Limitations of Newtonian-noise cancellation in underground detectors

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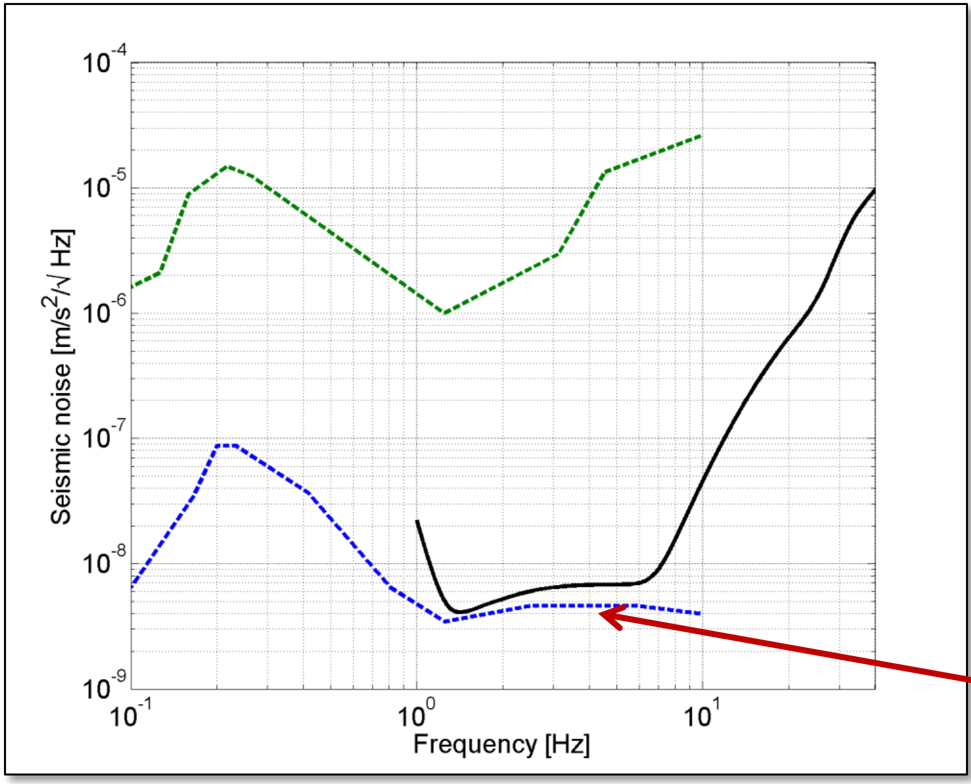
ET Requirement

ET-C sensitivity expressed as seismic-noise equivalent through gravitational coupling



