Quantum gases in free-fall

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Free falling laboratories allow to generate, study and exploit quantum gases and their mixtures at lowest kinetic energy scales. By exploiting collective excitations in a Bose-Einstein condensate (BEC), we succeeded to reduce its total internal kinetic energy in three dimensions to few tens of Pikokelvins making it an interesting source for interferometry where wave packets are coherently split and travel for seconds in an interferometer. Vice versa, interferometry is a powerful method to analyse the expansion of a quantum gas over macroscopic time scales and to optimize the protocols for manipulating the BECs.

Regarding mixtures, the absence of buoyancy is one of the most intriguing consequences of weightlessness. On ground gravity breaks symmetry of space and introduces e.g. a preferential axis for the layering and alignment of different types of fluids. The sounding rocket mission MAIUS-1, being a stepping stone for space-borne coherent atom optics, served to investigate the generation of Rubidium Bose-Einstein condensates (BECs) in space and their spatial coherence after release in free fall. Building on this heritage, we prepare a second mission for investigating the generation of BECs made of potassium (K-41) and rubidium (Rb-87) and their mixing for comparisons to ground based experiments.

Beyond studies of the behavior of quantum fluids in the absence of buoyancy, both species will be in future simultaneously exploited for interferometry validating the methods as proposed for a satellite-based quantum test of the universality of Einstein's principle of equivalence (STE-QUEST mission). The experiments will complement the studies foreseen with NASA's Cold Atom Laboratory in the near future and prepare the NASA-DLR Bose-Einstein-Condensate and Cold-Atom-Laboratory (BECCAL), a future multi-user facility for exploring quantum mixtures in tailored potentials such as blue detuned boxes.

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