Hydrodynamic Spin Lattices

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In this talk, we will introduce a hydrodynamic analog system that allows us to investigate simultaneously the wave-mediated self-propulsion and interactions of effective spin degrees of freedom in inertial and rotating frames. Millimetric liquid droplets can walk across the surface of a vibrating fluid bath, self-propelled through a resonant interaction with their own guiding wave fields. By virtue of the coupling with their wave fields, these walking droplets, or 'walkers', extend the range of classical mechanics to include certain features previously thought to be exclusive to the microscopic, quantum realm. A walker may be trapped by a submerged circular well at the bottom of the fluid bath, leading to a clockwise or counterclockwise angular motion centered at the well. When a collection of such wells is arranged in a 1D or 2D lattice geometry, a thin fluid layer between wells enables wave-mediated interactions between neighboring walkers. Through experiments and mathematical modeling, we demonstrate the spontaneous emergence of coherent droplet rotation dynamics for different types of lattices. For sufficiently strong pair-coupling, wave interactions between neighboring droplets may induce local spin flips leading to ferromagnetic or antiferromagnetic order. Transitions between these two forms of magnetic order can be induced through variations in non-equilibrium driving, lattice geometry and Coriolis forces mimicking an external magnetic field. Theoretical predictions based on a generalized Kuramoto model derived from first principles rationalize our experimental observations, establishing HSLs as a generic paradigm for active phase oscillator dynamics.

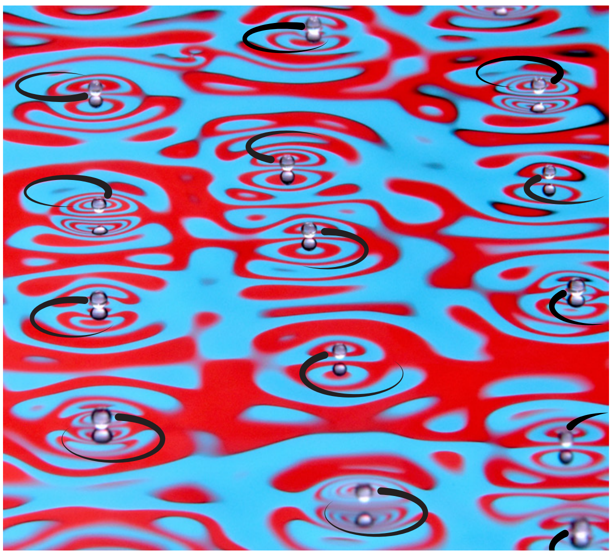

Fig. 1: Hydrodynamic Spin Lattice of walking droplets.

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 the Department of Mathematics at MIT. Pedro received his Ph.D. from the University of Edinburgh in 2014, and pursued brief post-doctoral studies at Imperial College London in 2015. His research blends experiments, numerical simulations and theory, to address fundamental problems that find motivation in Physics and Engineering.