BP 46: Active Matter II (Joint Session DY/BP/CPP)

Time: Thursday 9:30–13:00 Location: HÜL 186

Invited Talk BP 46.1 Thu 9:30 HÜL 186

Rolling, rolling, rolling – a new self-propulsion mechanism — •Falko Ziebert[1,2] and Igor Kulic[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, 79104 Freiburg, Germany — [2]Institut Charles Sadron UPR22-CNRS, 67034 Strasbourg Cedex 2, France

We describe a generic mechanism that induces an instability towards rolling motion of a rod along a heated plate. The mechanism, relying on geometric planar confinement, can be explained by an effective model combining elasticity of a rod with thermal advection-diffusion. We exemplify the versatility of the effect by investigating self-propellers, as well as simple motors and energy storage devices, both experimentally and theoretically.

BP 46.2 Thu 10:00 HÜL 186

Cluster Formation and Deformation of Spherical Circle Swimmers Dispersed on a Monolayer — •Guo-Jun Liao and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Inspired by recent experimental developments in manufacturing "active" colloidal particles with unusual, e.g. curved, modes of motion (such as form-anisotropic particles [1] or decorated metallodielectric Janus spheres [2]), as well as by the proceeding of a theoretical study on the collective behavior of curved polymers with circular paths [3], we computationally investigate models of spherical particles in which the colloids dispersed on a monolayer feel not only a propelling force, but also a propelling torque. In the absence of propulsion torque (without circular motion), we find clustering of "conventional" self-propelled disks, in accordance with Ref. [4]. We show that the motility-induced cluster formation is enhanced by polar interaction, and cumulatively hindered by increasing the propulsion angular velocity ω_0. Different from the model of curved polymers [3], in which the occurrence of stable vortices is attributed to the shape anisotropy, our generic model of isotropic "active" spheres also form clockwise vortices as ω_0 approaches the rotational diffusion coefficient D_r.

[1] F. Kümmel et al., Phys. Rev. Lett. **110**, 198302 (2013)
[2] S. Gangwal et al., Phys. Rev. Lett. **100**, 058302 (2008)
[3] J. Denk et al., Phys. Rev. Lett. **116**, 178301 (2016)
[4] J. Bialke et al., EPL **103**, 30008 (2013)

BP 46.3 Thu 10:15 HÜL 186

Effect of the orientational relaxation on the collective motion of patterns formed by self-propelled particles. — •Alexander Chervanyov[1], Hector Gomez[2], and Uwe Thiele[1] — [1]Institut für Theoretische Physik, WWU Münster, Germany — [2]Universidade da Coruna, A Coruna, Spain

We investigate the collective behavior of self-propelled particles (SPPs) undergoing competitive processes of pattern formation and rotational relaxation of their self-propulsion velocities. As a main result of this study, we quantitatively explain [1] transitions between different steady states of the SPPs caused by the intricate interplay among the involved effects of pattern formation, orientational order, and coupling between the SPP density and orientation fields. Based on rigorous analytical and numerical calculations, we prove that the rate of the orientational relaxation of the SPP velocity field is the main factor determining the steady states of the SPP system. Further, we determine the exact boundaries between domains in the parameter plane that delineate qualitatively different resting and moving states. In addition, we analytically calculate the collective velocity of the SPPs and show that it perfectly agrees with our numerical results. Our results can be effectively used to identify the regimes of collective behavior of SPPs in living systems in relevance to the domains of dominance of the above described effects of the self-propulsion, pattern formation and orientational relaxation of SPPs.

[1] A.I. Chervanyov, H. Gomez, U. Thiele, EPL 115, 68001 (2016).

BP 46.4 Thu 10:30 HÜL 186

Statistical features of active turbulence — •Martin James and Michael Wilczek — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Dense bacterial suspensions display rich dynamical features including turbulence-like behavior. Recent studies have shown that such turbulent dynamics of active fluids can be modeled by a generalized Navier-Stokes equation (Wensink et al., PNAS 2012). The statistical features of active turbulence, however, differ significantly from classical hydrodynamic turbulence (see, e.g., Bratanov et al., PNAS 2015). We further explore the statistical features of this active turbulence model both, numerically and analytically. In particular, we focus on scale-dependent statistics to characterize deviations from Gaussianity and the occurrence of extreme events. Moreover, we investigate the transport properties of active flow by using Lagrangian tracer techniques. Our results provide insight into mixing of microbial suspensions due to turbulent dynamics.

