Aktuelle Ergebnisse der Entwicklung des Quantengravimeters GAIN im Vergleich mit Supraleitgravimetern und FG5X-220

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Motivation

- Absolut Gravimetry is dominated by laser interferometers with falling corner cubes
- In recent years a number of Atom Interferometer (AI) gravimeters were developed
  - μQuans: commercial quantum gravimeter
  - LNE Syrte: Cold Atom Gravimeter
  - IQ LUH: in development (QUANTUS conversion)

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  - μQuans: commercial quantum gravimeter
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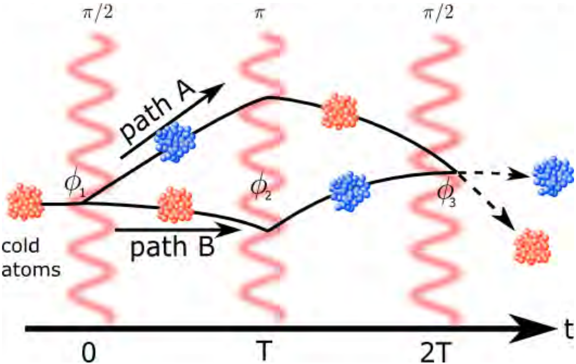
- HU Berlin: Gravimetric Atom Interferometer (GAIN)
  - Characterization by comparison with SG and AG

Agenda

- **Motivation**
- **Atom interferometry**
- **Review Wettzell 2013**
- **Comparison Onsala 2015**
- **Summary and Conclusion**

Atom interferometry

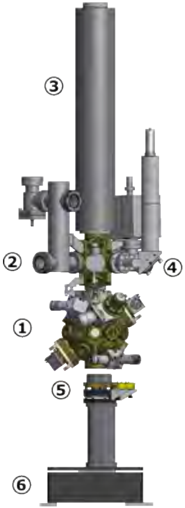


$$P_{|F=2\rangle} = \frac{1}{2}\left[1 - \cos(\Delta\Phi)\right]$$

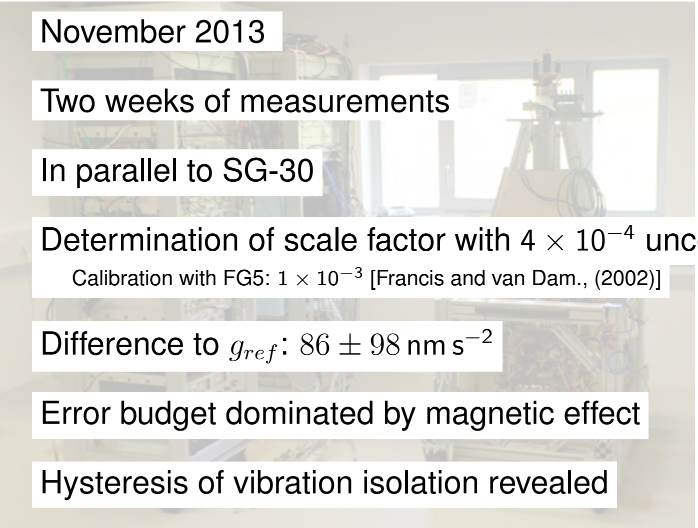
$$\Delta\Phi = k_{eff}\, g T^2$$

g-experiment sequence

1. Magneto-Optical-Trap
   → preparation of atoms
2. State selection
3. Light – atom interaction
4. Detection of state populations
5. Tip/tilt mirror
   → verticality and Coriolis
6. Vibration isolation



Review Wettzell 2013



November 2013

Two weeks of measurements

In parallel to SG-30

Determination of scale factor with 4×10^{-4} uncertainty

Calibration with FG5: 1×10^{-3} [Francis and van Dam., (2002)]

Difference to g_{ref}: $86 \pm 98\,\mathrm{nm\,s^{-2}}$

Error budget dominated by magnetic effect

Hysteresis of vibration isolation revealed

Comparison Onsala 2015

Four week campaign in February

- OSG-054 and GAIN: precision
  $\rightarrow$ almost 4 weeks of recordings
- FG5X-220 and GAIN: absolute accuracy
  $\rightarrow$ switch of positions after 4 days

