# Hybridization of atomic and electrostatic accelerometers for satellite control and gravity field recovery

A. Knabe[1], H. Wu[1], M. Schilling[2,1], J. Müller[1,2]

[1]Institute of Geodesy, Leibniz University Hannover, Germany
[2]DLR-Institute for Satellite Geodesy and Inertial Sensing, c/o Leibniz University Hannover, Germany

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# Motivation

GRACE → GRACE-FO

- Addition of laser ranging interferometer (LRI)
- Accelerometer: no improvement

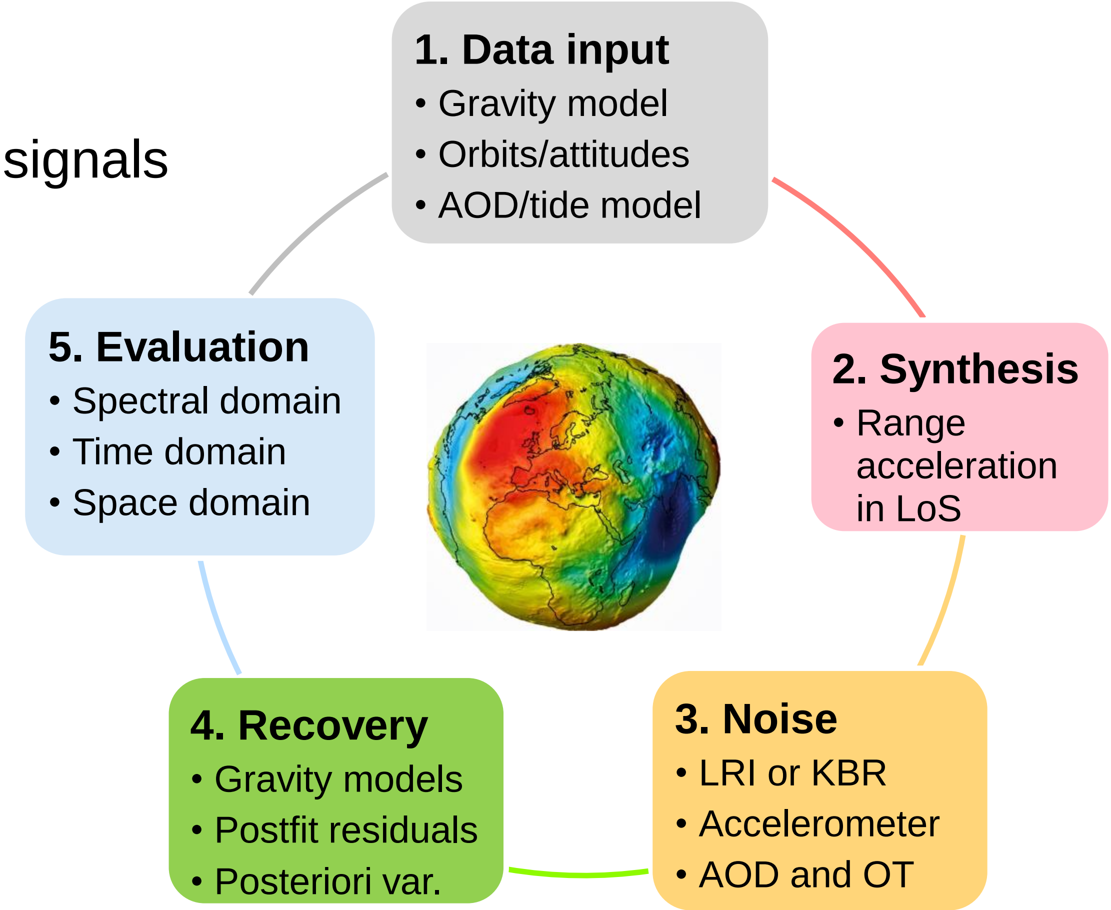
- Concept of our simulation study: combination of
  cold atom interferometry (CAI) & electrostatic accelerometer (EA)

| CAI | EA |
|---|---|
| + long-term stability | + high short-term stability |
| | − drift in low frequencies |
| | − calibration needed |

# Scheme of the simulation

The closed-loop simulation includes five modules:

1. Data input
2. Synthesis of noise-free signals
3. Different kinds of noise
4. Gravity field recovery
5. Model evaluation

