High-resolution hybrid atomic quantum gravimeter with real-time vibration compensation

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EGU

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Context

Absolute Quantum Gravimeter

- discrete sensor: DC - 1 Hz
- Sensitivity of 750 nm/s^2 ↔ 1.1×10^6 (nm/s)^2 /Hz
- Drift-free: long-term stability below 10 nm/ s^2

https://www.ixblue.com/quantum-gravimeter/

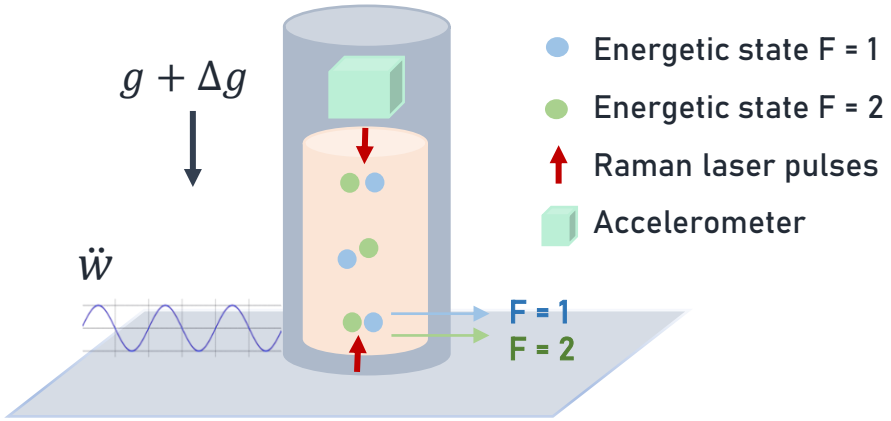
⚠ Limited by seismic vibration

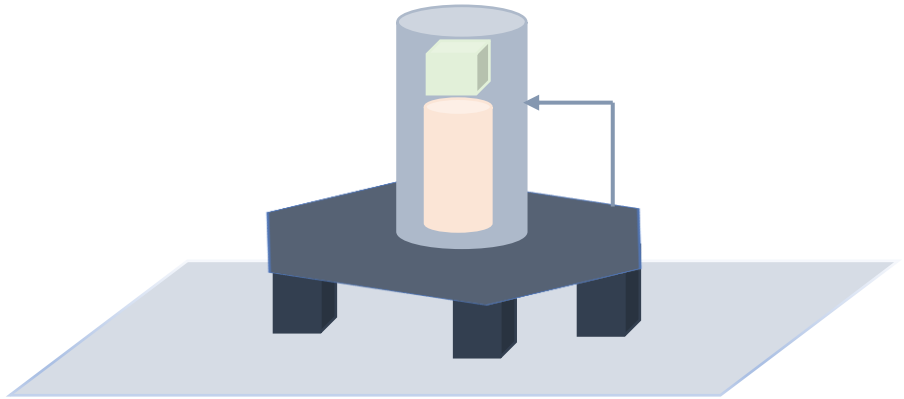
① Vibration compensation with an auxiliary sensor

