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

Time: Tuesday 14:00–15:30 Location: ZEU/0160

BP 13.1 Tue 14:00 ZEU/0160

Automated decision-making by chemical echolocation in active droplets — •Aritra K. Mukhopadhyay[1], Ran Niu[2], Linhui Fu[2], Kai Feng[2], Christopher Fujta[1], Qiang Zhao[2], Jinping Qu[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 that enables synthetic microswimmers, including autophoretic colloids, droplet swimmers, and ion-exchange-driven modular swimmers, to make autonomous navigational decisions. These swimmers generate chemo-hydrodynamic signals that interact with boundaries, producing echoes that encode structural information about the environment. These echoes trigger automatic responses, such as synthetic chemotaxis, allowing swimmers to avoid dead ends and autonomously find paths through complex mazes. We show the mechanism remains robust across different maze geometries, ensuring reliable navigation without external cues. Our findings illustrate how simple physical principles can endow synthetic systems with advanced navigation functionalities.

BP 13.2 Tue 14:15 ZEU/0160

Dead or alive?—Probing scale-dependent liveliness in multiscale active matter — •Joscha Mecke[1] and Klaus Kroy[2] — [1]Institute for Advanced Study, Shenzhen University, Shenzhen, China — [2]Institut für Theoretische Physik, Universität Leipzig, Leipzig, Germany

If you have ever watched live and dead trouts swimming upstream, side by side, you may have wondered how closer inspection of their mesoscale activity might help to tell them apart. But probing spatially heterogeneous activity in living matter is a major challenge. We demonstrate the emergence of multiple effective ("active") temperatures in nonequilibrium molecular- and Brownian-dynamics simulations of an active polymer. Energy injection at different length scales leads to mode coupling, inter-modal energy transfer, and entropy production. We put forward a generalised Langevin equation for a labelled monomer, which, by application of a harmonic potential, can serve as a spectroscopic device. Upon varying the trap stiffness, we can selectively scan through the emergent effective temperatures and thereby resolve the scale-dependent activity. Our approach thus provides a minimally invasive spectroscopic tool to generate quantitative maps of liveliness, across multiple scales.

BP 13.3 Tue 14:30 ZEU/0160

Tuning the velocity of thermophoretic microswimmers with thermo-sensitive polymers — Franziska M. Braun, Aritra K. Mukhopadhyay, Samad Mahmoudi, Benno Liebchen, and •Regine von Klitzing — Institute for Condensed Matter Physics, TU Darmstadt, Hochschulstrasse 8, 64289 Darmstadt

Understanding and controlling the motion of self-propelled particles in complex fluids is crucial for applications in targeted drug delivery, microfluidic transport, and the broader field of active matter. Here, we investigate the thermophoretic self-propulsion of partially gold-coated polystyrene Janus particles (Au-PS) in temperature-responsive linear Poly(N-isopropyl acrylamide) (PNIPAM) solutions across various PNIPAM concentrations and temperatures. Particle velocities are examined at three representative temperatures: far below, near but below and above the LCST. In pure water, Au-PS Janus particles propel with the PS hemisphere leading, driven by their intrinsic thermophoretic response. Conversely, the positive Soret coefficient of PNIPAM results in depletion forces that induce motion of the Janus particle towards the hot Au side. The experiments reveal a non-monotonic dependence of particle velocity on temperature, with a maximum near the LCST. Interfacial processes like ion movement in the electric double layer and PNIPAM adsorption at the Au-PS particles are separated from processes that are coupled to the bulk solution. Theoretical calculations are in good agreement with the experimental findings and are essential for the understanding of the complex interplay of microswimmers with thermoresponsive polymers.

BP 13.4 Tue 14:45 ZEU/0160

Non-reciprocal multifarious self-organization — •Saeed Osat[1] and Ramin Golestanian[2] — [1]Institute for Theoretical Physics IV, University of Stuttgart, Heisenbergstraße 3, 70569 Stuttgart, Germany — [2]Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Goettingen, Germany

Biological systems exhibit a unique ability to design diverse structures from a shared set of building blocks, with a plethora of proteins made from a limited set of amino acids as a prime example. Furthermore, these systems often use building blocks efficiently by introducing transformations between different structures. A structure might undergo structural transformations to form a new structure with different functional purposes, without the need to discard the current structure and start anew. To unravel this mystery, one must examine the underlying non-equilibrium processes that make this shape-shifting behavior feasible.

Here, we leverage non-reciprocal interactions between building blocks to provide a foundation for designing dynamic structures. We used a multifarious self-assembly (MSA) model, which is the molecular counterpart of the Hopfield associative memory. By upgrading the MSA model to its non-equilibrium counterpart with non-reciprocal interactions, we introduce the ability to not only self-assemble different structures on demand but also facilitate shifts and transformations that lead to shape-shifting behavior.

Invited Talk BP 13.5 Tue 15:00 ZEU/0160

Designing topological edge states in bacterial active matter — Yoshihito Uchida[1], Daiki Nishiguchi[2,1], and •Kazumasa A. Takeuchi[1] — [1]The University of Tokyo, Tokyo, Japan — [2]Institute of Science Tokyo, Tokyo, Japan

Besides its potential relevance to the life sciences, active matter also manifests as a novel, intrinsically non-equilibrium kind of matter, endowed with characteristic transport properties distinguished from conventional matter. A challenge is how to control and design transport in active matter. A potentially useful, emerging concept here is topological transport developed in condensed matter physics, which was extended to active matter successfully, but experimental realizations have thus far relied on the chirality of the active particles, which limits design capabilities.

Here we report a controlled realization of topological edge states in dense bacterial suspension, induced by microfabricated geometry instead of the bacteria's chirality. First we demonstrate that we can rectify bacterial collective motion by a channel with asymmetric shape. Then we construct networks made of asymmetric channels and show that we can control the emergence of topological edge states through the network design. Through modelling and experiments, we discuss what properties of the network and the bacterial flow are crucial to the observed topological phenomenon. We expect our results may pave the way for establishing a control and design principle of topological transport in such active matter systems.

Ref) Y. Uchida, D. Nishiguchi, and K. A. Takeuchi, to appear.