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 has made 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 quantum simulation 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 series of experiments with ultracold fermions trapped in a box of light [2-5]. First, I will present two studies of stability problems: the spin-1/2 Fermi gas with repulsive contact interactions [2] and the three-component Fermi gas with spin-population imbalance [3]. Next, I will show the first observation of the Joule-Thomson effect in Fermi systems [4]. Finally, I will show how properties of quasiparticles can be modified by a dressing field; in our case, Fermi polarons dressed with an rf field [5]. These studies have led to some surprising results, highlighting how spatial homogeneity not only simplifies the connection between experiments and theory, but can also unveil unexpected outcomes.

[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., Phys. Lev. Lett 132, 153402 (2024)

[5] F.J. Vivanco et al., arXiv:2308.05746