EINSTEIN TELESCOPE: Why and where?

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MGGL Collaboration
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ECT* 10. Okt. 2017, Trento

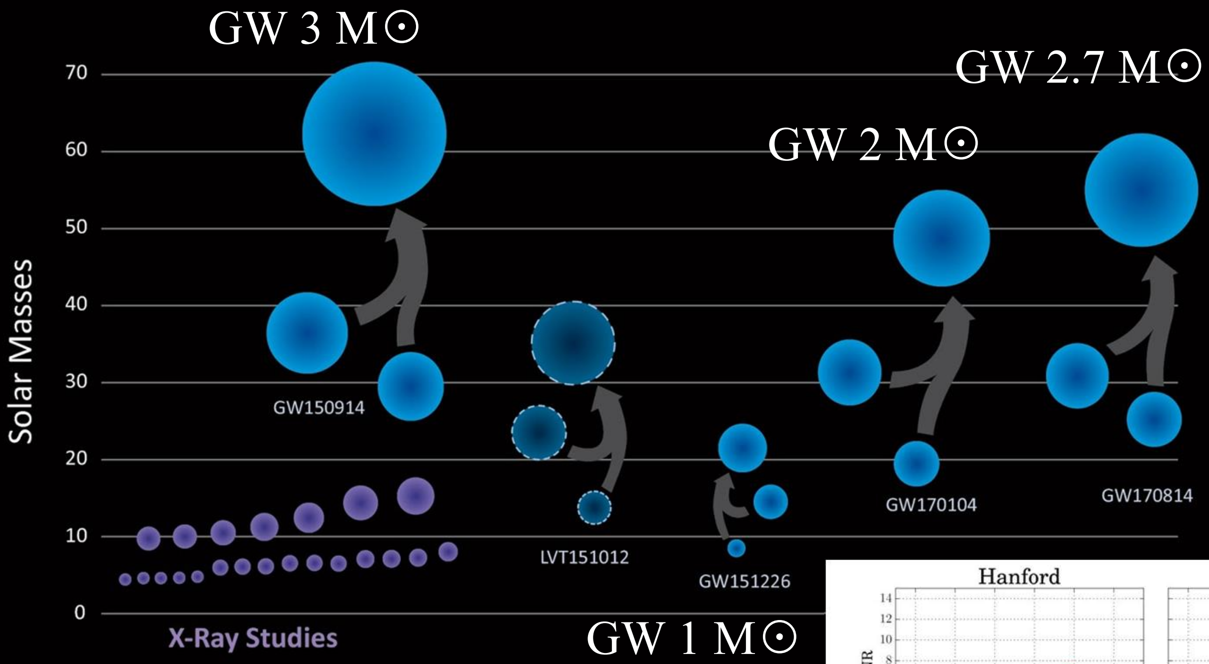
Outline

- Sort summary of detected gravitational waves
- Why 3rd gen. GW detectors?
- Noise budget of ET (low frequency)
- Site selection (Mátra mountain range, Hungary)
- Early results, future plans

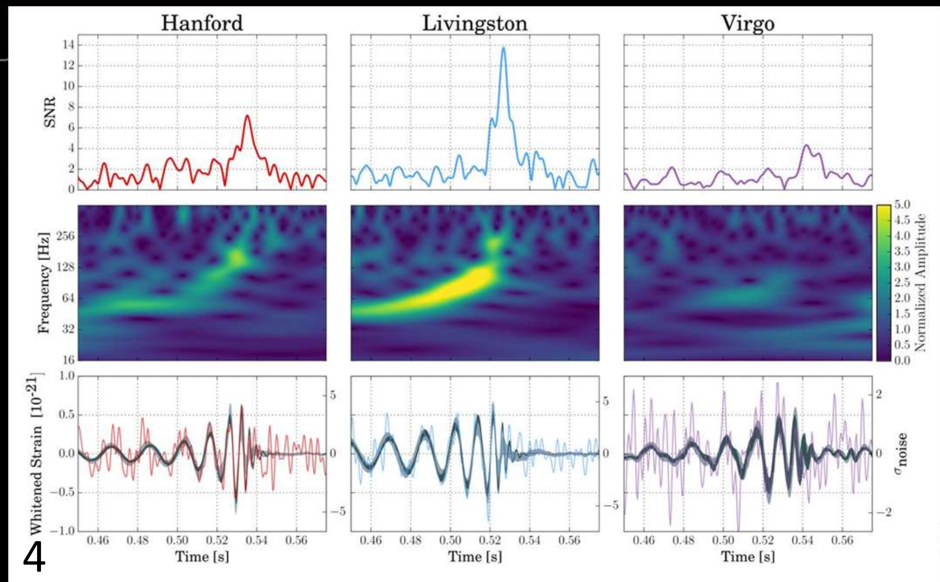
What are gravitational waves?

- Gravitational waves are perturbations of the spacetime metric, moving at the speed of light
- GWs can be emitted by astrophysical systems with rapidly changing mass distribution
- Binary systems with black holes and/or neutron stars, supernovae, spinning neutron starts, etc.
- These systems undergo strong quadrupole-type acceleration
- Both will collide after a certain time. A black hole may be created
- Expected strain at Earth 10^{-21} or smaller

Detected GW BBHs



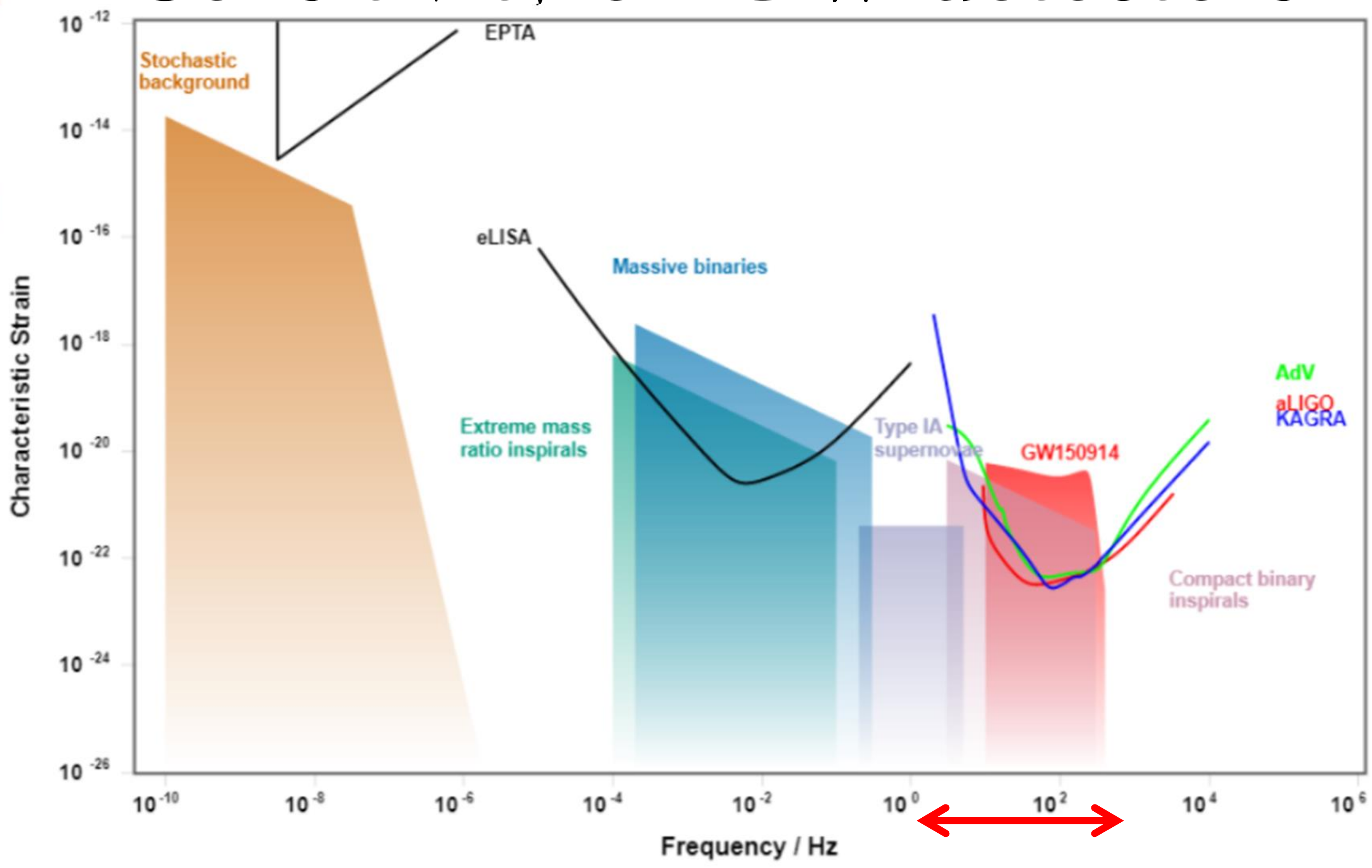
Event GW170814



Global GW Detector Network

Virgo joined O2 on August 1, 2017

Sensitivity of GW detectors



Ground based detectors:
- Compact binary inspirals
- EoS

Why 3rd gen.?

