Active microswimmers in nematic liquid crystals and liquid-crystalline order in crowds of microswimmers

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Active, self-propelled microswimmers can be generated artificially in the form of colloidal Janus particles that are self-driven by phoretic effects, or they are found in nature in the form of living bacteria or algal cells featuring an active propulsion mechanism [1].

Introducing reduced minimal models of such objects, we, on the one hand, study their swimming behavior in well-aligned nematic liquid crystals by analytical calculations [2]. Depending on the viscosity ratios of the nematic liquid crystal and the propulsion mechanism, we find alignment parallel or perpendicular to the nematic director, see figure 1 (a). Consequently, by adjusted director configurations or switching of the nematic director, individual microswimmers can be guided along a requested path.

On the other hand, we analyze the collective behavior and liquid-crystalline ordering in crowds of many interacting self-driven microswimmers [3,4]. Particularly, we concentrate on a situation in which these swimmers are spherically confined. As a consequence of selfpropulsion, each swimmer sets the surrounding fluid into motion, which affects all other swimmers. Remarkably, this so-called hydrodynamic coupling can lead to polar alignment of the microswimmers by spontaneous symmetry breaking, implying induced net fluid flows and also collective motion, see figures 1 (b) and (c). Additionally, we have studied the collective dynamics when the swimming trajectories show a persistent bending in the case of biaxial microscopic circle swimmers, resulting in collective chiral behavior [4].

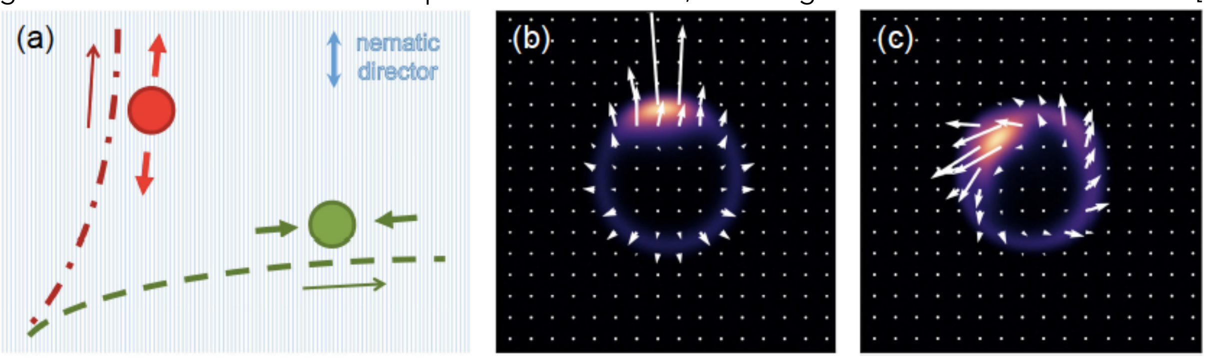

Figure 1: (a) Simplified active model microswimmers in an aligned nematic liquid crystal. Depending on the viscosity ratios and propulsion mechanism, the swimmers either align parallel to or propagate perpendicularly to the nematic director [2]. (b) Interacting microswimmers in an isotropic fluid under spherical confinement show polar ordering of their self-propulsion directions as a result of hydrodynamic interactions (brighter color reflects higher density, while white arrows indicate local swimmer orientations) [4]. (c) Increasing the active drive of self-propulsion, collective motion of the polarly ordered microswimmers around the confinement arises [4].

The next step shall be to combine these two situations and analyze the collective behavior and emergent liquid-crystalline order in crowds of active microswimmers suspended in aligned nematic liquid crystals.

References

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