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Engineering vortex matter in strongly-correlated superfluids

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Topological defects determine properties and structure of disparate out-of-equilibrium physical and biological matter over a wide range of scales, from planetary atmospheres, turbulent flow in hydrodynamic classical and quantum fluids, up to electrical signalling in excitable biological media [1]. In superfluids and superconductors, the motion of quantised vortices is associated with the onset of dissipation [2]. Understanding vortex dynamics is a formidable challenge because of the complex interplay between moving vortices, disorder and system dimensionality that encumbers predictability.
We realise a novel programmable vortex platform in planar and homogeneous atomic Fermi superfluids [3]. We engineer on-demand vortex configurations and we monitor their evolution by tracking vortex trajectories. The ultimate control on the vortex dynamics makes our platform the ideal "quantum laboratory"where to elucidate the intimate nature of vortex-driven instabilities [4], opening prospects towards the understanding of out-of-equilibrium dynamics and of exotic vortex-matter phase transitions in strongly-correlated superfluids.

[1] Spiral and Vortices, K. Tsuji and S. C.Müller Editors, Springer Nature Switzerland AG (2019)
[2] B. I. Halperin, G. Refael and E. Demler, Int. J. Mod. Phys, B 24, 20n21 (2010)
[3] W. J. Kwon et al., Nature, 600 (2021)
[4] D. Hernandez-Rajkov et al., arXiv:2303.12631 (2023)

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