CPP 112: Active Matter V (joint session DY/BP/CPP)

Time: Friday 10:00–11:30 Location: ZEU 160

CPP 112.1 Fri 10:00 ZEU 160

A particle-field approach bridges phase separation and collective motion in active matter — •Robert Grossmann[1,2], Igor Aranson[3], and Fernando Peruani[2] — [1]Institute of Physics and Astronomy, University of Potsdam, Potsdam, Germany — [2]Laboratoire J.A. Dieudonné, Université Côte d'Azur, Nice, France — [3]Department of Chemistry, Pennsylvania State University, University Park (PA), United States of America

Linking seemingly disconnected realms of active matter – active phase-separation of repulsive discs and collective motion of self-propelled rods – is a major contemporary challenge. We present a theoretical framework based on the representation of active particles by smoothed continuum fields which brings the simplicity of alignment-based models, enabling an analytical analysis, together with more realistic models for self-propelled objects including their steric, repulsive interactions. We demonstrate on the basis of the collision kinetics how nonequilibrium stresses acting among self-driven, anisotropic objects hinder the emergence of motility-induced phase separation and facilitate orientational ordering. Moreover, we report that impenetrable, anisotropic rods are found to form polar, moving clusters, whereas large-scale nematic structures emerge for soft rods, notably separated by a bistable coexistence regime. Thus, the symmetry of the ordered state is not dictated by the symmetry of the interaction potential but is rather a dynamical, emergent property of active systems. This theoretical framework can represent a variety of active systems: cell tissues, bacterial colonies, cytoskeletal extracts or shaken granular media.

CPP 112.2 Fri 10:15 ZEU 160

The role of inertia in active nematic turbulence — •Colin-Marius Koch and Michael Wilczek — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Suspensions of active agents with nematic interactions can exhibit complex spatio-temporal dynamics such as mesoscale turbulence. Continuum descriptions for such systems are inspired by the hydrodynamic theory of liquid crystals and introduce additional effects of active stresses. The resulting equations feature an advective nonlinearity which represents inertial effects. The typically low Reynolds number of such active flows raises the question of the importance of the inertial effects. To address this question, we numerically investigate turbulent flows in a two-dimensional dense suspension of active nematic liquid crystals. We qualitatively compare numerical simulations with and without nonlinear advection of the flow field. We find that for sufficiently high activity, the simulations considering the advection term display large-scale motion not observed when excluding inertia. Performing a spectral analysis of the energy budget, we identify an inverse energy transfer to the largest scales highlighting the importance of inertial effects in this model. We additionally show that surface friction, mimicked by a linear friction term, dissipates the transported energy and slows down the large-scale motion.

CPP 112.3 Fri 10:30 ZEU 160

Active Brownian particles show motility-induced spatially periodic patterns — •Samuel Grimm[1], Andreas Fischer[2], Thomas Speck[2], and Walter Zimmermann[1] — [1]Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Physics Institute, University of Mainz, 55099 Mainz, Germany

We suggest and investigate a model for active Brownian particles, that shows motility induced pattern formation. We complement a model of motility induced phase separation (MIPS) [J. Chem. Phys. 142, 224149 (2015)] by the dynamics of auto-inducer molecules. This results in a prototype model for spatially periodic patterns under conservation constraints, here the conservation of Brownian particles. By increasing the chemotactic sensitivity of active Brownian particles a transition from MIPS to motility induced periodic patterns takes place. They are found in a wide parameter range. Besides the phase diagrams for the onset of spatially periodic patterns also their nonlinear behavior beyond onset is investigated for selected parameter ranges.

CPP 112.4 Fri 10:45 ZEU 160

The role of advection in the diffusioosmosis of an active micropump — •Gonçalo Antunes[1,2], Paolo Malgaretti[1,2], Jens Harting[3,4], and Siegfried Dietrich[1,2] — [1]MPI-IS, Stuttgart, Germany — [2]U. Stuttgart, Stuttgart, Germany — [3]HI-ERN, Forschungszentrum Jülich, Nürnberg, Germany — [4]TU/e, Eindhoven, The Netherlands

Diffusioosmosis can be exploited to fabricate active colloids that swim in a fluid/solute mixture through a self-generated inhomogeneous concentration of solute [1]. Using the same mechanism, an active channel can be fabricated such as to pump fluid in a way that is tunable via the geometry and chemistry of the channel.

In this talk, we study the flow inside an active hourglass-shaped channel. Our Lattice Boltzmann simulations are combined with a finite-difference solver for the advection-diffusion equation that determines the solute dynamics [2]. We find that even when the channel is fore-aft symmetric, advection can lead to the pumping of fluid, in analogy to the steady motion of isotropic colloids [3,4]. Furthermore, sustained oscillations are found where the magnitude of the flow oscillates with a tunable frequency. Our findings are thus relevant for those who wish to exploit surface-driven flows at small scales.

[1] J. L. Anderson, Ann. Rev. Fluid Mech. **21** 61-99 (1989) [2] T. Peter, P. Malgaretti, N. Rivas, A. Scagliarini, J. Harting, S. Dietrich, arXiv:1911.06324 (2019) [3] S. Michelin, E. Lauga, and D. Bartolo, Phys. Fluids **25** 061701 (2013) [4] P. de Buyl, A. S. Mikhailov, and R. Kapral, EPL **103** 60009 (2013)

CPP 112.5 Fri 11:00 ZEU 160

Dynamical states in underdamped active matter — •Dominic Arold and Michael Schmiedeberg — Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

Many active matter systems are well approximated as overdamped, meaning that any inertial momentum is immediately dissipated by the environment. On the other hand, for macroscopic active systems, the time scale of inertial motion can become large enough to be relevant for the dynamics already on the single-particle level [1]. This raises the question of how collective dynamics in active matter is influenced by inertia. We propose a coarse-grained continuum model for underdamped active matter based on a dynamical density functional theory for passive systems [2]. Further, we apply the model to a system with short-range alignment of polar orientations whereas long-ranged correlations of orientational order are suppressed. Our simulations of under- and overdamped dynamics both predict a structured laning state. However, activity-induced convective flows only present in the underdamped model destabilize this state in a certain parameter regime, leading to a collective motion state which is not predicted in the overdamped limit. A turbulent transition regime between the two states is distinguished by strong density fluctuations.

[1] Scholz C et al. 2018 *Nature communications* **9** 5156
[2] Archer A J 2009 *The Journal of chemical physics* **130** 014509

CPP 112.6 Fri 11:15 ZEU 160

Predictive local field theory for interacting active Brownian spheres in two spatial dimensions* — Jens Bickmann and •Raphael Wittkowski — Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany

We present a predictive local field theory for the dynamics of interacting spherical active Brownian particles in two spatial dimensions. Alongside the general theory, which includes configurational order parameters and derivatives up to infinite order, we present reduced models that are easier to apply. We show that our theory contains popular models such as Active Model B + as special cases and that it provides explicit expressions for the coefficients occurring in these models. As further outcomes, the theory yields analytical expressions for the density-dependent mean swimming speed and the spinodal corresponding to motility-induced phase separation of the particles. The analytical predictions for the spinodal are found to be in very good agreement with the results of Brownian dynamics simulations. Furthermore, the critical point predicted by our analytical results agrees excellently with recent computational results from the literature.

**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*