

Seismic Newtonian Noise Reduction A Machine Learning Approach

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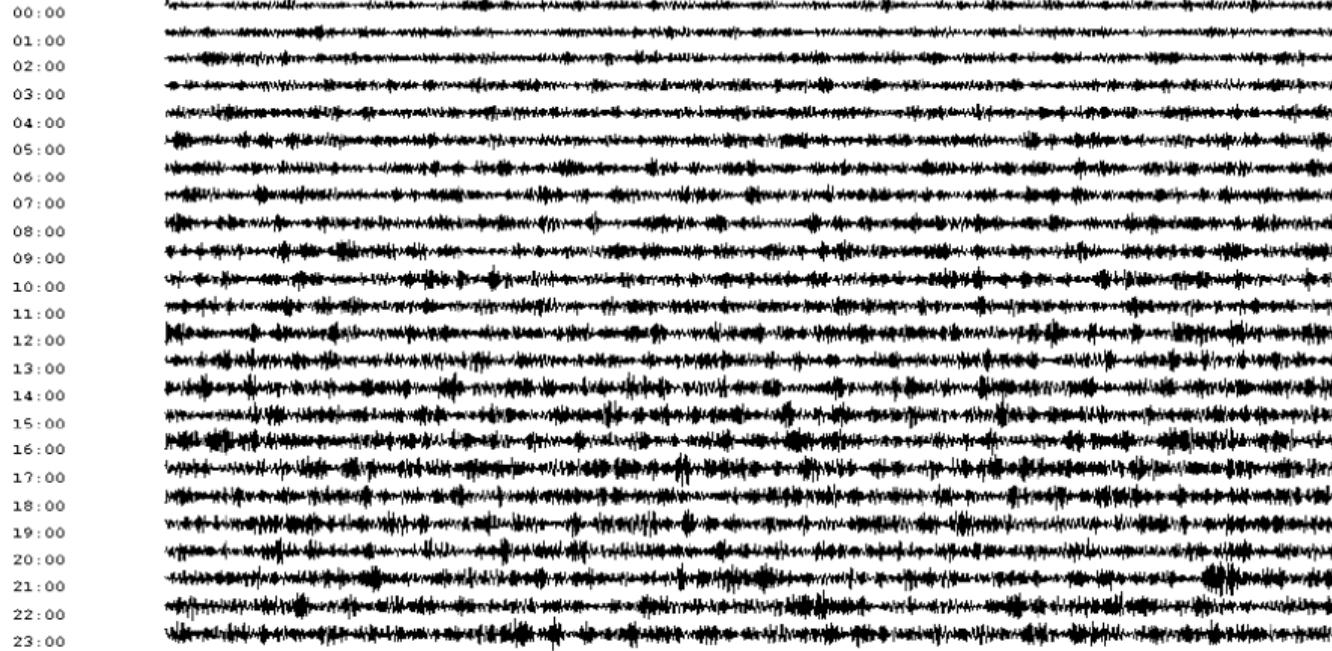


- ▶ Noise recording
- ▶ Noise analysis
- ▶ Noise model and noise prediction
- ▶ Noise reduction system

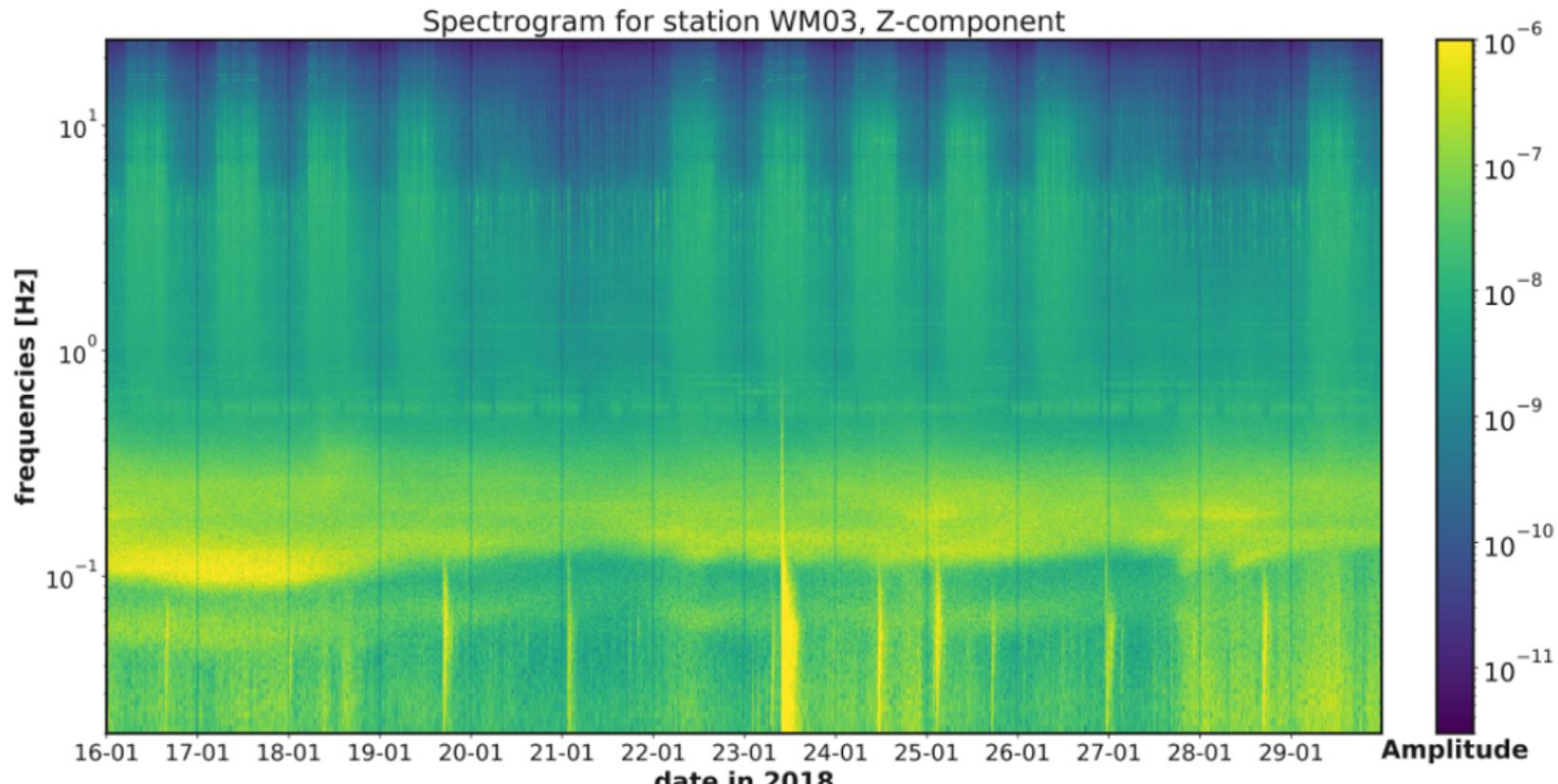
- ▶ ocean waves
- ▶ microseismic events
- ▶ traffic and other anthropogenic sources
- ▶ earthquakes (Münster)

Noise Recording – Seismogram

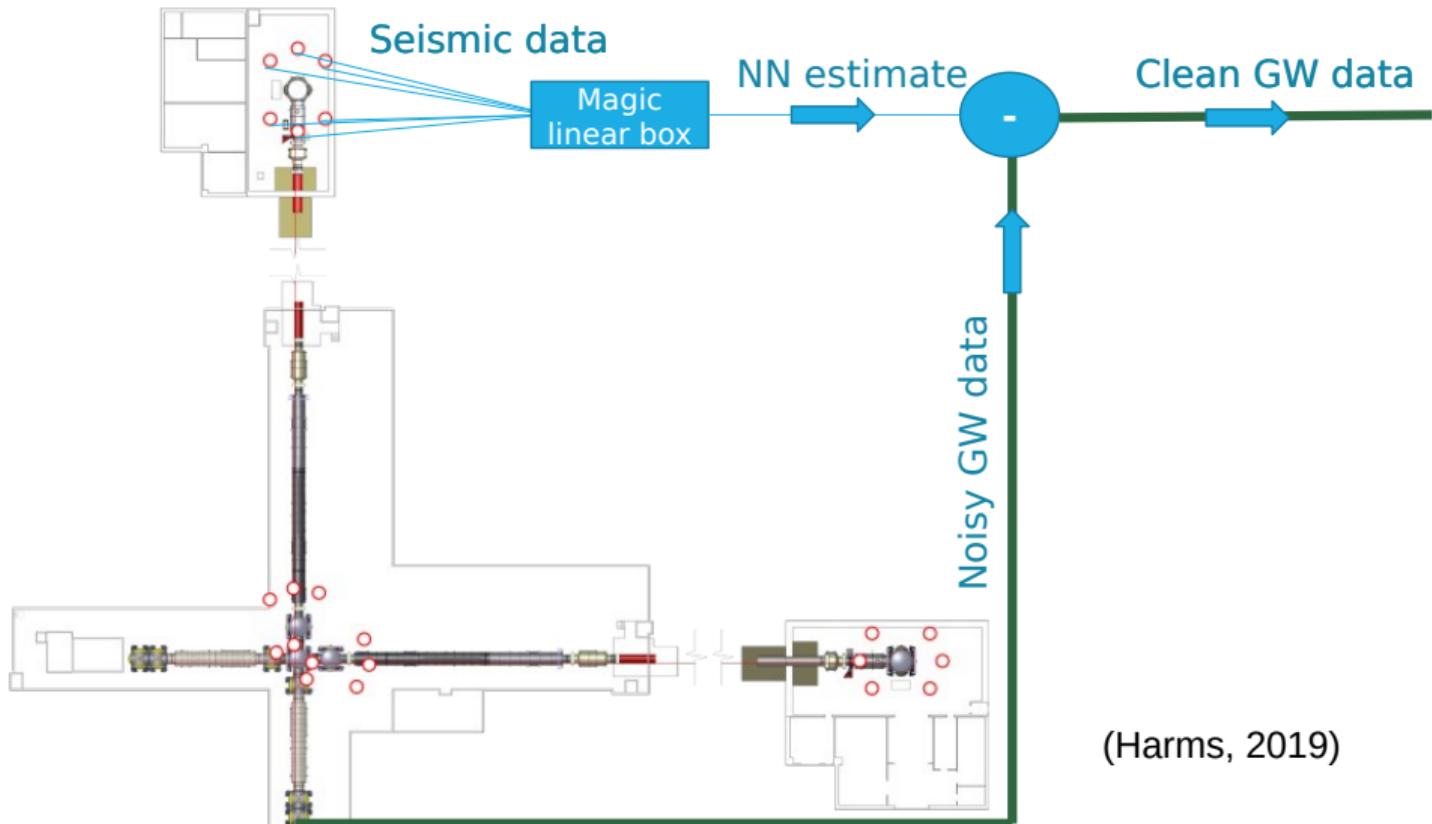
BFO LH Z 24-FEB-2000 FILTER LP_12SEC_4 ZOOM 10



Noise Recording – Spectrogram

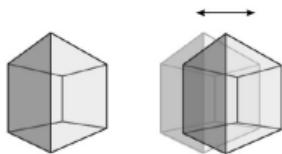


Noise Reduction System



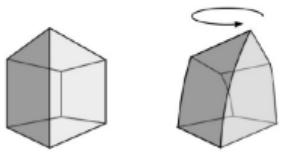
(Harms, 2019)

Types of Ground Motion



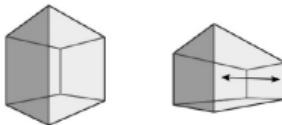
Displacement
"oscillation"
3 components
(degrees of freedom)

Seismometers measure translation motion (left-right, up-down) across broad band of frequencies and large range of amplitudes



Rotation
"twisting"
3 components

Rotational sensors (e.g. fiber-optic gyroscopes, Sagnac interferometers) measure “twisting” motion and tilts



Strain
"stretching"
6 components

Strainmeters or DAS measure stretching motions

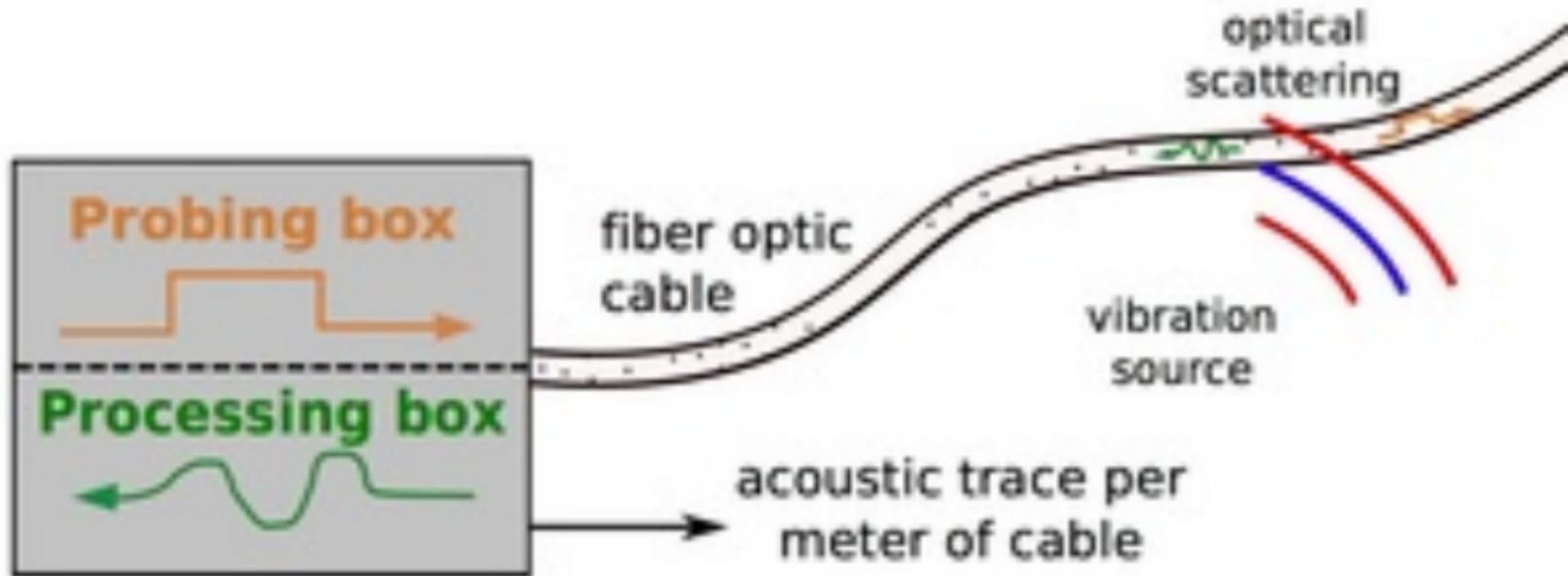
- ▶ broad band seismometers (translation, MS & HH)
- ▶ rotational seismometers (rotation, HH)
- ▶ Distributed Acoustic Sensing (strain, HH & MS)

Classical seismology is build on translational motions.

Rotational Seismology is an emerging field to study rotational motions.

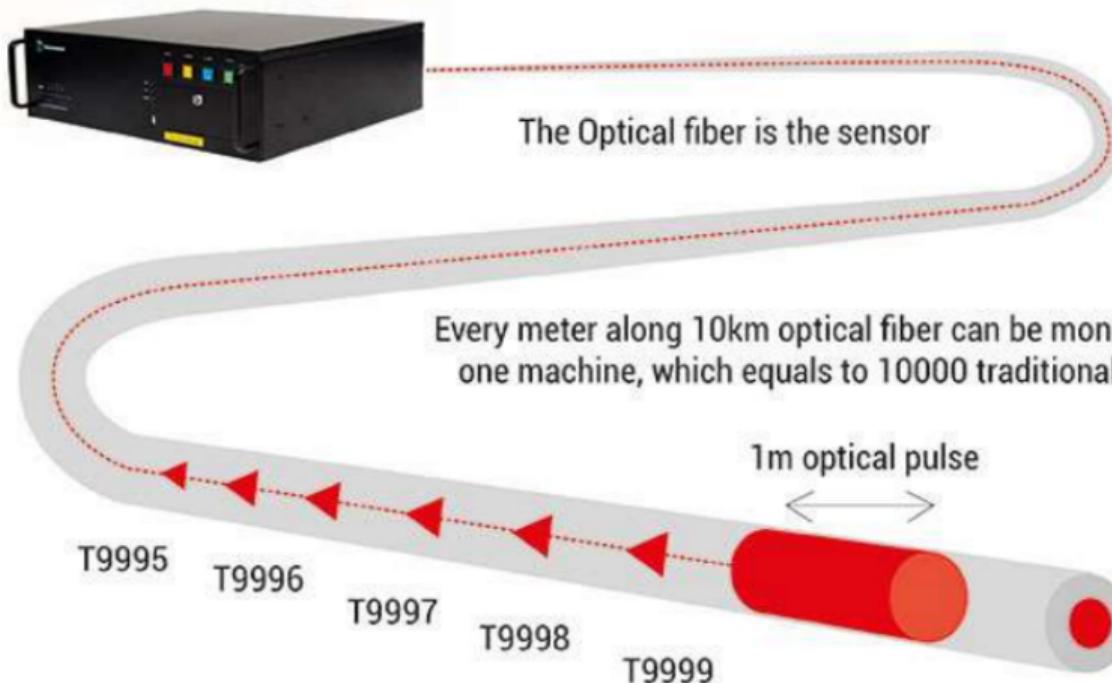
Distributed Acoustic Sensing: New acquisition system, measures strain

Future: Distributed Acoustic Sensing (DAS)



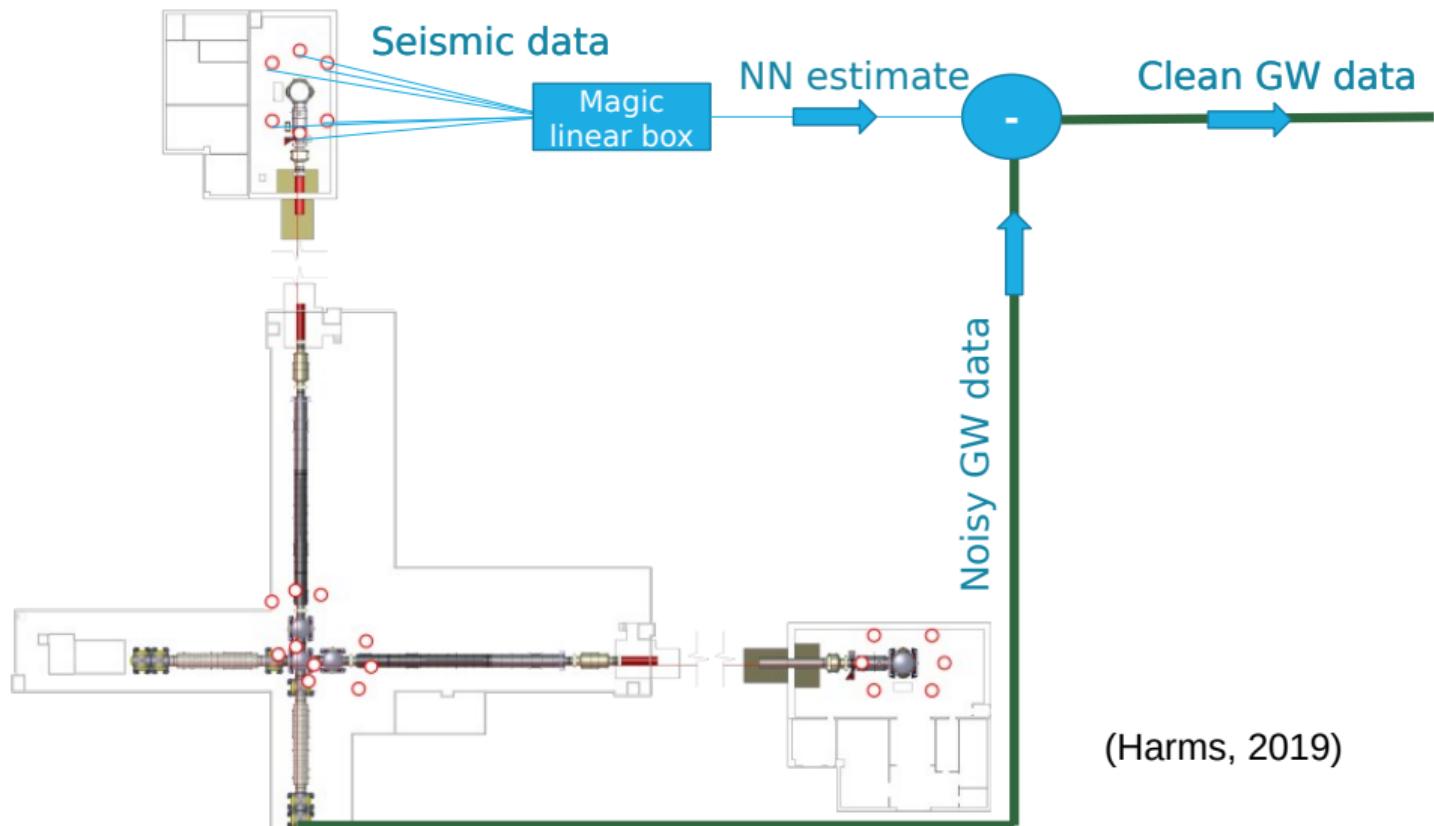
(Martin, 2015)

