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Optimal hydrodynamic synchronization of colloidal rotors

PIETRO CICUTA, JURIJ KOTAR, NICOLAS BRUOT, University of Cambridge, UK, LUKE DEBONO, STUART BOX, STEPHEN SIMPSON, DAVID PHILLIPS, SIMON HANNA, University of Bristol — Synchronization of driven oscillators is a key in flow generation in artificial and biological systems at the micro-scale. Flow can be driven efficiently by filaments undergoing periodic motion. These filaments are typically colloidal-scale and semi-flexible, and thus have many conformational degrees of freedom and are subject to thermal noise; in the case of biological cilia, they are driven in a complex fashion by internal molecular motors that induce bending. The question of synchronization is thus best addressed by simpler systems, such as individual driven spheres, in which the multiple degrees of freedom are coarse-grained into a few control parameters which can be tuned and understood theoretically, and in which the hydrodynamic interaction is readily described. The system of 'rotors' is considered here: spheres are driven along predefined trajectories, with a given force law. In this model it is possible to address quantitatively the conditions for hydrodynamic synchronization. Previous theoretical work pointed to the importance of two factors: modulation of the driving force around the orbit, or the deformability of the trajectory. We show via experiments, numerical simulations and theory that both factors are to be considered, and at play in biological systems.

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