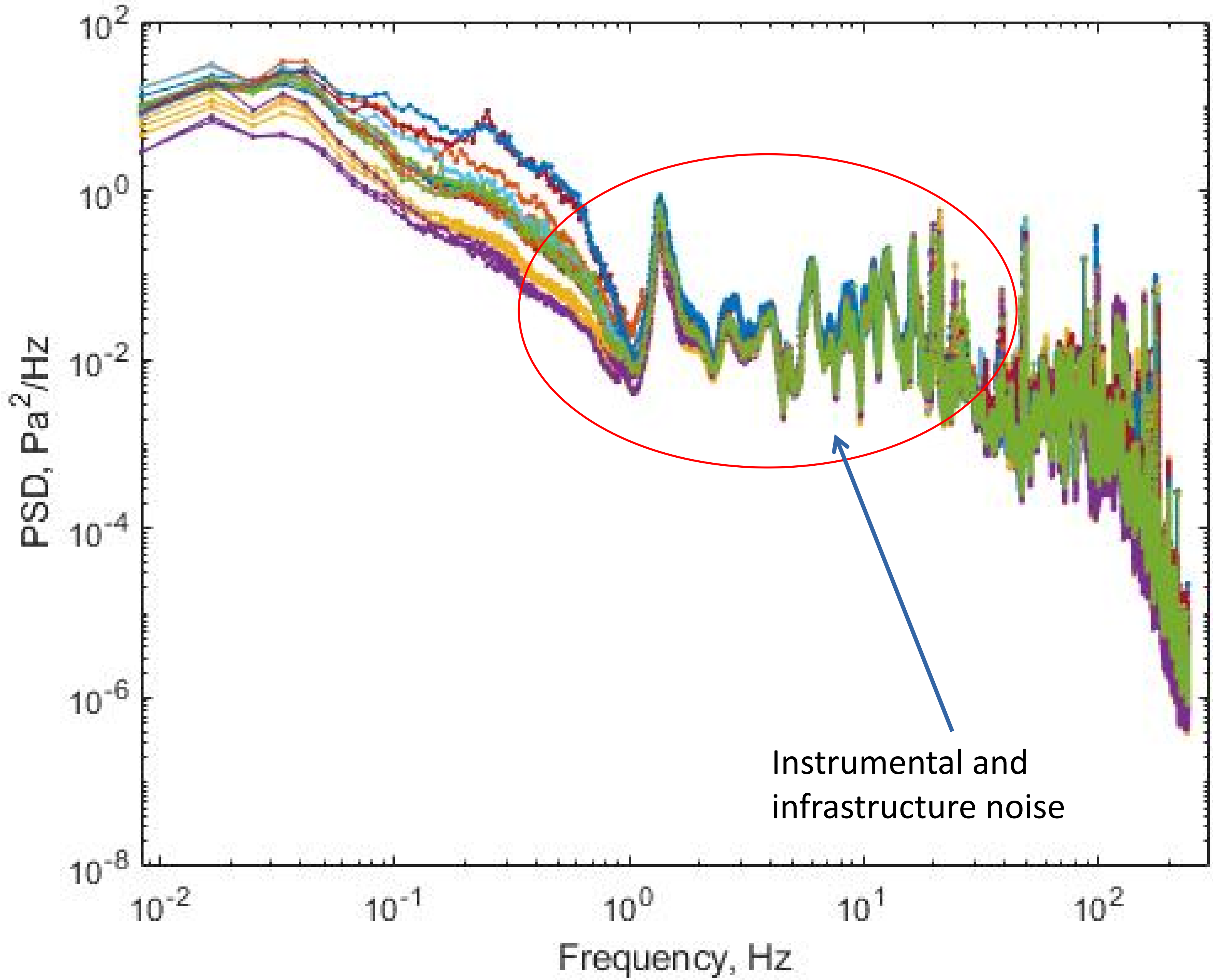


Quake frequency

- Expect a strongest quake with peak maximum velocity over 1 s of 1 mm/s, in 10 years
- 491 hours / 24 = 20,45 days



Sound spectra - averaged 22 days



Acoustic response of the hall

- hall dimensions, approx 100 m x 20 m x 25 m - acoustic resonator

$v \sim 350$ m/s,

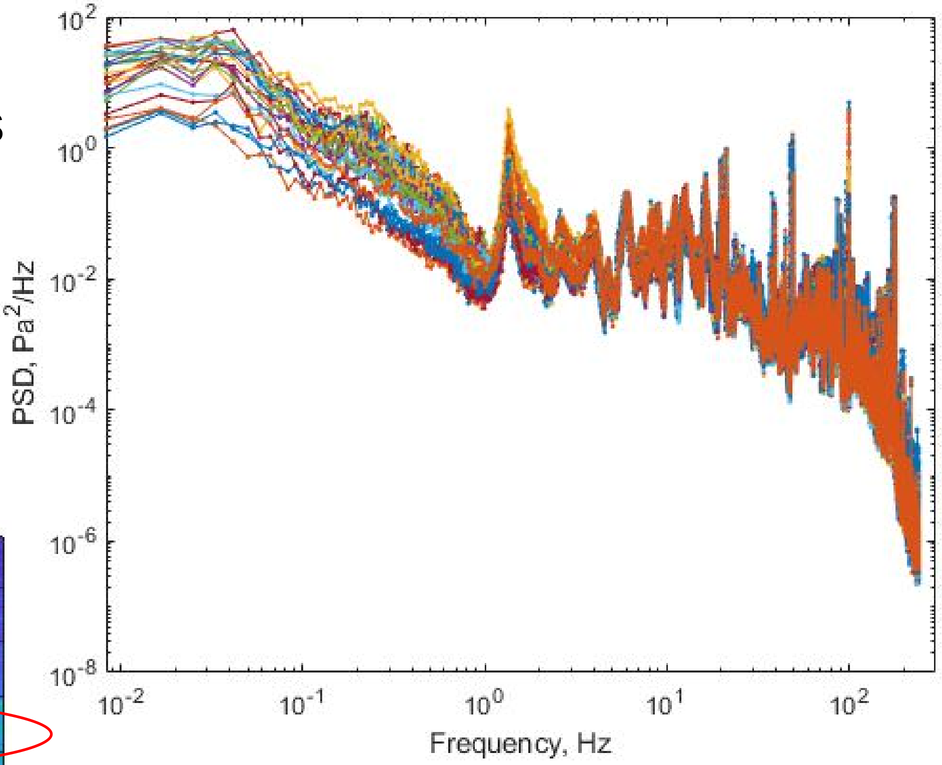
Estimation:

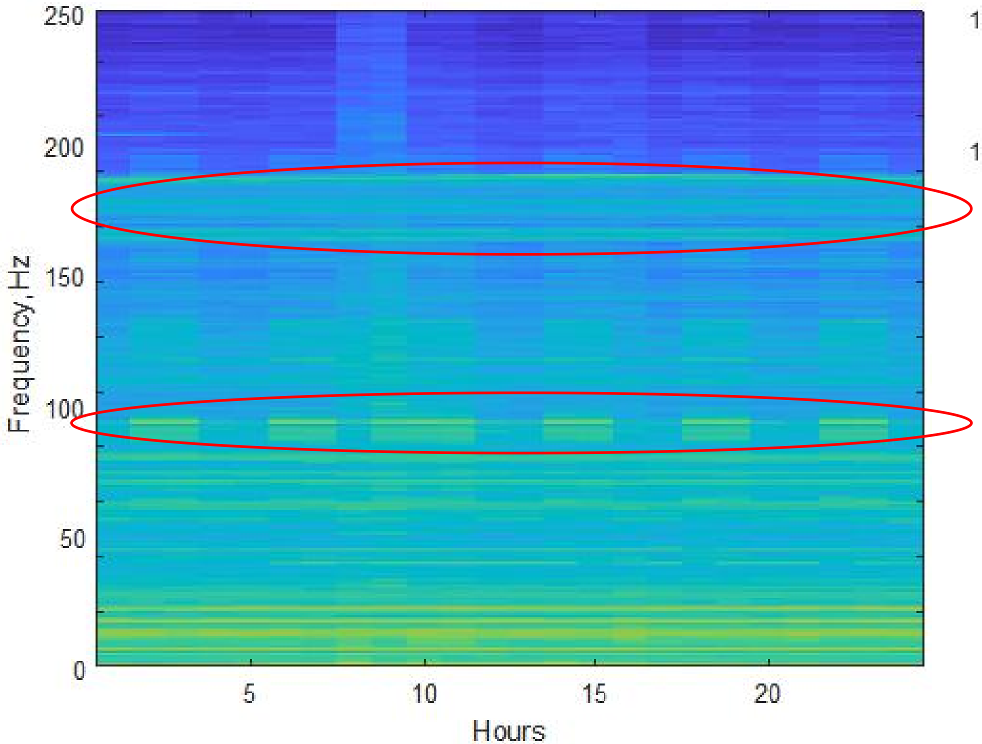
$f = 10$ Hz $\lambda = 35$ m ($\lambda/2 = 17.5$ m)

$f = 3.5$ Hz $\lambda = 100$ m ($\lambda/2 = 50$ m), $f = 1.75$ Hz $\lambda = 200$ m ($\lambda/2 = 100$ m)

Sound spectra - 10.03.2023 (24 hours)

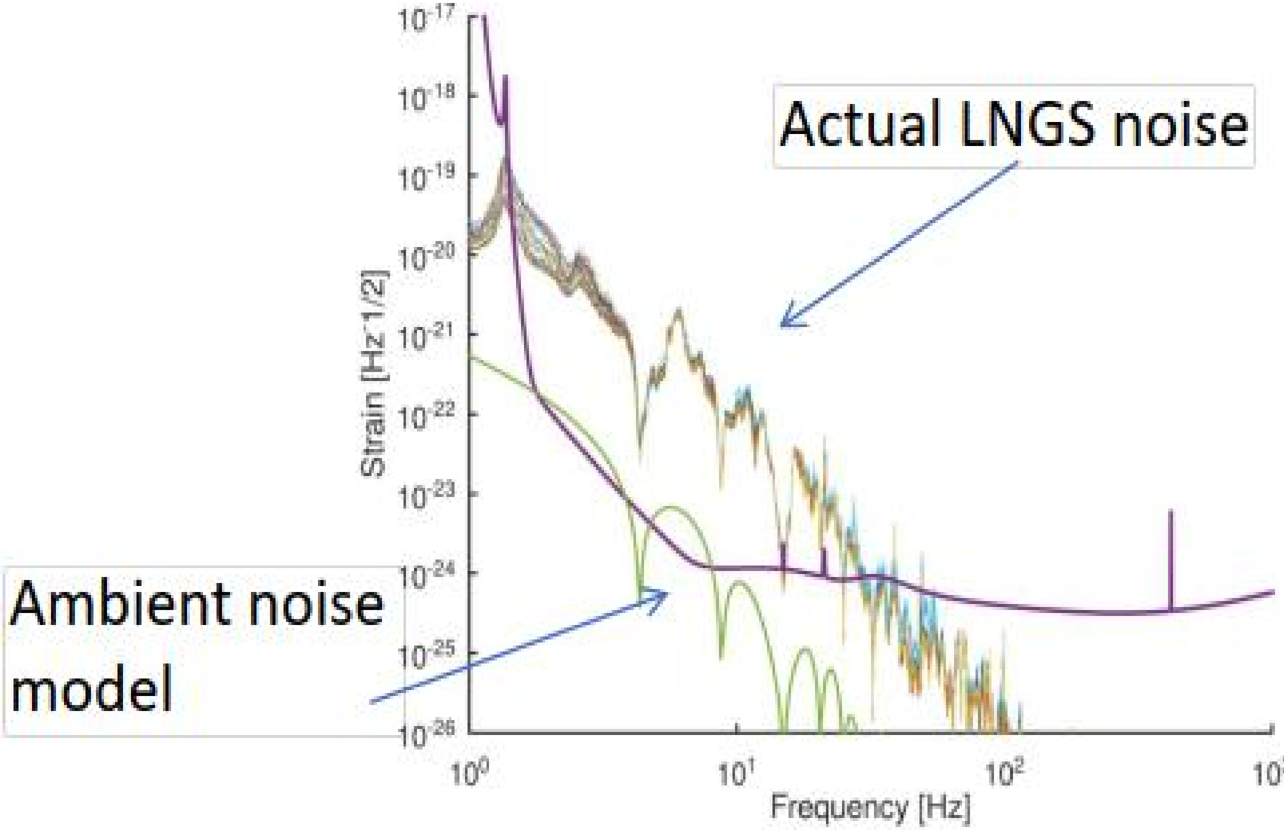
- noise at fixed frequencies
- and also occurring every few hours





Newtonian noise based on LNGS measurements

- Acoustic NN is not negligible
- Assume a geometry of detector: hall 100 m x 20 m x 25 m
- Noise level in tunnels is too high
- Lower limit - from ambient noise can also affect ET sensitivity



Conclusions

- Infrasound and seismic analysis (Newtonian noise = seismic + infrasound noise)

Seismic:

- Very low seismic noise
- We estimate that within 10 years the quake will be a maximum of 1 mm/s

Infrasound:

- Significiant infrasound noise
- A large hall where waves with a frequency of around 2 to 20 Hz freely propagate into the hall

The infrasound installation in Sardinia

- Characterization of the infrasound field in the mine, a place similar to the destination site for the telescope
- Multipoint infrasound measurements
- Infrasound are one of the components of the Newtonian noise

- More than 9 months of data (since 21st November 2022)
- Data stored at etrepo.df.unipi.it and info. also on wiki.et-gw.eu

