Poster Session #B
Observational and space tests of gravitation

B09

Novel atom-optics sensors for future satellite gravity missions

Hu Wu (IfE Leibniz Universität Hannover)

The advancements of atom-optics technology bring new opportunities to develop novel sensors and measurement concepts for accelerometry, gradiometry and chronometry. The atomic sensors, which utilize cooled atoms as test masses to observe accelerations or gravity gradients in a free-falling condition, show a very high sensitivity and long-term stability. These properties are very beneficial for their application in future satellite gravity missions. Another promising new technique for geodesy, i.e., optical clocks, use the electron transition frequency in the optical range of the electromagnetic spectrum of atoms as frequency standard. Today optical clocks can provide the frequency information with an uncertainty level of one part in 10^{18}. According to Einstein's theory of general relativity, one can observe the gravitational redshift effect through the comparison of clock frequencies, and thus obtain the gravity potential differences between the clock stations. In addition, laser interferometer ranging with nanometer accuracy – which has been realized in the GRACE-FO mission – belongs to these novel sensors where future missions may benefit from atomic optics. We will illustrate how gravity field determination can potentially benefit from these novel atom-optics sensors and show future perspectives for Earth's gravimetric observations in various scenarios. Clocks on-board orbiting satellites are proposed to obtain gravity potential values through the comparison to reference clocks on ground or in space. An atomic accelerometer, or its hybridization with a classical electrostatic accelerometer, is expected to largely improve the measurement of non-conservative forces in space. This will contribute to precisely reduce the non-conservative perturbations in GRACE-like measurements. In addition, gravity gradiometry can be realized based on cold atom interferometry. Full-scale simulations are performed to map the sensitivities of these types of measurements to gravity field coefficients. The benefit of these novel sensors for the determination of different gravity field parts and gravity variations over time are quantitatively evaluated.

We gratefully acknowledge the financial support by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy EXC-2123 "QuantumFrontiers" (Project-ID: 390837967). The study is also funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project-ID 434617780 – SFB 1464. A. Knabe acknowledges initial funding for the DLR Institute by the Ministry of Science and Culture of the German State of Lower Saxony from "Niedersächsisches Vorab".