CPP 35: Microswimmers and Microfluidics (joint session DY/BP/CPP)

Time: Thursday 15:00–17:45   Location: H37

Invited Talk   CPP 35.1   Thu 15:00   H37
**Light-Driven Manipulation of Passive and Active Micropar-
ticles** — •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 ma-
jority of the molecules in one of the possible isomers, emerging con-
centration 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 urtilizing light driven diffusioos-
motic (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.; Vino-
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S. J. Phys. D: Applied Physics, 51 (2017) 013002. [3] Arya, P.; Um-
landt, 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.

CPP 35.2   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 In-
stitute 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 repul-
sive 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 ac-
tive 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.

CPP 35.3   Thu 15:45   H37
Active particle steering in three dimensions — •Gordei An-
chutkin and Frank Cichos — Molecular Nanophotonics Group, Pe-
ter 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 dif-
ferent 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 syn-
thetic 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 experi-
ments, we explore the interplay of thermophoretic propulsion, grav-
ity, 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.

CPP 35.4   Thu 16:00   H37
***Trypanosoma brucei* in microchannels: the role of constric-
tions** — •Zihan Tan, Julian I. U. Peters, and Holger Stark —
Institute of Theoretical Physics, Technische Universität Berlin, Hard-
enbergstr. 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. bru-
cei* 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.

CPP 35.5   Thu 16:15   H37
**Helical motion of microorganisms can be more persistent
than straight motion** — •Leon Lettermann[1], Falko Ziebert[1],
Mirko Singer[2], Freddy Frischknecht[2], and Ulrich S. Schwarz[1]
— [1]BioQuant & Institute for Theoretical Physics, Heidelberg Univer-
sity — [2]Center 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 mi-
croorganisms, 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

CPP 35.6   Thu 16:45   H37
**Corrugated channels can filter ciliated microorganisms based
on the metachronal wavelength** — •Gonçalo Antunes and Hol-
ger Stark — Technische Universität Berlin, Institute of Theoretical
Physics, Hardenbergstr. 36, 10623 Berlin, Germany

Many microorganisms (e.g. Paramecium) move by a carpet of cycli-
cally 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 investi-
gate the swimming of such microorganisms in corrugated microchan-
nels. We model the motion of the cilia via a time-varying effective
slip velocity applied on the microorganism's surface, which we approx-
imate as an infinite slab. By employing the lubrication approximation,
we show analytically that the swimming speed of ciliated microorgan-
isms 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.

CPP 35.7   Thu 17:00   H37

Motion of a single particle partially exposed in a simple shear flow — •Dominik Geyer[1,2], Aouane Othmane[1], and Jens Harting[1,2] — [1]Helmholtz-Institut Erlangen-Nürnberg for Renewable Energy (IET-2), FZ Jülich — [2]Department 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.

CPP 35.8   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.

CPP 35.9   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.