Exploring vortex and impurity dynamics in strongly interacting fermionic systems

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Ultracold atoms provide a unique playground for exploring strong correlation phenomena in quantum many-body systems, owing to an exceptional control over the Hamiltonians and long coherent time scales. Recent advances in microscopic optical manipulation have extended our experimental control capabilities down to the level of single atoms or single excitation quanta, providing exciting opportunities to explore quantum many-body problems with a novel perspective. In this talk, I will first present a set of experiments where we have engineered on-demand few- and many-vortex states in strongly interacting fermionic fluids [1,2,3]. By imaging the motion of single quantized vortices, we could shed light on the elementary mechanisms behind quantized vortex energy relaxation in fermionic-pair superfluids, and observe the instability of deterministically prepared vortex crystals, reminiscent of the classical Kelvin-Helmholtz shear-flow instability. In the second part of the talk, I will report on our efforts to construct a new experimental platform in Trieste, aiming to assemble individual ytterbium atoms into mesoscopic many-particle systems with low entropy. Fermionic ytterbium isotopes especially present key features which make them ideal to investigate open questions in quantum impurity problems, such as the formation of Kondo resonances and the competition between quantum dephasing and thermal decoherence for localized spin impurities embedded in a fermionic band.

[1] Kwon et al., Nature 600, 64–69 (2021)

[2] Del Pace et al., Phys. Rev. X 12, 041037 (2022)

[3] Hernandez-Rajkov et al., arXiv:2303.12631 (2023)