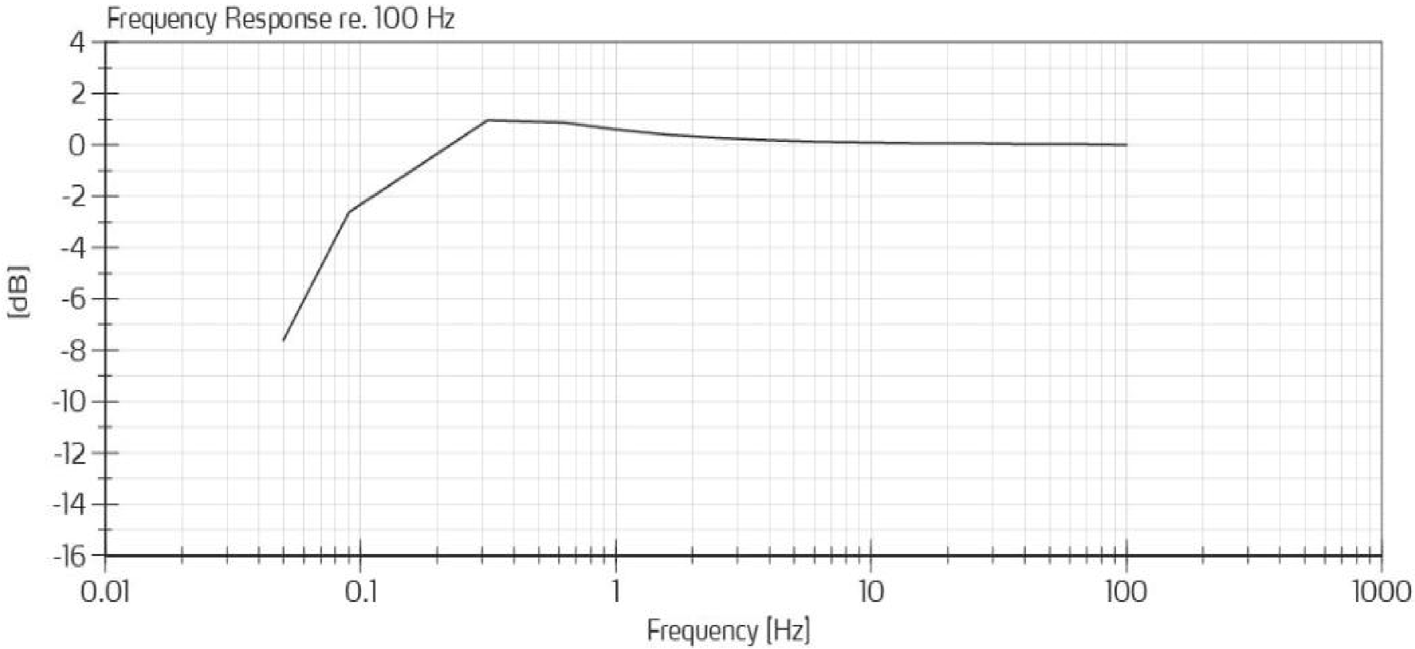
Two types of infrasound sensors (infrasound microphones):

- GRAS 47AC 1/2"
- Astrocent microphones

GRAS 47AC 1/2" CCP Infra-Sound Microphone Set

Condenser microphone set for infra-sound measurements in open acoustic fields

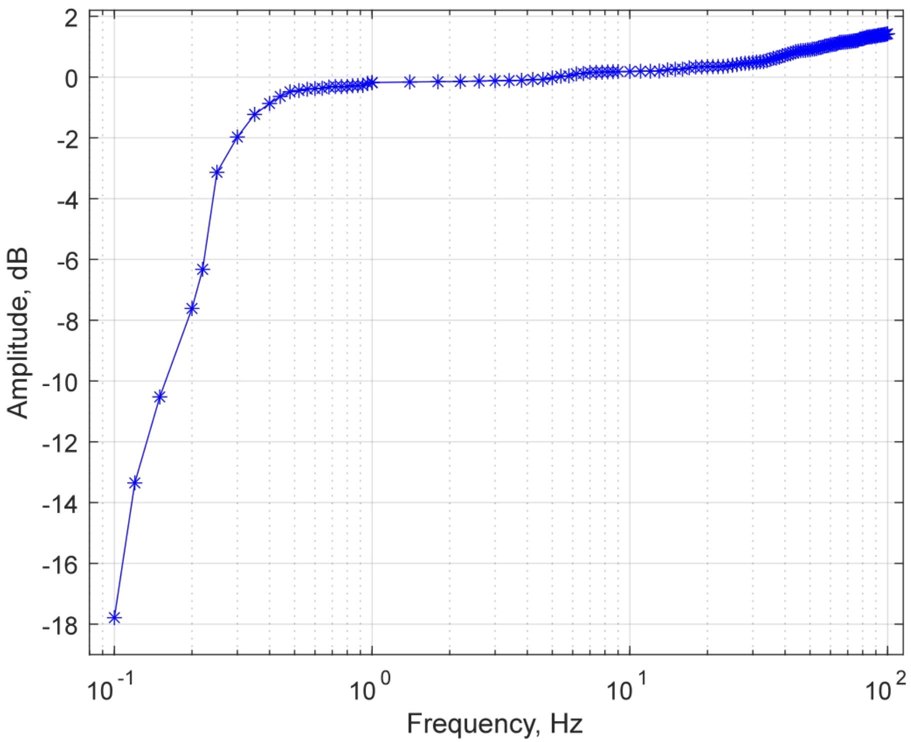
- frequency range: **0.09 Hz** to 10 kHz
- dynamic range: 20 dB(A) to 148 dB
- sensitivity: **8 mV/Pa**



https://www.grasacoustics.com/products/special-microphone/infra-sound-microphones/product/712-47ac

