GSSI

Seismic Newtonian-noise Modeling

Where we are – what we need

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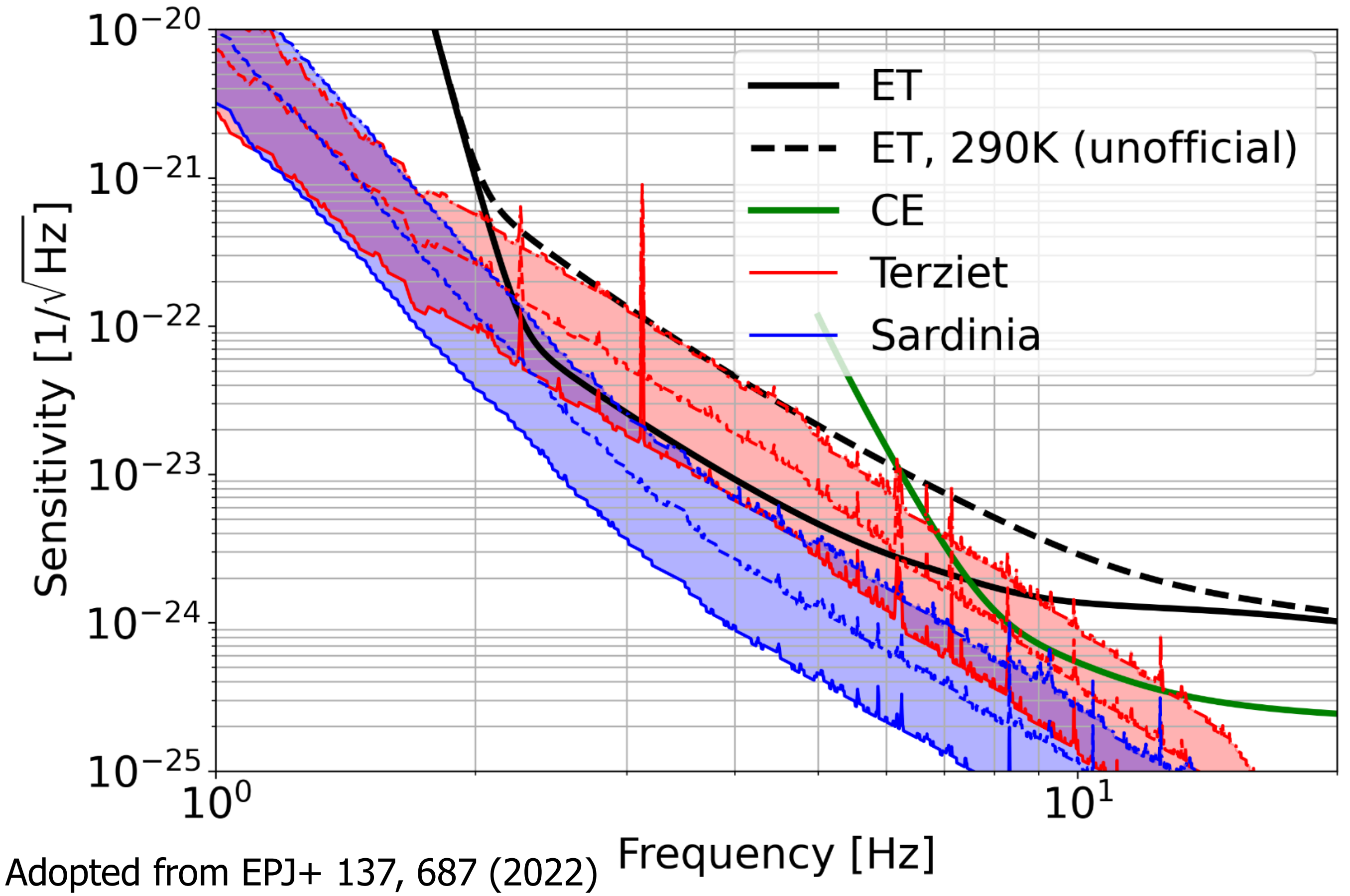
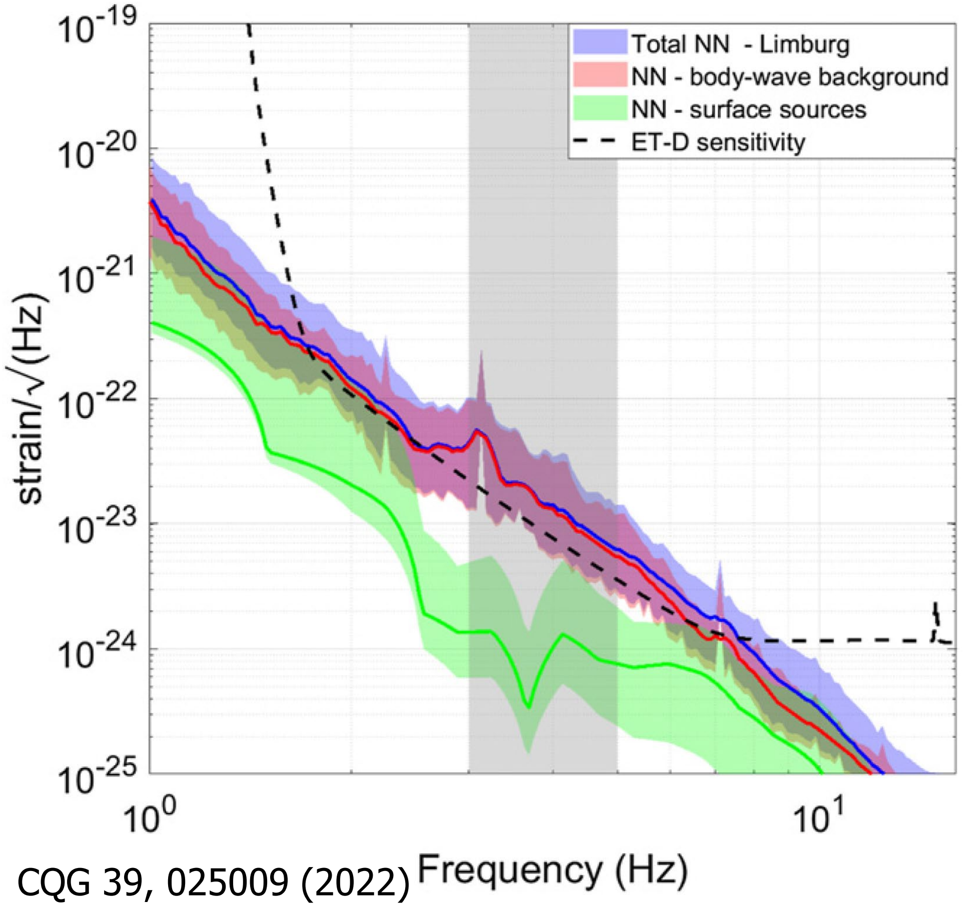
ET Newtonian Noise Predictions



