LONG TERM SEISMIC MEASUREMENTS IN THE MATRA MOUNTAIN RANGE

László Somlai MTA Wigner RCP

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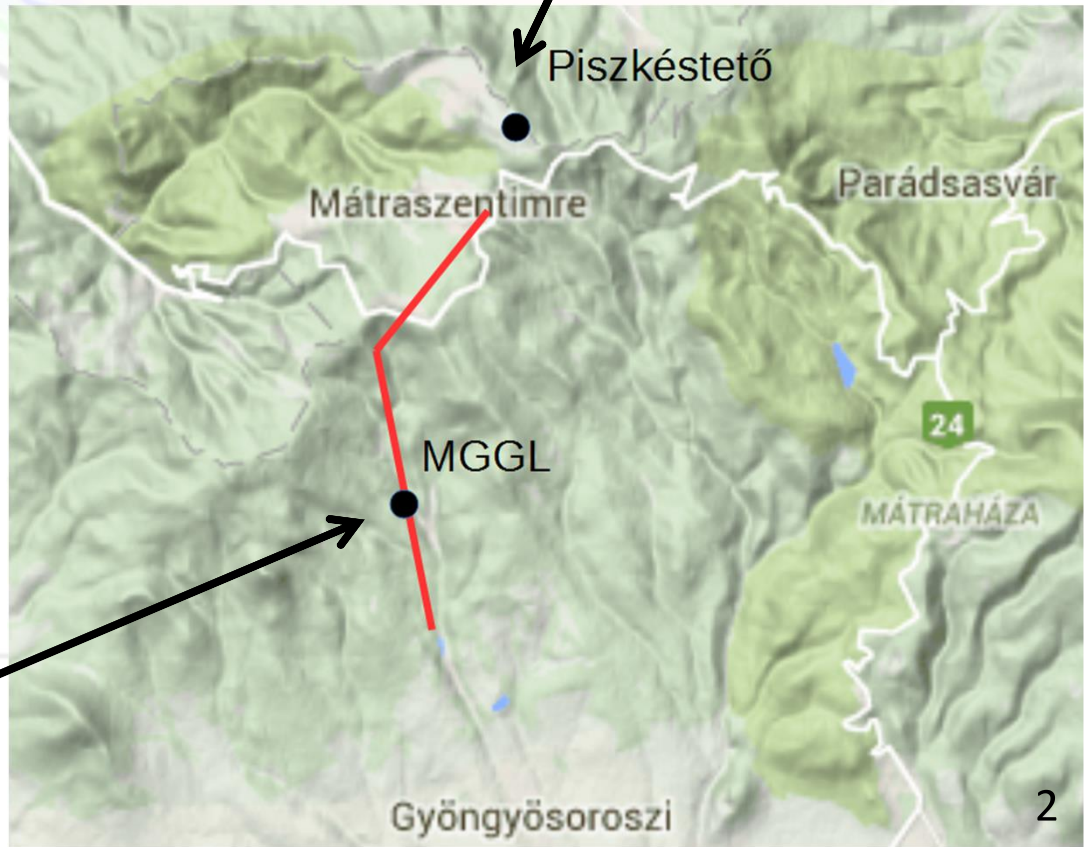
MGGL Collaboration

22 Aug. 2017, Gyöngyös

Introduction

- Why to measure?
- What can we measure?
- Noises
- Average data
- Work/night ration
- Quite day
- Internal sources

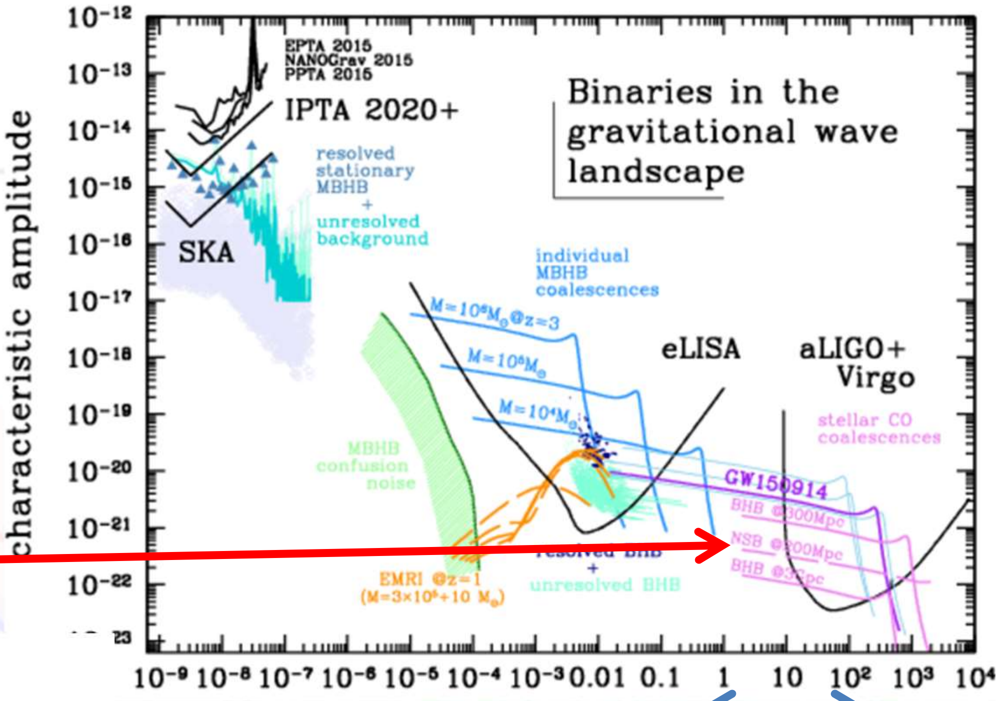
PSZ station



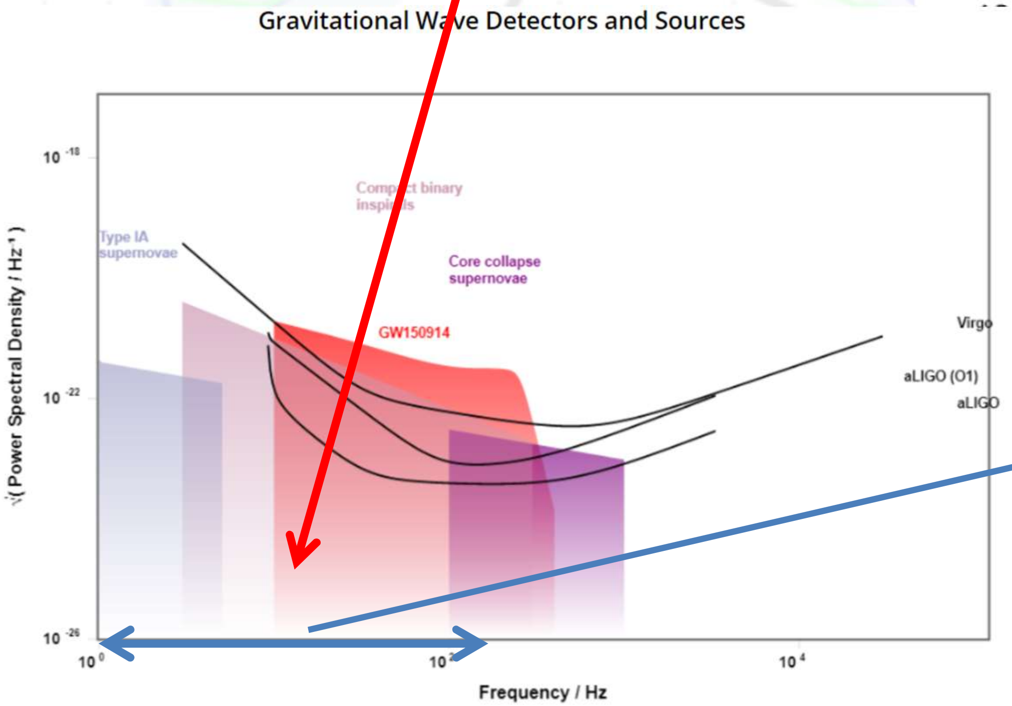
ET1H station

Why to measure?

