BP 28: Active Matter V (joint session DY/BP)

Time: Thursday 9:30–12:45 Location: ZEU/0160

Invited Talk BP 28.1 Thu 9:30 ZEU/0160

Active memory and non-reciprocity as pathways to pattern formation in conserved scalar fields — •Suropriya Saha and Vaishnavi Gajendragad — Max Planck Institute for Dynamics and Self-organisation

Active phase separation has emerged as a field within active matter that investigates pattern formation in number-conserving scalar fields. The field has also gained momentum from developments in biological systems, where phase separation has been implicated in the formation of biological condensates. In this talk, I will explore two different paths to non-Hermiticity in number-conserving scalar fields. Non-Hermiticity, or the emergence of complex eigenvalues in the linear dynamics of scalar densities, is associated with traveling patterns that break time-reversal symmetry and parity.

The first pathway I will discuss is a feedback mechanism in which particles store and use information about their past trajectories to influence their time evolution. I will present a model in which the particle velocity acquires an active contribution that depends on its past trajectory, weighted by a memory kernel. This memory kernel is independent of the thermal noise acting on the particle, implying a microscopic violation of detailed balance. The number density of these particles is described by a modified Cahn*Hilliard equation that incorporates this non-equilibrium effect. The second pathway involves non-reciprocal interactions between two or more species. I will describe the phenomenology observed in both cases, focusing on the role of fluctuations, nonlinearities, and the stability of the resulting patterns.

BP 28.2 Thu 10:00 ZEU/0160

Self-propulsion via non-transitive phase coexistence in chemically active mixtures — •Yicheng Qiang, Chengjie Luo, and David Zwicker — Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany

Chemical activity is common in many active matter systems. For example, active reactions can lead to the self-propulsion of particles, which can finally give rise to rich collective dynamics, including phase separation, even in the absence of attractive interactions. With interactions that already favor phase separation, chemical activity and multiple coexisting phases will further intertwine. To unveil the basic effect of active reactions on coexistence, we study mixtures where solvent species interconvert while solutes segregate. We demonstrate that active reactions alter the chemical potential balance between the coexisting phases and defy the construction of pseudo-pressure balance. As a result, the transitivity of phase coexistence is broken, and the bulk compositions depend on the contact topology among all the coexisting phases. With cyclic topologies, the pressure imbalance leads to self-propelled phases and other complex dynamics such as budding and engulfment.

BP 28.3 Thu 10:15 ZEU/0160

Contraction waves in pulsating active liquids: from pacemaker to aster dynamics — Tirthankar Banerjee[1], Thibault Desaleux[1], Jonas Ranft[2], and •Etienne Fodor[1] — [1]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg City, Luxembourg — [2]Institut de Biologie de l'ENS, Ecole Normale Supérieure, CNRS, Inserm, Université PSL, 46 rue d*Ulm, 75005 Paris, France

We propose a hydrodynamic theory to examine the emergence of contraction waves in dense active liquids composed of pulsating deformable particles. Our theory couples the liquid density with a chemical phase that determines the periodic deformation of the particles. This mechanochemical coupling regulates the interplay between the flow induced by local deformation, and the resistance to pulsation stemming from steric interaction. We show that this interplay leads the emergent contraction waves to spontaneously organize into a packing of pacemakers. We reveal that the dynamics of these pacemakers is governed by a complex feedback between slow and fast topological defects that form asters in velocity flows. In fact, our defect analysis is a versatile platform for investigating the self-organization of waves in a wide range of contractile systems. Our results shed light on the key mechanisms that control the rich phenomenology of pulsating liquids, with relevance for biological systems such as tissues made of confluent pulsating cells. Refs: arXiv:2509.19024, arXiv:2407.19955

BP 28.4 Thu 10:30 ZEU/0160

Topology of pulsating active matter: Defect asymmetry controls emergent motility — •Luca Casagrande[1], Alessandro Manacorda[2], and Étienne Fodor[1] — [1]Department of Physics and Materials Science, University of Luxembourg, Luxembourg City, Luxembourg — [2]CNR Institute of Complex Systems, Uos Sapienza, Rome, Italy

