# BP 13: Active Matter III (joint session DY/BP/CPP)

Time: Tuesday 9:30–13:00 Location: H47

BP 13.1 Tue 9:30 H47

**From micro to macro: systematic coarse-graining of active particle models and implications on phase separation** — •Sumeja Burekovic[1], Filippo De Luca[2], Cesare Nardini[1,3], Ananyo Maitra[4,5], and Michael E. Cates[2] — [1]CEA, Paris-Saclay, France — [2]DAMTP, University of Cambridge, UK — [3]LPTMC, Sorbonne Université, France — [4]LPTM, CY Cergy Paris Université, France — [5]LJP, Sorbonne Université, France

Significant insights into collective phenomena of active systems, such as phase separation, have been obtained through minimal field theories developed in a top-down manner. In contrast, the bottom-up approach seeks to link these continuum models to the microscopic dynamics of active particles, often formulated as Langevin equations for their position and orientation. This connection is typically achieved via explicit coarse-graining and allows active field theories to be expressed in terms of physically meaningful parameters. A major challenge in coarse-graining is the consistent elimination of irrelevant fast degrees of freedom to derive closed equations for the hydrodynamic variables or order parameters, such as the density field. We propose a systematic extension of standard homogenization/projection-operator techniques. As we show in minimal examples with few degrees of freedoms, our technique allows to go beyond the state of the art of homogenization in the mathematical literature. We then discuss the predictions of our coarse-graining methods for the large-scale phenomenology of non-aligning active particles, including cases in which microphase separation - rather than full phase separation - emerges due to activity.

BP 13.2 Tue 9:45 H47

**Active Quadrupolar Dumbbells** — •Margaret Rosenberg[1], Marco Musacchio[1], Lorenzo Caprini[2], and Hartmut Löwen[1] — [1]Heinrich-Heine University Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf — [2]Università di Roma Sapienza, P.le Aldo Moro 2, 00185 Rome, Italy

The field of Active Matter has thrived in recent years, driven both by the insight that it underlies fundamental processes in nature, and by its vast potential for applications. Although the self-propulsion mechanisms of Active Matter allow us to consider and control a wide range of motions, there is - by default - no obvious control over the orientation and rotation of the particles. One approach to resolve this is the use of anisotropic particles and interactions. This contribution presents a computational study of a novel system composed of active, quadrupolar dumbbells, the phase behavior of which is determined by the competition between active motion and the orthogonal alignment favored by quadrupolar attraction. We explore the novel phase behavior unlocked by these anisotropic interactions, and discuss options for experimental realizations and applications.

BP 13.3 Tue 10:00 H47

**Order by disorder in a swarm with obstacles** — Pradeep Kumar[1], Sanjay Puri[1], and •Martin Weigel[2] — [1]School of Physical Sciences, Jawaharlal Nehru University, New Delhi – 110067, India — [2]Institut für Physik, Technische Universität Chemnitz, 09107 Chemnitz, Germany

Simple models of swarming and active matter such as the Vicsek model [1] have been studied in detail, and the phase diagram as a function of noise strength and particle density is by now well understood. Real active systems are usually affected by impurities and random disorder, however. The presence of a quenched distribution of disc-like obstacles in the domain of the Vicsek model is observed to have a dramatic effect on the ordering behavior [2]: in contrast to the model without obstacles, where the strongest alignment is observed for the lowest noise, as soon as obstacles are added only the presence of a certain amount of noise leads to a global alignment of particles. This order by disorder phenomenon for active systems is traced back to the interplay of multiple length scales in the system: the typical inter-obstacle distance, the typical cluster size, and the resulting mean-free-paths of cluster-obstacle and cluster-cluster collisions. We present scaling arguments explaining these connections and provide an outlook towards similar phenomena in related systems.

[1] T. Vicsek, Phys. Rev. Lett. 75, 1226 (1995).
[2] O. Chepizhko, E. G. Altmann, and F. Peruani, Phys. Rev. Lett. 110, 238101 (2013).

BP 13.4 Tue 10:15 H47

**Autonomous navigation in synthetic microswimmers: solving mazes with chemical echolocation** — •Aritra K. Mukhopadhyay[1], Linhui Fu[2], Kai Feng[2], Ran Niu[2], and Benno Liebchen[1] — [1]Technische Universität Darmstadt, Darmstadt, Germany. — [2]Huazhong University of Science and Technology, Wuhan, China.