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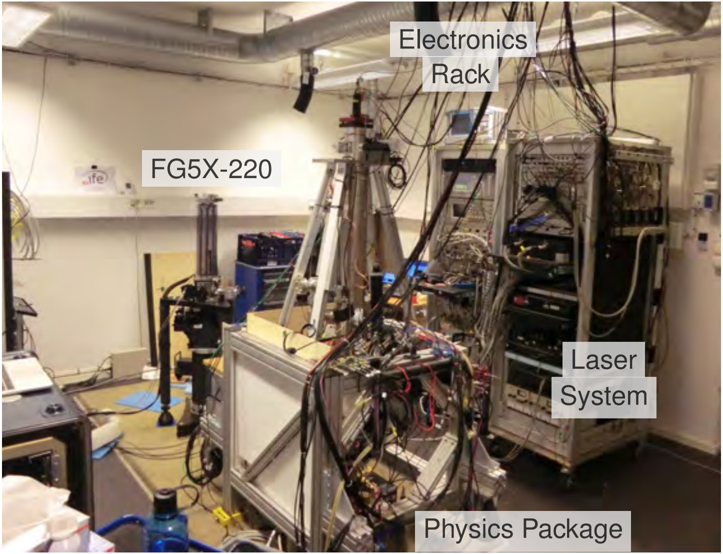
Improvements of GAIN after Wettzell

- Magnetic shielding of MOT
  $\rightarrow$ quicker setup of instrument
  $\rightarrow$ removal of systematic effect
- Readjustment of vibration isolation
- Post-correction for residual vertical mirror movement [Le Gouët et al., (2008)]

Comparison Onsala 2015



Comparison Onsala 2015

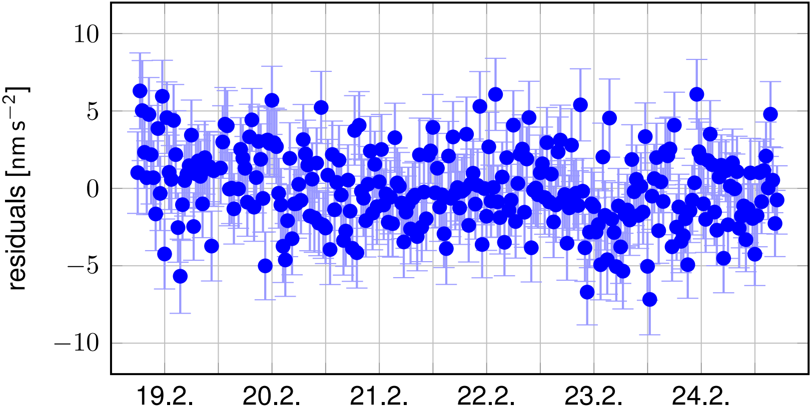


Figure: Difference of GAIN and OSG-054 from 30 minute averages.

Comparison Onsala 2015 vs. Wettzell 2013

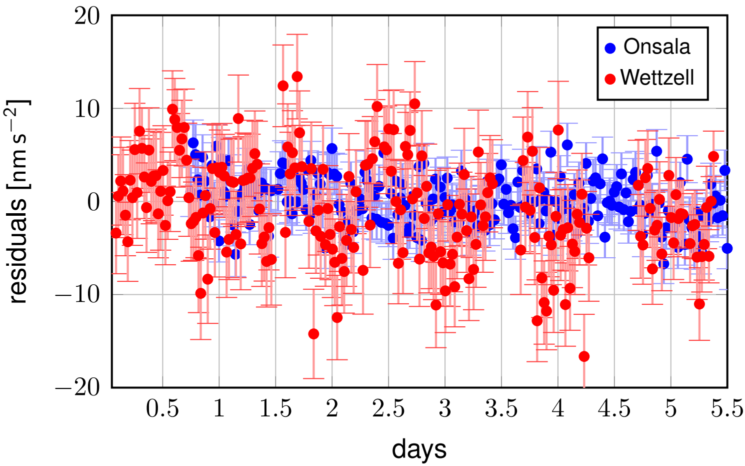


Figure: Difference GAIN – SG (RMS: $3\,\mathrm{nm\,s^{-2}}/11\,\mathrm{nm\,s^{-2}}$).

Comparison Onsala 2015 vs. Wettzell 2013

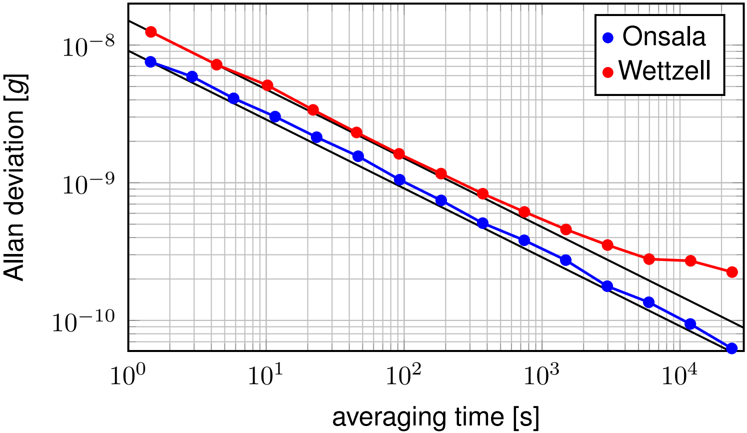


Figure: Allan deviation of GAIN – SG.

