Studies on Active Soft Matter: Model Hydrodynamic Synchronization and Targeted Delivery through Bacteria

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Active matter, matter with self-propelling constituents, has recently sparked the interest of the soft matter scientific community. Here we examine two aspects of active matter, hydrodynamic synchronization and rectification of thermal motion.

Hydrodynamic synchronization provides a general mechanism for the spontaneous emergence of coherent beating states in independently driven mesoscopic oscillators, such as cilia and flagella. We demonstrate that driving colloidal particles in rotating energy landscapes, experimentally by using holographic optical tweezers, results in a strong tendency towards synchronization, favoring states where all beads rotate in phase. The resulting dynamics can be described in terms of activated jumps with transition rates that are strongly affected by hydrodynamics leading to an increased probability and lifetime of the synchronous states. Exploiting motile micro-organisms for the transport of colloidal cargoes is a fascinating strategy to extract work from self-propelled entities. Here we experimentally show that properly designed three-dimensional micro-structures can delimit accumulation areas where bacteria spontaneously and efficiently spatially organize colloidal beads. The mechanism is solely stochastic in nature and results from the rectifying action of an asymmetric energy landscape over the fluctuating forces arising from collisions with swimming bacteria.

Besides the significance to technological applications, our experiments pose some important questions regarding the structure of stationary probability distributions in non-equilibrium systems. To address some of these issues, simulations employing varying classes of time-correlated noise have been employed, showing that the details of applied noises may significantly alter the steady state probability distributions over asymmetric barriers.