DY 52: Poster: Active Matter, Microswimmer, Microfluidics

Time: Thursday 15:00–18:00 Location: Poster B2

DY 52.1 Thu 15:00 Poster B2

Active Rotation of Janus particles — •Burelbach Jérôme and Stark Holger — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

The active motion of Janus particles offers a wide range of interesting applications, from dynamic clustering [1] and microrotation [2] to the self-assembly of rotating micro-machines [3]. We theoretically study the rotation of active particles based on Onsager's reciprocal relations [4], by exploiting the fact that the corresponding Onsager transport coefficients are skew-symmetric. In particular, we present a theoretical model for a self-rotating particle, showing that self-rotation relies on two asymmetries, one in the interfacial interaction with the surrounding fluid, and the other in the thermodynamic field created by the particle.

[1] Pohl, O., & Stark, H. (2015). Self-phoretic active particles interacting by diffusiophoresis: A numerical study of the collapsed state and dynamic clustering. European Physical Journal E, 38(8).

[2] Jiang, Hong-Ren, Natsuhiko Yoshinaga, and Masaki Sano. "Active motion of a Janus particle by self-thermophoresis in a defocused laser beam." Physical review letters 105.26 (2010): 268302.

[3] Maggi, Claudio, et al. "Self-assembly of micromachining systems powered by Janus micromotors." Small 12.4 (2016): 446-451.

[4] Onsager, Lars. "Reciprocal relations in irreversible processes. I." Physical review 37.4 (1931): 405.

DY 52.2 Thu 15:00 Poster B2

Motion of fronts and clusters in an active Allen-Cahn model — •Fenna Stegemerten and Uwe Thiele — Institute of Theoretical Physics Westfälische Wilhelms-Universität Münster

Active matter is composed of many particles which are able to transform different types of energy into motion. This may result in motility-induced clustering or directed collective motion. Such phenomena are observable for swarming in fauna as well as for artifical microswimmers. The collective structures may consist of disordered or well ordered arrangements and are referred to as active clusters and active crystals, respectively. In order to understand aspects of the behaviour of active clusters we employ a rather simple model for active matter, namely, the active Allen-Cahn (aAC) equation: The passive Allen-Cahn equation is coupled to a polarization field similar to the active phase field model (aPFC) in [1]. We then study occurring clusters and the motion of fronts in aAC. In particular, we provide bifurcation diagrams and show that the onset of motion occurring with increasing activity corresponds to a drift-ptichfork bifurcation similar to the case of aPCF [2]. Additionally, we we find that motion is not only controlled by the activity parameter but is also affected by the chemical potential. We track the drift-pitchfork bifurcation in the corresponding parameter space. Finally, we show that depending on the chemical potential the passive AC equation generates pulled and pushed fronts and discus their existence in the active case. [1] A. M. Menzel and H. Löwen Phys. Rev. Lett. (2013) [2] L. Ophaus, et al. Phys. Rev. E (2018)

DY 52.3 Thu 15:00 Poster B2

Probing the Dynamics of Self-Electrophoretic Swimmers using Lattice Boltzmann — •Michael Kuron[1], Georg Rempfer[1], Joost de Graaf[2], and Christian Holm[1] — [1]Institut für Computerphysik, Universität Stuttgart, Deutschland — [2]Institute for Theoretical Physics, Universiteit Utrecht, Nederland

Many simulational studies are available of the rich transient and collective behavior in catalytically-propelled colloids or microswimmers. However, virtually none consider both the hydrodynamic and phoretic fields and most do not take into account even one of them. We introduce a continuum model based on the lattice Boltzmann method that incorporates both effects and is capable of simulating the dynamic behavior of many swimmers. Our swimmers propel via experimentally relevant self-electrophoretic mechanisms with bulk reactions.

DY 52.4 Thu 15:00 Poster B2

Antimargination of microparticles and platelets in branching vessels — •Christian Bächer[1], Alexander Kihm[2], Lukas Schrack[1,3], Lars Kaestner[4], Matthias W. Laschke[5], Christian Wagner[2], and Stephan Gekle[1] — [1]Biofluid Simulation and Modeling, Bayreuth, Germany — [2]Experimental Physics, Saarland University, Saarbrücken, Germany — [3]Institute for Theoretical Physics, Innsbruck, Austria — [4]Institute for Molecular Cell Biology, Research Centre for Molecular Imaging and Screening, Center for Molecular Signaling (PZMS), Medical Faculty, Saarland University, Homburg/Saar, Germany — [5]Institute for Clinical & Experimental Surgery, Saarland University, Homburg/Saar, Germany

Microparticles in red blood cell suspension are studied in a vessel confluence and a bifurcation - typical geometries for blood vessel networks. Using three-dimensional Lattice-Boltzmann simulations we find strong effects on cell and particle distribution: flowing through a confluence triggers an additional, surprisingly stable cell-free layer in the center with microparticles undergoing antimargination into this central cell-free layer. In contrast to the perturbed margination in a vessel confluence, we obtain full microparticle margination in branching vessels. Margination in branching vessels and antimargination behind confluences may explain in vivo findings of strongly different platelet distribution in arterioles (mainly bifurcations) and venules (mainly confluences).