Motile microorganisms like bacteria and algae combine self-propulsion, cooperation, and decision-making at the micron scale. Inspired by these biological systems, synthetic microswimmers are emerging as human-made counterparts capable of self-propulsion. Recent breakthroughs provide a platform to integrate additional functionalities, bridging the gap between biology and synthetic systems.

We propose and experimentally demonstrate a mechanism enabling synthetic microswimmers, such as autophoretic colloids, droplet swimmers, and ion-exchange-driven modular swimmers, to make autonomous navigational decisions. These swimmers generate chemohydrodynamic signals that interact with boundaries, creating echoes that carry structural information about the environment. Remarkably, these echoes invoke automatic responses, such as synthetic chemotaxis, enabling the swimmers to avoid dead ends and autonomously find paths through complex mazes.

Our findings illustrate how simple physical principles can endow synthetic systems with advanced navigation functionalities, which could be useful for developing self-navigating micromachines with potential applications in targeted drug delivery and environmental sensing.

BP 13.5 Tue 10:30 H47

**Active Particles in Tunable Colloidal Environments** — •Abhimanyu Nowbagh[1], Venkata M.S.G. Tanuku[2], Thomas Palberg[2], and Ivo Buttinoni[1] — [1]Institute of Experimental Colloidal Physics, Heinrich-Heine University, 40225 Düsseldorf — [2]Institute of Physics, Johannes-Gutenberg University, 55128 Mainz

Active colloids are microscopic particles which propel through aqueous media by converting the externally available energy into directed motion. Using non equilibrium thermodynamics to understand biological systems: interactions of active colloids with crowded systems, and emergent phenomena of ensembles of active particles, remain an important and open question.

In this work, we investigate the dynamics of active particles in crowded environments subjected to alternating-current (AC) electric fields. The AC electric field is used to control: i) the velocity of active particles and ii) the inter-particle interaction between passive colloids. As we increase electric field strength, the velocity of active particles increases and the inter-particle interaction between passive colloids becomes stronger. We study the behaviour of active particles as a function of: i) the frequency of the applied AC electric field, ii) the area fraction of the passive crowd, iii) the active to passive particle number ratio, and iv) the velocity of the active particles.

Our experimental findings show that the active particles reorient faster with an increasing electric field strength. With an increase in the active to passive particle ratio, we show that cluster formation is non-monotonically sensitive to the passive crowd density.

**Invited Talk** BP 13.6 Tue 10:45 H47

**Beyond spheres - active matter in new shapes** — •Juliane Simmchen — University of Strathclyde, Cathedral street 295, Glasgow UK

Surface minimisation for a given volume is energetically favourable on the small scale - this is why most colloidal particles are spherical. In active matter they have the added advantage of facilitating comparison between experiment and theory, one of the reasons why spherical Janus particles dominate the field.

However, broadening the range of materials has led to interesting discoveries - behaviour that would not have been observable in the spherical regime. This talk will give an overview of the intriguing behaviour of non-spherical active materials at the microscale - from plates to truncated bipyramids and rods.

**15 min. break**

BP 13.7 Tue 11:30 H47

**Modeling Filamentous Cyanobacteria** — •Elias Fischer and Holger Stark — Institute Of Theoretical Physics, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Filamentous cyanobacteria play an important role in many ecosystems and the carbon cycle of our planet, both in the present and the past. They triggered the great oxygenation event about 2.5 billion years ago, generating the atmospheric oxygen of our planet while contributing large parts of our fossil fuel record.

Filamentous cyanobacteria exhibit gliding motility when in contact with solid surfaces or each other. Despite their ecological relevance and increased use in biotech applications, the exact nature of the force-generating process remains not fully understood. Furthermore, the gliding of cyanobacteria is strongly affected by external cues, most importantly light. They aggregate in regions with the highest light intensity, which means best environmental conditions for photosynthesis.

Following recent advances in understanding the self-organization of cyanobacteria, we present a novel approach for modeling the mechanical and behavioral aspects of individual cyanobacteria filaments, including force synchronization and response to light. Each filament is modeled as a bead-spring chain in 3D with bending and torsional elasticity, as well as a hard-core repulsion between the filaments. Notably, the propulsion forces that drive the individual parts of the filament forward are only considered locally where the filament comes into contact with another surface. First results on the 3D bending and twisting motion of a filament and its reaction to light are presented.

