DY 35: Active Matter (joint session DY/BP)

Time: Wednesday 9:30–12:45 Location: H46

Invited Talk DY 35.1 Wed 9:30 H46

Nonreciprocal forces in soft matter systems: passive particles become active — •Hartmut Löwen — Institute of Theoretical Physics: Soft Matter, Heinrich-Heine University Duesseldorf,

There is a variety of situations in which Newton's third law is violated. Generally, the action-reaction symmetry can be broken for mesoscopic colloidal particles, when their effective interactions are mediated by a nonequilibrium environment. Here, we investigate different classes of nonreciprocal interactions relevant to real experimental situations and present their basic statistical mechanics analysis verify the principal theoretical predictions in experimental tests performed with two-dimensional binary complex plasmas [1]. For underlying Brownian dynamics [2], nonreciprocal forces result in active particle pairs thus linking nonreciprocal interactions to the field of microswimmers.

References:

[1] A. V. Ivlev, J. Bartnick, M. Heinen, C.-R. Du, V. Nosenko, H. Löwen, Physical Review X **5**, 011035 (2015).

[2] J. Bartnick, M. Heinen, A. V. Ivlev, H. Löwen, J. Phys.: Condensed Matter **28**, 025102 (2016).

DY 35.2 Wed 10:00 H46

Kinetic theory of self-driven particles: Invasion waves and correlation effects — •Thomas Ihle — Institute for Physics, Ernst-Moritz-Arndt University Greifswald, Germany

Models of self-driven agents similar to the Vicsek model are studied by means of kinetic theory. In these models, particles try to align their travel directions with the average direction of their neighbors. At strong alignment a globally ordered state of collective motion forms. An Enskog-like kinetic theory is derived from the exact equation for a Markov chain in phase space using Boltzmann's mean-field approximation of molecular chaos. The kinetic equation is solved numerically by a nonlocal Lattice- Boltzmann-like algorithm. Steep soliton-like waves are observed that lead to an abrupt jump of the global order parameter if the noise level is changed. The shape of the wave is shown to quantitatively agree within 3% with agent-based simulations at large particle speeds. This provides a mean-field mechanism to change the second-order character of the flocking transition to first order. At small densities and realistic particle speeds, the mean-field assumption of Molecular Chaos is invalid near the onset of collective motion, and correlation effects become relevant.

I will show how to self-consistently include correlation effects at the level of ring-kinetic theory. Instead of just one kinetic equation, an additional equation for the time evolution of two-particle correlations will be derived. This equation is solved numerically for a homogeneous system and shown to be in excellent agreement with agent-based simulations in certain parameter ranges.

DY 35.3 Wed 10:15 H46

Model of aerotactic bands — •Marco Giacomo Mazza — Max Planck Institute for Dynamics and Self-Organization, Göttingen

Some bacteria exhibit surprising behavior in the presence of an oxygen concentration. They perform an aerotactic motion along the gradient until they reach their optimal oxygen concentration. And they often organize collectively by forming dense regions, called 'bands', that travel towards the oxygen source. We have developed a model of swimmers with stochastic interaction rules moving in proximity of an air bubble. We perform MD simulations that reproduce the aerotactic behavior of bacteria. If the oxygen concentration in the system sinks locally below a threshold value, the formation of a migrating aerotactic band toward the bubble can be observed. We reproduce quantitatively the experimental observations on the aerotactic band.

DY 35.4 Wed 10:30 H46

Phase Behavior of Active Particles — •Jonathan Tammo Siebert[1], Janina Carmen Letz[1,2], and Peter Virnau[1] — [1]Johannes Gutenberg University Mainz, Department of Physics, Staudingerweg 7, 55128 Mainz, Germany — [2]University of Utah, Department of Mathematics, Salt Lake City, UT 84112-0090, USA

We have studied the phase behavior of active colloidal particles. Such systems undergo phase separation into a dense liquid-like and a dilute gas-like phase due to self trapping when a certain critical activity is exceeded both in experiment and simulation (Buttinoni et al., Phys. Rev. Lett., 110 (2013)). Starting point of our studies are the well known two dimensional active brownian particles. Further investigations were done on three dimensional as well as systems of active dimers. For all systems the phase diagrams were computed by extensive brownian dynamics simulations. Employing methods from equilibrium statistical physics we have aimed for an accurate estimate of the binodal line in a bulk system. Starting from a simple model system has allowed us to separate the influence of dimensionality and bonding of particles. In agreement with earlier studies we have found that active velocities needed for phase separation are much larger in the three dimensional system. Also active dimers only phase separate at higher activities than active disks.

