Results of the long-term measurements from the Mátra Gravitational and Geophysical Laboratory

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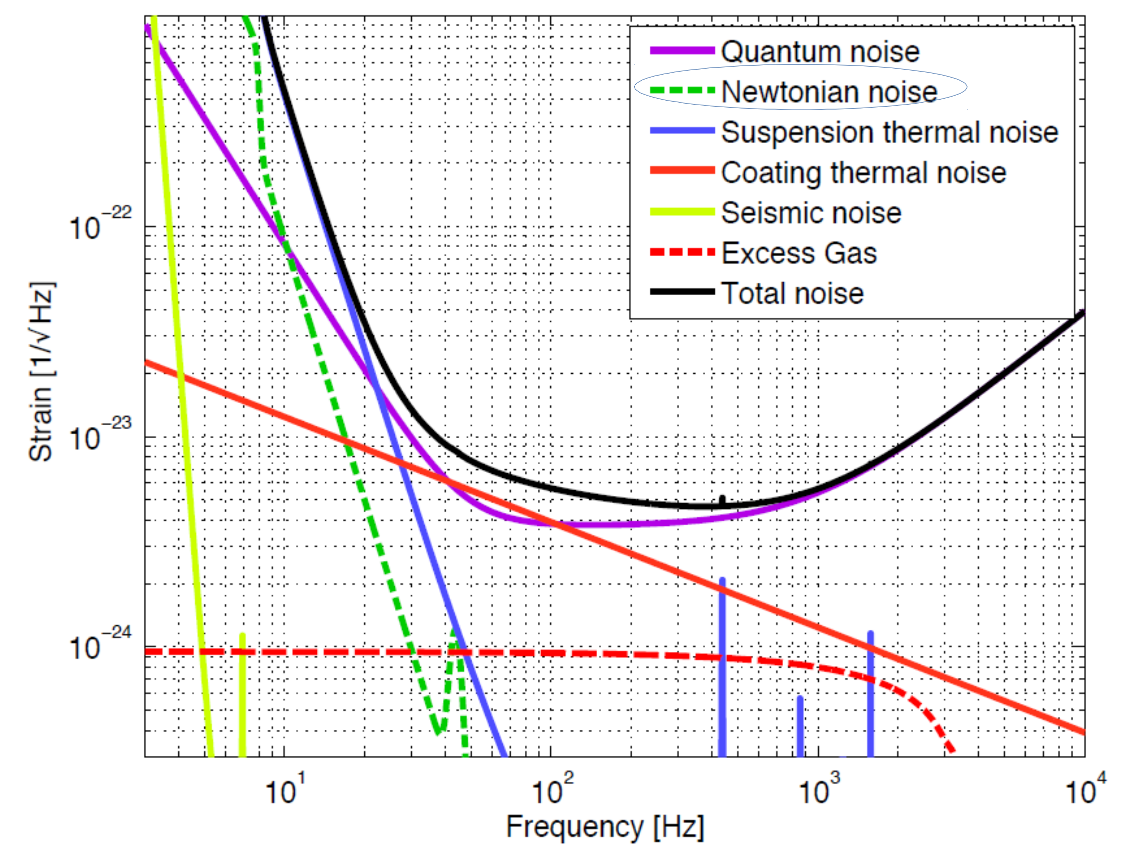
GRASS 2019, Padova, Italy

Newtonian noise



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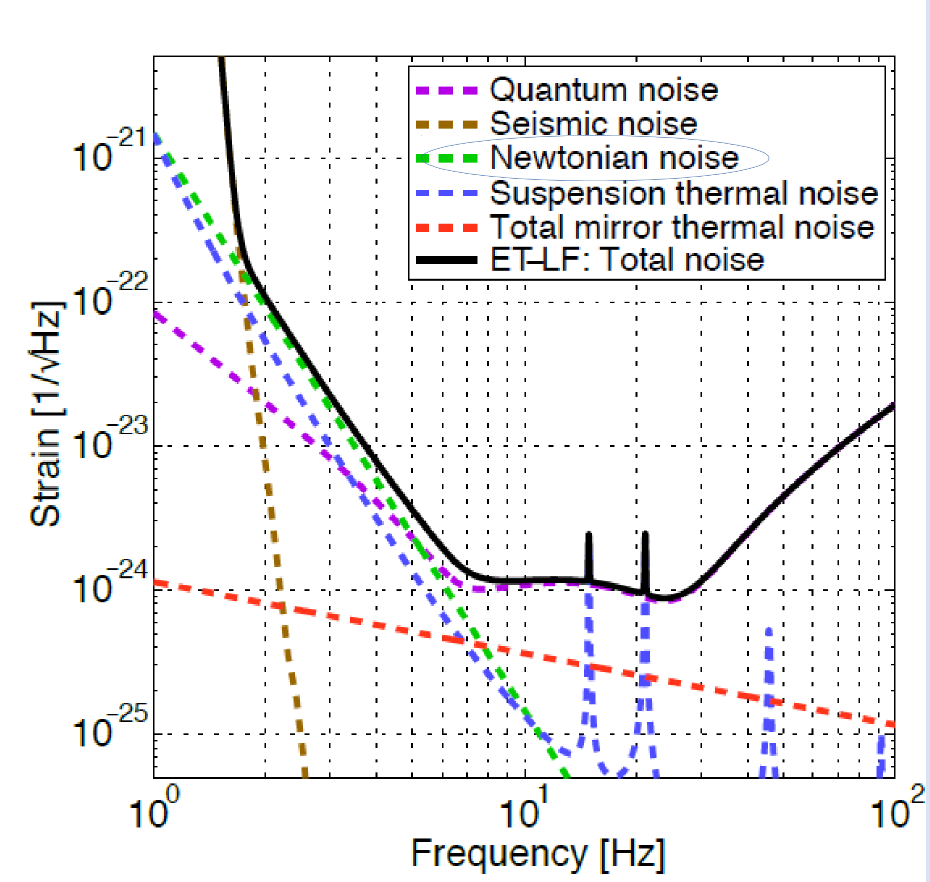
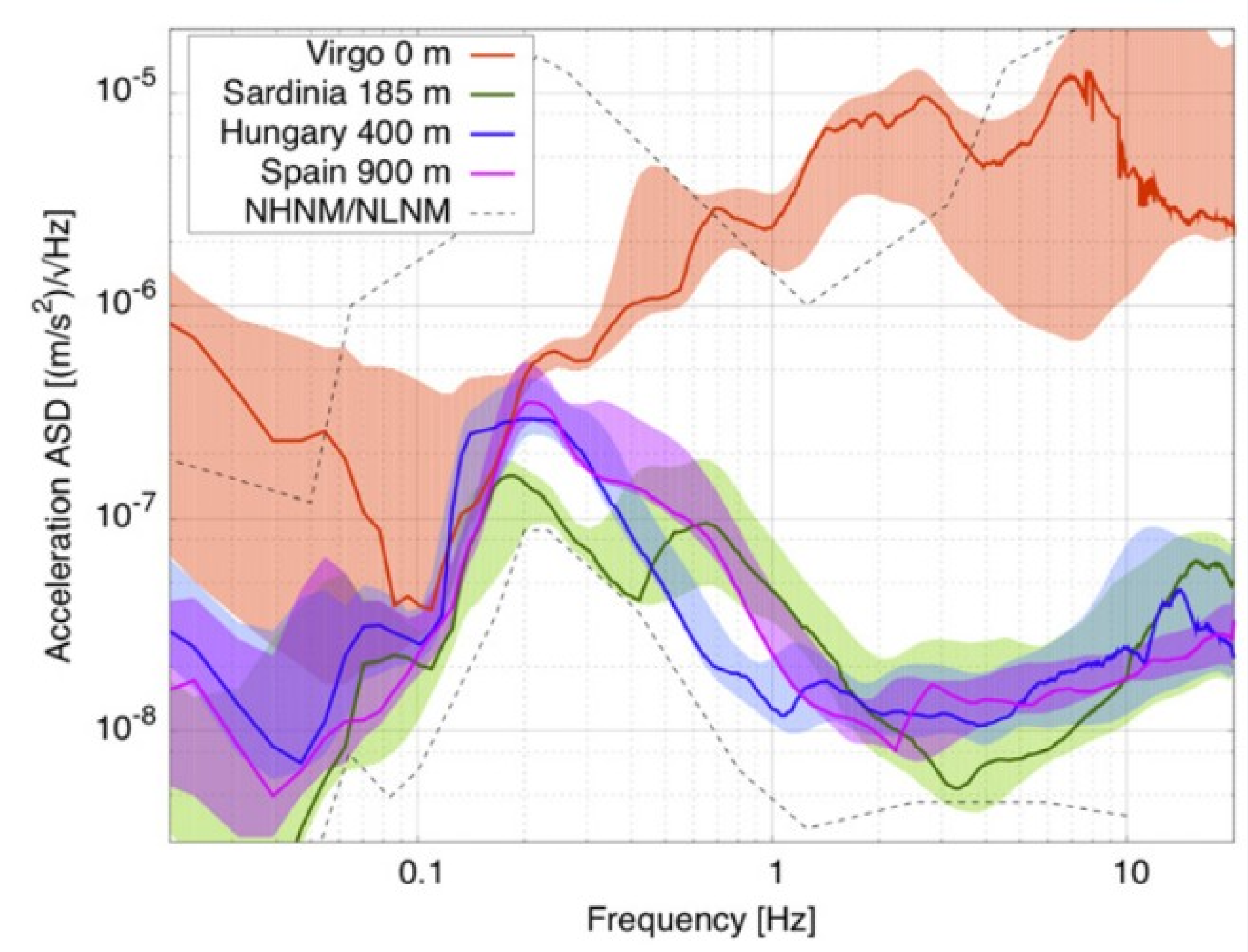


