Flipping and Bound Microswimmers

- *Dispersion of self-propelled rods undergoing fluctuation-driven flips,* Daisuke Takagi, Adam B. Braunschweig, Jun Zhang and Michael J. Shelley, Phys. Rev. Le*tt* **110**, 038301, 2013.
- *Hydrodynamic capture of microswimmers into sphere-bound orbits,* Daisuke Takagi, Jérémie Palacci, Adam B. Braunschweig, Michael J. Shelley and Jun Zhang*,* Soft matter **10,** 1784-1789, 2014.

Recommended with a commentary by Arezoo M. Ardekani, University of Notre Dame

In recent years, multiple studies have been conducted to investigate the dynamics of synthetic microswimmers exhibiting self-propelled swimming in order to gain insight regarding the behavior of active systems [1-2]. These microscopic active particles, not only provide a rigorous basis for the experimental study of the motility and hydrodynamic interaction of microorganisms in various environmental conditions, but also, thanks to their intrinsic simplicity, facilitate the investigation of collective behavior.

The paper titled "Dispersion of self-propelled rods undergoing fluctuation-driven flips" by Takagi *et al.* [3] reports a system made of Pt-Au rods that display a spontaneous swimming pattern in a solution of hydrogen peroxide serving as fuel. These Pt-Au rods, with a length of approximately 2 μm and a diameter of about 0.4 μm, are not always straight and may contain minor shape defects which interestingly affect their macroscopic trajectory and dispersion.

By considering a rod of a constant curvature and slip velocity along its surface, the authors explained the most intriguing trajectory of self-propelled rods, namely spontaneous switch between clockwise (CW) and counterclockwise (CCW) orbital trajectories. These flipping motions are the consequence of the proximity of the rods to the surface, which limits the rotational motion of curved rods. The rods can flip and switch sides only when their thermal fluctuations are large enough so that they can overcome the potential energy needed to lift their center of mass and rotate around the axis of the rod. The authors show that the flipping frequency, *f*, is directly proportional to the curvature ($\hat{k}$) of the rods:$f = f_0 \exp\left(-\frac{\hat{k}L^2}{24h_0}\right)$, where f_0 is the rotation rate around the axis of the straight rod, h_0 is the height from a base level, and L is the length of the rod. The long term effect of flipping on the dispersion of rods is nicely predicated using the Fokker-Planck equation including rotational and translational diffusivities and the results are in excellent agreement with the experimentally measured diffusion of the Pt-Au rods.

The same system consisting of Pt-Au rods is considered in the paper titled "Hydrodynamic capture of microswimmers into sphere-bound orbits" by Takagi *et al.* [4] with the objective of examining the short-range interaction of the rods with boundaries. The experimental setup consists of the self-propelling rods (with lengths of 1-4 μm) in hydrogen peroxide, interacting with spheres of diameters ranging from 1 to 125 μm. The authors showed that regardless of the size of the spheres and the rods and independent of the spheres' material, the self-propelled rods orbit around the passive spheres. The trapping time is affected by thermal fluctuations which can cause spontaneous flips, allowing the rods to escape their orbiting trajectories (Figure 1).

An important aspect in understand the trapping of the rods by the spheres is the evolution of the swimming velocity of the rods. The collected data by the authors shows that the rods maintain their bulk swimming speed in the proximity of the spheres, suggesting that the hydrogen peroxide concentration does not change in the confined space near the spheres. This is explained by the small Péclet number of the system, excluding the exhaustion of fuel beneath the sphere as a possible explanation for the capturing mechanism.

Monitoring marked spheres while rods are orbiting around them reveals that the spheres are not rotating because of the swimming of the rods. To justify the experimental observations, the authors developed a two-dimensional model based on lubrication theory and showed that microswimmers can be captured by obstacles without applying a net force or torque to them.

It is important to consider the strong hydrodynamic interactions between self-propelled and passive particles, discussed in this article, when using tracer colloids to quantify active systems.

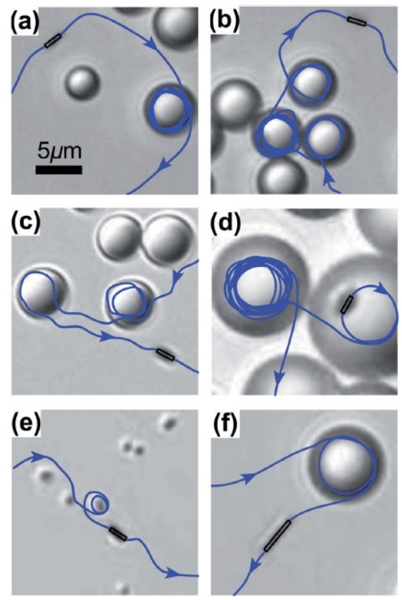

Figure 1. Trajectories of self-propelled rods orbiting around passive spheres of different size and material. Figure adapted from [4].

References:

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2. J.L. Moran and J.D. Posner, Electrokinetic locomotion by reaction induced charge auto-electrophoresis, *Journal of Fluid Mechanics*, **680**, 31-66, 2011.
3. D. Takagi, A.B. Braunschweig, J. Zhang, M.J. Shelley, Dispersion of self-propelled rods undergoing fluctuation-driven flips, *Physical Review Letters*, **110**, 038301, 2013.
4. D. Takagi, J. Palacci, A.B. Braunschweig, M.J. Shelley, J. Zhang, Hydrodynamic capture of microswimmers into sphere-bound orbits, *Soft matter*, **10**, 1784-1789, 2014.