Active matter at high density

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Active matter is a rapidly growing field that has potential applications to biological systems from the organism scale to the sub-cellular level. A key outstanding question relevant especially to biological tissues remains the behaviour of active particle systems at high density. In an effort to map the fundamental properties of dense active materials, we perform a numerical study of a dense collection of self-propelled particles with soft repulsive interactions in two dimensions. Incorporating self propulsion as a force and alignment as a torque into fully overdamped equations, our model is an appropriate template for active colloids and similar systems.

In a first system with alignment, we observe an active jammed phase at high density and low self-propulsion speed (Figure 1, left). The dynamics of this phase is controlled by the low-frequency modes of the underlying jammed packing, in a reverse fluctuation cascade from the microscale to global oscillations.

The non-aligning system was recently shown to exhibit active phase separation in two dimensions in the absence of any attractive interaction or breaking of the orientational symmetry. We construct a phase diagram in terms of activity and packing fraction and identify three distinct regimes: a homogeneous liquid with anomalous cluster size distribution, a phase-separated state both at high and at low density, and a frozen glassy phase with fluctuations resembling dynamical heterogeneities and shear flow.

We develop scaling arguments for the melting transition and for the boundaries separating the liquid and the cluster phase in both the low and high density regions.

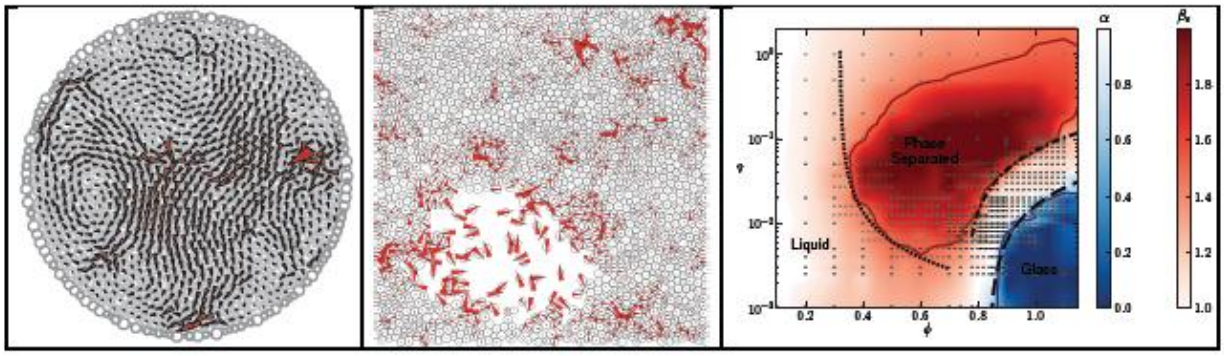

Figure 1: Simulated dense active systems. Left: Confined aligning system in the active jammed phase, red arrows represent particle velocity. Middle: High density clustering phase for the non-aligning system. Right: Phase diagram in the packing fraction and self propulsion axes for the non-aligning system, showing the locations of the glassy phase (blue) and the clustering phase (deep red).