Active particles stabilise emulsions of phase-separating mixtures

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Binary mixtures (BMs) that phase separate *via* Ostwald ripening exhibit a monotonic droplet growth following the power law[1] $R(t) \sim t^{\alpha}$, with the equilibrium morphology achieved in macrophase separation. Active particles (APs), are intrinsically out-of-equilibrium, consuming energy to produce work, commonly self-propulsion. Using a hybrid discrete/continuous diffusive simulation model, it is found that non-surfactant APs can arrest phase separation, inducing an activity-stabilised emulsification of the BM and preventing complete demixing. The rich steady-state phase behaviour includes isotropic droplets with a well-defined characteristic size, and hexatic order (see Fig. 1).

The mechanism of emulsification is found to be due to the global active pressure exerted by the APs onto the BM interface. Despite APs being completely solvable in one of the BM phases, activity leads to their accumulation at interfaces, where the competition between the active pressure and the surface tension of the BM leads to the arrest in the droplet size growth. A rich reentrant phase behaviour is found for higher activity rates leading firstly to unstable droplets with anisotropic shape, and finally to de-coupling between APs and the BM dynamics.
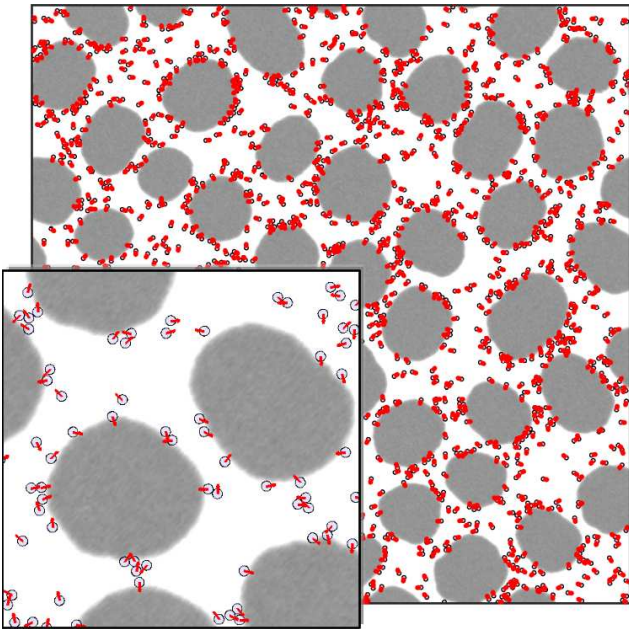
Conversely, APs can destabilise macrophase-separated BMs. The active energy provided by the APs' work can drive an equilibrated BM away from its equilibrium configuration, resulting in the same steady state morphologies as BM phase-separating after a quench. This highlights the rich emergent behavior of systems composed of active and passive elements and its relationship with the equilibrium morphologies[2].

Fig. 1. Active particles accumulate at the binary mixture interface and exter active pressure, stabilising the emulsion morphology.

[1] Lifshitz, I.M. and Slyozov, V.V., 1961. The kinetics of precipitation from supersaturated solid solutions. Journal of physics and chemistry of solids, 19(1-2), pp.35-50.

[2] Bechinger, C., Di Leonardo, R., Lwen, H., Reichhardt, C., Volpe, G. and Volpe, G., 2016. Active particles in complex and crowded environments. Reviews of Modern Physics, 88(4), p.045006.