Adopted from EPJ+ 137, 687 (2022)



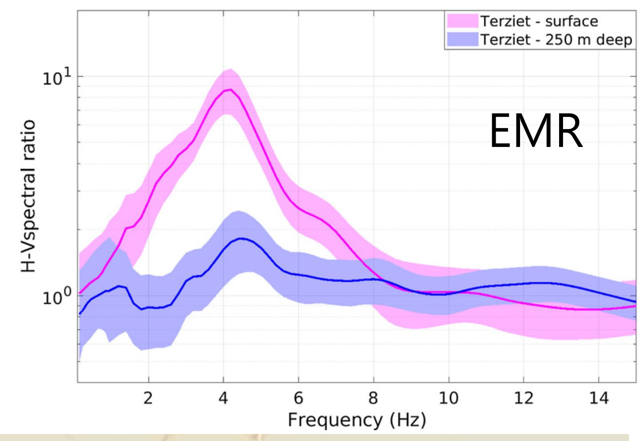
CQG 39, 025009 (2022)

Seismic NN Models

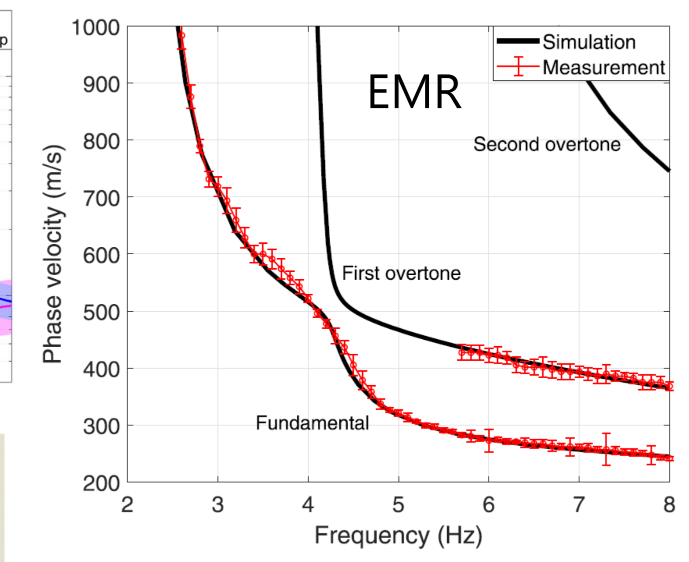
- Seismic NN models set important constraints on the low-frequency sensitivity targets, and NN reduction is the main science-driven motivation to construct ET underground.
- We need to be able to model every potentially important aspect: source distribution, polarization content, topography, geology, caverns, NN correlations between test masses, nonstationarity, structural vibrations.
- There will always remain unknown properties of the seismic field, which limit the accuracy of the NN prediction.
- None of the existing NN models is good enough to plan ET

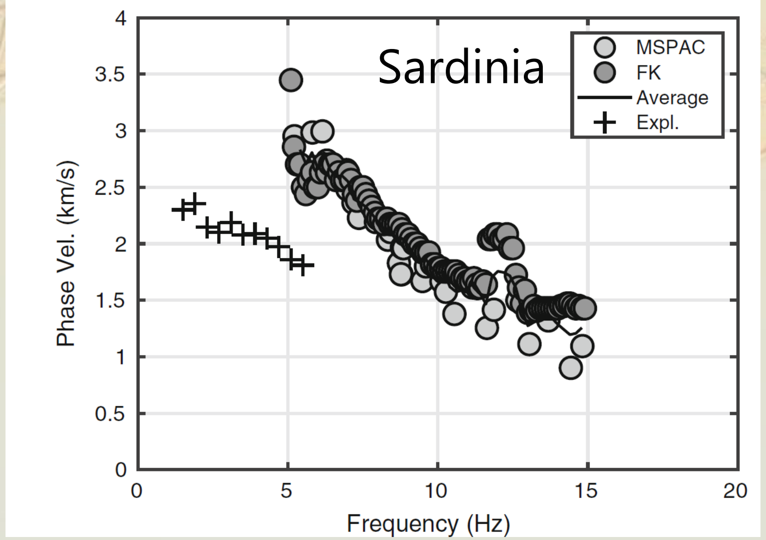
Status: Geology

- Layered geology has an important impact on seismic NN from surface waves (influences suppression with depth). It is included in the current ET NN models for the EMR and Sardinia sites.
- We need to *simulate ambient seismic fields with realistic geological models representing the vertex locations of the candidate sites*.



CQG 39, 025009 (2022)



