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Experiments with Multi-component Ultracold Fermions

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Abstract:

Ultracold gases of neutral atoms are a powerful resource for engineering synthetic many-body quantum systems. In a “quantum simulation” perspective, it is possible to control the atomic state to provide direct experimental realizations of fundamental theoretical models, often introduced in the context of condensed-matter physics, e.g. to describe the physics of strongly-correlated electronic systems.

I will report on recent experiments performed at University of Florence with degenerate gases of ultracold ^{173}Yb fermions. These two-electron atoms exhibit a rich internal structure, with distinct degrees of freedom – nuclear spin and electronic state – that can be both manipulated in a quantum coherent way. In particular, the control of the nuclear spin allowed us to study the physics of multicomponent fermions with SU(N) interaction symmetry, with intriguing properties emerging when the atoms are trapped in low dimensions [1]. Furthermore, by coupling different internal states we have demonstrated the possibility of engineering “synthetic dimensions”, in which effective lattice dynamics are encoded in the internal Hilbert space of single atoms. By using this approach, we have demonstrated new techniques for the production of synthetic gauge fields for neutral atoms and observed the emergence of edge currents in fermionic ladders with tunable flux [2,3].

I will also discuss perspectives of using these ultracold fermionic systems to study the physics of the metal-insulator transition in strongly correlated multi-component materials with tunable couplings.

[1] G. Pagano et al., Nature Phys. 10, 198 (2014).

[2] M. Mancini et al., Science 349, 1510 (2015).

[3] L. F. Livi et al., Phys. Rev. Lett. 117, 220401 (2016).