BP 14: Microswimmers DY I (joint session DY/BP/CPP)

Time: Tuesday 14:00–15:45 Location: BH-N 243

BP 14.1 Tue 14:00 BH-N 243

Active colloidal propulsion over a crystalline surface — Udit Choudhury[1], •Arthur Straube[2], Peer Fischer[1], John Gibbs[3], and Felix Höfling[2] — [1]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [2]Freie Universität Berlin, Institute of Mathematics, Berlin, Germany — [3]Department of Physics and Astronomy, Northern Arizona University, Flagstaff, USA

We study both experimentally and theoretically the dynamics of chemically self-propelled Janus colloids moving atop a two-dimensional (2d) crystalline surface [1]. The surface is a hexagonal close-packed monolayer of colloidal particles of the same size as the mobile one. The dynamics of the self-propelled colloid reflects the competition between hindered diffusion due to the periodic surface and enhanced diffusion due to active motion, which can be tuned by changing the concentration of a chemical fuel. Our experimental data for the mean-square displacements (MSDs) are consistent with a Langevin model for the effectively 2d translational motion of an active Brownian particle in a periodic potential, combining the confining effects of gravity and the crystalline surface with the free rotational diffusion of the colloid. Approximate analytical predictions are made for the MSD describing the crossover from free Brownian motion at short times to active diffusion at long times. The results are in semi-quantitative agreement with numerical results of a refined Langevin model that treats translational and rotational degrees of freedom on the same footing.

[1] U. Choudhury, A. V. Straube, P. Fischer, J. G. Gibbs, F. Höfling, New J. Phys. (2017), doi: 10.1088/1367-2630/aa9b4b

BP 14.2 Tue 14:15 BH-N 243

Dynamics of a single circular microswimmer in a quenched crowded media — •Oleksandr Chepizhko and Thomas Franosch — Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria

The motion of active particles, for example, bacteria or unicellular organisms, in nature occurs in crowded environments such that the walls, boundaries, and obstacles strongly influence the dynamics of the microswimmers. Here we present a generic model for a deterministic circular microswimmer in a disordered two-dimensional quenched random array of obstacles. The microswimmer moves in circular orbits between the collisions with the obstacles, and after colliding with an obstacle the microswimmer follows the obstacle's surface for some time before detaching again.

The diffusivity of the system is studied via event-driven computer simulations for a wide range of obstacle densities and orbit radii. We find to phase boundaries of a conducting phase with an insulating and a localized phase. The phase behavior is investigated both close to these two transition lines, as well as deep in the conducting phase. The phase transitions correspond to critical phenomena with both an underlying static percolation transition, while the dynamic exponents reveal different universal classes. Furthermore, we find that the diffusivity grows with the density of obstacles up to a narrow region in the vicinity of the localization transition where it rapidly drops to zero.

BP 14.3 Tue 14:30 BH-N 243

Controlled Control of Cargo Delivery Performed by Self-Propelled Janus Droplets — •Menglin Lee[1], Martin Brinkmann[1], Ignacio Pagonabarraga[2], Ralf Seemann[1], and Jean-Baptiste Fleury[1] — [1]Saarland University, Saarbruecken, Germany — [2]University of Barcelona, Bracelona, spain

We propose a class of programmable carrier droplets that can be made of a water/ethanol mixture dispensed in a continuous oil/surfactant solution. While swimming, the droplets pass through up to three stages whose appearance and duration are determined by the chemical composition of the droplet and the surrounding phase. A spontaneous de-mixing of the initially homogeneous droplet phase controlled by an uptake of surfactant and simultaneous loss of ethanol is generally observed. The phase segregation can lead to the formation of characteristic Janus droplets which consist of a water-rich and an ethanol-rich droplet. During de-mixing cargo molecules, like DNA, can be separated in the trailing ethanol–rich droplet and are "carried like in a backpack". Delivery is obtained whenever the trailing droplet touches a wettable target. Selective attraction or repulsion from targets is determined by the long–range hydrodynamic interactions of the swimmers with the geometric shape of the targets. In combination with a controlled delay of phase separation by the initial chemical composition of the droplets, we can exploit this selectivity to deliver DNA molecules dissolved in the ethanol-rich droplet at specific target sites and during a specific timeframe.

(under review - 2017)

BP 14.4 Tue 14:45 BH-N 243

Clearing out a Maze: Chemotaxis and Percolation — Tanja Schilling[1] and •Thomas Voigtmann[2,3] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, 79104 Freiburg, Germany — [2]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR), 51170 Köln, Germany — [3]Department of Physics, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany

We study chemotactic motion in a random environment of obstacles by means of a lattice model that bears resemblance to the arcade game PAC-MAN®: A random walker moves on the percolating cluster of a square lattice, with steps that are biased towards the food that is initially placed on the accessible lattice sites and that is then consumed by the walker. Anomalous diffusion emerges, and is best described by a power-law with a non-trivial dynamical exponent that depends continuously on the propensity of the walker to move towards food. Although its food propensity biases the walker to explore previously unvisited sites more easily than the unbiased random walk, and thus intuitively serves to stretch out the walker's trajectories in comparison to the non-chemotactic case, the asymptotic growth of the mean-squared displacement is weaker. We suggest that getting lost in the culs-de-sac is a mechanism to explain why the chemotactic exploration of a maze thus becomes less effective than the pure diffusive one.