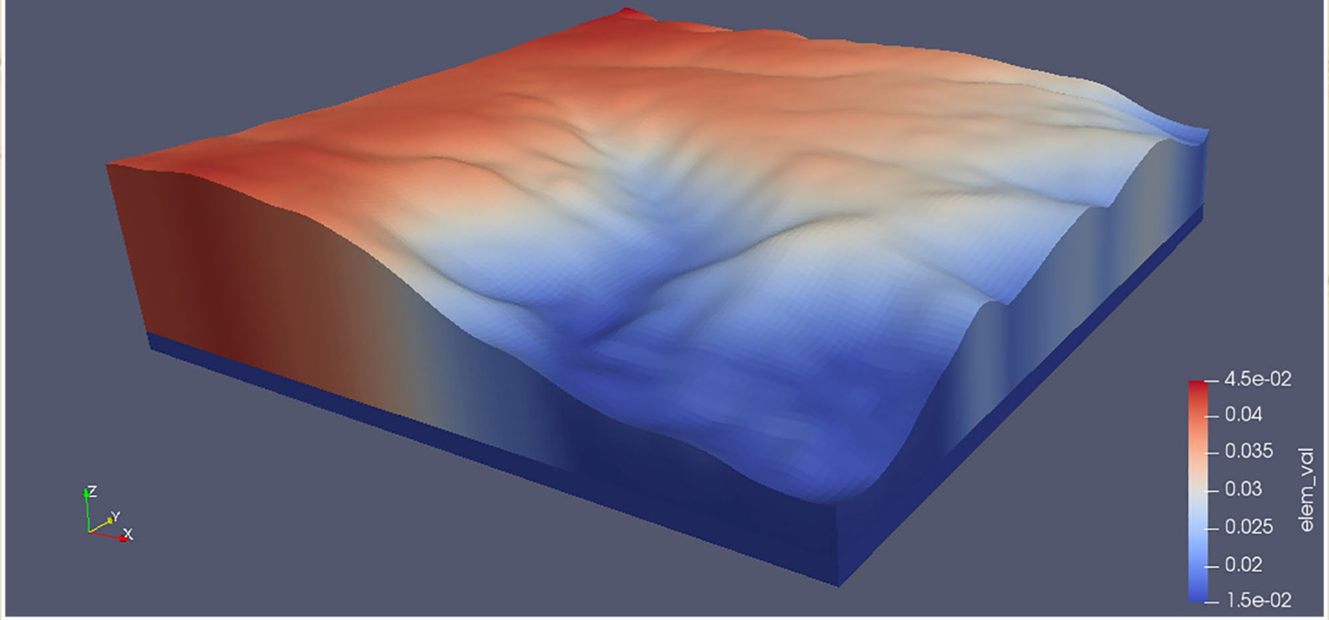


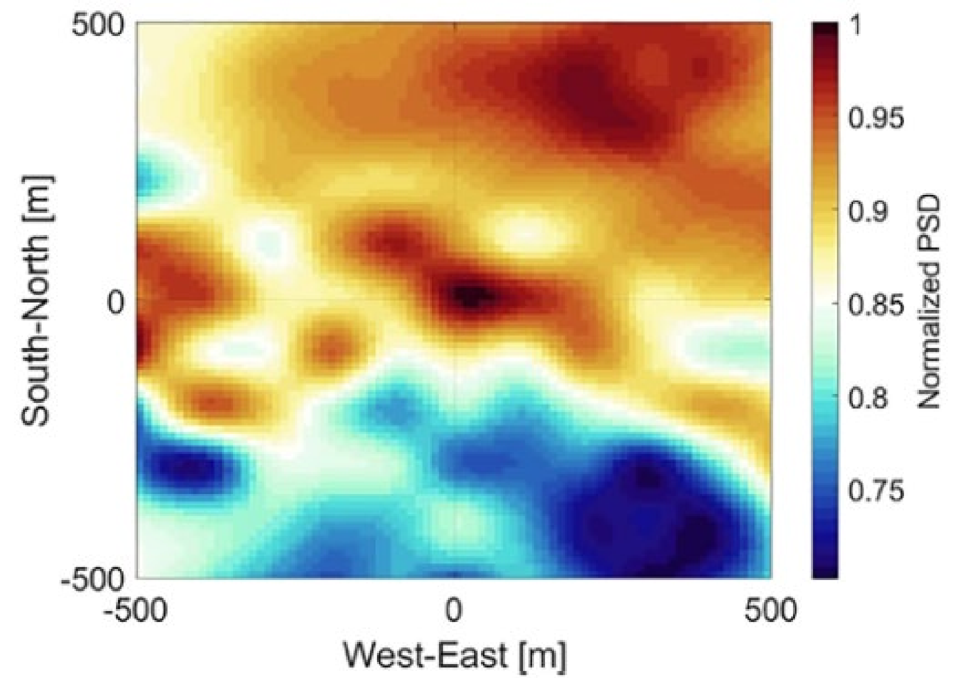
EPJ+ 138, 793 (2023)

Status: Topography

- Fully generic simulations of the impact of topography on ambient seismic fields and seismic NN were performed with SPECFEM3D Cartesian.
- Topographic information is readily available for all sites. Technically, the data need to be implemented in a mesh, e.g., using software like Coreform Cubit

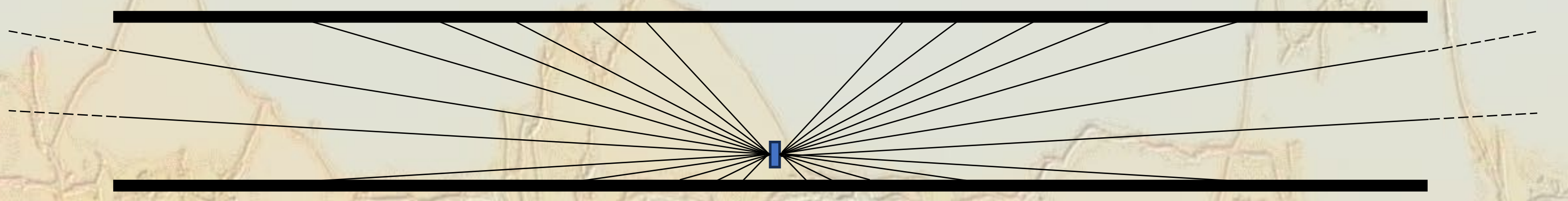
J Geophys Res: Solid Earth **125**, e2020JB020401 (2020)