Einstein Telescope

As part of Einstein Telescope's design phase, M. Beker et al. performed a ground motion study to determine the **seismic noise** characteristics at various sites across the globe[1].

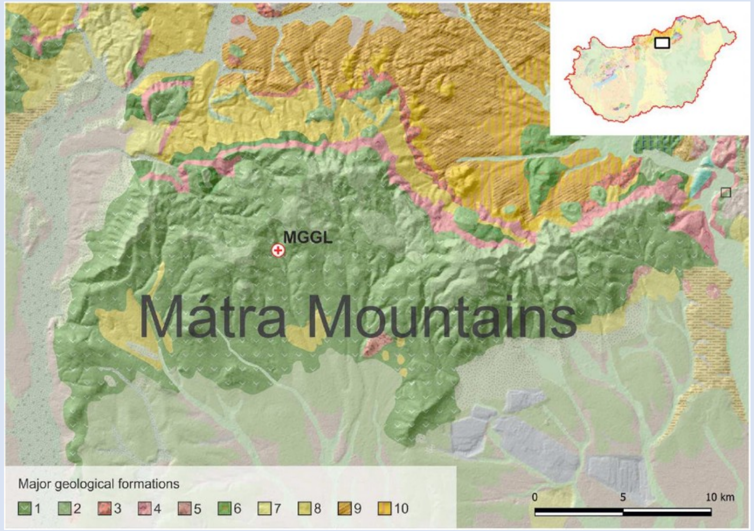
Reference lines:
New Noise Models of Peterson[2]

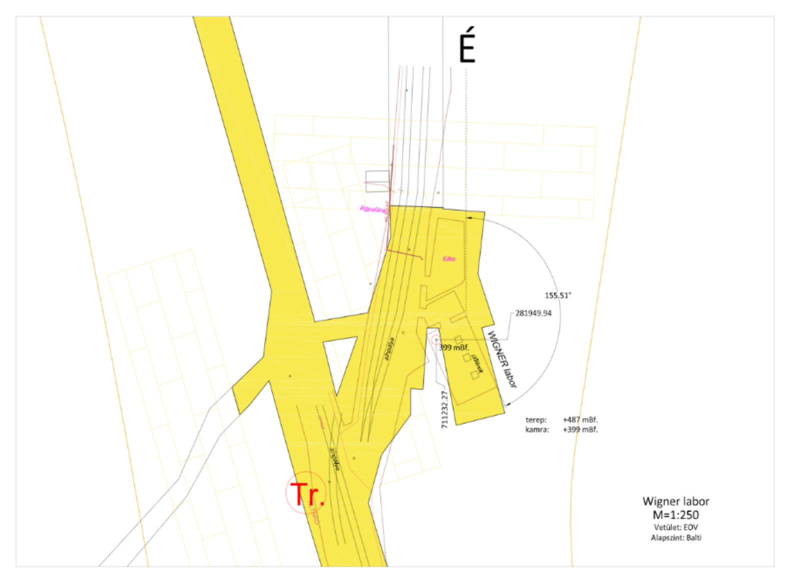
- NHNM: New High Noise Model
- NLNM: New Low Noise Model

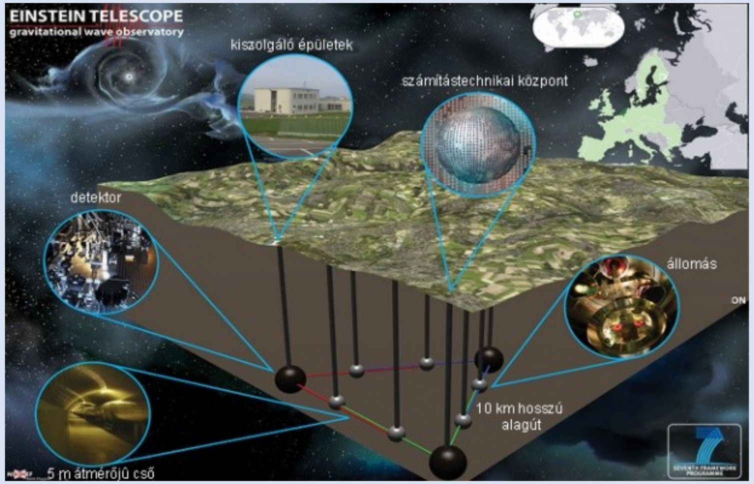


Mátra Gravitational and Geophysical Laboratory (MGGL)

- At Mátra Mountin Range, Hungary
- In an ore mine , **88 m below surface**, where recultimation work is done in shifts
- Operated by Wigner RCP Hungary since 2015
- Aim: **to investigate the challenges and possible advantages of installing a third generation GW detector under the ground** [3][4][5][6]
- Collaboration: Technical University of Warsaw & several Hungarian research centres and universities

