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

Time: Monday 15:00–17:00 Location: H37

DY 7.1 Mon 15:00 H37

Emerging cellular dynamics from turbulent flows steered by active filaments — Mehrana Nejad[1,4], Julia Yeomans[2], and •Sumesh Thampi[2,3] — [1]Department of Physics, Harvard University, Cambridge, MA 02138 — [2]The Rudolf Peierls Centre for Theoretical Physics, Parks Road, Oxford OX1 3PU, UK — [3]Department of Chemical Engineering, Indian Institute of Technology, Madras, Chennai, India 600036 — [4]School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138, USA

Describing the mechanics of cell collectives and tissues within the framework of active matter, without resorting to the details of biology is an exciting area. We develop a continuum theory to describe the dynamics of cellular collectives, discerning the cellular force-generating active filaments from cells shape. The theory shows that active flows and straining part of the active turbulence can elongate isotropic cells, which form nematic domains. This is important as cell morphology is not only an indicator of diseases but it can affect the nucleus morphology, gene expression and other biochemical processes inside the cells. Our theory highlights the importance of distinguishing the roles of active filaments from cell shape and explains outstanding experimental observations such as the origin of cell-filament alignment patches. Further, we reconcile how the contractile forces generated by the cytoskeletal network makes the cells to exhibit flow behaviours similar to that of extensile active systems. Revealing the crucial role of activity and rheology to describe the dynamics of cellular layers, our study is in consonance with a number of experimental observations.

DY 7.2 Mon 15:15 H37

Defects in active solids: self-propulsion without flow — •Fridtjof Brauns[1], Myles O'Leary[2], Arthur Hernandez[3], Mark Bowick[1], and Cristina Marchetti[4] — [1]Kavli Institute for Theoretical Physics, Santa Barbara, USA — [2]Princeton University, Princeton, USA — [3]Leiden University, Leiden, the Netherlands — [4]University of California Santa Barbara, Santa Barbara, California 93106, USA

Topological defects are a key feature of orientational order and act as organizing centers of orientation fields. Self-propulsion of $+1/2$ defects has been extensively studied in active nematic fluids, where the defects are advected with the fluid through the flow field they generate. Here, we propose a minimal model for defect self-propulsion in a nematic active solid: a linear elastic medium with an embedded nematic texture that generates active stress and in turn is coupled to elastic strain. We show that such coupling gives rise to self-propelled $+1/2$ defects that move relative to the elastic medium by local remodeling of the nematic texture. This mechanism is fundamentally different from the fluid case. We show that this mechanism can lead to unbinding of defect pairs and stabilize $+1$ defects. Our findings might help explain how orientational order, e.g. of muscle fibers, is reconfigured during morphogenesis in solid-like tissues. For instance, motility and merging of $+1/2$ defects play a crucial role in setting up the body axis during Hydra regeneration.

DY 7.3 Mon 15:30 H37

Isovolumetric dividing active matter — Samantha R. Lish[1], Lukas Hupe[1], Ramin Golestanian[1,2], and •Philip Bittihn[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, United Kingdom

We introduce and theoretically investigate a minimal particle-based model for a new class of active matter where particles exhibit directional, volume-conserving division in confinement while interacting sterically, mimicking cells in early embryogenesis. We find that complex motion, synchronized within division cycles, displays strong collective effects and becomes self-similar in the long-time limit. Introducing the method of normalized retraced trajectories, we show that the transgenerational motion caused by cell division can be mapped to a time-inhomogenous random walk with an exponentially decreasing length scale. Analytical predictions for this stochastic process allow us to extract effective parameters, indicating unusual effects of crowding and absence of jamming. Robustness of our findings against desynchronized divisions, cell size dispersity, and variations in confinement hints at universal behavior. Our results establish an understanding of the complex dynamics exhibited by isovolumetric division over long timescales, paving the way for new bioengineering strategies and perspectives on living matter.

