The hydrodynamic genesis of colloidal creatures

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Combining experiments, simulations and continuum models, we show that the strong hydrodynamic coupling between torque-driven particles, called microrotors, leads to the emergence of compact motile clusters, made of thousands of microrotors [1]. These “colloidal creatures” form an attractor of the system and demonstrate that self-assembly can be achieved without potential interactions.

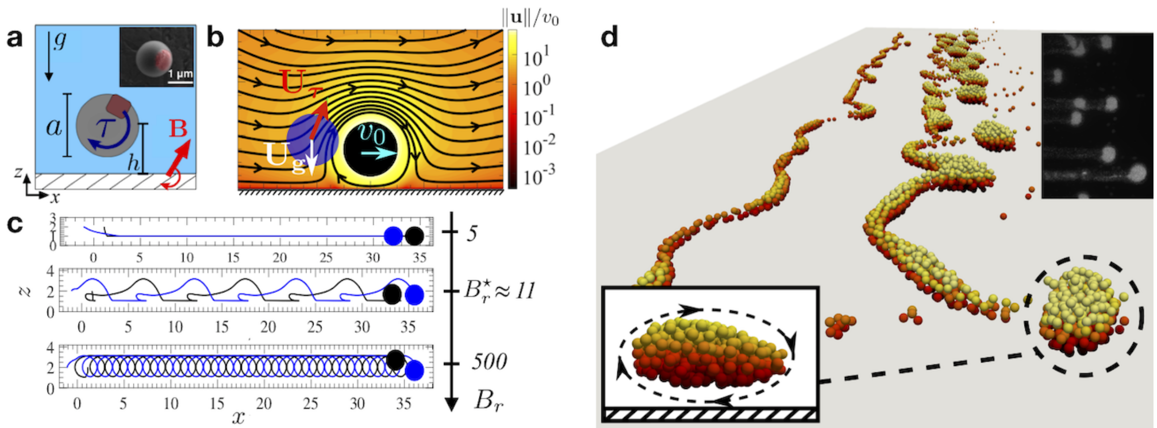

Figure 1. a, Sketch of a microrotor rotating above the floor. Inset : SEM image. **b**, Flow field around a microrotor (simulation). Colorbar : flow speed $\|\mathbf{u}\|$ normalized by the self-induced speed v_0. **c**, Trajectories of a pair of microrotors for $B_r = 5, 11$ and 500. **d**, Emergence of stable clusters from a fingering instability. Particle coloring : translational speed. Top inset : top view of experiments. Bottom inset : side view of a cluster.

Microrotors are suspended in a sealed chamber and sediment near the floor at an equilibrium height $h \approx 1\mu$m. They are rotated by a magnetic field, $\mathbf{B}$, rotating parallel to the floor (Fig. 1a). Hydrodynamic coupling plays a crucial role in the dynamics of this system. The self-induced speed of an isolated particle, v_0, is much smaller than the velocity it induces on neighboring particles : $\|\mathbf{u}\|/v_0 \gg 1$ (Fig. 1b). This strong coupling leads to hydrodynamic bound states whose existence is conditioned by a dimensionless number : $B_r = U_\tau/U_g = \tau/mga$, where τ is the magnetic torque and m the particle mass. When $B_r \gg 1$, the upward torque-induced flow, U_τ, can overcome downward gravity, U_g, and lead to periodic orbits (Fig. 1b). A dynamical system description for a pair of microrotors shows that there is a critical value, $B_r^\star \approx 11$, above which the pair exhibits a leapfrog limit cycle (Fig. 1c), whose basin of attraction increases with B_r [2]. When many particles are involved, these leapfrog orbits lead to the emergence of stable motile clusters, made of thousands of particles, translating at high speeds (Fig. 1d). A stability analysis shows that the width of these creatures is controlled by the wavelength of the fingering instability from which they detach. Our system offers promising applications for guided particle transport in microfluidic environments.

Références

1. Driscoll⋆, M., Delmotte⋆, B., Youssef, M., Sacanna, S., Donev, A., Chaikin, P. *Nat. Phys.*, 13(4), 375, 2017.
2. Delmotte, B. *Phys. Rev. Fluids*, 4(4), 044302, 2019.