A new estimate of the STS-2 self-noise

An experiment in the Conrad Observatory, Austria

Reinoud Sleeman [1] , Peter Melichar [2]

(1) KNMI, Netherlands, sleeman@knmi.nl
(2) ZAMG, Austria

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Outline

Introduction and motivation

Origin of seismic sensor self-noise

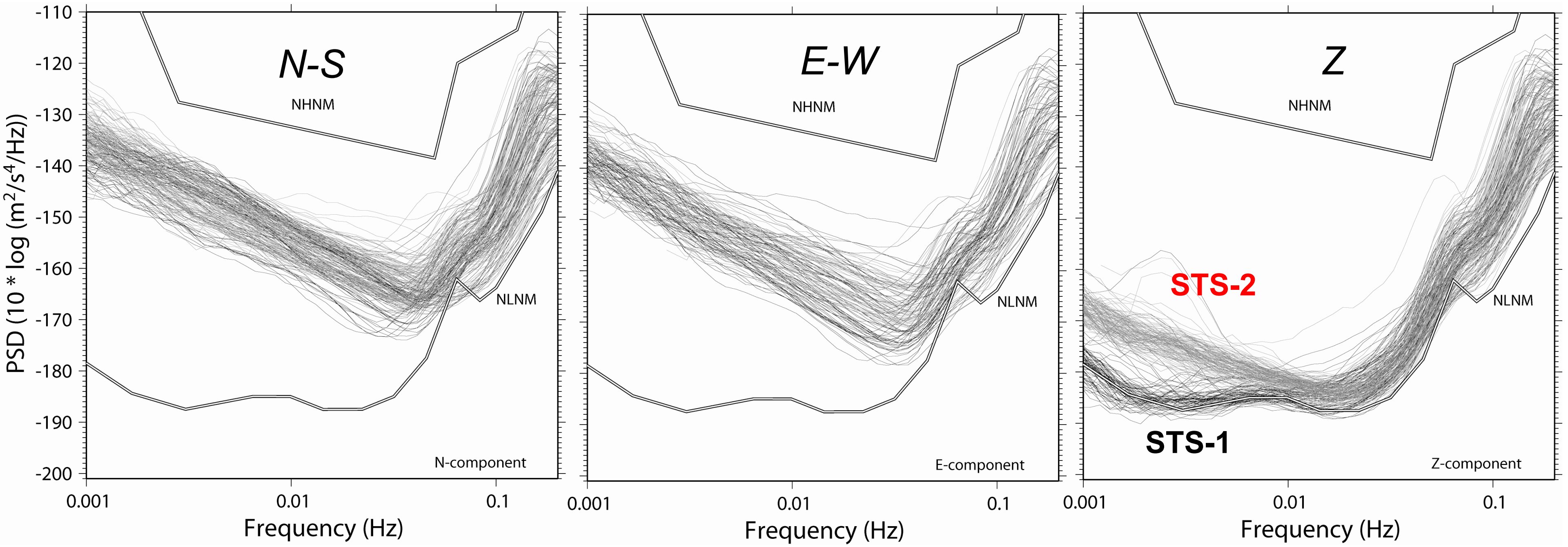
How to measure self-noise (correlation technique collocated sensors)

PSD estimate and representation

Results of the Conrad experiment

Conclusions and recommendations

Seismic background noise (m/s^2) power spectral density measured at seismic station Heimansgroeve (HGN), Netherlands during 2002: 302- 309 and 2003: 029 - 043



Possible causes:

- sensor noise
- digitizer noise
- installation conditions
- ....

Recorded noise at a seismic station depends on:

- natural sources of noise close to and far from the site
- the design and quality of the seismic vault
- the installation method of the seismic instrumentation
- the instrumental noise of the equipment itself

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In any research on the nature and contribution of each one of these noise sources and its interpretation, it is necessary to identify, isolate or reduce the contribution of the other noise types.

Motivation for knowledge of instrumental noise:

- bias of data by the recording system
- selection of instrumentation
- improving installation conditions

Origin of self-noise:

- feedback and amplifiers electronics
- fundamental Brownian (thermal) motion of the seismic mass

The electronic noise is partly fundamental in its nature, with a Gaussian character:

- thermal (Johnson) noise (random fluctuations at the atomic level)
- shot noise (fluctuations in electrical current; discreteness of charge

Non-fundamental nature of electronic noise:

- burst noise or "popcorn" noise
- a frequency-dependent noise known as "1/f" or flicker noise
- avalanche noise

Origin of self-noise:

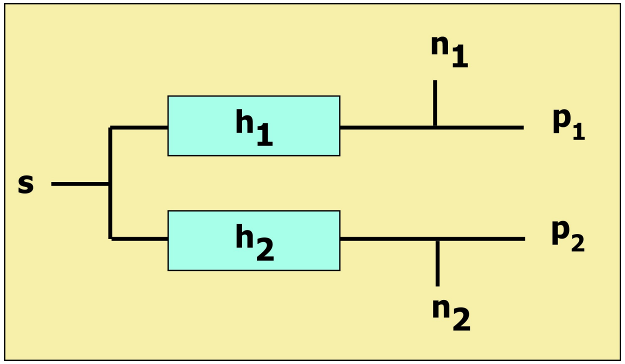
- small scale magnetic fluctuations
- electromagnetic noise of the displacement sensor (LVDT)
- stress release within the mechanical part
- cross-channel leakage

External sources:

- small variations in the background magnetic field
- currents in the seismic recording equipment
- temperature fluctuations and convection
- pressure effects (induced tilt, deformation, ...)
- humidity
- ..

Correlation technique using collocated sensors

Conventional 2-channel correlation



$$N_{11} = P_{11} - P_{12}\frac{H_1}{H_2}$$

3-channel correlation method (triplet method):

- direct method for estimating system noise and relative transfer functions

  based on the recordings only

- no *a-priori* information required about transfer functions or their accuracy;

  method is not sensitive for errors in gain

Instrumental self noise is non-deterministic, stochastic signal ⇨ Power Spectral Density

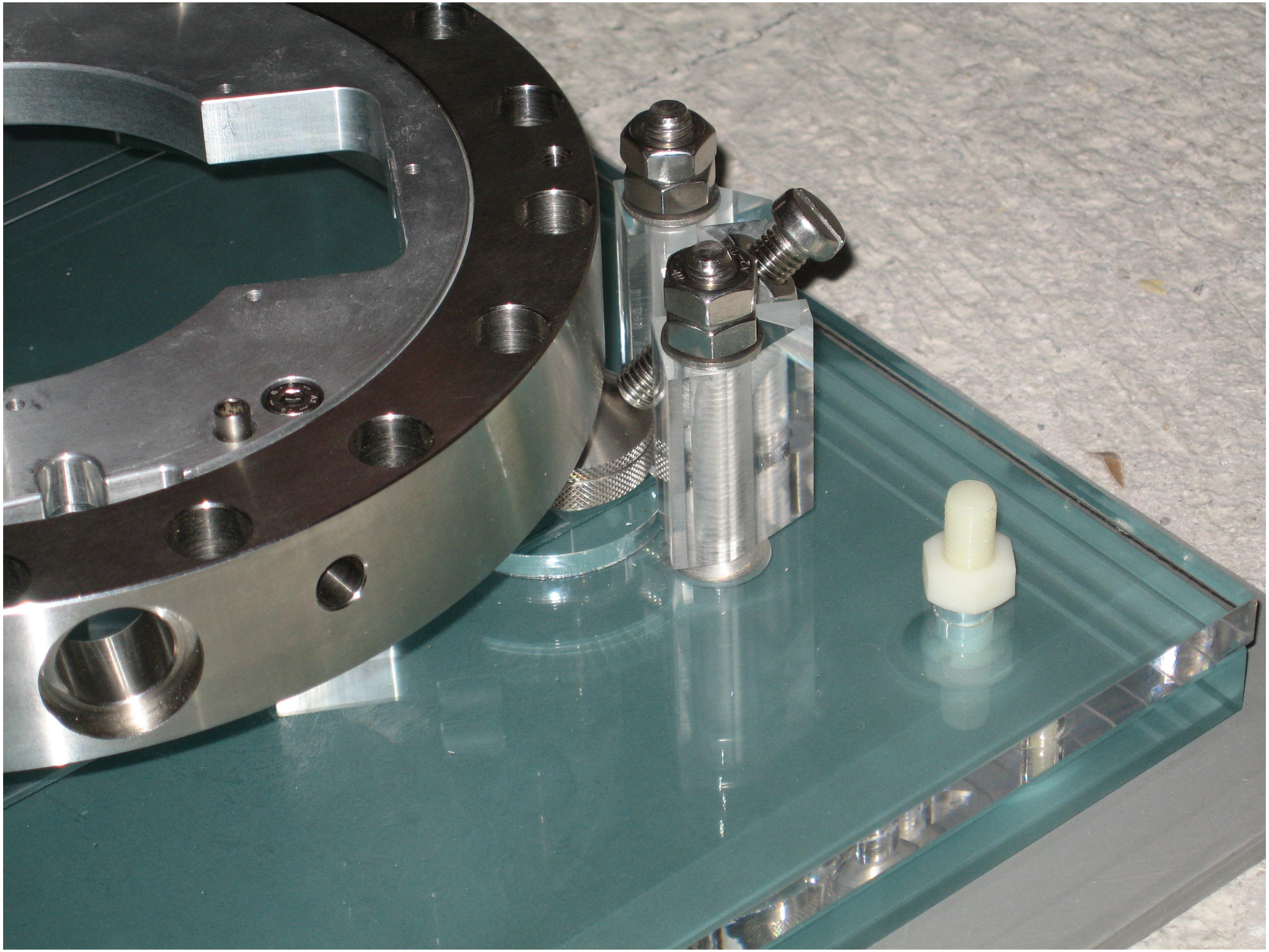
Powers Spectrum Density (PSD) estimation (Welch, 1978)