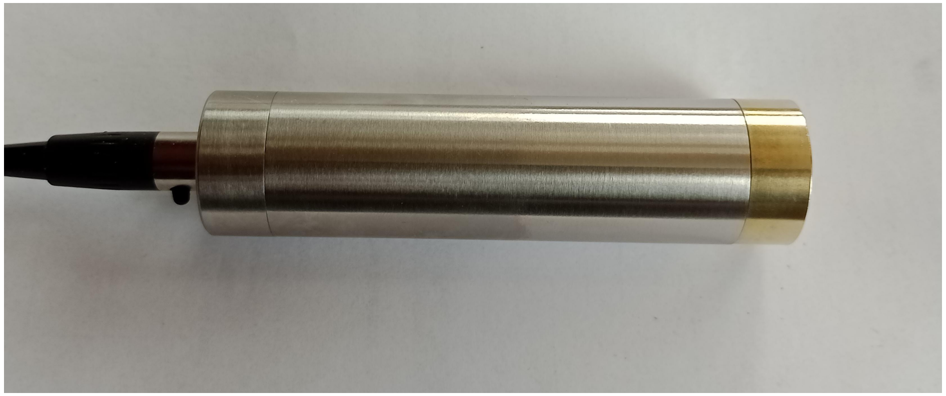
Infrasound microphones - Astrocent

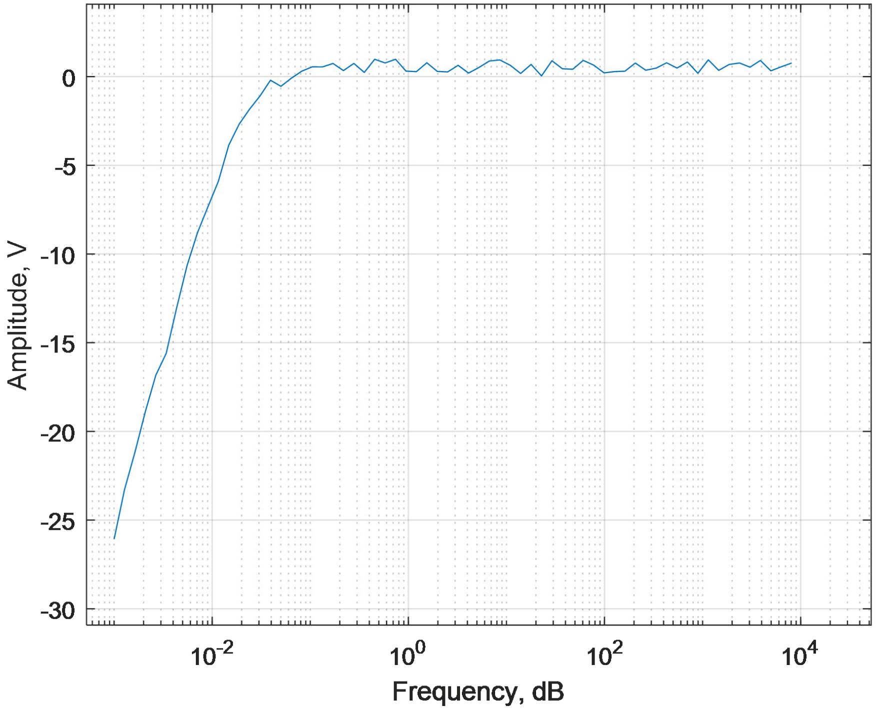
- developed by the Astrocent team
- low-cost infrasound microphone ~100 EU
- frequency range from **0.1 Hz** to 120 Hz (AC47 Gras from 0.09 Hz to 20 kHz)
- sensitivity: **2.5 mV/Pa**
- distortion max. 1.5 dB



Improved Infrasound microphones - Astrocent

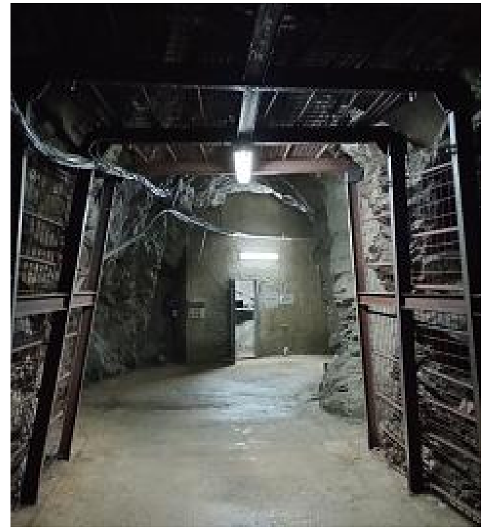
- developed by Astrocent team
- low-cost infrasound microphone ~100 EU