Performances of AQG with Titan from Nanometrics

Ground compensation with home made sensor

② Active isolation vibration platform





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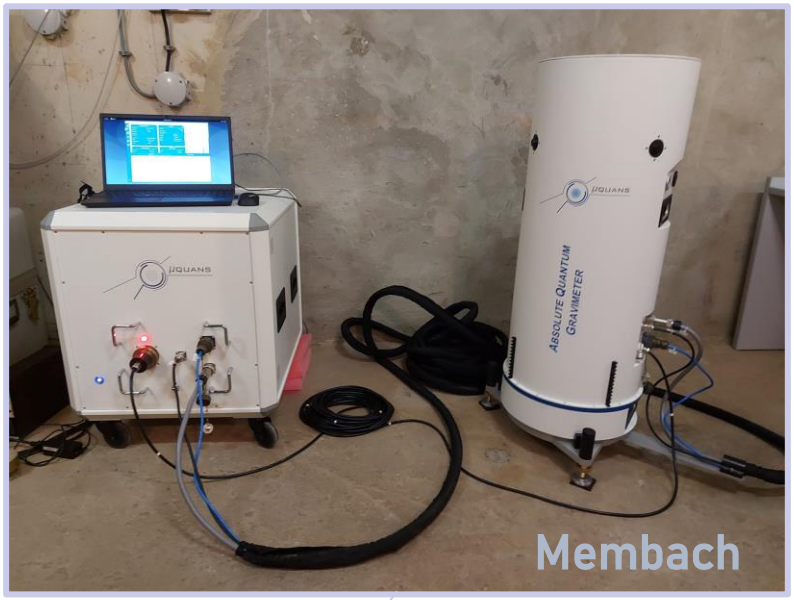
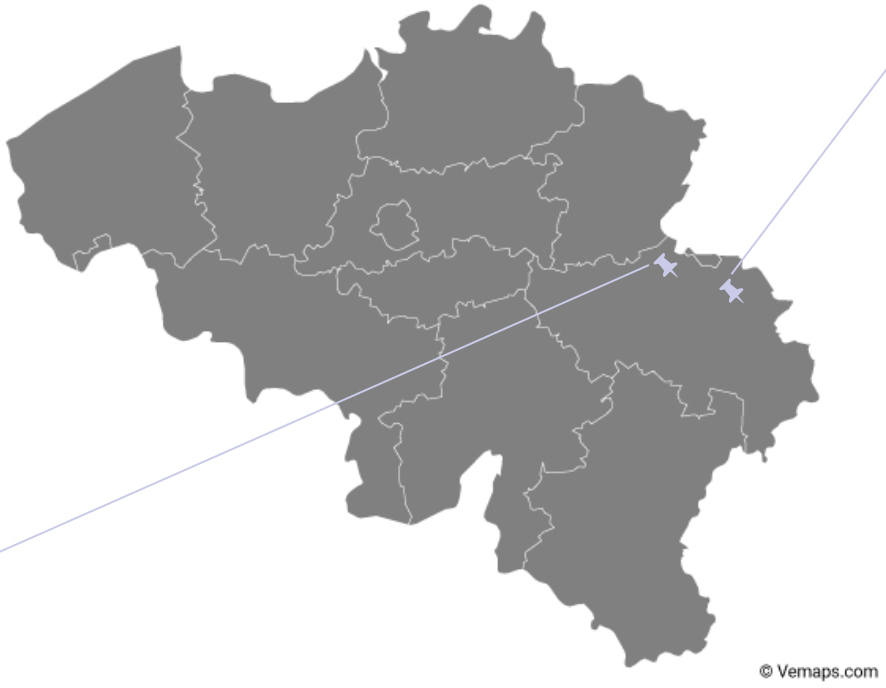
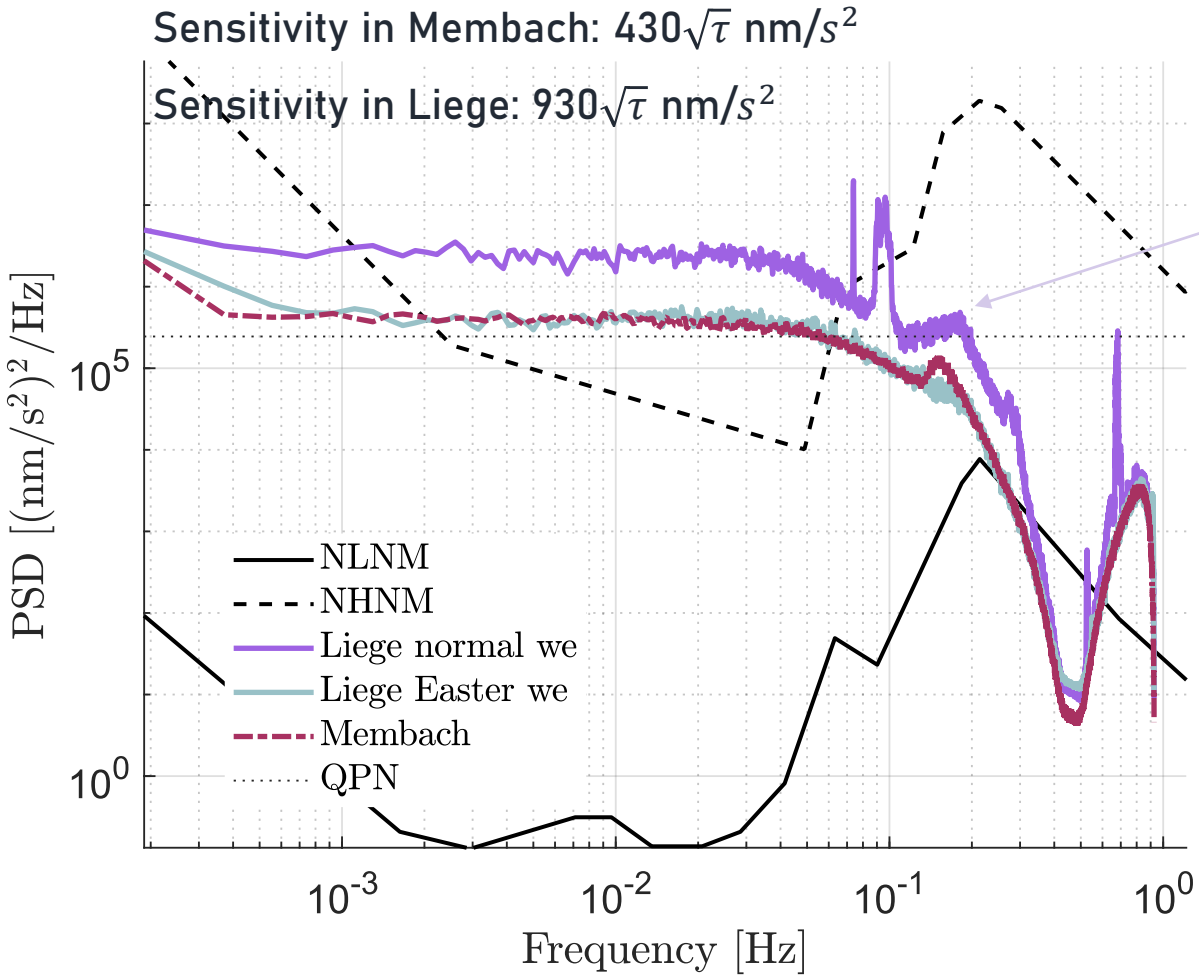
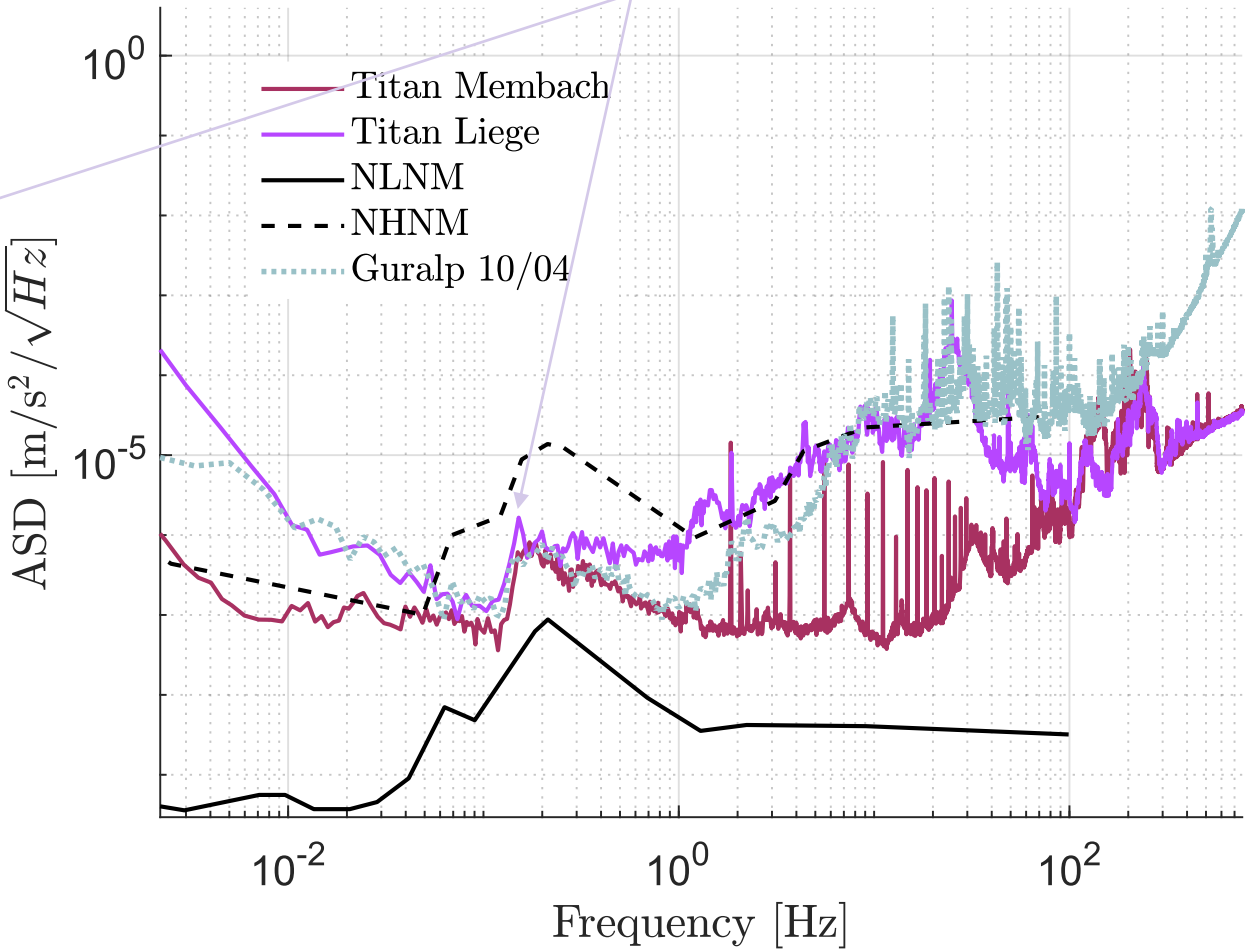




1. Real time ground compensation with Titan

Slight increase in the ASD of the gravity residuals due to the microseismic peak ? At 0,15 Hz





Lower the seismic motion, lower is the gravity signal

→ Which part of ground motion is impacting gravity ?
→ Which part of ground motion is not well subtracted ?

