

Stages of the relaxation for a far-from-equilibrium trapped superfluid

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Understanding the initial conditions that drive many-body quantum systems out of equilibrium is essential for getting into their thermalization dynamics. In this work [1,2,3], we identify two excitation regimes that lead a trapped Bose-Einstein condensate into turbulence regime evolving resulting in distinct final states. In the subcritical regime, the condensate partially reemerges after turbulence, whereas in the supercritical regime it dissolves completely into a thermal state. Despite these differences, both cases exhibit relaxation stages with common features: a direct energy cascade, the emergence of a nonthermal fixed point (characterized by identical scaling exponents), a prethermalization plateau, and eventual thermalization. Our results show that turbulence relaxation develops independently of the system's initial conditions or its ultimate state. At late times, both regimes display universal scaling dynamics consistent with predictions from wave turbulence theory. Finally, by analyzing the time evolution of the condensate's momentum distribution center of mass, we demonstrate how kinetic-energy dominance reflects the thermalized nature of the final states in each regime. The present results advance the field by showing that thermalization in far-from-equilibrium quantum systems follows universal relaxation dynamics, even when final states differ, thereby deepening our understanding on time evolution of many body quantum system thermalization. We shall present a new possible interpretation for the pre-thermalization as well as an analysis of the construction of the coherent length during the last stage of thermalization of the system.

GURI, CRI, CPRIT-grant RR220054, FAPESP - CEPID program, INCT - CNPq

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[2] L. Madeira et al - Proc. Nat. Acad. Sci. - PNAS 121, 24044828121 (2024)

[3] A. D. Garcia-Orozco et al - Phys. Rev. A 106, 023314 (2022)