Planned 3rd generation GW detector



Colpy, Monica et al. arXiv: 1610.05309 [astro-ph.HE]



1-100 Hz

Stellar-mass black hole binary
Compact binary

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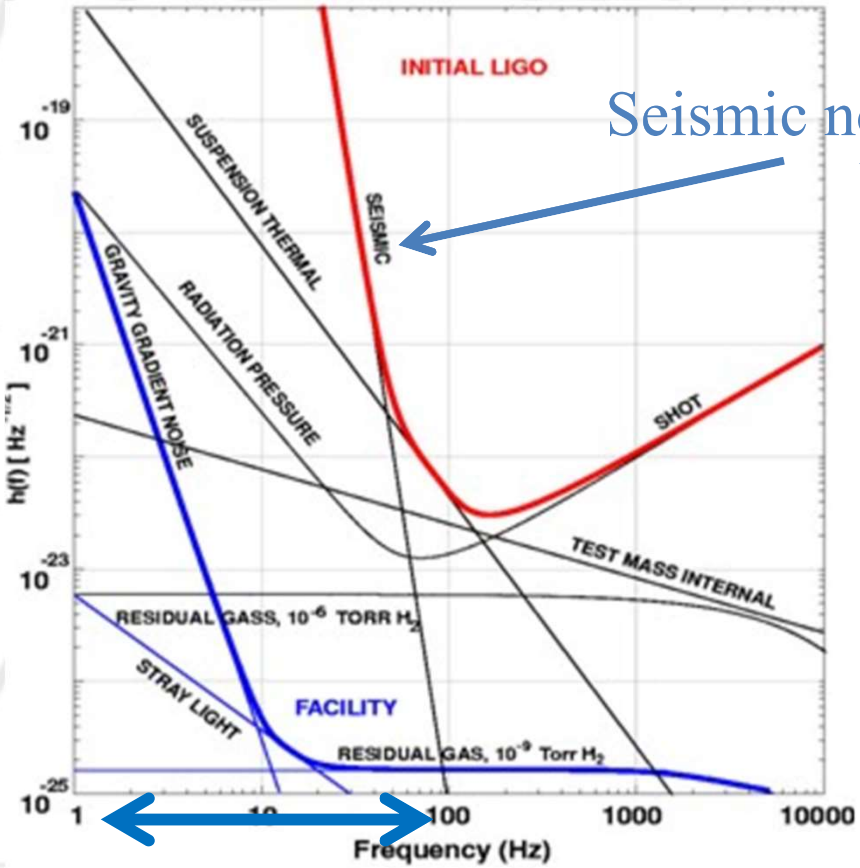
http://rhcole.com/apps/GWplotter/

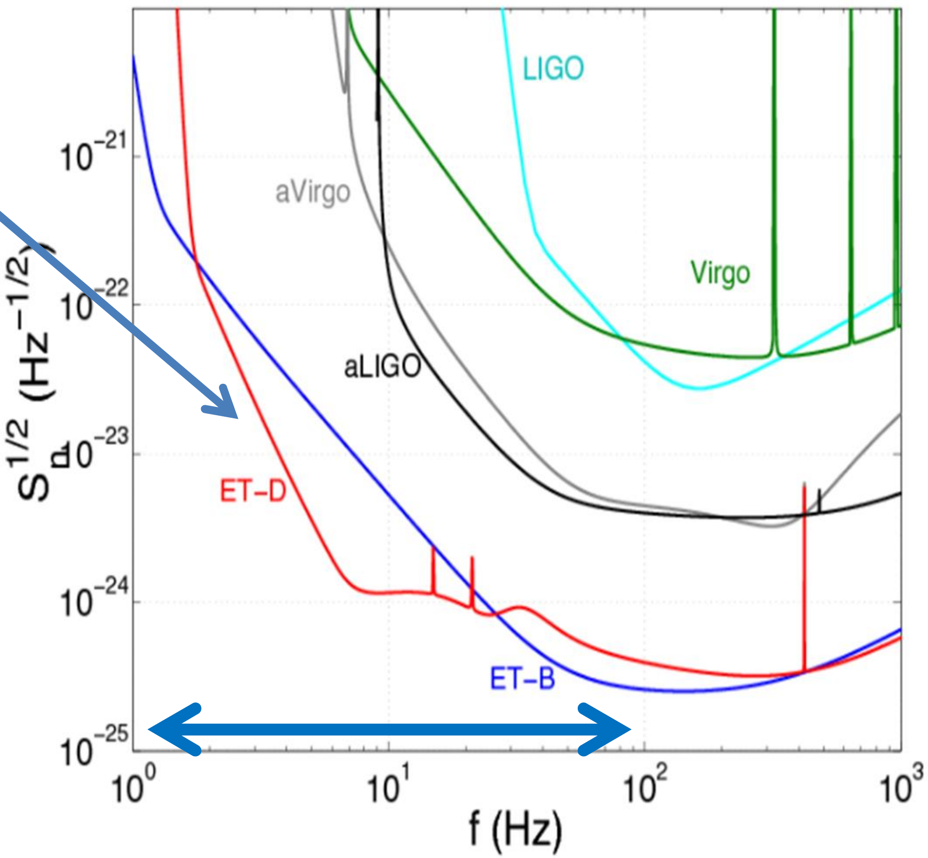
Why to measure?

”Fundamental” noise sources (initial Ligo)

Planned GW detector, Einstein Telescope

Seismic noise





R. Weiss, D. Shoemaker, NSF Review, Caltech, 30 April 2001

Regimbau, Tania et al. Phys. Rev. D86 (2012) 122001

What can we measure?

Raw data

↓

Linear detrend

↓

Highpass filter (f = 0.01 Hz)

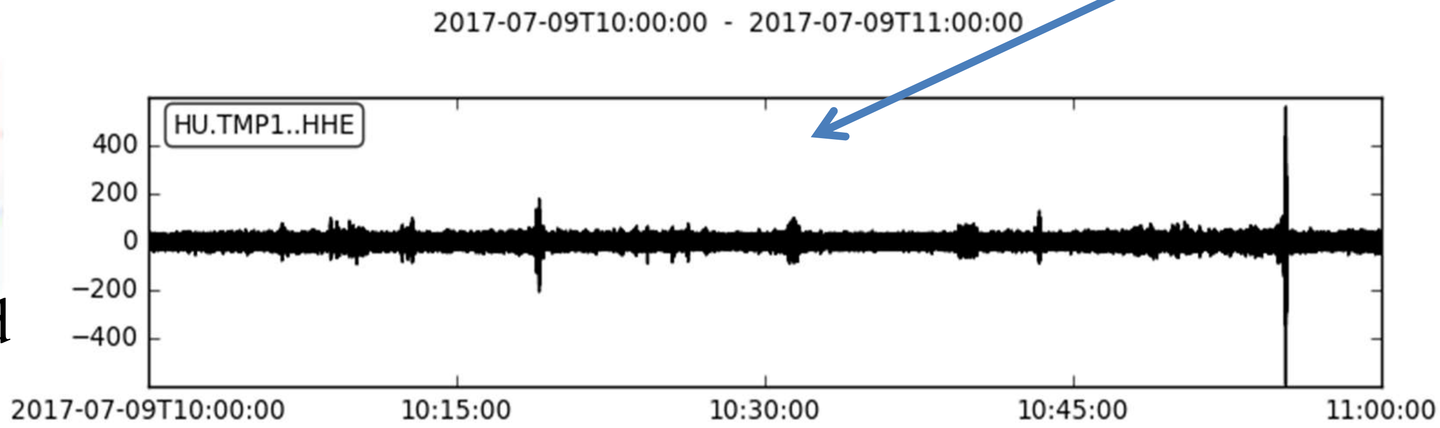
↓

PAZ remove

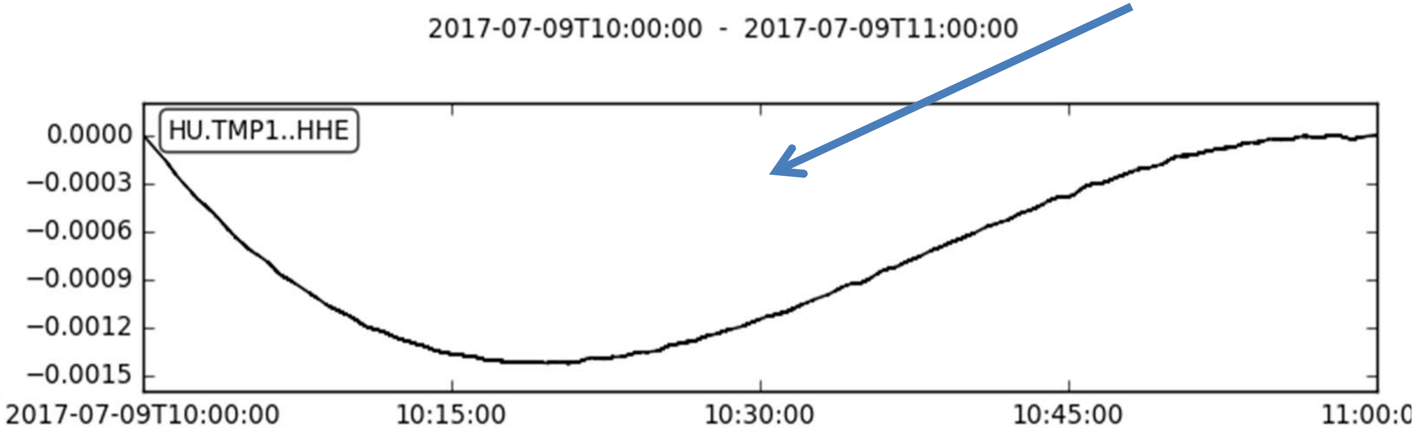
↓

Raw velocity data

Raw data
+ Linear detrend
+ Highpass filter



Raw velocity data



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Measurement I.

