Walking droplets & Galloping bubbles

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In the first part of this talk, we present a classical wave-particle analog of Anderson localization with walking droplets, which self-propel across the surface of a vibrating fluid bath through a resonant interaction with its own guiding wave field. These walking droplets, or 'walkers', push the boundaries of classical mechanics to include behaviors previously thought to be exclusive to the quantum realm. By investigating the erratic motion of walkers over submerged random topographies, we demonstrate the emergence of localized statistics analogous to those of quantum particles. Consideration of an ensemble of walker trajectories reveals a suppression of diffusion when the guiding wave field extends over the disordered topography. The emergent statistics are rationalized mechanistically by virtue of the wave-mediated resonant coupling between the droplet and topography, which generates an attractive wave potential about the localization region. This hydrodynamic quantum analog demonstrates how a classical particle may localize like a wave, and so suggests new directions for future research.

The second part of this talk is dedicated to introducing a new symmetry breaking that prompts bubbles to 'gallop' along horizontal surfaces inside a vertically-vibrated fluid chamber, self-propelled by a resonant interaction between their shape oscillation modes. These active bubbles exhibit distinct trajectory regimes, including rectilinear, orbital, and run-and-tumble motions, which can be dynamically tuned via external forcing. Through periodic body deformations, galloping bubbles swim by leveraging inertial forces rather than vortex shedding, enabling them to maneuver even when viscous traction is not viable. The galloping symmetry breaking provides a robust self-propulsion mechanism, arising in bubbles whether separated from the wall by a liquid film or directly attached to it. The bubble's spectrum and a perturbative stability analysis show that the galloping instability results from the coupling between symmetric and asymmetric shape modes. Through proof-of-concept demonstrations, we showcase the technological potential of galloping locomotion for applications involving bubble generation and removal, transport and sorting, navigating complex fluid networks, and surface cleaning. The rich dynamics of galloping bubbles suggest opportunities in heat transfer, microfluidics, soft robotics, and active matter.

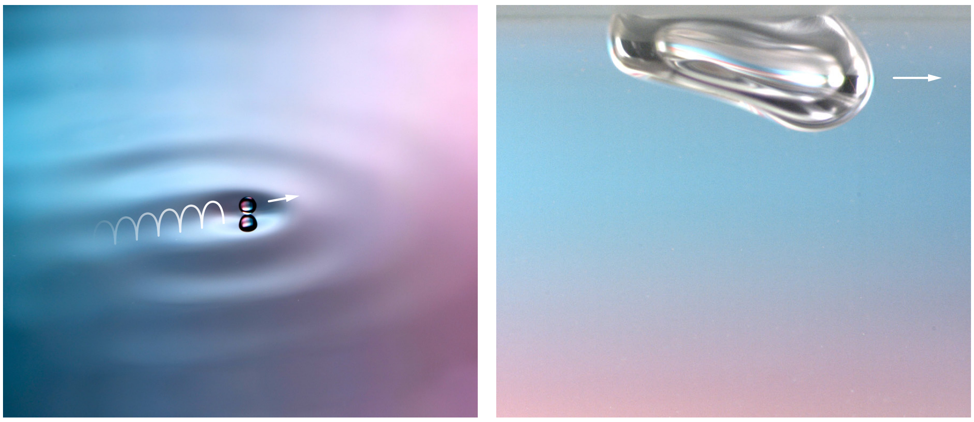

Fig. 1: A walking droplet and a galloping bubble.

Biosketch – Pedro is an Assistant Professor and the director of the Physical Mathematics Laboratory (www.pml.unc.edu) in the Department of Mathematics at UNC. From 2015 to 2019, he was an Instructor in Applied Mathematics at MIT. Pedro received his Ph.D. from the University of Edinburgh in 2014 and was a post-doctoral fellow at Imperial College London in 2015. He was awarded an Alfred P. Sloan Research Fellowship in 2023 and an NSF CAREER award in 2021. Pedro has also received multiple scientific visualization awards, including the American Physical Society Gallery Fluid of Motion award in 2017 and 2022. His research blends experiments, numerical simulations, and theory to address fundamental problems that find motivation in physics and engineering.