BP 20: Active Matter 4 (joint session DY/BP/CPP)

Time: Wednesday 15:00–17:30 Location: H18

BP 20.1 Wed 15:00 H18

Clusters and fractals in non-reciprocally interacting colloids — •Sebastian Fehlinger and Benno Liebchen — Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Hochschulstraße 8, D-64289 Darmstadt, Germany

Non-reciprocal interactions are widespread in nature. For the specific case of a binary mixture of passive particles, the breaking of the action reaction principle can lead to formation of active colloidal molecules which are capable of self-propulsion. For small systems, such active molecules have already been realized in experiments based on phoretically interacting binary colloidal mixtures [1,2].

The focus of the present work is to understand the many body behaviour of active molecules. Using particle based simulations and continuum theory, we find that non-reciprocal attractions in a binary mixture of non-motile particles can destabilize the uniform disordered phase and lead to clusters which grow in time. Surprisingly, for a wide parameter range, the clusters only grow up to a certain size such that coarsening is arrested. We attribute this to an effective screening effect which hinges on the characteristic spatiotemporal organization of the two species within the clusters. In addition, remarkably, in a different parameter regime, we find porous macroclusters featuring significant holes and a fractal dimension which differs from the one expected for conventional diffusion limited aggregation.

[1]F. Schmidt et al. J. Chem. Phys. 150, 094905 (2019)
[2]J. Grauer et al. Nat. Commun. 12, 6005 (2021).

BP 20.2 Wed 15:15 H18

Analysis of transient dynamics of bioconvection in swimming algae — •Alexander Jarosik, Florian von Rüling, and Alexey Eremin — Otto-von-Guericke Universität, Magdeburg, Germany

Swimming unicellular algae Chlamydomonas reinhardtii exposed to light form intricate hydrodynamic instability patterns called bioconvection. High-density plumes of cells are formed in the top layer, descend to the container's bottom, and rise again to the top. This instability arises from coupling between the gyro- and phototactic behaviour of the cells, their physical properties and the flow. In this work, we analyse the microswimmer's dynamics as a function of the cell density, confinement of the environment and light. The transient behaviour of the plume formation is analysed using the Continuous Wavelet Transformation (CWT). We demonstrate that the plume formation can be controlled by local illumination.

BP 20.3 Wed 15:30 H18

Optimal turbulent transport in microswimmer suspensions — •Henning Reinken[1], Sabine H. L. Klapp[1], and Michael Wilczek[2] — [1]Technische Universität Berlin — [2]Universität Bayreuth

Microwsimmer suspensions, a paradigmatic example of an active fluid, self-organize into complex spatio-temporal flow patterns, including regular vortex lattices and mesoscale turbulence. This work investigates the transport properties of these suspensions by tracking the diffusive motion of passive tracers in the turbulent flow. We apply a continuum model for the effective microswimmer velocity field [1,2], where the dynamics is governed by the competition between relaxation to a regular vortex lattice and destabilization by nonlinear advection. Varying the strength of nonlinear advection, we observe two qualitatively different regimes of flow transport that we distinguish with the help of the dimensionless Kubo number K, which compares different time scales. Right above the transition to turbulence, the flow field evolves very slowly ($K \gg 1$) and the spatial vortex structures lead to dominant trapping effects. In contrast, for large advection strength, much faster dynamics ($K \ll 1$) leads to transport properties completely determined by the temporal correlations of the flow. In between ($K \approx 1$), we observe a regime of optimal transport, where the diffusion coefficient reaches a maximum.

[1] Reinken, Klapp, Bär, Heidenreich, Phys. Rev. E **97**, 022613 (2018)
[2] James, Bos, Wilczek, Phys. Rev. Fluids **3**, 061101(R) (2018).

BP 20.4 Wed 15:45 H18

Interfacial activity dynamics of confined active droplets — •Prashanth Ramesh[1,2], Babak Vajdi Hokmabad[1], Arnold J.T.M. Mathijssen[3], Dmitri O. Pushkin[4], and Corinna C. Maass[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization — [2]University of Twente — [3]University of Pennsylvania — [4]University of York

Active emulsions exhibit a complex hydrodynamic mode spectrum driven by chemical advection-diffusion instabilities. We study such an active emulsion consisting of oil droplets that dynamically solubilize in a supramicellar aqueous surfactant solution. It has been predicted that the interaction with self-generated chemical fields leads to multistable higher-mode flow fields and chemorepulsive phenomena. To investigate such chemodynamic effects, we study cylindrical droplets pinned between the top and bottom surfaces of a microfluidic reservoir, such that they only produce pumping flows, while we simultaneously quantify the chemical concentration field and the hydrodynamic velocity field. With increasing droplet radius we observe: vortical structures generated by the droplet migrating around the interface, bistability between a dipolar and quadrupolar flow mode, and, eventually, a transition to multipolar modes. We further measured flow fields by particle image velocimetry and compared them to a hydrodynamic model based on a Brinkman squirmer. A simultaneous quantification of the flow fields and oil-filled micelle distribution suggests that a local buildup of chemical products leads to a saturation of the surface, which affects the propulsion mechanism and eventually suppresses all activity.

