Dynamics of Colloids in Liquid Crystals

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Behavior of small particles in fluids has fascinated scientist for centuries. Phenomena such as Brownian motion, sedimentation, and electrophoresis continue to inspire cutting-edge research and innovation. The fluid in which the colloidal particles move is typically isotropic, such as water or a dilute polymer solution. There is a growing interest to the dynamics of colloids in crowded environments with some elements of order. As a model system, we explore colloidal dynamics in a nematic liquid crystal. Orientational order of the liquid crystal leads to long-range elastic interactions that dramatically alter static behavior of the colloids (*1*) and support their levitation (*2*). Equally strong changes are seen in the dynamics. The liquid crystalline environment enables anomalous Brownian diffusion (*3*) and new mechanisms of electrokinetics with nonlinear (quadratic) dependence of flow velocities on the applied electric field (*4*). Addition of swimming bacteria to a non-toxic liquid crystal creates an experimentally controlled active system, which exhibits a cascade of transitions from equilibrium to non-equilibrium orientational patterns triggered by an increase of activity (*5*). Patterned director fields (*6*) including those with topological defects (*7*) control the threshold and polarity of active flows and spatial distribution of microswimmers (*8*). The new phenomena are rooted in anisotropy of the liquid crystals properties, such as surface tension, viscosity and elasticity, dielectric permittivity and conductivity (*2*).

1. P. Poulin, H. Stark, T. C. Lubensky, D. A. Weitz, Novel colloidal interactions in anisotropic fluids. *Science* **275**, 1770 (1997).
2. O. D. Lavrentovich, Active colloids in liquid crystals. *Curr Opin Colloid In* **21**, 97 (2016).
3. T. Turiv *et al.*, Effect of Collective Molecular Reorientations on Brownian Motion of Colloids in Nematic Liquid Crystal. *Science* **342**, 1351 (2013).
4. O. D. Lavrentovich, I. Lazo, O. P. Pishnyak, Nonlinear electrophoresis of dielectric and metal spheres in a nematic liquid crystal. *Nature* **467**, 947 (2010).
5. S. Zhou et al, Living liquid crystals. *P Natl Acad Sci USA* **111**, 1265 (2014).
6. R. Green, J. Toner, V. Vitelli, The geometry of threshold-less active flow in nematic microfluidics. *Arxiv*, 1602.00561 (2016).
7. L. Giomi et al, Defect dynamics in active nematics. *Philos T R Soc A* **372**, 20130365 (2014).
8. C. Peng et al, Command of active matter by topological defects and patterns. *Science* **354**, 882 (2016).