BP 13.8 Tue 11:45 H47

**Self-assembly and control of active and passive triblock Janus colloids** — •Juri Franz Schubert, Salman Fariz Navas, and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Triblock Janus colloids belong to the family of patchy particles, interacting with hydrophobic attraction at opposite poles and electrostatic repulsion in the equatorial region. They are known to self-assemble into a colloidal kagome crystal from experiments [1] and theory [2,3,4]. However, investigating the self-assembly of such systems via Brownian Dynamics can result in timescales inaccessible to brute force simulations, often requiring complex sampling techniques [3]. Recently, it has been shown that introducing self-propulsion can significantly accelerate self-assembly and enhance the Kagome yield [4]. Here, we study the model introduced in [4] and further investigate the self-assembled structures in active and passive systems. Using simple time-dependent activity protocols, we are able to sample a temperature-density state diagram of the passive system. Our results closely match with earlier studies [2,3], where different triblock models and sampling techniques were used.

[1] Q. Chen, S. C. Bae, S. Granick, Nature 469, 7330 (2011).
[2] F. Romano, F. Sciortino, Soft Matter 7, 12 (2011).
[3] K. Bahri, H. Eslami, and F. Müller-Plathe, JCTC 18, 1870 (2022).
[4] S. A. Mallory, A. Cacciuto, JACS 141, 6 (2019).

BP 13.9 Tue 12:00 H47

**Enhanced Diffusion and Universal Rouse-like Scaling of an Active Polymer in Poor Solvent** — Suman Majumder[1], Subhajit Paul[2], and •Wolfhard Janke[3] — [1]Amity Institute of Applied Sciences, Amity University Uttar Pradesh, Noida 201313, India — [2]Department of Physics and Astrophysics, University of Delhi, Delhi 110007, India — [3]Institut für Theoretische Physik, Universität Leipzig, IPF 231101, 04081 Leipzig, Germany

By means of Brownian dynamics simulations we study the steady-state dynamic properties of a flexible active polymer in a poor solvent condition. Our results show that the effective diffusion constant of the polymer $D_{\text{eff}}$ gets significantly enhanced as activity increases, much like in active particles. The simulation data are in agreement with a theoretically constructed Rouse model of active polymer, demonstrating that irrespective of the strength of activity, the long-time dynamics of the polymer chain is characterized by a universal Rouse-like scaling $D_{\text{eff}} \sim N^{-1}$, where $N$ is the chain length. We argue that the presence of hydrodynamic interactions will only have an insignificant effect on the observed scaling behavior.

BP 13.10 Tue 12:15 H47

**A Pulsating Active Solid** — •Umang A Dattani[1], Francesco Serafin[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 Superieure, CNRS

Active matter has garnered significant attention in recent decades due to its numerous parallels with biological systems. Inspired by recent studies of biological tissues, such as cardiac cells, where constituent cell sizes periodically vary, a new form of activity termed "pulsating active matter" has been introduced recently. We propose a model of a pulsating active solid, consisting of size-changing particles linked by a triangular spring network. Despite the fixed connectivity, our model exhibits a variety of patterns and topological phase defects, akin to previous studies. Additionally, we explore the elastic continuum limit, which successfully predicts several essential features of the microscopic model. We conclude by highlighting intriguing properties of this system and its different potential parallels.

**Invited Talk** BP 13.11 Tue 12:30 H47

**Emergent correlations and boundary fluctuations in epithelial cell sheets** — •Silke Henkes — Lorentz Institute, Leiden University, Leiden, The Netherlands

In soft active materials, the driving motion of individual constituents competes with their mechanical interactions, giving rise to active liquids, solids or glasses. An especially important example of this are epithelial cell sheets, which form a barrier function in the body and where the active crawling motion of cells over the substrate acts against cell-cell adhesion and repulsion.

I will show that a minimal model of cell sheets with uncorrelated activity, based on active Brownian dynamics and a vertex model, is a good quantitative match to data from two experiments on corneal and MDCK cell sheets. Its core feature is an emergent correlation length, arising from the diffusive spread of active forces through an elastic solid. This is a very general result that emerges in many active solids.

The boundary of such cell sheets exhibits a 'fingering instability' where the initially straight boundary develops large, spatiotemporally correlated fluctuations. Despite previous interpretations within many frameworks as an instability, I will show that it can be fully explained as arising from the active correlations of the cell sheets driving the boundary.