BP 7: Active Matter II (joint session DY/BP/CPP)

Time: Monday 15:00–18:15 Location: ZEU 160

BP 7.1 Mon 15:00 ZEU 160

Chiral motion of actively driven objects in discrete steps towards a remote target — •Andreas M. Menzel — Otto-von-Guericke-Universität Magdeburg, Magdeburg, Germany

We address the motion of chiral actively driven objects that move in discrete steps on a flat substrate [1]. While closed polygon-shaped trajectories are found in the case of unperturbed motion, the dynamics becomes surprisingly rich and nonlinear, if the objects additionally head for a fixed remote target. In that situation, cycloidal-like, straight, zigzag-type, doubled zigzag, quadrupled zigzag, and further period-doubled types of trajectory emerge, besides chaotic behavior. Additionally, we investigate the motion of crowds of such objects under explicit mutual alignment interaction. In the absence of fluctuations, collective orientational ordering occurs also in the chaotic regime, in combination with spatial gathering of the particles. Conversely, fluctuations and polydispersity in target alignment counteract orientational ordering. Our results may apply to various types of actively driven objects, for instance, light-responsive bacteria, laser-controlled colloidal particles, or hoppers on vibrated substrates.

[1] A. M. Menzel, resubmitted.

BP 7.2 Mon 15:15 ZEU 160

Polar flocks with discretized directions: the active clock model approaching the Vicsek model — •Matthieu Mangeat, Swarnajit Chatterjee, and Heiko Rieger — Universität des Saarlandes, Saarbrücken, Germany

We study the off-lattice two-dimensional q-state active clock model (ACM) [EPL **138**, 41001 (2022)] as a natural discretization of the Vicsek model (VM) [PRL **75**, 1226 (1995)] describing flocking. The ACM consists of particles able to move in the plane in a discrete set of q equidistant angular directions, as in the active Potts model (APM) [EPL **130**, 66001 (2020); PRE **102**, 042601 (2020)], with a local alignment interaction inspired by the ferromagnetic equilibrium clock model. A collective motion emerges at high densities and low noise. We compute phase diagrams of the ACM and explore the flocking dynamics in the region, in which the high-density (polar liquid) phase coexists with the low-density (gas) phase. We find that for a small number of directions, the flocking transition of the ACM has the same phenomenology as the APM, including macrophase separation and reorientation transition from transversal to longitudinal band motion as a function of the particle self-propulsion velocity. For a larger number of directions, the flocking transition in the ACM becomes equivalent to the one of the VM and displays microphase separation and only transverse bands, i.e. no reorientation transition. Concomitantly also the transition of the $q \to \infty$ limit of the ACM, the active XY model, is in the same universality class as the VM. We also construct a coarse-grained hydrodynamic description akin to the VM.

BP 7.3 Mon 15:30 ZEU 160

Tracer-induced temperature difference in motility-induced phase separation — •Lukas Hecht, Iris Dong, and Benno Liebchen — Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Hochschulstr. 8, D-64289 Darmstadt, Germany

Previous studies of overdamped active Brownian particles (ABPs) mixed with passive tracers have shown that self-propulsion can induce motility-induced phase separation (MIPS) for large enough particle density and self-propulsion speed [1]. Here, we present our study on overdamped ABPs mixed with inertial passive tracers. We show that MIPS features different kinetic temperatures in the dense and the dilute phase if the passive tracers are sufficiently heavy (inertial). Remarkably, unlike for underdamped ABPs [2,3], neither the overdamped ABPs nor the passive tracers alone would feature such a temperature difference in coexisting phases. The observed temperature difference is accompanied by a violation of the equipartition theorem and strongly depends on the self-propulsion speed and the particle density. This allows us to tune the temperature difference from a cold dense and hot dilute phase to the counterintuitive opposite case in which the dense phase is hotter than the dilute phase. These findings open a route to create active materials with a persistent temperature profile by inserting active particles and tuning their self-propulsion speed accordingly.

[1] J. Stenhammar et al., Phys. Rev. Lett. 114, 018301 (2015).
[2] S. Mandal et al., Phys. Rev. Lett. 123, 228001 (2019).
[3] L. Hecht et al., Phys. Rev. Lett. 129, 178001 (2022).