BP 20.5 Wed 16:00 H18

Hydrodynamics and fluctuations in bacterial models — •Subhadip Chakraborti — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — Max-Planck-Zentrum für Physik und Medizin, Erlangen, Germany

Motivated by a biological example of the persistent motion of bacteria, we propose two one-dimensional models of active lattice gases with hardcore interactions. Using macroscopic fluctuation theory (MFT), we analytically derive hydrodynamics for those models and calculate two density-dependent transport coefficients – the bulk-diffusion coefficient and the conductivity, and verify the Einstein relation (ER) by comparing the ratio of those transport coefficients with subsystem number fluctuation. The first model consisting of particles with competing mechanisms of short and long-range hopping obeys the Einstein relation, and exhibits, in the limit of infinite range hopping, upon tuning density (or activity), a 'superfluid' transition from a finitely conducting state to an infinitely conducting one. Interestingly, the bulk-diffusion coefficient remains constant throughout. The diverging conductivity induces 'giant' number fluctuations in the system. In the second model, consisting of hardcore run and tumble particles with persistent motion in one direction decided by an associated spin variable until the direction of spin is reversed, we perform a similar calculation and find that the Einstein relation is violated. This analytic framework could be useful for a better understanding of the collective behavior of many biological systems such as bacterial colonies and other multicellular aggregates, in the context of dynamics and transport properties.

15 min. break

BP 20.6 Wed 16:30 H18

Shearing an Active Glass — •Rituparno Mandal and Peter Sollich — Institut für Theoretische Physik, Göttingen, Germany

Recent experiments and simulations have revealed glassy features of cytoplasm, tissues and dense assemblies of self propelled colloids. This prompts the fundamental question of whether non-equilibrium (active) amorphous materials are essentially equivalent to their passive counterparts, or whether they can present qualitatively different behaviour. To tackle this challenge we investigate the yielding and mechanical behaviour of a model active glass former, a Kob-Andersen glass in two dimensions where each particle is driven by a constant propulsion force whose direction varies diffusively over time. Using extensive Molecular Dynamics simulations, we focus in particular on the effects of the intermittent dynamics in the regime of highly persistent activity and reveal a novel type of shear induced orientational ordering in the system.

BP 20.7 Wed 16:45 H18

Active motion with varying self propulsion — Lorenzo Caprini[1], Alexander R. Sprenger[1], Umberto M. B. Marconi[2], Hartmut Löwen[1], and •René Wittmann[1] — [1]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine Universität Düssel-

dorf, Germany — [2]School of Sciences and Technology, University of Camerino, Italy

Active Brownian Particles (ABPs), commonly perceived as the standard model for (dry) active motion, are characterized by a constant self-propulsion velocity along the direction of a unit vector which performs rotational diffusion. In nature, however, the swim velocity is usually not a constant in time and space. Here, we present a generic form of the equations of motion of active particles, which account for two aspects of varying self propulsion. First, we introduce a general stochastic process with fluctuating modulus of the self-propulsion vector, which defines a parental active model (PAM). We argue that the two well-known models of ABPs and Active Ornstein-Uhlenbeck Particles (AOUPs) emerge as limiting cases of the PAM [1], i.e., they are rather sisters than cousins. Second, we demonstrate that a position-dependent swim-velocity field can be consistently introduced for any self-propulsion mechanism [2]. Finally, we discuss the effects of varying self propulsion in external confinement [1,3] and predict the stationary probability distributions in terms of effective interactions [3].

[1] L. Caprini et al., J. Chem. Phys. 156, 071102 (2022).
[2] L. Caprini et al., Soft Matter, 18, 1412 (2022).
[3] L. Caprini et al., arXiv:2203.00603 (2022).

BP 20.8 Wed 17:00 H18

Perturbing the athermal jamming transition by activity — •Michael Schmiedeberg — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

By minimizing the interaction energy in a soft sphere system without crossing energy barriers the discontinuous athermal jamming transion can be observed at a packing fraction of about 0.64 in three dimensions [1]. We consider the jamming of active particles where the activity corresponds to a perturbation to the athermal jamming process. We find that due to the activity the transition becomes continuous and the transition packing fraction might occur at a different density [2]. The critical exponents agree to those of the universality class of directed percolation. As a consequence, athermal jamming of passive particles seems to be a (singular) limit of the jamming transition in an active system. Note that other perturbation like thermal fluctuations lead to a similar behavior [3]. Therefore, athermal active particles can be seen as a prototype system that leads to new insights how jamming with perturbations (as also studied in [2-5]) can be related to glassy dynamics.

[1] C.S. O'Hern et al., Phys. Rev. Lett. 88, 075507 (2002) and Phys. Rev. E 68, 011306 (2003).
[2] M. Maiti and M. Schmiedeberg, EPL 126, 46002 (2019).
[3] M. Maiti and M. Schmiedeberg, Scientific Reports 8, 1837 (2018); for 2D: Eur. Phys. J. E 42, 38 (2019).
[4] L. Milz and M. Schmiedeberg, Phys. Rev. E 88, 062308 (2013).
[5] S. Wilken et al., Phys. Rev. Lett. 127, 038002 (2021).

BP 20.9 Wed 17:15 H18

Non-equilibrium phase separation in mixtures of catalytically active particles: size dispersity and screening effects — •Vincent Ouazan-Reboul[1], Jaime Agudo-Canalejo[1], and Ramin Golestanian[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, D-37077, Göttingen, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, OX1 3PU, Oxford, UK

Biomolecular condensates in cells are often rich in catalytically active enzymes. This is particularly true in the case of the large enzymatic complexes known as metabolons, which contain different enzymes that participate in the same catalytic pathway. One possible explanation for this self-organization is the combination of the catalytic activity of the enzymes and a chemotactic response to gradients of their substrate, which leads to a substrate-mediated effective interaction between enzymes. These interactions constitute a purely non-equilibrium effect and show exotic features such as non-reciprocity. Here, we analytically study a model describing the phase separation of a mixture of such catalytically active particles. We show that a Michaelis-Menten-like dependence of the particles' activities manifests itself as a screening of the interactions, and that a mixture of two differently sized active species can exhibit phase separation with transient oscillations. We also derive a rich stability phase diagram for a mixture of two species with both concentration-dependent activity and size dispersity.