Distributed Acoustic Sensing



(courtesy of Bandweaver)

Noise Reduction System



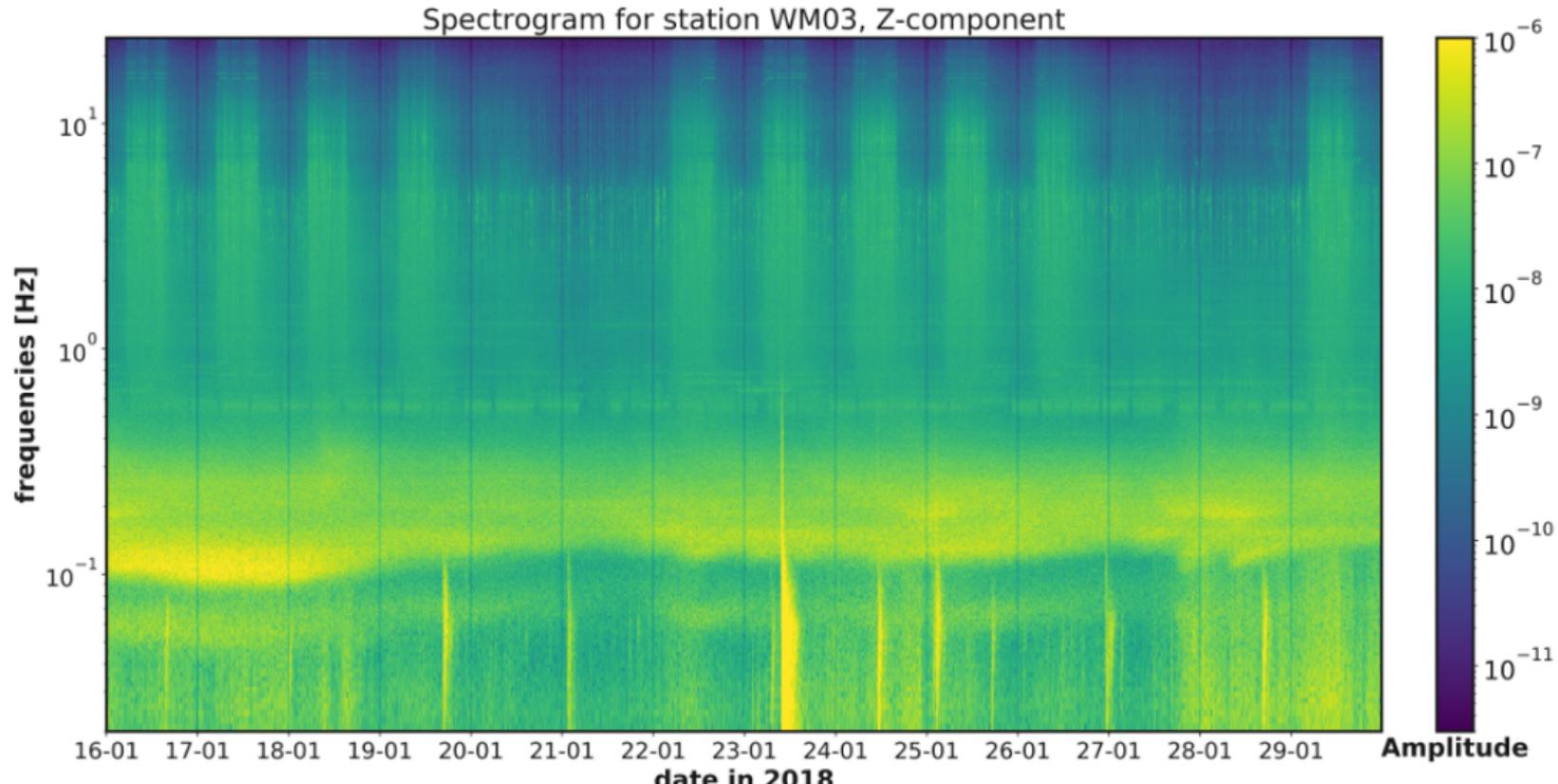
(Harms, 2019)