DY 35.5 Wed 10:45 H46

Active Brownian particles at interfaces: An effective equilibrium approach — •René Wittmann and Joseph Brader — Departement für Physik, Universität Fribourg, 1700 Fribourg, Schweiz

Understanding self-organization in active Brownian systems is a subject of increasing theoretical interest. Recently, a microscopic equilibrium theory was developed from first principles [1], which accounts for the motility-induced phase separation (MIPS) observed in numerous experiments. This is achieved by mapping the active system onto an effective (static) interaction potential.

So far, experimental studies of active systems have focused on bulk properties. We apply our effective equilibrium theory [1] to inhomogeneous systems using density functional theory (DFT) with a simple perturbative treatment of the (effective) attractive interaction. In this case, the activity induces an effective external (wall) potential [2,3].

For a passively repulsive active fluid at a passively repulsive wall, the theory predicts motility-induced wetting as the MIPS transition is approached. For a Lennard-Jones interparticle potential the wall first dries with increasing activity, followed by a re-entrant wetting phenomenon. In a slit pore we observe motility-induced capillary condensation or evaporation, depending on the passive potential. These findings [3] constitute a compelling motivation to study such systems experimentally or using Brownian dynamics simulations.

[1] T. F. F. Farage, P. Krinninger and J. M. Brader, Phys. Rev. E **91**, 042310 (2015). [2] A. Pototsky and H. Stark, Europhys. Lett. **98** 50004 (2012). [3] R. Wittmann and J. M. Brader, in preparation.

15 min. break

DY 35.6 Wed 11:15 H46

Using motility patterns to manipulate self-propelled particles — •Celia Lozano[1,2], Borge ten Hagen[3], Hartmut Löwen[3], and Clemens Bechinger[1,2] — [1]2. Physikalisches Institut, Universitaet Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max-Planck-Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany — [3]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany.

Active colloidal particles capture many aspects of motile microorganisms and are therefore considered to provide a suitable model system to understand self-organization and pattern formation in living and non-equilibrium systems. Contrary to most experimental situations where the particle motility is position-independent, here we investigate a system where the self-propulsion velocity is spatially modulated. This is achieved by a light-induced propulsion mechanism and a spatially modulated light field [1]. By subjecting a dilute active colloidal suspension to an asymmetric and periodic light field, we demonstrate directed particle motion. In addition, we show, that particle transport is highly sensitive to the particle size and thus acts also as a filtering device for active suspensions [2].

[1] VOLPE G, BUTTINONI I, VOGT D, KÜMMERER H J AND BECHINGER C 2011 MICROSWIMMERS IN PATTERNED ENVIRONMENTS SOFT MATTER 7, 8810 (2011) [2] C. Lozano, B. ten Hagen, H. Löwen, and C. Bechinger. In preparation

DY 35.7 Wed 11:30 H46

Dynamics of self-propelled Janus particles in viscoelastic fluids — •Juan Ruben Gomez-Solano[1] and Clemens Bechinger[1,2] — [1]2. Physikalisches Institut, Universitaet Stuttgart, Pfaffenwaldring

57, 70569 Stuttgart, Germany — [2]Max-Planck-Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany

The motion of many natural micro-swimmers, such as bacteria and spermatozoa, commonly takes place in viscoelastic media. The understanding of their swimming mechanisms has triggered a lot of experimental and theoretical work in recent years as well as the development of artificial self-propelled particles. Although the motion of microswimmers in Newtonian fluids has been extensively studied, so far only few investigations have focused on the swimming of microorganisms in viscoelastic fluids. In this work, we experimentally investigate the dynamics of spherical Janus colloidal particles in a viscoelastic fluid. The particles are self-propelled by local demixing of a critical binary polymer mixture induced by laser illumination. We observe a dramatic enhancement of both translational and rotational diffusion with increasing particle velocity, even at low Weissenberg number, where the drag force on the particle exerted by the fluid obeys the Stokes law. We observe a similar enhancement for passive particles driven by an external constant force, e.g. gravity. Our results suggest that these effects originate from the coupling between the thermal fluctuations of the particle and the surrounding flow field, which displays large relaxation times of several seconds.

DY 35.8 Wed 11:45 H46

Hydrodynamicaly-Tuned Phase Separation of Spherical Micro-Swimmers — •Johannes Blaschke, Karthik Menon, Maurice Maurer, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany

Active motion of microorganisms and artificial micro-swimmers is relevant both to real world applications, as well as for posing fundamental questions in non-equilibrium statistical physics. A striking feature of their collective behaviour is that, for sufficiently strong self-propulsion dense clusters coexists with a low-density disordered surrounding. Due to the required computational effort, active particles are often modelled by neglecting the full hydrodynamic interactions.