Raw velocity data (v_k)

FFT + window function

PSD (velocity)

$$P_k^{(v)} = \frac{2}{f_s \cdot N \cdot W} |V_k|^2$$

f_s: sampling rate
N: number of data point
W: average of window f.

ASD (velocity)

$$A_k^{(v)} = \sqrt{P_k^{(v)}}$$

ASD (displacement)

$$A_k^{(x)} = \sqrt{P_k^{(v)} (2 \cdot \pi \cdot f_s)^{-2}}$$

RMS (displacement)

$$rms_l^{(x)} = \sqrt{\frac{f_s}{N} \sum_{k=l}^{N/2+1} P_k^{(v)} \cdot (2 \cdot \pi \cdot f_k)^{-2}}$$

Limits on the measurements

- Peterson's New Noise Model: curves of high and low seismic background displacement based on a worldwide survey of station noise

(J. Peterson, "Observations and Modelling of Seismic Background Noise", U. S. Department of Interior Geological Survey, Open-File Report 93-322, 1993)

- Beker's limit: RMS displacement (2 Hz) 0.1 nm

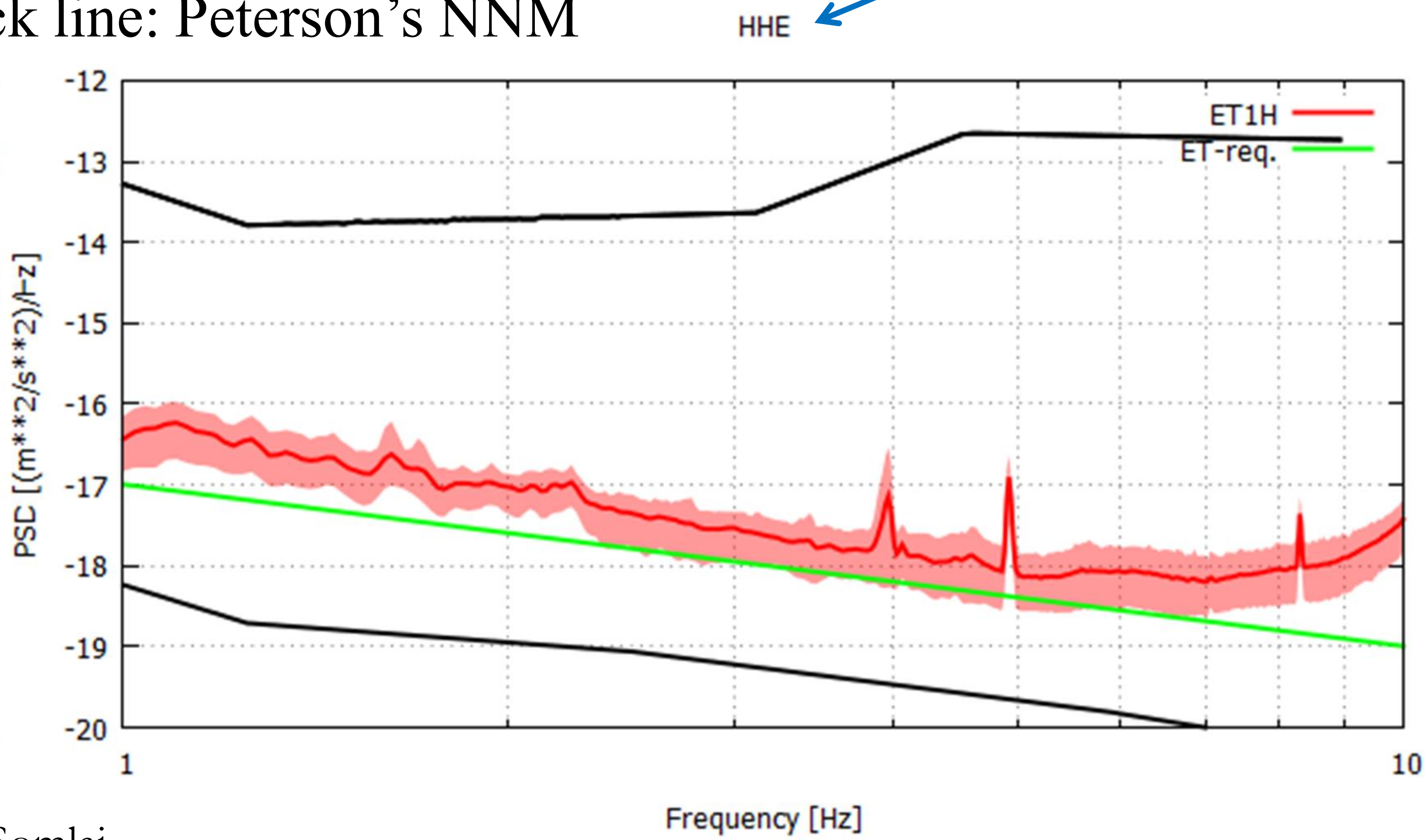
(M. G. Beker, J. F. J. van der Brand and D. S. Rabeling, "Subterranean ground motion studies for the Einstein Telescope", Class. Quantum Grav. **32** (2015) 025002)

- Low frequency noise budget for the Einstein Telescope
  (Hild S. et al." Sensitivity studies for third-generation gravitational wave observatories" 2011 Class. Quantum Grav. **28** 094013)

Measurement II.

- Red line: average PSD :The transparent color region is bounded by the 90 and 10 percentiles
- Green line: ET requirement
- Black line: Peterson's NNM

