



Optimization of seismometer arrays for the cancellation of Newtonian noise from seismic body waves

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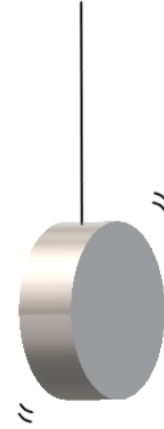
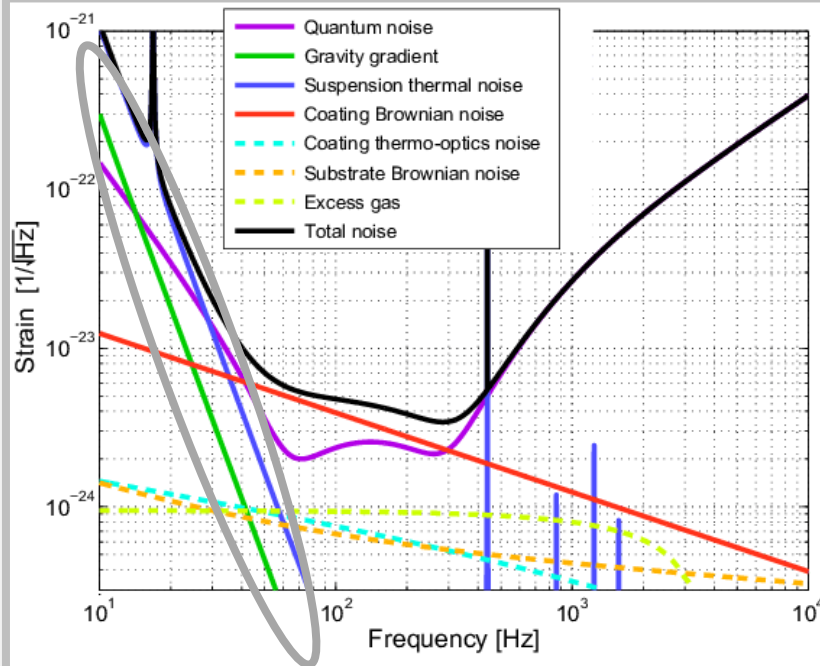
Speaker:

Badaracco F.

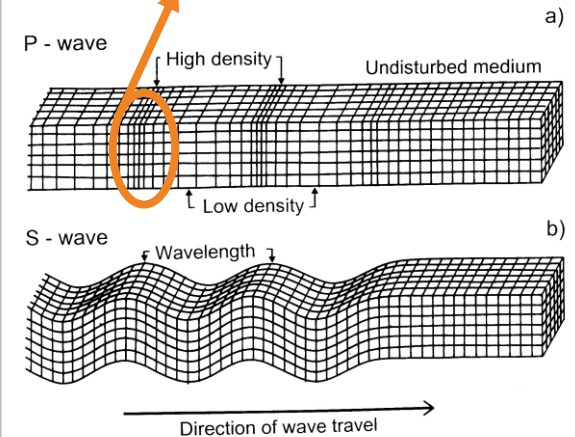
What is Newtonian Noise (NN):

Perturbation of the gravity field due to a variation in the density ($\delta\rho$) of the surrounding media.

Example of
NN in Virgo:



$$\delta\rho \rightarrow NN$$





Basic idea: seismometers →

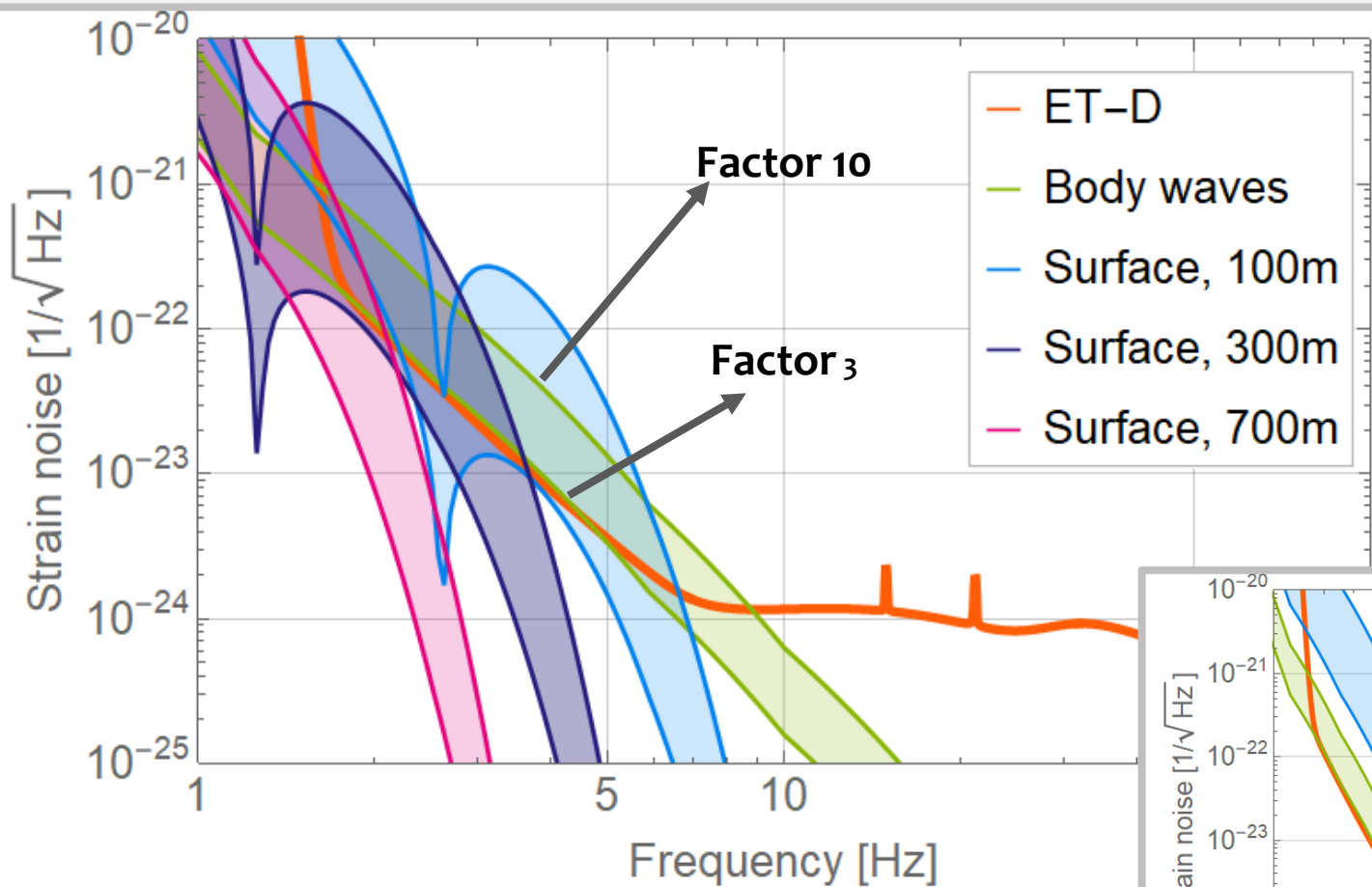
Coherent Newtonian Noise (NN) estimate →
NN subtraction

What has been already done:

Advanced Virgo/LIGO →
Rayleigh waves

What we did:

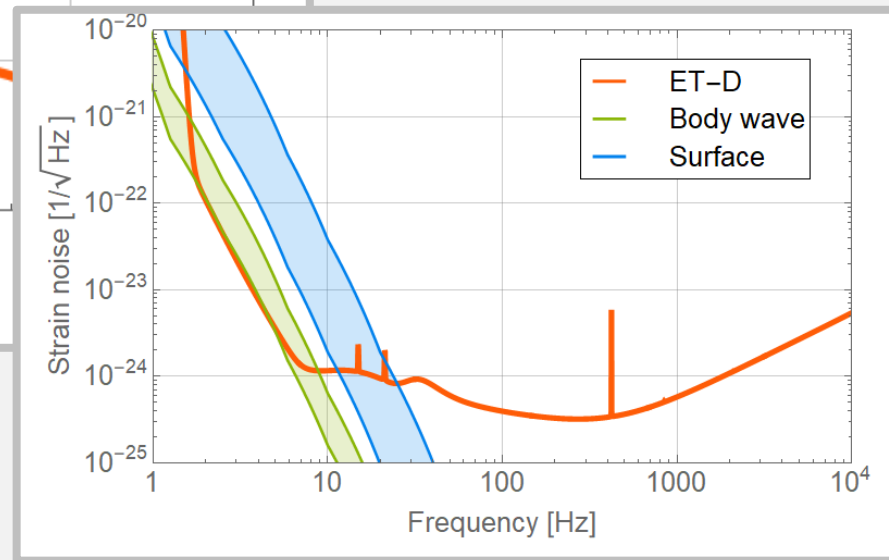
Einstein Telescope (ET) → Body
waves



Surface

Underground

Suppression up to a
factor 10



$$R(\omega) = 1 - \frac{\vec{C}_{\text{SN}}^\dagger(\omega) \cdot \left(\vec{C}_{\text{SS}}(\omega)\right)^{-1} \cdot \vec{C}_{\text{SN}}(\omega)}{C_{\text{NN}}(\omega)}$$