Comparison Onsala 2015: FG5X-220

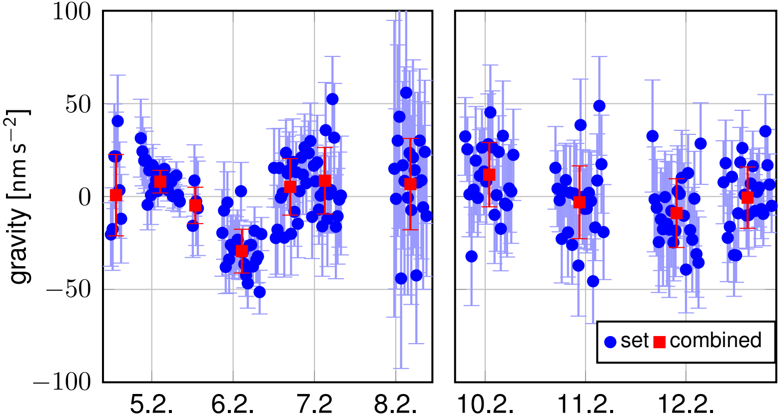


Figure: Pillar AC ($\sigma = 5\,\mathrm{nm\,s^{-2}}$) and AA ($\sigma = 9\,\mathrm{nm\,s^{-2}}$) with the mean gravity of each pillar subtracted.

Comparison Onsala 2015: FG5X-220 and GAIN

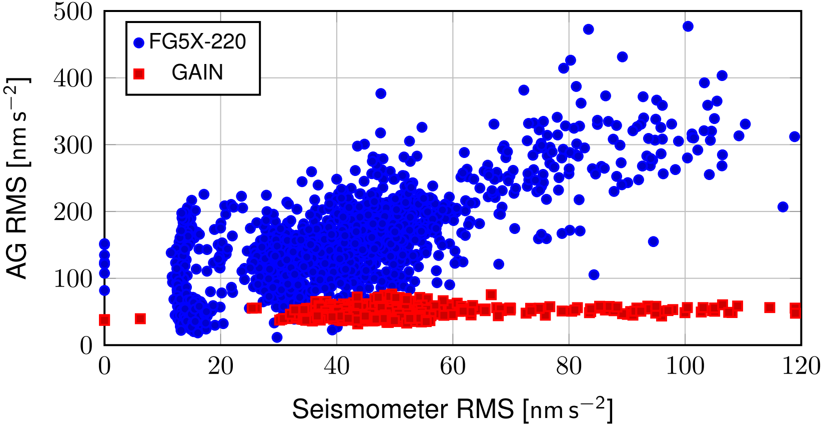


Figure: RMS of Seismometer vs. Absolute Gravimeter (FG5X-220 from 4.2.-12.2. and GAIN from 7.2.-12.2).

Summary and Conclusion

Results GAIN

- Continuous operation with minor down time
- Improvement of sensitivity $< 1 \times 10^{-10}\, g$
- Difference to FG5X-220 $56 \pm 58\, \mathrm{nm\, s^{-2}}$
- Error budget dominated by wavefront aberration [Schkolnik et al. (2015)]
- Confirmation of SG scale factor with uncertainty 2.6×10^{-4}

Summary and Conclusion

Results FG5X-220

- Measurements under unfavorable conditions due to microseismic activity
- Results fit to land-uplift determined with previous FG5 Measurements [Timmen et al. (2015)]
- Currently no indication for orientation dependent instrumental effect $\rightarrow$ improvement over FG5-220 [Gitlein, (2009)]

Summary and Conclusion

Next Steps

- Comparison with SG essential for characterization of AI sensitivity and identification of instrumental effects
- Reduction of systematic effect
- Participation international comparison of absolute gravimeters

Thank you for your attention

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Microseismic activity due to weather conditions

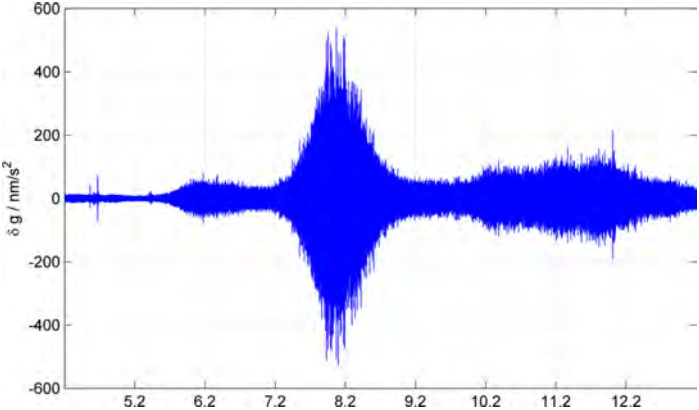

Figure: Time derivation of 1 Hz SG data.