3 direction: E,N,Z



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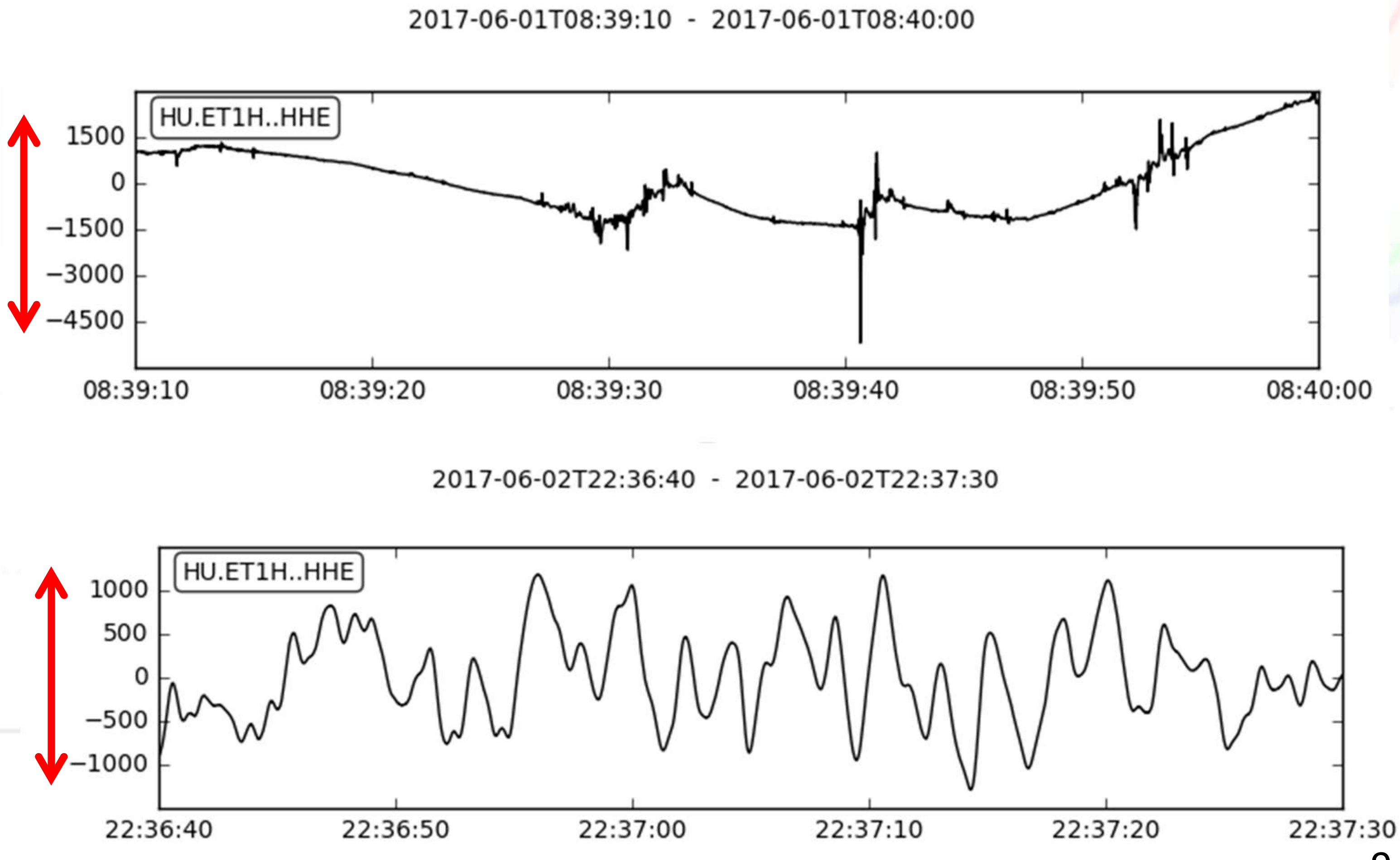
Noises I. (Detector ”noises”)

mV differences < 2000mV

6000 mV

2200 mV



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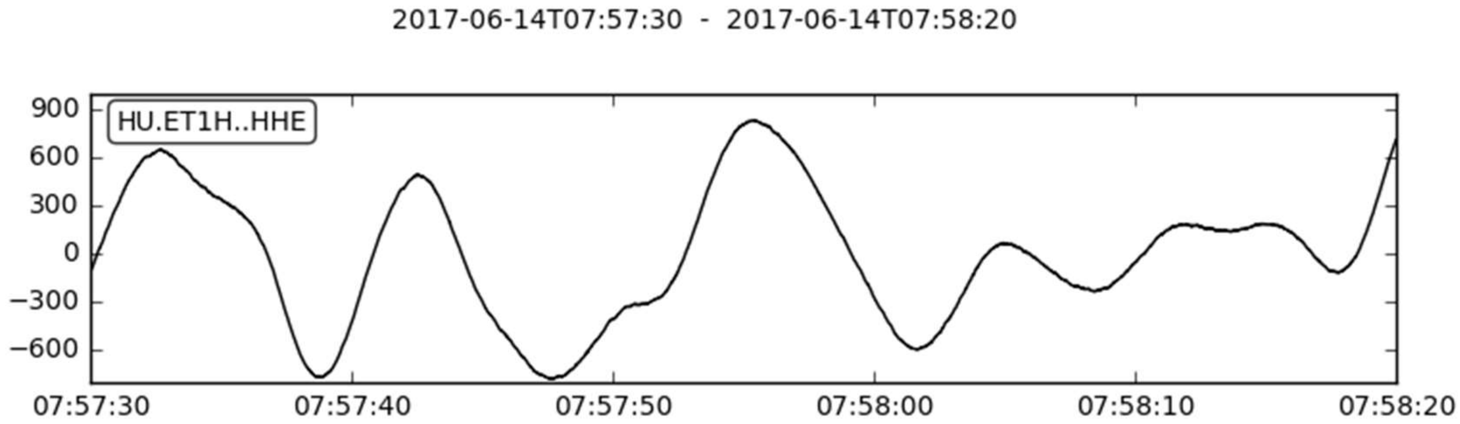
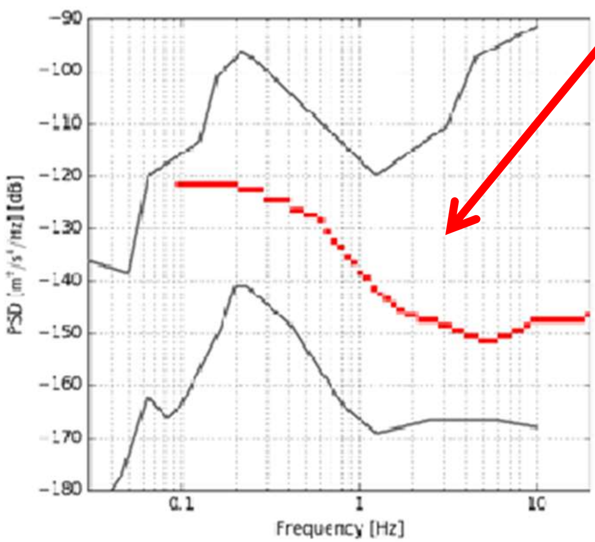
Noises I. (Detector ”noises”)





PSD ratio

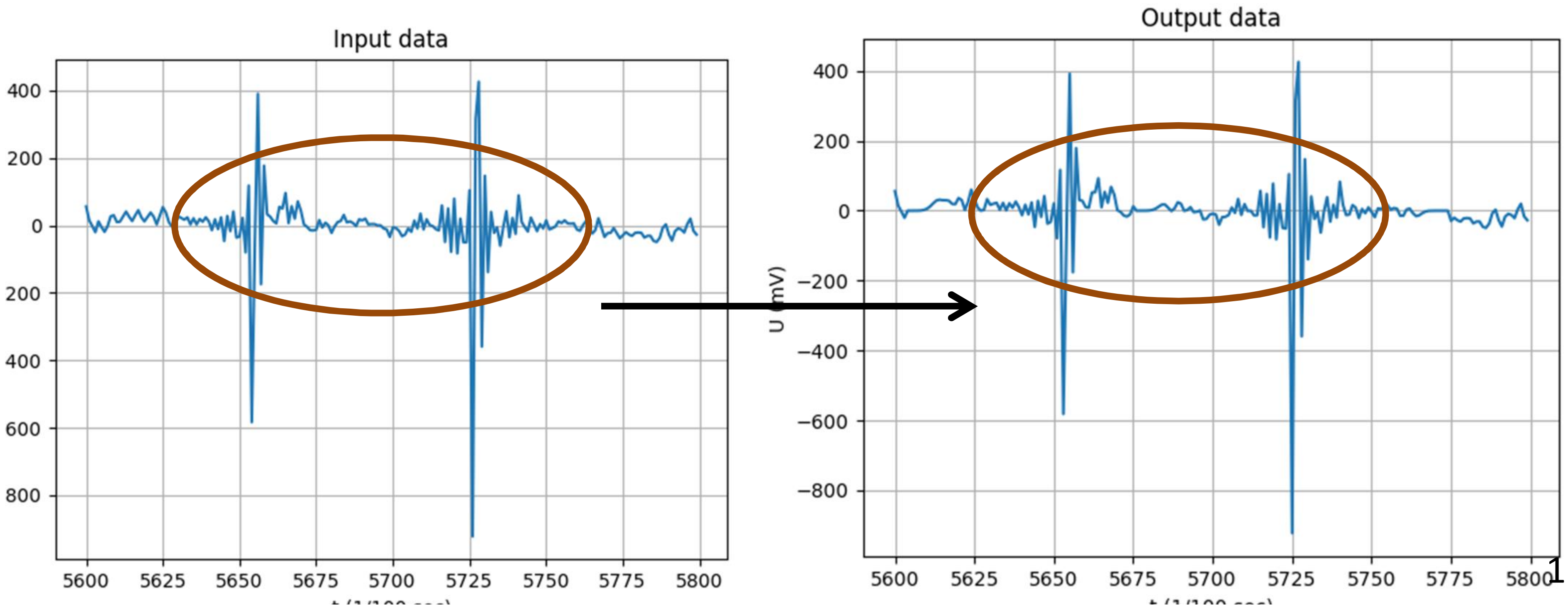
$\log10(\overline{P^{(v)}})_{0.22-0.4}/\log10(\overline{P^{(v)}})_{0.08-0.2} < 1.15$

These ”noises” are sensor noises
We do not use them (2% of data)

Noises II.