CPSDs between
seismometers and
test mass

Gravitational coupling model:
mirror <-> field

Cross Power Spectral
Densities (CPSDs)
between
seismometers

Power Spectral
Density of test mass

$$\delta \vec{a}(\omega) = \frac{4}{3} \pi G \rho_0 (2 \vec{\xi}^{\text{P}}(\omega) - \vec{\xi}^{\text{S}}(\omega))$$

Isotropic & Homogeneous
seismic field hypothesis

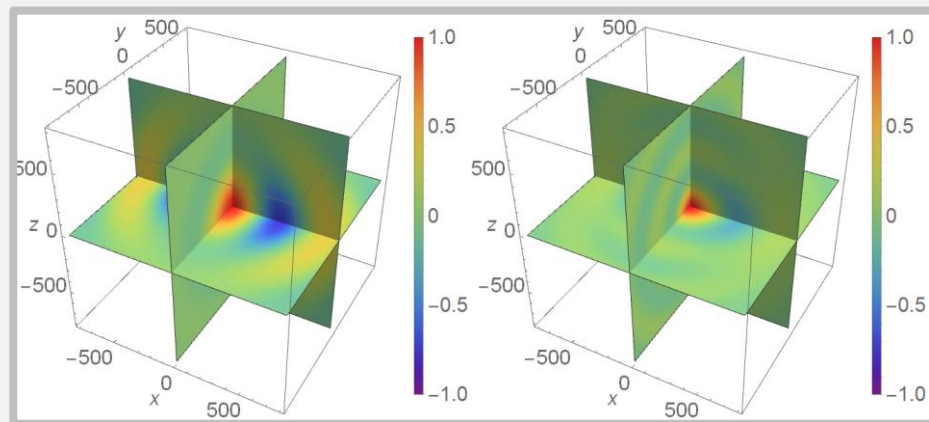
Body waves
P (compressional) & S (shear)

+



&

$$k^{\text{P,S}} a \ll 1$$

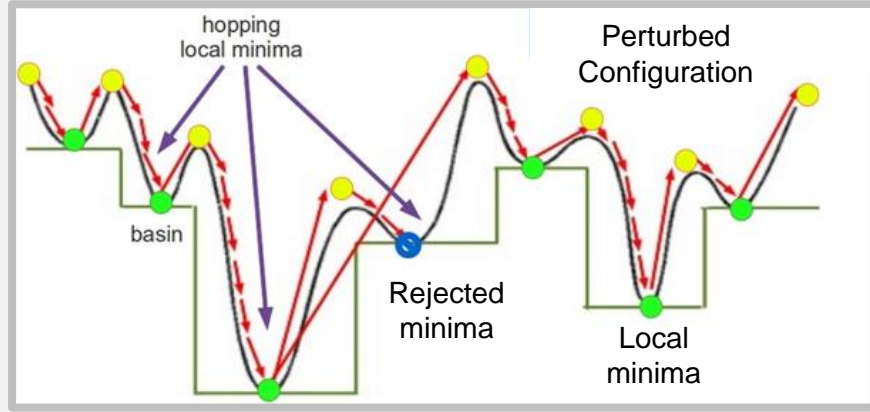


only P-waves

P & S mixture

Optimization algorithms:

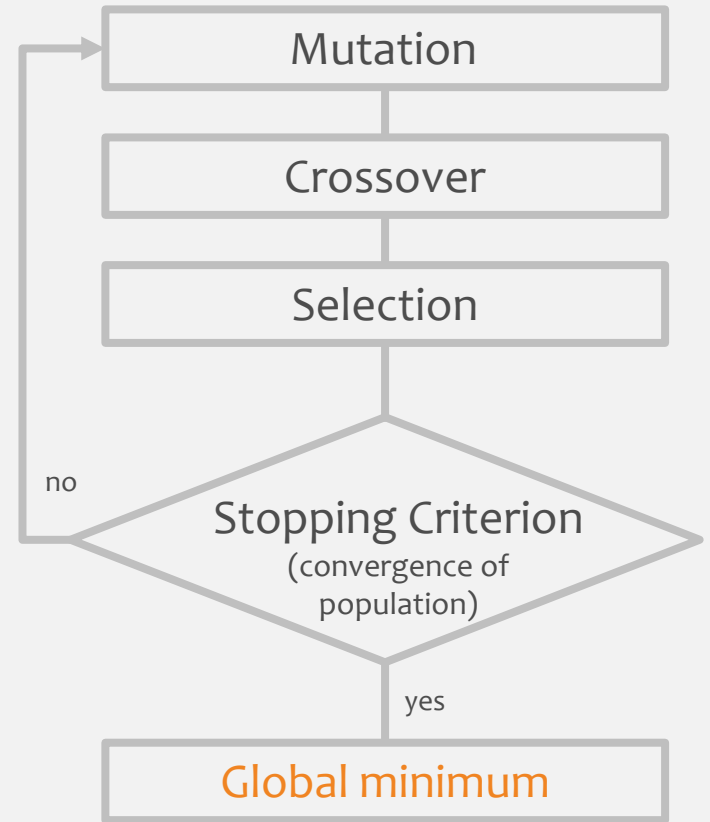
Basin Hopping:



- 1) Perturbation
- 2) Local minimization
- 3) Acceptance/Rejection

Metropolis

Differential Evolution:



$p = 1/3$

N fixed (6)

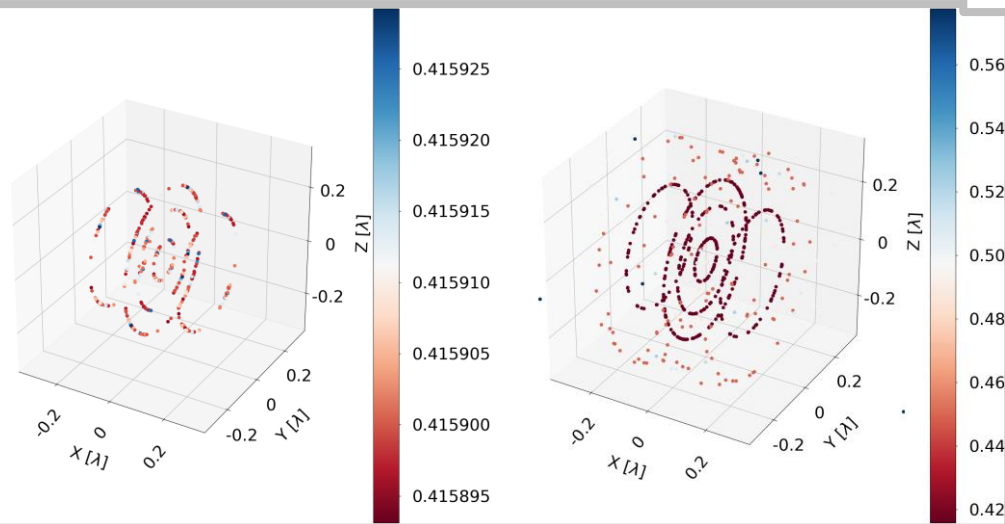
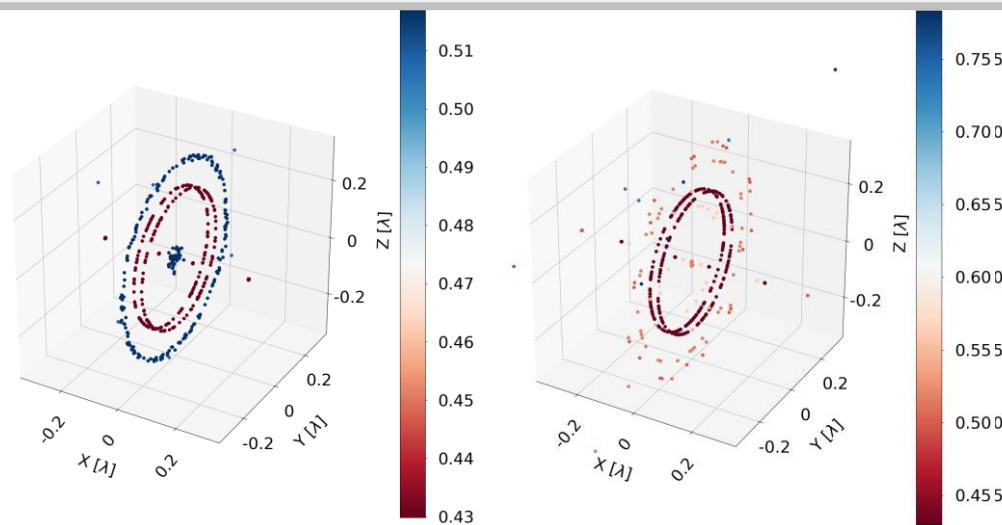
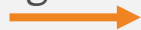
$f = 10$ Hz

$\text{SNR} = 15$

$v_P = 6000$ m/s

$v_S = 4000$ m/s

Test mass moving along X axis:



6

DE

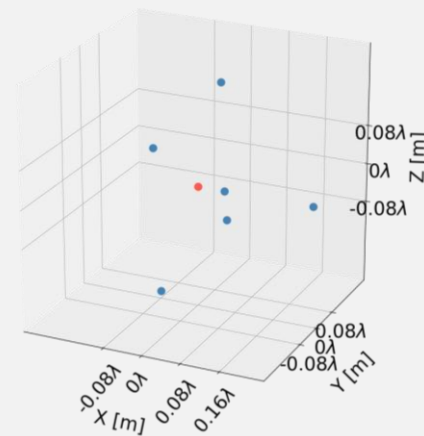
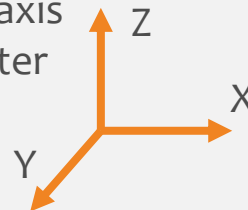
BH