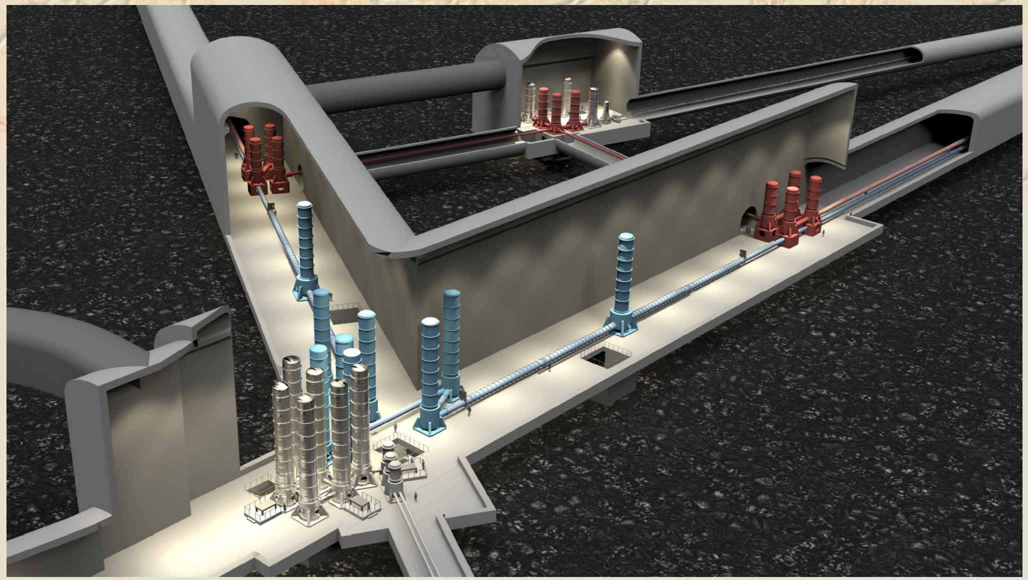




Status: Caverns

- Seismic NN can be significantly reduced in large caverns, and some of the ET-LF caverns are very large.
- Numerical simulations are being carried out to investigate the dependence of seismic NN on cavern/tunnel shape and size. Work in progress.





Cavern A:
170m x 17m x 22m

Cavern A influences NN only at the ET-LF input test masses. End-test mass caverns are too small to significantly reduce seismic NN.

Source Distribution + Polarization Content

- Polarization content of the ambient field was simulated using SPECFEM3D for arbitrary source distributions.
- Most analytical results were obtained for arbitrary polarization content.
- My opinion: done or not a serious challenge anymore

Gravitational coupling constants

Compressional waves produce stronger NN than shear waves

$\kappa \approx 8$, for compressional waves and underground test mass;

$\kappa \approx 4$, for shear waves and underground test mass;

$\kappa \approx 4-6$, for Rayleigh waves and surface test mass.

LRR 22, 6 (2019)

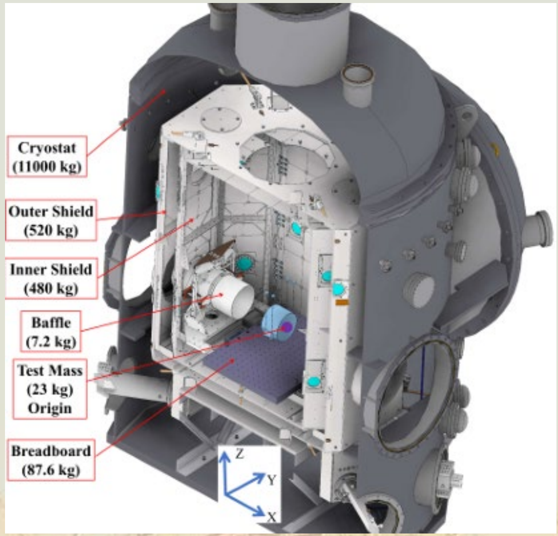
Rayleigh NN strongly suppressed underground