Noise filtering method:
Z. Zimboras and P. Kicsiny
Test runs

More details:
M. Dobróka, H. Szegedi, J. Somogyi Molnár, P. Szűcs, ” On the Reduced Noise Sensitivity of a New Fourier Transformation Algorithm”, Math Geosci (2015) 47:679-697, DOI 10.1007/s11004-014-9570-x



Data from ~490 day

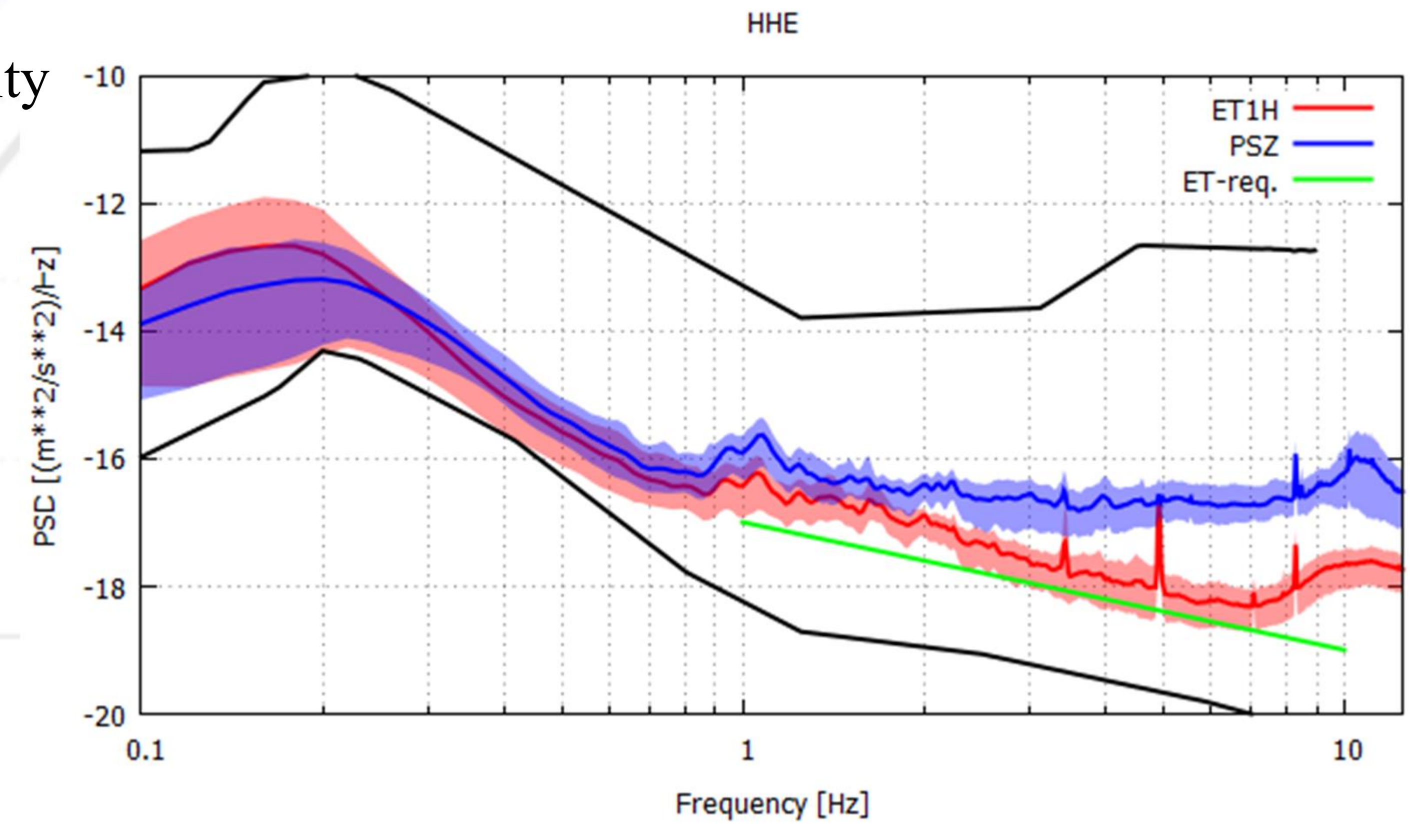
Beker's limit: 0.1 nm

	ET1H	PSZ
HHE	0.196 nm	0.568 nm
HHN	0.213 nm	0.521 nm
HHZ	0.259 nm	0.417 nm

Data collecting from March of 2016
ET1H is -88 m
PSZ is 0 m

- Human activity in the mine
- Water pump
- Train

etc.



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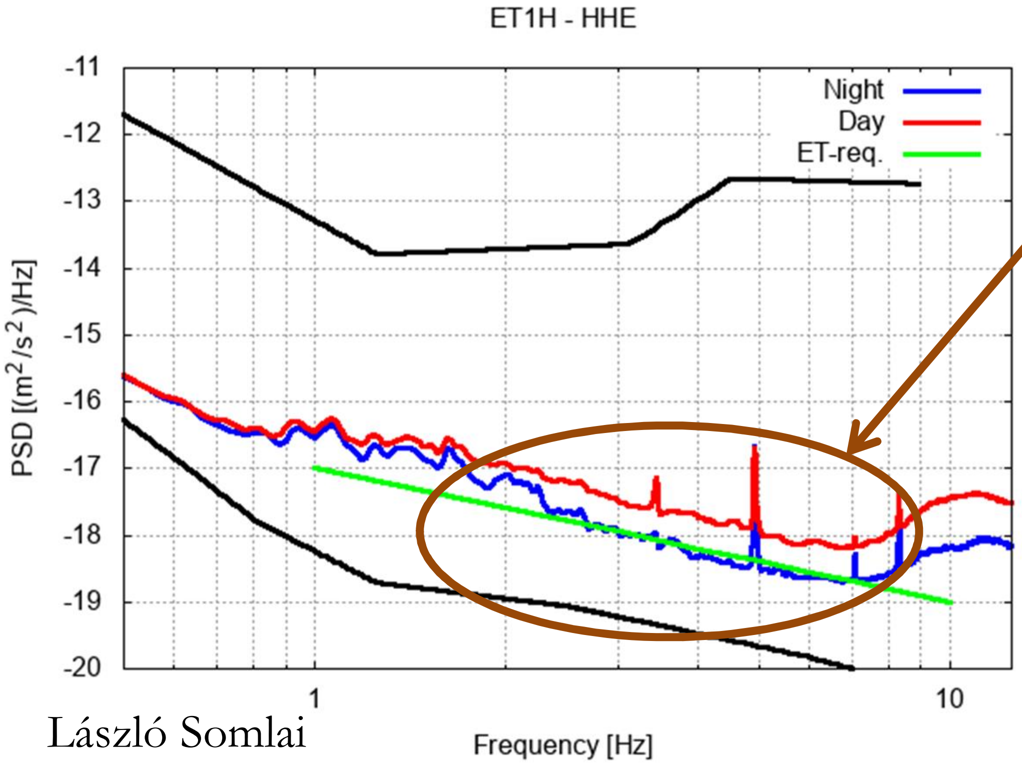
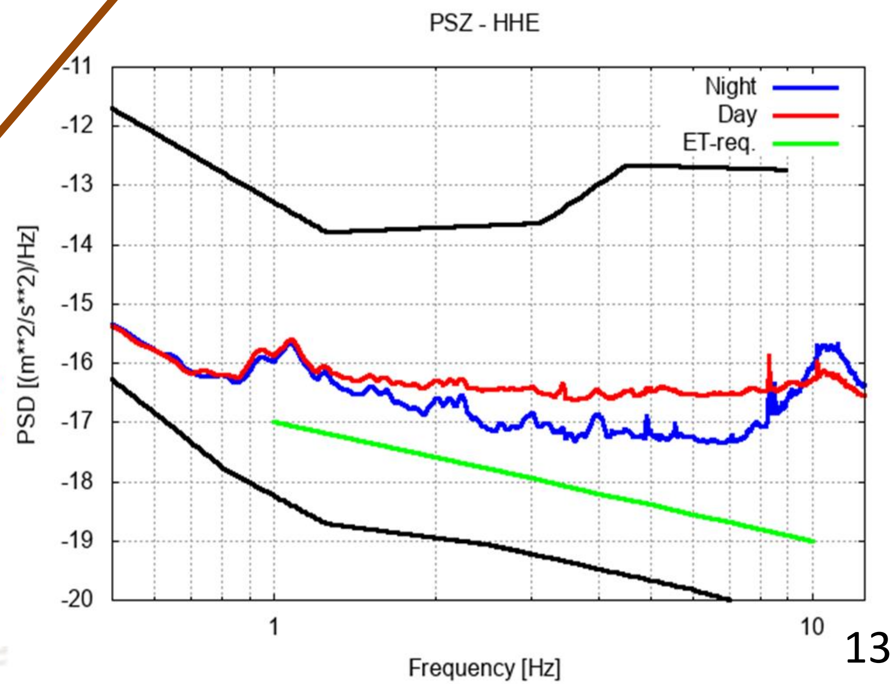
Day/night

Night period : 00:00 -- 03:00 21:00 -- 24:00 UTC

Working period: 10:00 – 16:00 UTC

Close to ET-req.





