Microswimmers:
From collective swimming patterns to smart navigation

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Active motion of biological and artificial microswimmers is relevant in the real world, in microfluidics, and biological applications but also poses fundamental questions in non-equilibrium statistical physics. Microswimmers interact by their self-generated flow fields and thereby show appealing dynamic patterns as a consequence of the non-equilibrium. A new development in the field is how microswimmers learn to navigate in a complex environment.

Using multi-particle collision dynamics, we simulate squirmer model swimmers and study how they behave under gravity. We find a variety of different phenomena depending on the ratio of swimming to bulk sedimentation velocity. Single squirmers can float or slide above the bottom wall. A collection of squirmers exhibits a very dynamic sedimentation profile with dense layering at the bottom and exponential decay towards the top, where large-scale convective flow arises. When they become bottom-heavy, they exhibit inverted sedimentation, convective plumes, and spawning clusters, while a single layer of squirmers under strong gravity shows different collective dynamics including "hydrodynamic Wigner fluids" and swarming.

At the end I show how smart microswimmers can use reinforcement learning to optimize their travel time in a potential landscape.