2nd gen.:

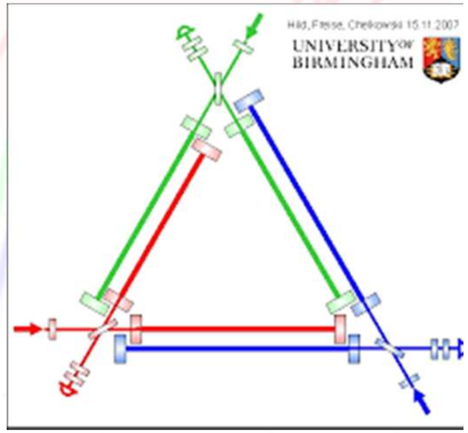
- GW signals from NS coalescing 10/ year
- SNR is too low for precise astronomical studies
- Difficult to upgrade („old" facilities), fix arm-length
- Improvements of sensitivity will be limited by site and infrastructure

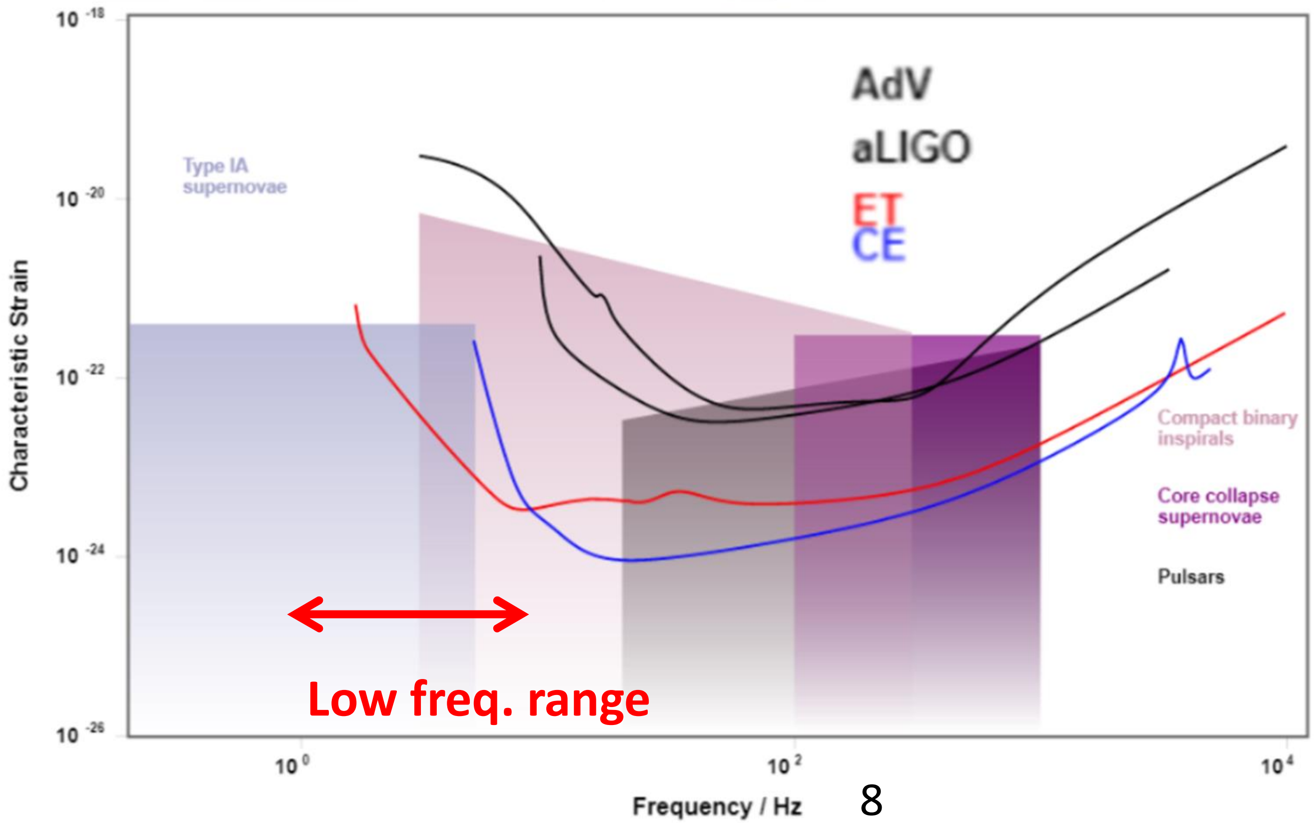
Sensitivity of ground-based GW detectors

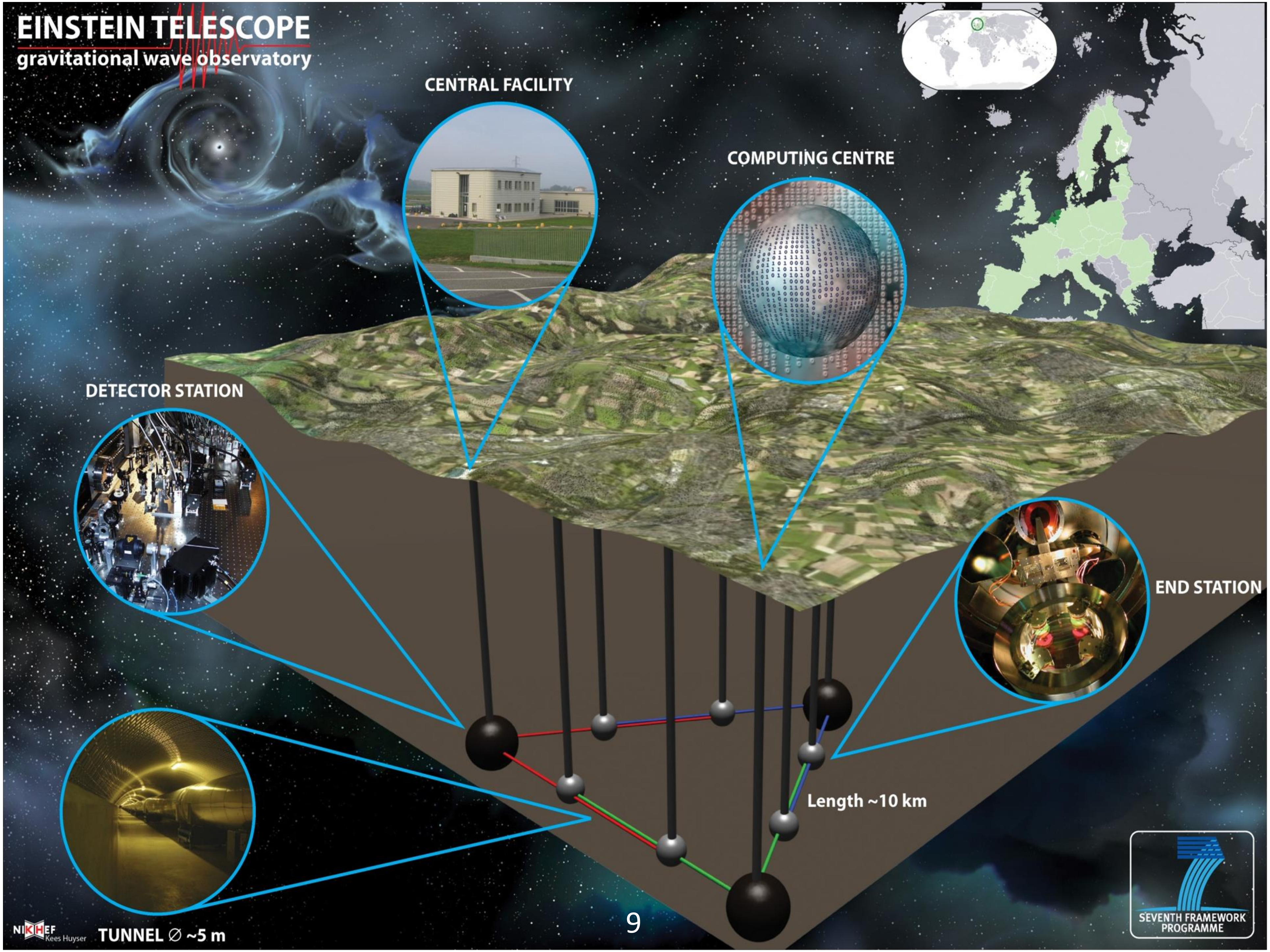
Two planed 3rd gen. detectors:

- CE (Cosmic Explorer) [ArXiv:1607.08697]
- ET (Einstein Telescope)

- Low- and high-frequency interferometer
- 100-200 m under the surface
- Triangle form (3 + 3 interferometer, xylophone design)



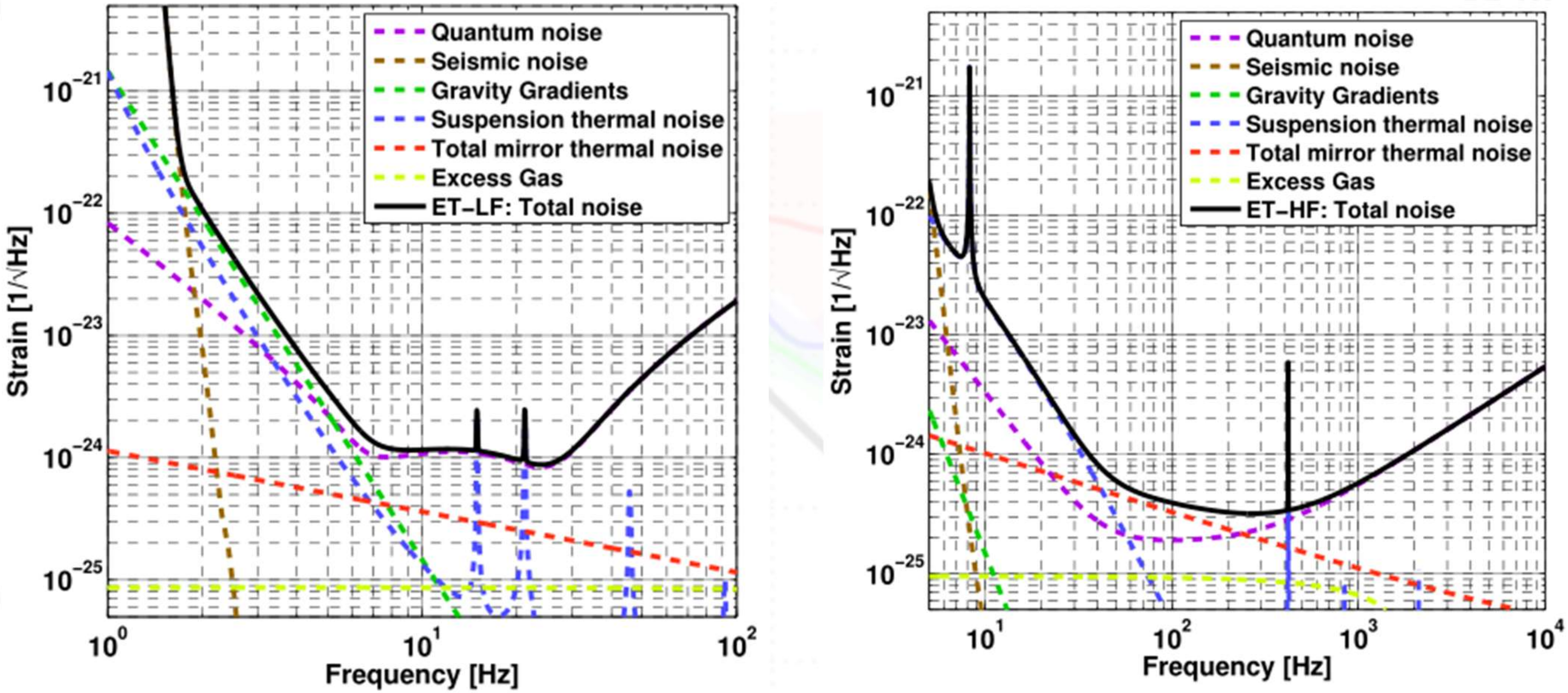



EINSTEIN TELESCOPE
gravitational wave observatory
CENTRAL FACILITY
COMPUTING CENTRE
DETECTOR STATION
END STATION
Length ~10 km
TUNNEL ∅ ~5 m
NIKHEF
Kees Huyser
SEVENTH FRAMEWORK PROGRAMME

Why low frequency (1-10 Hz)?

- Early warning (1000s-10ks)
- Sky localization for EM followup (xylophone design →one detector only)
- Long inspiral → improved CBC parameter estimation, EoS, testing GR
- No other observatory at this frequency range

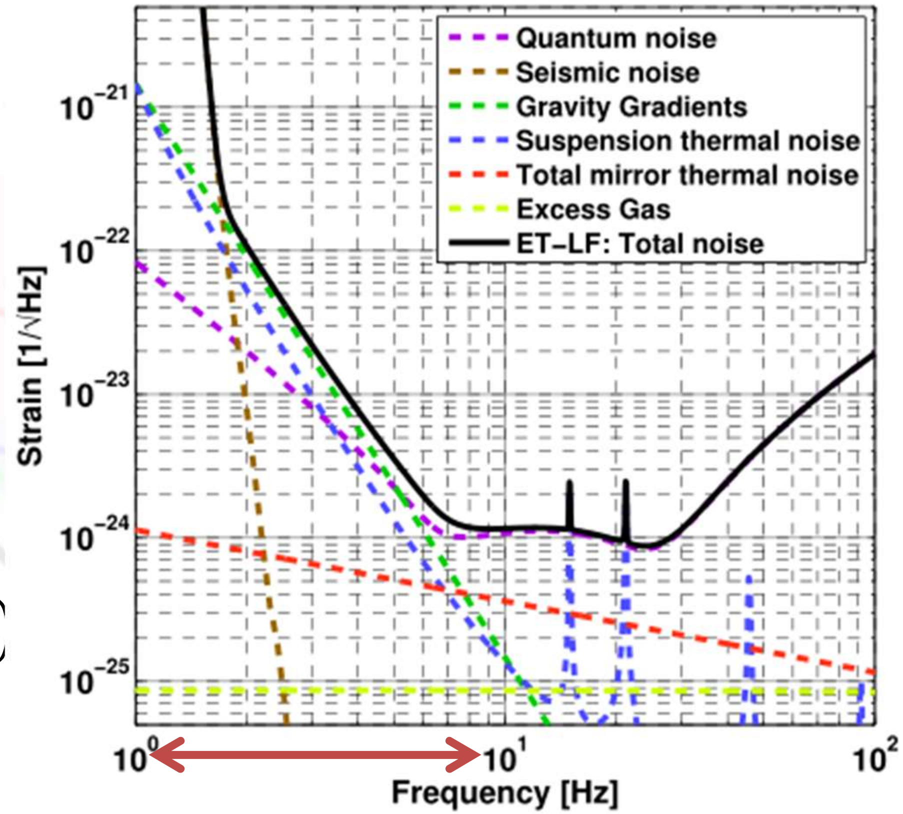
Sensitivity of ET



Noise budget for the low- (left) and high- (right) frequency interferometer

Low frequency noises

- At low frequency the seismic noise is the limit
- Gravity gradients (inhomogeneous of surrounding soil)
- Suspension thermal noise does not depend on the site)
- ET – requirements for 1-10 Hz
- Different underground site properties → selection

