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Many-body Physics with Fermions in an Optical Box

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For the past two decades harmonically trapped ultracold atomic gases have been used with great success to study fundamental many-body physics in flexible experimental settings. However, the resulting gas density inhomogeneity in those traps makes it challenging to study paradigmatic uniform-system physics (such as critical behavior near phase transitions) or complex quantum dynamics.

The realization of homogeneous quantum gases trapped in optical boxes has marked a milestone in the quantum simulation program with ultracold atoms [1]. These textbook systems have proved to be a powerful playground by simplifying the interpretation of experimental measurements, by making more direct connections to theories of the many-body problem that generally rely on the translational symmetry of the system, and by altogether enabling previously inaccessible experiments.

I will present a set of studies with ultracold fermions trapped in a box of light [2-4]. This platform is particularly suitable to study problems of Fermi-system stability, of which I will discuss two cases: the spin-1/2 Fermi gas with repulsive contact interactions [2], and the three-component Fermi gas with spin-population imbalance [3]. Both studies lead to surprising results, highlighting how spatial homogeneity not only simplifies the connection between experiments and theory, but can also unveil unexpected outcomes. Finally, I will discuss two ongoing efforts to tackle far-from-equilibrium dynamics of uniform fermions. One focuses on an impurity embedded in a Fermi bath and strongly driven between internal states; the second one aims at understanding the nonlinear density-density response of the weakly and strongly interacting Fermi gases.

[1] N. Navon, R.P. Smith, Z. Hadzibabic, Nature Phys. 17, 1334 (2021)
[2] Y. Ji et al., Phys. Lev. Lett 129, 203402 (2022)
[3] G.L. Schumacher et al., arXiv:2301.02237
[4] Y. Ji et al., arXiv:2305.16320

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