

DY 36: Microswimmers and Microfluidics (joint session DY/BP/ CPP)

Time: Thursday 15:00–17:45

Location: H37

Invited Talk

DY 36.1 Thu 15:00 H37

Light-Driven Manipulation of Passive and Active Microparticles — ●SVETLANA SANTER — Institute of Physics and Astronomy, University of Potsdam, Germany

Chemical gradient near a solid/liquid can result in lateral long-range fluid transport termed diffusioosmotic (DO) flow. For instance, when photosensitive surfactant is irradiated with light converting the majority of the molecules in one of the possible isomers, emerging concentration gradient of isomers generates an osmotic pressure gradient tangent to the wall actuating the surrounding liquid to flow. [1-3] In my talk I will show how one can manipulate microparticles and even induce their self-propulsion by light utilizing light driven diffusioosmotic (LDDO) phenomenon. Depending on the applied wave length one can either disperse/remove or gather particles. We will discuss how to establish light-driven hydrodynamics as a useful and versatile tool for investigating collective motion of self-propelled particles and aggregation

[1] Feldmann, D.; Maduar S.R.; Santer, M.; Lomadze, N.; Vinogradova O.I.; Santer, S. *Scientific Reports*, 6 (2016) 36443. [2] Santer, S. *J. Phys. D: Applied Physics*, 51 (2017) 013002. [3] Arya, P.; Umlandt, M.; Jelken, J.; Feldmann, D.; Lomadze, N.; Asmolov, E. S.; Vinogradova, O. I.; Santer, S. A. *The European Physical Journal E*, 44(50) (2021), 1-10.

DY 36.2 Thu 15:30 H37

Regulated polarization of active particles in local osmotic flow fields — ●LISA ROHDE, DESMOND QUINN, DIPTABRATA PAUL, and FRANK CICHOS — Molecular Nanophotonics Group, Peter Debye Institute for Soft Matter Physics, University Leipzig, Leipzig, Germany

Regulation in living systems is a fundamental principle for achieving robust functionality and maintaining specific non-equilibrium states. The control of certain properties and functionalities of systems on the microscale presents particular challenge since thermal fluctuations and environmental perturbations dominate. While synthetic active matter has demonstrated remarkable self-organization capabilities, examples of autonomous regulation processes at the single-particle level remain scarce. Here, we show experimentally that the interplay of two non-equilibrium processes leads to a regulated polarization state of active particles in local osmotic flow fields. Based on thermophoretic repulsive and attractive forces that are generated by a single heat source at the boundary, the active particles encircle the heat source at a stable distance depending on the heat source temperature. The balance of these temperature-induced processes causes a polarization of the active particles that is independent of the heat source temperature. The individual control of heat source and active particles in the experiment allows detailed investigation of the self-regulated polarization effect in which we find hydrodynamic interactions to dominate. As the effects rely on osmotic flows and phoretic interactions, we expect that the observed phenomena can be generalized to other active systems and flow fields.

DY 36.3 Thu 15:45 H37

Active particle steering in three dimensions — ●GORDEI ANCHUTKIN and FRANK CICHOS — Molecular Nanophotonics Group, Peter Debye Institute for Soft Matter Physics, Leipzig University, Leipzig, Germany

Synthetic active particles serve as a model system that mimic the self-propulsion of living matter to explore fundamental aspects of non-equilibrium physics. Various collective phenomena of active agents have been studied, but mostly in the presence of hydrodynamic and physicochemical boundary effects. While theoretical works predict different collective dynamics in 3D, experimental investigations remain limited due the lack of experimental control over active swimmers in three dimensions.

Here we introduce three-dimensional control to the study of synthetic active matter. We demonstrate simultaneous control of thermophoretic microswimmers in 3D using single-particle tracking through digital holography and darkfield pattern tracking, with real-time wavefront shaping for steering. With the help of these experiments, we explore the interplay of thermophoretic propulsion, gravity, and optical forces for the active particles. By creating a three-dimensional active ensemble, we reveal how bulk interactions and

boundary effects shape the collective behavior of active particles.

DY 36.4 Thu 16:00 H37

Trypanosoma brucei in microchannels: the role of constrictions — ●ZIHAN TAN, JULIAN I. U. PETERS, and HOLGER STARK — Institute of Theoretical Physics, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Trypanosoma brucei (*T. brucei*), a single-celled parasite and natural microswimmer, is responsible for the fatal sleeping sickness in infected mammals, including humans. Understanding how *T. brucei* interacts with fluid environments and navigates through confinements is crucial for elucidating its movement through blood vessels and tissues, and across the blood-brain barrier.

Using a hybrid multiparticle collision dynamics (MPCD)–molecular dynamics (MD) approach, we investigate the locomotion of an in-silico *T. brucei* in three types of fluid environments: bulk fluid, straight cylindrical microchannels, and microchannels with constrictions. We observe that the helical swimming trajectory of the in-silico *T. brucei* becomes rectified in straight cylindrical channels compared to bulk fluid. The swimming speed for different channel widths is governed by the diameter of the helical trajectory. The speed first slightly increases as the channel narrows and then decreases when the helix diameter is compressed. An optimal swimming speed is achieved when the channel width is approximately twice the bulk helix diameter. Furthermore, *T. brucei* notably slows down when entering the narrow constriction in a microchannel and strongly speeds up upon exiting due to a release of deformation energy of the straightened cell body.