DE 1 channel axis
seismometer

BH

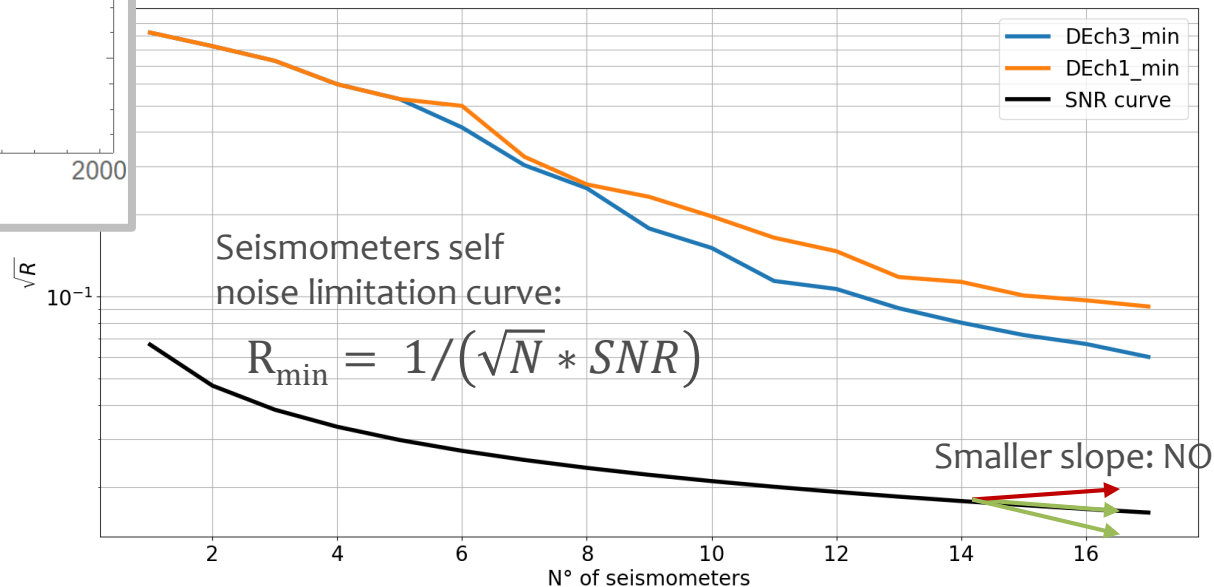
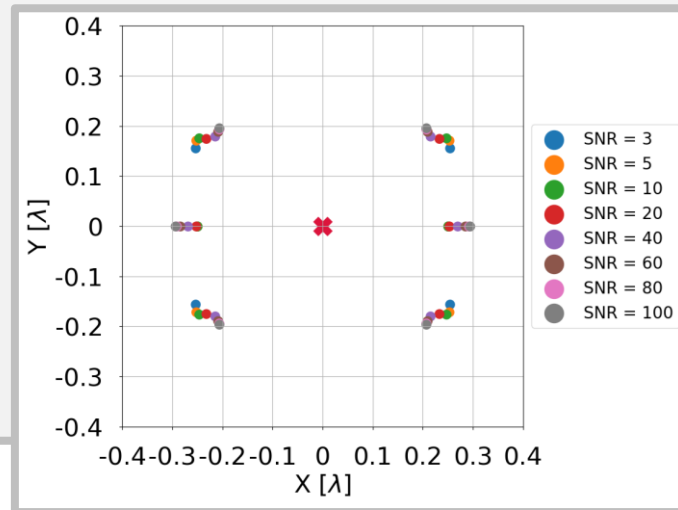
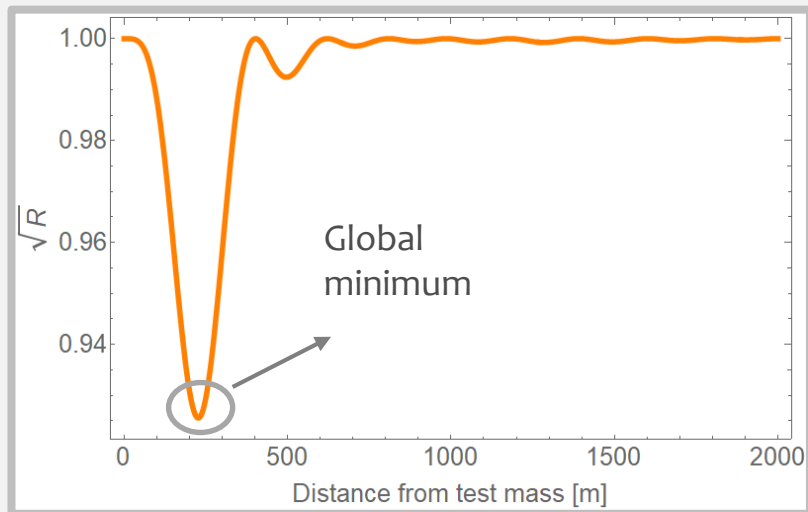
3 channel axis
seismometer