BP 7.4 Mon 15:45 ZEU 160

Collective motion in two-dimensional colloidal systems with effective (active) self-propulsion due to time-delayed feedback — •Robin A. Kopp and Sabine H. L. Klapp — ITP, TU Berlin, Berlin, Germany

In recent years, delayed feedback in colloidal systems has become an active and promising field of study [1,2], key topics being history dependence and the manipulation of transport properties. Here we study the dynamics of a two-dimensional colloidal suspension, subject to time-delayed feedback, where time-delayed feedback can be interpreted as a mechanism of effective self-propulsion, i.e., activity [3]. To this end we perform overdamped Brownian dynamics simulations, where the particles interact through a Weeks-Chandler-Andersen potential. Furthermore, each particle is subject to a Gaussian, repulsive feedback potential, that depends on the difference of the particle position at the current time, and at an earlier time. We observe and quantitatively study the emergence of dynamical clustering and collective motion characterized by a nonzero mean velocity and provide a possible explanation for the underlying mechanism combining single-particle and mean-field-like effects.

[1] S. A. M. Loos, and S. H. L. Klapp, Scientific Reports **9**, 2491 (2019)
[2] M. A. Fernandez-Rodriguez et al., Nature Communications **11**, 4223 (2020)
[3] R. A. Kopp and S. H. L. Klapp, arXiv:2210.03182 (2022)

BP 7.5 Mon 16:00 ZEU 160

Inverted Sedimentation of Active Particles in Unbiased ac Fields — •José Carlos Ureña Marcos and Benno Liebchen — Institut für Physik Kondensierter Materie, TU Darmstadt, Darmstadt, Germany

Biological microswimmers can steer autonomously and use this ability to perform sophisticated tasks. Synthetic microswimmers do not yet reach the same degree of autonomy, and need to be controlled externally if they are to carry out tasks such as targeted cargo delivery or microsurgery. While much progress has been made recently to control their motion based on external forces or gradients, e.g. in light intensity, which have a well-defined direction or bias, little is known about how to steer APs in situations where no permanent bias can be realized.

Here, we show that ac fields with a vanishing time average provide an alternative route to steering APs. We exemplify this route for inertial APs in a gravitational field, observing that a substantial fraction of them persistently travels in the upward direction upon switching on the ac field, resulting in an inverted sedimentation profile at the top wall of a confining container. Our results offer a generic control principle which could be used in the future to steer active motion, to direct collective behaviors and to purify mixtures.

15 min. break

Invited Talk BP 7.6 Mon 16:30 ZEU 160

Long-range communications enable the hierarchical self-organization of active matter — •Igor Aronson[1], Alexander Ziepke[2], Ivan Maryshev[2], and Erwin Frey[2] — [1]Pennsylvania State University, USA — [2]Ludwig-Maximilians-University, Munich, Germany

The most distinct markers of life are the ability to move (locomotion), consume energy (metabolism), process information, and form multi-cellular aggregates. Many biological systems exhibit long-range signaling strategies for evolutionary advantage. We explore the multiscale self-organization of interacting self-propelled agents that locally process information transmitted by chemical signals. The communication capacity dramatically expands their ability to form complex structures, allowing them to self-organize through a series of collective dynamical states at multiple hierarchical levels.

The consequent study shows that information exchange by acoustic waves between the self-propelled units creates a slew of multifunctional structures. Each unit is equipped with an acoustic emitter and a detector in this realization. The swarmers respond to the resulting acoustic field by adjusting their emission frequency and migrating toward the strongest signal. We find self-organized structures with different morphology, including snake-like self-propelled entities, localized aggregates, and spinning vortices. Our results provide insights into the design principles of communicating active particles capable of performing complex tasks.

BP 7.7 Mon 17:00 ZEU 160

Arrested by heating — •Corinna C. Maass[1,2], Prashanth Ramesh[2,1], and Maziyar Jalaal[3] — [1]University of Twente, Enschede, Netherlands — [2]MPI for Dynamics and Self-organization, Göttingen, Germany — [3]Universiteit van Amsterdam, Amsterdam, Netherlands

Active droplets are a class of microswimmers driven by chemical reactions at the droplet interface. Typically, the activity is powered by an advection-diffusion instability in the chemohydrodynamic fields around the droplet that is characterised by the Péclet number Pe of chemical transport. With increasing Pe, higher hydrodynamic modes at the interface cause the droplet to transition from inactivity, to steady, to reorienting, to fully unsteady motion. Here, we demonstrate that it is possible to change Pe reversibly and in situ by thermally activated changes in the chemical enviroment, and thereby to control the motility of the droplet.