However, real micro-swimmers, such as ciliated microorganisms, catalytic janus particles, or emulsions of active droplets, employ propulsion mechanisms reliant on hydrodynamics.

Here we examine the influence of the full hydrodynamic interactions on the motility-induced phase separation of spherical micro-swimmers in quasi-2D confinement. We follow up on previous work [1] by increasing the total system size allowing us to quantitatively resolve the phase-coexistence regime.

[1] A. Zöttl and H. Stark, PRL **112**, 118101 (2014)

DY 35.9 Wed 12:00 H46

Comparison of external control strategies for optimized payload delivery — •Tobias Bäuerle[1], Jakob Steiner[1], Lena Bremicker[2], Daniel Häufle[2], and Clemens Bechinger[1] — [1]2. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart, Germany — [2]Institut für Sport- und Bewegungswissenschaft, Universität Stuttgart, 70569 Stuttgart, Germany

Synthetic microswimmers, i.e. self-propelled particles, constitute an interesting class of non-equilibrium systems which exhibit structural and dynamical features similar to those observed in assemblies of motile organisms like bacteria or cells. In addition, they may find applications as microrobots which will deliver payloads to specific sites in liquid environments.

In our studies, we addressed the question how the delivery process can be optimized by the choice of the control strategy. Experimentally, this was achieved by light-activated microswimmers, where the propulsion velocity was controlled by the light intensity. Depending on the particle orientation and its distance from the target, the illumination was turned on and off, resulting in an intermittent change between Brownian and active motion. Even for slight variations of control strategies, we find large changes e.g. in the ratio of the delivery time and the total propulsion energy. Our results are in excellent agreement with numerical simulations.

DY 35.10 Wed 12:15 H46

Self-propelled janus droplets for gene extraction and controlled cargo delivery — •Menglin Li[1], Martin Brinkmann[1,2], Ralf Seemann[1,2], and Jean-Baptiste Fleury[1] — [1]Experimental Physics, Saarland University, Saarbrücken, Germany — [2]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

We report the existence of a new type of self-propelled Janus droplets, that are obtained from the spontaneous phase separation between two fully miscible fluids (water/solvent) in the presence of surfactants which are preferentially soluble in the solvent phase. At start, the related self-propulsion mechanism is generated by a Marangoni flow mediated by the solvent dissolution into the oily phase. During this motion, the droplets are absorbing a large amount of surfactant. This dynamic surfactant adsorption leads to spontaneous water/solvent demixing and the formation of Janus droplet. We characterize the hydrodynamics properties of these microwimmers during their different stages of evolution. Interestingly, the squirmer properties evolve in time from a weak pusher to a neutral squirmer and potentially to a dimer of neutral squirmers. Finally, we used this active system as a smart carrier to extract genes in situ and delivering them at a target location. (Submitted)

DY 35.11 Wed 12:30 H46

Pattern Formation and Clustering in Chemorepulsive Active Colloids — •Benno Liebchen[1], Davide Marenduzzo[1], Ignacio Pagonabarraga[2], and Michael E Cates[3] — [1]SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom — [2]Departament de Fisica Fonamental, Universitat de Barcelona-Carrer Marti i Franques 1, 08028-Barcelona, Spain — [3]DAMTP, Centre for Mathematical Sciences, University of Cambridge, Cambridge CB3 0WA, United Kingdom

Chemotaxis is the directed motion of particles in response to a gradient in a chemical signal. It allows micro-organisms, like bacteria, to find food and to escape from toxins. Some micro-organisms can produce the species to which they respond themselves and use chemotaxis for signalling. This can, in the case of chemoattraction where particles migrate up chemical gradients, induce a clustering-instability of the uniform state. This instability currently attracts renewed attention in artificial Janus colloids that swim by catalysing reactions in a chemical bath and show a similar signalling behaviour as micro-organisms.

Here, we demonstrate that also the previously underappreciated case of chemorepulsion (where particles migrate away from high chemical density) can induce clustering. The underlying instability may either rely on anisotropy in the chemical production at the particle surface or on delay effects. In contrast to chemoattractive clustering our chemorepulsive route predicts clusters of self-limiting size. This size increases with self-propulsion velocity which agrees qualitatively with recent experimental observations of dynamic clustering in active Janus colloids.