Single example

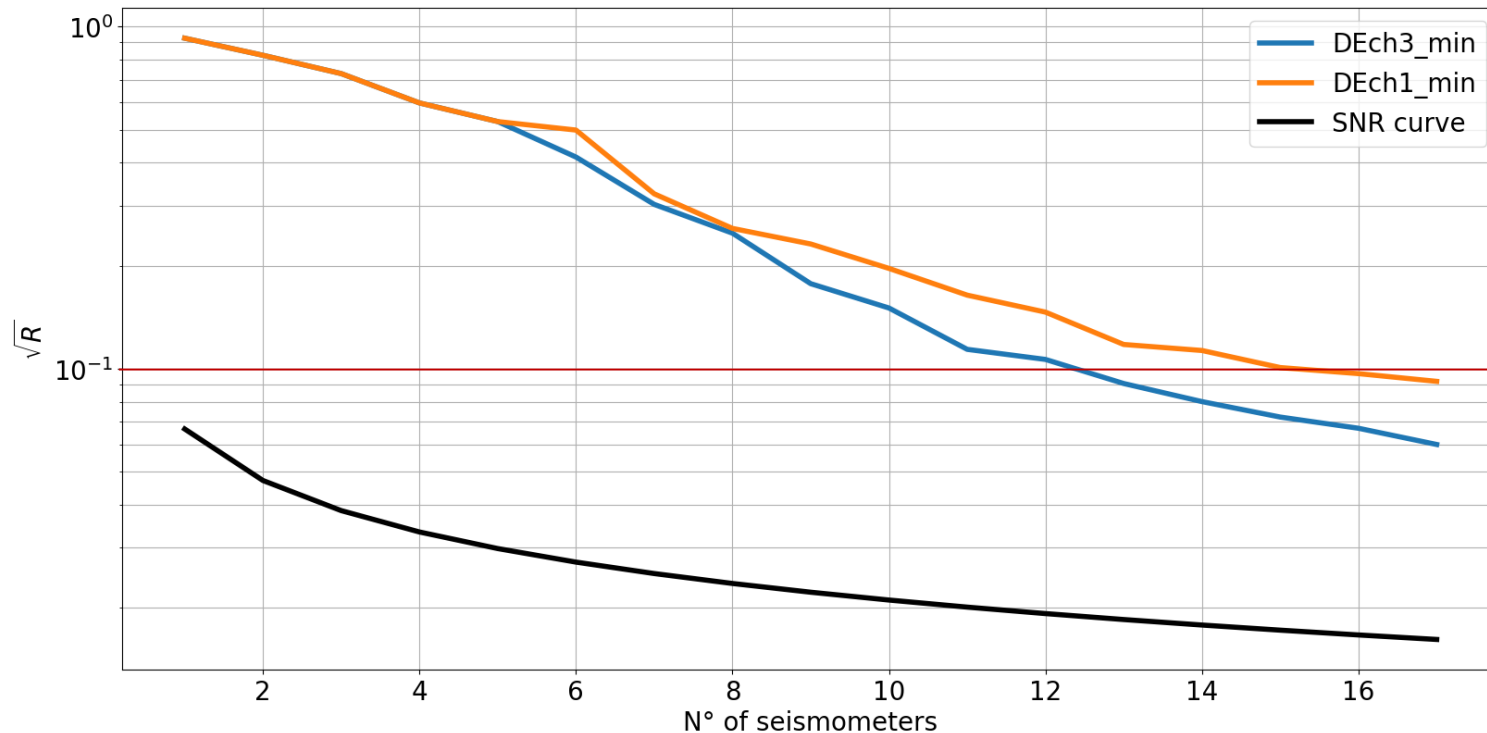


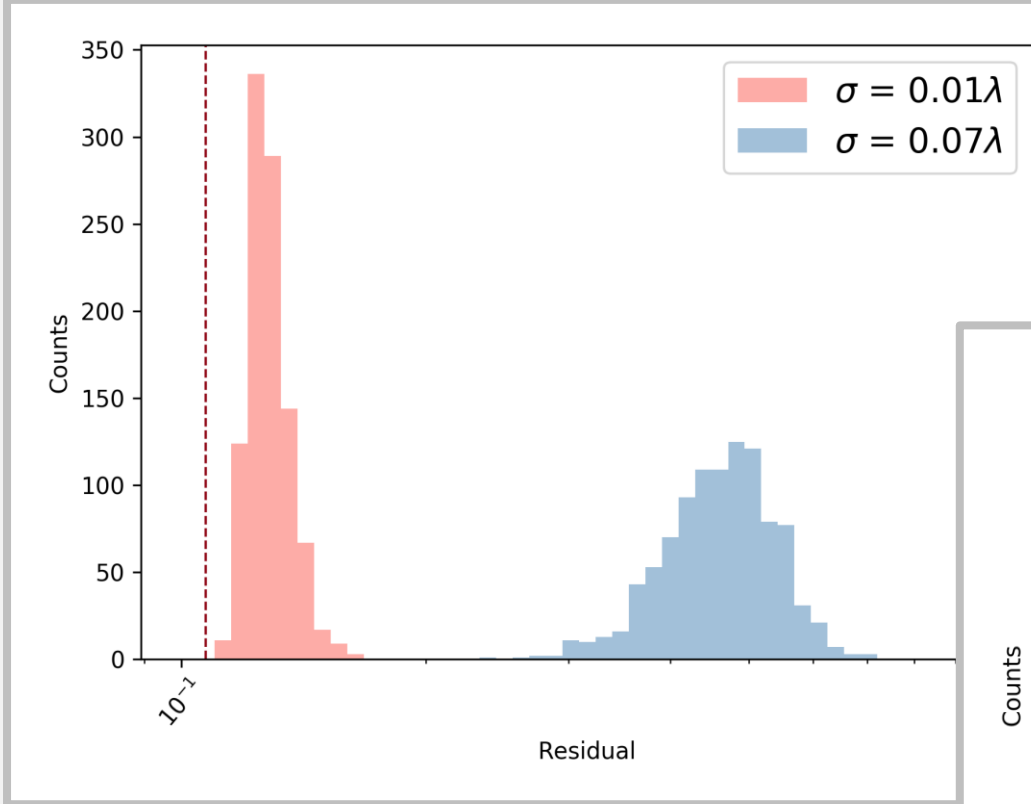
Validation:

Analytical solution for $N = 1$