- frequency range from 0.04 Hz to 120 Hz (AC47 Gras from 0.09Hz to 20 kHz)
- sensitivity: 46 mV/Pa
- distortion max. 1 dB





Sos Enattos mine

The mine consists of tunnels with caverns



Caverns:

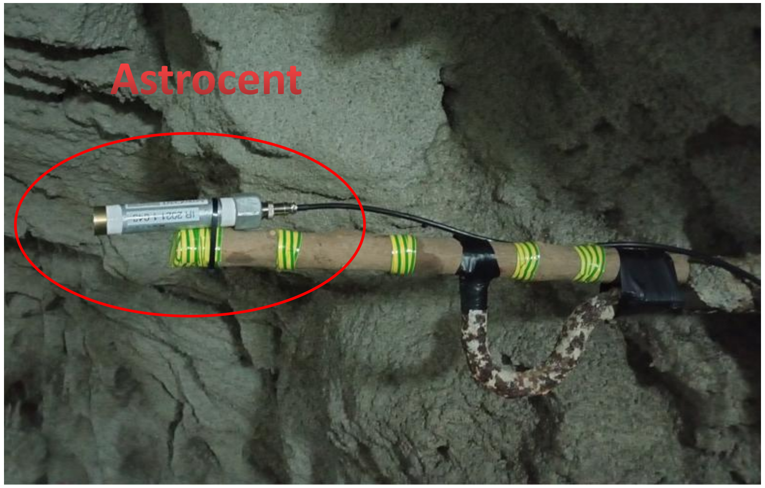
ST0 - Surface Station

- power supply from solar panels
- 1x GRAS 47AC 1/2", 1x microphone developed by Astrocent
- data synchronized by GPS, 1 pps signal (1 Hz)

Stations

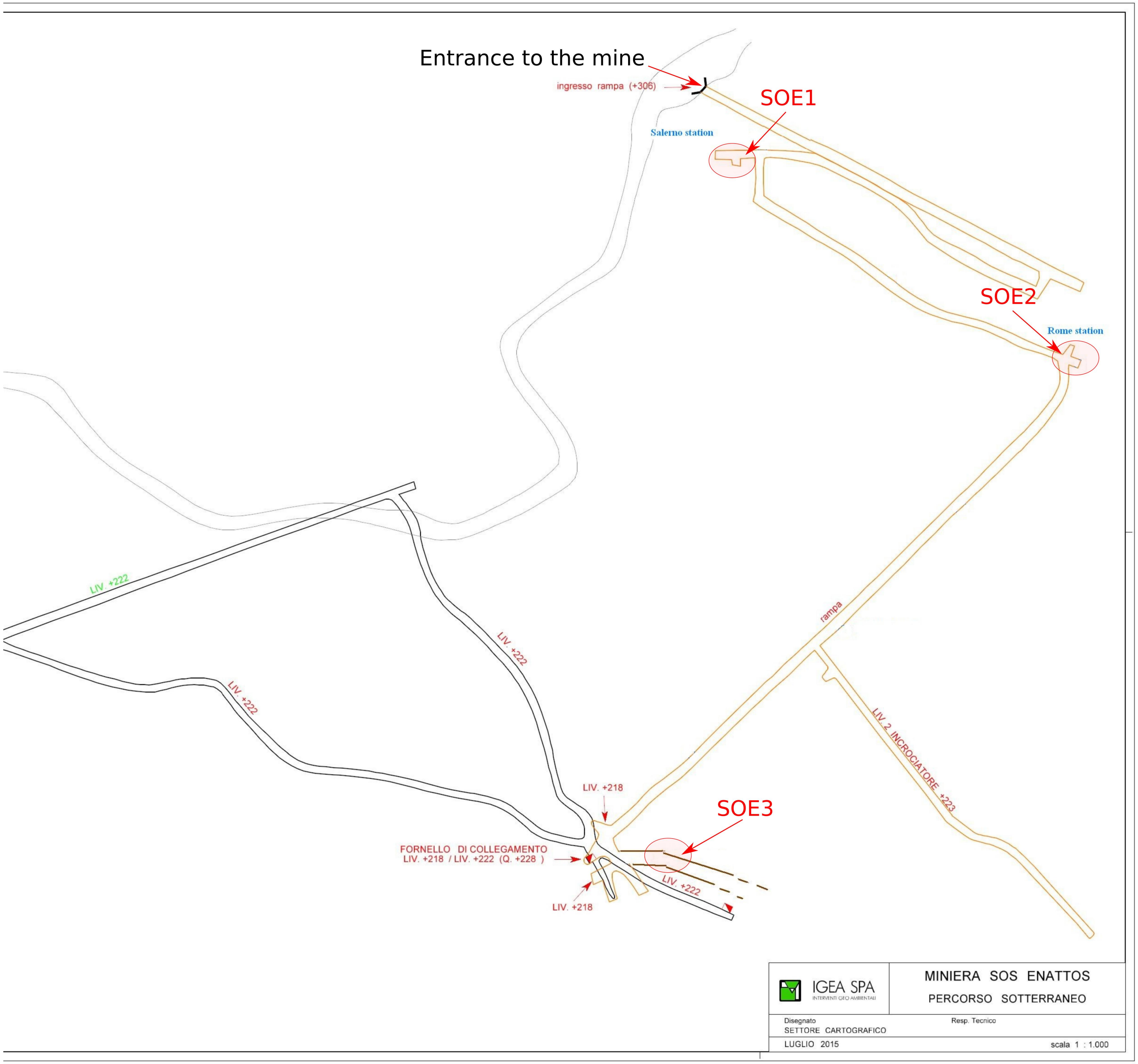
ST1, ST3 - in every station 3x infrasound microphones

- data synchronized by NTP serwer via Internet
- 1x Gras + 1x Astrocent microphone (inside the cavern)
- 1x Astrocent (outside the cavern)



Sardinia - Sos Enattos Mine

SOE1-3



Sardinia - Sos Enattos Mine SOE3

Inside the cavity

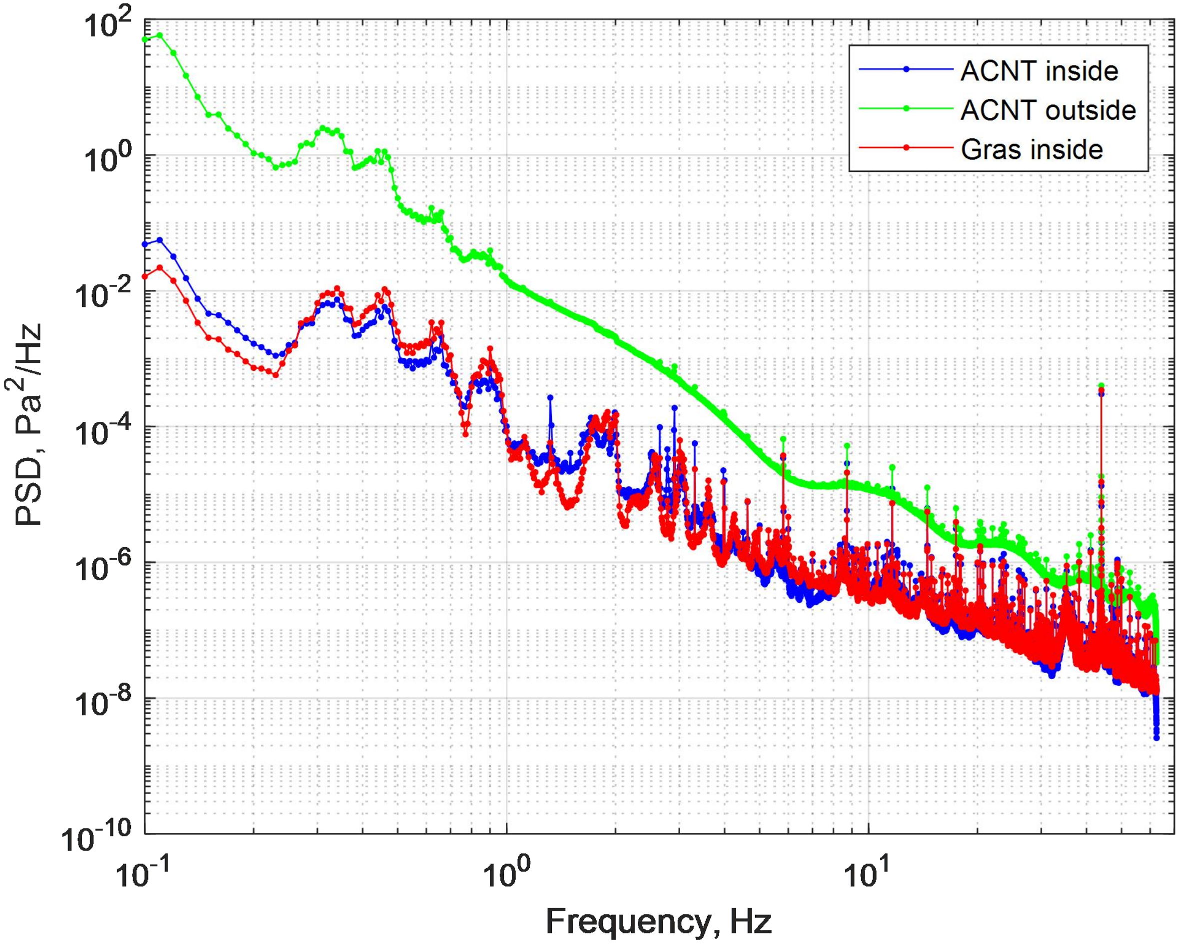
1x Gras - red

1x Astrocent - blue

Outside the cavity

1x Astrocent - green

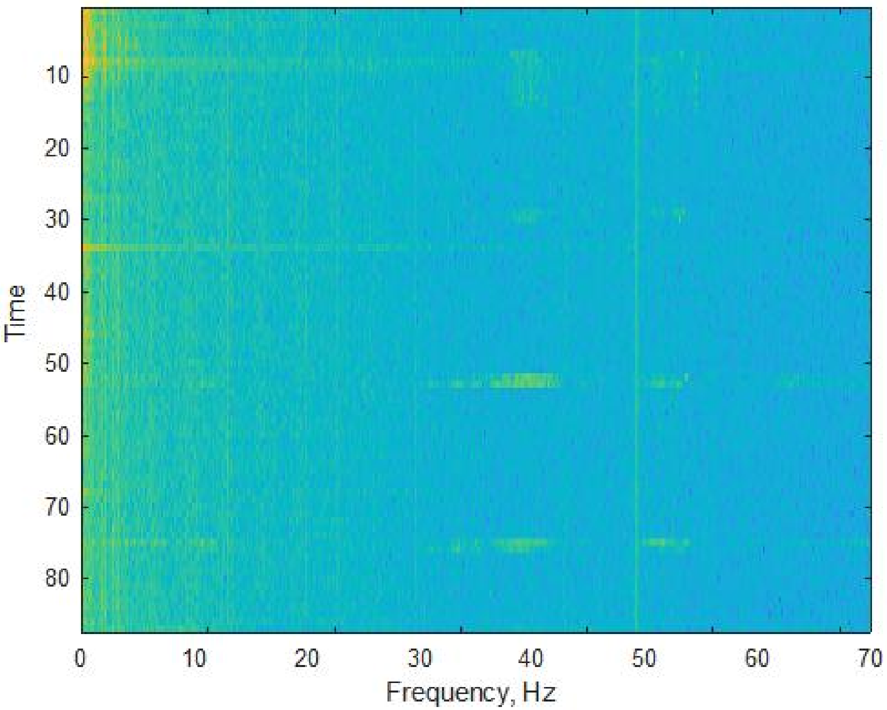
10th December



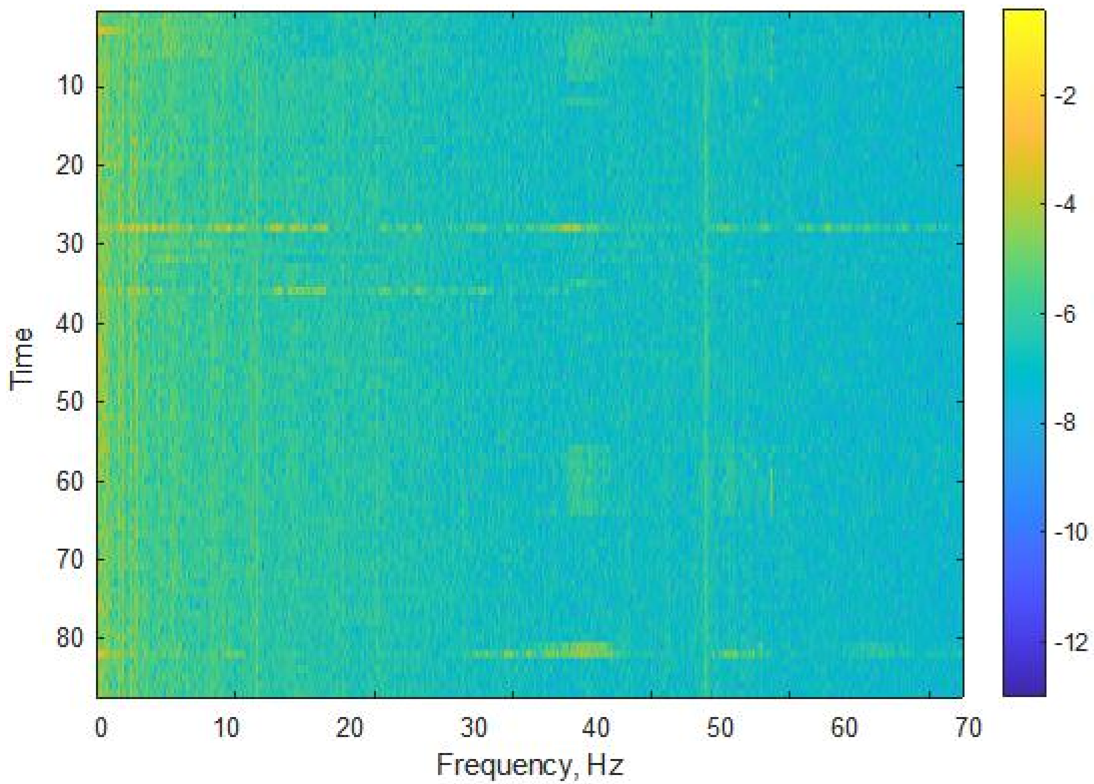
Sardinia - Sos Enattos Mine SOE3

10th and 11th of December - all day as a function of time (Gras microphone)

10th December



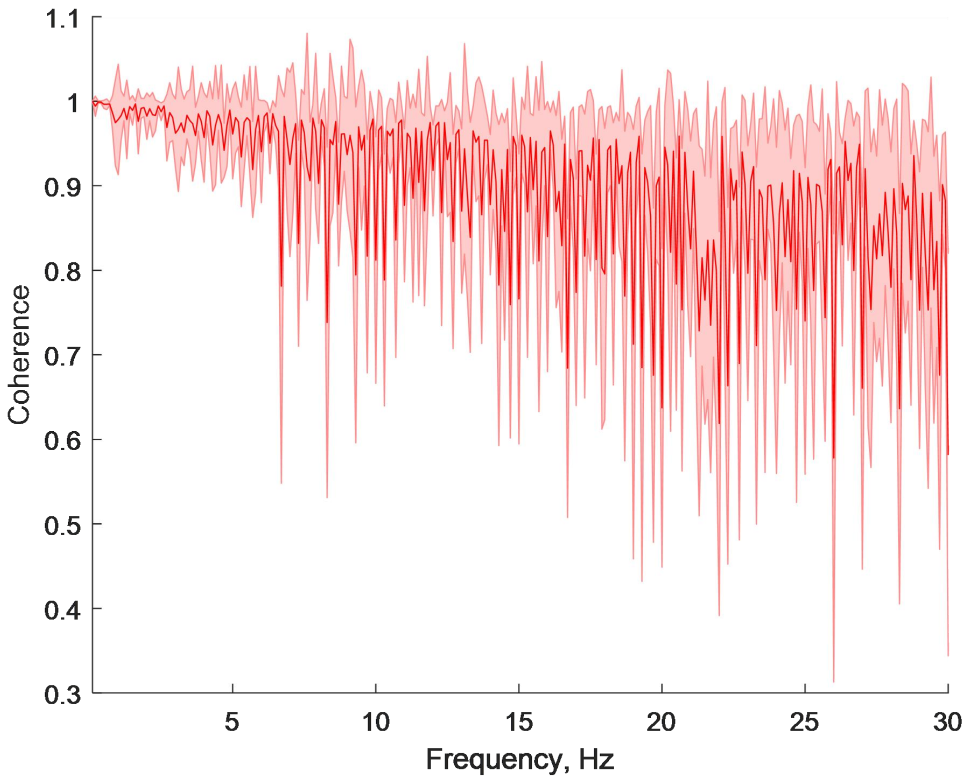
11th December



Coherence ST3

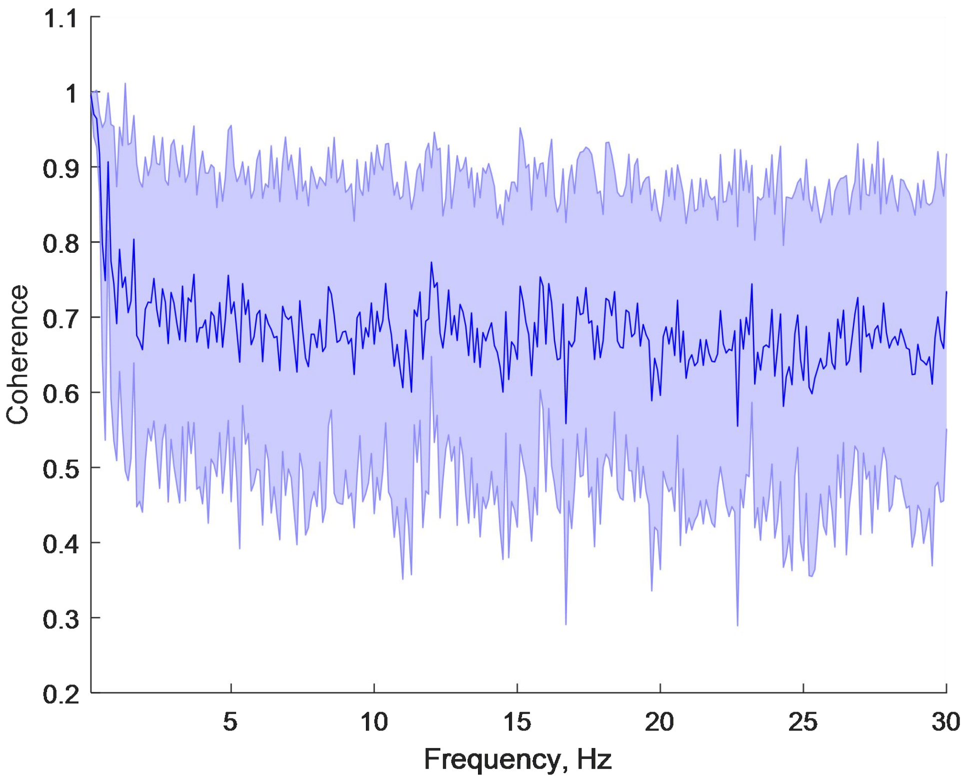
Inside cavity microphones

Gras-Astrocent



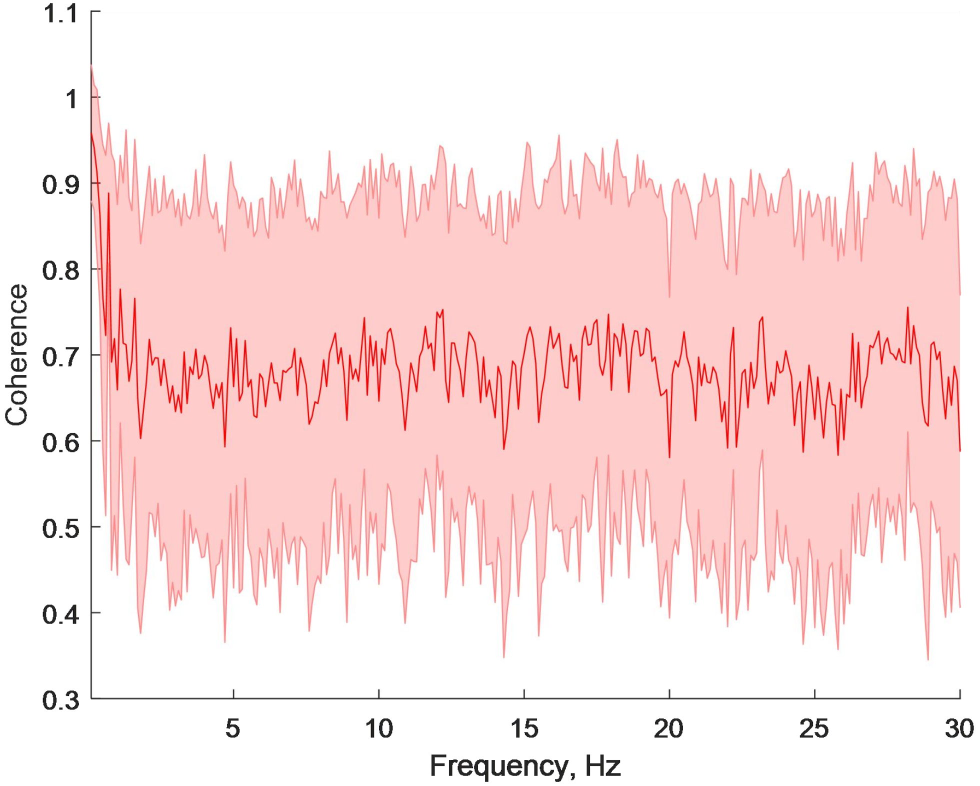
Inside and outside cavity

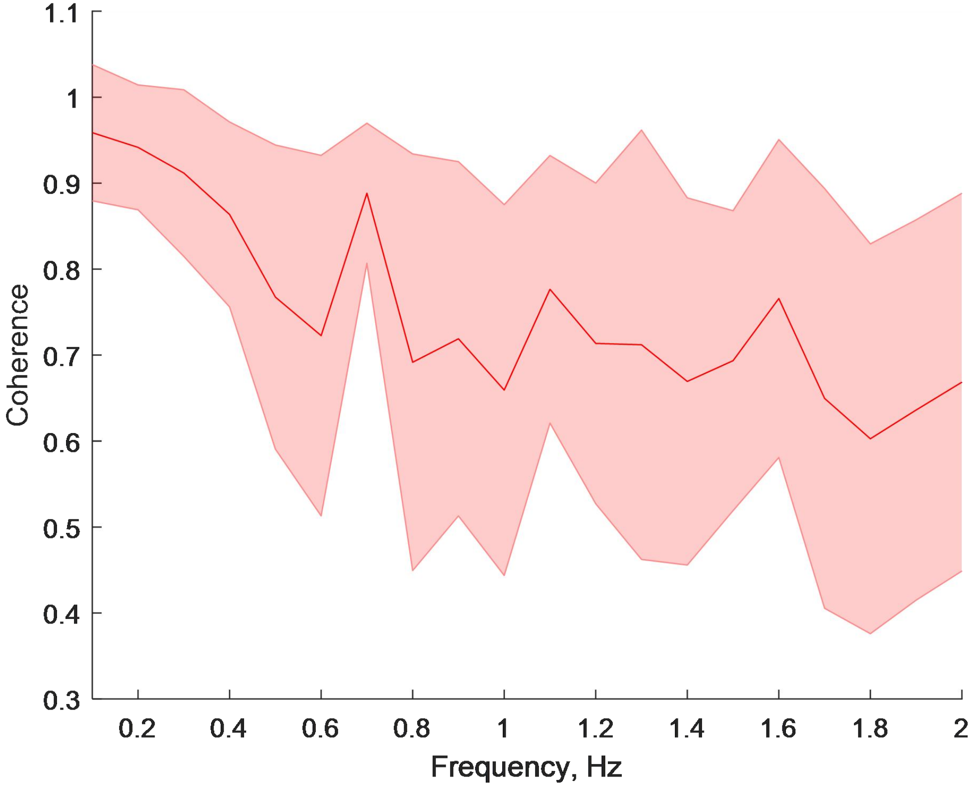
Astrocent-Astrocent



Coherence ST1 (inside) & ST3 (inside)

