BP 47: Microswimmers, Active Liquids I (joint CPP/BP/DY)

Time: Thursday 15:45–18:00 Location: PC 203

Invited Talk BP 47.1 Thu 15:45 PC 203

Flagellar synchronisation through direct hydrodynamic interactions — •Marco Polin[1], Douglas Brumley[2], Kirsty Wan[3], and Raymond Goldstein[3] — [1]University of Warwick, Coventry. UK — [2]MIT, Boston, MA. US — [3]University of Cambridge, Cambridge. UK

Microscale fluid flows generated by ensembles of beating eukaryotic flagella are crucial to fundamental processes such as development, motility and sensing. Despite significant experimental and theoretical progress, the underlying physical mechanisms behind this striking coordination remain unclear. We describe a novel series of experiments in which the flagellar dynamics of two micropipette-held somatic cells of Volvox carteri, with measurably different intrinsic beating frequencies, are studied by high-speed imaging as a function of their mutual separation and orientation. From analysis of beating time series, we find that the interflagellar coupling, which is constrained by the lack of chemical and mechanical connections between the cells to be purely hydrodynamical, exhibits a spatial dependence that is consistent with theoretical predictions. At close spacings it produces robust synchrony which can prevail for thousands of flagellar beats, while at increasing separations this synchrony is systematically degraded by stochastic processes. Through dynamic flagellar tracking we quantify the associated waveforms and show that they are significantly different in the synchronised state. This study unequivocally reveals that flagella coupled only through a fluid medium are capable of exhibiting robust synchrony despite significant differences in their intrinsic properties.

Invited Talk BP 47.2 Thu 16:15 PC 203

Active motion: From single microswimmers to their emergent collective behavior — •Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, D-10623 Berlin

Active motion of artificial and biological microswimmers is relevant in microfluidics and biological applications but also poses fundamental questions in nonequilibrium statistical physics. Mechanisms of single microswimmers need to be understood and a detailed modeling of microorganisms helps to explore their complex cell design and their behavior. The collective motion of microswimmers generates appealing dynamic patterns.

In this talk I review some of our work modeling biological microswimmers such as *E. coli* [1] and the African trypanosome [2], the causative agent of the sleeping sickness, in order to contribute to their better understanding. Using simpler model microswimmers such as active Brownian particles, I will demonstrate their emerging collective behavior. Hydrodynamic interactions lead to a clustering transition dependent on swimmer type [3] or to the formation of fluid pumps in 3D harmonic traps [4]. Self-phoretic active colloids show biomimetic autochemotactic behavior, which can induce dynamic clustering, oscillating clusters, or a chemotactic collaps [5].

[1] R. Vogel and H. Stark, Phys. Rev. Lett. **110**, 158104 (2013).
[2] D. Alizadehrad et al., to be published in PLoS Comp. Biol.
[3] A. Zöttl and H. Stark, Phys. Rev. Lett. **112**, 118101 (2014).
[4] M. Hennes et al., Phys. Rev. Lett. **112**, 238104 (2014).
[5] O. Pohl and H. Stark, Phys. Rev. Lett. **112**, 238303 (2014).

BP 47.3 Thu 16:45 PC 203

Collective behavior and clustering of self-propelled rod shaped catalytic motors: A theoretical study — •Davoud Pouladsaz[1] and Zahra Eskandari[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute for Intelligent Systems, Stuttgart, Germany

In the last few years, catalytic micro-motors have attracted considerable attention and different experiments have performed in order to investigate their applicability in biology, e.g. colloidal cargo transportation. The collective behaviour of these micro-engines and their dynamic self-organization have recently been studied in experiments. In our study, we did Brownian dynamics simulation of rigid rods as a model for the interaction of catalytic motors, in a framework of stochastic processes which explain the force generating chemical reactions, and theoretically investigated the effect of spatial geometry of these active rods in the pattern formation of their clusters.

BP 47.4 Thu 17:00 PC 203

Vortex pattern formation of curved active polymers — •Lorenz Huber, Jonas Denk, Emanuel Reithmann, and Erwin Frey — Ludwig-Maximilians-Universität, München, Deutschland

During bacterial cytokinesis FtsZ filaments assemble into a ring-like structure. Recent experiments with reconstituted FtsA-dependent recruitment of FtsZ filaments to supported membranes have observed self-organization into vortex patterns. Accounting for the treadmilling dynamics of curved FtsZ on the membrane, we propose a model for systems of polymers with equal length and curvature that undergo effective propulsion. The FtsZ filaments are assumed to sterically repel each other. Employing Brownian dynamics simulations and a kinetic Boltzmann ansatz to study these systems on microscopic and mesoscopic length scales, respectively, we identify activity, intrinsic curvature, and steric repulsion as sufficient to control the stability of vortex patterns. In our microscopic approach we modeled the FtsZ membrane dynamics as a two-dimensional system of propelled elastic polymers and find a parameter regime of dense and stable vortices. Furthermore, we employed a mesoscale description in terms of a kinetic Boltzmann approach to investigate general effects of intrinsic curvature on collective behavior in active systems. We obtain a phase diagram featuring a confined parameter region of steady dense swirls. Our results provide a generic and robust mechanism for pattern formation in actual biological systems of curved filaments.

