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Dynamics of massive superfluid vortices

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Quantum vortices are generally thought of as funnel-like holes around which a quantum fluid exhibits a swirling flow. In this picture, vortex cores are empty regions where the superfluid density goes to zero.

Here we generalize this framework, by allowing the vortices to have a non-zero mass. The latter may arise for example due to atoms which are distinguishable from the ones composing the superfluid, or are excited out of it as a result of thermal or quantum fluctuations and remain trapped in the vortex cores.

Providing vortices with a mass alters dramatically their dynamics, since the particles trapped in the vortex core experience an effective synthetic gauge field provided by the surrounding superfluid component, which leads to a density-dependent synthetic magnetic field.

In a hard-walled cylindrical container [1] and on an annulus [2] the additional mass leads to a modification of the precession frequency, and the usual precession turns into a cyclotron motion, which for large mass eventually becomes unstable. In a generic trapping potential $V \propto r^k$, the dynamics acquires an additional intriguing feature which may be easily observed: the direction of precession changes sign for sufficiently large mass [3].

[1] A. Richaud, V. Penna, and A. L. Fetter
Dynamics of massive point vortices in a binary mixture of Bose-Einstein condensates
Phys. Rev. A **103**, 023311 (2021)

[2] M. Caldara, A. Richaud, M. Capone, and P. Massignan
Massive superfluid vortices and vortex necklaces on a planar annulus
Scipost Phys., in press (arXiv:2301.08493)

[3] A. Richaud, P. Massignan, V. Penna, and A. L. Fetter
Dynamics of a massive superfluid vortex in r^k confining potentials
Phys. Rev. A **106**, 063307 (2022).

Primary author: MASSIGNAN, Pietro (Universitat Politècnica de Catalunya)

Co-authors: FETTER, Alexander (Stanford University, Stanford, USA); RICHAUD, Andrea (Universitat Politècnica de Catalunya); CAPONE, Massimo (Scuola Internazionale Superiore di Studi Avanzati (SISSA), Trieste, Italy); CALDARA, Matteo (Scuola Internazionale Superiore di Studi Avanzati (SISSA), Trieste, Italy); PENNA, Vittorio (Politecnico di Torino, Torino, Italy)

Presenter: MASSIGNAN, Pietro (Universitat Politècnica de Catalunya)

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