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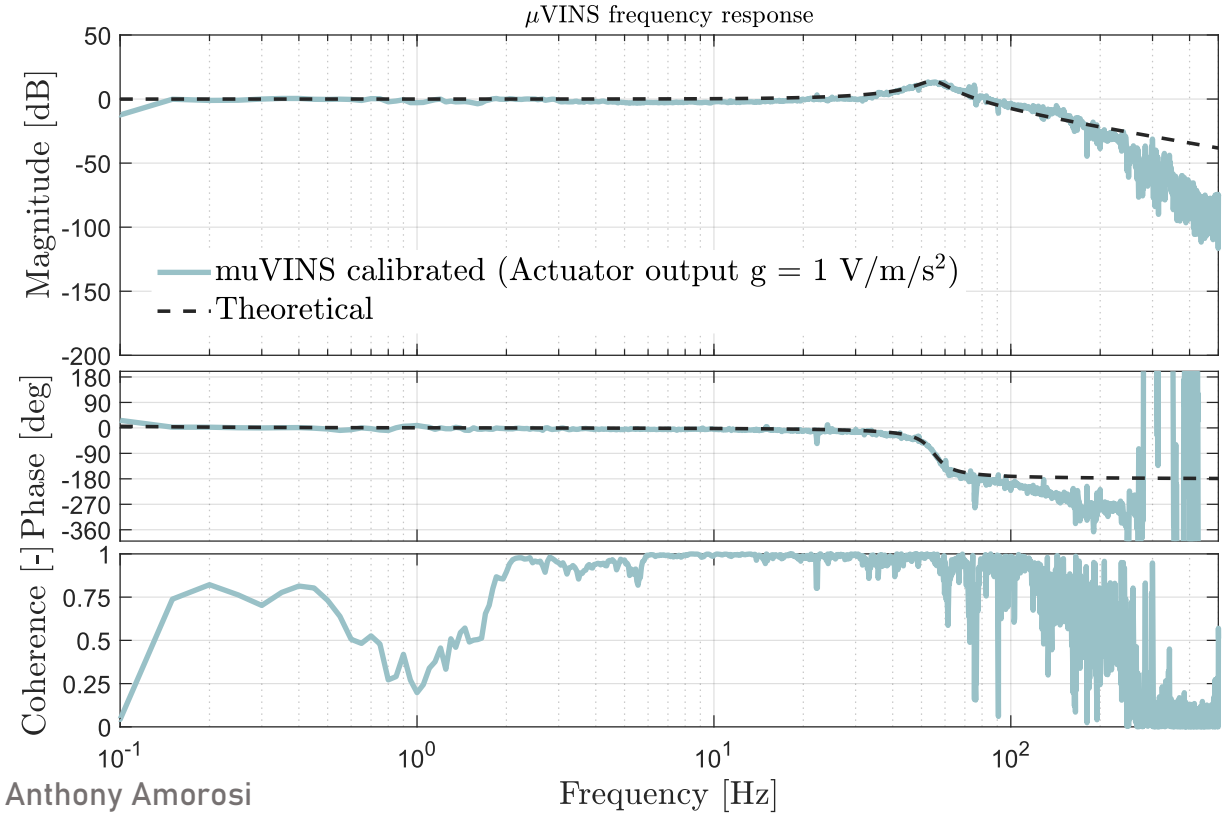
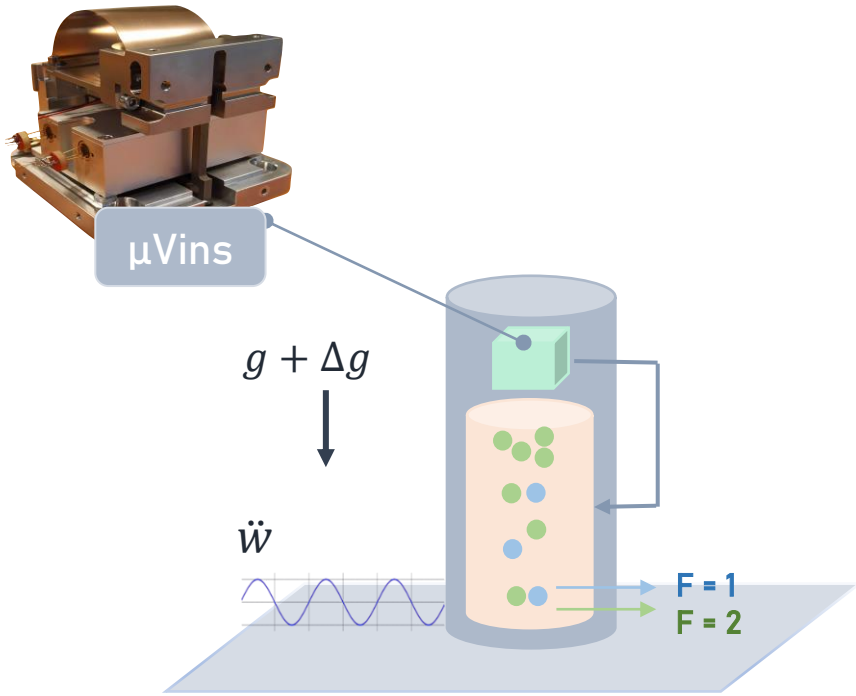
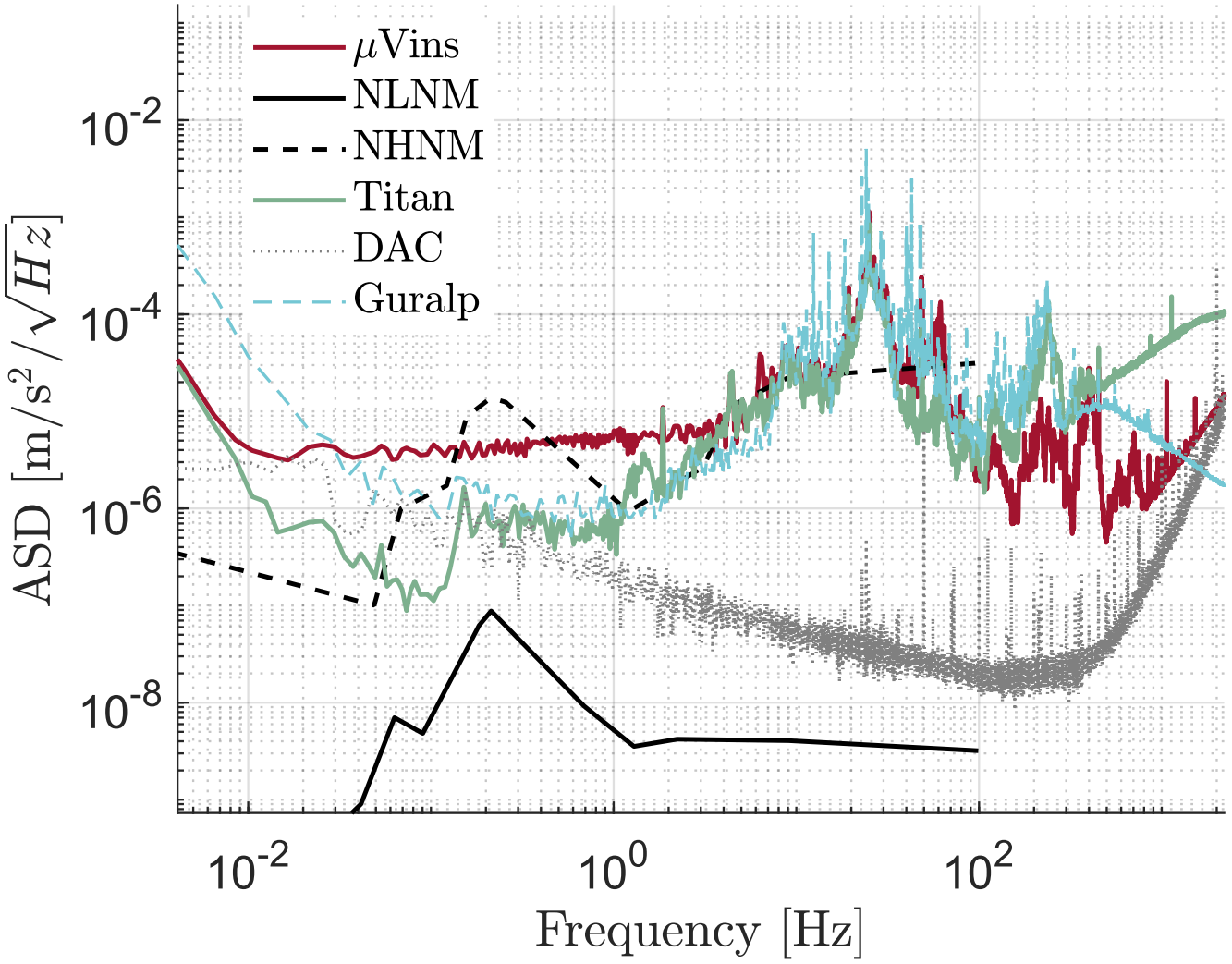