DY 52.5 Thu 15:00 Poster B2

The role of inertia in active nematic turbulence — •Colin-Marius Koch and Michael Wilczek — Max Planck Institute for Dynamics and Self-Organization, Göttingen

Suspensions of active agents with nematic interactions exhibit complex spatio-temporal dynamics such as mesoscale turbulence. Continuum descriptions for such systems are typically inspired by the theory of liquid crystals and combine hydrodynamics with active nematic stresses. The resulting equations feature an advective nonlinearity which represents inertial effects. The generically low Reynolds number of such active flows raises the question of the importance of the inertial effects. To address this question, we investigate active turbulence in a two-dimensional dense suspension of active nematic liquid crystals. We quantitatively compare numerical simulations with and without nonlinear advection of the flow field. This study will help to better understand the interplay of self-induced turbulent flow and local ordering.

DY 52.6 Thu 15:00 Poster B2

Validity of the low Reynolds number approximation for collective microswimmer hydrodynamics — •Jan Cammann[1], Jörn Dunkel[2], Jonasz Słomka[3], and Michael Wilczek[1] — [1]Max Planck Institute for Dynamics and Self-Organization — [2]Department of Mathematics Massachusetts Institute of Technology — [3]ETH Zürich

Microswimmers, such as bacteria, sperm cells and motile algae, are typically found in regimes where the relevant length and velocity scales allow their hydrodynamic interactions to be studied in the limit of low Reynolds numbers (Re). This simplifies the Navier-Stokes to the Stokes equation. In this approximation inertial effects are completely neglected. For individual swimmers this approximation is known to work well, whereas for large numbers of swimmers the hydrodynamic flows produced by the individuals may interfere constructively to produce higher local values of Re. Using a combination of analytical and numerical approaches, we study the dependence of the local Reynolds number on different configurations of microswimmers modeled as extended point force dipoles acting upon the fluid. Thus, we explore the limits of low Re approximations and whether inertial effects become relevant for the collective hydrodynamics of dense microswimmer suspensions.

DY 52.7 Thu 15:00 Poster B2

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

Active components that constitute active matter, as for example bacteria or active filaments, are often elongated in shape. The shape and the stiffness of the active components clearly influence both their individual as well as their collective dynamics and pattern formation.

On length scales several orders larger than the size of the constituents, active materials exhibit many fascinating phenomena distinct from their passive counterparts such as the formation of vortices or turbulent structures. While these phenomena have already been studied both in experiments and simulations [1,2], identifying the individual role of thermal fluctuations as well as direct steric and hydrodynamic interactions is still subject of current research.

In this context, we numerically model shape-anisotropic microswimmers with rod shape by composing them from overlapping spherical squirmers [3]. We simulate the hydrodynamic flow field initiated by the active rods using the method of multi-particle collision dynamics. We present results for the collective dynamics of the active rods varying their area fraction, Peclet number, and aspect ratio.

[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 52.8 Thu 15:00 Poster B2

Measurement of the fluid-flow-field generated by an attached self-thermo-phoretic micro swimmer — •Nicola Söker and Frank Cichos — Leipzig University

We measure the 3D flow field induced by a heated metal caped polystyrene micro particle adherent to a glass surface in water. In current literature it is assumed, that thermo-phoresis can be well described by an induced slip flow proportional to the temperature gradient along a surface or phase boundary. The motion performed by a self thermo-phoretic micro-swimmers is then given by slip flows along the swimmers surface and boundary slip-flows in the environment. We look at an adherent micro-swimmer since then the flow field is long ranged. Also a freely moving swimmer would also sample different environmental conditions. The average fluid velocity field is recorded using gold nanoparticle tracers. Three dimensional motion is extracted from the defocused images of the gold nanoparticles. The flow fields are compared to numerical calculations of the flow field including all hydrodynamic boundaries.

