Motile Bacteria in 2D Complex Environments: A Statistical Physics Perspective

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We present our experimental work, in which we employ motile bacteria as 'active colloids' in complex environments to explore nonequilibrium statistical physics.

First, we investigate how the active motility of these 'colloids' affects their partitioning behavior between two immiscible phases in an aqueous two-phase system, reminiscent of a two-level system in statistical mechanics. While 'dead' colloids follow the Boltzmann distribution, active motility facilitates barrier crossing. Our optical tweezer experiments, where we drag the bacteria across these interfaces, further elucidate the crossing events associated with interfacial tension. We conclude this section by introducing our Smoluchowski-style interpretation of the experimental data.

Second, we address the trap-and-escape dynamics of a 'colloid' within a soft confinement generated by another colloid. A bacterium swimming in a viscoelastic, slowly relaxing polymeric environment leaves behind a transient polymer-depleted trail that can 'trap' another swimming bacterium. Combining fluorescence optical microscopy, rheometry, and statistical analysis, we explain our experimental observations, showing that a higher polymer concentration and a shorter time lag between the leading and trapped bacteria result in longer mean escape times.

[1] J. Cheon, K. H. Choi, K. J. Modica, R. J. Mitchell, S. C. Takatori, J. Jeong, Phys. Rev. Lett. 135 (12), 128401 (2025)