BP 46.5 Thu 10:45 HÜL 186

Large scale vortex-patterns in dense suspensions of microswimmers — •Sebastian Heidenreich[1], Jörn Dunkel[2], Sabine H. L. Klapp[3], and Markus Bär[1] — [1]Physikalisch-Technische Bundesanstalt — [2]Massachusetts Institute of Technology — [3]Technische Universität Berlin

In this talk we consider a prominent examples of an active biological fluid - dense suspension of swimming bacteria (e. g. Bacillus subtilis). For dense suspensions of bacterial swimmers, we have proposed a simple phenomenological model that predicts regular and turbulent vortex lattices and reproduces recent experimental findings of mesoscale turbulence in two- and three-dimensional suspensions of Bacillus subtilis in a quantitative manner [1]. A continuum model that couples the orientation of the swimmers with the surrounding velocity field was derived from stochastic equations of motions for individual active swimmers for a realistic hydrodynamical model of swimmers in a fluid [2]. This model contains the simple phenomenological model used in [1] as a special case. Furthermore, the continuum model enables us to understand the mechanism and properties of pattern formation in microswimmer suspensions and relate the physical parameters characterizing the individual swimmers and their interaction to the coefficients for continuum model equations.

[1] Dunkel, S. Heidenreich, K. Drescher, H. H. Wensink, M. Bär & R. E. Goldstein Phys. Rev. Lett. 110; New. J. Phys. (2013).

[2] S. Heidenreich, J. Dunkel, S. L. Klapp, and M. Bär (2016). Phys. Rev. E, 93

BP 46.6 Thu 11:00 HÜL 186

Collective Effects of Active Particles at Fluid-Fluid Interfaces. — •Irina Kistner, Paolo Malgaretti, Mihail Nicolae Popescu, and Siegfried Dietrich — Max-Planck-Institut fuer Intelligente Systeme, Stuttgart, Germany

Micrometer sized particles capable of self-induced motility are of high interest for various applications in medicine, sensing and environmental science. Recent works report of different types of collective motion such as clustering, swarming or fluid-solid phase separation. Moreover different phenomena may arise when active particles are bounded or reside in the proximity of a fluid-fluid interface [1], [2].

The model system we are investigating consists of two or more chemically active, spherical colloidal particles located close to a fluid-fluid interface. Due to the Marangoni stresses self-induced at the interface, the particles experience a repulsive long-ranged effective force field under harmonic confinement. We show that this effective interaction results in a crystal-like pattern formation of collectively rotating particles and define a gas-crystal phase separation governed by the Marangoni force constant.

[1] A. Dominguez, P. Malgaretti, M. N. Popescu, and S. Dietrich: Effective interaction between active colloids and fluid interfaces induced by Marangoni flows, Phys. Rev. Lett. 117, 079902 (2016)

[2] A. Dominguez, P. Malgaretti, M. N. Popescu, and S. Dietrich: Collective dynamics of chemically active particles trapped at a fluid interface, Soft Matter, 12, 8398-8406 (2016)

15 min. break

BP 46.7 Thu 11:30 HÜL 186

Mechanical Instabilities in Active Systems — •Christoph A. Weber and Lakshminarayanan Mahadevan — Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138, USA

Active stress can affect the stability of biological systems and drive macroscopic changes of matter on very short time scales that cannot be explained by the liquid-like transport of the constituents. Examples are contracting active gels or the compaction of cells in tissues. For these systems the solid-like response to active stress is the key to understand the physics underlying the change of matter. Here we study a generic framework to describe mixtures composed of an active solid and a passive liquid phase. We find that such a mixture is unstable for large enough activity and can demix into regions mostly consisting of solid or fluid, respectively. The instability leads to the formation of disintegrated patches of a length scales which arises from the competition between the shear transport in the solid phase versus the solid-liquid momentum transfer. This mechanical instability might be relevant for many very dense active systems where liquid-like particle transport is mostly jammed.

BP 46.8 Thu 11:45 HÜL 186

Defect dynamics in topological active matter — •Axel Voigt and Francesco Alaimo — Institute für Wissenschaftliches rechnen, TU Dresden

If active systems are confined on curved surfaces, topological constraints strongly influence the emerging spatiotemporal patterns. Using these topological constraints to guide collective cell behavior might be a key in morphogenesis and active nematic films on surfaces have been proposed as a promising road to engineer synthetic materials that mimic living organisms. Recent experiments consider an active nematic film of microtubules and molecular motors encapsulated within a lipid vesicle. As in passive systems the mathematical Poincare-Hopf theorem forces topological defects to be present in the nematic film. On a spherical vesicles this leads to an equilibrium defect configuration with four $+1/2$ disclinations arranged as a tetrahedron. In active systems unbalanced stresses drive this configuration out of equilibrium. But in contrast to planar active nematics with continuous creation and annihilation of defects the creation of additional defect pairs can be suppresses on curved surfaces. This led to the discovery of a tunable periodic state that oscillates between the tetrahedral and a planar defect configuration. We confirm this finding by computer simulations. For non-constant Gaussian curvature constraints local geometric properties can be used to control defect dynamics. We are concerned with a systematic investigation of the impact of such constraints on the emergence of complex patterns and oscillations.