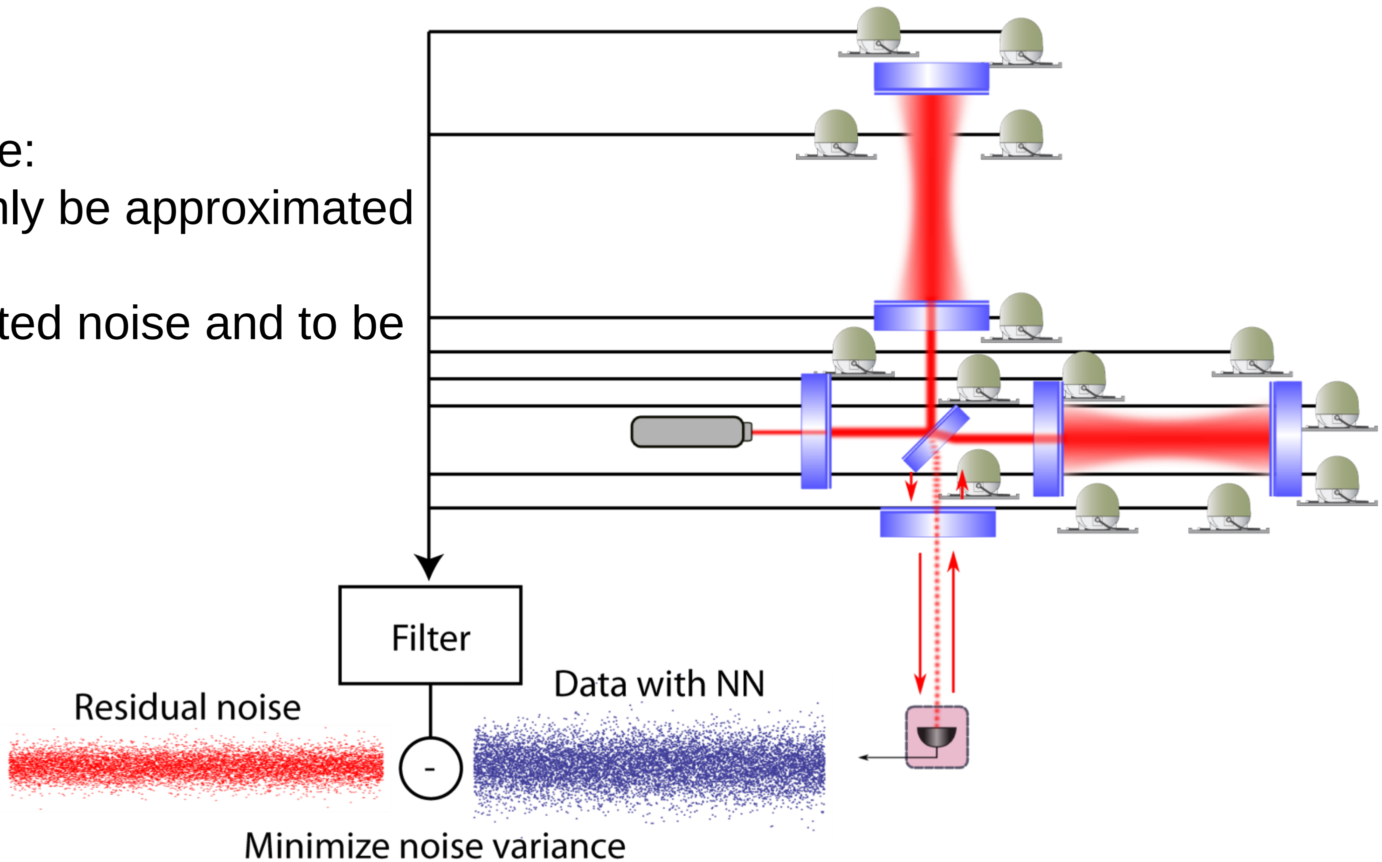
Worst case assumption: All seismic displacement due to P-waves.

No site on Earth with average temperature above 0°C has seismic noise below this line.

Coherent Noise Cancellation

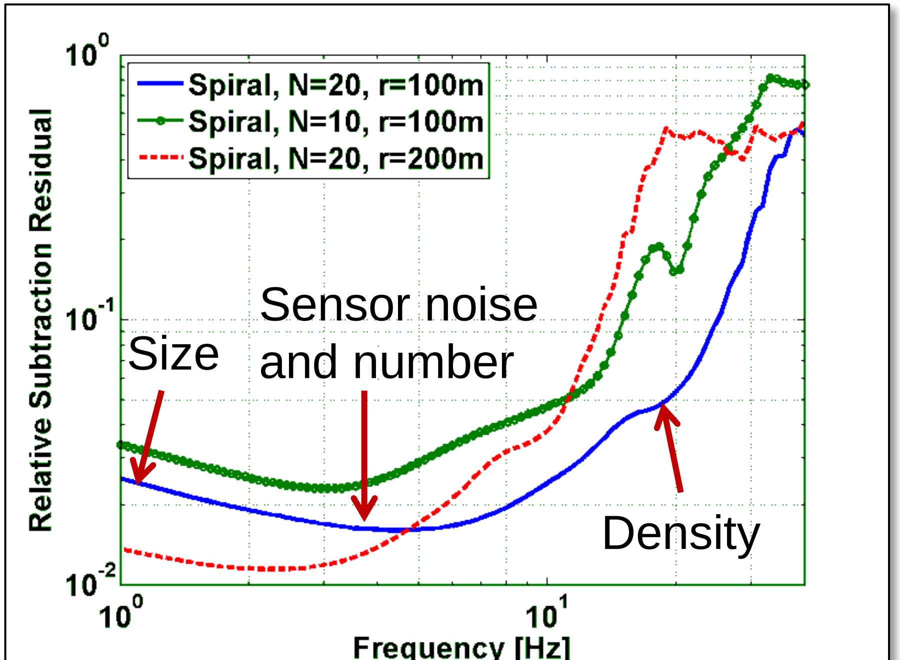
Challenges:

1. Non-stationary noise:
   Optimal filter can only be approximated
2. Correlated noise:
   Disentangle correlated noise and to be eliminated signal

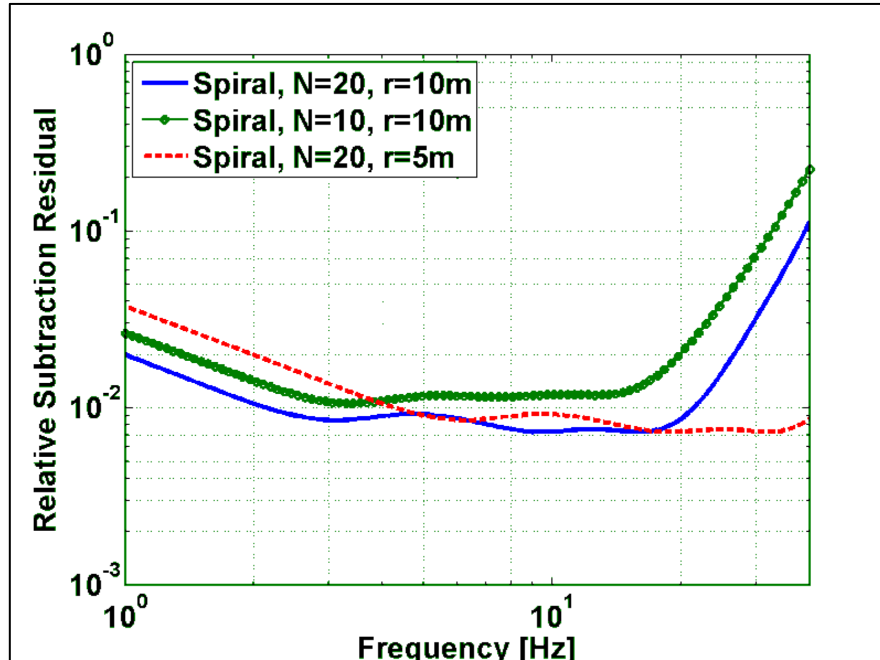


Previously

Rayleigh-NN cancellation



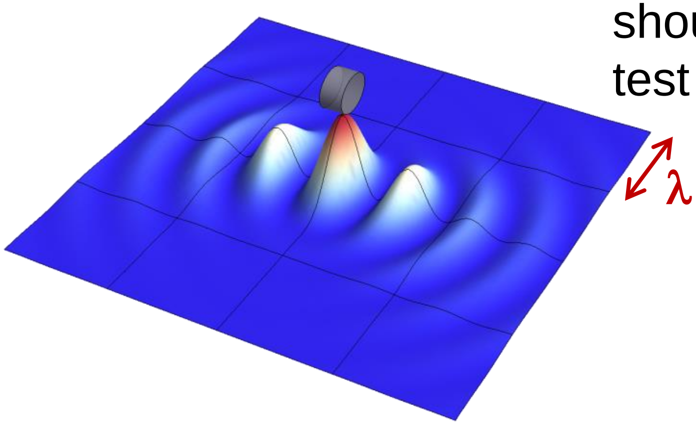
Infrasound-NN cancellation



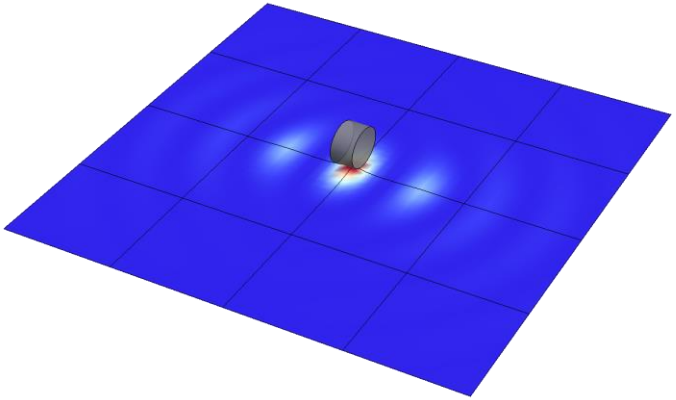
Challenges:
ξ_z at TM uncorrelated with NN
ξ_{hor} has S-wave contribution