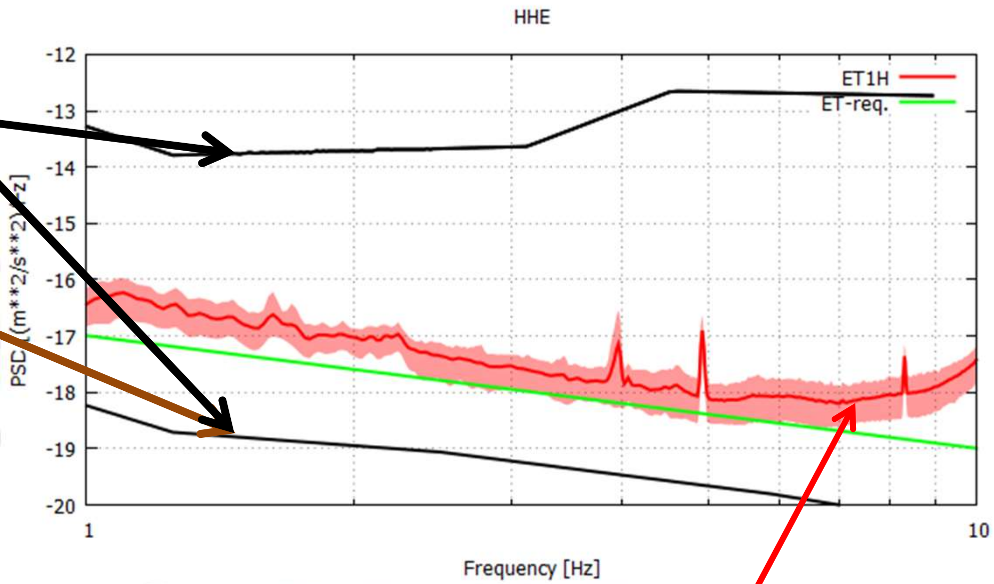


Limits on the measurements

- Peterson's New Noise Model:

curves of high and low seismic background displacement based on a worldwide survey of station noise (practical minimum)

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



The transparent color region is bounded by the 90 and 10 percentiles

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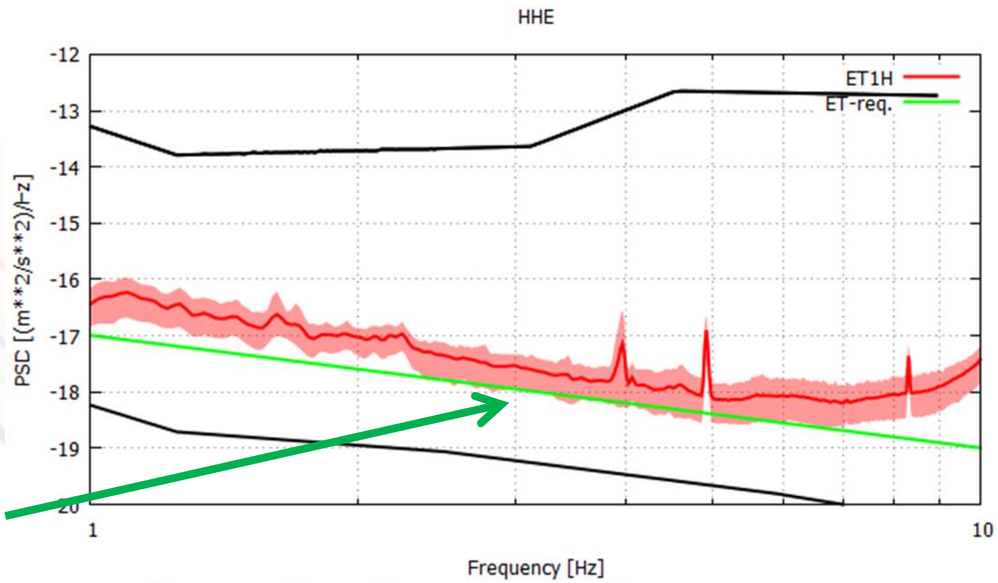
- Low frequency noise budget for the Einstein Telescope

(Hild S. et al.” Sensitivity studies for third-generation gravitational wave observatories” 2011 Class. Quantum Grav. **28** 094013)



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- Low frequency noise budget for the Einstein Telescope

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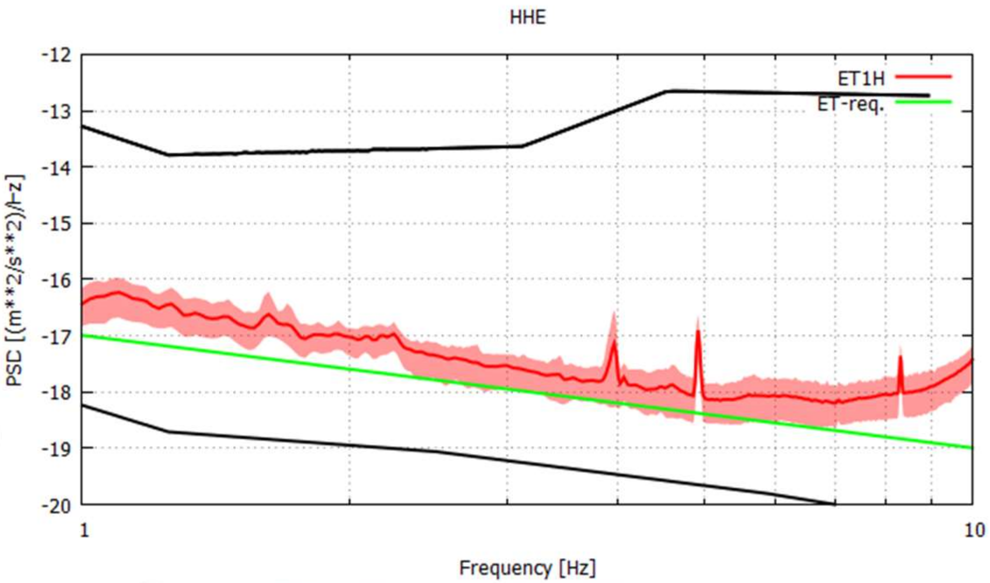
- Beker's limit: RMS displacement (2 Hz) 0.1 nm

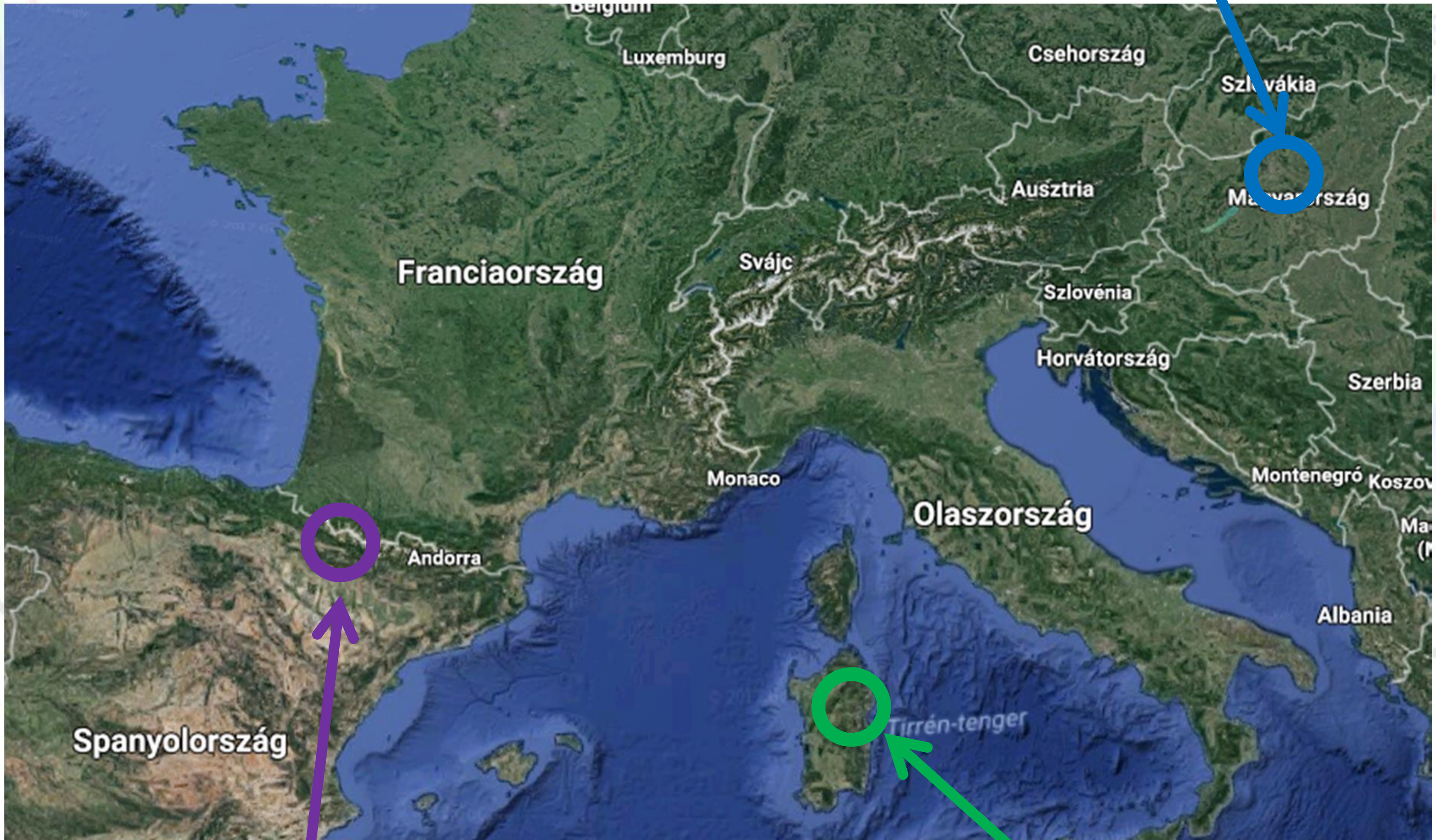
(M. G. Beker, J. F. J. van den Brand and D. S. Rabeling, "Subterranean ground motion studies for the Einstein Telescope", Class. Quantum Grav. **32** (2015) 025002)



