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
  - $\mu$Quans: commercial quantum gravimeter
  - LNE Syrte: Cold Atom Gravimeter
  - IQ LUH: in development (QUANTUS conversion)
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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

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

\[ \Delta \Phi = k_{eff} gT^2 \]
Atom interferometry

$g$-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
November 2013

Two weeks of measurements

In parallel to SG-30

Determination of scale factor with $4 \times 10^{-4}$ uncertainty

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

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

Error budget dominated by magnetic effect

Hysteresis of vibration isolation revealed
Comparison Onsala 2015

Four week campaign in February
- OSG-054 and GAIN: precision  
  → almost 4 weeks of recordings
- FG5X-220 and GAIN: absolute accuracy  
  → switch of positions after 4 days
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Improvements of GAIN after Wettzell
- Magnetic shielding of MOT
  → quicker setup of instrument
  → removal of systematic effect
- Readjustment of vibration isolation
- Post-correction for residual vertical mirror movement
  [Le Gouët et al., (2008)]
Figure: Difference of GAIN and OSG-054 from 30 minute averages.
Comparison Onsala 2015 vs. Wettzell 2013

Figure: Difference GAIN – SG (RMS: 3 nm s⁻²/11 nm s⁻²).
Comparison Onsala 2015 vs. Wettzell 2013

Figure: Allan deviation of GAIN – SG.
Figure: Pillar AC ($\sigma = 5 \text{ nm s}^{-2}$) and AA ($\sigma = 9 \text{ nm s}^{-2}$) 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 $56 \pm 58 \, \text{nm s}^{-2}$
- Error budget dominated by wavefront aberration [Schkolnik et al. (2015)]
- Confirmation of SG scale factor with uncertainty $2.6 \times 10^{-4}$
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 → 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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**Figure:** Time derivation of 1 Hz SG data.