Status: Structural Vibrations + Infra Noise

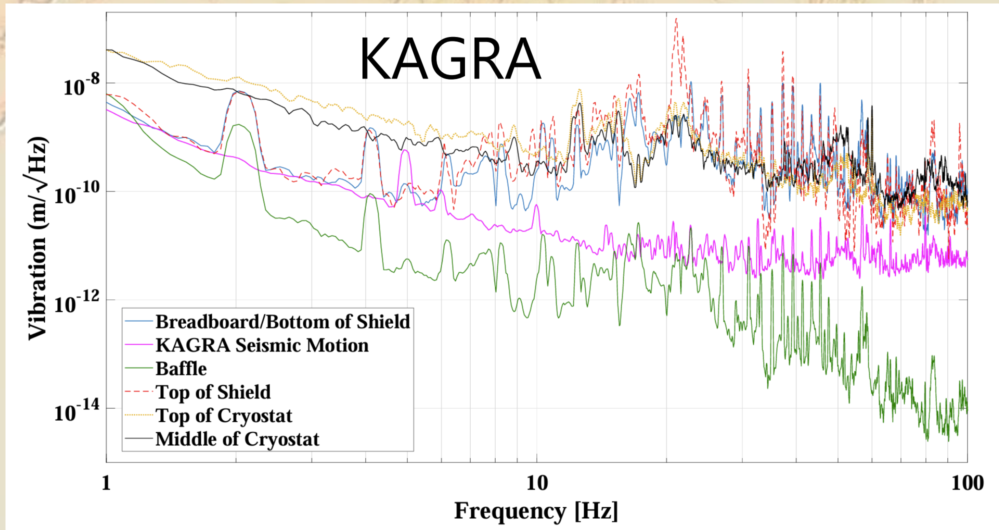
A: vibration along arm, B: horizontal, perpendicular to arm, C: vertical [kg/m^3]

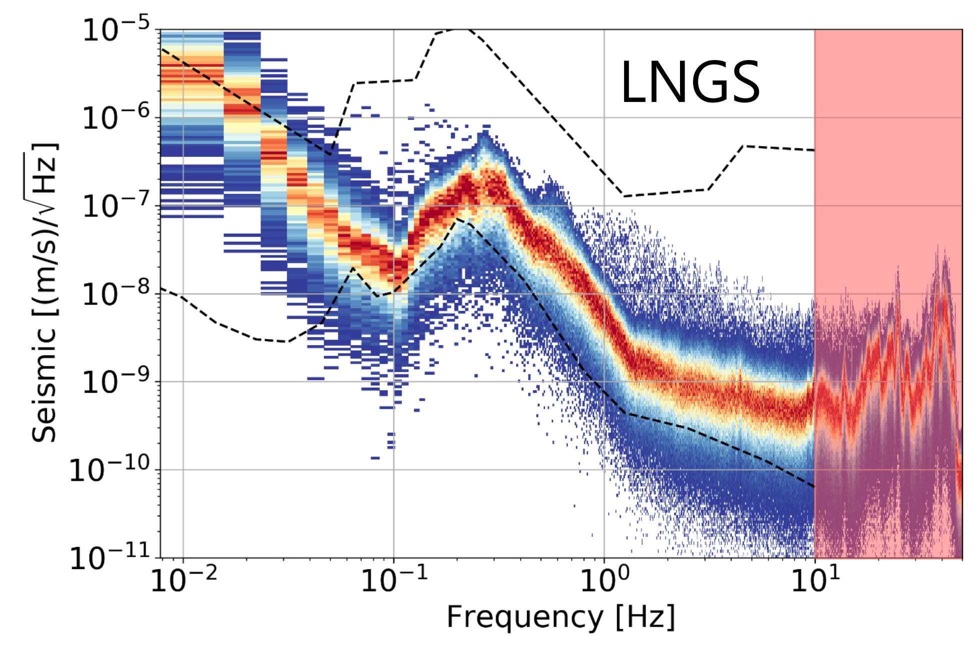
Component	A	B	C
Breadboard	550.69	-5.4×10^{-16}	-1.2×10^{-14}
Baffle	-23.4	-6.97	-0.11
Inner Shield	124.15	-0.28	-4.64
Outer Shield	97.52	0.53	-1.95
Cryostat	-298.34	-6.22	-0.03

PRD 107, 042001 (2023)