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

Site selection

Mátra (Hungary)



LSC, Canfranc (Spain)

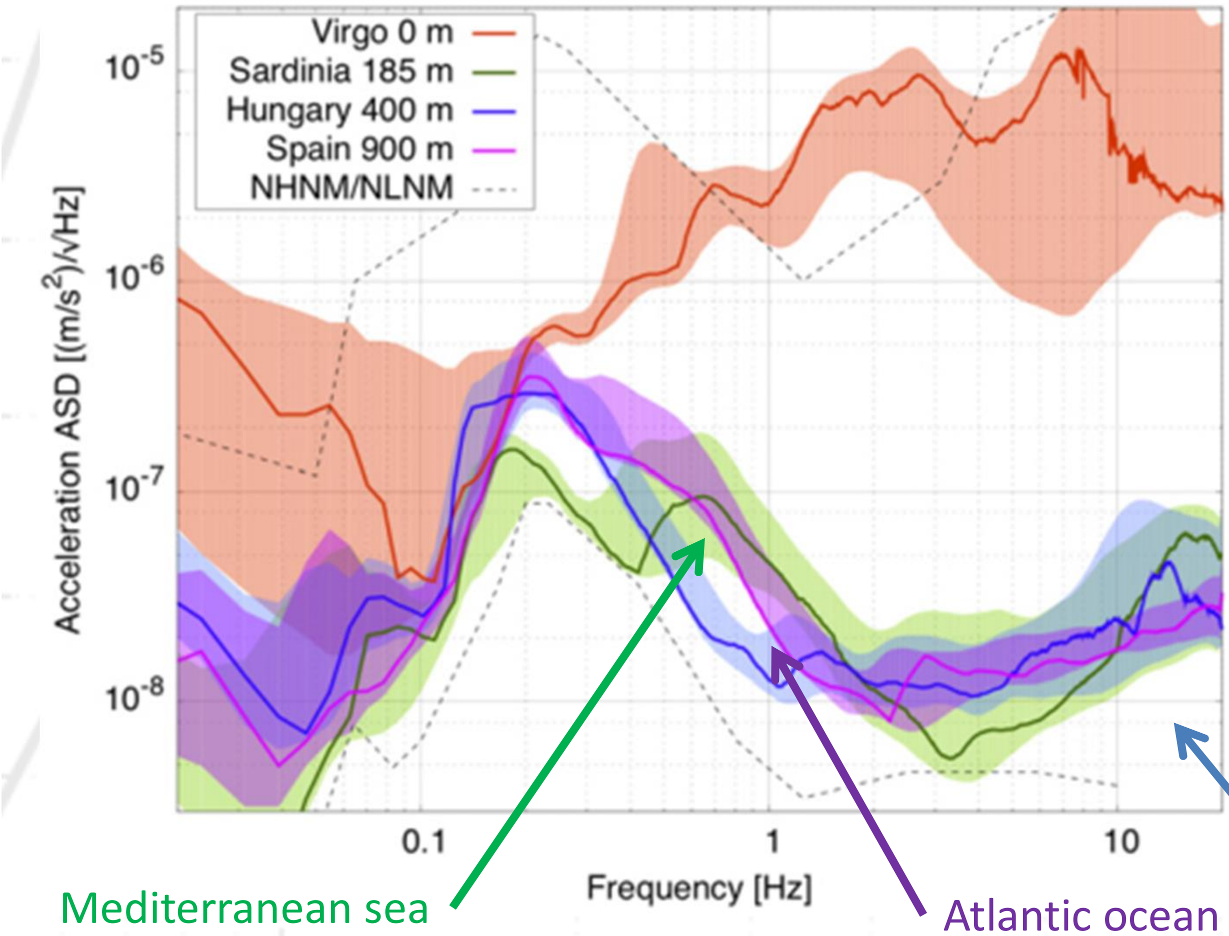
Sardinia (Italy)

Site selection

Sardinia (Italy)

Mátra (Hungary)

LSC, Canfranc (Spain)



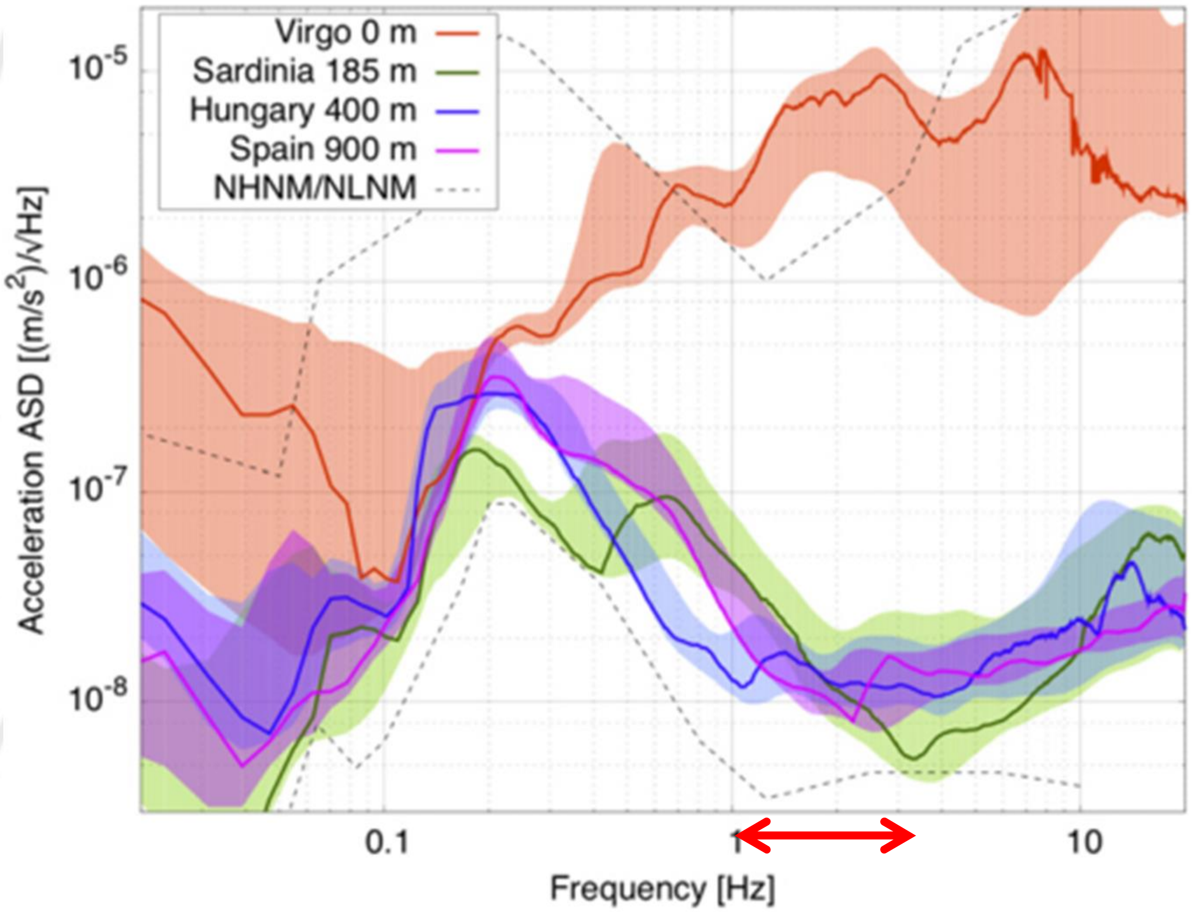
M. G. Beker, J. F. J. van den Brand and D. S. Rabeling, Class. Quantum Grav. **32** (2015) 025002

Site selection

Sardinia (Italy)