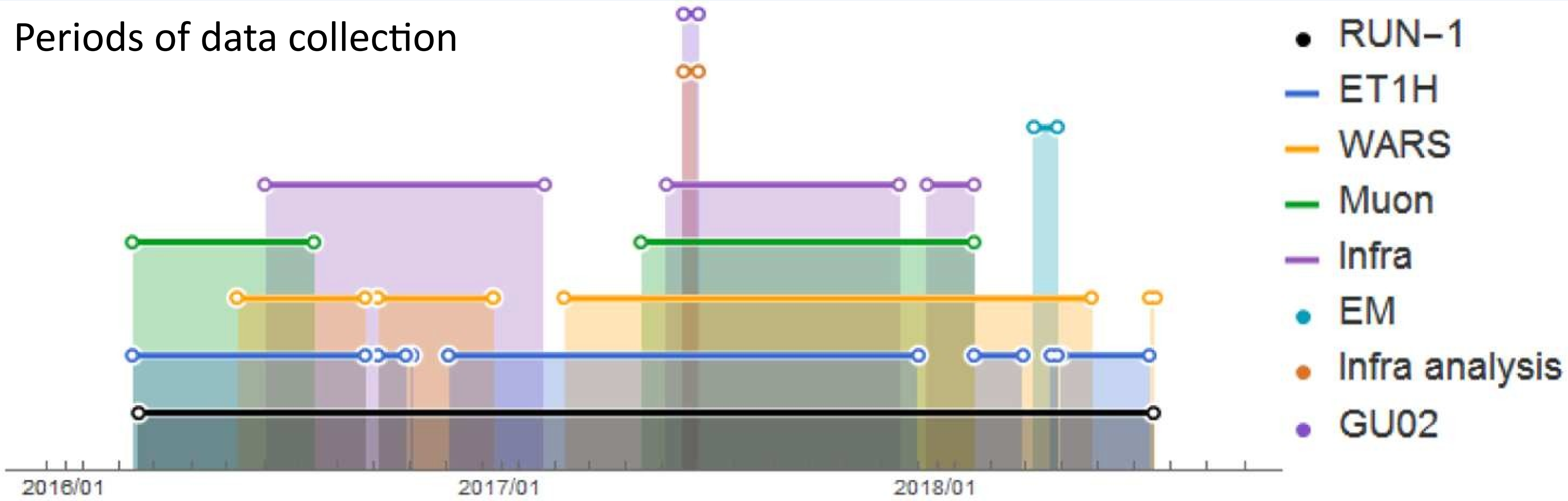




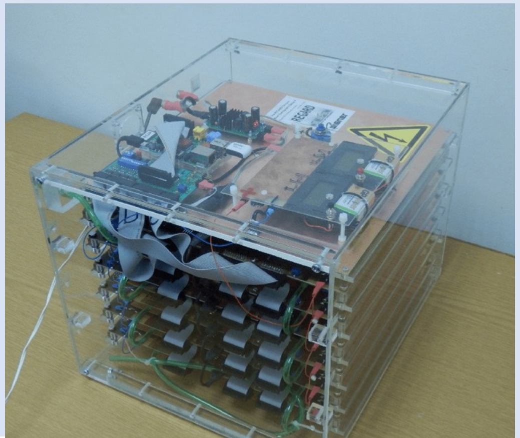


http://einsteinteleszkop.hu

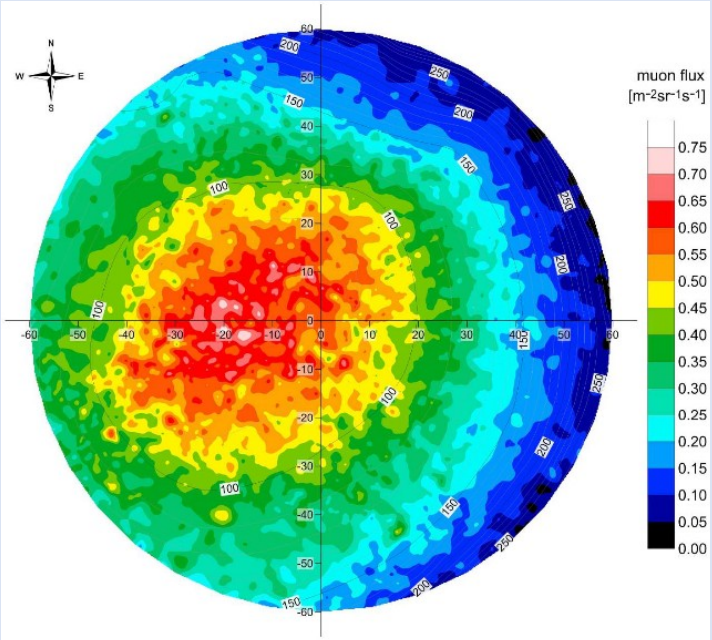
Measurement	Detector	Manufacturer
seismic	Güralp CMG-3T	Güralp
	seismic sensor	Warsaw University
electromagnetic	Lemi-423	LEMI
infrasound	ISM1	Atomki (HUN)
cosmic muon	Muon detector	Wigner RCP (HUN)


Periods of data collection

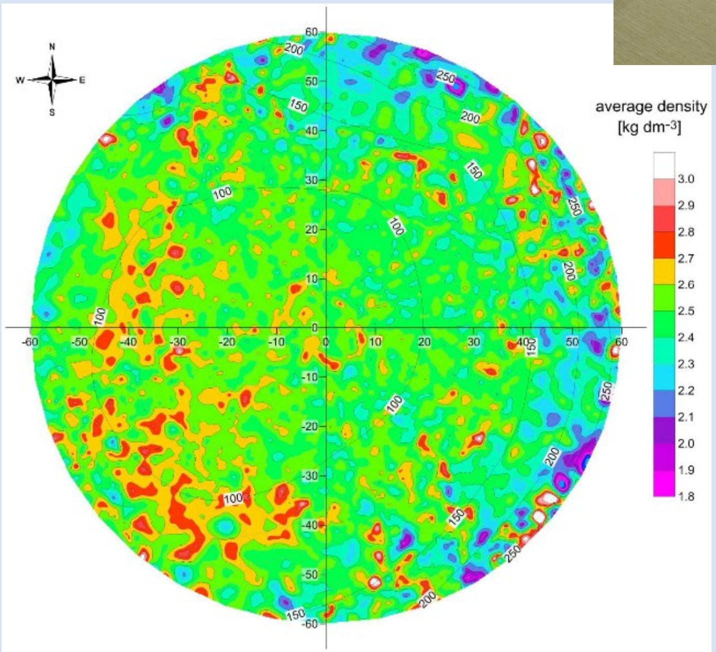
Cosmic muon tomography



- 404 days long measurement
- To map the rock density and its inhomogeneities above MGGL at large scale
- We verified this novel measurement technique by obtaining the typical andesite rock density
- No large scale density inhomogeneities (≤ 0.2 kg dm–3) measured in the rock mass [6]