Compare with expected seismic coupling (κ ρ): 11,000 - 22,000 kg/m^3

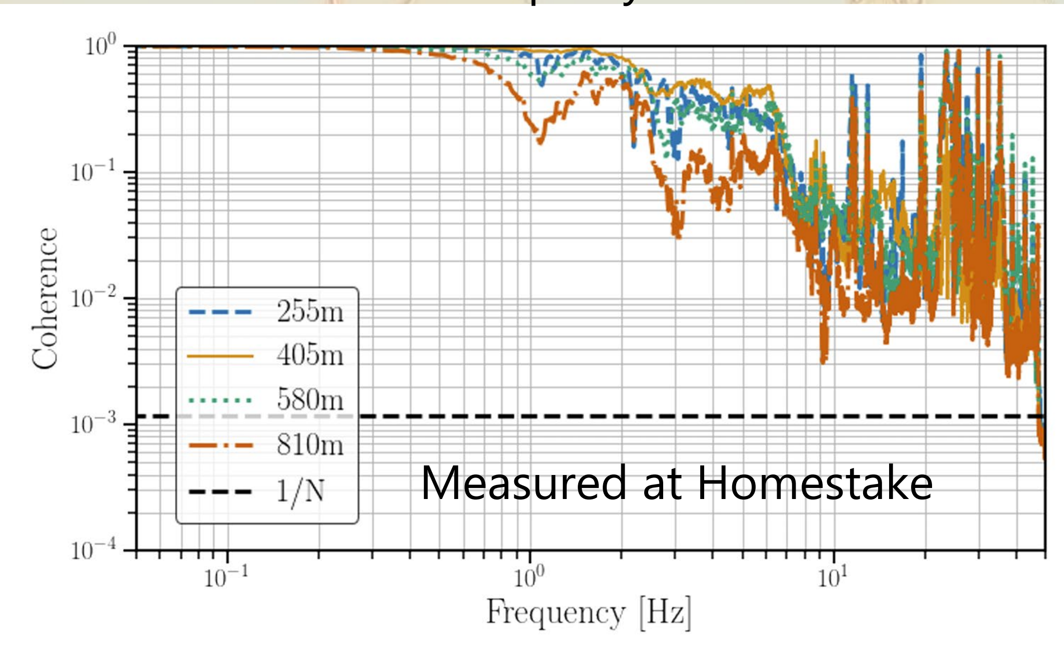




Status: NN Correlations Between TMs

- First studied for ET in the context of stochastic GW searches not as a correction of NN spectra, but as correlated environmental noise in the ET Delta configuration.
- Corrections on NN spectra not accurately estimated yet

Seismic coherence as proxy for NN coherence



PRD 106, 042008 (2022)

Coherence must be quite high (above 0.3 or so) to significantly impact total NN from input-test masses.

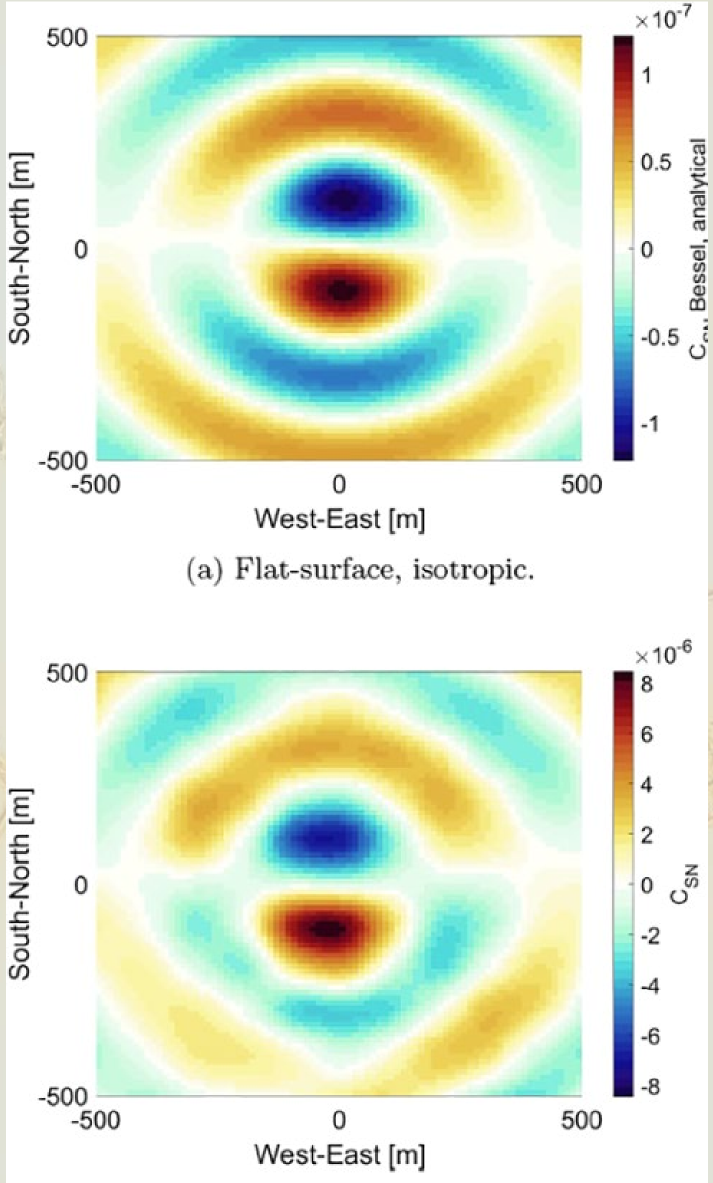
Taking the Homestake results, correlations are negligible for NN spectra above 6Hz if TM distance >= 255m.