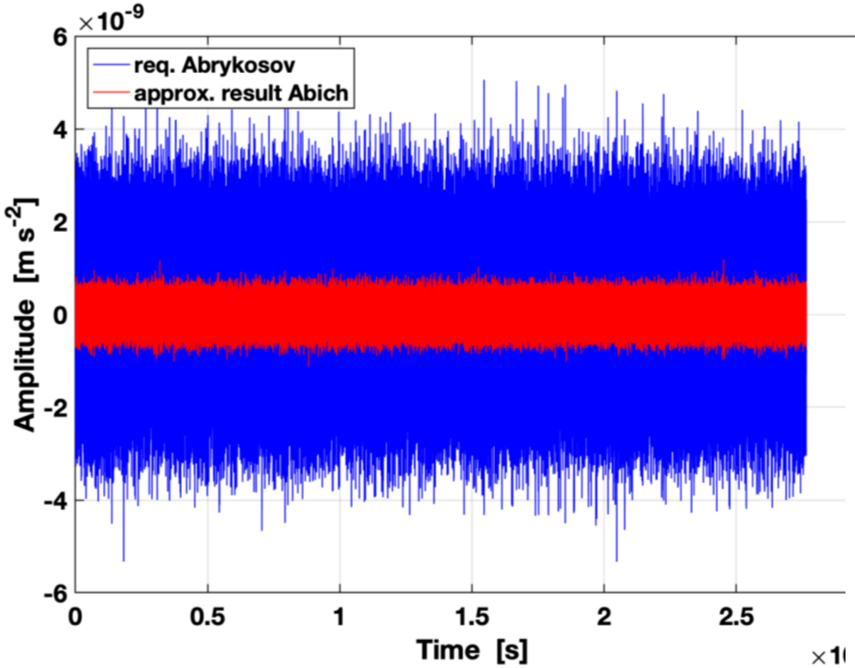


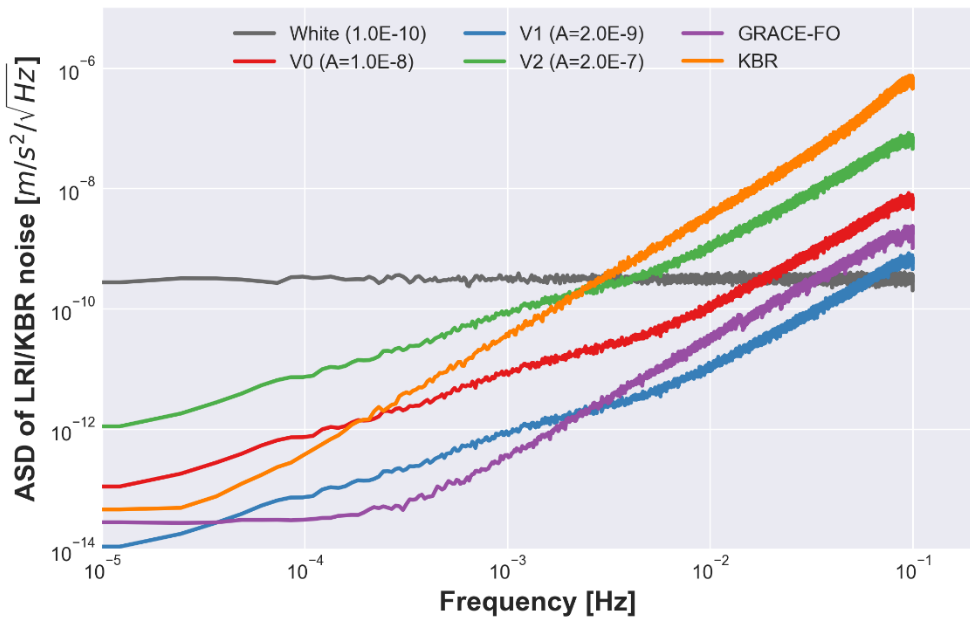
# LRI/KBR noise

Noise of LRI ranging acceleration (Abrykosov et al., 2019):

$$ASD_{LRI} = A \cdot (2\pi f)^2 \cdot \sqrt{\left(\frac{10^{-2}}{f}\right)^2 + 1} \ \ \mathrm{m}/\sqrt{\mathrm{Hz}}$$

