Glassy dynamics and jamming in persistent active matter

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In several biological systems, such as bacterial cytoplasm, cytoskeleton-motor complexes and epithelial sheets of cells, self-propulsion or activity is found to fluidize a glassy state that exhibits characteristic glassy features in the absence of activity. Recent experiments on dense systems of Janus colloids and vibrated granular systems have provided detailed information about how activity affects glassy dynamics and jamming. To develop a theoretical understanding of these non-equilibrium phenomena, we have studied, using molecular dynamics and Brownian dynamics simulations, the effects of activity in several model glass-forming liquids. The activity in these systems is characterized by two parameters: the magnitude of the self-propulsion force and its persistence time. If the persistence time is short, then the observed behavior is similar to that near the usual glass transition in passive systems. The introduction of activity reduces the glass transition temperature and decreases the kinetic fragility. Some of these effects can be understood from a generalization of the Random First Order Transition (RFOT) theory of the glass transition to active systems. For large but finite persistence times, the approach to dynamical arrest at low propulsion force goes through a phase characterized by intermittency. This intermittency is a consequence of long periods of jamming followed by bursts of plastic yielding, akin to the response of dense amorphous solids to an externally imposed shear. In the limit of infinite persistence time, the homogeneous liquid state obtained for large values of the active force and no thermal noise exhibits several unusual properties: the average kinetic energy and the width of the distribution of the kinetic energy increase with increasing system size and a length scale extracted from spatial velocity correlations increases with system size without showing any sign of saturation. This active athermal liquid evolves to a force-balanced jammed state when the self-propulsion force is decreased below a threshold value that depends on the system size. The jamming proceeds via a three-stage relaxation process whose timescale grows with the magnitude of the active force and the system size. We relate the dependence of this timescale on the system size to the large correlation length observed in the liquid state. Some of the properties of the jammed state obtained for small active force are substantially different from those of passive jammed systems. In particular, the distribution of the magnitude of contact forces in the jammed state near the jamming threshold is found to exhibit a gap for small values.

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