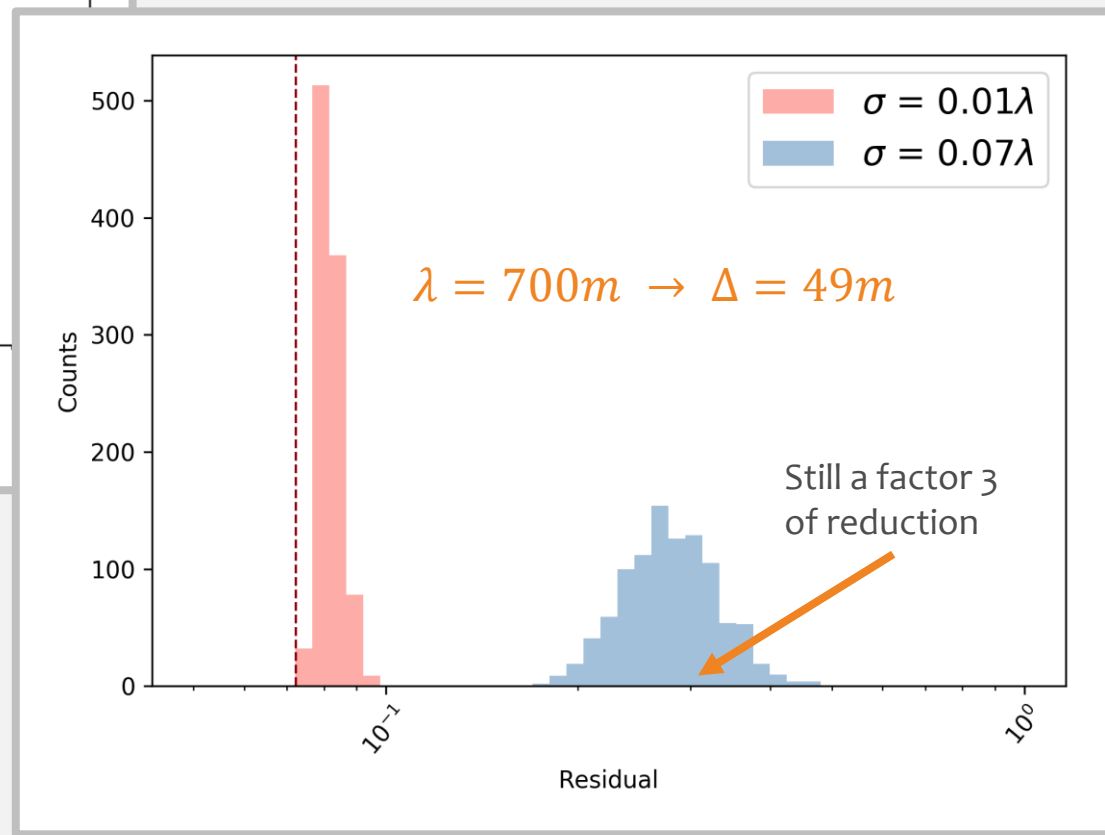
Successful mission: factor 10 of reduction already
with 13 seismometers per test mass