**V0**: $A = 1.0 \times 10^{-8}$
**V1**: $A = 2.0 \times 10^{-9}$
**V2**: $A = 2.0 \times 10^{-7}$



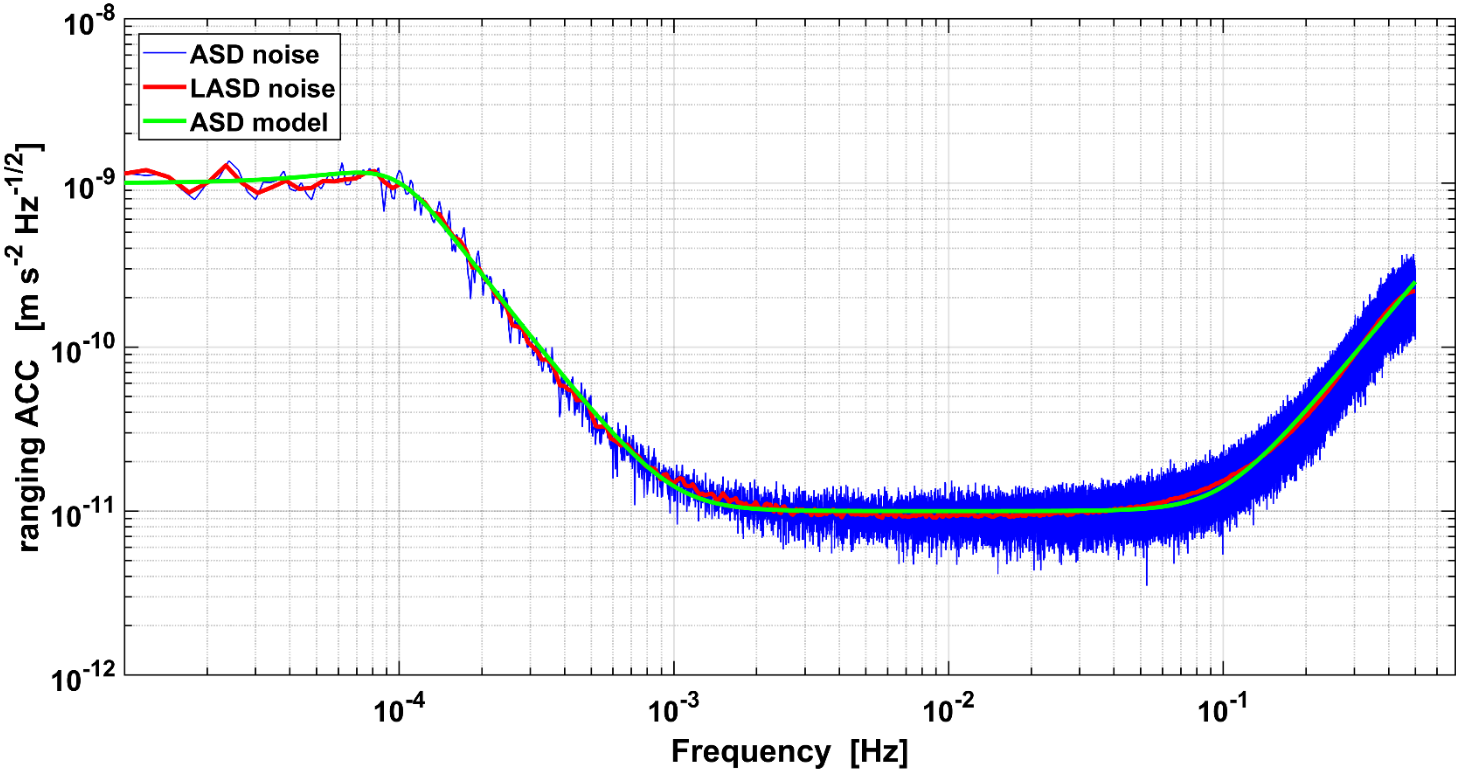




Approximation to (Abich et al., 2019): $ASD_{LRI} = 2 \times 10^{-9} \cdot f^{-0.003} \cdot \left(\frac{3\times10^{-7}}{f}\right)^3 \ \mathrm{m}/\sqrt{\mathrm{Hz}}$