DY 7.4 Mon 15:45 H37

Tracking plankton-to-biofilm transition in phototrophic bacteria — •Anupam Sengupta — Physics of Living Matter Group, Department of Physics and Materials Science, University of Luxembourg, Luxembourg — Institute for Advanced Studies, University of Luxembourg, Luxembourg

Phototrophic bacteria commonly inhabit natural aquatic and marine ecosystems, exhibiting both motile and sessile lifestyles [1]. Yet, how and when they switch between the two states has remained unknown. Using quantitative imaging, AFM and mathematical modeling, we track the conditions and phenotypic changes across multiple generations in Chromatium okenii, a motile phototrophic purple sulfur bacterium [2]. Enhanced cell-surface adhesion together with changes in the cell shape and cellular mass distribution facilitate the motile-to-sessile shift. Our results, supported by cell mechanics model, establish a synergistic link between motility, mass distribution and surface attachment in promoting biofilm lifestyle. [1] T. Sommer et al., Geophys. Res. Lett. 44, 2017. [2] F. Di Nezio,.., & A. Sengupta, Plos one 19, e0310265, 2024.

15 min. break

DY 7.5 Mon 16:15 H37

How localized active noises influence the conformations and dynamics of semiflexible filaments — •Shashank Ravichandir[1], Jens-Uwe Sommer[1,2], and Abhinav Sharma[1,3] — [1]Leibniz-Institut für Polymerforschung, 01069 Dresden, Germany — [2]Technische Universität Dresden, 01069 Dresden, Germany — [3]Universität Augsburg, 86159 Augsburg, Germany

The structure and dynamics of active polymers have been recently studied in some detail. In these works all the monomers are considered to be active. However, in most biological systems non-equilibrium fluctuations manifest as activity only at isolated locations within the polymer. There have been only few studies of such polymers, in which the active monomers occur periodically along the polymer contour. We consider arbitrary active-passive copolymers and isolate the effects of the number and locations of active monomers on the conformational and dynamical properties of polymers. We use Langevin dynamics simulations to calculate the end-to-end distance, radius of gyration, and mean-squared displacement of such semiflexible filaments and classify the various states of these polymers based on their conformational properties. We also present preliminary results of polymers in which the location of active monomer moves dynamically along the chain contour. This is an idealized model of biopolymers such as DNA, during DNA transcription, and microtubules, which are driven by kinetic motors that traverse along its length.

DY 7.6 Mon 16:30 H37

Sequence-specific folding of partially active polymers — •Shibananda Das — Department of Physics, Indian Institute of Science, Bengaluru, India

Biological polymers like actin filaments and microtubules exhibit important physical properties due to their out-of-equilibrium behavior induced by ATP or GTP. In contrast, synthetic polymers rely on energy from their surrounding environment, often using local chemical, electrical, or thermal gradients to remain far from equilibrium. Theoretically, active polymers serve as minimal models for these systems, enabling systematic study of the competition between thermodynamic and active forces while they undergo conformational changes.

Using a combined analytical and numerical approach, we investigate an active polymeric chain composed of multiple self-avoiding units, representing good solvent condition in the absence of active forces. For partially active polymers without orientational constraints, we find that distribution of the active units in distinct sequences along the backbone can induce a significant collapse into folded, globular structures. Detailed analysis shows that this activity-dependent collapse is driven by a reduction in swim pressure of the monomers, linking the distribution of active forces along the polymer contour to its folded

conformations.

DY 7.7 Mon 16:45 H37

Effect of interactions on the chemotactic response of active-passive chains — •Hossein Vahid[1], Jens-Uwe Sommer[1,2], and Abhinav Sharma[3] — [1]Leibniz-Institut für Polymerforschung, Dresden, Germany — [2]Technische Universität Dresden, Germany — [3]University of Augsburg, Augsburg, Germany

Living organisms, from single cells to populations, exhibit complex behaviors driven by the need to navigate toward favorable environments. These behaviors are often shaped by interactions within clusters or mixed populations, where collective dynamics play a crucial role in the characteristic properties of multicellular systems.

Chemotactic bacteria, found in diverse environments such as the gastrointestinal tract, plant surfaces, and aquatic ecosystems, demonstrate the significance of chemotaxis at the population level. While extensive research has focused on the properties of active polymers in spatially homogeneous activity fields, their behaviors in inhomogeneous fields remain less explored.

This study investigates the behavior of self-propelled polymers in activity gradients, emphasizing the effects of inter- and intra-chain interactions, such as steric and excluded volume effects, on chemotactic responses. These interactions give rise to distinct phases or collective behaviors that influence the stability and persistence of chemotaxis. Additionally, polymer density emerges as a critical factor impacting diffusion and the overall efficiency of chemotaxis. This work aims to study the dynamics of the active polymer populations in non-uniform environments systematically.