

Aharonov-Bohm, Kennard Phase, and Three-Slit Dynamics in Pilot-Wave Hydrodynamics

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A millimetric droplet bouncing on a vertically vibrating fluid bath may self-propel through a resonant interaction with its own wave field. The resulting “walker”, a particle dynamically coupled to a guiding wave, provides a macroscopic realization of de Broglie’s pilot-wave conception of quantum dynamics, and has revealed hydrodynamic analogs of phenomena once thought exclusive to the microscopic quantum realm. We present several recent advances. First, we report an experimental analog of the Aharonov-Bohm effect: a walker orbiting in an annular cavity that encircles a shielded vortex, lying beyond the reach of its flow, nonetheless acquires a force-free, flux-dependent shift in its orbital speed, yielding Wigner-like phase-space distributions with a rigid, gauge-like translation. Second, we characterize a hydrodynamic analog of the cubic-in-time Kennard phase, and identify a Kennard critical point marking a sharp transition in the walker’s drift dynamics. Third, we present exotic looped trajectories, novel orbital states reminiscent of the looping paths summed over in Feynman’s path-integral construction of the propagator. Finally, we show how the pilot-wave framework may be tuned to emulate rotating black holes, capturing ergoregion-like structure and superradiant energy exchange. Collectively, these results extend the reach of hydrodynamic quantum analogs from gauge physics to analog gravity, deepening their connection to the foundations of quantum mechanics.

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