# How anisotropy reshapes dense active phases: from hexatic order to MIPS


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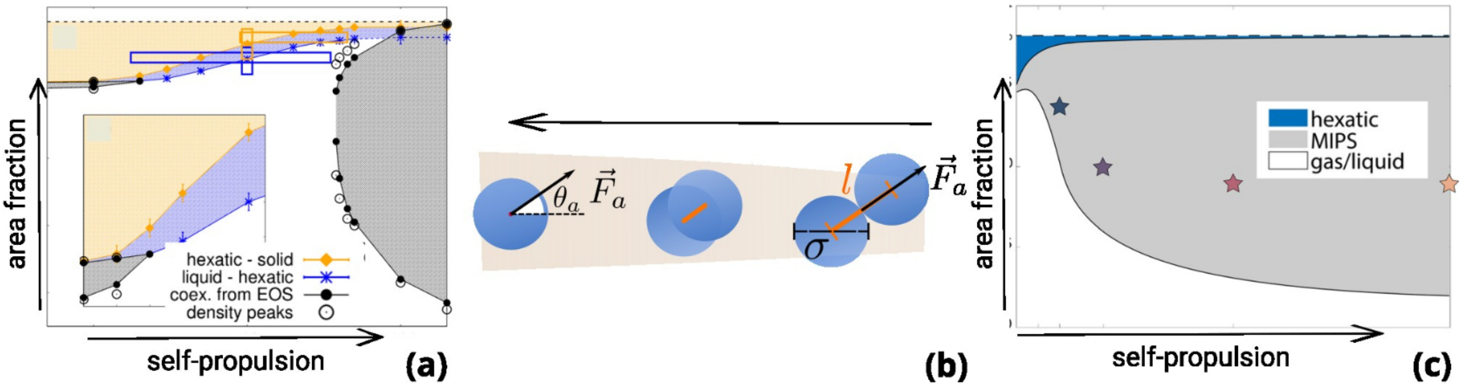
Many mesoscopic phenomena in soft and living matter arise under non-equilibrium conditions, where thermal, mechanical, or chemical imbalances lead to behaviors beyond equilibrium statistical mechanics. Active matter physics has developed coarse-grained models to describe such systems, where energy injection at the microscopic scale drives emergent collective phases with complex structural and dynamical properties. A paradigmatic example is active Brownian particles (ABPs), spherical self-propelled units modeling systems such as bacteria or catalytic colloids. In two dimensions, ABPs exhibit crystalline and hexatic order at high density and low activity, while strong self-propulsion induces motility-induced phase separation (MIPS) even in the absence of attractive interactions [1].
Introducing anisotropy qualitatively changes this picture. In active dumbbell systems, ordered phases evolve continuously with activity, and a coexistence region emerges, connecting the passive liquid–hexatic transition to the high-activity MIPS regime [2,3].
Here, we investigate how anisotropy reshapes this landscape using self-propelled dimers with tunable bond length. Through extensive numerical simulations, we map the state diagram as a function of packing fraction, activity, and anisotropy, bridging the behavior of spherical ABPs and elongated dumbbells.
Preliminary results reveal a rich phase behavior at intermediate dimer bond lengths [4], with the appearance of rotator and oriented crystals, besides to low-symmetry phases such as hexatic liquids and phases with quasi-long-range nematic order, whose properties are strongly influenced by the presence of topological defects, representing singular points in the order of the phase. Our research highlights how particle anisotropy provides a unifying control parameter that links classical phase transitions to active MIPS, offering new insight into the interplay of geometry, self-propulsion, and collective organization in determining phase transitions and materials properties in dense active matter systems.


**Keywords:**
Active Phase Transitions, Non-equilibrium Systems, Hexatic Liquids, State Diagrams, Coarse-grained Modeling


*State diagrams of active Brownian particles (a) and active dumbbells (c). (b) Model of rigid dimers with variable bond length and a self-propelling force directed along the axis, interpolating smoothly between the limiting cases (a) and (c). Panels (a) and (c) are readapted from [1] and [3].*


**References:**

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