Ch1, N=15

Ch3, N= 15

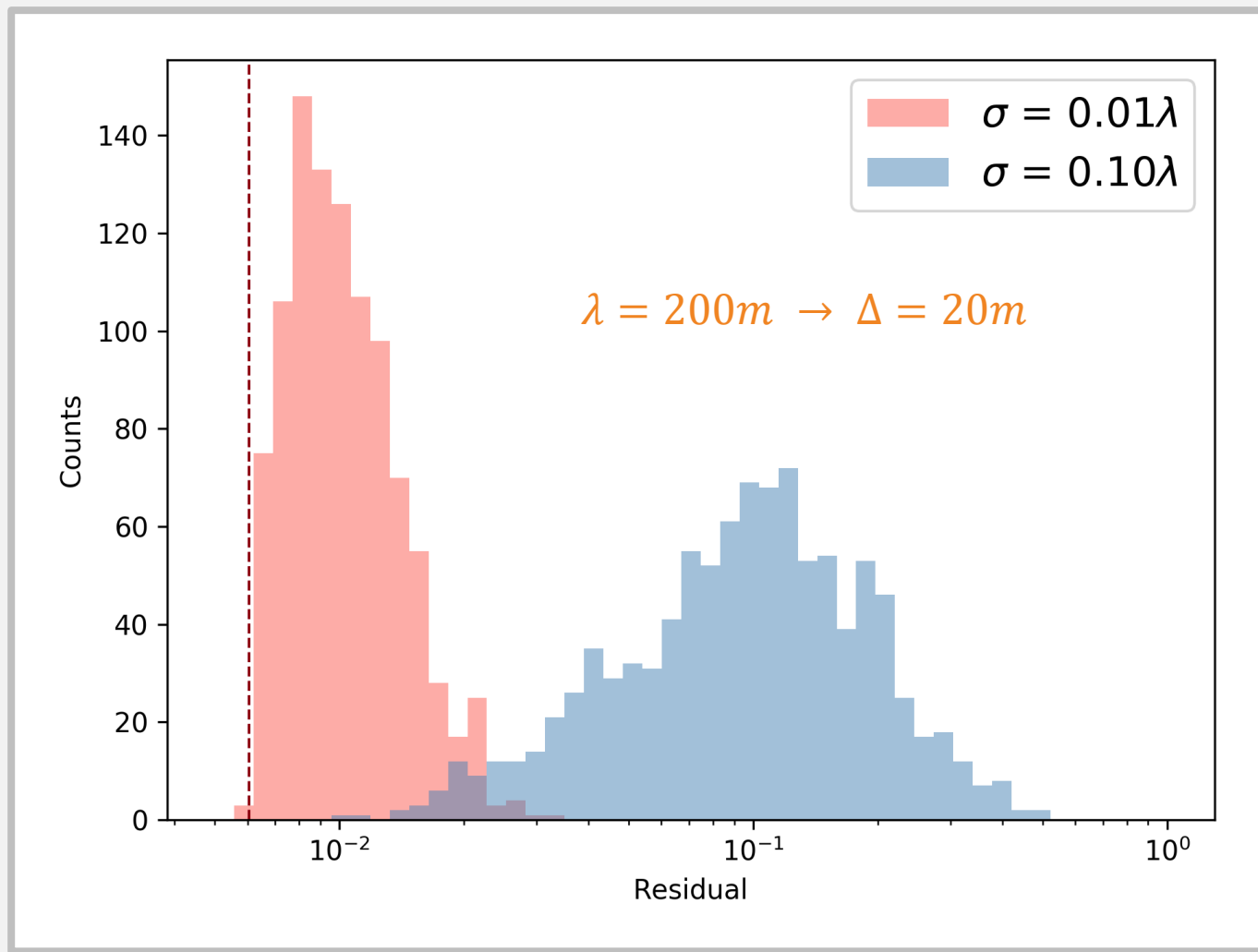


Conclusions:

- NN cancellation up to a factor 10 should be **feasible**
- Important result: even a **degraded** array can still work
- A **simplified** analysis
- Still, n° of seismometers, related residual and stability of solution should be **robust**
- Optimization based on real data (**site characterization**) required for accurate seismometer placement

Thanks for the attention!
Questions?

Rayleigh, $N = 6$ Already limited by the self noise



↓
This entails a worse NN reduction for a degraded array configuration

Broadband optimization:

