104th MSS-Seminar
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Nägelsbachstr. 49b

Hydrodynamics of Microswimmers: Phase-Separation and the Influence of Gravity

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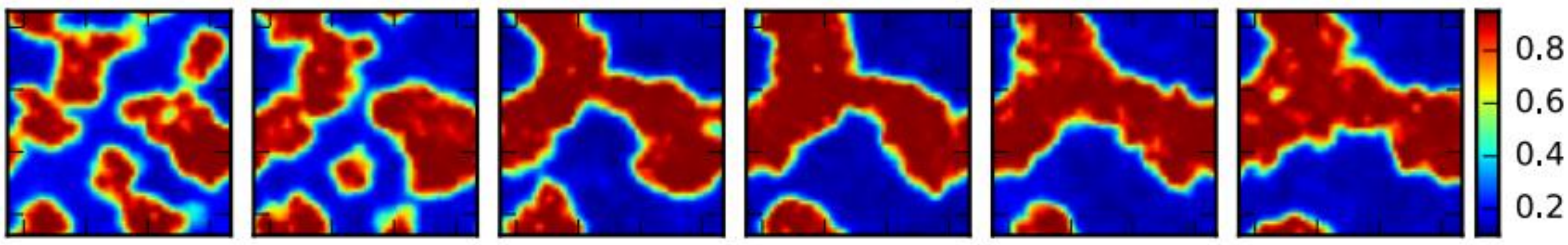

Figure 1: *Left to right: Temporal evolution of the local density function (cf. color bar).*

Active motion of microorganisms and artificial microswimmers is relevant both to real world applications as well as for posing fundamental questions in non-equilibrium statistical physics. Microswimmers are often modelled as active Brownian particles, neglecting hydrodynamic interactions between them. However, real microswimmers, such as ciliated microorganisms, catalytic Janus particles, or active emulsion droplets, employ propulsion mechanisms reliant on hydrodynamics. Therefore, we use the particle-based simulation method of multi-particle collision dynamics to explore the influence of hydrodynamics on the collective behavior microswimmers in a quasi-two-dimensional geometry [1] and on their motion under gravity. A striking feature of the collective behavior of spherical microswimmers is that for sufficiently strong self-propulsion they phase separate into dense clusters coexisting with a low-density disordered surrounding [2, 3]. Here we examine the influence of hydrodynamic interactions on this motility-induced phase separation [1, 4]. For a range of mean densities and Péclet numbers, we observe how the system decomposes into a dilute and a cluster phase, which then coarsens over time (cf. Fig. 1). The most striking difference with the phase diagram of active Brownian particles [2, 3] is that a larger mean density results in a lower density of the coexisting dilute phase, which is a clear signature of hydrodynamics. Furthermore, we find that pushers or pullers suppress phase separation by increasing the critical Péclet number. Inspired by experiments [5, 6] and theoretical work [7], we also examine collective dynamics in the presence of gravity. We observe a rich phenomenology, depending not only on the relativestrength of gravity but also on the long-range hydrodynamic interactions between swimmers and with the container's walls. For example, by carefully tuning sedimentation velocity close to selfpropulsion speed, squirmers are able to float above the bottom wall due to the height-dependent friction coefficient. Furthermore, a system of dense squirmers exhibits layering followed by an exponential sedimentation profile in agreement with experiments [5].

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