- 50 % overlapping time sections
- tapering (Hanning window)
- autocorrelation
- Fourier transform
- averaging over the number of time sections
- one-sided PSD (USGS noise models)
- instrument response deconvolution (to acceleration)
- PSD smoothing over 1/10-th of a decade

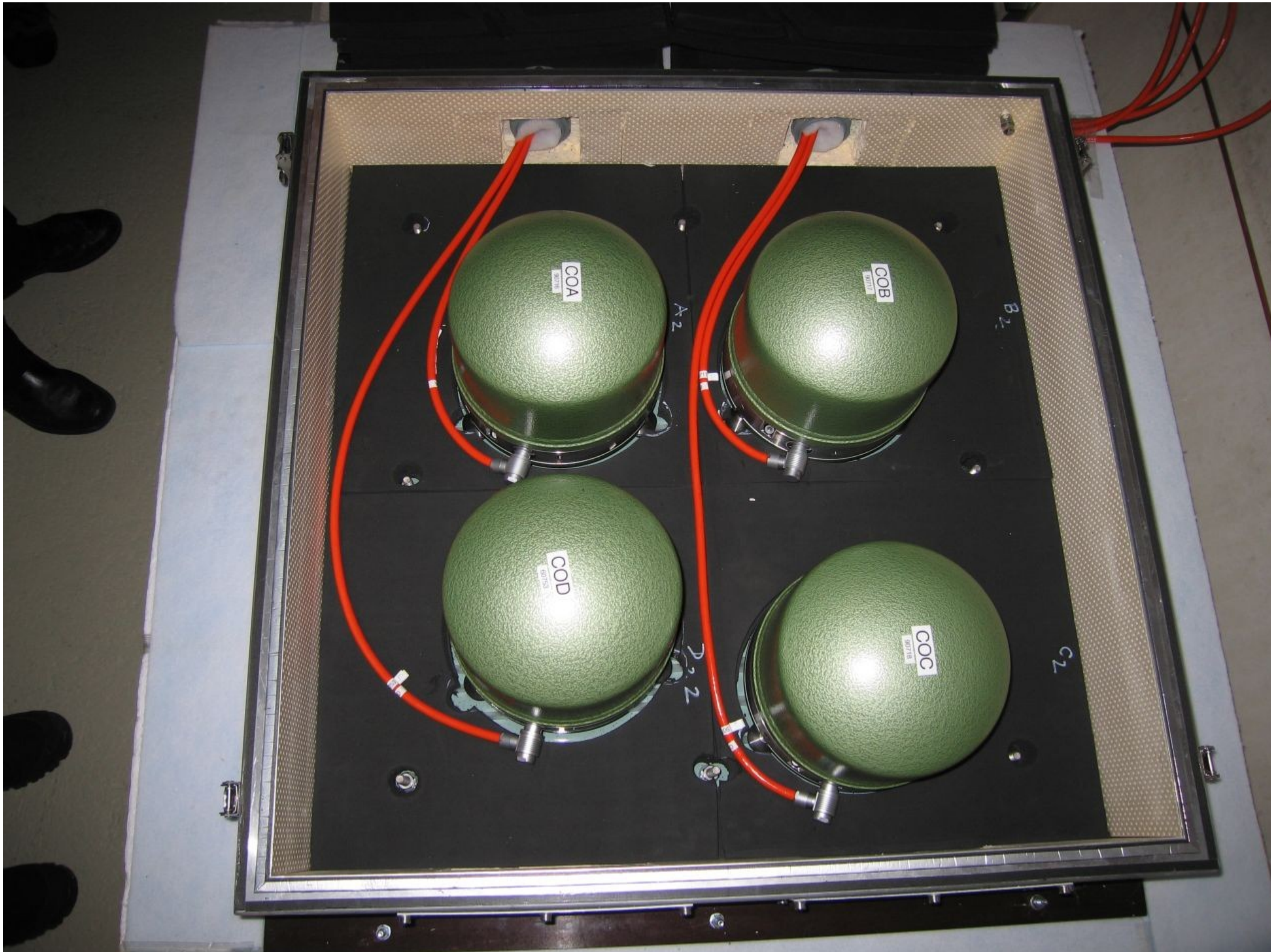
The Conrad Observatory Experiment

- NERIES framework (TA5) (funding)
- Conrad Observatory (infrastructure, local conditions)
- 4 STS-2 (same generation)
- 4 Q330-HR, enabled pre-amplifier
- Antelope ® acquisition