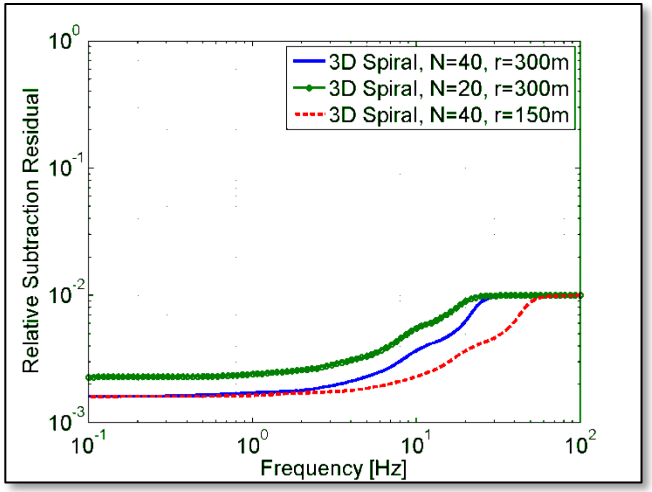
Challenges:
Subtract NN from 3D field with 2D array
No directional information from sensors

P-Wave Subtraction



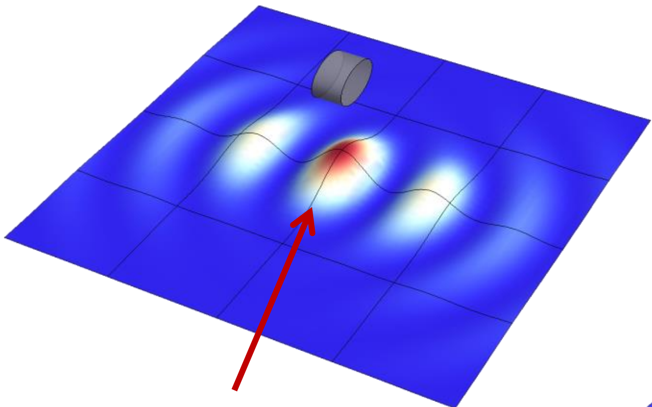
If there are only P-waves, all seismometers should be placed as close as possible to the test mass.





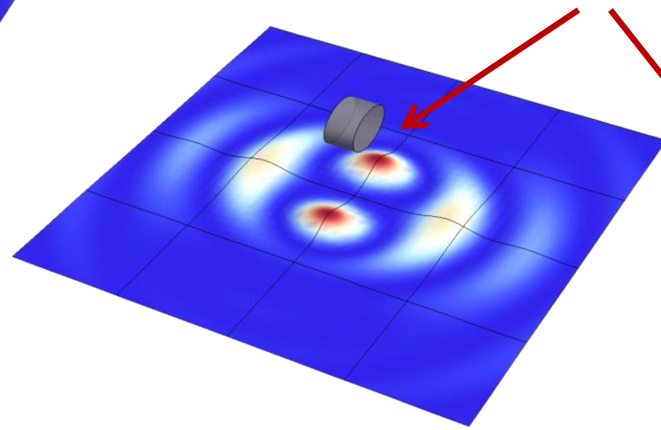
Subtraction residuals determined by number and SNR of seismometers.

