Internship project on Modelling Quantum Sensors for Geodesy

Starting date: 2023 - Duration: 3 - 6 months. Location: Paris, France

Project description: Conventional electrostatic accelerometers used until now in space gravimetry missions exhibit a degradation in measurement sensitivity at low-frequency and long-term drifts which limit their ability to faithfully reconstruct the Earth's gravity field and accurately model its time fluctuations. The improvement in the long-term stability of quantum sensors offers an important advantage, which in principle can significantly reduce errors in geoid determination or the study of large-scale mass transport processes. Dedicated studies are however necessary to accurately assess the gain provided by these sensors for restoring the Earth's gravity field.

The objective of the project is to examine realistic mission scenarios, based in particular on twin satellites, or satellite networks, with on-board quantum accelerometers or gradiometers, whose on-board performance are to be evaluated with precision. To this end, detailed instrument models will be developed, which will take into account the intrinsic measurement noise of atomic sensors (ideally limited by quantum projection noise), but also additional contributions related to the attitude control of the satellite (parasitic rotations and non-inertial vibrations) and to the environment (such as fluctuations in the magnetic field). This requires an in-depth evaluation of a large number of effects, related to the control of the parameters of the atomic sources (temperature, initial position and velocity), of the laser beams of the interferometer (quality of the front of wave, stability of the alignment), of the geometry of the detection ... In addition, the error contributions due to the limited knowledge of models of temporal variations of the gravity field (such as related for example to high frequency mass variations in the oceans and the atmosphere) will be quantified. Hybrid systems combining electrostatic accelerometers and quantum sensors will be studied, which will make it possible to optimize the sensitivity and the measurement frequency band but also to possibly implement a drag compensation.

With an adequate model of the measurement noise, synthetic signals will be generated and used to assess the impact of measurement errors in the reconstruction of the Earth's gravity field via end-to-end simulations. In these simulations, models of the static and dynamic contributions to the Earth's gravity field are used, to which are added noise sources, including not only the measurement noise, but also the errors and uncertainties in the knowledge of the aforementioned models, as well as than in other complementary observables (such as orbitography for example). The error in the restitution of the gravity field will be finally evaluated by taking the difference between the reconstructed model and the input models. End-to-end simulations for selected mission scenarios will be performed with different levels of noise sources, which will determine their respective and combined impact on the final errors of the gravity field determination.

Context: This project will be undertaken in the frame of an ambitious European project, CARIOQA-PMP, which aims at the development of a prototype of a cold atom accelerometer for a future in-flight demonstration mission, and at the study of possible scenarios for future geodesy mission. SYRTE is collaborating in this project with experts in geodesy, who will deal more particularly with simulations and gravity field models. We will focus at SYRTE on the modelling of different interferometer configurations, of relevance for the envisioned mission scenarios and measurement protocols.

Profile of the applicant: we are looking for a candidate motivated by this challenging interdisciplinary project, ideally with a training in atomic physics, but if not in space engineering or geodesy.

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