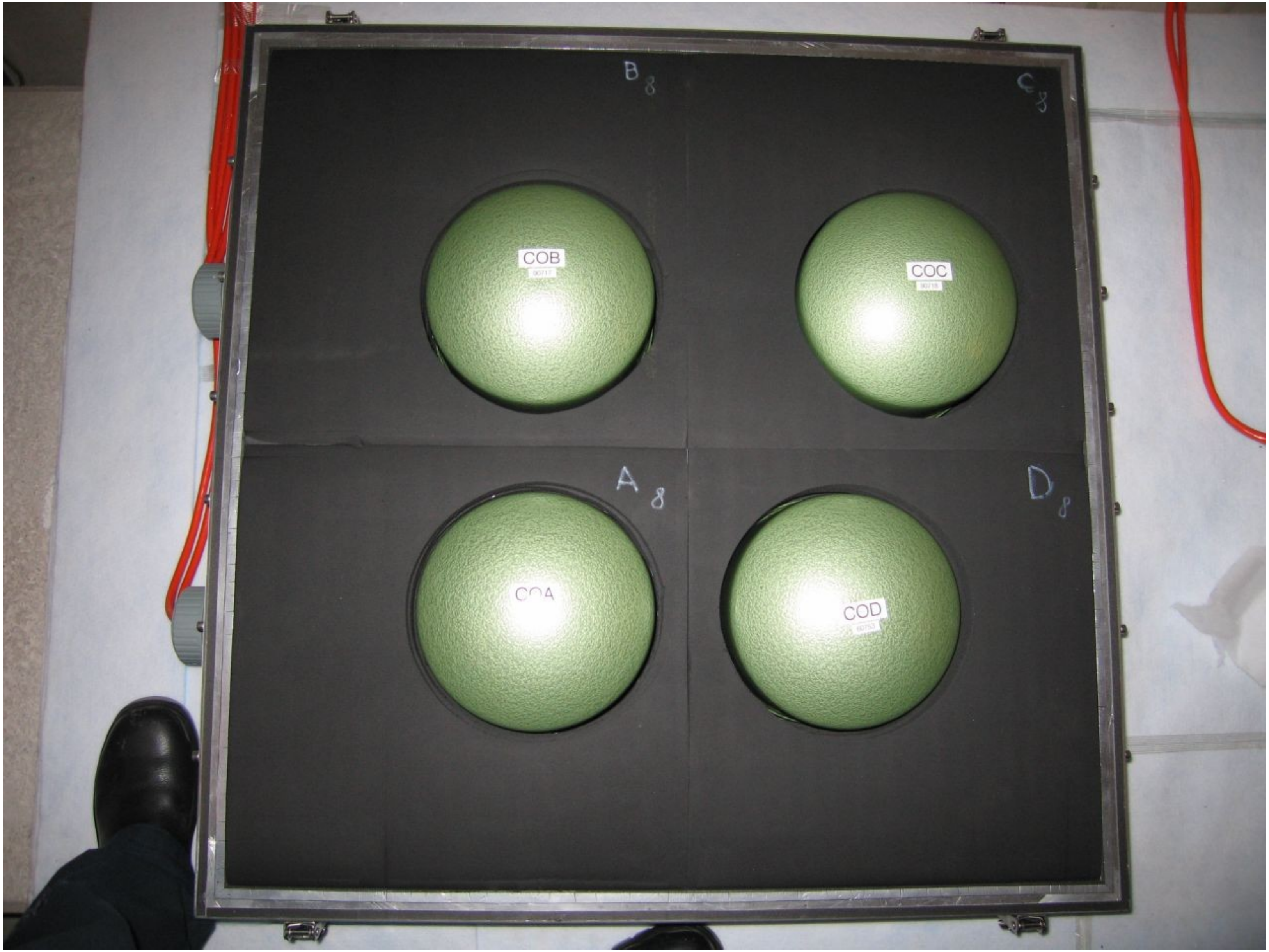
Conrad experiment



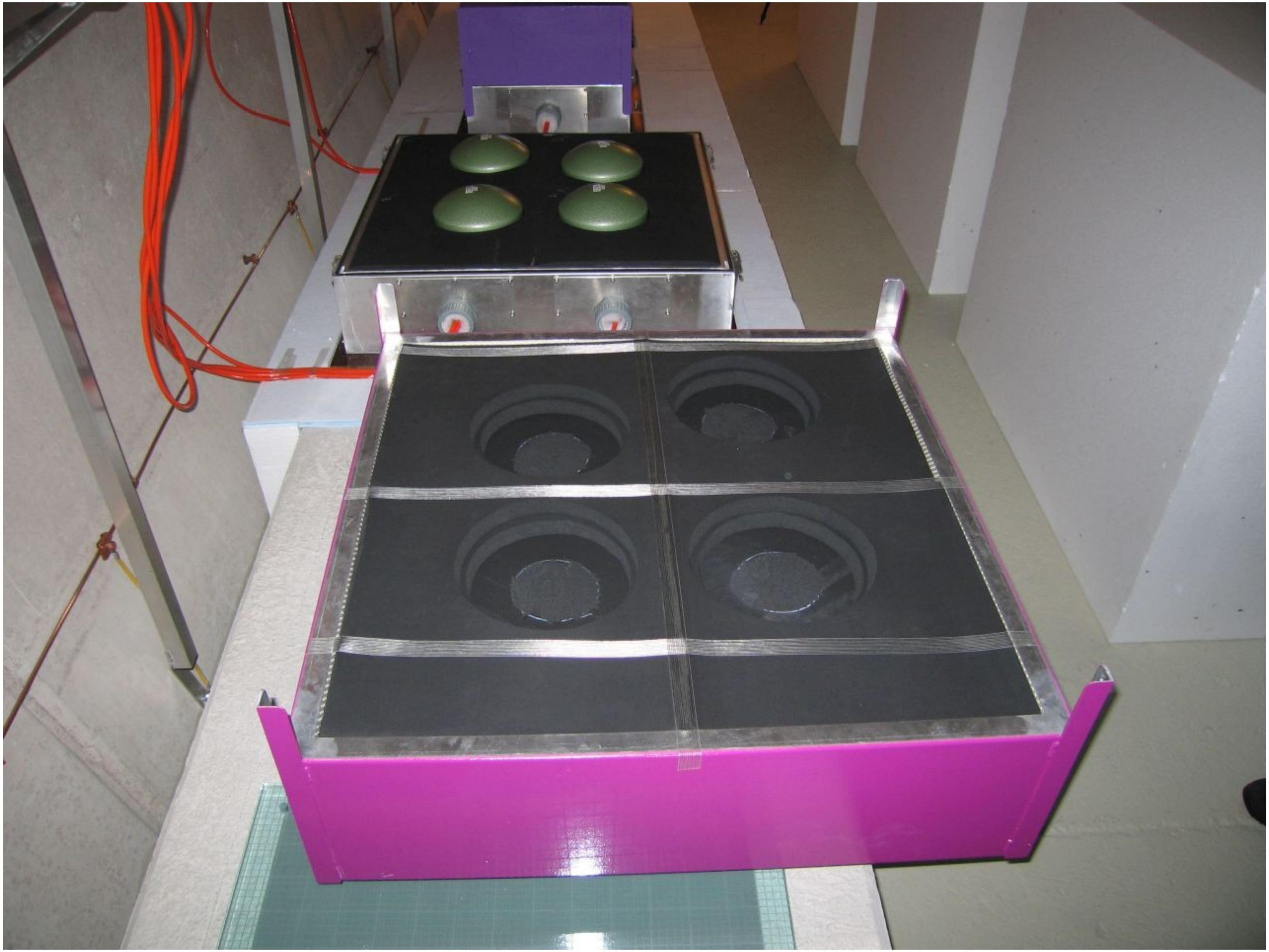
Conrad experiment



Conrad experiment



Conrad experiment



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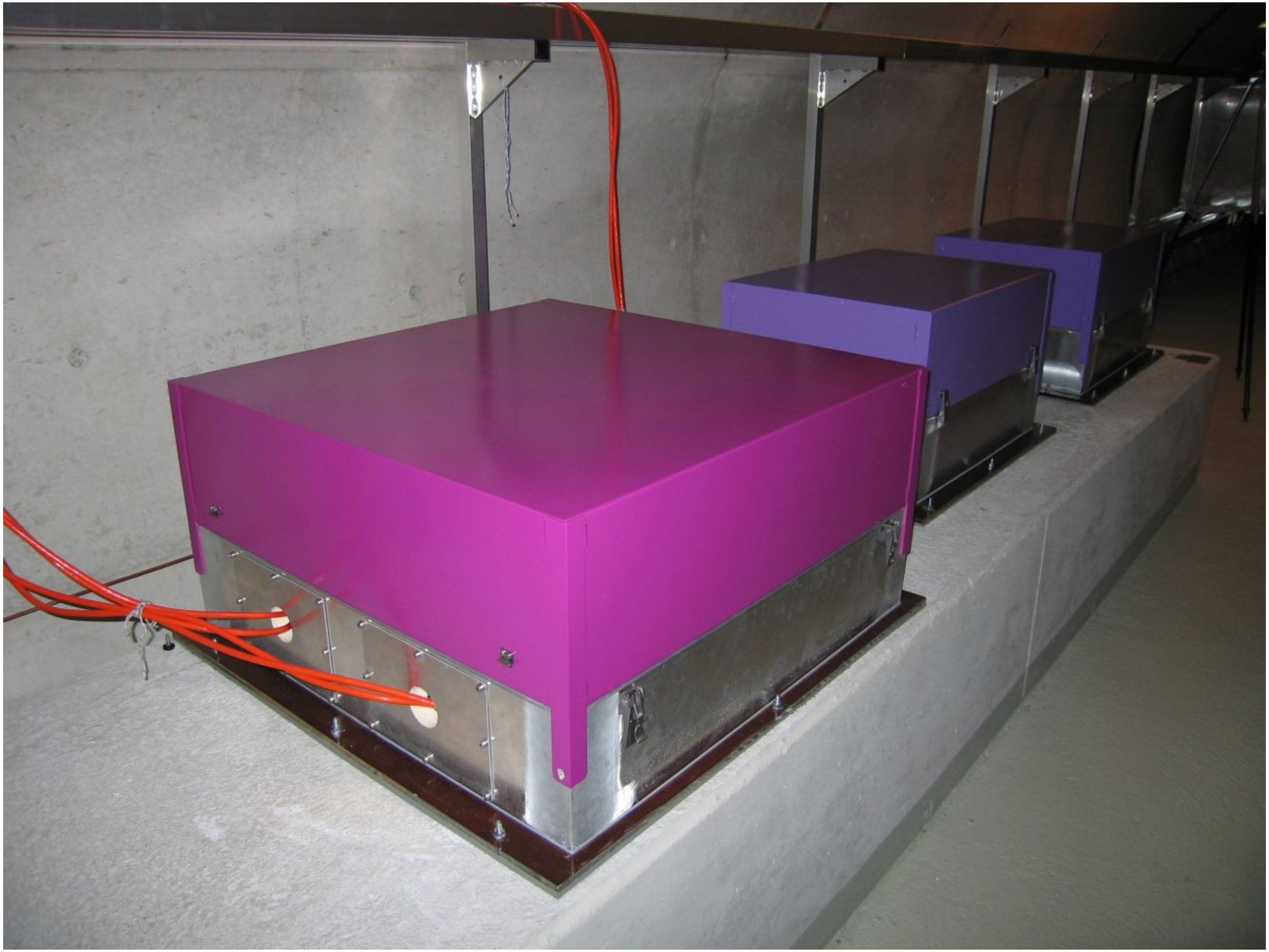