DY 36.5 Thu 16:15 H37

Helical motion of microorganisms can be more persistent than straight motion — ●LEON LETTERMANN¹, FALKO ZIEBERT¹, MIRKO SINGER², FREDDY FRISCHKNECHT², and ULRICH S. SCHWARZ¹ — ¹BioQuant & Institute for Theoretical Physics, Heidelberg University — ²Center for Integrative Infectious Disease Research, Heidelberg University

The movement of microorganisms has been extensively modeled by stochastic active particle models. In three dimensions, both swimming microorganisms, like sperm cells and some bacteria, and gliding microorganisms, like malaria sporozoites in the skin, often exhibit helical trajectories. If the internal driving force is the primary source of noise in the system, it induces random, yet time-correlated variations in the torque. To investigate this effect, we introduce a three-dimensional active rotational Ornstein-Uhlenbeck particle model. We find that the presence of a rotational component and the resulting helical path can mitigate the effect of intrinsic noise in the drive, allowing for larger long-time mean square displacements than straight movement at the same speed. The model not only provides qualitative insights into the constraints faced by microbes that may have led to the evolutionary selection of certain motility patterns, but also presents an analytical, quantitative tool for extracting information from these movements. We present and analyze corresponding data for malaria parasites gliding through hydrogels.

15 min. break

DY 36.6 Thu 16:45 H37

Corrugated channels can filter ciliated microorganisms based on the metachronal wavelength — ●GONÇALO ANTUNES and HOLGER STARK — Technische Universität Berlin, Institute of Theoretical Physics, Hardenbergstr. 36, 10623 Berlin, Germany

Many microorganisms (e.g. Paramecium) move by a carpet of cyclically beating cilia that cover their surface. These cilia often beat in an organized fashion, such that the beating phases form a traveling wave, referred to as a metachronal wave. In this study, we investigate the swimming of such microorganisms in corrugated microchannels. We model the motion of the cilia via a time-varying effective slip velocity applied on the microorganism's surface, which we approximate as an infinite slab. By employing the lubrication approximation, we show analytically that the swimming speed of ciliated microorganisms placed inside a corrugated channel is sensitive to the corrugation height, provided that the wavelength of the corrugation matches that of the metachronal wave. Indeed, the direction of motion itself may

invert with respect to swimming in bulk fluid, with the channel acting as a virtual barrier which blocks microorganisms under specific conditions for corrugation and slip-velocity modulations, but allow others to pass through. We also show that the interplay between the corrugation and the slip velocity profile allows for the swimming of microorganisms with zero time-averaged slip velocity, which thus cannot swim in bulk fluid. Finally, we complement our theory with preliminary results from hydrodynamic simulations for radially-symmetric microorganisms of finite length in radially-symmetric corrugated channels.

DY 36.7 Thu 17:00 H37

Motion of a single particle partially exposed in a simple shear flow — ●DOMINIK GEYER^{1,2}, AOUANE OTHMANE¹, and JENS HARTING^{1,2} — ¹Helmholtz-Institut Erlangen-Nürnberg for Renewable Energy (IET-2), FZ Jülich — ²Department of Physcis, FAU Erlangen-Nürnberg

Sand immersed in the water can be imagined as a wet granular matter. Besides sedimentation, friction, and surface roughness are two relevant physical phonemes within this system. Many body systems in a turbulent regime have been studied using discrete elements methods for a long time, but a single particle in the Stokes flow regime is particularly interesting for biological systems and microfluidic devices.

A layer of quadratic-arranged spheres models the rough surface. The question arises of how to describe the motion of a single traveling particle over this substrate.

We choose a combined numerical and analytical approach. The Stokes equation is solved analytically for the sphere near a rough wall. Lattice Boltzmann simulations with momentum-exchange particle coupling are performed for different wall roughness and friction coefficients.

Although, the Stokes equation assumes that the particle Reynolds number is zero. Surprisingly, the numerical results match our theoretical description until a particle Reynolds number of two. In this regime, friction between the moving particle and the substrate significantly influences the angular velocity but has a minor influence on the traveling velocity in the flow direction.

DY 36.8 Thu 17:15 H37

Rational Design of Smart Microfluidics in Responsive Channels — ●ARWIN MARBINI — Albert-Ludwigs Universität Freiburg

Responsive microfluidics offers exciting potential for self-regulating biomimetic systems. This study explores bifurcating microchannel networks with pressure-sensitive resistances, combining experiments with simulations based on the Hagen-Poiseuille equation and a linear model. These methods extract critical, experimentally inaccessible parameters under steady-state and dynamic conditions. Our findings enable the design of adaptable microfluidic networks, unlocking precise flow control for future applications in biology, soft robotics, and advanced material systems.

DY 36.9 Thu 17:30 H37

Blue Water: A passive, reusable microfiltration device for water purification — ●TIM R. BAUMANN, IOANNIS GKEKAS, MARTINA VIEFHUES, and DARIO ANSELMETTI — Experimental Biophysics, Bielefeld University

Water is the most vital resource for life on Earth. Due to pollution of freshwater and oceans, this valuable resource has become globally endangered. The effects of microplastic pollution are widely discussed in scientific, political, and socioeconomic contexts. Despite regulations on single-use plastics and microplastic output, efforts should also focus on reintegrating microplastics to achieve a sustainable circular economy. Furthermore, microplastic-sized particles can migrate through organic tissue and can therefore be classified as contaminants of emerging concern. However, filtering plastics of this size is a challenging task.

Thus, this work examines and extends the findings of Divi et al. regarding the suspension feeding mechanisms of various ray species. We studied the filtration performance and efficiency for different geometric ratios of channel widths in simulations and laboratory environments. First, we have the main inner channel connected to the pressure inlet. From this, two rows of tilted lamellae structures branch off laterally to the outer secondary channels.

By applying sufficiently high pressure ($> 6 \cdot 10^5 Pa$) to the inlet and achieving flow and particle velocities of $> 35 \frac{m}{s}$, we can purify 82 % of half of the initial fluid. To prevent rupturing of our microfluidic chip under this pressure, we further investigated using glass fiber reinforced PDMS and lowering the operating pressure.