[1] T. Schilling and Th. Voigtmann, J. Chem. Phys. (in press, 2017); arXiv:1607.01123.

BP 14.5 Tue 15:00 BH-N 243

Theoretical study of triangular magnetocapillary microswimmers — •Alexander Sukhov[1], Sebastian Ziegler[2], Oleg Trosman[2], Ana-Suncana Smith[2], and Jens Harting[1,3] — [1]Helmholtz Institute Erlangen-Nuernberg for Renewable Energy (IEK-11), Forschungszentrum Juelich GmbH, 90429 Nuernberg, Germany — [2]Institute for Theoretical Physics, Friedrich-Alexander University Erlangen-Nuernberg, 91054 Erlangen, Germany — [3]Department of Applied Physics, Eindhoven University of Technology, NL-5600MB Eindhoven, The Netherlands

As demonstrated experimentally (for a recent review see Ref. [1]), magnetocapillary swimmers - a system of three or more magnetic beads trapped at a fluid-gas interface - prefer to form equilateral triangles due to an interplay of attractive capillary and repulsive magnetic dipole-dipole interactions. By applying additionally a time-dependent magnetic field the position of the swimmer and its velocity direction can be wirelessly manipulated. Combining the lattice Boltzmann method with the analytical force-based bead-spring model [2, 3] extended for a triangular configuration, we explain a sharp dependence of the average speed of the swimmer on the frequency of the time-dependent magnetic field and compare our results with the experiment. In addition, we demonstrate numerically and analytically the control of the direction of the swimmer motion using magnetic fields. [1] G. Grosjean, M. Hubert and N. Vandewalle, Adv. Colloid Interface Sci., in press (2017); [2] B.U. Felderhof, Phys. Fluids **18**, 063101 (2006); [3] J. Pande *et al.*, New J. Phys. **19**, 053024 (2017).

BP 14.6 Tue 15:15 BH-N 243

The frequency-dependent behavior of microswimmers in oscillating shear flow — Kevin Schröer[1], •Patrick Kurzeja[2], and Lothar Brendel[1] — [1]Faculty of Physics and CeNIDE, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]Institue of Mechanics, Technical University Dortmund, 44227 Dortmund, Germany

One possibility to alter the macroscopic properties of a self-propelled nanoparticle suspension is the introduction of inhomogeneities in the propulsion mechanism, which leads to drastic changes in the collective behavior [1].

A new approach is presented for sheared suspensions: the control via oscillating walls. The oscillation frequency determines the thickness of a viscous boundary layer that surrounds the inertia-dominated center region. This is characterized by the Womersley number Wo, being the ratio between viscous and inertial forces [2]. As a result, regions of particle rotation and translation can be varied by this frequency.

Using this setup, we investigate the impact of Wo on the rheology of a dilute microswimmer suspension by means of Multi-Particle Collision Dynamics (MPC) simulations. This method is suited to capture hydrodynamics and thermal fluctuations and has been used in related topics like dilute suspensions in a gravity perturbed annular shear [3] or bidisperse segregation in a Hagen-Poiseuille flow [4].

[1] M. P. Magiera and L. Brendel, Phys. Rev. E 92, 1 (2015)
[2] P. Kurzeja et al., JASA 140, 4378 (2016)
[3] K. Schröer et al., EPJ Web of Conferences, 140 (2017)
[4] P. Kanehl and H. Stark, J. Chem. Phys. 142, 214901 (2015)

BP 14.7 Tue 15:30 BH-N 243

Buckling instability and swimming of elastic spherical shells — •Adel Djellouli[1], Philippe Marmottant[1], Henda Djeridi[2], Catherine Quilliet[1], and Gwennou Coupier[1] — [1]Univ. Grenoble Alpes, CNRS, LIPhy, 38000 Grenoble, France — [2]Univ. Grenoble Alpes, Grenoble INP, CNRS, LEGI, 38000 Grenoble, France

Under pressure, a hollow elastic sphere becomes unstable and collapses. It reinflates back when the pressure is decreased. The shape hysteresis associated to this deformation cycle makes this simple object a good candidate for becoming a microswimmer, that is, a swimmer able to move at low Reynolds number.

We explore this possibility through a macroscopic experiment in fluids of varying viscosities so as to explore different flow regimes [1]. We show that not only the shape sequence hysteresis leads to swimming but the asymetry in the deformation velocity makes the fast buckling phase an efficient mechanism for propulsion that implies inertial effects and subtle coupling between shape post-buckling oscillations and fluid flow patterns. Our modeling shows that such an inertial regime could even be reached at microscopic scale.

We anticipate that a conveyor made of a few of microbubbles with different shell thicknesses, would constitute a microrobot whose 3D displacement can be remotely controlled by an echographic device - a relatively cheap and widely available tool in the hospitals.

[1] A. Djellouli, P. Marmottant, H. Djeridi, C. Quilliet and G. Coupier, Phys. Rev. Lett. 119, 224501 (2017). See also P. Ball, "Focus: Elastic Spherical Shell Can Swim", Physics 10, 128 (2017).