BP 8: Active Matter DY II (joint session DY/CPP/BP)

Time: Monday 15:30–18:45 Location: BH-N 243

BP 8.1 Mon 15:30 BH-N 243

Run-and-Tumble-like Motion of Synthetic Microswimmers in Viscoelastic Media — •Celia Lozano, J. Ruben Gomez-Solano, and Clemens Bechinger — Fachbereich Physik, Universität Konstanz, Konstanz D-78457, Germany

Run-and-tumble (RNT) motion is a prominent locomotion strategy employed by many living microorganisms. It is characterized by straight swimming intervals (runs), which are interrupted by sudden reorientation events (tumbles). In contrast, directional changes of synthetic microswimmers (active particles, APs) are caused by rotational diffusion, which is superimposed with their translational motion and, thus, leads to rather continuous and slow particle reorientations. Here we demonstrate that APs can also perform a swimming motion where translational and orientational changes are disentangled, similar to RNT. In our system, such motion is realized by a viscoelastic solvent and a periodic modulation of the self-propulsion velocity. Experimentally, this is achieved using light-activated Janus colloids, which are illuminated by a time-dependent laser field. We observe a strong enhancement of the effective translational and rotational motion when the modulation time is comparable to the relaxation time of the viscoelastic fluid. Our findings are explained by the relaxation of the elastic stress, which builds up during the self-propulsion, and is suddenly released when the activity is turned off. In addition to a better understanding of active motion in viscoelastic surroundings, our results may suggest novel steering strategies for synthetic microswimmers in complex environments.

BP 8.2 Mon 15:45 BH-N 243

Effective viscosity of active suspensions — Levan Jibuti[1], Walter Zimmermann[1], Salima Rafai[2], and •Philippe Peyla[2] — [1]Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany — [2]LIPhy, Université Grenoble Alpes and CNRS, F-38402 Grenoble, France

Micro-organisms usually can swim in their liquid environment by flagellar or ciliary beating. In this numerical work, we analyze the influence of flagellar beating on the orbits of a swimming cell in a shear flow. We also calculate the effect of the flagellar beating on the rheology of a dilute suspension of microswimmers. A three-dimensional model is proposed for Chlamydomonas Reinhardtii swimming with a breaststroke-like beating of two anterior flagella modeled by two counter-rotating fore beads. The active swimmer model reveals unusual angular orbits in a linear shear flow. This peculiar behavior has some significant consequences on the rheological properties of the suspension. We calculate Einstein's viscosity of the suspension composed of such isolated modeled microswimmers (dilute case) in a shear flow. The results show an increased intrinsic viscosity for active swimmer suspensions in comparison to nonactive ones as well as a shear thinning behavior in accordance with our previous experimental measurements.

Effective viscosity of a suspension of flagellar-beating microswimmers: Three-dimensional modeling Levan Jibuti, Walter Zimmermann, Salima Rafaï, and Philippe Peyla Phys. Rev. E 96, 052610 (2017)

BP 8.3 Mon 16:00 BH-N 243

Self propulsion of droplets driven by an active permeating gel — •Reiner Kree and Annette Zippelius — Inst. f. Theoret. Physik, Univ. Göttingen, Friedrich-Hund. Pl. 1, 37077 Göttingen

We discuss the flow field and velocity of active droplets, which are driven by body forces residing on a rigid gel. The latter is modeled as a porous medium which gives rise to permeation forces. In the simplest model, the Brinkmann equation, the porous medium is characterized by a single length scale l, the square root of the permeability. We compute the flow fields, the translational and rotational velocity of the droplet and the energy dissipation as a function of l. We show that the model gives rise to non-monotic behaviour of the droplet velocities and the dissipated power as functions of the gel fraction. As l changes from large to small values, the properties of the medium change from a simple viscous fluid to a Darcy medium. We discuss the behaviour of flow, velocities and force densities as these limits are approched.

BP 8.4 Mon 16:15 BH-N 243

Viscotaxis: a theory for microswimmer navigation in viscosity gradients — •Benno Liebchen[1], Paul Monderkamp[1], Borge ten Hagen[2], and Hartmut Loewen[1] — [1]Institut fuer Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universitaet Duesseldorf, D-40225 Duesseldorf, Germany — [2]Physics of Fluids Group, Faculty of Science and Technology, University of Twente, 7500 AE Enschede, The Netherlands

The survival of many microorganisms, like Leptospira or Spiroplasma bacteria, which swim poorly in low-viscosity fluids, depends on their ability to navigate up viscosity gradients. While this ability, called viscotaxis, has been observed in several experiments with microorganisms, the underlying mechanism remains unclear. In the present talk, we present a simple theory for viscotaxis of self-propelled swimmers [1] in slowly varying viscosity gradients: this theory unveils specific mechanisms for viscotaxis based on a systematic imbalance of viscous forces acting on different body parts of a swimmer and allows to classify microswimmers regarding their ability to perform viscotaxis based on their body shapes. Besides shedding new light on microorganism viscotaxis, our results may be useful to design synthetic swimmers with the ability to navigate in viscosity gradients (akin to synthetic chemo- or thermotactic swimmers [2]).