# Hybrid accelerometer noise

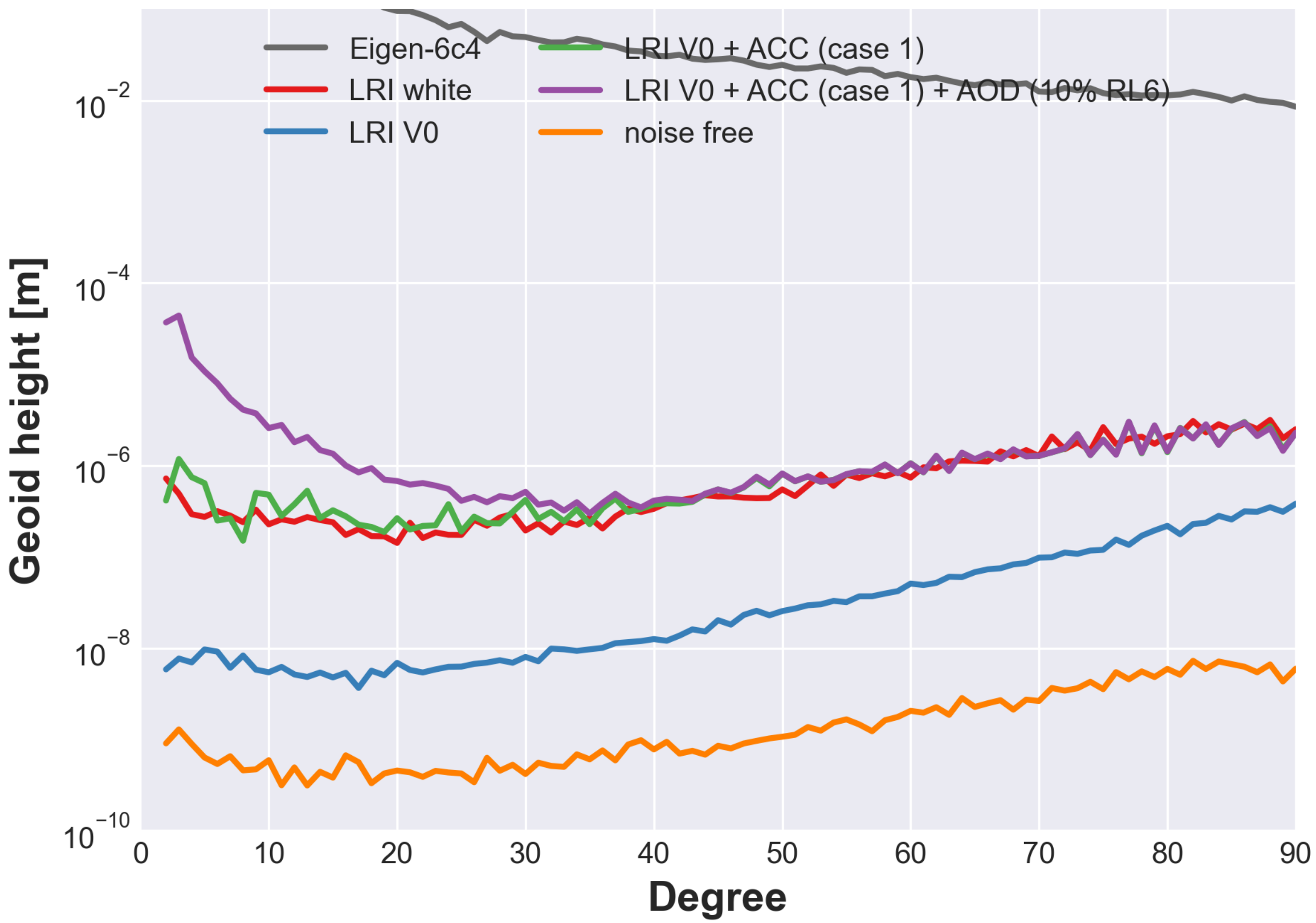
Combination of

- $ASD_{CAI}(f) = 10^{-9}\ \mathrm{m/s^2/\sqrt{Hz}}$ (Abrykosov et al., 2019)
- $ASD_{EA}(f) = 10^{-11}\sqrt{\left(\left(\frac{10^{-3}}{f}\right)^4 / \left(\left(\frac{10^{-5}}{f}\right)^4 + 1\right) + 1 + \left(\frac{f}{10^{-1}}\right)^4\right)}\ \mathrm{m/s^2/\sqrt{Hz}}$ (Darras and Pail, 2017)