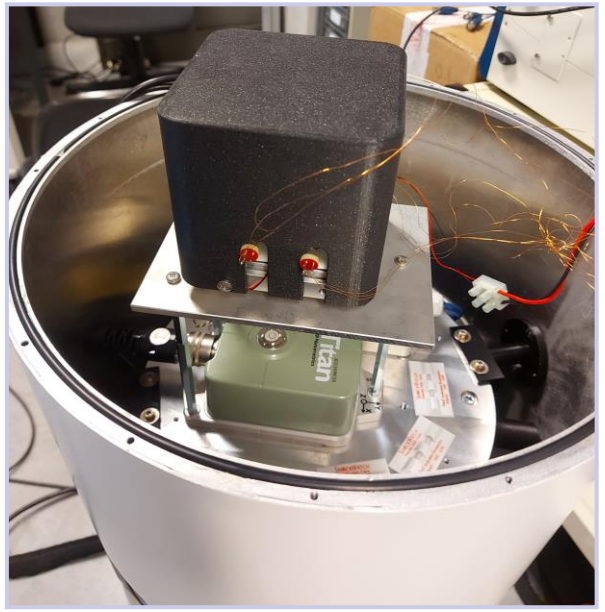


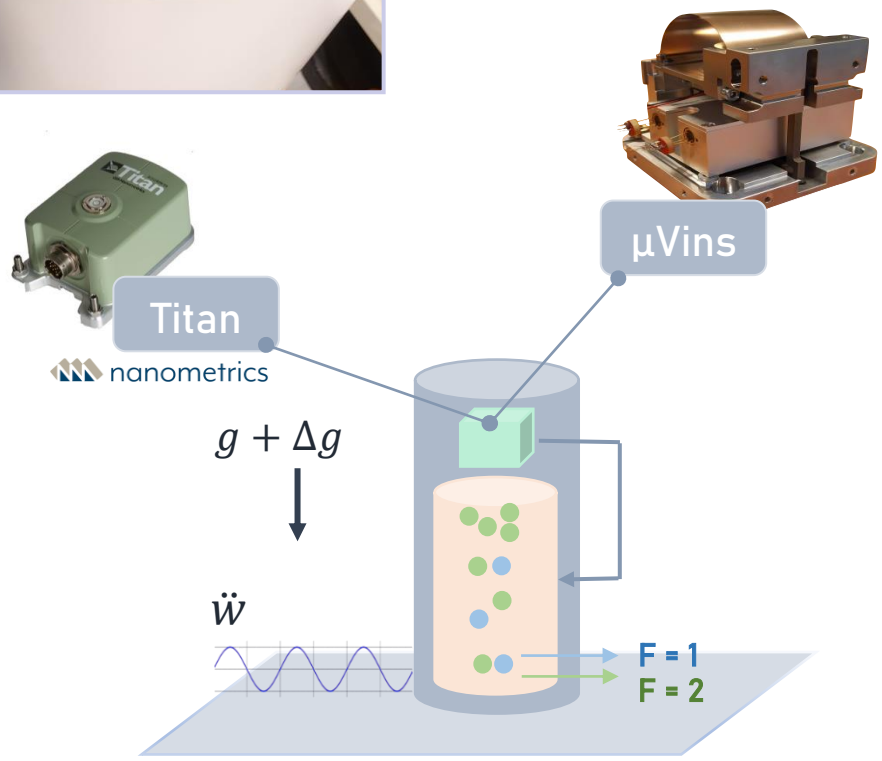
1. Real time ground compensation with µVins

Preliminary result



Saturated from 4 Hz ? Work in progress





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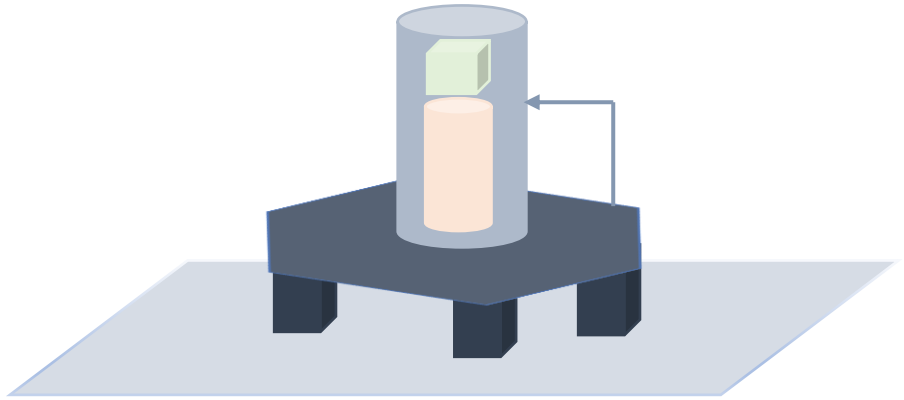
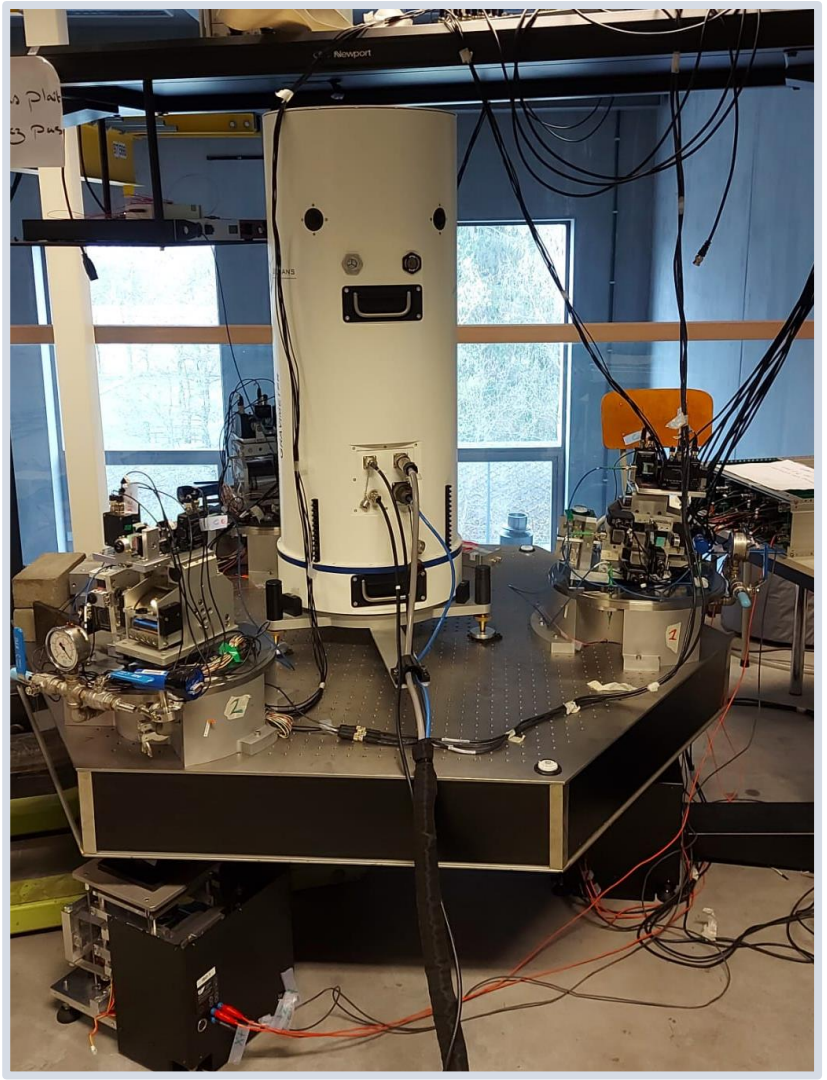
② **Active isolation vibration platform**