DY 52.9 Thu 15:00 Poster B2

Polarization of Brownian swimmers with spatially heterogeneous activity — •Sven Auschra[1], Nicola Söker[2], Paul Cervenak[1], Viktor Holubec[1], Klaus Kroy[1], and Frank Cichos[2] — [1]Institute for Theoretical Physics, University of Leipzig, 04103 Leipzig, Germany — [2]Peter Debye Institute for Soft Matter Physics, University of Leipzig, 04103 Leipzig, Germany

Janus particles fuelled by laser heating are paradigmatic autophoretic microswimmers. Their dynamics under constant driving has been well characterized [1-3]. We consider situations in which the particles' propulsion strength fluctuates in space and time, due to a variable fuel supply. Specifically, we analyze their spatial and orientational distribution experimentally, realizing prescribed spatial and temporal activity variations via the laser heating. We find depletion in regions of higher activity and polarization in activity gradients. Using Brownian dynamics simulations and a powerful numerical solver for Fokker-Planck equations [4], we can reproduce the experimental observations. A simple run-and-tumble process captures the observed features, qualitatively, and provides some analytical insights.

[1] A. Bregulla and F. Cichos: Faraday Discuss. 184, 381*391 (2015).
[2] H. Jiang, N. Yoshinaga, and M. Sano: PRL 105, 268302 (2010).
[3] A. Würger: Rep. Prog. Phys. 73, 126601 (2010).
[4] V. Holubec, K. Kroy and S. Steffenoni: arXiv:1804.01285v2 (2018).

DY 52.10 Thu 15:00 Poster B2

Brownian molecules formed by delayed harmonic interactions — •Daniel Geiss and Viktor Holubec — Institut für theoretische Physik, Uni Leipzig, Deutschland

A time-delayed response of individual living organisms to information exchange within groups or swarms leads to the formation of complicated collective behavior. A recent experimental setup where Brownian particles interact via time-delayed forces aims to mimic this behavior [1]. We study a system of N Brownian particles interacting via a harmonic, time-delayed potential. For $N < 4$, we model the problem analytically by linear stochastic delay differential equations, and for $N > 3$ we use Brownian dynamics simulations. The particles form molecular-like structures which become increasingly unstable with the number of particles and the length of the delay. We evaluate the entropy fluxes in the system and develop an appropriate time-dependent transition state theory to characterize transitions between different isomers of the molecules.

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

DY 52.11 Thu 15:00 Poster B2

Isotropic - Nematic Phase Transition of Active Rods — •Felix Winterhalter and Matthieu Marechal — Theroetische Physik I - Friedrich Alexander Universität Erlangen, Erlangen, Deutschland

The Isotropic - Nematic transition of spherocylinders is a well studied phenomenon. This transition gets modified for spherocylinders with active motion along its orientation axis. We found that for short rods the Isotropic-Nematic transition is shifted to higher packing fractions depending on the velocity.

DY 52.12 Thu 15:00 Poster B2

Passive swimming of deformable particles in shaken fluids — Matthias Laumann[1], •Andre Förtsch[1], Eva Kanso[2], and Walter Zimmermann[1] — [1]Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Aerospace and Mechanical Eng., University of Southern California, Los Angeles, California 90089, USA

It was demonstrated recently that deformable, passive and asymmetric particles of different mass density than the fluid exhibits in a shaken fluid a net motion [1] with respect to the fluid. We give an explanation in terms of semi-analytical calculations why passive elastic particles show a net motion in shaken fluids. We also demonstrate that common symmetric particles can display a net motion if the time-dependence of the fluid motion is nonsymmetric with respect to an half-period of fluid oscillation. We further show results from simulations of capsules and provide parameters for which a capsule allows to rise in shaken fluid against gravity. The results may be helpful to assemble artificial microswimmers or may be useful for cell sorting and manipulation in microfluidic devices.

DY 52.13 Thu 15:00 Poster B2

Oscillatory bifurcations in active particle systems — •Andreas Förtsch, Fabian Bergmann, Lisa Rapp, and Walter Zimmermann — Theoretische Physik, Universität Bayreuth, 95440 Bayreuth

We introduce a model with two types of interacting active species A and B. We assume A-A attraction, A-B attraction and B-B repulsion/attraction. The use continuum and Brownian dynamics modelling of the two chemotactically interacting active particles. The continuum model for the two interacting species shows either a stationary or an oscillatory instability of the homogeneous particle distribution. Since the both particle types are conserved the instabilities lead either to a non-oscillatory active phase separation [1] or to an oscillatory type of active phase separation. Above the oscillatory onset of active phase separation, we find in simulations traveling and spatio-temporal dynamics of clusters.

[1] F. Bergmann, L. Rapp, W. Zimmermann, Active phase separation: A universal approach, Phys. Rev. E 98, 020603(R) (2018)