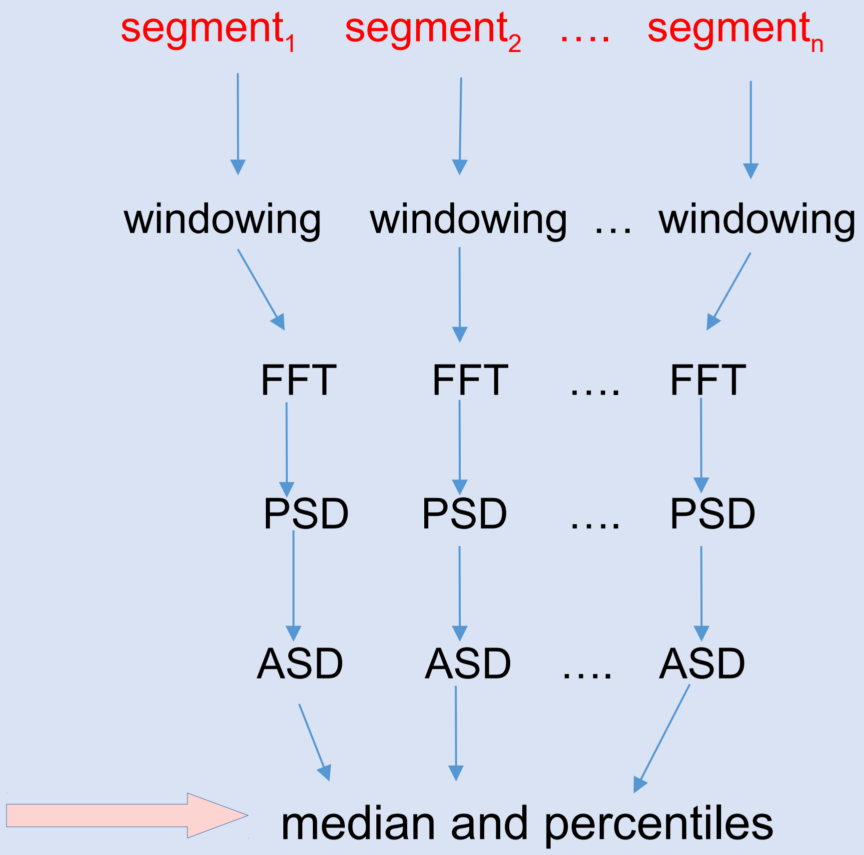
The cosmic muon flux map measured in MGGL plotted as a function of azimuth and zenith angles from the detector position.



The angular distribution of the density.

Data evaluation of environmental noise

- **FFT-based methods** for seismic, electromagnetic and infrasound noise
- To get **representative spectra with variations** of the subterranean environment
- To **compare to a reference spectrum** of the Earth's surface
- Problem: mining activity causes undesirable noise:
  - **continuous noise**
  - **transients**
- Controlled noise generating: on one day, workers in the mine systematically turned on and off machinery
- We used novel data evaluation methods for treating the undesirable anthropogenic noise
- computation of the representative spectrum adjusted to long-time measurements [4][5]