2. Active Isolation

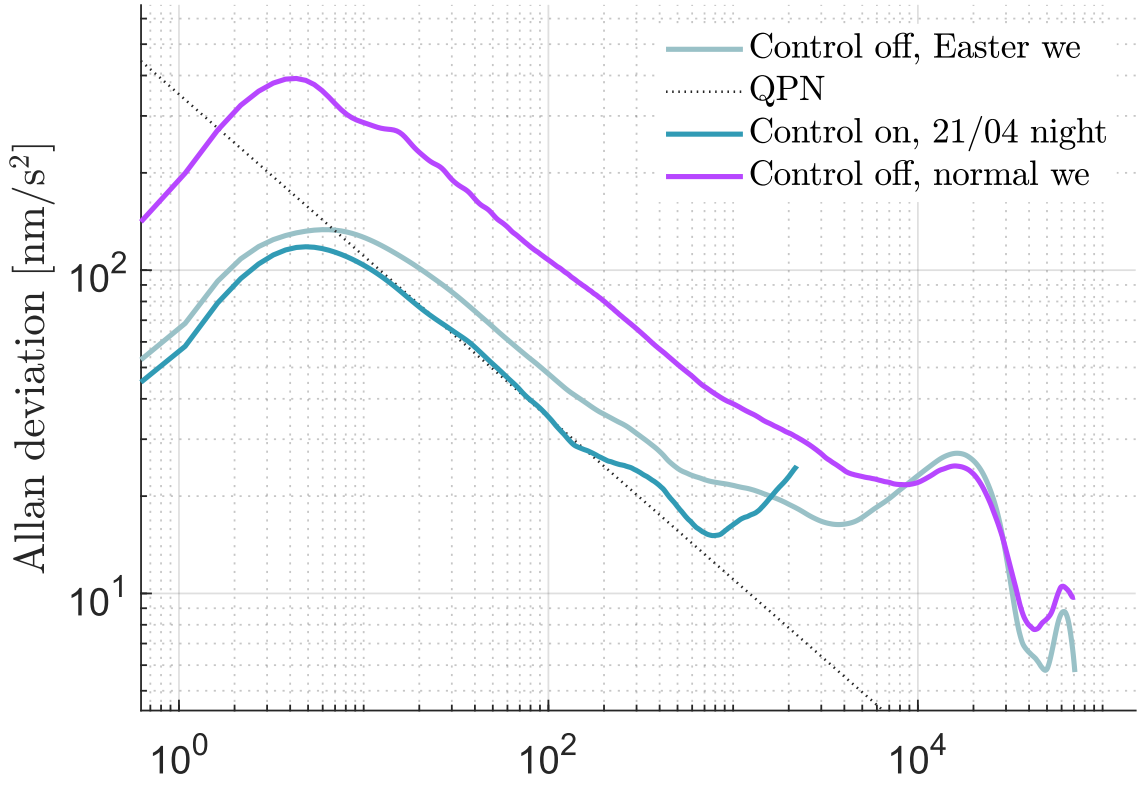
Preliminary result

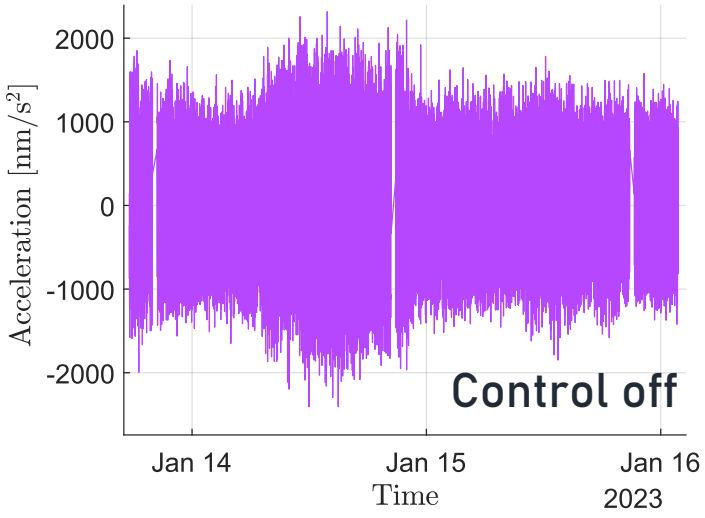
Lower the seismic motion, lower is the gravity signal

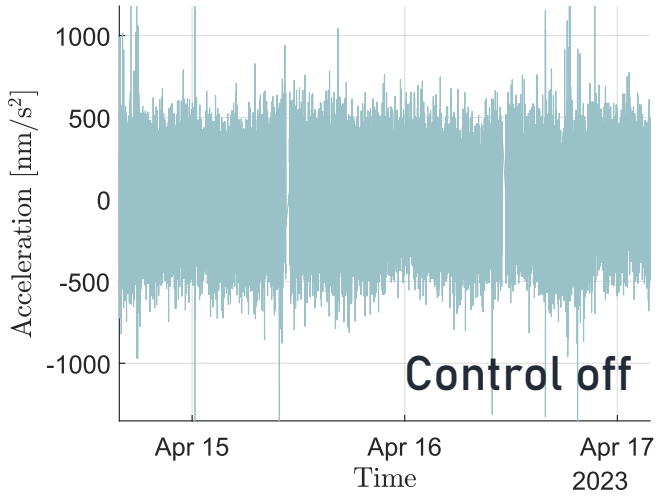
→ Reaching the intrinsic noise of the gravimeter with active control:
Quantum Projection Noise at $350\sqrt{\tau}$ nm/s^2

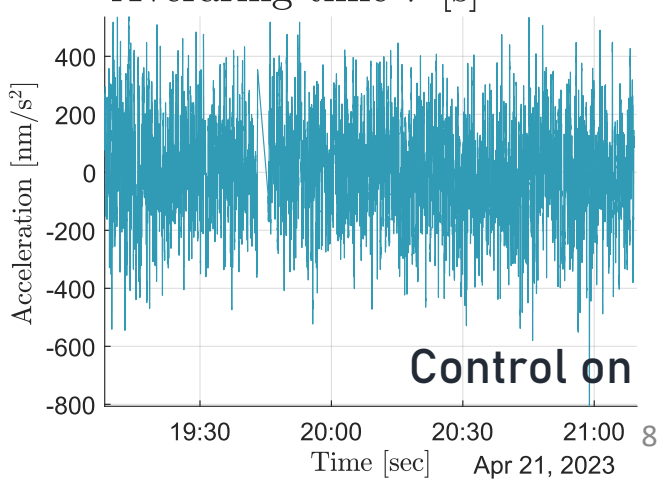
→ Titan noise, Acquisition noise are not limiting the AQG