When heartbeats become irregular, spiral waves and motile defects emerge at the surface of cardiac tissues [1]. Capturing the emergence of defect motility despite the absence of any cellular flows is a theoretical challenge which has recently been tackled by models of actively deforming particles [2-4]. The interplay between individual pulsation of particles sizes, synchronization, and repulsion yields deformation waves resembling those of cardiac tissues. Combining particle-based and hydrodynamic approaches, we examine the statistics of defects in the collective deformation of particles. We rationalize defect motility as stemming from the breakdown of time-reversal and spatial symmetries, and provide predictions for the deformation profile near the defect core to quantify motility. [1] A. Karma, Annu. Rev. Condens. Matter Phys., 4, 313-337 (2013) [2] Y. Zhang, É. Fodor, Phys. Rev. Lett., 131, 238302 (2023) [3] A. Manacorda, É. Fodor, Phys. Rev. E, 111, L053401 (2025) [4] W. Piñeros, É. Fodor, Phys. Rev. Lett., 134, 038301 (2025)

BP 28.5 Thu 10:45 ZEU/0160

Avalanche statistics in dense active matter — •Vinay Vaibhav[1] and Peter Sollich[1,2] — [1]Institut für Theoretische Physik, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Department of Mathematics, King's College London, The Strand, London, UK

Reorganization processes in dense active matter remain a central open question in non-equilibrium physics. In particular, how persistent self-propulsion drives local rearrangements and triggers collective failure events is not well understood. Here, we investigate such activity-induced rearrangements, that sometimes rapidly cascade to avalanches, in a dense assembly of self-propelled particles with extremely persistent activity. These systems evolve through abrupt transitions between mechanically stable configurations, giving rise to rich intermittent behavior. Using large-scale simulations, we systematically characterize avalanche statistics across a range of system sizes and activity protocols. We quantify the scaling properties of avalanche-size distributions for two widely studied active matter models: active Brownian particles and active Ornstein-Uhlenbeck particles. By comparing these classes of dynamics, we identify how the nature of the propulsion mechanism influences the exponents associated with the avalanche size distribution. In addition, we report the frequency and temporal organization of avalanches. Our results provide a unified picture of how persistent activity drives rearrangements in dense active systems and highlight the connections between active intermittency, mechanical stability, and avalanche dynamics.

15 min. break

BP 28.6 Thu 11:15 ZEU/0160

Coupling intracellular processes and extracellular environment in a Cellular Potts model — •Cornelis Mense[1,2], Falko Ziebert[1,2], and Ulrich Schwarz[1,2] — [1]ITP, Heidelberg — [2]BioQuant, Heidelberg

The Cellular Potts Model (CPM) is a computationally very efficient framework to study cell dynamics, wherein cells are simulated through Hamiltonian based update rules on a discretised lattice. The model has traditionally been used to predict cell migration and shape in scenarios such as immune response, morphogenesis, cancer, and wound healing. In contrast to e.g. active gel models, however, the CPM usually does not represent subcellular processes. Here, we propose an extension to the CPM by which cells can contract their bulk to both actively transport material and strain their substrate. This model allows us to represent feedback loops between intracellular processes, cell shape and the mechanical and geometrical properties of the extracellular environment. Migration can emerge both as internal symmetry break or as response to an external gradient. We apply it to some standard situations of experimental interest, in particular 3D-printed scaffolds for cell adhesion and migration.

BP 28.7 Thu 11:30 ZEU/0160

Exact Stationary State of a d-dimensional Run-and-Tumble Particle in a Harmonic Potential — •Mathis Guéneau[1], Grégory Schehr[2], and Satya N. Majumdar[3] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Sorbonne Université, Laboratoire de Physique Théorique et Hautes Energies, CNRS UMR 7589, 4 Place Jussieu, 75252 Paris Cedex 05, France — [3]LPTMS, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France

We study the stationary state of a run-and-tumble particle (RTP) confined in a harmonic potential in arbitrary dimension d. Owing to isotropy, all statistical properties of the steady state are fully encoded in the distribution of a single coordinate. This coordinate follows an effective one-dimensional dynamics with a piecewise-constant self-propulsion velocity drawn from a prescribed distribution. We obtain the exact stationary distribution by identifying a stick-breaking process and a Dirichlet process in the dynamics, and by using known results for these processes. This framework allows us to compute exactly the full radial distribution, the joint law of the coordinates, and their moments, and to extend these results to include thermal noise. We further characterize the shape transition of the stationary state, from active-like to passive-like behavior, and show that it can be analyzed for arbitrary external potentials.