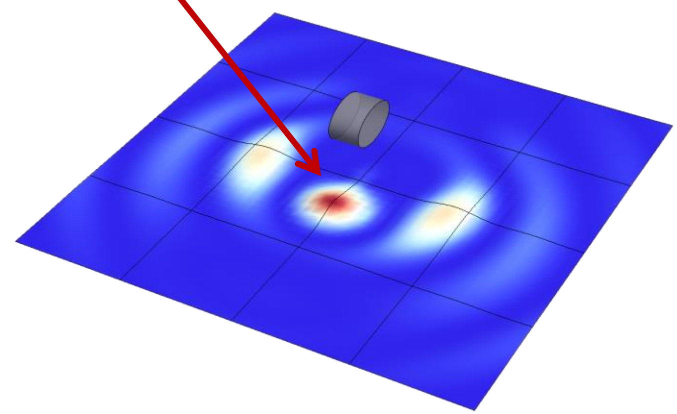
Body-Wave Subtraction



If ET budget can only pay for one seismometer per test mass, place it here.

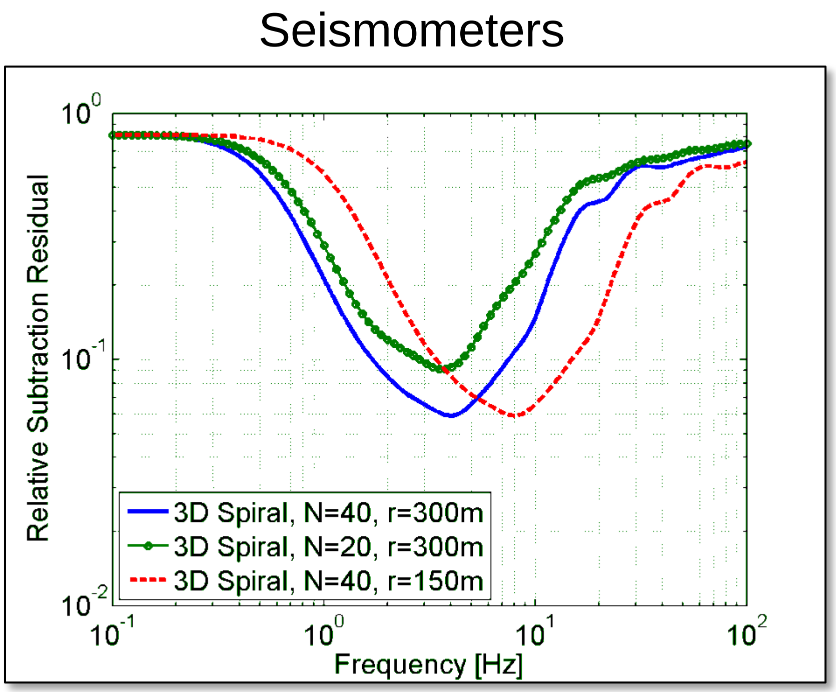
Second and third seismometer at right angle to distinguish between S and P waves (no correlation with NN).