BP 47.5 Thu 17:15 PC 203

The many faces of drag in micro-swimming — •Jayant Pande[1], Laura Merchant[1,2], Jens Harting[3], and Ana-S. Smith[1,4] — [1]Inst. for Theo. Phys., Friedrich-Alexander Univ., Erlangen, Germany — [2]School of Phys. and Astronomy, Univ. of St. Andrews, Scotland — [3]Dept. of Appl. Phys., Eindhoven Univ. of Technology, Eindhoven, the Netherlands — [4]Ruđer Bošković Inst., Zagreb, Croatia

Although the theoretical study of micro-swimming is becoming increasingly important, the role of the drag force faced by swimmers–clearly one of the cornerstones of micro-locomotion–remains inadequately understood. We shed light in this talk on some of the fundamental ways in which this force affects micro-swimming, using a very simple yet versatile model of a bead-spring swimmer, based on the three-sphere design of Najafi and Golestanian. The drag force on these swimmers enters in various guises–through the influence of the mean bead shape, through any induced transitory shape changes during the swimming cycle if the beads are non-rigid, and through the fluid viscosity. We consider the effect of each contribution separately by letting the beads be of any shape as well as of rigid or flexible material, and by analyzing the various forces on them in fluid. We show that in general an increase in the drag force can have a net positive or a negative impact on the velocity, and it is the swimmer elasticity which decides this. Depending on the latter, we present precise expressions for the parameter ranges where the drag has opposing effects. We support the theory using lattice Boltzmann method-based simulations, and discuss the parts of the theoretical parameter space which are accessible to the simulations.

BP 47.6 Thu 17:30 PC 203

Formation, compression and surface melting of colloidal clusters by active particles — •Felix Kümmel[1], Parmida Shabestari[1], and Clemens Bechinger[1,2] — [1]2. Physikalisches Institut, Universität Stuttgart, D-70569 Stuttgart, Germany — [2]Max-Planck-Institut für Intelligente Systeme, D-70569 Stuttgart, Germany

Artificial active swimmers, i.e. Janus particles, suspended in a critical binary mixture, are capable of a self-diffusiophoretic motion upon illumination [1][2]. In previous experiments, the dynamics of such swimmers close to walls and periodic arrays of rigid obstacles has been investigated [1]. Here, we experimentally examine the structural changes in a mixture of passive and a small number of active colloidal particles of equal diameters in a two-dimensional system. With increasing passive particle area fraction, we observe the formation of clusters with passive particles in the interior and active particles at their boundaries. Further increase of the passive area fraction leads to the merging and compression of such clusters and eventually to local melting of crystalline regions by enclosed microswimmers. Our results demonstrate that the addition of only a small amount of active particles largely changes the structure and the dynamics of colloidal suspensions.

[1] VOLPE G, BUTTINONI I, VOGT D, KÜMMERER H J AND BECHINGER C 2011 MICROSWIMMERS IN PATTERNED ENVIRONMENTS SOFT MATTER 7, 8810 (2011) [2] B. TEN HAGEN, F. KÜMMEL, R. WITTKOWSKI, D. TAKAGI, H. LÖWEN, AND C. BECHINGER, NATURE COMMUNICATIONS 5 (2014)

BP 47.7 Thu 17:45 PC 203

Detention times of microswimmers close to surfaces — •Andreas Zöttl[1], Konstantin Schaar[1,2,3], and Holger Stark[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, D-10623 Berlin — [2]Robert Koch-Institut, D-13353 Berlin — [3]Institut für Theoretische Biologie, Humoldt Universität Berlin, D-10115 Berlin

The locomotion of biological microswimmers such as bacteria in aqueous environments is determined by low-Reynolds-number hydrodynamics and influenced by thermal and intrinsic biological noise. In many relevant environments such as in the human body or in the ocean microorganisms swim in the presence of soft or solid boundaries. When bacteria approach surfaces they accumulate there and form aggregates such as biofilms. A key ingredient for the observed near-wall accumulation are the relatively large times the microswimmers reside at a surface before leaving the surface. Recently, the role of noise compared to hydrodynamic interaction with the surface for the dynamics of microswimmers at a surface has been discussed controversially.

In our work we study theoretically the collision of microswimmers with surfaces by including both hydrodynamic interactions and noise. We introduce a general framework to calculate their wall detention time distribution, i.e., the time they stay at the surface. We map the escape of the microswimmer from the surface to a mean-first passage problem and apply our theory to different swimmer models (pusher, puller, source-dipole swimmer). While source dipole swimmers have a reduced and pullers an increased detention time compared to a simple active Brownian particle, pushers can have both.