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How many particle do make a fluid? Searching for hydrodynamic behavior in mesoscopic ultracold gases

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Collective phenomena in quantum many-body systems are often described in terms of hydrodynamics, an appropriate framework when the involved particle numbers are effectively macroscopic. Motivated by the recent observation of collective phenomena in high-energy proton-proton and proton-nucleus collisions, where particle numbers are small and a fluid description is a priori inapplicable, we discuss the possibilities offered by experiments of expanding clouds of ultracold atom gases as a means to study emergent hydrodynamic behavior as a function of particle number. We consider the inversion of the shape of gases prepared in elliptical traps. Shape inversion is a salient signature of an effective pressure-gradient force, ascribable to hydrodynamics. We borrow techniques from the analysis of collective phenomena in the context of high-energy hadron collisions to devise meaningful statistical measures of the cloud shapes and the shape inversion, which allow us to overcome the finiteness of the number of particles. We discuss our qualitative expectations as well as quantitative hydrodynamic predictions for experiments ongoing at Heidelberg University on expanding few-body Fermi gases. We argue, in particular, that genuine collective effects emerging from atom-atom interactions can be easily detected on top of a background of quantum effects induced by the trapping potential that disappear quickly with the atom number.

Based on: Floerchinger et al., Phys. Rev. C 105, 044908 (2022), and work in progress

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