ASD: Amplitude Spectral Density
LASD: Logarithmic frequency axis ASD

# Comparison of the models




**ACC (case 1)**: accelerometer noise according to slide 5
**AOD**: Atmospheric and Ocean De-aliasing model, RL6

**Eigen-6c4**: Static gravity field model
**LRI**: laser ranging acceleration noise according to slide 4

# Impact on Drag-free System

- Requirement on drag compensation

$$ASD(f) = \frac{1}{2}\frac{ASD_{acc}(f)}{s_{known}}$$ (Gruber et al., 2014)

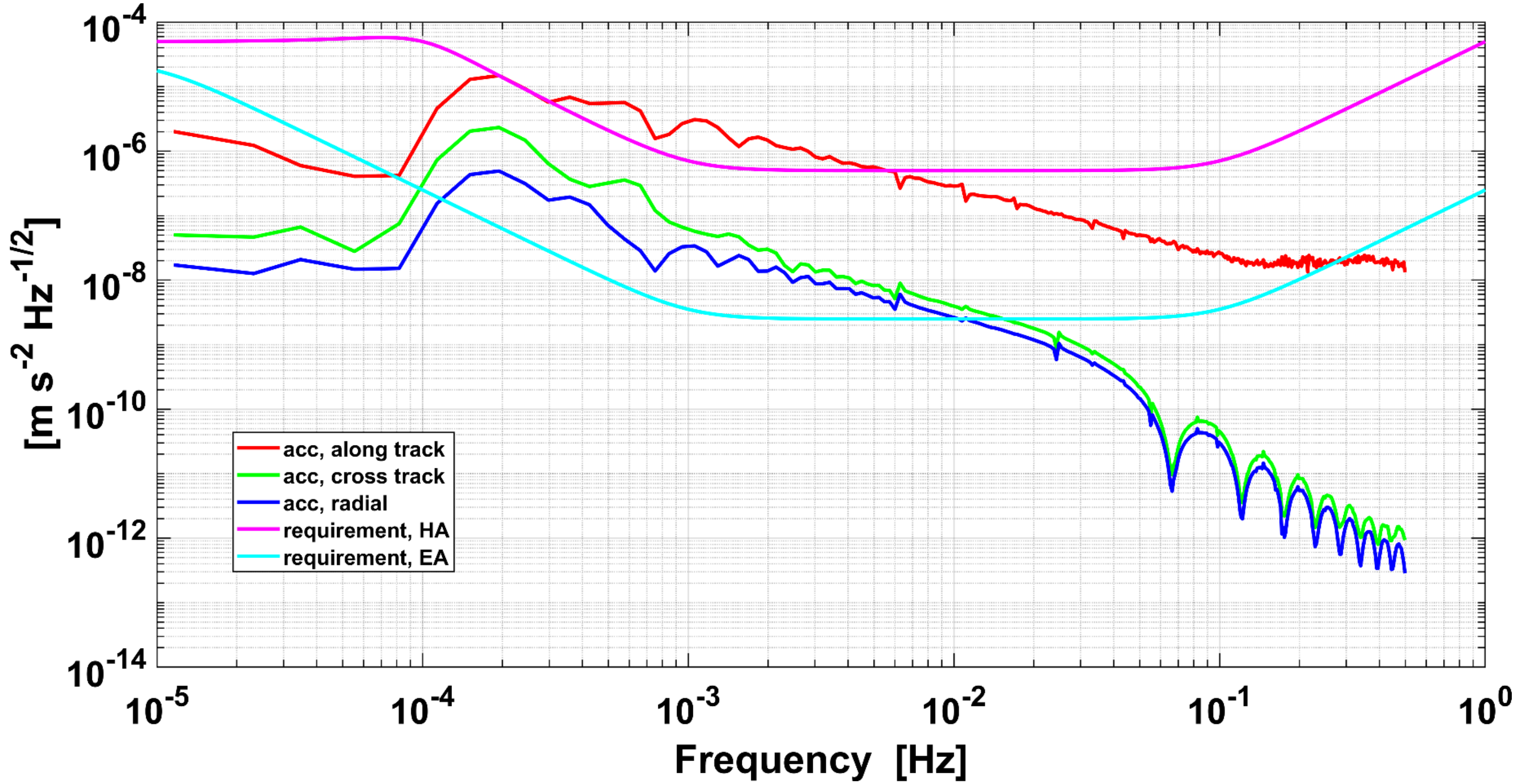
  - $s_{known}$: scale factor knowledge
  - $ASD_{acc}$: noise of the accelerometer measurement

- Assumption for scale factor knowledge
  - Electrostatic accelerometer 0.2%
  - Hybrid accelerometer 0.001%

- Impact studied for different orbit configurations and drag-free system parameters, see slides 8, 9 and 10

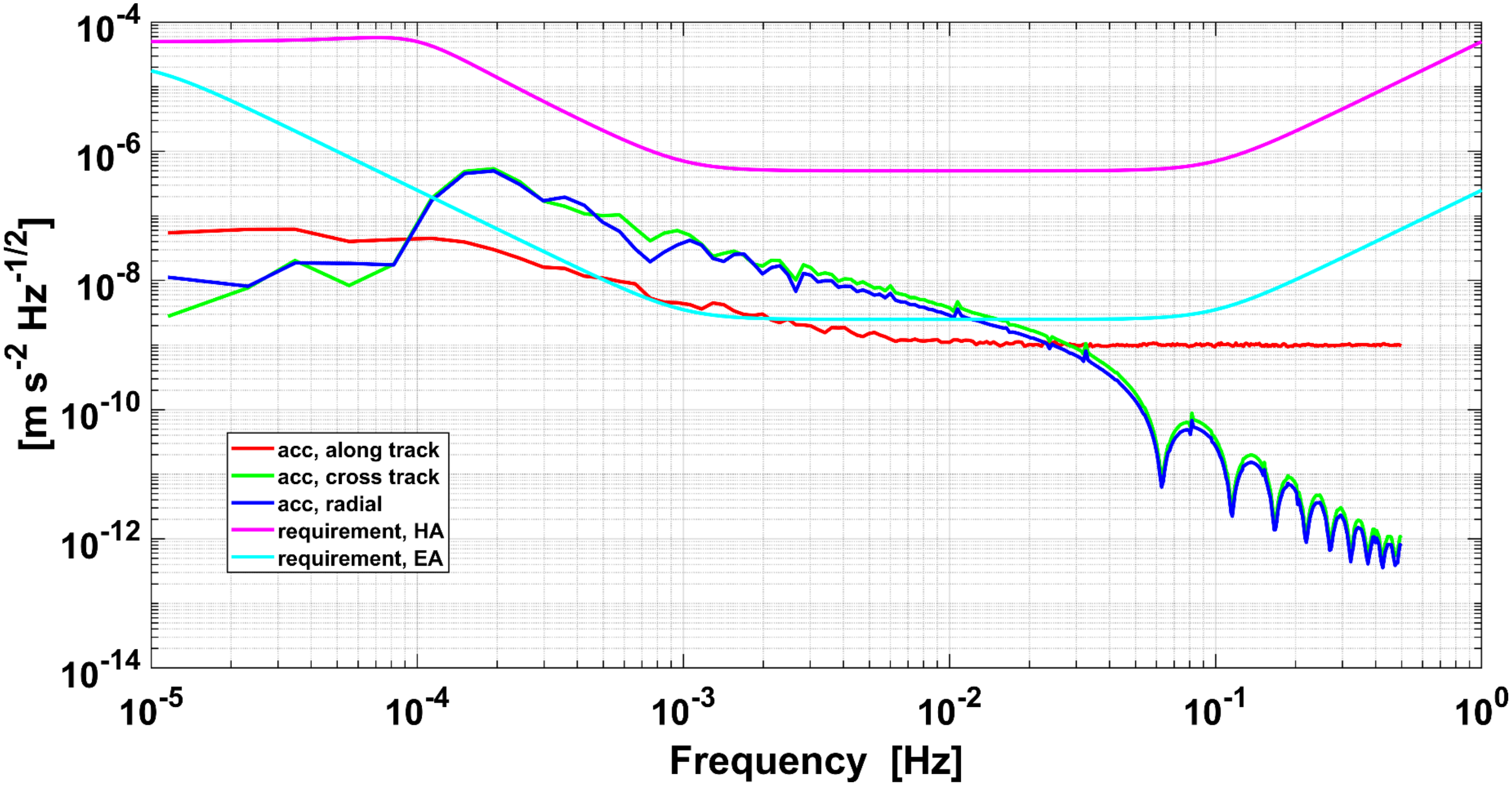
# Impact on Drag-free System

- h=303km
- drag compensation in along track direction
- control system parameters of the GOCE mission



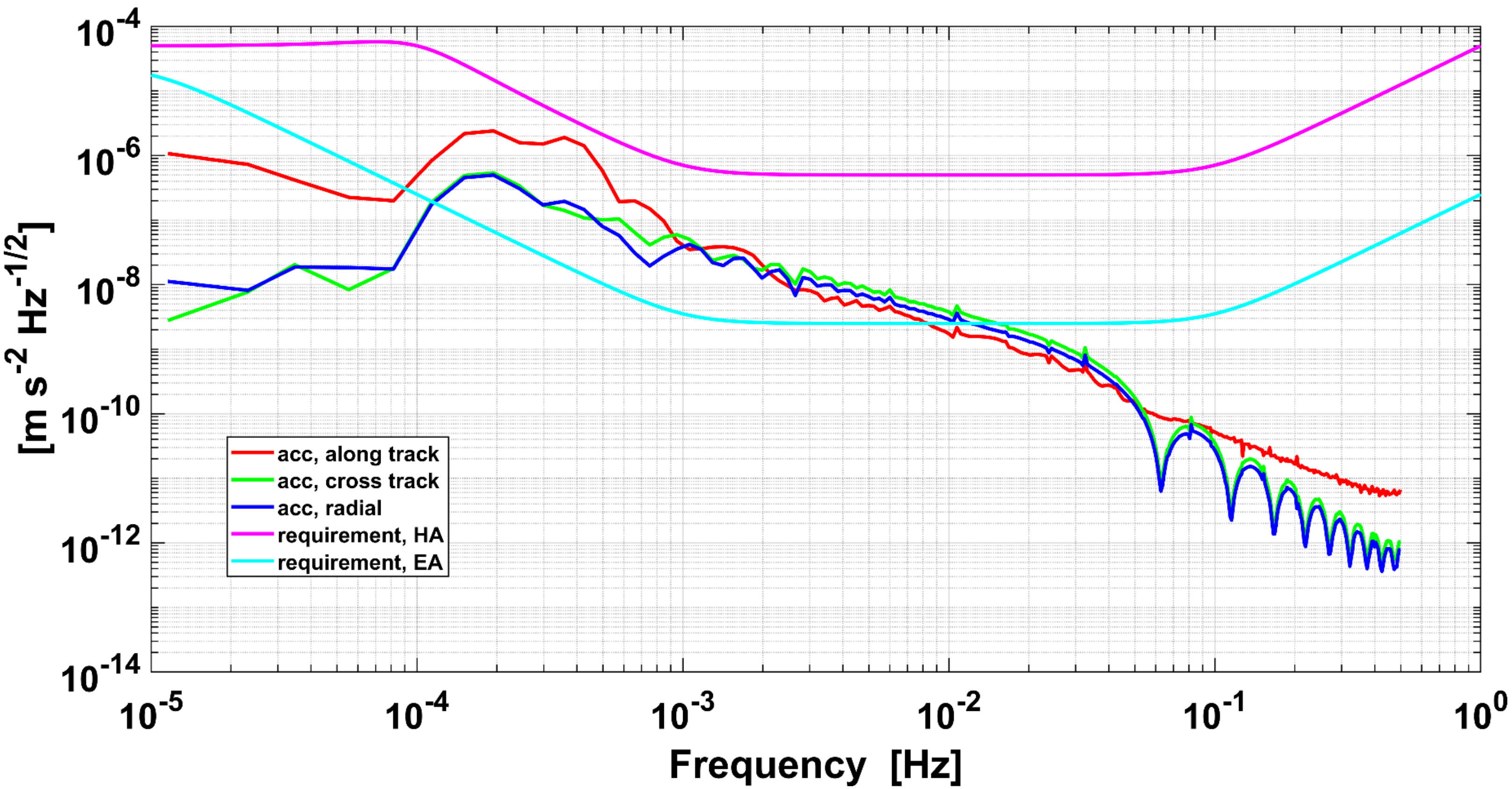
# Impact on Drag-free System

- h=361km
- drag compensation in along track direction
- control system parameters improved



# Impact on Drag-free System

- h=361km
- no drag compensation

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# Summary

- CAI concept can improve gravity field solutions (Trimeche et al., 2019)

- Using CAI measurements for the calibration of the EA
  - better knowledge of the scale factor
  - large impact on drag free requirement

- Next steps
  - Refine CAI noise behavior depending on architecture of the sensor
  - Investigate impact of further parameters: orbit configurations, perturbation sources, …

# References


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