segment$_1$ segment$_2$ …. segment$_n$

windowing windowing … windowing

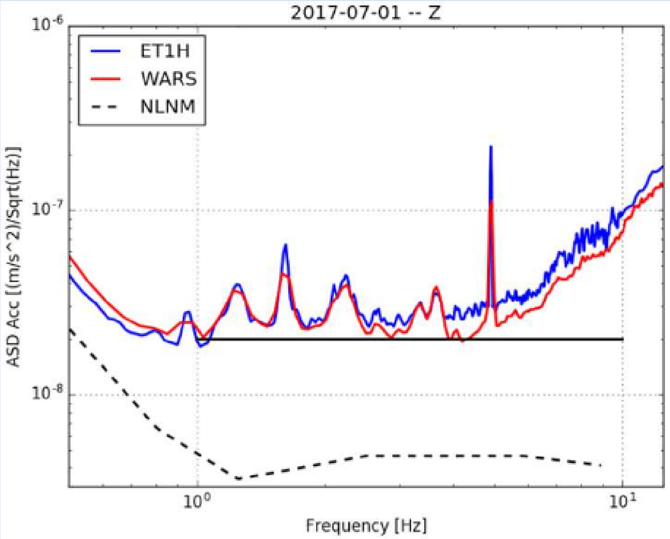
FFT FFT …. FFT

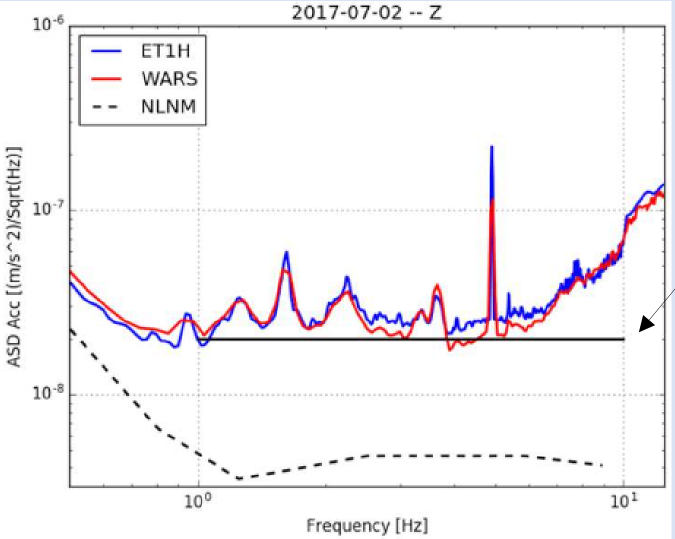
PSD PSD …. PSD

ASD ASD …. ASD

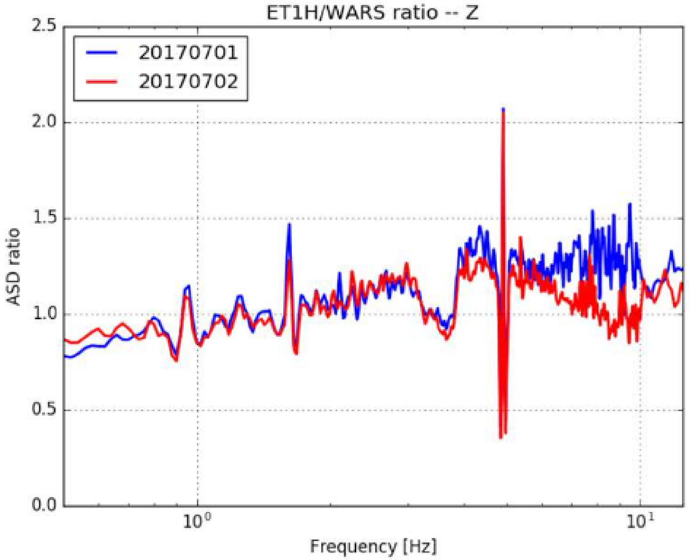
median and percentiles

Seismometers

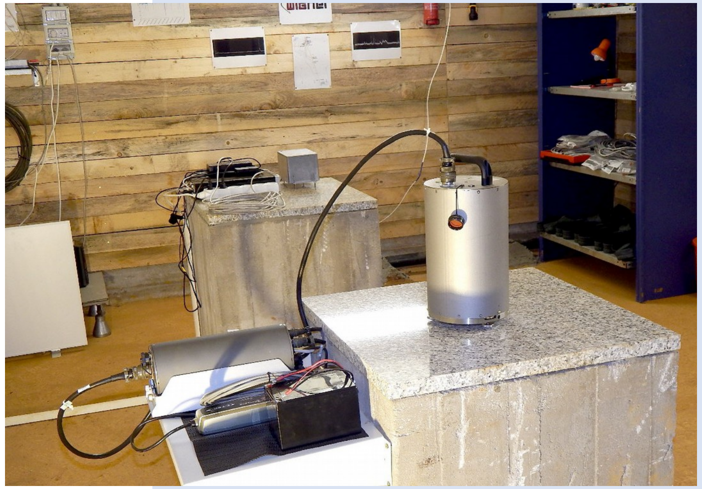




Black Forest line



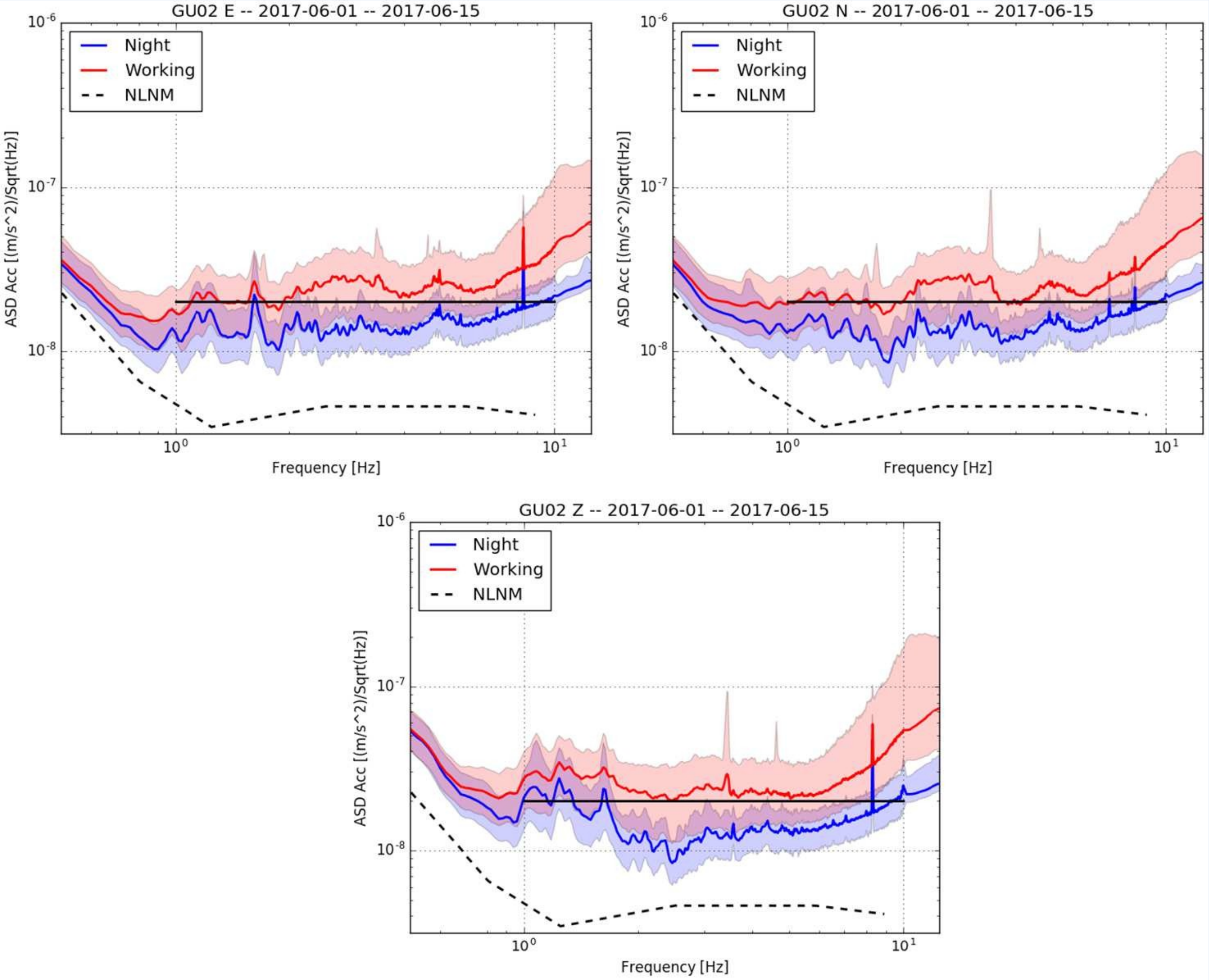
Seismometer of Warsaw University: three geophones in the metal housing

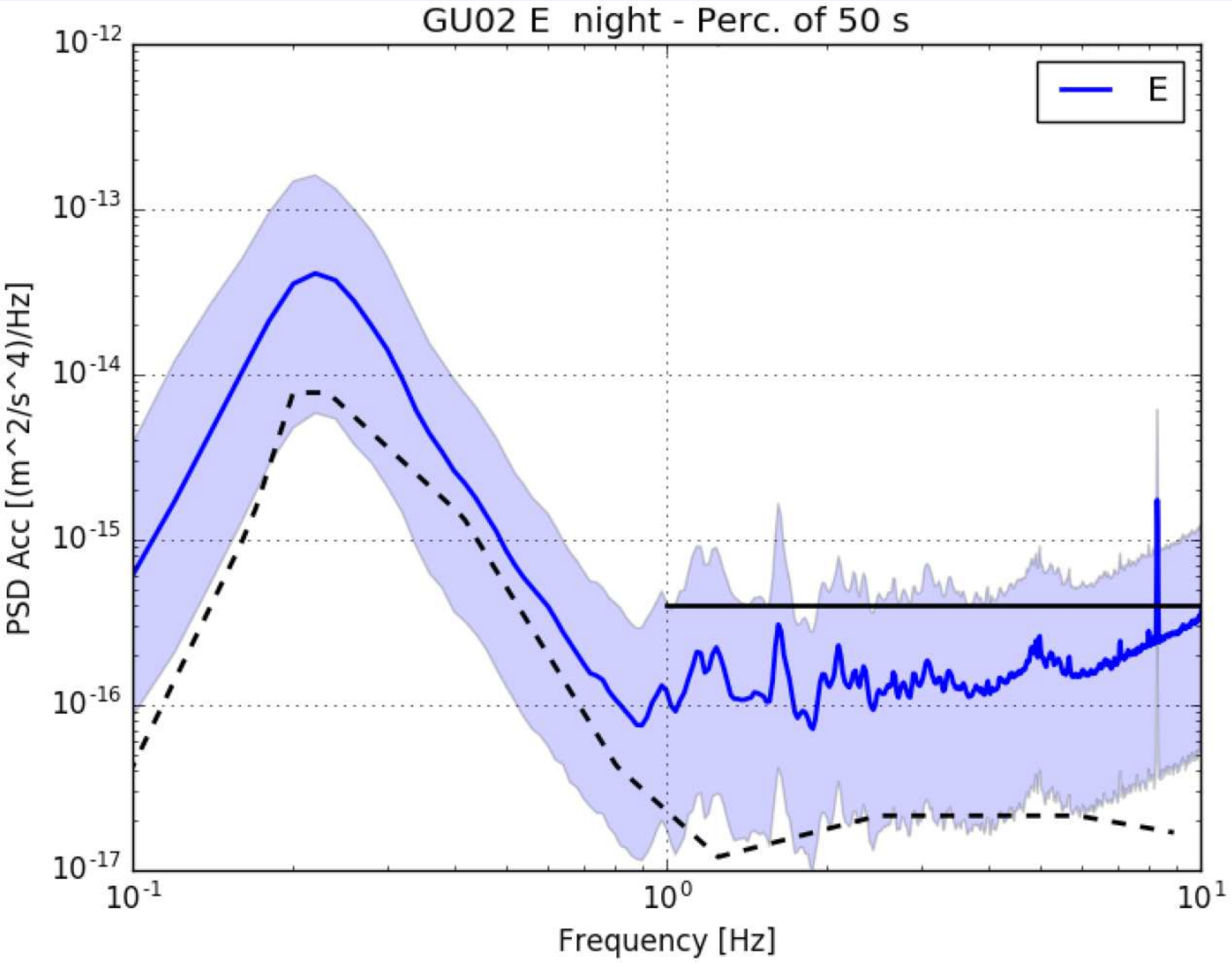


Güralp (referred as ET1H)

Seismic results

- For higher than 2 Hz frequencies, there were no significant annual changes[6]
- But for 1-2 Hz the spring-summer time had an annual minimum
- Comparing the deeper (-404 m) and shallower (-88 m) noise data we have observed that the decrease of seismic noise spectral amplitudes in the 1-8 Hz frequency range is approximately 60% (see next slide).
- We emphasize, that almost in 90% of the observation period detected the noise level below the Black Forest line at night (see Fig.).