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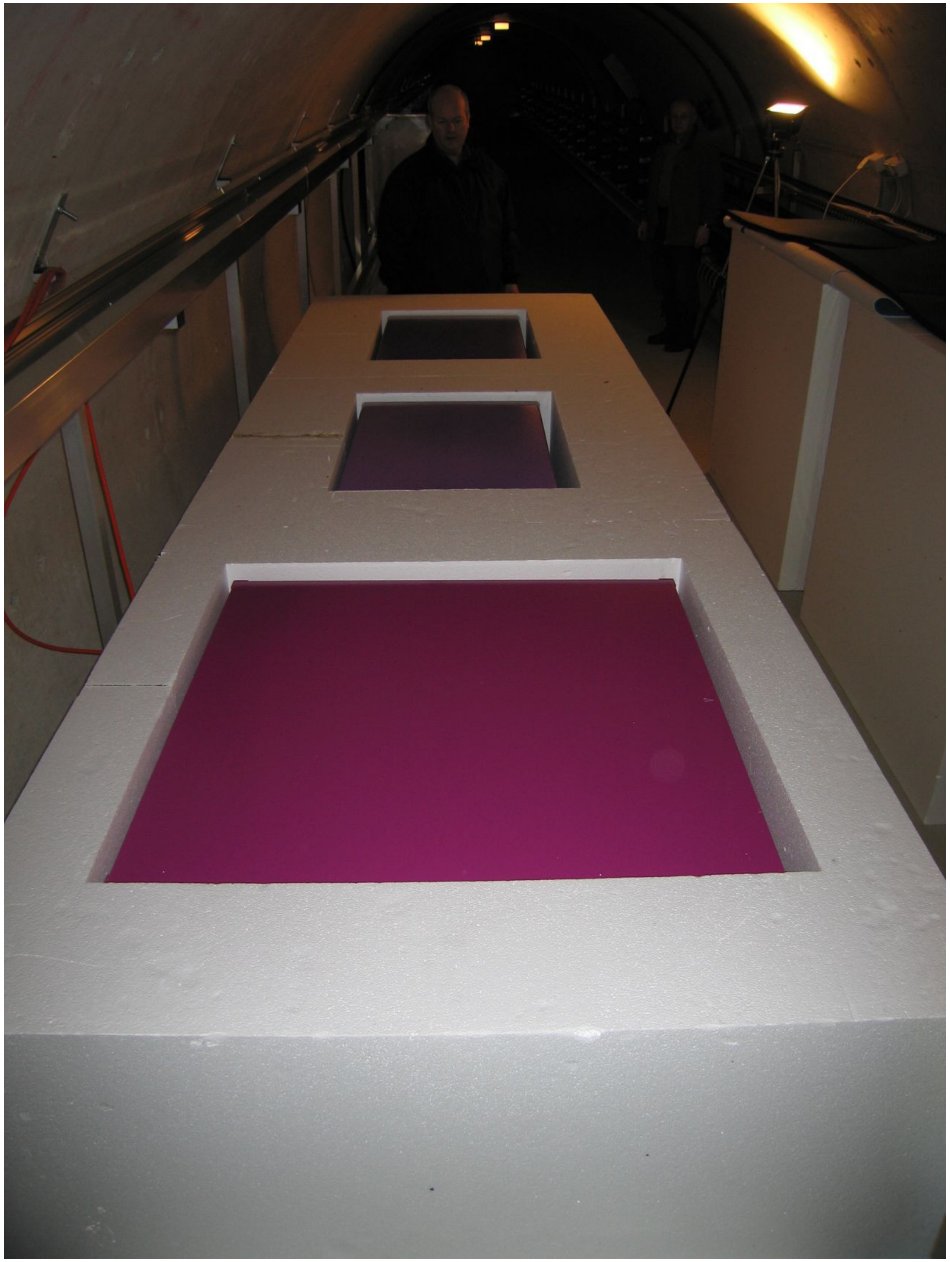
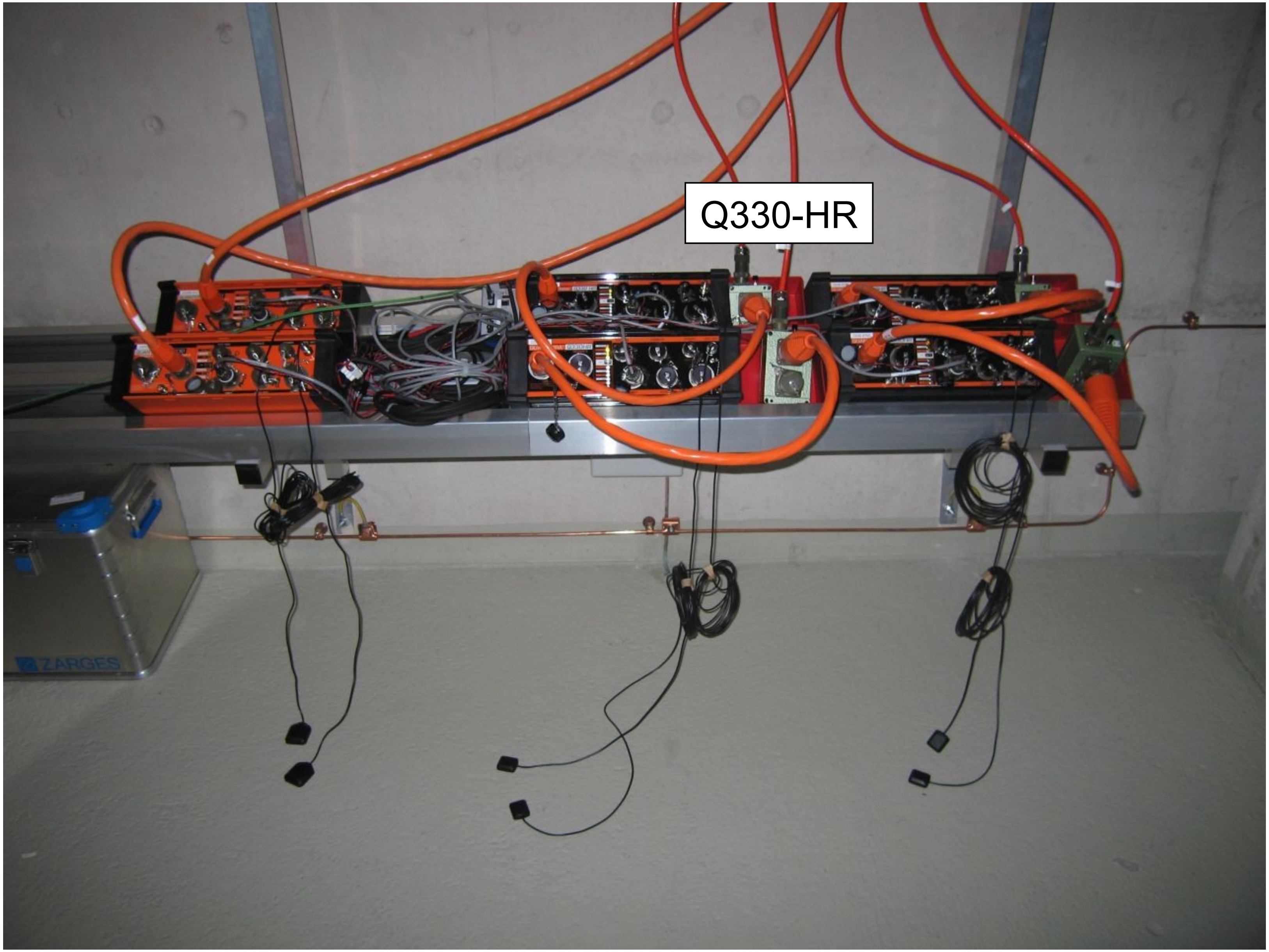
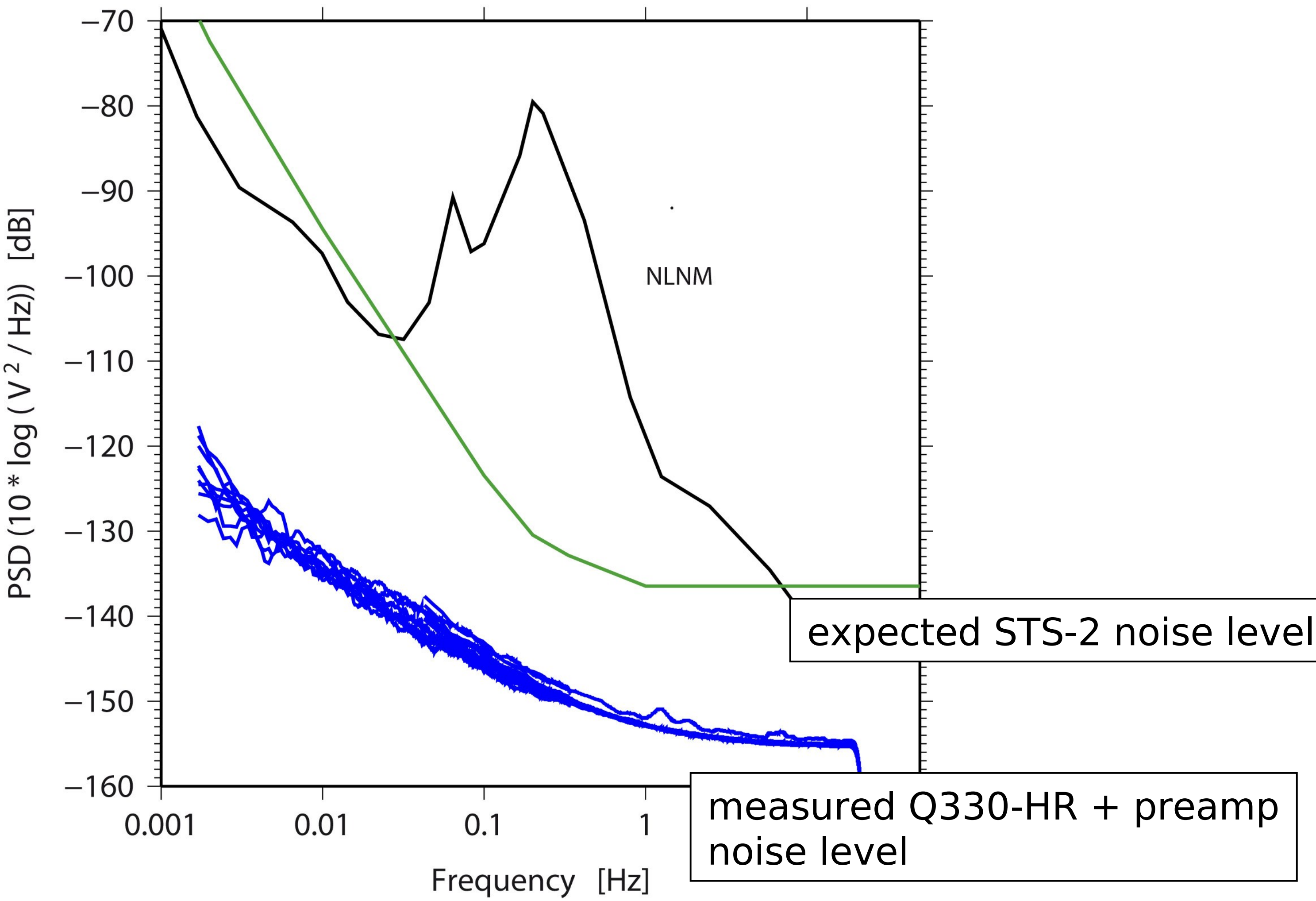