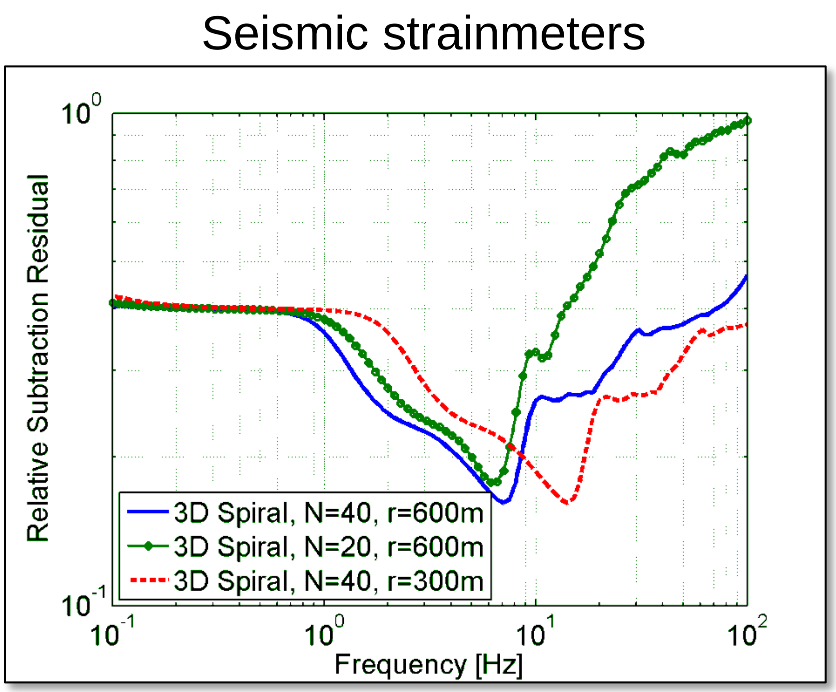




Mixing ratio: P/(S+P)=0.33

Subtraction Residuals





1. All sensors oriented along arm
2. Mixing ratio: P/(S+P)=0.33

Possible Solutions

1. Calculate residuals using three-axis seismometers
2. Calculate residuals using seismic strainmeters in arbitrary orientations
3. Combine seismometers and strainmeters
4. Investigate optimal array configurations
5. Look at seismic data to estimate mixing ratio

Limits in Array Size

Array needs to be big enough so that all significant density perturbations happen inside confines of the array. → How big is big enough?

Immediate perturbation

Example: grav acc from point force

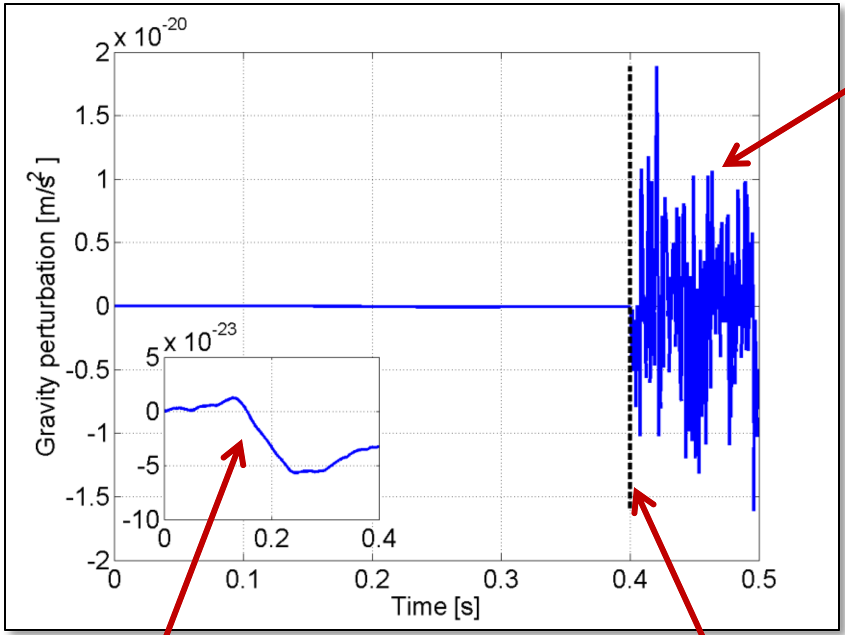
$$\delta\vec{a}(\vec{r}_0,t) = \frac{G}{r_0^3}(\vec{e}_f - 3(\vec{e}_f\cdot\vec{e}_{r_0})\vec{e}_{r_0})\int\limits_0^{r_0/\alpha}\mathrm{d}\tau\,\tau F(t-\tau)$$
$$+\frac{G}{r_0\alpha^2}(\vec{e}_f\cdot\vec{e}_{r_0})\vec{e}_{r_0}F(t-r_0/\alpha)$$

Distance between point force and test mass

Delayed perturbation

Radiating Point Source

All seismic noise coming from one point source switched on at t=0:



Conventional NN from ambient seismic fields

While NN from approaching wavefronts cannot be subtracted, it is also very low frequency and likely unimportant.

NN from approaching wavefront

Arrival of wavefront at test mass