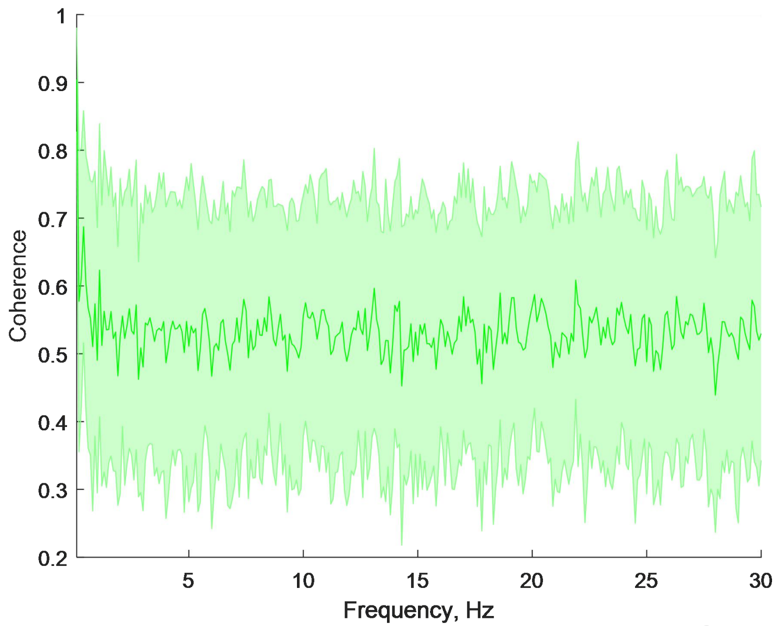
ST1 & ST3 Gras

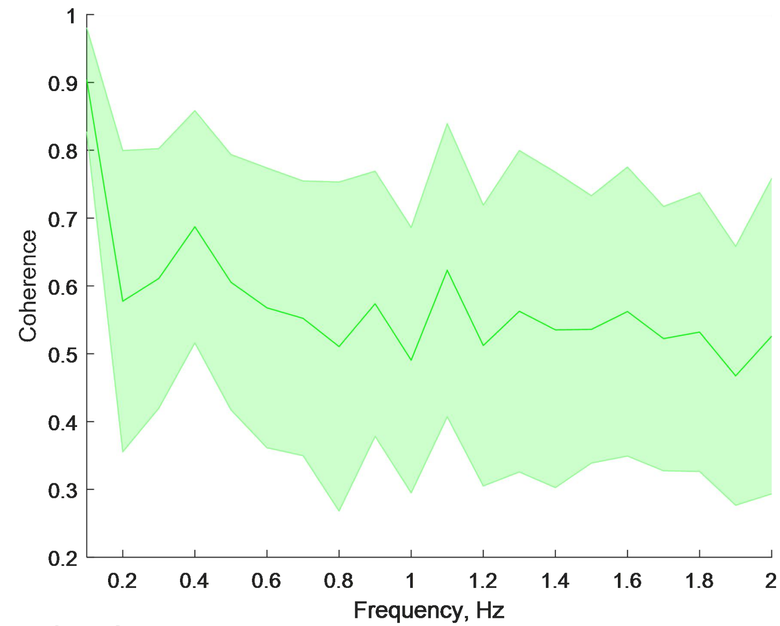




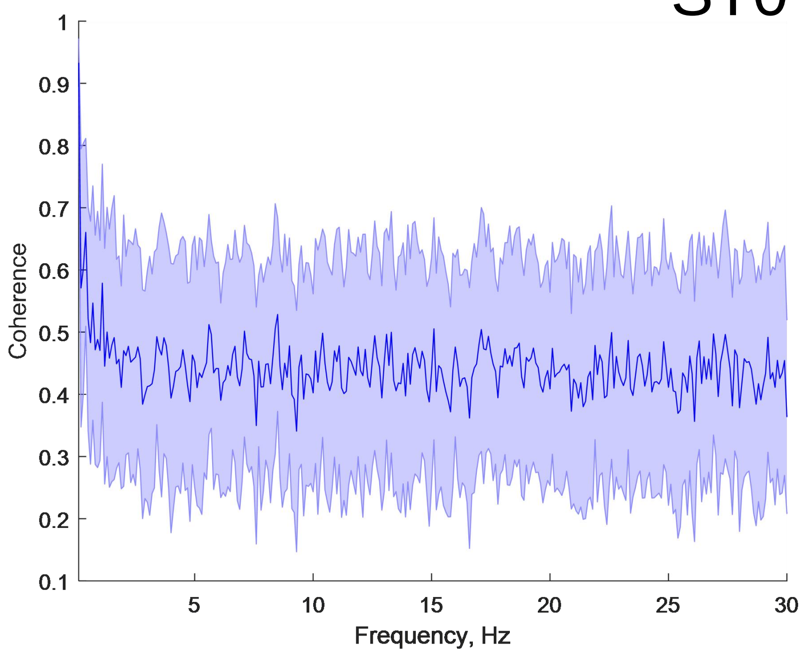
Coherence ST0 (surface) & ST1/3 (inside)

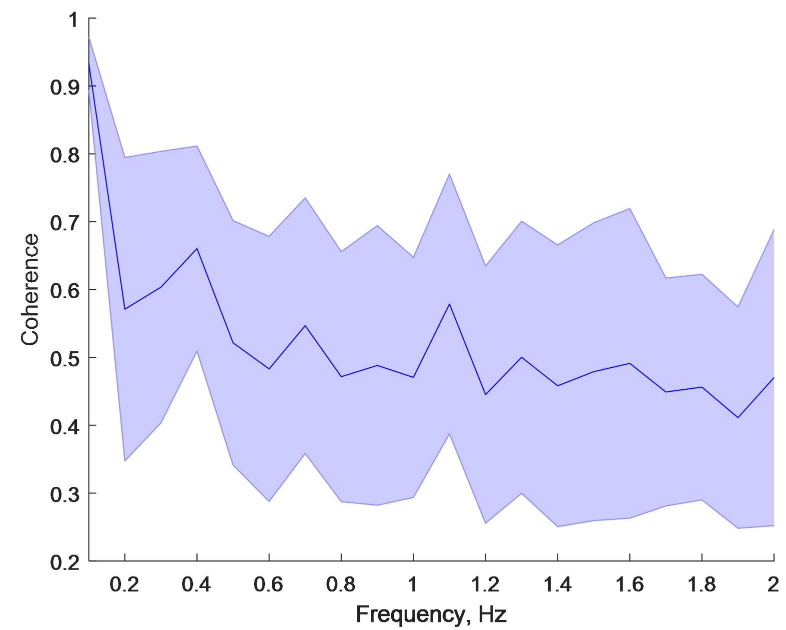
ST0 & ST1 Gras





ST0 & ST3 Gras





Conclusions

- Sosenattos 6x infrasound microphones inside the mine, 2 outside (installation since 21st November 2022)
- distributed infrasound measurements
- ST1, ST3 - 3x infrasound microphones 1x Gras + 1x Astrocent microphone (inside the cavern) + 1x Astrocent (outside the cavern)
- damping of the wall between the tunnel and the cavern about factor 10x (amplitude, 100x PSD)
- very high coherence between microphones below 0.6 Hz

Thank you for your attention

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ASTROCENT

NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES

Dark Wave

European Funds Smart Growth

Republic of Poland

FNP Foundation for Polish Science

European Union European Regional Development Fund

Power spectrum & coherence

Power spectrum

$$S_{xx,f} = \frac{2dt^2}{T} X_f X_f^*$$

$$S_{xy,f} = \frac{2dt^2}{T} X_f Y_f^*$$

X, Y - spectrum of signal

T - total time of recording

dt - samplig time

Coherence

$$K_{xy,f} = \frac{|< S_{xy,f} >|}{\sqrt{< S_{xx,f} >< S_{yy,f} >}}$$