Conrad experiment

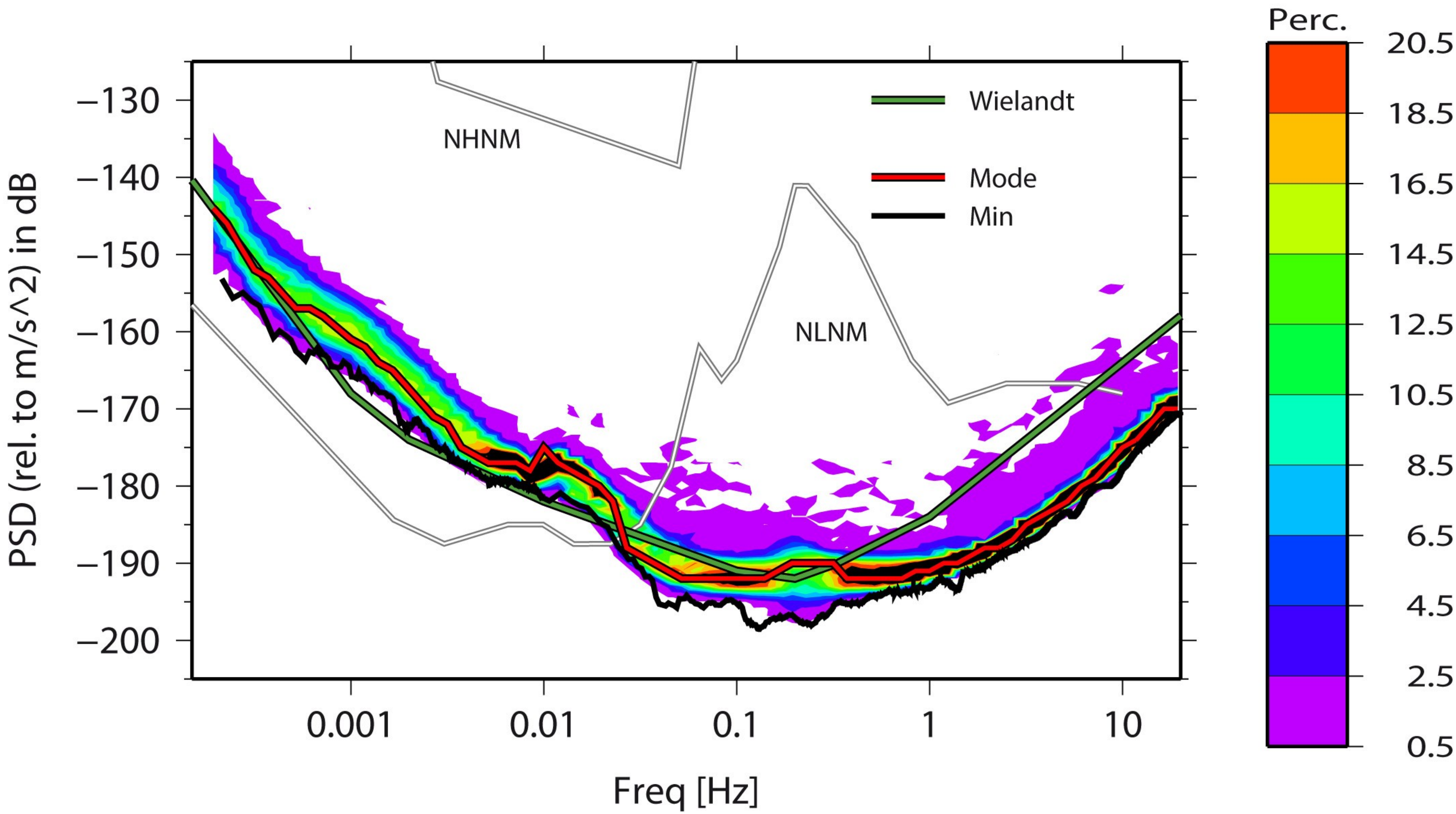


Results

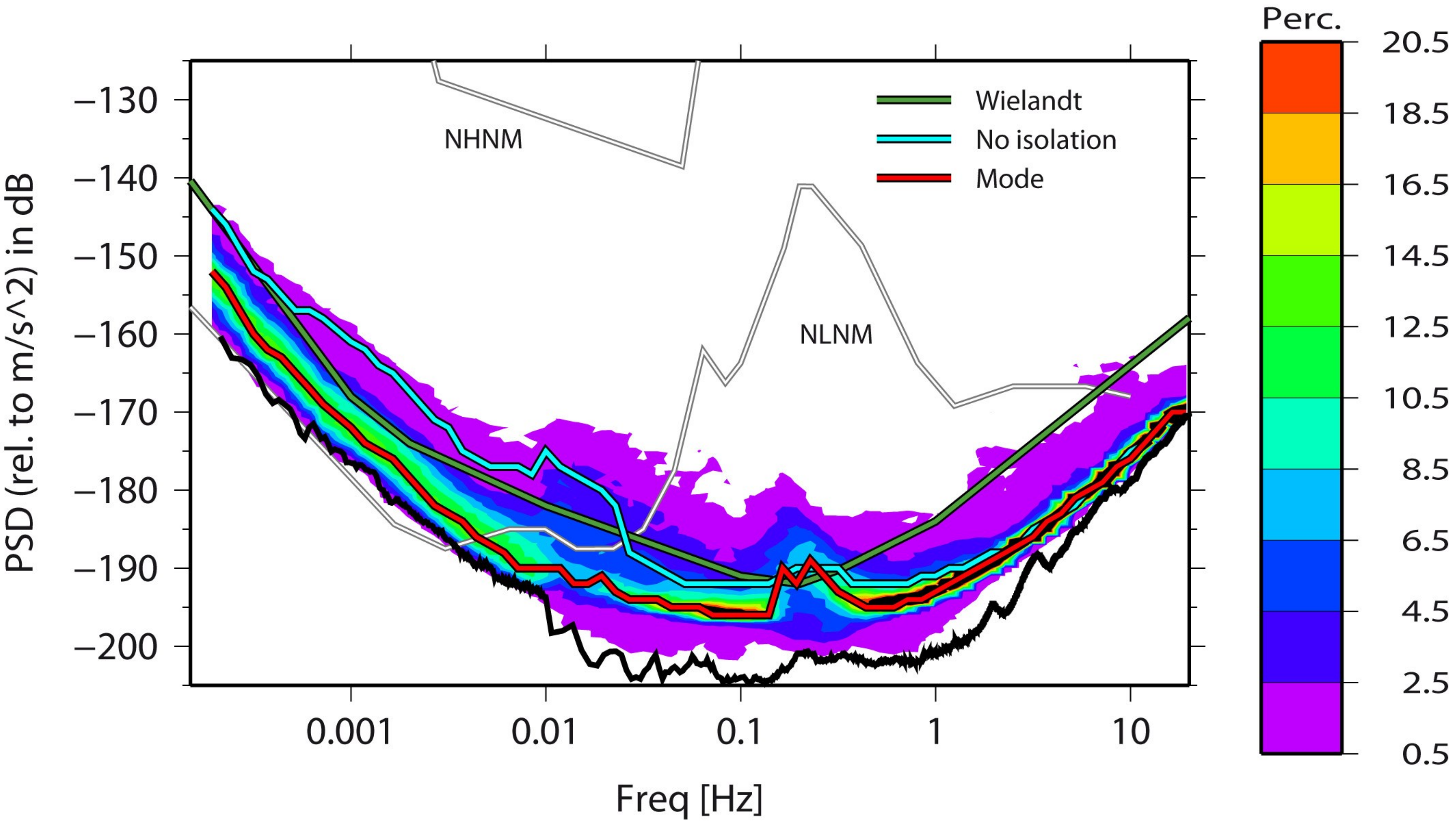


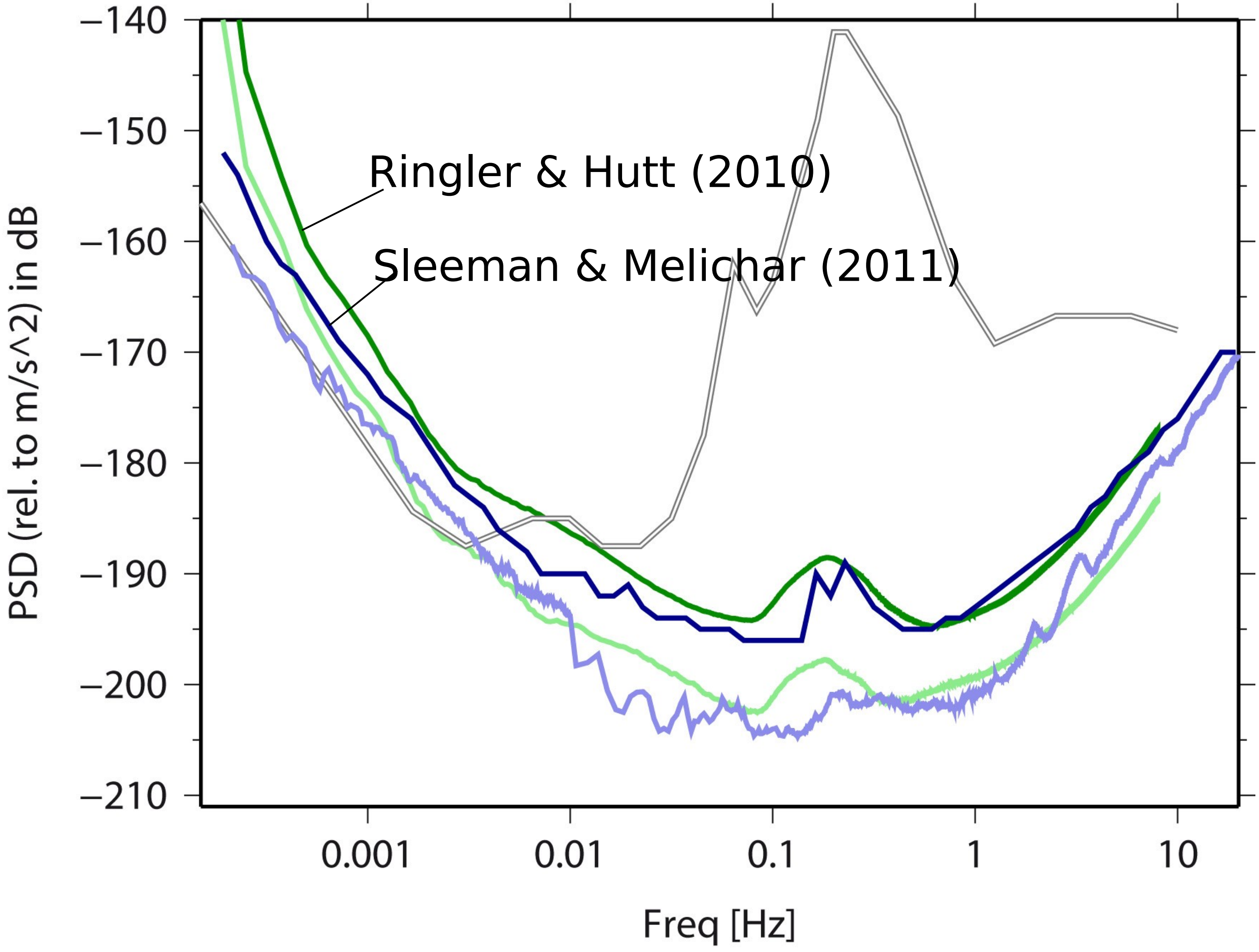
PSD (10 * log (V 2 / Hz)) [dB]
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
0.001
0.01
0.1
1
Frequency [Hz]
NLNM
expected STS-2 noise level
measured Q330-HR + preamp noise level