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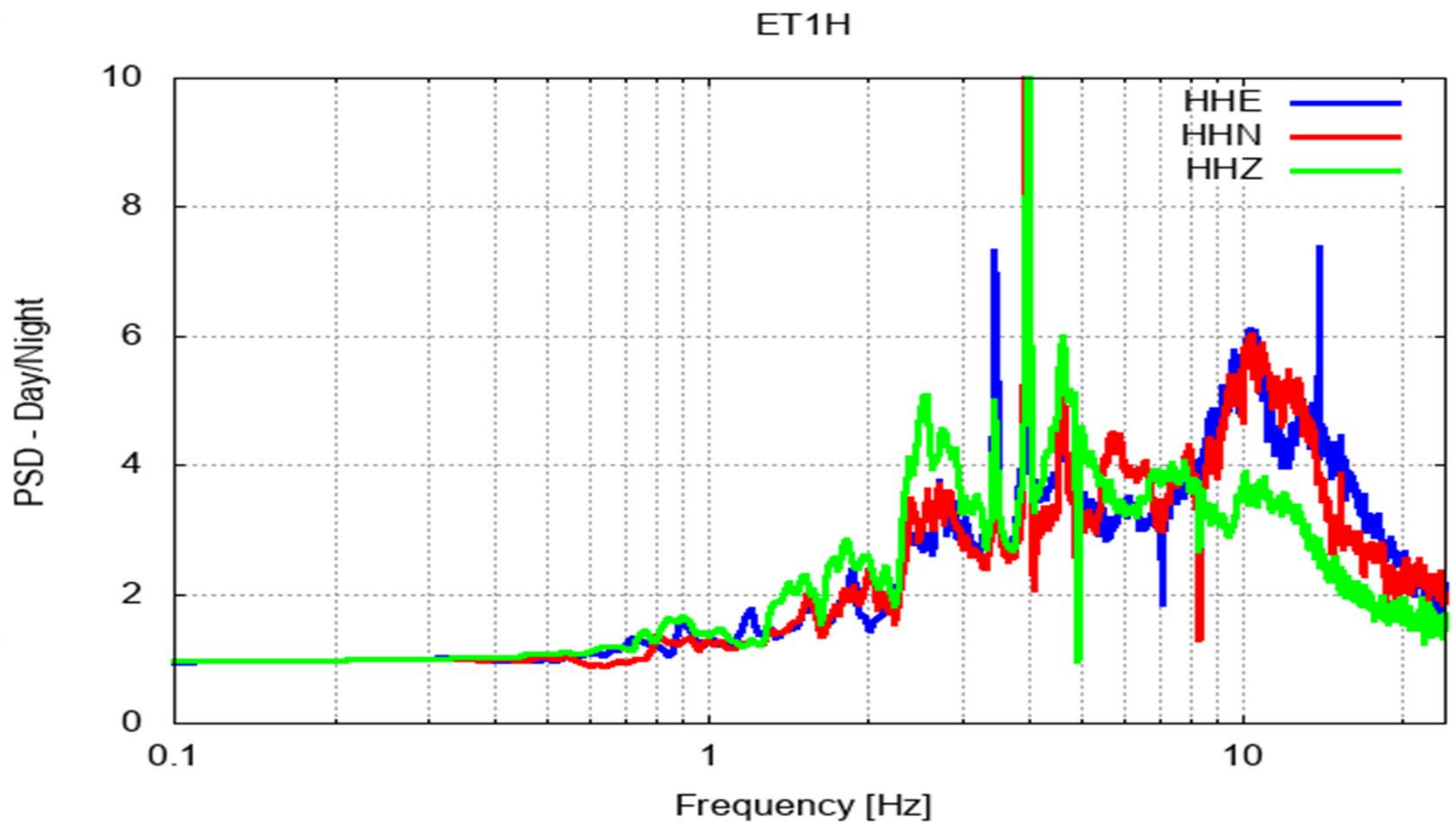
Day/night ratios

Cultural noise is present 2 – 20 Hz
Average values ~ 3.8 (HHE)
3.7 (HHN)
3.0 (HHZ)

		ET1H	PSZ
HHE	day	0.217 nm	0.653 nm
	night	0.141 nm	0.459 nm
HHN	day	0.230 nm	0.616 nm
	night	0.142 nm	0.379 nm
HHZ	day	0.301 nm	0.473 nm
	night	0.177 nm	0.328 nm

