BP 41: Microswimmers II (Joint Session with DY)

Joint Session with DY organized by BP.

Time: Wednesday 11:30–13:00 Location: H45

BP 41.1 Wed 11:30 H45

Interactions of self-thermophoretic swimmers — •Santiago Muiños Landin, Andreas Bregulla, and Frank Cichos — Molecular Nanophotonics, Universität Leipzig, Institut for Experimental Physics I, Linnéstrasse 5, 04103 Leipzig, Germany

Propulsive mechanisms and collective behavior of self propelled microswimmers are interesting and challenging topics which had been studied in different natural and artificial systems during last years. Given that the collective behavior depends on how do these swimmers interact, and the fact that the aspects of these interactions are directly related to their propulsive mechanisms, we can say that these both aspects are coupled. Here we present an experimental method, based on previous own related work[1,2]. The developed Photon Nudging technique allows us to collect a well defined number of self-thermophoretic Janus particles in a small sample volume. Based on this we show results of a free expansion study of an active particle gas in solution which provides information in the mutual interactions between these photophoretic swimmers

[1] B.Qian, D. Montiel, A. Bregulla, F. Cichos, Chem. Science 4, 1420 (2013) [2] A. Bregulla, H. Yang, and F. Cichos, ACS Nano 8(7), 6542 (2014)

BP 41.2 Wed 11:45 H45

Escaping turbulence? Phytoplankton use active shape control to rapidly adapt swimming strategies — •Anupam Sengupta[1,2], Francesco Carrara[1], and Roman Stocker[2] — [1]Massachusetts Institute of Technology, 15 Vassar Street, Cambridge MA 02139, USA — [2]ETH Zurich, Institute for Environmental Engineering, Stefano-Franscini-Platz 5, 8093 Zurich, Switzerland

Turbulence has long been known to affect phytoplankton fitness and species succession, yet, a mechanistic view of how turbulence affects phytoplankton migration has been lacking. Here we report on the first observations demonstrating that phytoplankton can actively respond to turbulence-like cues. Using the red-tide producing species Heterosigma akashiwo as a model system, we show that hydrodynamic cues mimicking overturning by Kolmogorov-scale turbulent eddies trigger a diversification in the migration behavior. Upon exposure to repeated overturning, an originally upward swimming population robustly splits in two equi-abundant subpopulations, one swimming upward and one swimming downward. Quantitative image analysis at the single-cell level showed that the behavioral switch was accompanied by a rapid morphological change at the sub-micrometer scale, and a mathematical model of the cell's mechanical stability confirms that this shape change can flip the swimming direction and ultimately induce downward migration. The results indicate that certain phytoplankton species may have evolved subtle strategies to actively change their migratory behavior in response to turbulent cues, possibly a bet-hedging strategy to escape from turbulent microzones in the ocean.

BP 41.3 Wed 12:00 H45

Run-reverse-flick strategy of interacting bacteria — •Fabian Schwarzendahl, Stephan Herminghaus, and Marco Giacomo Mazza — Max Planck Institute for Dynamics and Self-Organization, Göttingen Am Fassberg 17, 37077 Göttingen, Germany

Bacteria have different swimming strategies for finding nutrition. *Escherichia coli* follow a run and tumble strategy whereas *Vibrio alginolyticus* have a run-reverse-flick pattern [1]. We simulate the latter using molecular dynamics to integrate the underlying stochastic equations. Without interactions between the bacteria, the analytical result by Theves [2] is recovered. Furthermore, hard-core interactions are used. Here, we study the effect of particle interactions by varying the filling fraction as well as the ratio of mean forward-to-backward run time (biased run). We find that the diffusion-density coupling parameter has a minimum at a forward to backward runtime ratio of 0.6, which is the value that was measured for *Vibrio alginolyticus* by Xie et. al. [1]. Furthermore we present an analytical model based on a Fokker-Planck approach.