Collocated STS-2 sensors ***without*** thermal insulation

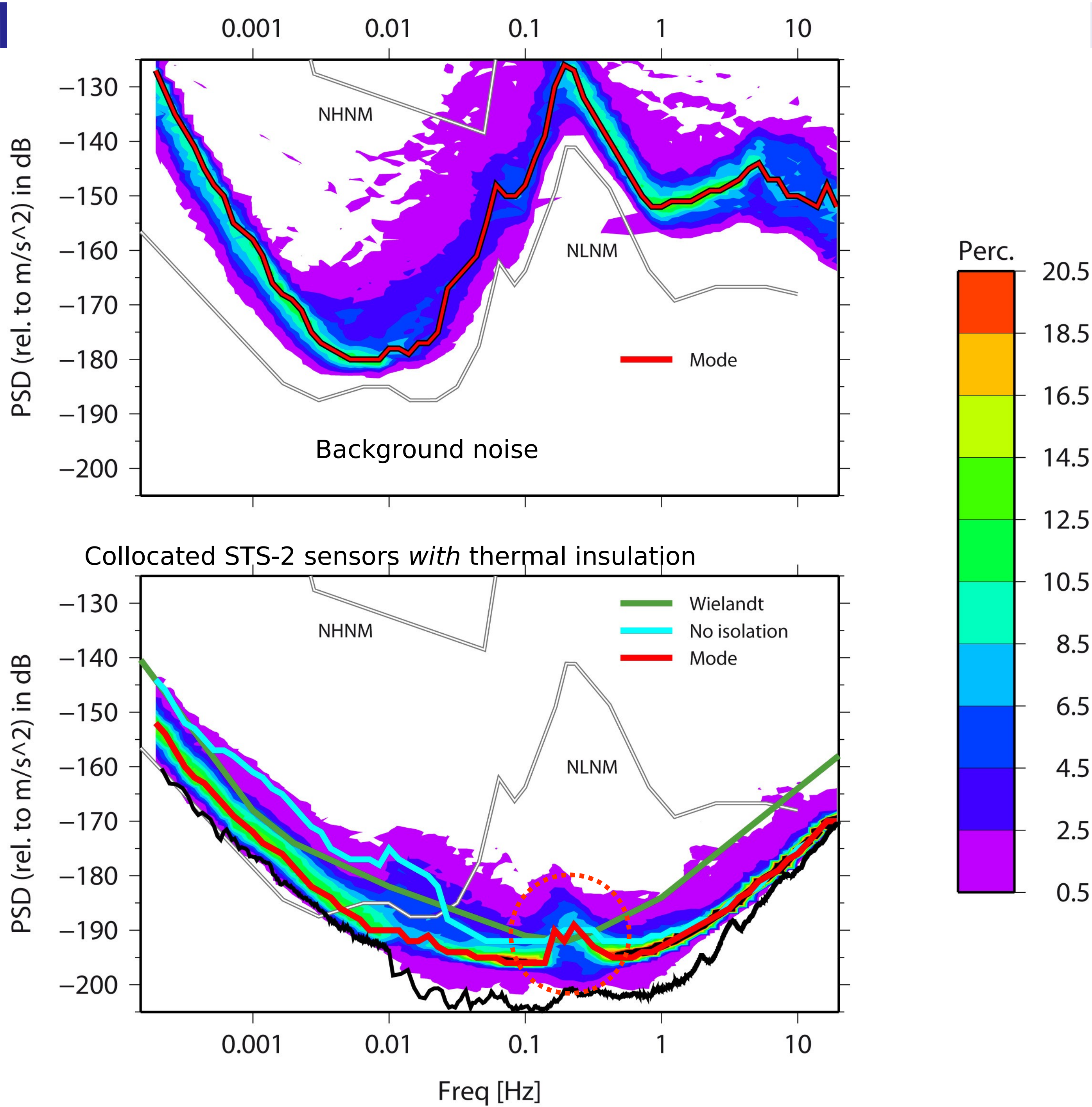


Collocated STS-2 sensors ***with*** thermal insulation



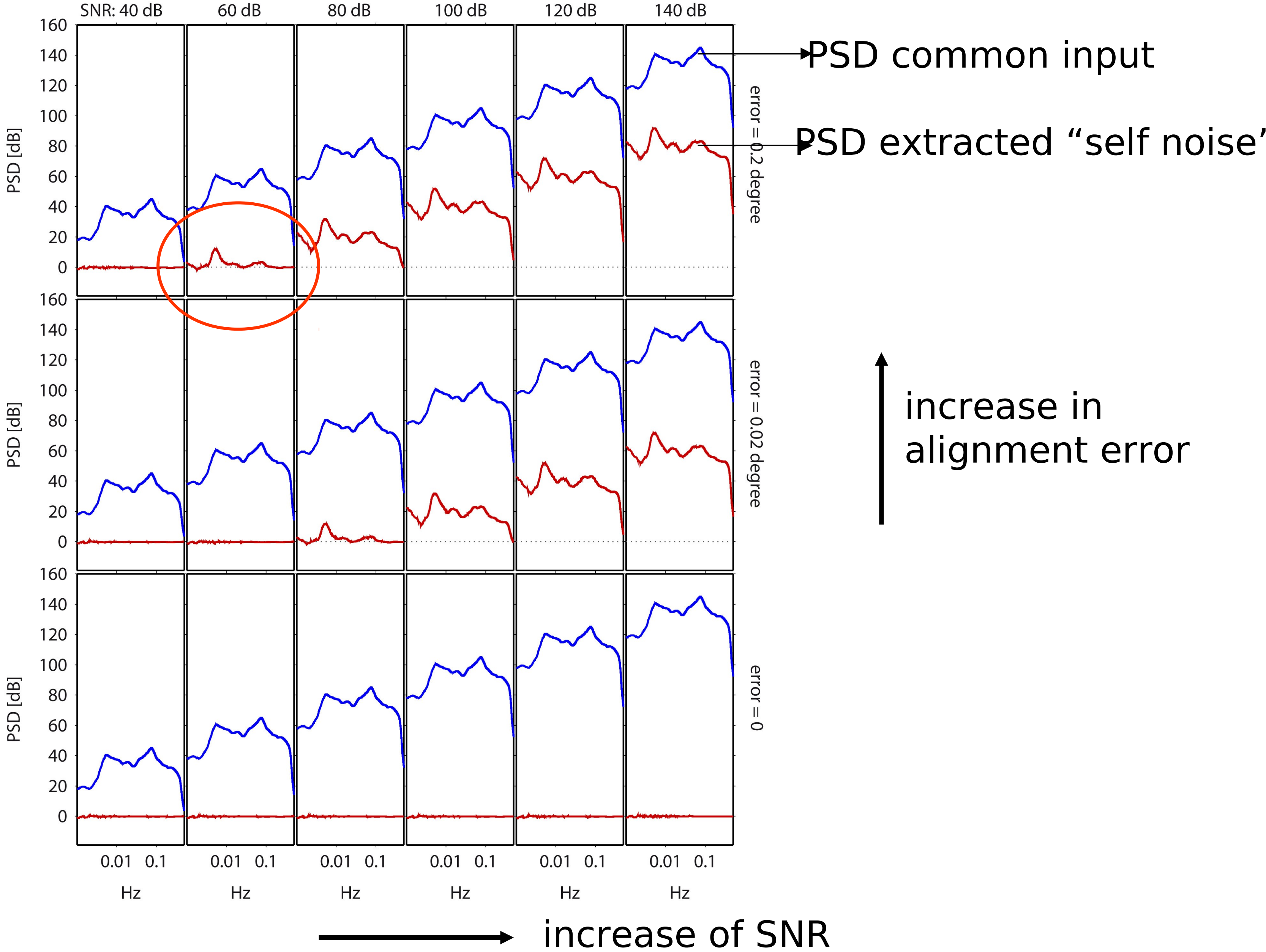

−140
−150
−160
−170
−180
−190
−200
−210
PSD (rel. to m/s^2) in dB
Ringler & Hutt (2010)
Sleeman & Melichar (2011)
0.001
0.01
0.1
1
10
Freq [Hz]