Mátra (Hungary)

LSC, Canfranc (Spain)



- 0.1-1 Hz microseismic noises:

domainly natural (oceanic, large-schale meteorogical), non-cultura, non-local

- 1 Hz:

Meterological condition shows up

- <1 Hz:

Mainly human activity

1-2 Hz: low reduction by suspension

M. G. Beker, J. F. J. van den Brand and D. S. Rabeling, Class. Quantum Grav. **32** (2015) 025002

Site selection

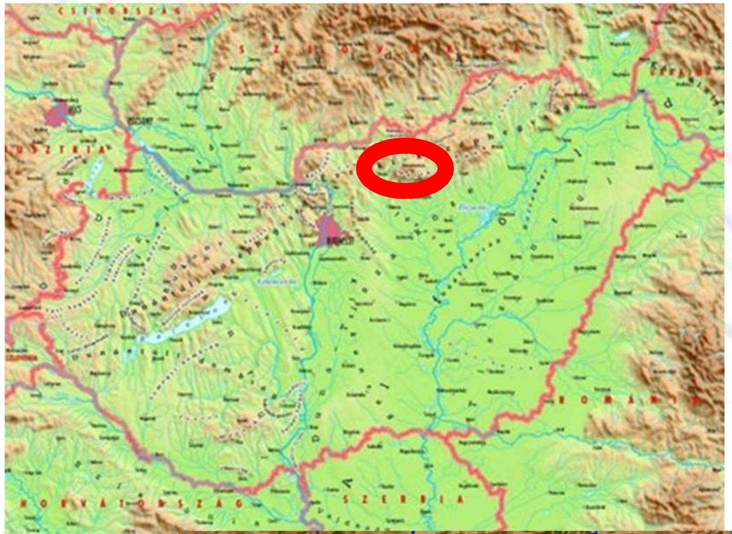
Beker's limit: 0.1 nm

- At least 2 years of data (yearly change)
- Isolate local noise sources (wind, sea waves, etc.)
- Cultural noises (in the mine, external)

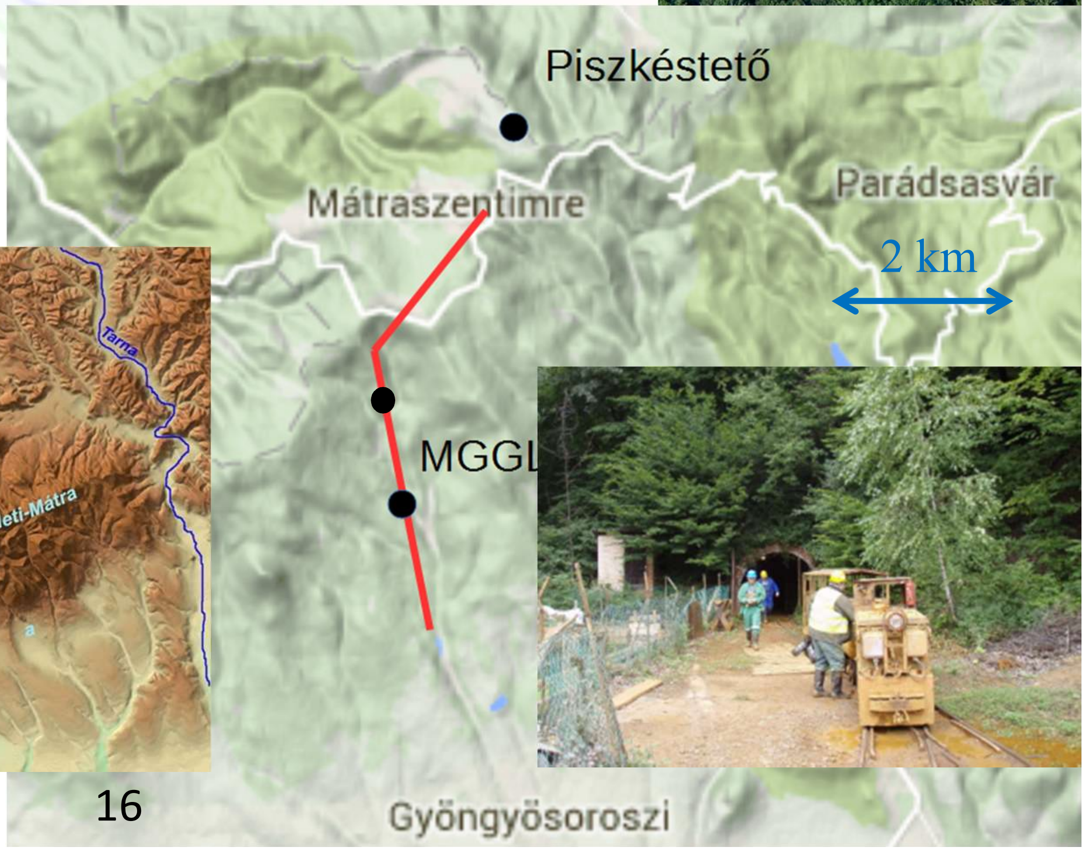
Location		Depth	RMS
LSC, Canfranc	Spain	900 m	0.07 nm
Lula	Italy, Sardinia	185 m	0.077 nm
Gyöngyösoroszi	Hungary	70 m	0.12 nm
Gyöngyösoroszi	Hungary	400 m	0.082 nm
LSM, Frejus	France	1750 m	0.1 nm
Kamioka	Japan	1000 m	0.11 nm
Sumiainen	Finland	0 m	0.11 nm
Gran Sasso	Italy	1400 m	0.13 nm
Black Forest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

M. G. Beker, J. F. J. van der Brand and D. S. Rabeling, Class. Quantum Grav. **32** (2015) 025002

Gyöngyösoroszi, Hungary



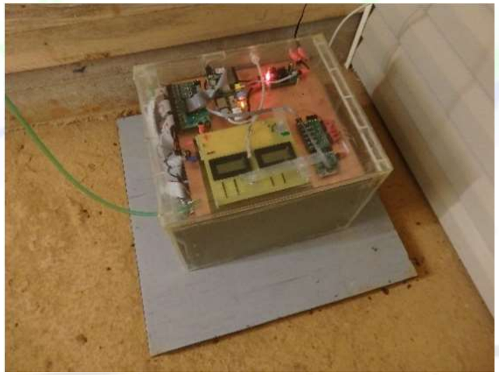
- 1 hour from Budapest Airport by car
- 10 hours from here

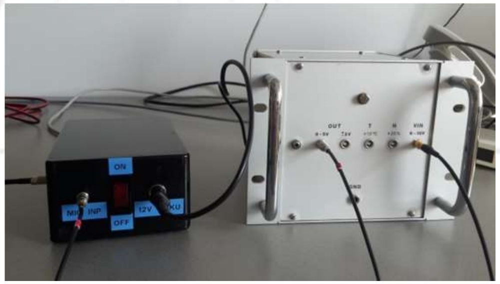


MGGL (Mátra Gravitational and Geological Laboratory)

The collaboration is to collect and analyse the collected data from Mátra mine

- Guralp CMG-3T seismometer
- Seismometer from the Warsaw University
- Infrasound detector
- Lemi-120 magnetometer
- Muon detector (Muontomograph)





MGGL Collaboration

- Collaboration (31 participants) with many Institutions
  - Wigner FK
  - MTA CSFK GGKI
  - Atomki
  - Univ. of Miskolc
  - Budapest University of Technology and Economics
  - Eötvös Loránd University
  - Univ. of Warsaw
  - Univ. of Zielona Góra
- Report of the first data collection period, (arXiv:1610.07630)