Conditions for successful application noise should be

- ▶ non-deterministic
- ▶ “infinite” time series
- ▶ stationary

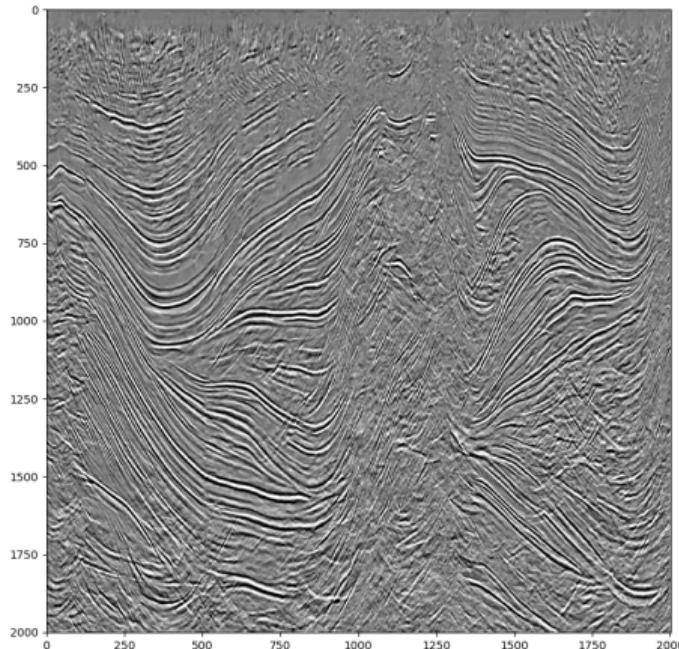
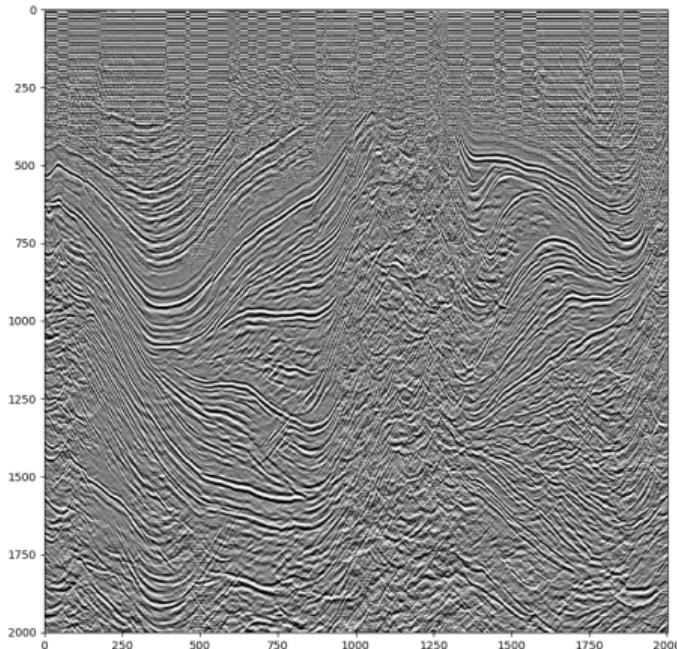
Filter coefficients are derived by the autocorrelation of noise and data.

Spectrogram Billwerder



- ▶ description in space and time
- ▶ recurrent neural networks (RNN)
- ▶ convolutional neural networks (CNN)
- ▶ combination of both
- ▶ encoder-decoder systems
- ▶ supervised/unsupervised training

Example Seismic Image



- ▶ Is the combination of RNNs and CNNs a suitable structure for the analysis of seismic Newtonian noise?
- ▶ How do they compare to the current approaches based on Wiener prediction filters?
- ▶ What are the requirements for an effective training of the networks?
- ▶ Is an unsupervised training possible?
- ▶ Are training results transferable to different sites?
- ▶ Is the use of the permanent regional seismic network sufficient after training with a dense deployment of seismic sensors?
- ▶ What is the best implementation (feed forward, feed back, adaptive subtraction)?
- ▶ Are absorbing boundaries an alternative to current systems?