BP 20: Microswimmers, Active Liquids II (joint DY/BP/CPP)

Time: Tuesday 9:30–12:30 Location: BH-N 128

BP 20.1 Tue 9:30 BH-N 128

Trapping of active particles in inhomogeneous systems — •Martin P. Magiera, Kevin Schröer, and Lothar Brendel — Fakultät für Physik, Universität Duisburg-Essen

Inhomogeneities in a system containing active particles can lead to an inhomogeneous particle distribution if they influence the particles' velocities [Schnitzer, PRE **48**, 2553]. Those may be caused, e.g., by inhomogeneous tumble rates of bacteria or inhomogeneous drive of men-made microswimmers [e.g. Buttinoni et al, PRL **110**, 238301].

Using Brownian dynamics simulations we show that such inhomogeneities can lead to particle accumulation in a prescribed passivity region where the activity of particles is suppressed, an effect interesting for applications. We derive a corresponding accumulation parameter with an extended Fick's law for inhomogeneous systems. Depending on the overall particle density a complete particle trapping can be observed. However, even if only a minority of particles is trapped, a tiny yield can act as a nucleation seed for larger agglomerates generated by dynamical clustering [Fily and Marchetti, PRL **108**, 235702] and pinned to the passivity region.

BP 20.2 Tue 9:45 BH-N 128

Statistics of passive tracers in an active fluid — •Levke Ortlieb[1], Matthias Mussler[1], Christian Wagner[1], Thomas John[1], Philippe Peyla[2], and Salima Rafaï[2] — [1]Universität des Saarlandes — [2]Université Joseph Fourier - CNRS - LIPHY, Grenoble

In all aqueous suspension on earth there are various microswimmers, e.g. algae. In our experiments we tracked passive polystyrene particles with diameters from 1 to 3μm in suspension with the green alga Chlamydomonas reinhardtii at various concentrations. We used dark field microscopy for observations. The alga has a nearly spherical body of 5 to 10μm diameter and two flagella, which allow it to swims as a puller. We analysed the trajectories of the colloids statistically, in particular, the mean squared displacement and the probability density function (pdf) of position were computed. We found similarities to Brownian motion, as the mean squared displacement is proportional to time, but interestingly also a significant deviation was found: a non gaussian pdf of the tracer particle positions.

BP 20.3 Tue 10:00 BH-N 128

Characterization of Swimming Bacillus Subtilis — •Javad Najafi[1], Thomas John[1], Gert Bange[2], and Christian Wagner[1] — [1]Experimental Physics, Saarland University, D-66123 Saarbruecken, Germany — [2]LOEWE Center for Synthetic Microbiology (Synmikro), Marburg, Germany

Bacteria can use flexible appendages called flagella to swim in aqueous environment. Our goal is to understand the influence of the number of flagella on the swimming behavior and efficiency. We study wild type strain of bacillus subtilis as a model system to unravel a few fundamental questions on swimming behavior of bacteria. Our microorganism is a peritrichous bacterium with about 25 flagella, and uses run and tumble strategy to explore its surrounding. Using dark field microscopy and tracking of single cell movements, we calculate statistics of swimming velocity, running and tumbling times, turning angles, diffusion coefficients and the temporal auto-correlations in changes of swimming directions. In further steps, we will investigate the influence of number of flagella on genetically engineered bacillus subtilus in aforementioned quantities.

BP 20.4 Tue 10:15 BH-N 128

Non-linear dynamics of self-organized ciliary beats — •pablo sartori and frank julicher — Max Planck Institute for the Physics of Complex Systems. Noethnitzer Strasse 38 , 01187, Dresden, Germany.

The dynamic bending of cilia is driven by forces generated by dynein motor proteins. These forces slide adjacent microtubule doublets within the cilium. To create oscillatory beating patterns the activities of the dyneins must be coordinated both spatially and temporally. It is believed that this coordination occurs via the self-organization of the motors along the cilium, which are regulated by local strains such as sliding or cuvature. Yet which strain is the most relevant in regulation remains an elusive question.