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

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CrossMark

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

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

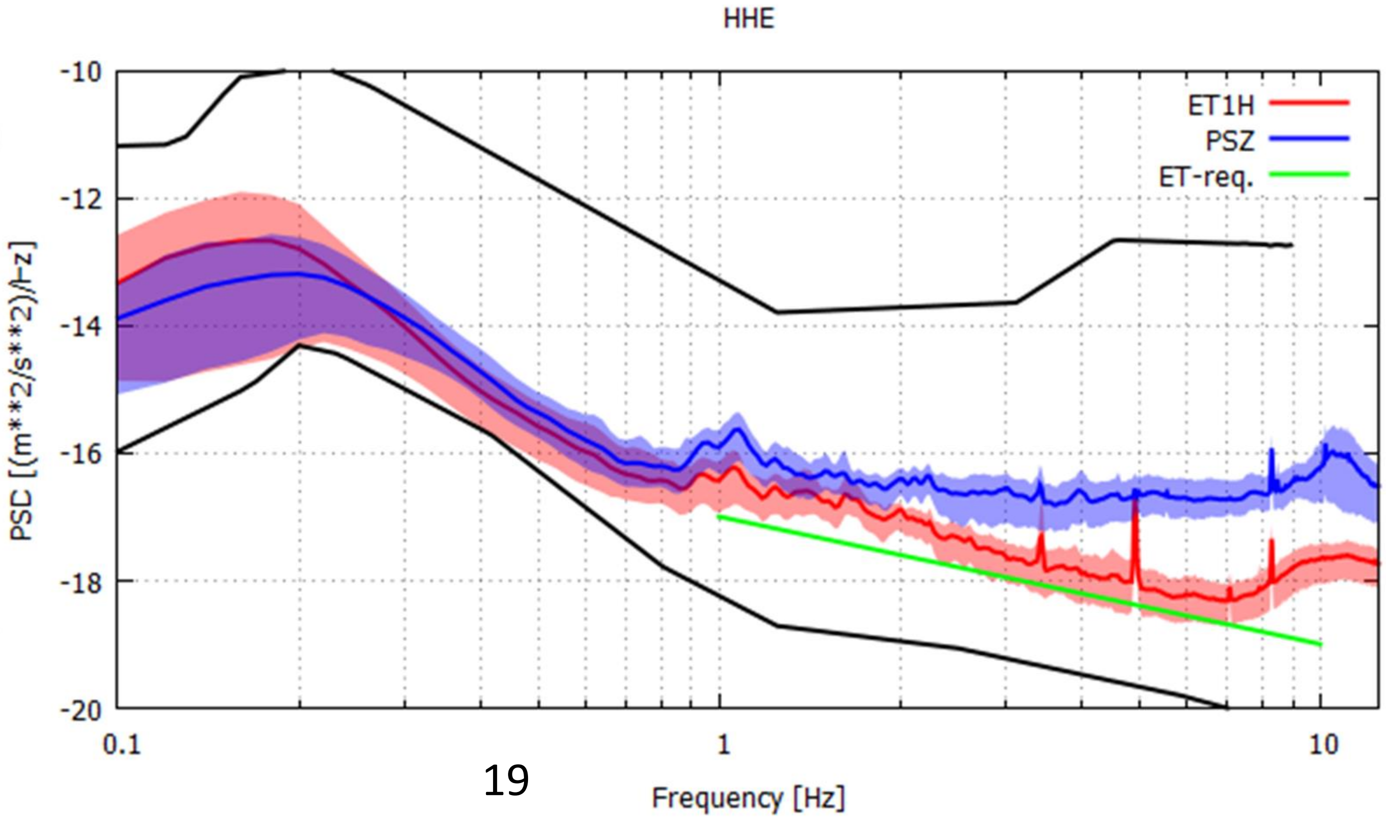
Preliminary results: Data from ~490 day

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

Beker's limit: 0.1 nm

	ET1H	PSZ
East	0.196 nm	0.568 nm
North	0.213 nm	0.521 nm
Z	0.259 nm	0.417 nm

Working in the mine
-> human activity
-> water pump
-> air-condition
-> small train
Etc.



Day/night

Less cultural noise

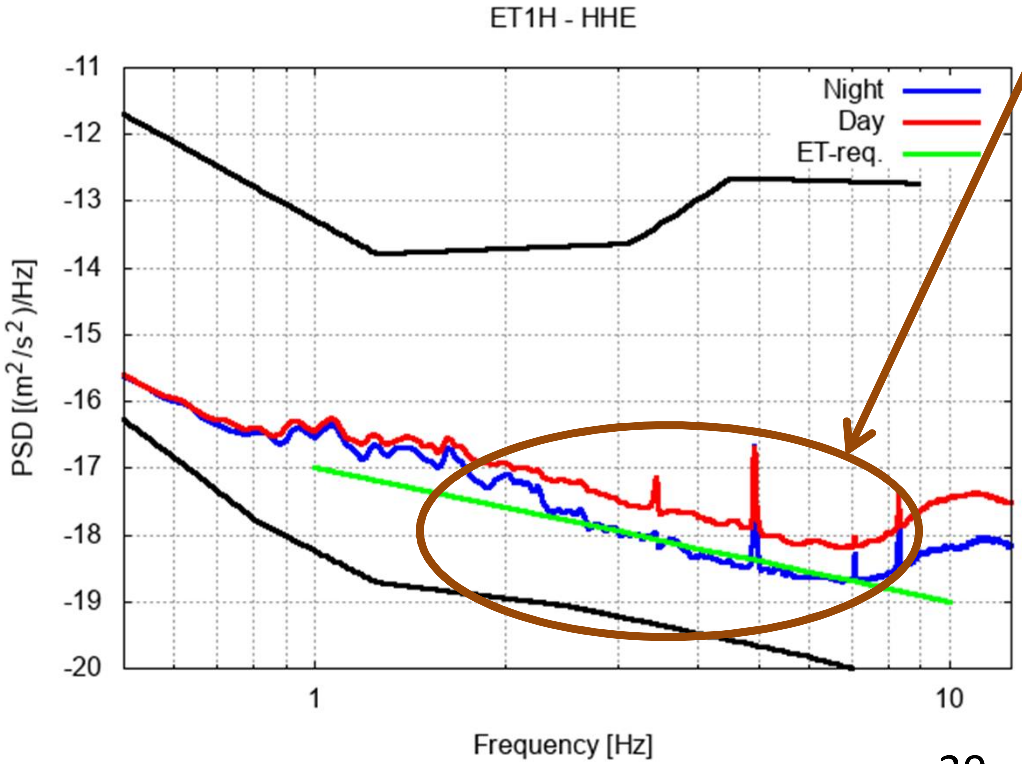
Night period : 00:00 -- 03:00 21:00 -- 24:00 UTC

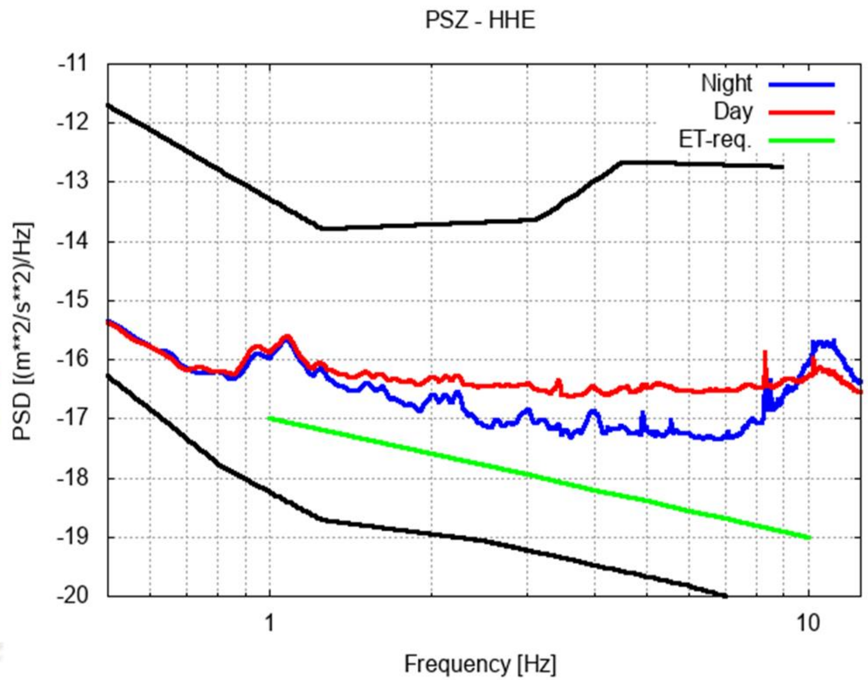
Working period: 10:00 – 16:00 UTC

RMS (2 Hz) :

- Night 0.141 nm
- Daily 0.196 nm

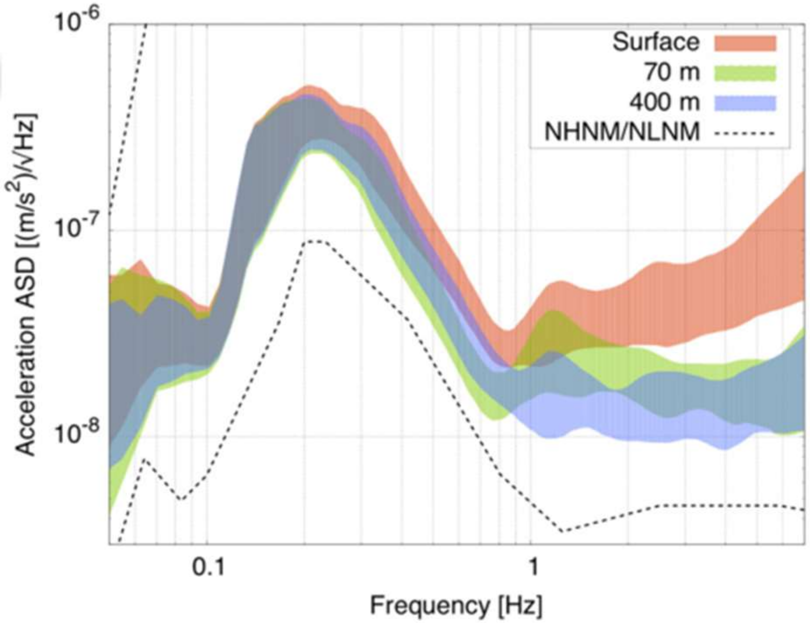
Close to ET-req.