[1] B. Liebchen, P. Monderkamp, B.t. Hagen and H. Löwen, in preparation.

[2] B. Liebchen, D. Marenduzzo, and M. E. Cates, Phys. Rev. Lett. 118, 268001 (2017).

BP 8.5 Mon 16:30 BH-N 243

Photo-gravitaxis in synthetic microswimmers — •William Uspal[1,2], Dhruv Singh[1], Mihail Popescu[1,2], Laurence Wilson[3], and Peer Fischer[1,4] — [1]Max-Planck-Institut für Intelligente Systeme — [2]IV. Institut für Theoretische Physik, Universität Stuttgart — [3]Department of Physics, University of York — [4]Institut für Physikalische Chemie, Universität Stuttgart

We study the dynamics of active Janus particles that self-propel in aqueous solution by light-activated catalytic decomposition of chemical "fuel." In experiments, the particles, initially sedimented at a bottom wall, exhibit wall-bound states of motion, dependent on the size of the particle, when illuminated from underneath the wall. Upon increasing the intensity of the light above a threshold value, which is also dependent on the size of the particle, the particles lift off the wall and move way from it, i.e., they exhibit a photo-gravitactic behavior similar to some planktonic microorganisms. The dependencies on the particle size are rationalized by using a theoretical model of self-phoresis that explicitly accounts for the "shadowing" effect of the opaque catalytic face of the particle. Our model allows us to unequivocally identify the photochemical activity and phototactic response as the key mechanisms beyond the observed phenomenology. Consequently, one has the means to design photo-gravitatic particles that can reversibly switch between operating near a boundary or in the volume away from the boundary by judiciously adjusting the light intensity, i.e., simply by "turning a knob".

15 min. break

BP 8.6 Mon 17:00 BH-N 243

Active Rods in a Converging Flow — •Andreas Kaiser[1], Mykhailo Potomkin[2], Leonid Berlyand[2], and Igor Aranson[1,2] — [1]Department of Biomedical Engineering, Pennsylvania State University, University Park, 16802, USA — [2]Department of Mathematics, Pennsylvania State University, University Park, 16802, USA

We consider active rodlike particles swimming in a convergent fluid flow in a trapezoid nozzle by using mathematical modeling to analyze trajectories of these particles inside the nozzle and numerical simulations to show that trajectories are strongly affected by the background fluid flow and geometry of the nozzle leading to wall accumulation and rheotaxis. We describe the non-trivial focusing of active rods depending on physical as well as geometrical parameters. It is also established that the convergent component of the background flow leads to stability of both downstream and upstream swimming at the centerline. The stability of downstream swimming enhances focusing, and the stability of upstream swimming enables rheotaxis in the bulk.

BP 8.7 Mon 17:15 BH-N 243

Guidance of self-phoretic Janus particles by chemically

patterned surfaces — William Uspal[1,2], •Mihail Popescu[1,2], Mykola Tasinkevych[3], and Siegfried Dietrich[1,2] — [1]M.P.I. for Intelligent Systems, Stuttgart, Germany — [2]University of Stuttgart, Germany — [3]University of Lisbon, Portugal

Self-phoretic Janus particles move by inducing – via non-equilibrium chemical reactions occurring on their surfaces – gradients in chemical composition along the surface of the particle, as well as along any nearby boundaries. The chemical gradients along a wall can give rise to chemi-osmosis, which, in turn, drives flow in the volume of the solution and thus couples back to the particle. This response flow induced and experienced by a particle encodes information about any chemical patterning of the wall. Here, we show by analytical calculations, complemented with numerical solution, that wall-patterning by chemical steps can provide the means for docking of achieving a step-guided motion of such an active particle, and we discuss the dependence of the phenomenology on the shape (spherical or rod-like) of the particle. Furthermore, we show that such chemically active particles in general align with, and follow, spatial gradients in the surface chemistry of the wall (i.e., they exhibit thigmo-taxis).

