MAR14-2013-020694

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Bacteria as self-propelled liquid crystals: non-equilibrium clustering, polar order, collective motion, and aggregation

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Bacteria exhibit fascinating collective phenomena such as collective motion and aggregation. It is usually believed that such kind of collective effects require cells to coordinate their motion via chemotactic signaling. Despite of this common belief, I will show that in experiments with myxobacteria such collective effects emerge in absence of biochemical regulation, and even hydrodynamic interactions, and result from simple physical interaction among the motile bacteria. As proof of principle, I will show that collective phenomena such as collective motion and aggregation naturally emerge in models of simple self-propelled rods that interact by volume exclusion. Combining experiments and theoretical models, we will explain that the interplay of bacterial self-propulsion and steric interactions among the elongated bacteria leads to an effective velocity alignment mechanism (VAM). Such VAM allows cells to display a non-equilibrium clustering transition that marks the onset of collective motion. I will argue that even though the symmetry of the resulting VAM is clearly nematic, it induces, counter intuitively, polar order. Finally, I will show that by increasing the cell density, or alternatively the aspect ratio of bacteria, collective motion patterns become unstable, and cells form aggregates. In short, our results indicate that for bacteria moving on surfaces, the cell shape plays a crucial role in the bacterial self-organization process. By thinking of bacteria as self-propelled liquid crystals, we can explain complex behaviors such as collective motion and aggregation.

References: Peruani and Baer, NJP 15, 056009 (2013); Peruani et al. PRL 108, 098102 (2012); Interface Focus 2, 774 (2012); PRE 74, 030904 (2006).