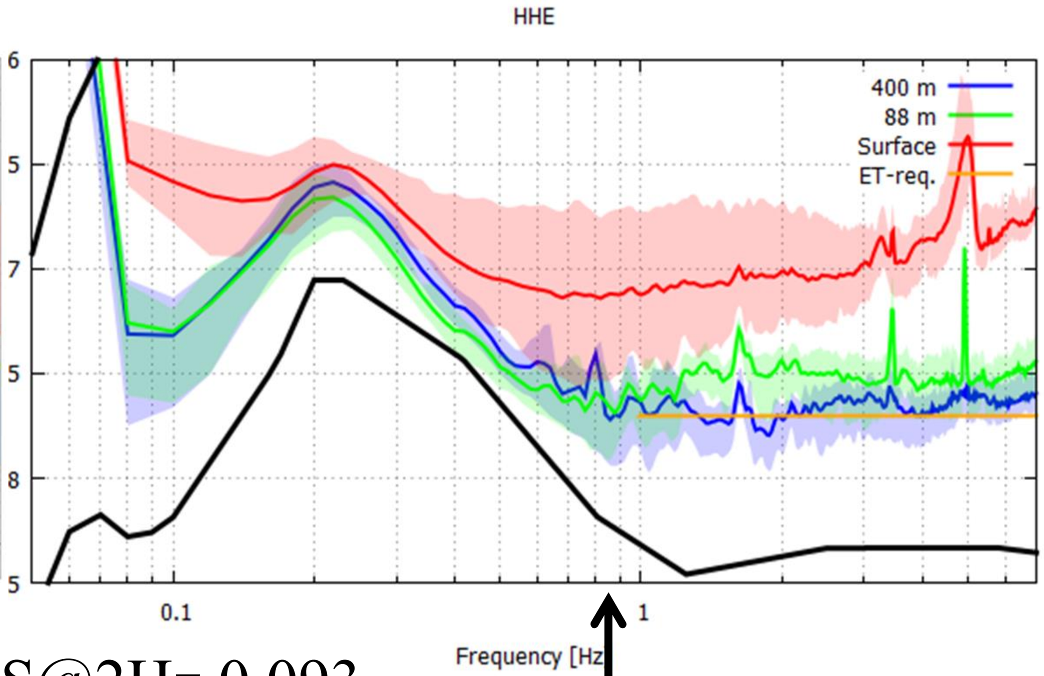




400m under the surface

3 days -> 14 days
No planned quite days





RMS@2Hz 0.093

3-6 April 2010

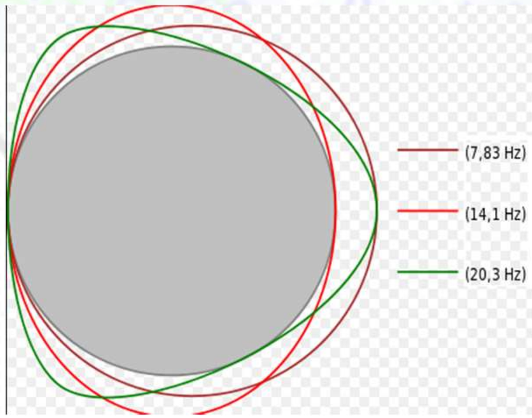
1-15 June 2017

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

Our result

Future plans

- Low frequency regime (0.1-10 Hz) with infrasound detector data
- Depth dependence $e^{-4d/\lambda}$
  - Janossy mine (at Budapest, Wigner RCP)
  - MGGL (at Mátra)
- Schumann resonances →
- Studying Newtonian noise
- Rock characterization



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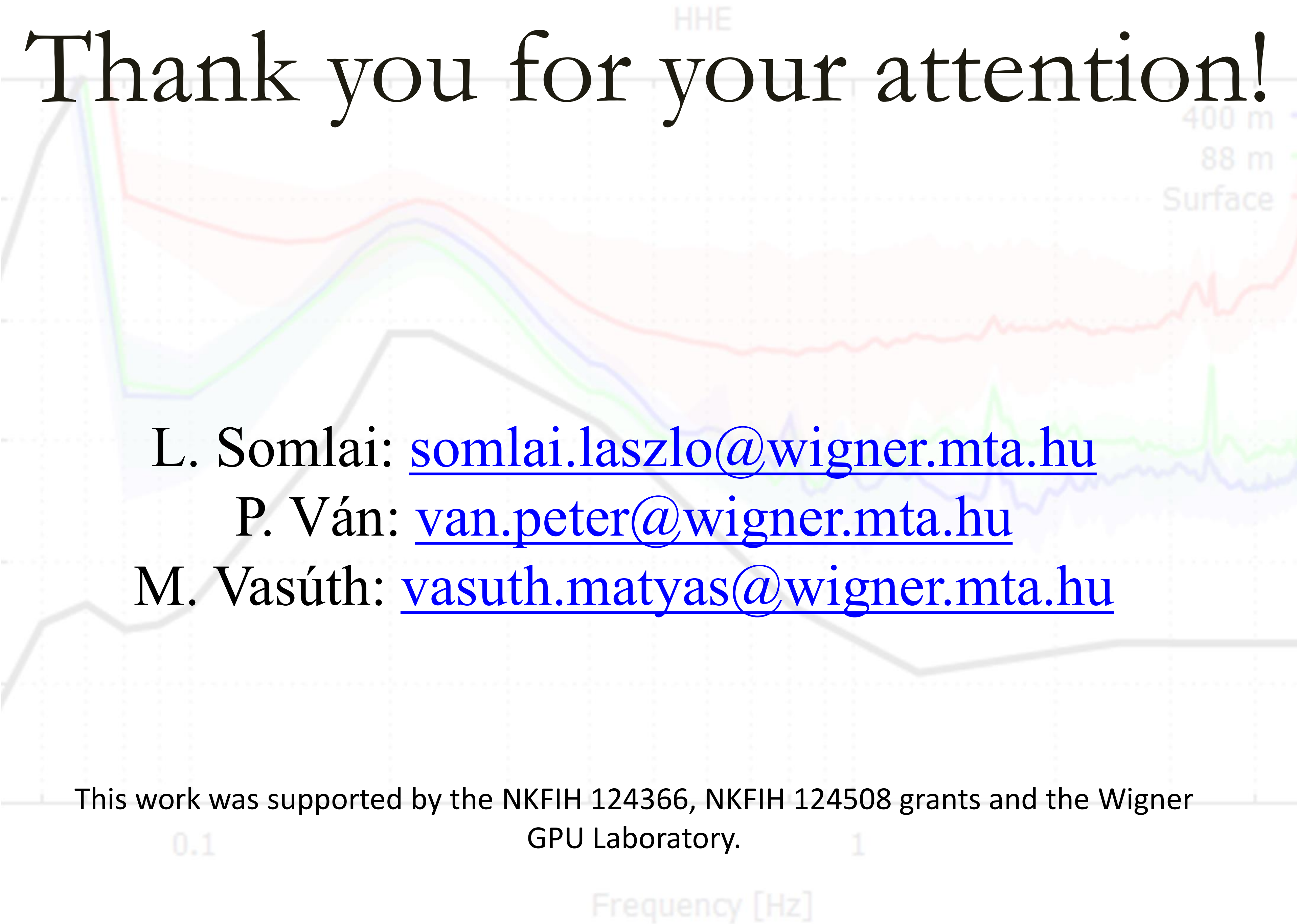

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