BP 46.9 Thu 12:00 HÜL 186

Dancing disclinations in living fluids — •Amin Doostmohammadi, Tyler Shendruk, Kristian Thijssen, and Julia Yeomans — University of Oxford

The spontaneous emergence of collective flows is a generic property of active fluids and often leads to chaotic flow patterns characterised by swirls, jets, and topological disclinations in their orientation field. However, the ability to achieve structured flows and ordered disclinations is of particular importance in the design and control of active systems. By confining an active nematic fluid within a channel, we find a regular motion of disclinations, in conjunction with a well defined and dynamic vortex lattice. As pairs of moving disclinations travel through the channel, they continually exchange partners producing a dynamic ordered state, reminiscent of Ceilidh dancing. We anticipate that this biomimetic ability to self-assemble organised topological disclinations and dynamically structured flow fields in engineered geometries will pave the road towards establishing new active topological microfluidic devices.

BP 46.10 Thu 12:15 HÜL 186

Effective interactions between catalytic particle and fluid-fluid interfaces — •Paolo Malgaretti, Mihail Nicolae Popescu, and Siegfried Dietrich — Max Planck Institute for Intelligent Systems, Heisenbergstr. 3 70569 Stuttgart Germany

When catalytic particles, such as Janus particles, or enzymes are in the vicinity of a fluid-fluid interface, their is strongly modulated by the pres-ence of the interface and/or by the inhomogeneity in the transport properties of the two fluid phases. Hence, the effective interaction with the interface can lead to novel dynamical regimes absent in homogeneous fluids. For example, if the by-products of the catalysis are surfactants their spatial distribution will affect the local value of the surface tension. In such a scenario, when catalytic particles approache a fluid-fluid interface a Marangoni flow will set up in response to the inhomogeneity in the surface tension induced by the byproducts of the catalysis. The onset of such a flow attracts the catalytic particle towards the interface. Interestingly the strength of such an effective attraction is strongly affected by the affinity of the byproduct to the interface as well as by the transport properties of the two fluid phases. In particular, for water-oil interfaces such an effect overwhelms other means of active transport such as self-diffusiophoresis and makes it suitable to enhance particle accumulation close to fluid-fluid interfaces. Finally I will discuss the onset of collective behavior.

BP 46.11 Thu 12:30 HÜL 186

Active crystals on the sphere — •Simon Praetorius[1], Axel Voigt[1], Raphael Wittkowski[2], and Hartmut Löwen[3] — [1]Institute of Scientific Computing, Technische Universität Dresden, D-01062 Dresden, Germany — [2]Institut für Theoretische Physik Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [3]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

Two-dimensional crystals on curved manifolds like a sphere exhibit nontrivial defect structures. Here we consider "active" crystals on the sphere which are composed of self-propelled particles. A coarse-grained model is proposed by unifying the Phase-Field Crystal approach with a Toner-Tu-like theory which involves a density and a polarization field on the sphere. Depending on the strength of the self-propulsion, four different dynamical modes are found: a resting crystal, a self-spinning "vortex-vortex" crystal containing two vortical poles with integer defects of the polarization, a "source-sink" crystal and a travelling/spinning lamellar. We analyze the dependence of orientational and translational defects on the activity of the crystal.

BP 46.12 Thu 12:45 HÜL 186

Green-Kubo approach to active Brownian systems — •abhinav sharma and joseph Brader — Universite de Fribourg, Rue du Musee 3, ch 1700, Fribourg

We develop an exact Green-Kubo formula relating nonequilibrium averages in systems of interacting active Brownian particles to equilibrium time-correlation functions. The method is applied to calculate the density-dependent average swim speed, which is a key quantity entering coarse grained theories of active matter. The average swim speed is determined by integrating the equilibrium autocorrelation function of the interaction force acting on a tagged particle. We generalize our approach to a spatially and time varying activity. Analytical results are validated using Brownian dynamics simulations.