→ Ground compensation strategy is not fully subtracting ground signal





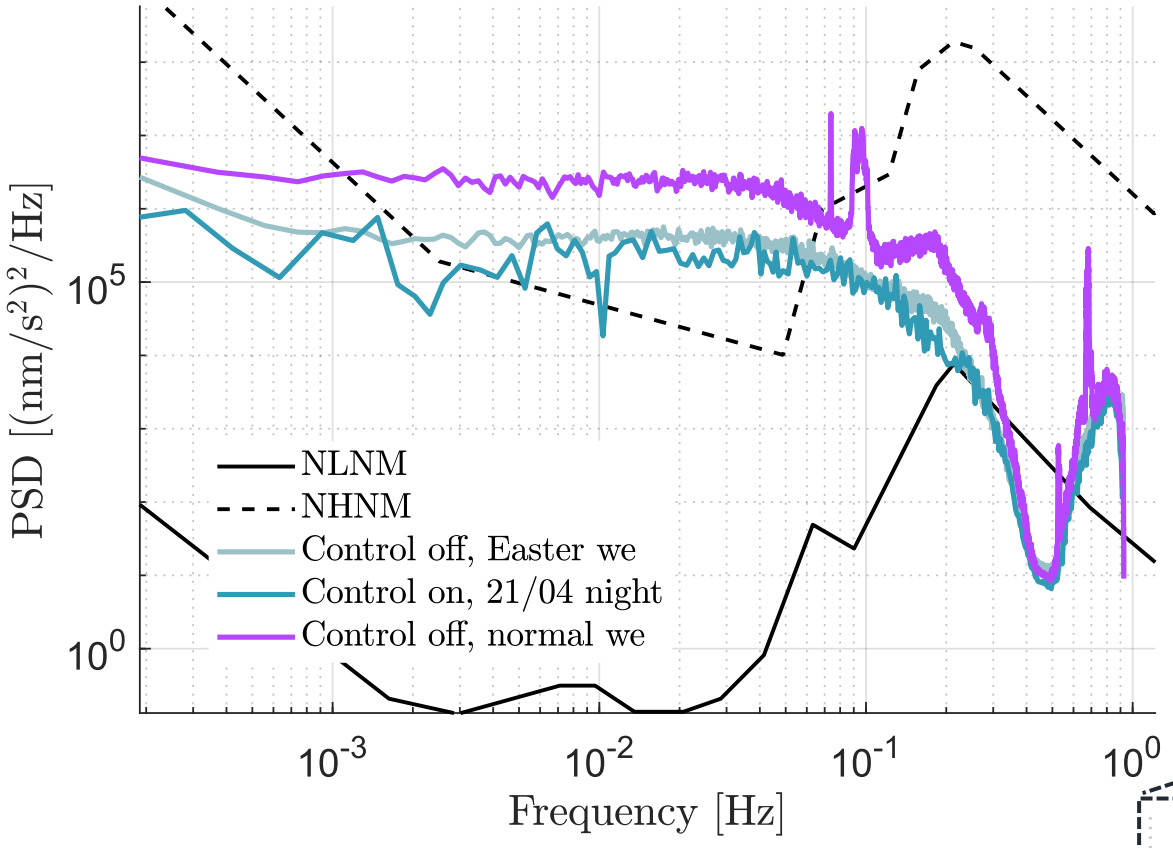


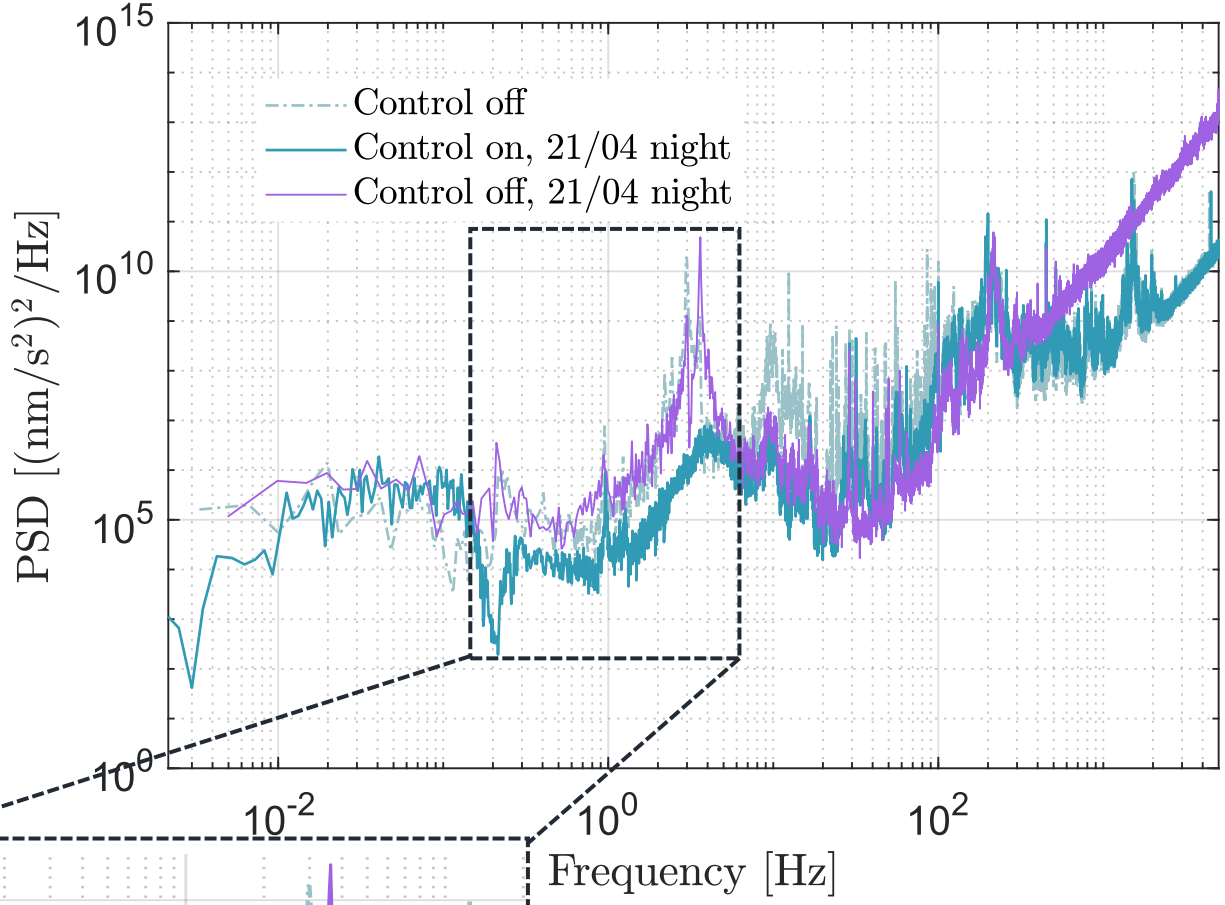


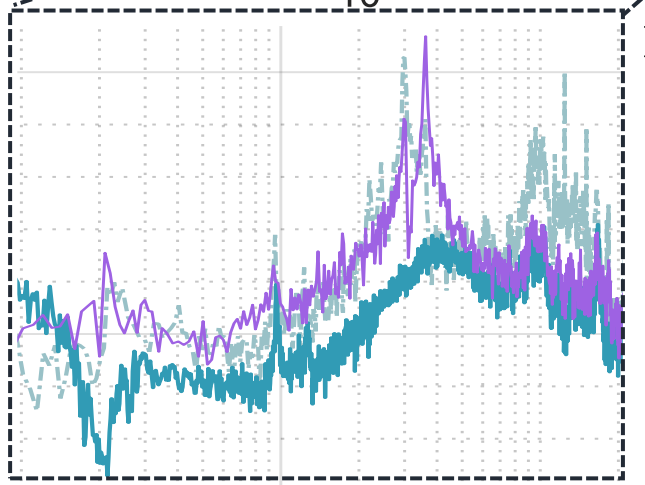
2. Active Isolation

Preliminary result

Mouhamad Haidar Lakkis



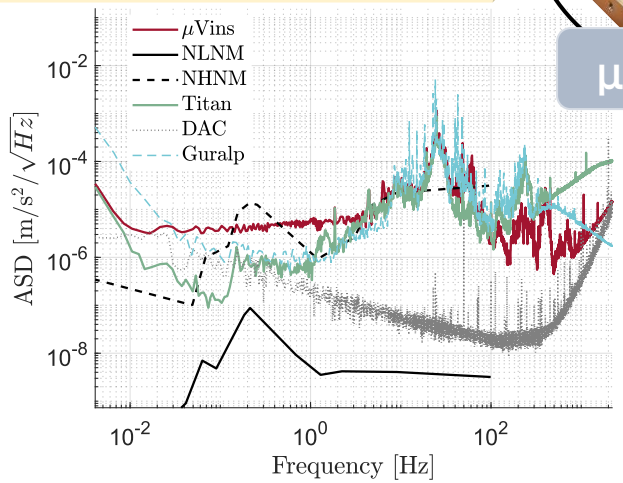


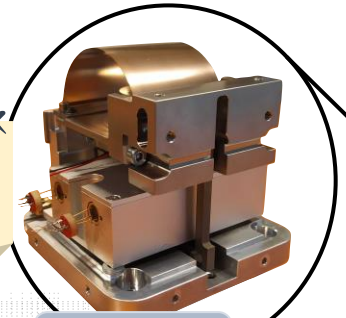


Active isolation in 0.1 – 10 Hz frequency range

Summary

Limiting noise below 4 Hz
To be investigated

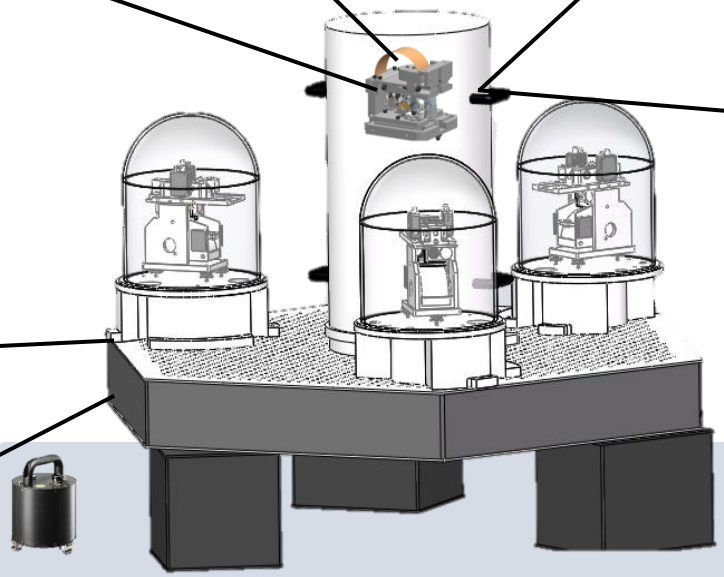




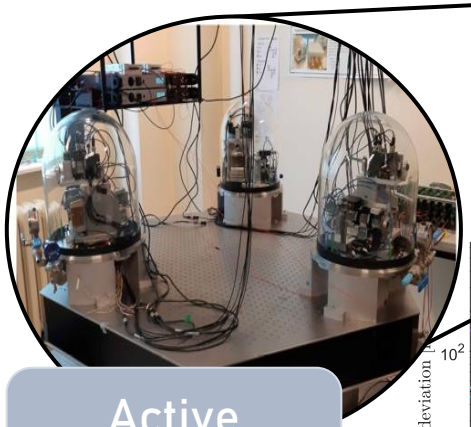
μVins

Hybrid sensor: AQG + classical accelerometer

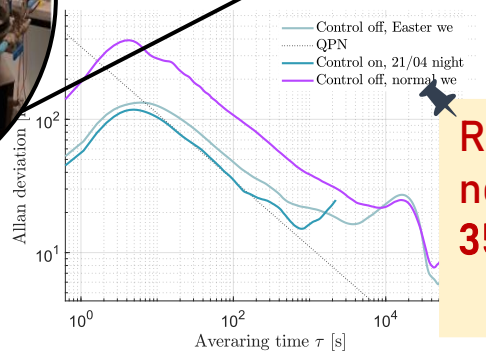
Atomic Quantum Gravimeter



Performance limited by ground compensation strategy: ground poorly subtracted in noisy environment



