Collective Dynamics and Emergent Phases in Active Mixtures

Shradha Mishra
Associate Professor
Department of Physics, Indian Institute of Technology (BHU), Varanasi

Brief Biographical Sketch

Dr. Shradha Mishra is an Associate Professor of Physics at the Indian Institute of Technology (BHU), Varanasi. Her research focuses on theoretical and computational soft and active matter, with particular interests in nonequilibrium statistical physics, active fluids, phase separation, collective dynamics, and the development of coarse-grained theoretical and computational models. Her work combines analytical theory, field-theoretic approaches, and particle-based simulations to understand emergent phenomena in complex nonequilibrium systems. Her current research interests include active phase separation, two-temperature systems, flocking and turbulence, defect dynamics, and data-driven approaches to statistical physics.

Abstract

Active mixtures provide a versatile platform for exploring nonequilibrium phase behavior and collective dynamics arising from the interplay of different types of self-driven and passive components. In this talk, I will discuss our recent studies of active–passive and polar–apolar mixtures, spanning phenomena from phase separation and unconventional coarsening to collective swirling and spatiotemporal chaos.

I will first discuss how an active bath can mediate effective interactions between passive particles, leading to distinct clustering and phase-separated states. I will then show how active fluctuations can produce unconventional growth kinetics and fractal interfaces during colloidal phase separation. Moving to mixtures of polar and apolar active components, I will discuss the emergence of dynamical swirl structures and, at higher levels of dynamical competition, spatiotemporal chaos accompanied by topological defect proliferation.

Together, these studies demonstrate the diverse collective states that can emerge when distinct active and passive components interact, and highlight active mixtures as a route to discovering new mechanisms of nonequilibrium organization and dynamical pattern formation.