Acceleration ASD values of the representative two-week period of GU02 seismometer (-404 m), in one of the horizontal directions. The median is solid blue and the borderlines of the blue area are the 10th and the 90th percentiles. The dashed line is the NLNM curve of Peterson, the Black Forest line is solid black.

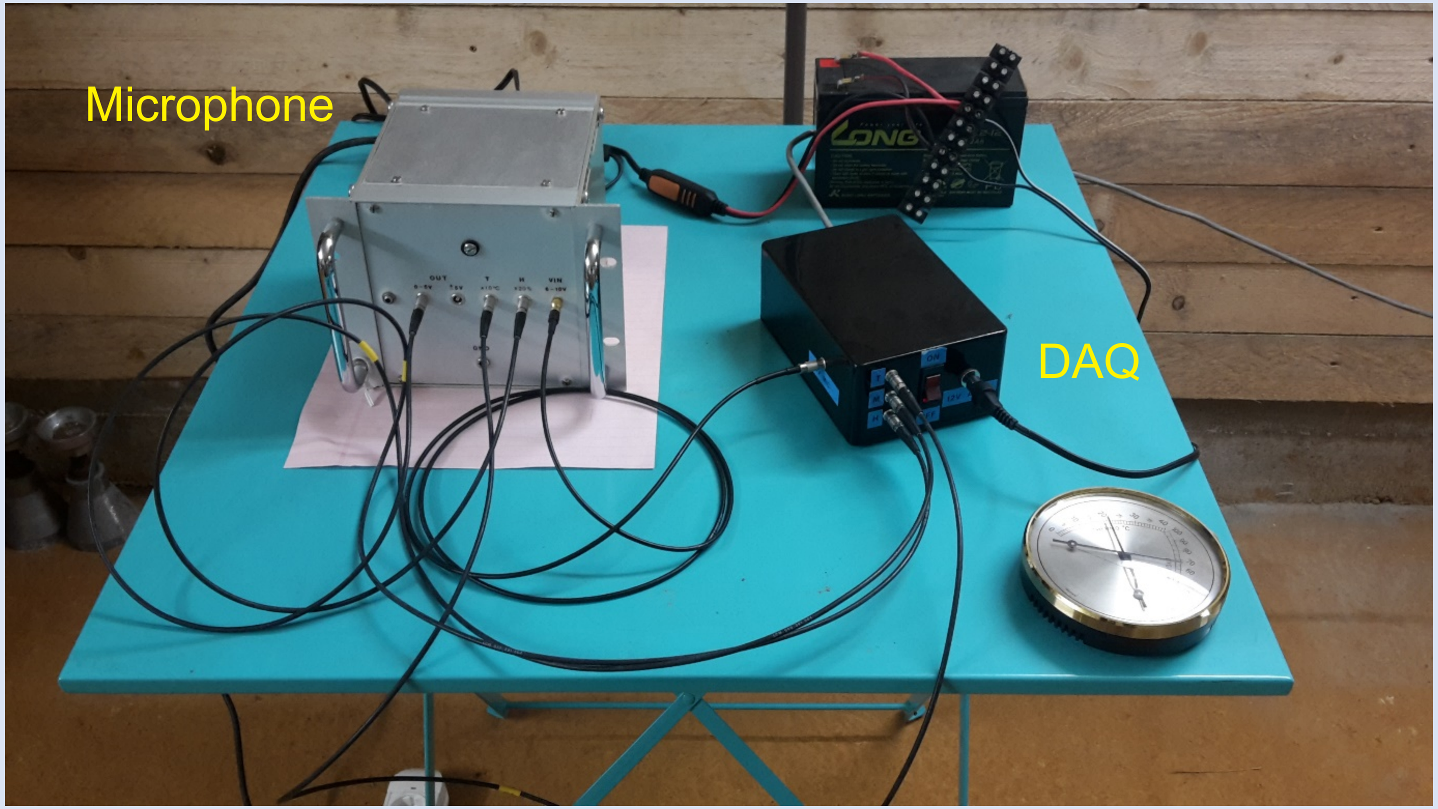
Electromagnetic attenuation

- Estimated the electromagnetic attenuation by the andesite rock mass in the lower extremely low frequency range (3 Hz to 30 Hz) [6]
- Especially at the frequency of the first **Schumann resonance** component
- Comparing the data of the external surface reference station, we obtained the **skin depth** 3520 m
- For the **bulk resistivity** at the Schumann resonance frequency 387 Ωm was obtained.
- This value (supporting the validity of this measurement) **meets well to the literature** value of vulcanic, andesite rocks (170–45000 Ωm)

https://lemisensors.com/?p=485

Infrasound measuring system

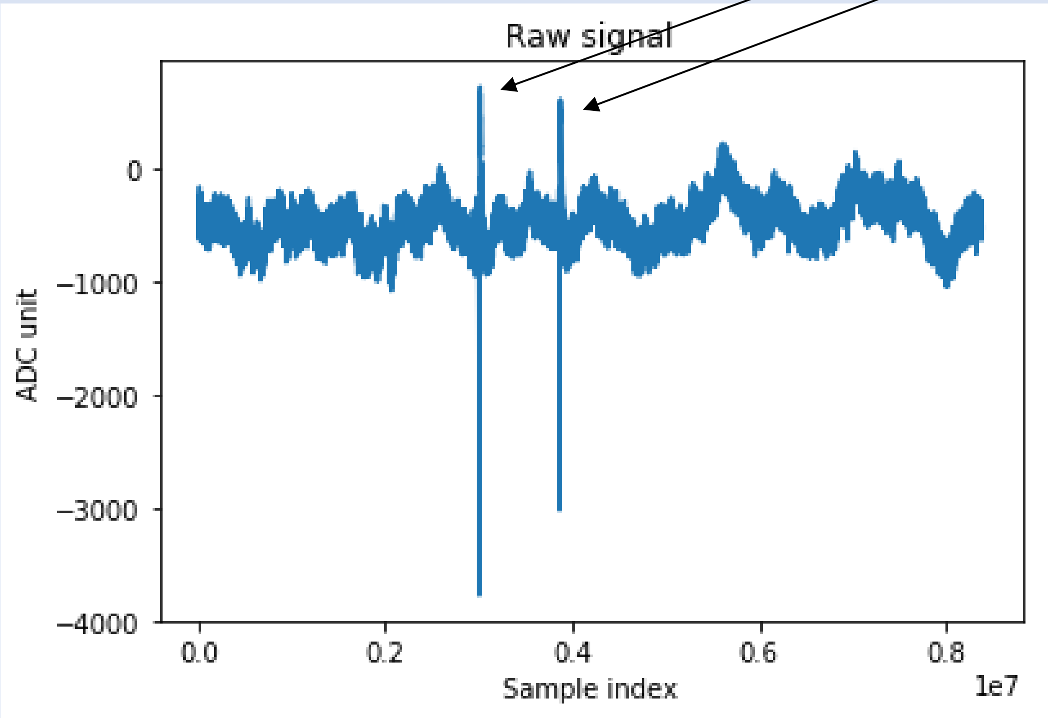
	Microphone
Input voltage (V)	6 - 10
Output volt. (V) (analog)	0 - 5 (or -5 - 5)
Sensitivity (V/Pa)	0.2
Pressure range (Pa)	-12.5 - 12.5
Frequency range (Hz)	0.01 - 10
Temperature sensor	yes
Humidity sensor	yes

