DY 14: Microswimmers (joint session DY/CPP)

Time: Monday 15:00–17:45 Location: ZEU 160

Invited Talk DY 14.1 Mon 15:00 ZEU 160

Microswimmers in (semi-)dilute suspensions: binary mixtures, trapping, orientational ordering, collective motion, and imposed shear flows — Christian Hoell, Giorgio Pessot, Hartmut Löwen, and •Andreas M. Menzel — Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany

Active microswimmers self-propel while setting the surrounding fluid into motion. This leads to hydrodynamic swimmer interactions and can enable emergent collective behavior. Extending our corresponding statistical characterization of (semi-)dilute microswimmer suspensions, we have derived a dynamical density functional theory to describe binary microswimmer mixtures [1]. First, we address mixtures of pushers and pullers of otherwise identical properties [1]. We find that the majority species hydrodynamically imposes its behavior onto the minority species, both under spherical confinement and for unbounded planar motion [1,2]. Particularly, this concerns emergent polar orientational order. Second, we consider trapped active microswimmers confined by a ring of driven passive particles [1]. Through resulting imposed hydrodynamic fluid flows, the enclosed microswimmers concentrate in a centered spot, mimicking the behavior of active circle swimmers [3]. Since frequently in nature many active species interact with each other under confinement, we consider our extensions essential on the path of statistically characterizing corresponding biological systems.

[1] C. Hoell et al., *J. Chem. Phys.* **151**, 064902 (2019).
[2] G. Pessot et al., *Mol. Phys.* **116**, 3401 (2018).
[3] C. Hoell et al., *New J. Phys.* **19**, 125004 (2017).

DY 14.2 Mon 15:30 ZEU 160

Fine balance of chemotactic and hydrodynamic torques: When microswimmers orbit a pillar just once — •Chenyu Jin[1,2], Jérémy Vachier[1], Soumya Bandyopadhyay[3], Tamara Macharashvili[4], and Corinna Maass[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany. — [2]University of Bayreuth, Bayreuth, Germany — [3]Purdue University, West Lafayette, USA — [4]Princeton University, Princeton, USA

Self-propelling liquid crystal droplets in an aqueous surfactant solution is an excellent model system for biological microswimmers: they exhibit chemotaxis and negative autochemotaxis, and they interact with boundaries. Here we study the detention statistics of these droplet microswimmers attaching to microfluidic pillars. The repulsive trail of spent fuel shed by themselves biases them to detach from pillars in a specific size range after orbiting the pillars just once. We have designed a microfluidic assay recording microswimmers in pillar arrays of varying diameter, derived detention statistics via digital image analysis, and interpreted these statistics via the Langevin dynamics of an active Brownian particle model. By comparing data from orbits with and without residual chemical field, we can independently estimate quantities such as hydrodynamic and chemorepulsive torques, chemical coupling constants and diffusion coefficients, as well as their dependence on environmental factors such as wall curvature. This type of analysis is generalizable to many kinds of microswimmers.

DY 14.3 Mon 15:45 ZEU 160

Active dynamics of microalgae in an anisotropic porous environment — •Florian von Rüling and Alexey Eremin — Otto von Guericke University Magdeburg

Understanding the motion of active colloids in porous media is essential for fundamental physics and a wide range of biological and medical applications. Cell growth and motion is often restricted by complex environments such as the cytoskeleton. Here, we report experimental studies on the motion of the unicellular microalgae Chlamydomonas reinhardtii through a flexible anisotropic lattice of chains formed by magnetic particles. In a thin cell or capillary, the microalgae interact with chain-like aggregates that form in a magnetic field. Shape-anisotropic structures guide the swimmers or initiate tumbling. They affect the persistence time of the microswimmer's motion. As the chains of magnetic particles disintegrate quickly after turning off the magnetic field, the system transforms into an unperturbed state. We investigate the effect of the chains on the orientational velocity correlations in the active dynamics of the algae.

DY 14.4 Mon 16:00 ZEU 160

Percolation transition of pusher-type microswimmers — •Fabian Jan Schwarzendahl[1,2] and Marco G. Mazza[2,3] — [1]Department of Physics, University of California, Merced,5200 N. Lake Road, Merced, California 95343, USA — [2]Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany — [3]Interdisciplinary Centre for Mathematical Modelling and Department of Mathematical Sciences,Loughborough University, Loughborough, Leicestershire LE11 3TU, United Kingdom

In this talk I will present the presence of a continuum percolation transition in model suspensions of pusher-type microswimmers. The clusters dynamically aggregate and disaggregate resulting from a competition of attractive and repulsive hydrodynamic and steric interactions. As the microswimmers' filling fraction increases, the cluster size distribution approaches a scale-free form and there emerge large clusters spanning the entire system. We characterize this microswimmer percolation transition via the critical exponents, analytical arguments, and scaling relations known from percolation theory. This finding opens new vistas on microswimmers' congregative processes.

DY 14.5 Mon 16:15 ZEU 160

Self-assembling complex and functional structures at the (sub)millimeter scale — •Nicolas Vandewalle — GRASP, Institut de Physique B5a, Sart Tilman, Universite de Liege, B4000 Liege, Belgium

When soft ferromagnetic particles are suspended at air-water interfaces in the presence of a vertical magnetic field, dipole-dipole repulsion competes with capillary attraction such that structures self-assemble. The complex arrangements of such floating bodies are emphasized. By adding a horizontal and oscillating magnetic field, periodic deformations of the assembly are induced. We show herein that collective particle motions induce locomotion at low Reynolds number. The physical mechanisms and geometrical ingredients behind this cooperative locomotion are identified. These physical mechanisms can be exploited to much smaller scales, offering the possibility to create artificial and versatile microscopic swimmers. Moreover, we show that it is possible to generate complex structures that are able to capture particles, perform cargo transport, fluid mixing, etc...