BP 8.8 Mon 17:30 BH-N 243

Randomly shaped magnetic Micropropellers — •Felix Bachmann[1], Agnese Codutti[1,2], Klaas Bente[1], and Damien Faivre[1] — [1]Max Planck Institute of Colloids and Interfaces, Department of Biomaterials, Science Park Golm — [2]Max Planck Institute of Colloids and Interfaces, Department of Theory & Bio-Systems, Science Park Golm

Over the last decade many different actuation mechanisms for swimming at low Reynolds number have been suggested and implemented. Magnetic micropropellers are a promising example that combines remote and fuel-free actuation with precise control. Now, the realization of the envisioned, mostly medical application is the next step. Therefore, automation and additional control strategies have to be developed. In this regard, randomly shaped micropropellers offer the possibility to find and test new actuation schemes and the associated propeller shapes. We screen a pool of such randomly shaped magnetic micropropellers by applying different magnetic fields and record their swimming behavior by optical high speed microscopy, which additionally enables tomographic 3D-shape reconstructions of interesting propellers. This is the basis for their reproduction through micro- and nanofabrication and eventually facilitates the formulation of micropropeller design guidelines for special applications.

BP 8.9 Mon 17:45 BH-N 243

Active Brownian particles in a inhomogeneous activity or magnetic field — •Hidde Vuijk and Abhinav Sharma — Leibniz-Institut für Polymerforschung Dresden, Institut Theorie der Polymere, 01069 Dresden

We study spherically symmetric active particles in a spatially inhomogeneous activity or magnetic field. In both cases the particles spontaneously orient themselves, which results in an inhomogeneous distribution of particles. Using Green-Kubo approach we obtain analytical expression for the orientation of the particles. We find that the relevant equilibrium correlation function is the self-part of the Van Hove function, which can be approximated accurately. Density does not have a linear response to the activity; however, an expression for the density is derived by using the orientation as input to dynamic density functional theory. All theoretical predictions are validated using Brownian dynamics simulations.

BP 8.10 Mon 18:00 BH-N 243

Active colloidal particles in evaporating liquid droplets — •Borge ten Hagen[1], Maziyar Jalaal[1], Hai Le The[2], Christian Diddens[1], Alvaro Marin[1], and Detlef Lohse[1,3] — [1]Physics of Fluids Group and Max Planck Center Twente, University of Twente, Enschede, The Netherlands — [2]MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands — [3]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Inspired by biological microswimmers, various types of artificial self-propelled particles have been developed and thoroughly characterized in recent years. While in most studies quiescent solvents or stationary flow fields were considered, much less is known about the behavior of synthetic microswimmers in more complicated flow environments as they often occur in biological systems under non-laboratory conditions. Here, we investigate the dynamics of self-propelling Janus particles in an evaporating droplet of hydrogen peroxide solution. The competition between the flows due to the evaporation and the active motion of the particles leads to a complex dynamical behavior. The system is analyzed using three-dimensional particle tracking measurements and numerical simulations of the nontrivial fluid flow within the evaporating droplet. It will also be discussed how the particle activity affects the coffee-ring formation in the final state of evaporation, where the orientation of the Janus particles introduces a new order parameter.

BP 8.11 Mon 18:15 BH-N 243

Active droplet model of cellular aggregates — •Hui-Shun Kuan, Frank Jülicher, and Vasily Zaburdaev — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Active systems appear in various biological contexts such as cell cytoskeleton and bacterial colonies. Such systems may exhibit phase separation, which is not governed by free energy minimization. In this talk, we use the concept of phase separation to study the formation of bacterial colonies, of N. gonorrhoeae, due to active force generation by cell appendages type IV pili. We use a hydrodynamics approach, representing bacterial colonies as active droplets, which exhibit different surface profiles and position-dependent motility gradients. In addition, the coalescence of two such droplets exhibits two time scales which cannot be understood by the surface tension and viscosity. Our theoretical description of active droplets provides means of describing bacterial colonies and can be extended to other cell types.

BP 8.12 Mon 18:30 BH-N 243

3D dynamics of synthetically assembled microtubules and motors — •Smrithika Subramani, Christian Westendorf, Eberhard Bodenschatz, and Isabella Guido — Max Planck Institute for dynamics and self-organization, Göttingen, Germany

Cytoskeletal filaments such as microtubules play a major role in cell division, organelle transport and cellular motility. These diverse biological functionalities are driven by bending, looping and buckling of microtubule (MT) filaments. In our study, we intend to gain a deeper understanding of these phenomena by synthetically reconstituting dynamic MT structures.

We hierarchically build a model active matter system using depletion-driven MT bundles and the processive motor Kinesin-1, assembled in a tetrameric complex. By hydrolyzing ATP and undergoing a conformational change, the motor complex is able to effectively 'walk' along MT bundles and generate motion in a 3D environment. Our observations include continuous sliding, bending and buckling of MT bundles into long-wavelength arcs, resembling their in vivo behaviour. By using the Fluorescence Recovery After Photobleaching (FRAP) method, we are able to analyze the MT structure distribution. A multi-plane fluorescence microscopy technique enables us to observe the bundle dynamics in 3D.