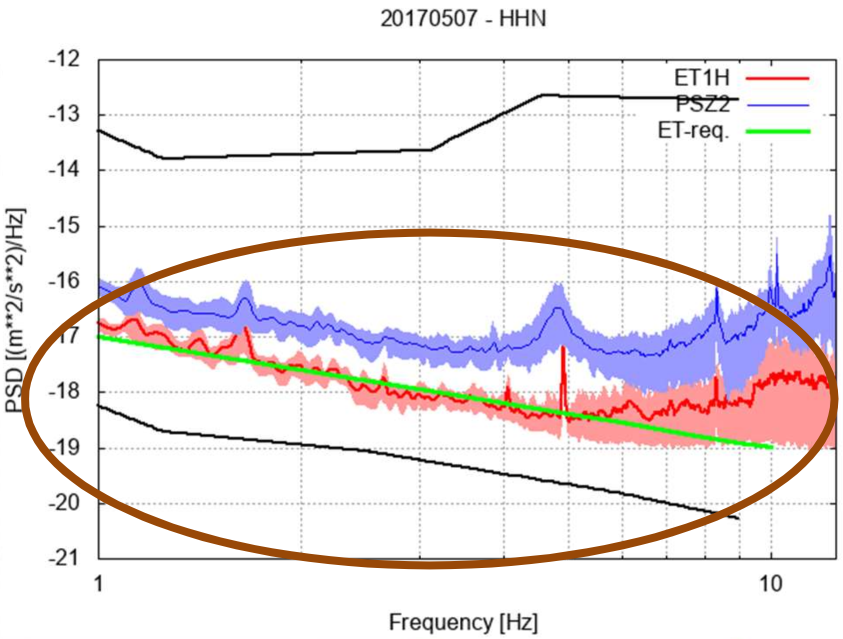


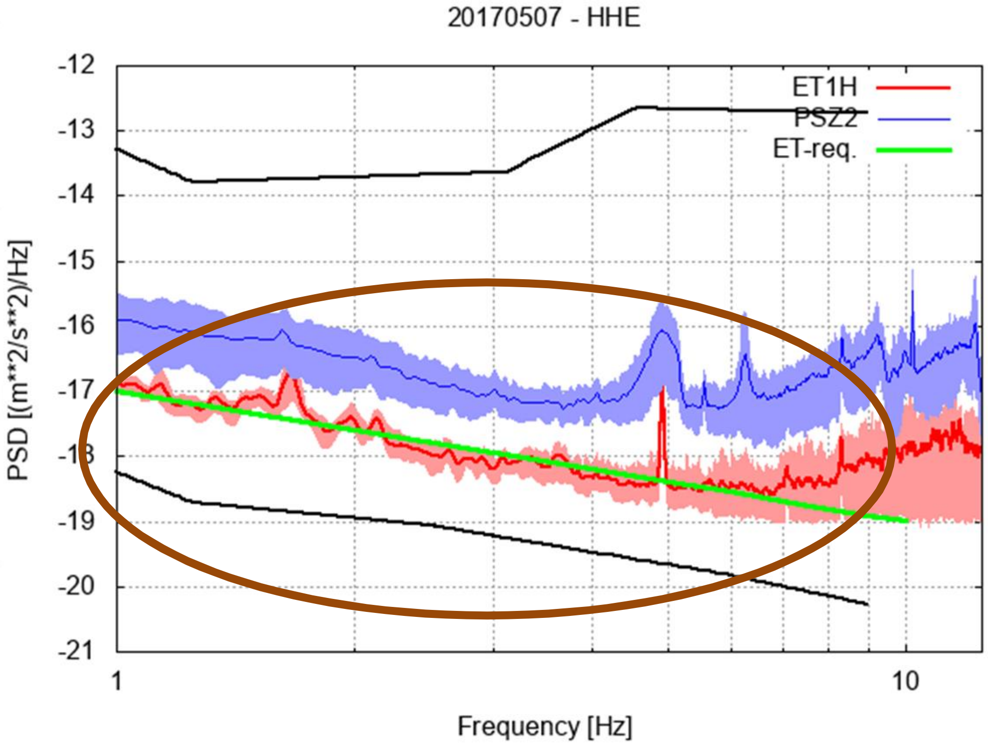
Quite day (not planned)

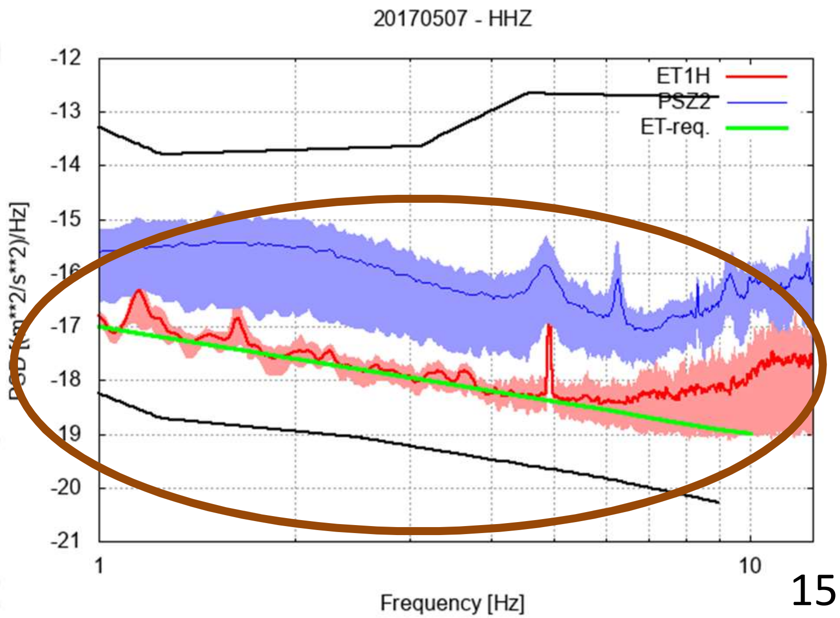
07. 05. 2017

Beker's limit: 0.1 nm

HHE	0.117 nm
HHN	0.118 nm
HHZ	0.147 nm







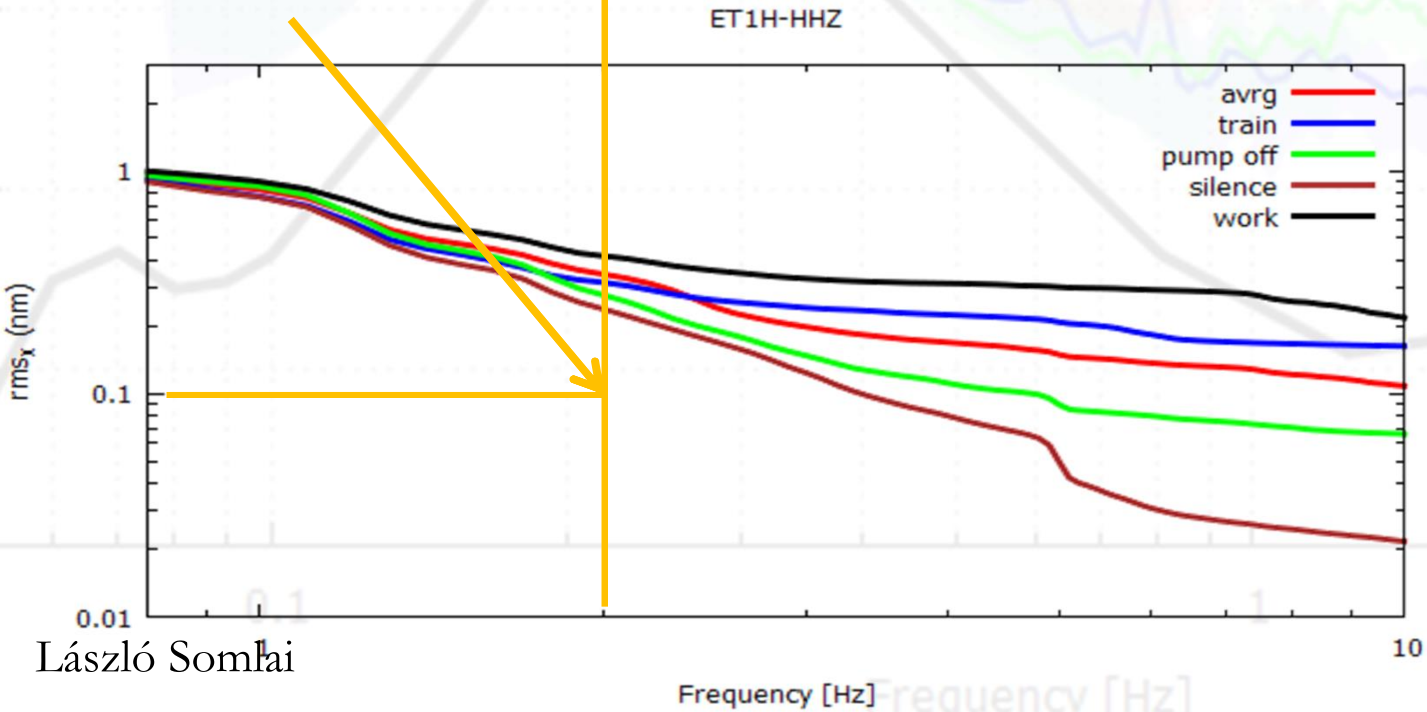
Internal noise sources

$$rms_l^{(x)} \sim \sqrt{\sum_{2Hz}^{50\ Hz} P_k^{(v)} \cdot \omega_k^{-2}}$$

RMS values (nm) at 2 Hz
15.12.2016,
MGGL controlled
mine operation

	train	pump off	silence	work	average
HHZ	0.316	0.278	0.240	0.416	0.344
HHN	0.232	0.229	0.212	0.362	0.249
HHE	0.218	0.222	0.213	0.371	0.252