15 min. break.

DY 14.6 Mon 16:45 ZEU 160

Shape-anisotropic microswimmers: Influence of hydrodynamics — •Arne W. Zantop and Holger Stark — Institute of Theoretical Physics, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Constituents of active matter, e.g. bacteria or active filaments, are often elongated in shape. The shape and the stiffness of the active components clearly influence their individual dynamics and collective pattern formation. On length scales much larger than the size of the constituents, active materials exhibit many fascinating phenomena such as the formation of vortices or turbulent structures [1,2]. To identify how steric and hydrodynamic interactions as well as thermal fluctuations influence collective behavior is subject of current research.

In this context, we model shape-anisotropic microswimmers with rod shape by composing them of overlapping spherical squirmers [3]. We simulate their hydrodynamic flow fields using the method of multi-particle collision dynamics. With increasing aspect ratio of the rods, we find that a force quadrupole moment dominates the hydrodynamic flow field, whereas in quasi-2D confinement between two parallel plates (Hele-Shaw geometry) the far field is determined by a two-dimensional source dipole moment. Investigating the collective dynamics of the squirmer rods, we identify with increasing density and aspect ratio of the rods a disordered, a swarming, and a jamming state.

[1] Dunkel *et al.*, PRL 110.22 (2013): 228102.
[2] Wensink *et al.*, PNAS 109.36 (2012): 14308-14313.
[3] Downton *et al.*, J. of Ph.: Cond. Mat. 21.20 (2009): 204101.

DY 14.7 Mon 17:00 ZEU 160

Chemokinesis causes trapping and avoidance by dynamic scattering — •Justus Kromer — Stanford University, Stanford, United States of America

A minimal control strategy for artificial microswimmers with limited information processing capabilities is chemokinesis: the regulation of random directional fluctuations or speed as function of local, non-directional cues. In contrast to chemotaxis, it is not well understood whether chemokinesis is beneficial for the search for hidden targets.

We present a general theory of chemokinetic search agents that regulate directional fluctuations according to distance to a target. We characterize a dynamic scattering effect that reduces the probability to penetrate regions with strong directional fluctuations. If the target is surrounded by such a region, dynamic scattering causes beneficial inward-scattering of agents that had just missed the target, but also disadvantageous outward-scattering of agents approaching the target for the first time. If agents respond instantaneously to positional cues, outward-scattering dominates and chemokinetic agents perform worse than simple ballistic search. Yet, agents with just two internal states can decouple both effects and increase the probability to find the target significantly. Interestingly, these agents violate a mean-chord-length theorem. We apply our analytical theory to the biological example of sperm chemotaxis of marine invertebrates. Sperm cells need to pass a 'noise zone' surrounding the egg, where chemokinesis masks chemotaxis.

Kromer et al. arXiv:1904.11020

DY 14.8 Mon 17:15 ZEU 160

Feedback Control of Multiple Active Microswimmers — •Alexander Fischer and Frank Cichos — Uni Leipzig

Collective motion created by the interaction of autonomous individuals plays a major role in flocks of birds, bacterial growth or the motion of robotic swarms. Sensing and reacting to signals is a fundamental issue of life. Microswimmers, which are artificial objects that mimic the active motion of biological systems, do not have such sensing and response features built in yet, but may gain them through an external control of their propulsion. Here we explore the emergent collective behavior as a result of an information exchange between artificial microswimmers by computer-controlled feedback processes. We have created a setup where multiple active microswimmers can react to their position in space or their distance to other microswimmers [1]. Our system consists of autonomous agents performing directed motion in a plane and their orientation is subject to noise. We study in particular the delayed response of the swimmers to environmental signals, where the swimmers remember previous information on a signaling landscape or infer future signals from the experience. We find that this type of delayed response is changing the collective behavior.

[1] U. Khadka, V. Holubec, H. Yang, F. Cichos, Nat. Commun. 9, 3864 (2018)

DY 14.9 Mon 17:30 ZEU 160

Viscosity destabilizes the propulsion dynamics of active droplets — •Babak Vajdi Hokmabad[1], Maziyar Jalaal[2], Ranabir Dey[1], Kyle Baldwin[1,3], Detlef Lohse[1,2], and Corinna Maass[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Physics of Fluids Group, Max Planck Center for Complex Fluid Dynamics, Enschede, The Netherlands — [3]Nottingham Trent University, Nottingham, United Kingdom

Biological micro-organisms have developed sophisticated swimming behaviors such as run-and-tumble or switch-and-flick. These complex functions depend on their complicated biophysical machinery. In efforts to develop artificial micro-swimmers, the aim is to build a minimal system based on the principles of out-of-equilibrium physics that is able to mimic such complex behaviors. In this work, we show that an active droplet, undergoing micellar solubilization, experiences unsteady self-propulsion in response to an increase in the viscosity of the swimming medium. The origins of this seemingly counterintuitive behavior is explained using theory in conjunction with a novel experimental technique to simultaneously visualize the hydrodynamic and chemical fields around the droplet. By varying the viscosity we can tune the propulsion dynamics and observe behaviors reminiscent of natural micro-swimmers.