44th COSPAR Scientific Assembly 2022

Fundamental Physics in Space (H)
Enabling Technologies for Fundamental Physics Experiments and Missions (H0.6)
Consider for oral presentation.

ATOM INTERFEROMETRY WITH BOSE-EINSTEIN CONDENSATES ON THE INTERNATIONAL SPACE STATION

Matthias Meister, matthias.meister@dlr.de
German Aerospace Center (DLR), Ulm, Germany
Naceur Gaaloul
Institute for Quantum Optics, Leibniz Universität Hannover, Hannover, Germany, gaaloul@iqo.uni-hannover.de
Nicholas Bigelow
University of Rochester, Rochester, United States, nicholas.bigelow@rochester.edu
Consortium for Ultracold Atoms in Space
Matthias Meister, Naceur Gaaloul, Holger Ahlers, Patrick Boegel, Eric Charron, Robin Corgier, Enno Giese, Waldemar Herr, Gabriel Müller, Holger Müller, Annie Pichery, Albert Roura, Christian Schubert, Robert J. Thompson, Jason R. Williams, Wolfgang P. Schleich, Ernst M. Rasel, and Nicholas P. Bigelow

Quantum technologies are on the rise to change our daily life and thinking triggered by enormous advances in quantum enhanced communication, computation, metrology, and sensing. For many of these fields an operation in space will be essential to improve the relevance and significance of future applications. In particular, space-based quantum sensing will enable Earth observation missions, studies of relativistic geodesy, and tests of fundamental physical concepts with outstanding precision.

The basis for these prospects is the realization of ultracold quantum gases in a microgravity environment. Ultracold quantum gases like Bose-Einstein condensates (BECs) offer an excellent control over their external as well as internal degrees of freedom allowing for extremely low expansion energies. Under microgravity conditions this control enables unrivaled long free observation times which render BECs exquisite sources for atom interferometry, where the sensitivity typically scales quadratically with the interrogation time.

Here we report on a series of BEC experiments performed with NASA's Cold Atom Lab [1,2] aboard the International Space Station demonstrating first atom interferometers in orbit. By employing various Mach-Zehnder-type geometries we have realized magnetic gradiometers and successfully compared their outcome to complementary non-interferometric measurements. Moreover, we have characterized the atom source in great detail and have analyzed the current experimental limitations of the apparatus. Finally, we will provide an outlook on future experiments with CAL and beyond. These results pave the way towards future precision measurements with atom interferometers in space.

[1] Aveline, D. C. et al. Observation of Bose-Einstein condensates in an Earth-orbiting research lab. Nature 582, 193-197 (2020).

[2] Gaaloul, N. et al. A space-based quantum gas laboratory at picokelvin energy scales. arXiv:2201.06919 (2022).