[1] Li Xie et. al., Proc. Natl. Acad. Sci. USA **108**, 2246 - 2251 (2010)

[2] Matthias Theves et. al., Biophys. J. **105**, 1915 - 1924 (2013)

BP 41.4 Wed 12:15 H45

Swimming dynamics of a polar multi-flagellated bacterium — •Marius Hintsche[1], Matthias Theves[1], Marco Kühn[2], Kai Thormann[2], and Carsten Beta[1] — [1]Universität Potsdam, Germany — [2]Justus-Liebig-Universität Giessen, Germany

Bacterial motility patterns and chemotaxis strategies are very diverse and depend on factors such as flagellation as well as the typical environment the species encounters. For some bacteria the motility pattern and the underlying flagellar dynamics have already been elucidated – as in the paradigmatic run-and-tumble behavior of *E. coli.* We study the swimming motility and chemotactic behavior of the polar multi-flagellated soil dwelling bacterium *Pseudomonas putida*. Its run-and-reverse motility pattern with many sharp reversal events is reminiscent of the behavior of some monoflagellated species. However, upon a reversal, *P. putida* changes its swimming speed by a factor of two on average. We also analyze the swimming pattern in the presence of chemical gradients. Using benzoate as a chemoattractant, we measure key motility parameters in gradients of different strength in order to quantify the directional bias these conditions introduce in this swimmer's random walk. Our results indicate a change in the reversal frequency depending on changes in the chemoattractant concentration consistent with earlier qualitative reports. Using high-speed fluorescence microscopy, we examine the dynamics of the polar bundle of flagella during smooth swimming and turning and discuss some recent hypotheses concerning the bundle dynamics of these bacteria in the light of our new observations.

BP 41.5 Wed 12:30 H45

Sperm navigation along helical paths in 3D chemoattractant landscapes — •Jan F. Jikeli[1], Luis Alvarez[1], Benjamin Friedrich[2], Laurence G. Wilsion[3], and U.Benjamin Kaupp[1] — [1]research center caesar; Ludwig-Erhard-Allee 2; 53175 Bonn Germany — [2]Biological Physics, Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany — [3]Department of Physics, University of York, YO10 5DD Heslington, York, UK

Sperm require a sense of direction to locate the egg for fertilization. They follow gradients of chemical and physical cues provided by the egg or the oviduct. However, the principles underlying three-dimensional (3D) navigation in chemical landscapes are unknown. Here using holographic microscopy and optochemical techniques, we track sea urchin sperm navigating in 3D chemoattractant gradients. Sperm sense gradients on two timescales, which produces two different steering responses. A periodic component, resulting from the helical swimming, gradually aligns the helix towards the gradient. When incremental path corrections fail and sperm get off course, a sharp turning manoeuvre puts sperm back on track. Turning results from an "off" Ca2+ response signifying a chemoattractant stimulation decrease and, thereby, a drop in cyclic GMP concentration and membrane voltage. These findings highlight the computational sophistication by which sperm sample gradients for deterministic klinotaxis. We provide a conceptual and technical framework for studying microswimmers in 3D chemical landscapes.

BP 41.6 Wed 12:45 H45

Elastic microswimmers in confined spaces — •Jayant Pande[1], Timm Krüger[2], Jens Harting[3,4], and Ana-Sunčana Smith[1,5] — [1]PULS group, Dept. of Phys. and EAM Cluster of Excellence, Friedrich-Alexander Univ., Erlangen, Germany — [2]School of Engg., Univ. of Edinburgh, Edinburgh, U.K. — [3]Dept. of Appl. Phys., Eindhoven Univ. of Technology, Eindhoven, The Netherlands — [4]Research Centre Jülich, Helmholtz-Inst. Erlangen-Nuremberg, Nuremberg, Germany — [5]Div. of Phys. Chem., Ruđer Bošković Inst., Zagreb, Croatia

Both natural microswimmers such as bacteria and artificial ones such as microscopic drug delivery systems (as currently foreseen) commonly move through constrained spaces such as thin films or biological channels. This constrainment alters their conditions of motion, relative to swimming in an infinite expanse of fluid, due to effects such as fluid reflection from channel walls, heightened drag forces, etc., and is manifested in fundamentally different fluid flow fields. We study these effects by employing the LB3D simulation system, based on the lattice-Boltzmann and immersed boundary methods, to simulate the three-sphere swimmer of Najafi and Golestanian as it moves through narrow and wide channels. We modify the original three-sphere model to allow different degrees of elasticity in the swimmer, and investigate the interplay of these degrees of elasticity with the channel shapes and dimensions in determining the swimming efficiency. We present ways to take the swimmer elasticity into consideration analytically, and show that motion within channels may be understood in terms of the swimming regimes that depend on the drag force faced by the swimmer.