Active platform



Reaching the intrinsic noise of the AQG!
$350\sqrt{\tau}$ nm/s²

Thank you for the attention

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Additional slides

Mayana Teloi: mayane.teloi@ulb.be

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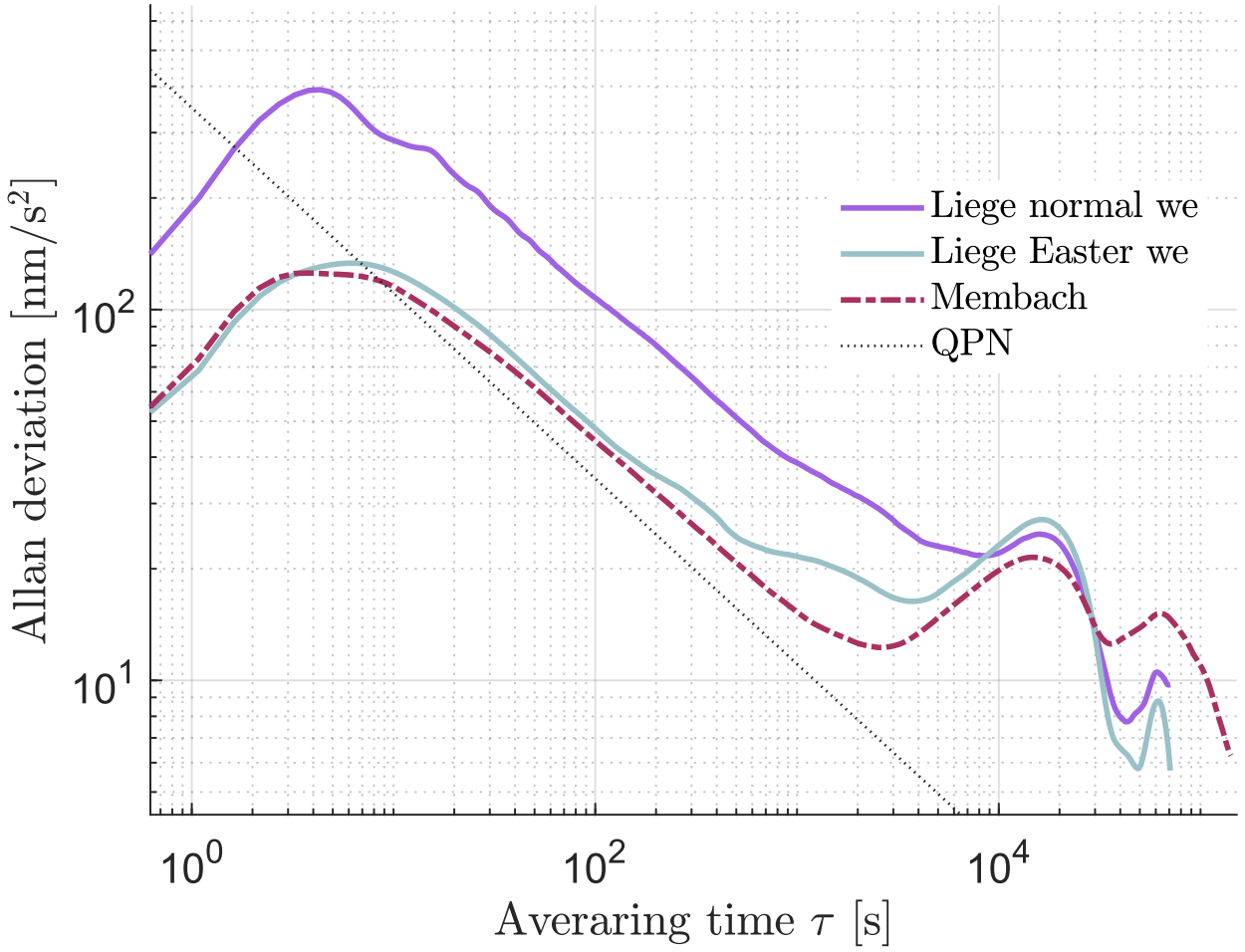
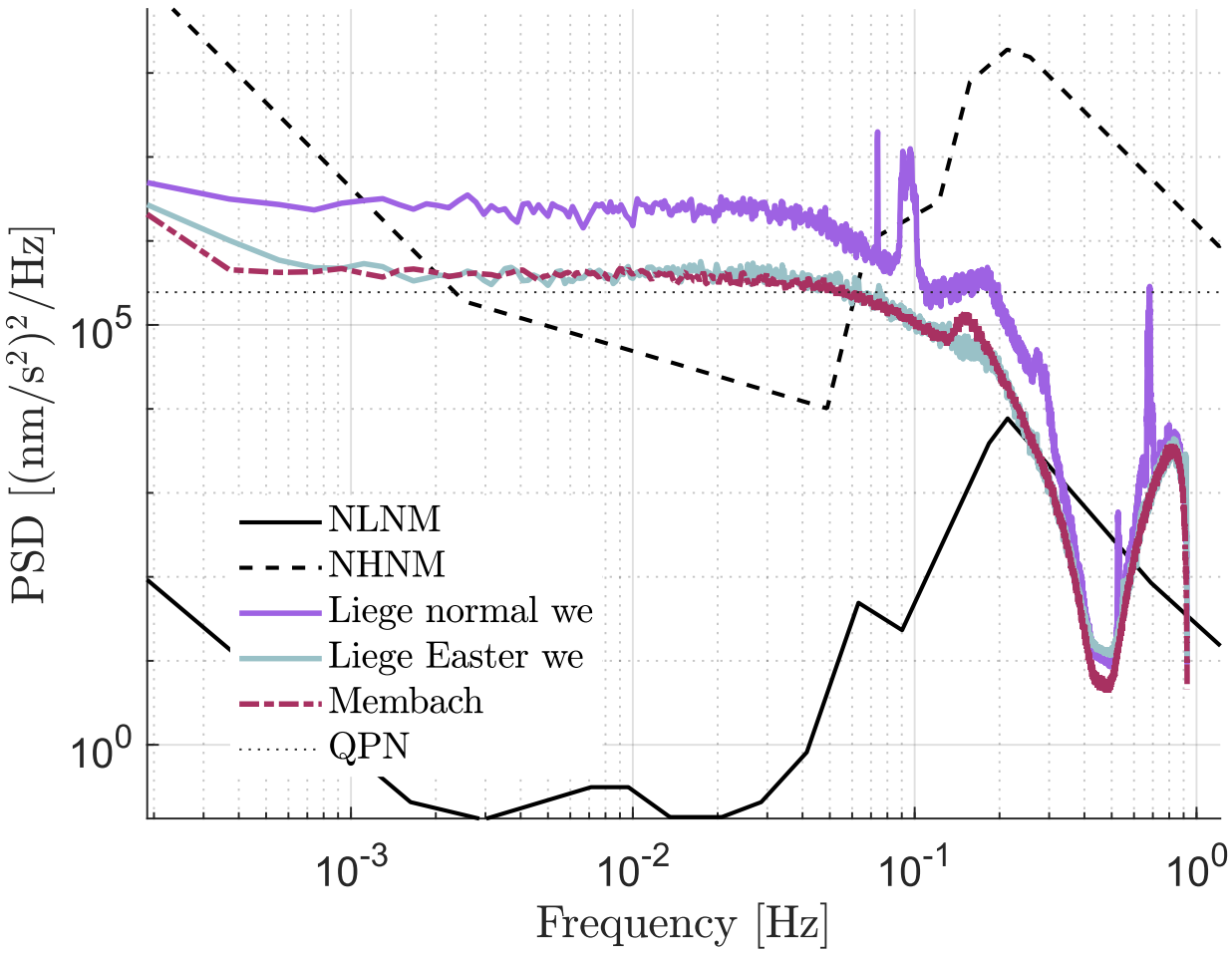