Beker's limit 0.1 nm



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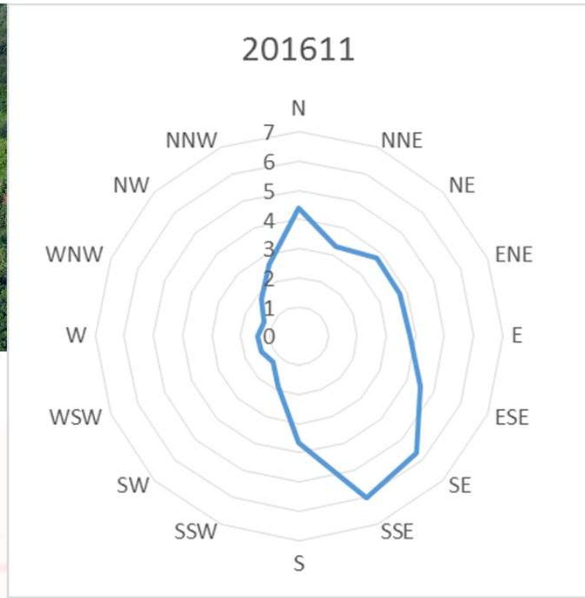
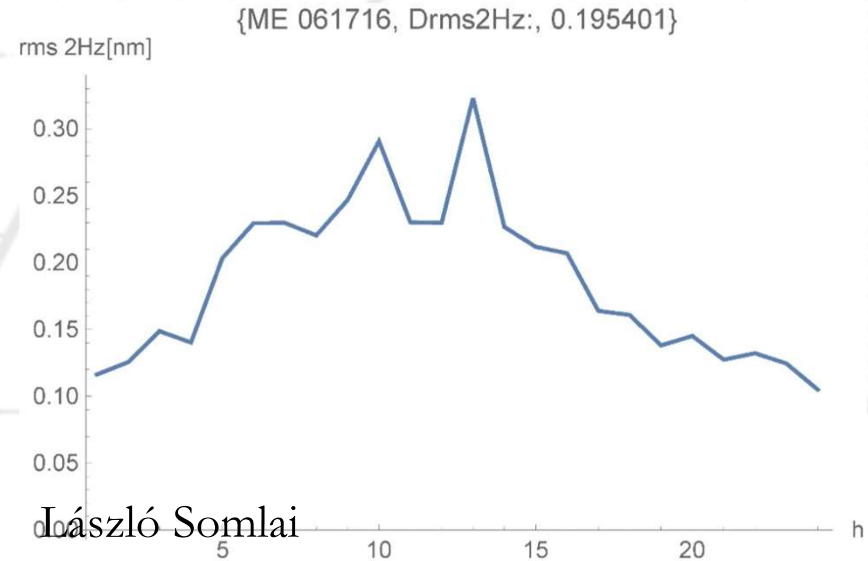
Effect of wind

- No significant effect
  - Location of weather station
  - No effect below 100 m for 8 m/s and lower wind (Young *et al.* 1996)



Direction of wind

Meteorological data analysis:
T. Novák, Zs. Bernát, A. Molnár



MGGL Collaboration

- Collaboration (31 participants) with many Institutions
  - Wigner FK
  - MTA CSFK GGKI
  - Atomki
  - Univ. of Miskolc
  - BME
  - ELTE
  - Univ. of Warsaw
  - Univ. Of Zielona Góra
- Report of the first data collection period,

(arXiv:1610.07630)

IOP Publishing Classical and Quantum Gravity
Class. Quantum Grav. 34 (2017) 114001 (22pp) https://doi.org/10.1088/1361-6382/aa69e0

First report of long term measurements of the MGGL laboratory in the Mátra mountain range

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Abstract
Matra Gravitational and Geophysical Laboratory (MGGL) was established near Gyöngyösoroszi, Hungary in 2015, in the cavern system of an unused ore mine. The laboratory is located 88 m below the surface, with the aim of measuring and analysing the advantages of the underground installation's

 1

" First report of long term measurements of the MGGL laboratory in the Mátra mountain range", Class. Quantum Grav. **34** (2017) 114001

Summary

- More than a year of data collected
- No effect of rain and wind
- Averaged RMS - E: 0.196 nm at 88 m below surface (night 0.141 nm)
  in mine cultural noise:
  ~30 %
  external cultural noise:
  ~30 %
  these can be reduced!

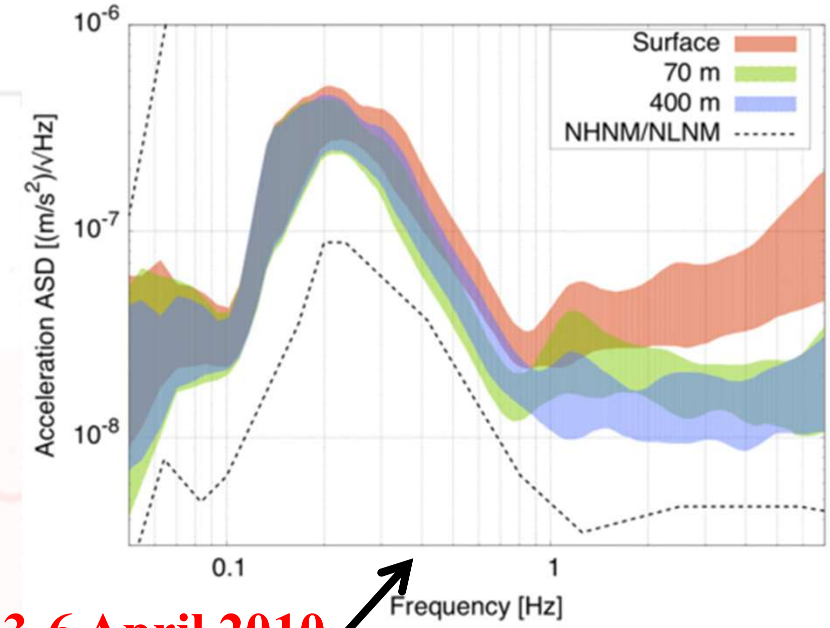
Location		Depth	RMS
LSC, Canfranc	Spain	900 m	0.07 nm
Lula	Italy, Sardinia	185 m	0.077 nm
Gyöngyösoroszi	Hungary	70 m	0.12 nm
Gyöngyösoroszi	Hungary	400 m	0.082 nm
LSM, Frejus	France	1750 m	0.1 nm
Kamioka	Japan	1000 m	0.11 nm
Sumiainen	Finland	0 m	0.11 nm
Gran Sasso	Italy	1400 m	0.13 nm
Black Forest	Germany	95 m	0.2 nm

Beker et al. Class. Quantum Grav. (2015) 32 025002

Beker et al. Class. Quantum Grav. (2015) 32 025002

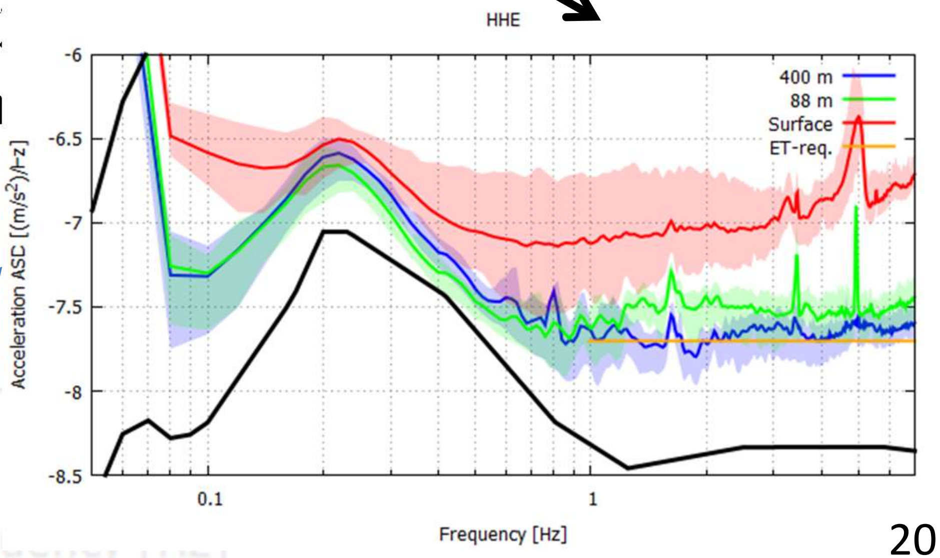
Future plans

- Low frequency regime (0.1-1 Hz) with infrasound detector data
- Noise filtering
- Depth dependence
  - Janossy mine: 0, -10, -20, -
    m (at Budapest, Wigner In
  - MGGL -88, -400 m (at Mátra)



3-6 April 2010

1-15 June 2017



Our result

Acknowledgments

G. G. BARNAFÖLDI, Zs. BERNÁT, T. BULIK, M. CIESLAR, E. DÁVID, M. DOBRÓKA, E. FENYVESI, D. GONDEK ROSINSKA, Z. GRÁCZER, G. HAMAR, G. HUBA, Á. KIS, R. KOVÁCS, I. LEMPERGER, P. LÉVAI, J. MOLNÁR, D. NAGY, A. NOVÁK, L. OLÁH, P. PÁZMÁNDI, D. PIRI, P. RACSKÓ, Á. ROMÁN†, L. SOMLAI, T. STARECKI, M. SUCHENEK, G. SURÁNYI, S. SZALAI, P. VÁN, D. VARGA, B. VÁSÁRHELYI, P. VASS, M. VASÚTH, Z. WÉBER, V. WESZTERGOM

Nitrokemia Zrt. (Á. VÁRADI és V. ROFRITS),

Geofaber Zrt.,

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Thank you for your attention!

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