In this work we show that self-organization of the motors is possible via a dynamic instability. We study the emerging beat patterns close and far from the critical point. By comparing two different motor regulatory mechanisms, sliding and curvature regulation, we conclude that the first only produces propulsion for long cilia, while the second does so also for short cilia. Our work thus suggests that short cilia may be regulated via curvature, and not sliding of the filaments.

BP 20.5 Tue 10:30 BH-N 128

Simulation of a microswimmer consisting of a four bead ring — •Hendrik Ender and Jan Kierfeld — Lehrstuhl für Theoretische Physik I, Technische Universität Dortmund

Bead-spring structures undergoing cyclic shape changes in a viscous liquid can serve as model systems for artificial microswimmers. Closed ring-like bead-spring models can propel by cyclic shape changes, for example, induced by cyclic expansion and contraction of springs. Using multi-particle collision dynamics, we simulate a four-bead swimmer model in which the spheres are linked into a square-shaped ring structure. We show that cyclic changes of linker lengths give rise to a net swimming motion. The model can be generalized by including more beads into the ring structure and represents the first step towards the simulation of bigger ring or spherical swimmers, which propel by cyclic swelling and shrinking.

BP 20.6 Tue 10:45 BH-N 128

Spontaneous chiral symmetry breaking in model bacterial suspensions — Rebekka E. Breier[1], Robin L. B. Selinger[2], Giovanni Ciccotti[3,4], Stephan Herminghaus[1], and •Marco G. Mazza[1] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), Am Fassberg 17, 37077 Göttingen, Germany — [2]Chemical Physics Interdisciplinary Program, Liquid Crystal Institute, Kent State University, Kent, OH, USA — [3]Department of Physics, University of Rome "La Sapienza", P.le A. Moro 5, 00185 Rome, Italy — [4]School of Physics, University College Dublin, Belfield, Dublin 4, Ireland

Chiral symmetry breaking is ubiquitous in biological systems, from DNA to bacterial suspensions. A key unresolved problem is how chiral structures may spontaneously emerge from achiral interactions. We study a simple model of bacterial suspensions in three dimensions that effectively incorporates active motion and hydrodynamic interactions. We perform large-scale molecular dynamics simulations (up to 10^6 particles) and describe stable (or long-lived metastable) collective states that exhibit chiral organization although the interactions are achiral. We elucidate under which conditions these chiral states will emerge and grow to large scales. We also study a related equilibrium model that clarifies the role of orientational fluctuations.

15 min. break

BP 20.7 Tue 11:15 BH-N 128

Velocity distributions in active Brownian suspensions — •Zahra Mokhtari and Annette Zippelius — Institute for Theoretical Physics, Georg-August University of Goettingen

We study numerically a model of self-propelled polar disks in suspension. The active particles interact via hard-core elastic interactions and are driven along their axes, which are subject to rotational noise. We study the distribution of linear and rotational velocities, which are predicted to show strongly anomalous but largely universal features. We furthermore analyze the correlations due to the coupling of translational and rotational motion and show that the alignment of particles' velocities and orientations can be controlled by the damping.

BP 20.8 Tue 11:30 BH-N 128

Experimental setup for 3D tracking of artificial active microswimmers — •Gunnar Klös, Carsten Krüger, Corinna C. Maass, and Stephan Herminghaus — Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany

During solubilisation in an aqueous surfactant solution well above the critical micelle solution, droplets of nematic liquid crystal show self-propelled swimming, driven by a Marangoni flow at the droplet interface [1]. These active pusher-type swimmers provide a potential physical model-system for micro-bioswimmers. We expect dimensional confinement to have a significant impact on their dynamics [2].

We have designed an experimental setup combining a microfluidic cell with a selective plane microscope using a scanning fluorescent light sheet [3]. At densities within the single scattering limit, trajectories of single swimmers or ensembles can be recorded under varying conditions of buoyancy, particle activity and cell geometry.