Mean AQG: 9810467017.68093 +/- 190 µGal

Mean FG5: 9810467725.6 +/- 0.8 µGal

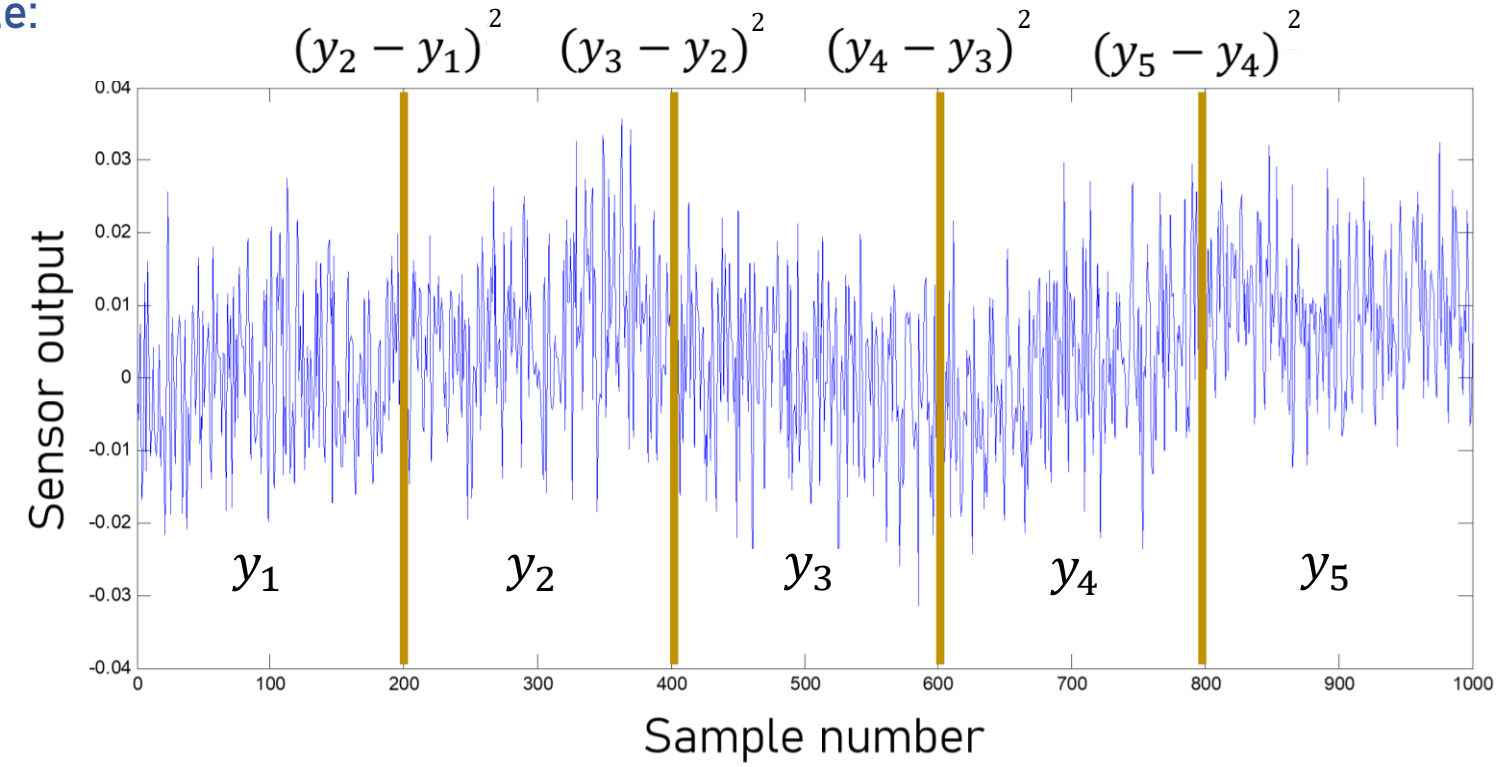
Allan Deviation

What is it ?

Allan Variance: $\sigma_y^2(\tau) = \frac{1}{2}\langle (y_{n+1} - y_n)^2 \rangle$

Allan Deviation: $\sigma_y(\tau) = \sqrt{\sigma_y^2(\tau)}$

Example:



1. Partition the data
2. Compute the mean in each partition
3. Evaluate the difference of the means of adjacent sections
4. Square each differences
5. Compute the average

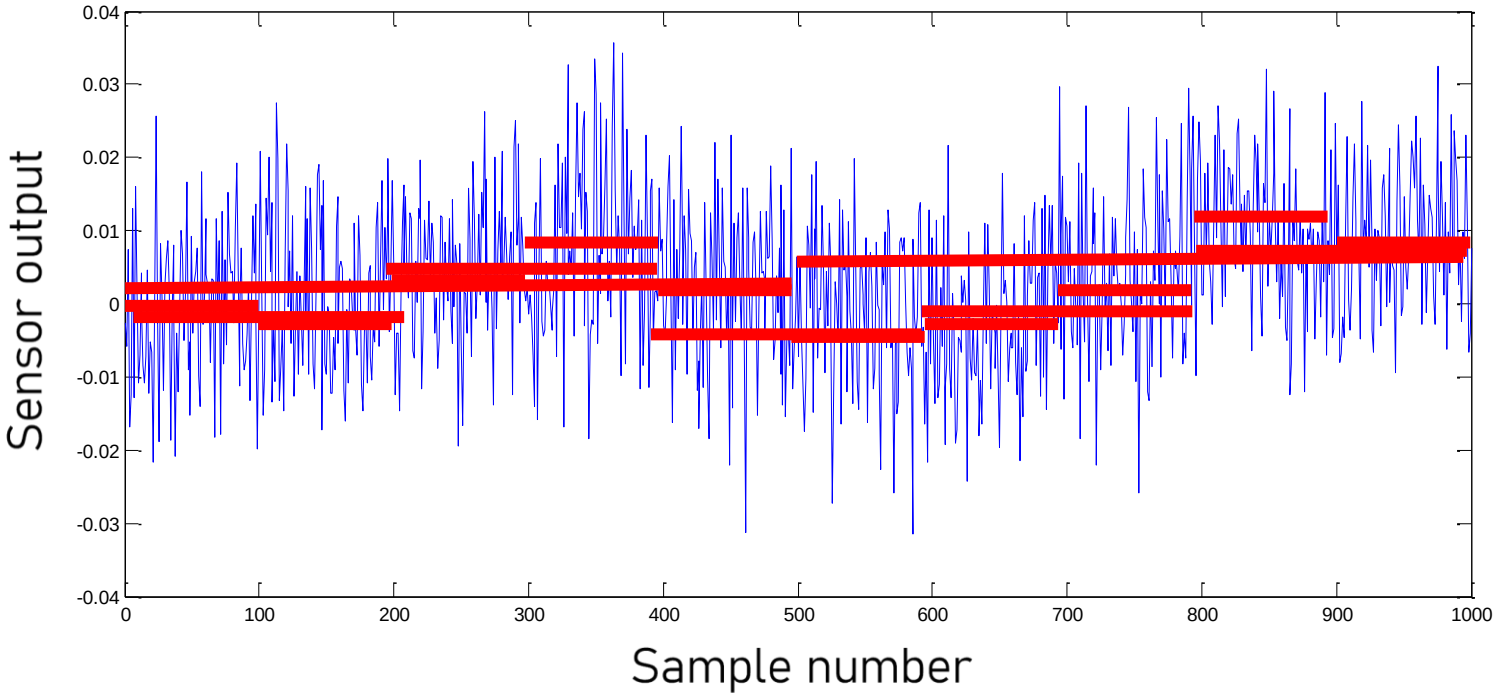
$$\rightarrow \sigma_y^2(\tau) = \frac{1}{2}\frac{\{(y_2 - y_1)^2 + (y_3 - y_2)^2 + (y_4 - y_3)^2 + (y_5 - y_4)^2\}}{4}$$

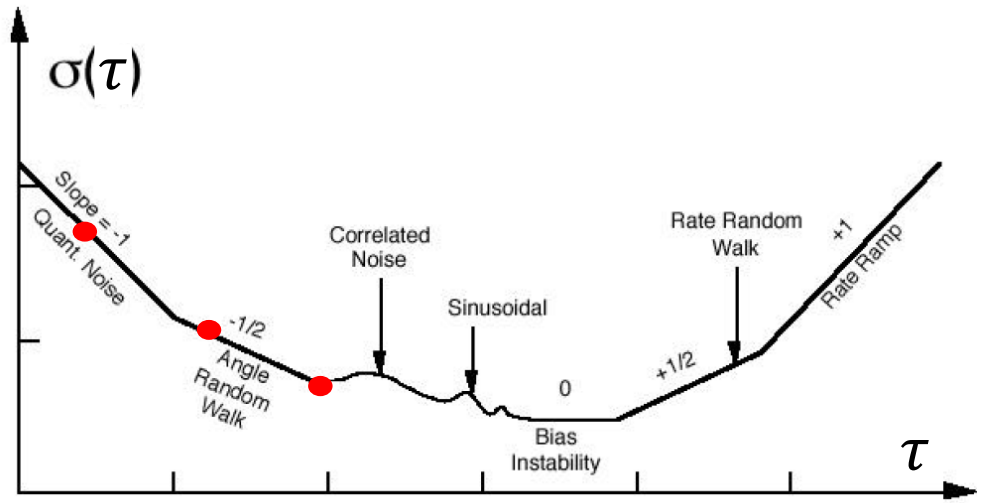
Allan Deviation

How to compute it?

$\sigma - \tau$

Example:





$$\rightarrow \sigma_y^2(\tau) = \frac{1}{2}\frac{\{(y_2 - y_1)^2 + (y_3 - y_2)^2 + (y_4 - y_3)^2 + (y_5 - y_4)^2\}}{4}$$

→ Analysis of the frequency stability of the signal in the time domain ↔ PSD in the frequency domain

→ Highlights noise originated from random process: *bias drift*, *quantization noise*, …

→ Sensitivity of the AQG at short-term and stability at long-term