BP 7.8 Mon 17:15 ZEU 160

Chiral active particles with non-reciprocal couplings: results from particle-based simulations — •Kim L. Kreienkamp and Sabine H. L. Klapp — Technische Universität Berlin, Germany

Non-reciprocal interactions manifest their drastic impact on the collective dynamics of active matter systems by changing, for example, the general type of observed instabilities [1] and leading to time-dependent states [2,3]. In particular, the combination of non-reciprocity and chirality in terms of intrinsically rotating chiral active particles ("circle swimmers") reveals intriguing non-trivial time-dependent collective dynamics [1].

After having developed an understanding of the collective dynamics on the continuum level in previous work [1], we here present first results of particle-based simulations of chiral active particle systems with non-reciprocal alignment couplings. Indeed, quantitative predictions from continuum approaches are somewhat limited by the approximations made during the coarse-graining process. Thus, the first goal of our particle-based simulations is to explore the validity of the previously obtained continuum results regarding the overall state diagram. Second, we aim at investigating microscopic aspects of the various time-dependent states. Finally, we discuss possibilities to characterize the thermodynamic behavior of the non-reciprocal chiral system based on the stochastic trajectories obtained in particle-resolved simulations.

[1] K. L. Kreienkamp and S. H. L. Klapp, New J. Phys. (2022).
[2] M. Fruchart et al., Nature 592, 363 (2021).
[3] Z. You et al., PNAS 117, 19767 (2020).

BP 7.9 Mon 17:30 ZEU 160

Lattice-induced freezing in active systems unveils dynamic crystallites with square ordering — •Aritra K. Mukhopadhyay[1], Peter Schmelcher[2,3], and Benno Liebchen[1] — [1]Technische Universität Darmstadt, 64289 Darmstadt, Germany. — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany. — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany.

Active matter, comprising self-propelled particles like bacteria, colloidal microswimmers, or granular microflyers is currently attracting enormous attention for its ability to self-organize into complex nonequilibrium structures. In this work, we report on a new state of dynamic active crystallites, which occurs when exposing active particles to a spatially periodic potential. These crystallites require activity to emerge, adopt the structure of the underlying lattice (e.g. square rather than hexagonal close packing), and are continuously in motion. This new phase unifies the structural properties of crystals with the dynamical properties of disordered fluids. Our work thus unveils a route to creating a new state of active materials with an intrinsic structure that can be externally controlled.

BP 7.10 Mon 17:45 ZEU 160

Shape-dependent collective motion: cohesive groups and cargo transport of colloidal rods — Philipp Stengele, •Anton Lüders, and Peter Nielaba — Universität Konstanz, Konstanz, Deutschland

In active toy model systems where colloids interact via predefined social interaction rules as well as steric collisions, the shape of the individual particles strongly influences emerging collective behavior. We study this based on two example systems using Brownian dynamics simulations (without hydrodynamic interactions). Firstly, we investigate a simple perception model in which colloidal rods move actively if predefined visual stimuli exceed a certain threshold. Here, we find an aspect ratio range where the rods form a dilute cohesive group with a time-independent particle distribution. If the aspect ratio surpasses this range, the rods slowly drift apart. Secondly, we look into the cargo capture and transport of a passive rod using a dense swarm of active spheres which form a hexagonal cage with a cavity for the cargo. Again, the aspect ratio of the rod proves to be crucial, as we find geometric restrictions that must be met to stabilize the cavity. Our work underlines that the shape (here, the aspect ratio) of the particles in active matter systems must be carefully considered while defining interaction rules to perform specific tasks.

BP 7.11 Mon 18:00 ZEU 160

Active Chiral Nematics — •Rüdiger Kürsten[1,2,3] and Demian Levis[1,2] — [1]Departament de Física de la Matèria Condensada, Universitat de Barcelona, Barcelona, Spain — [2]Universitat de Barcelona Institute of Complex Systems (UBICS), Barcelona, Spain — [3]Institut für Physik, Universität Greifswald, Greifswald, Germany

We study inherently chiral self-propelled particles in two dimensions that are subjected to nematic alignment interactions and rotational noise. By means of both, homogeneous and spatially resolved mean field theory we identify various different flocking states. We confirm the presence of the predicted phases using agent-based simulations. We emphasize that special care has to be taken within the simulations in order to avoid artifacts. We present a non-standard simulation technique in order to avoid those artifacts.