Supplementary information

A theory for the phase behavior of mixtures of active particles

Sho C Takatori and John F Brady

Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California 91125, USA

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Description of videos

We conducted Brownian dynamics (BD) simulations of a mixture of active and passive Brownian particles, whose dynamics are governed by the N-particle Langevin equations (see Appendix A of main text). In the simulations we varied the total area fraction ϕ (active plus passive particles), the active particle composition x_a, and the reorientation Péclet number $Pe_R \equiv a/(U_0\tau_R)$ which is a ratio of the swimmer size a to its run length $U_0\tau_R$. As shown in the phase diagrams in the main text, Pe_R is a key parameter controlling the phase behavior of active systems. We have assumed that swimmer reorientation is thermally induced so that the translational and reorientational diffusivities are related via the Stokes-Einstein-Sutherland expressions: $(D_0/a^2)/\tau_R = 4/3$. This is not a requirement; one can also vary independently a swim Péclet number, $Pe_s \equiv U_0 a/D_0$, in addition to Pe_R.

The attached videos are BD simulations with active and passive particles of equal size shown in red and white circles, respectively. The active swimmers have $Pe_R = 0.01$ and the active composition is fixed at $x_a = 0.05$. The first and second videos show the total area fraction for $\phi = 0.35$ and $\phi = 0.6$, respectively.

In both videos, the active swimmers create tunnels in the sea of passive particles, which open a path for other trailing swimmers to move through. This leads to the formation of large clusters composed of purely passive particles and individual swimmers moving in the dilute phase. These observations agree with the recent experiments of Kümmel et al. For $\phi = 0.35$ we see that the passive Brownian particles have sufficient time to "melt" from the crystal before being pushed back into it by an active swimmer. In contrast, for $\phi = 0.6$ the large clusters remain compressed due to the frequent collisions between the particles. Based upon our mechanical theory and phase diagrams (Figs. 5 and 6), there is an equality between the Brownian collisional pressure of the dense passive clusters and the swim pressure of the dilute active swimmers compressing the crystals.