Results

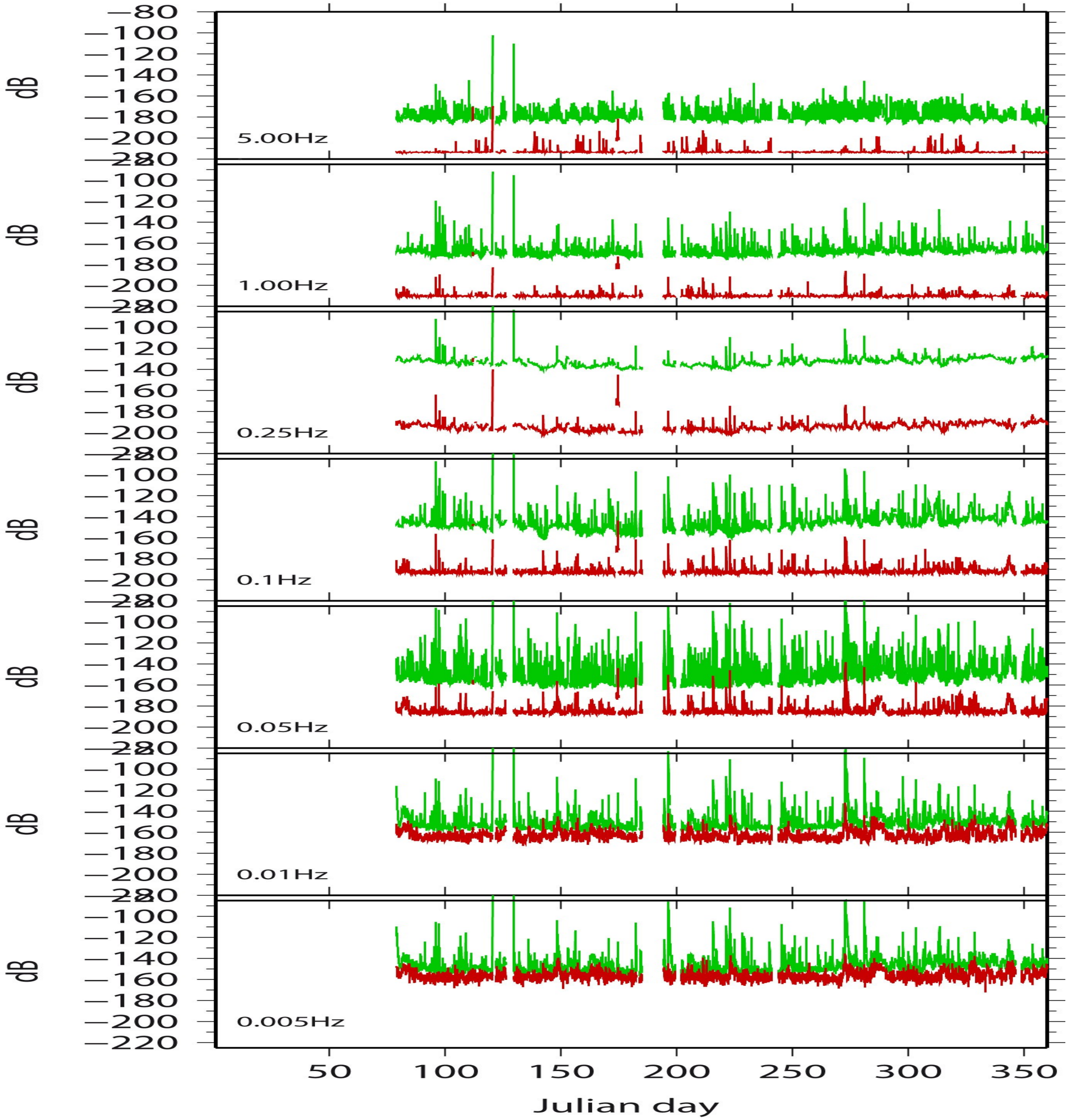


0.001
0.01
0.1
1
10
−130
−140
−150
−160
−170
−180
−190
−200
PSD (rel. to m/s^2) in dB
NHNM
NLNM
Mode
Background noise
Collocated STS-2 sensors *with* thermal insulation
Wielandt
No isolation
Mode
Freq [Hz]
Perc.
20.5
18.5
16.5
14.5
12.5
10.5
8.5
6.5
4.5
2.5
0.5

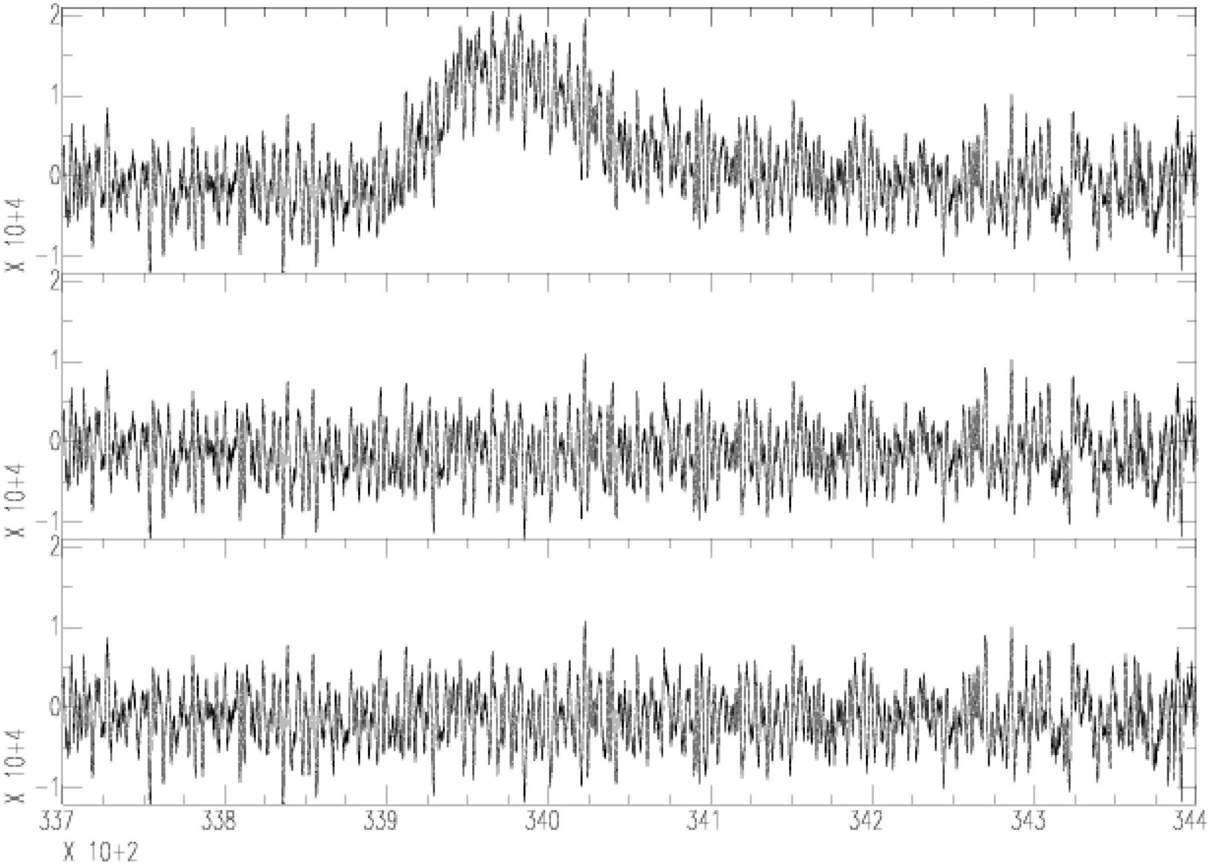
Synthetic experiment



Results


5.00Hz
1.00Hz
0.25Hz
0.1Hz
0.05Hz
0.01Hz
0.005Hz
dB
Julian day
50
100
150
200
250
300
350

Results



2
1
0
-1
X 10+4
2
1
0
-1
X 10+4
2
1
0
-1
X 10+4
337
338
339
340
341
342
343
344
X 10+2

Conclusions

- Q330-HR with enabled pre-amplifier required for estimating the self-noise of the STS-2.
- Quiet site required, only vertical components.
- STS-2 self-noise below NLNM above 4mHz and only 6 dB above the NLNM down to 0.2 mHz. In optimal conditions the self-noise even reaches the NLNM, down to 0.2 mHz.
- Long-term analysis required instead of window shopping.
- High and low frequency spurious signals.