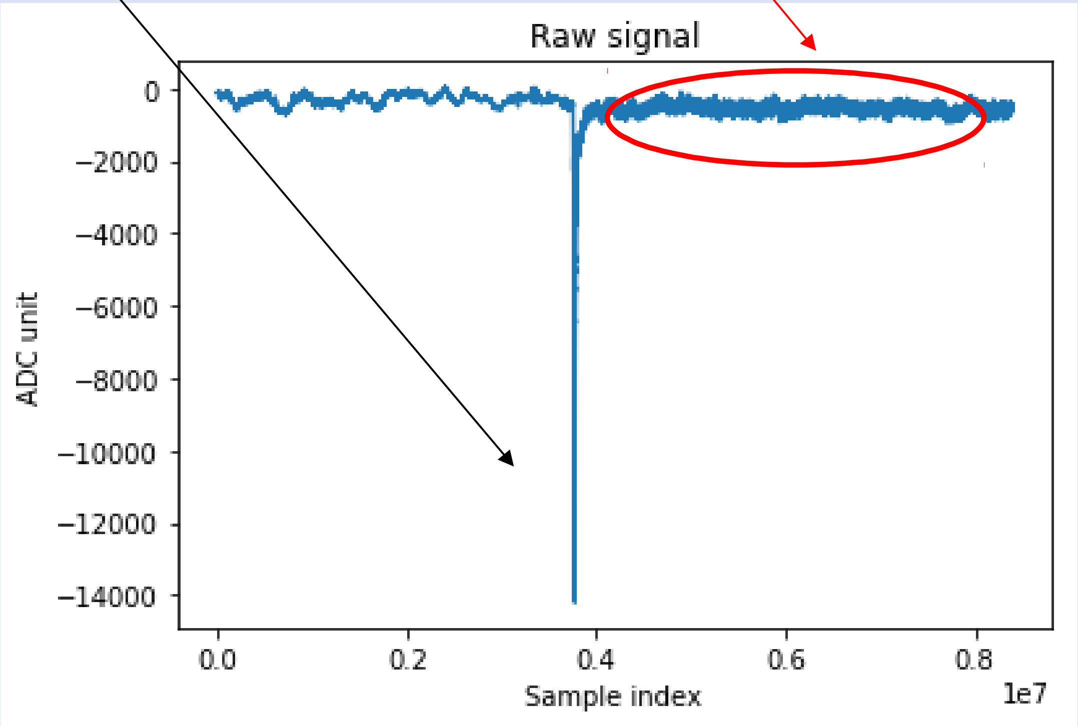


https://arxiv.org/pdf/1907.00396.pdf

Types of infrasound noise

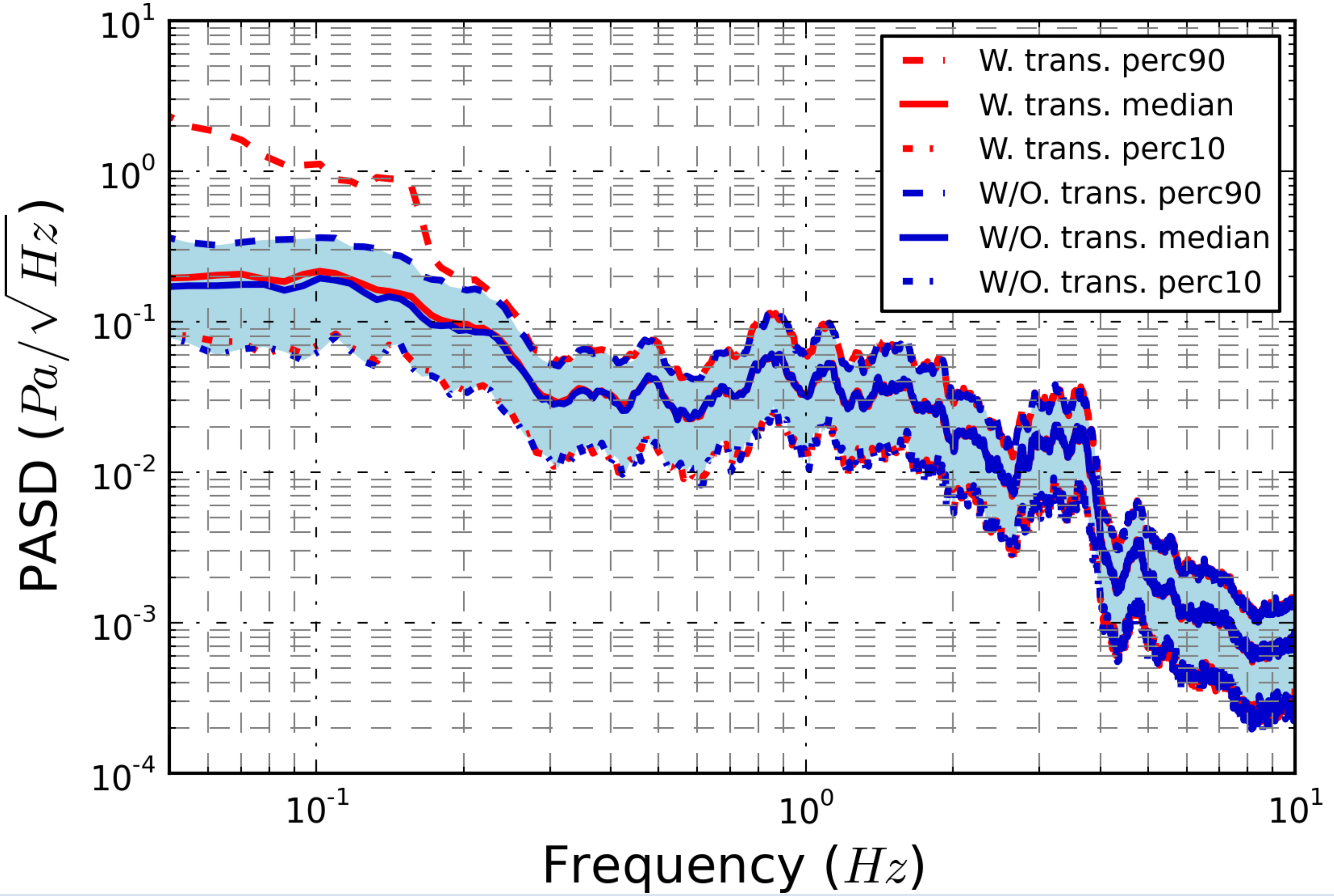
Different types of noise: short duration with excess power or continuous