BP 28.8 Thu 11:45 ZEU/0160

Jerky active particles — •Hartmut Löwen and Stephy Jose — Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

We introduce jerky active particles, a generalization of inertial active Brownian particles subjected to jerk, the time derivative of acceleration. These particles can be realized by feedback in active macroscopic granules or in mesoscopic colloids moving in a viscoelastic background with memory. We analytically derive their mean squared displacement (MSD) and show that there is a gigantic dynamical spreading with extremely high scaling exponent of the MSD as a function of time [1]. We also generalize jerky dynamics to a chiral active particle and demonstrate that the mean displacement shows damped and exploding Lissajous-like patterns alongside the well-known classical spira mirabilis [2]. Our work on jerky chiral active particles opens a new route to explore rich dynamical effects in active matter.

[1] H. Löwen, Physical Review E 112, 045412 (2025)
[2] S. Jose, H. Löwen, Chiral jerky active particles, New Journal of Physics (in press), see also arXiv:2508.18180

BP 28.9 Thu 12:00 ZEU/0160

Diffusion of active particles on curved manifolds — •Maxim Root[1], Lorenzo Caprini[2], and Hartmut Löwen[1] — [1]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [2]Physics Department, Sapienza University of Rome, 00185 Rome, Italy

Active Matter rarely exists in isolated idealized systems. In nature, it is rather typical that active particles are surrounded by complex environments and experience external forces. So far, passive Brownian motion constrained to curved surfaces [1,2] was studied extensively and similar work was done on clusters of active particles [3]. In this talk we explore the emergent effects of active particles constrained to two-dimensional curved surfaces and in presence of an external homogeneous force field, e.g., gravity. This is done for an overdamped active particle that exhibits persistent motion on a short time scale and diffusion in the long-time limit. The lateral long-time diffusion coefficient is computed for different scenarios and criteria for localization are derived.

[1] T. Ohta and S. Komura, *Lateral diffusion on a frozen random surface*, EPL **132**, 50007 (2020)
[2] A. Naji and F. L. H. Brown, *Diffusion on ruffled membrane surfaces*, J. Chem. Phys. **126**, 235103 (2007)
[3] E. D. Mackay et al., *Emergent Dynamics of Active Systems on Curved Environments*, arXiv:2505.24730 (2025)

BP 28.10 Thu 12:15 ZEU/0160

Modeling dissipation in quantum active matter — Alexander P. Antonov[1], Sangyun Lee[2], Benno Liebchen[3], Hartmut Löwen[1], Jannis Melles[1], Giovanna Morigi[4], Yehor Tuchkov[2], and •Michael te Vrugt[2] — [1]Institut für Theoretische Physik II, Weiche Materie, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz — [3]Institut für Physik der kondensierten Materie, Technische Universität Darmstadt — [4]Theoretische Physik, Universität des Saarlandes

In classical active matter systems, dissipation plays a major role. Currently, there is an increased focus in exploring quantum mechanical active matter systems, for which the question of how to model dissipation is far from obvious. In fact, for open quantum systems, a variety of quantum heat bath models have been proposed that are valid in different physical situations. Here, we compare the effects of different quantum heat baths based on a recently proposed quantum active matter model [Phys. Rev. Res. **7**, 033008 (2025)]. We find that the choice of the quantum heat bath strongly influences the dynamics at short timescales, which is the regime in which quantum effects are most relevant.

BP 28.11 Thu 12:30 ZEU/0160

Active Magnetic Particles in Magnetic Gradient Fields — •Laris Berekovic, Margaret Rosenberg, and Hartmut Löwen — Heinrich-Heine University Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf

Active particles are common in nature, underlying many complex phenomena. Since the motion of active particles has no intrinsic directionality, steering the particles' motion requires an additional control parameter, such as a magnetic interaction. In this contribution, we present an analysis of the effect of magnetic vortex fields created by a current carrying wire on the ground states and motion of active Brownian particles (ABP) carrying a fixed magnetic dipole moment. We present an analytical solution for the single-particle case, compute the ground state for multiple particles via simulated annealing in the passive case and explore the activity-induced phase transition created by increasing the self-propulsion. We find new forms in the ground state, as well as a rich variety of activity-induced structures. These results can be applied to ferrofluid systems, biophysical systems of magnetotactic bacteria or form the basis of more complex industrial applications.