[1] S. Herminghaus et al., Soft Matter **10**, 7008 (2014). [2] E. Lauga et al., Biophys. J. **90**, 400 (2006). [3] J. Huisken et al., Science **305**, 1007 (2004).

BP 20.9 Tue 11:45 BH-N 128

Liquid crystal droplets as artificial microswimmers — Carsten Krüger, Gunnar Klös, Chenyu Jin, Corinna C. Maass, •Christian Bahr, and Stephan Herminghaus — Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany

Droplets of common nematic mesogens show self-propelled motion (velocity up to 50 μm/s, typical droplet diameter 10 - 100 μm) when placed into aqueous phases containing ionic surfactants at concentrations considerably above the critical micelle concentration [1]. The self-propelled motion is fueled by the solubilization of the nematic droplet in the aqueous phase, resulting finally in the formation of a microemulsion in which all mesogenic molecules have been transferred from the initial droplet into the micelles of the ionic surfactant.

We report results concerning the dependence of the swimming behavior on various parameters (droplet size, surfactant concentration, etc.), the trajectories in different confinements, the collective behavior, and the influence of the nematic or isotropic state of the mesogenic droplets.

[1] S. Herminghaus, C. C. Maass, C. Krüger, S. Thutupalli, L. Goehring, and C. Bahr, Soft Matter **10**, 7008 (2014).

BP 20.10 Tue 12:00 BH-N 128

3D-tracking reveals how sperm find the egg — Jan F. Jikeli[1], Luis Alvarez[1], •Benjamin M. Friedrich[2], and Laurence Wilson[3] — [1]CAESAR, Bonn, Germany — [2]MPI PKS, Dresden, Germany — [3]University of York, York, UK

Sperm cells are guided to the egg by chemical cues in a process termed chemotaxis. We have previously put forward a theory of how sampling a concentration gradient along helical paths allows sperm of marine species to steer up-gradient [1]. Now, high-speed tracking in three space dimensions allows to probe sperm navigation live. We find that sperm display deterministic steering responses, which sets their chemotaxis strategy apart from those employed by most bacteria (biased random walk) or immune cells (spatial comparison). We dissect the control logic that links sensation and motor actuation in sperm chemotaxis. We find that control delays are close to their theoretical optimum for up-gradient navigation. The resultant navigation strategy is particularly well suited for fast swimmers operating at the limits of chemical detection. The choice of optimal navigation strategy of a search agent is tightly linked to its susceptibilities for noise [2].

[1] B.M. Friedrich *et al.*: Chemotaxis of sperm cells, *PNAS* **33**, 2007.
[2] L. Alvarez *et al.*: The computational sperm cell, *Trends in Cell Biology* **24**, 2014.

BP 20.11 Tue 12:15 BH-N 128

Complex lane formation in asystem of dipolar mircroswimmers — •Florian Kogler and Sabine H. L. Klapp — Institute of Theoretical Physics, Secr. EW 7-1, Technical University Berlin, Hardenbergstrasse 36, D-10623 Berlin, Germany

We investigate the non-equilibrium structure formation of an experimentally motivated [1] two-dimensional (2D) binary system of dipolar colloids propelling in opposite directions. Using Brownian Dynamics simulations we find a transition towards a laned state, reminiscent of the laning transition in colloidal systems with isotropic repulsive inter actions. However, the strongly anisotropic dipolar interactions induce two novel features: First, lanes are characterized by a complex internal structure. Second, the laning transition displays reentrance with respect to the interaction strength. We interprete our findings by simple theoretical arguments relating the observed behaviour to general equilibrium properties of phase-separating fluids [2].

[1] S. Gangwal and O. J. Cayre and M. Z. Bazant and O. D. Velev, PRL 100 (2008) 058302.
[2] F. Kogler and S. H. L. Klapp, preprint