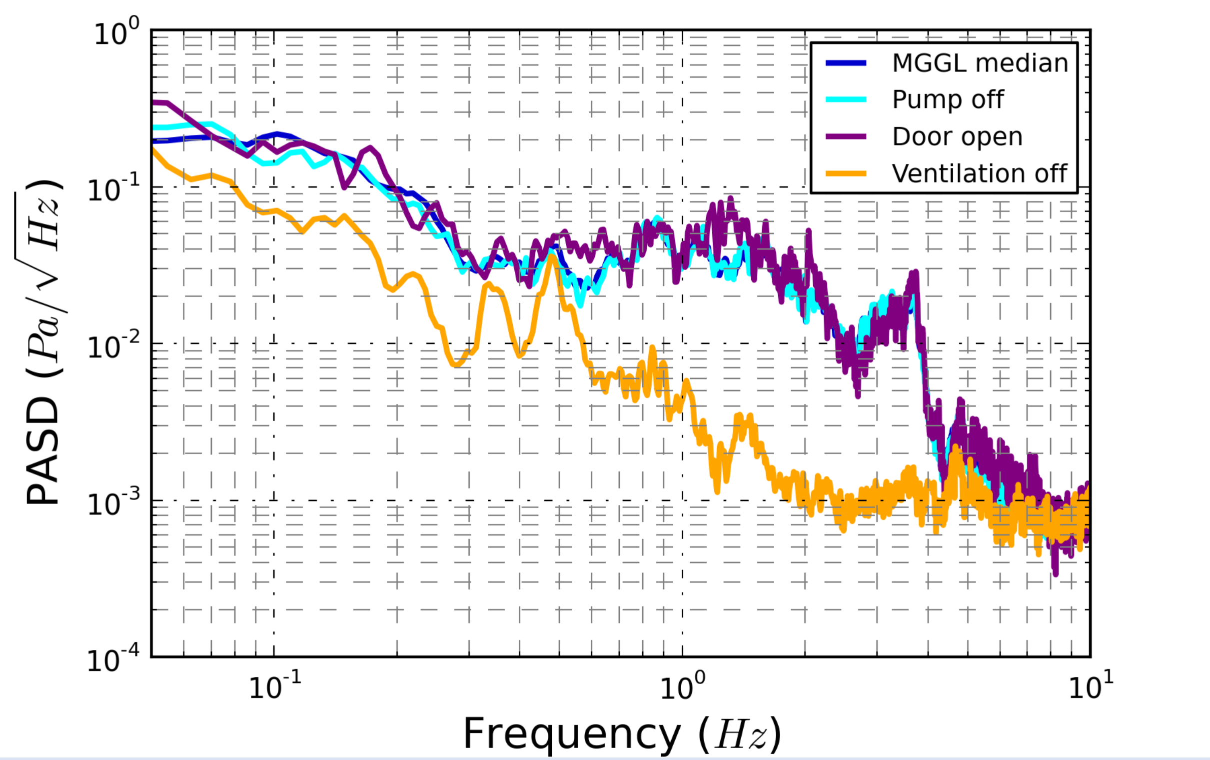


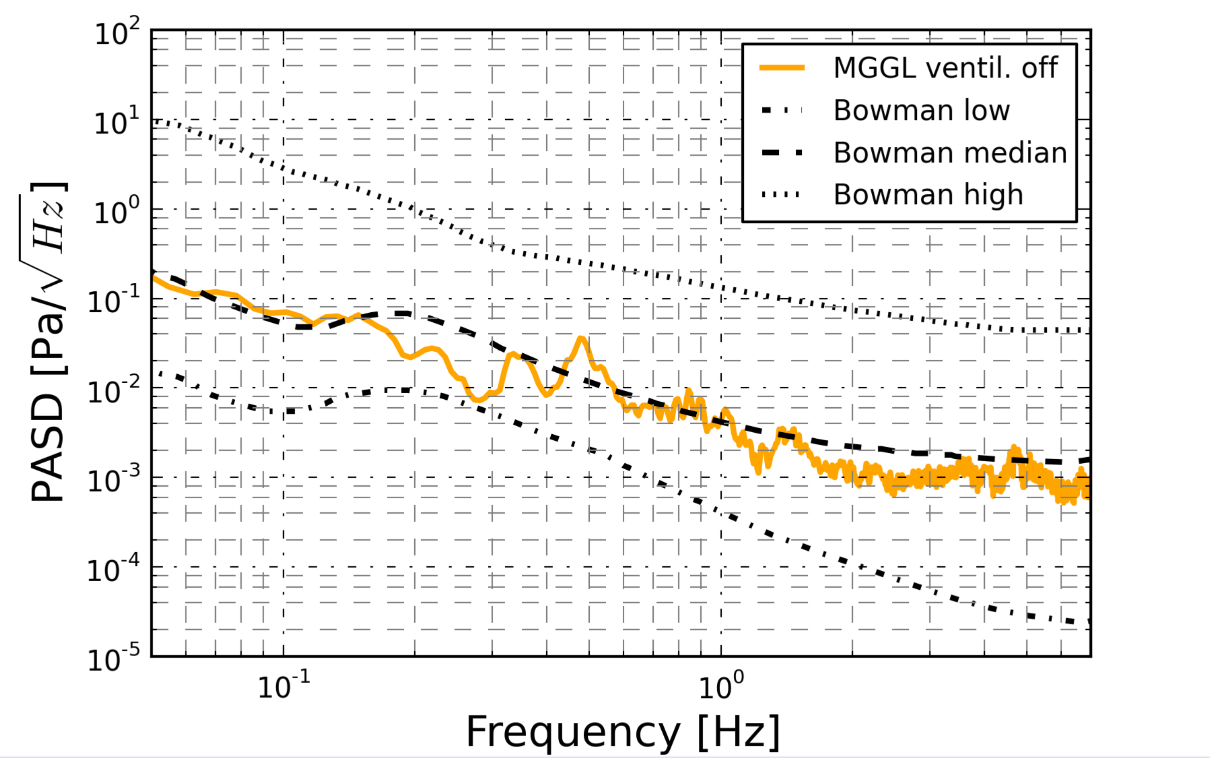
Our Haar-transformation-based method to find transients is presented: https://arxiv.org/pdf/1907.00396.pdf

Effect of removing transients



Infrasound results





Rheological investigations

- We got the **static and dynamic elastic moduli of the andesitic rock** of the mine from time dependent laboratory experiments
- We interpreted these measurements in a rheological modelling framework
- and justified the obtained model parameters with elastic propagation speed measurements of the P and S waves.
- Investigations showed that the **hard rock of Mátra cannot be considered ideal elastic** in a characteristic frequency range [6]
- The **influence of this property for Newtonian noise** should be investigated.

Conclusion

- We used various standard methods in parallel to novel approaches of investigating the geophysical environment, electromagnetic attenuation, infrasound noise, cosmic muon tomography of the surrounding rock mass, and long term seismic noise.

See EPJ Special Topics (2019 September):
https://link.springer.com/content/pdf/10.1140%2Fepjst%2Fe2019-900153-1.pdf

Conclusion

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- **The collected data could enable us to cross check and and compare standard measurements and techniques applied in earlier investigations with the new ones.**

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- **Alongside this, the geological and rheological properties of the base rock were summarized.**

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- The collected data could enable us to cross check and and compare standard measurements and techniques applied in earlier investigations with the new ones.
- Alongside this, the geological and rheological properties of the base rock were summarized.
- **We strongly believe that applying our results for the site selection can significantly improve the signal to nose ratio of the multi-messenger astrophysics era.**

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https://link.springer.com/content/pdf/10.1140%2Fepjst%2Fe2019-900153-1.pdf

The MGGL group

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Industrial partners

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Váradi Árpád, Rofrits Vilmos

Geo-Faber Zrt., Pécs
Töllösy Pál CEO,
Weisz Róbert, Nógradi Tamás

References:

[1] Beker M G, van den Brand J F J and Rabeling D S 2015 Subterranean ground motion studies for the Einstein telescope Class. Quantum Grav. 32 025002

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[3] G. G. Barnaföldi et al., First report of long term measurements of the MGGL laboratory in the Mátra mountain range. Class. Quant. Grav., 2017, 34(11), 114001, doi:10.1088/1361-6382/aa69e3.

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[5] E Fenyvesi et al. INVESTIGATION OF INFRASOUND NOISE BACKGROUND AT MÁTRA GRAVITATIONAL AND GEOPHYSICAL LABORATORY (MGGL) https://arxiv.org/pdf/1907.00396.pdf

[6] P. Ván et al.: Long term measurements from the Mátra Gravitational and Geophysical Laboratory, The European Physical Journal Special Topics 228(8), 1693-1743 (2019).

[7] J. R. Bowman, G. E. Baker, M. Bahavar, Ambient infrasound noise. Geophysical Research Letters, 2005, 32(9), L09803, doi:10.1029/2005GL022486.

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Thank you for your attention!