ET-LF input-test masses are closer (less than 100m apart), but are rotated by 60deg with respect to each other. Still need to have better correlation estimates.

Additional Requirements on NN Models for NNC Design

- To be able to estimate the NNC performance and to calculate optimal array configurations, we need gravitoelastic correlations.
- SPECFEM3D is a suitable tool for these simulations

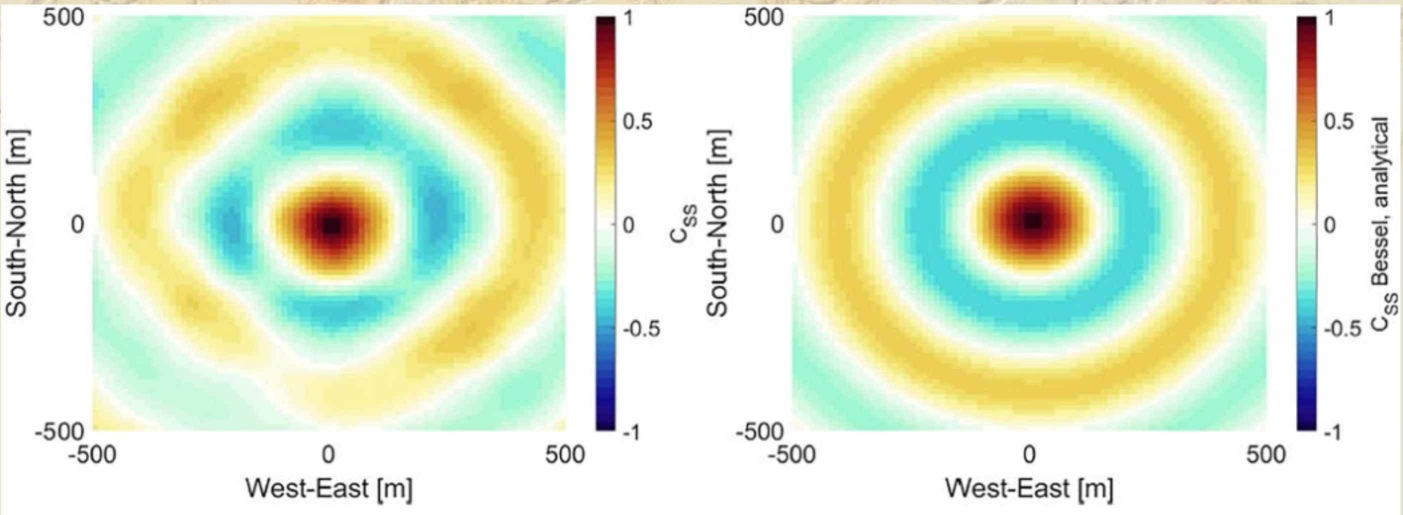
Seismic-gravity correlations



(a) Flat-surface, isotropic.

(c) SPECFEM3D simulation.

Seismic correlations



(a) SPECFEM3D simulation.

(b) Flat-surface, isotropic.

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Resources for Most Important Tasks

Only for NN modeling (not including NNC design):

- SPECFEM3D or similar:
  geology, topography, source distribution
  - 1 FTE*year per site (meshed geological model for three vertices assuming that geological information is readily available)
  - 2 FTE*year (finite-element simulation)
- Specialized simulations:
  caverns, NN correlations
  - each topic 1 FTE*year
  nonstationarity, structural vibrations
  - each topic 2 FTE*year