BP 30: Active Matter V (joint session BP/CPP/DY)

Time: Friday 9:30–12:00 Location: TOE 317

Invited Talk BP 30.1 Fri 9:30 TOE 317

Experiments on Active Polymer-Like Worms — •Antoine Deblais[1], Daniel Bonn[1], and Sander Woutersen[2] — [1]Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, 1098XH Amsterdam, The Netherlands — [2]Van't Hoff Institute for Molecular Sciences, University of Amsterdam, Science Park 904, 1098XH Amsterdam, The Netherlands

We propose a new 'active particle' system in which the particles are in fact polymer-like: the Tubifex tubifex or 'sludge' worm. I will discuss three recent experiments that highlight the richness of this active system. In the first experiment, we perform classical rheology experiments on this entangled polymer-like system. We find that the rheology is qualitatively similar to that of usual polymers, but, quantitatively, the (tunable) activity of the particle changes the flow properties. In a second experiment, we disperse the worm in a quasi-2D aquarium and observe their spontaneous aggregation to compact, highly entangled blobs; a process similar to polymer phase separation, and for which we observe power-law growth kinetics. We find that the phase separation of active polymer-like worms occurs through active motion and coalescence of the phase domains. This leads to a fundamentally different phase-separation mechanism, that may be unique to active polymers. Finally, in the remaining time, I will briefly show that we can efficiently separate by size and activity these living polymers using hydrodynamic chromatography technics.

BP 30.2 Fri 10:00 TOE 317

Filamentous Cyanobacteria Aggregate at Light Boundaries — •Maximilian Kurjahn[1], Leila Abbaspour[1], Philip Bittihn[1], Ramin Golestanian[1,2], Benoît Mahault[1], and Stefan Karpitschka[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, OX1 3PU, Oxford, UK

Filamentous cyanobacteria are among the oldest, yet still most abundant phototrophic prokaryotes on Earth, fixing vast amounts of atmospheric carbon by photosynthesis. Gliding motility, coupled to photophobic responses (direction reversals in response to light intensity gradients), are believed to drive accumulation in suitable light conditions. Here, we demonstrate that photosensitivity goes beyond simple accumulation: Super-filamentous aggregates, capable of collective mechanical action, form at the boundaries of illuminated regions and may, for instance, contract and detach from the substrate, once grown to a critical mass. We explore how the light pattern, in particular its boundary curvature, impacts aggregation. A minimal model of active rods captures the behavior qualitatively. The ecological impact of such behavior is still unclear, but may enable colonies to escape from saturated habitats by switching to a planktonic state.

BP 30.3 Fri 10:15 TOE 317

Odd dynamics of living chiral crystals — •Tzer Han Tan[1,2,3,4], Alexander Mietke[4,5], Junang Li[4], Yuchao Chen[4], Hugh Higinbotham[4], Peter Foster[4], Shreyas Gokhale[4], Jorn Dunkel[4], and Nikta Fakhri[4] — [1]MPI-PKS, Dresden, Germany — [2]MPI-CBG, Dresden, Germany — [3]CSBD, Dresden, Germany — [4]MIT, Cambridge, USA — [5]University of Bristol, Bristol, UK

Active crystals are highly ordered structures that emerge from the self-organization of motile objects, and have been widely studied in synthetic and bacterial active matter. Whether persistent crystalline order can emerge in groups of autonomously developing multicellular organisms is currently unknown. Here we show that swimming starfish embryos spontaneously assemble into chiral crystals that span thousands of spinning organisms and persist for tens of hours. Combining experiments, theory and simulations, we demonstrate that the formation, dynamics and dissolution of these living crystals are controlled by the hydrodynamic properties and the natural development of embryos. Remarkably, living chiral crystals exhibit self-sustained chiral oscillations as well as various unconventional deformation response behaviours recently predicted for odd elastic materials. Our results provide direct experimental evidence for how non-reciprocal interactions between autonomous multicellular components may facilitate non-equilibrium phases of chiral active matter.

BP 30.4 Fri 10:30 TOE 317

Optimal collective durotaxis through active wetting — Macià-Esteve Pallarès[1], Irina Pi-Jaumà[2], Isabela Corina Fortunato[1], Valeria Grazu[3], Manuel Gómez-González[1], Pere Roca-Cusachs[1], Jesus de la Fuente[3], •Ricard Alert[4], Raimon Sunyer[1], Jaume Casademunt[2], and Xavier Trepat[1] — [1]Institute for Bioengineering of Catalonia — [2]University of Barcelona — [3]Instituto de Nanociencia y Materiales de Argón — [4]Max Planck Institute for the Physics of Complex Systems

The directed migration of cell clusters enables morphogenesis, wound healing and collective cancer invasion. Gradients of substrate stiffness are known to direct migration of cell clusters in a process called collective durotaxis, but underlying mechanisms remain unclear. Combining theory and experiments, we reveal a connection between collective durotaxis and the wetting properties of cell clusters. Our experiments show that durotaxis is non-monotonic with substrate stiffness, being optimal at intermediate stiffness. Modeling the cell clusters as active droplets, we explain this non-monotonic durotaxis in terms of a balance between active traction, tissue contractility, and surface tension. Finally, we show that the distribution of cluster displacements has a heavy tail, with infrequent but large cellular hops that contribute to durotactic migration. Our study demonstrates a physical mechanism of collective durotaxis based on the wetting properties of active droplets.

15 min. break

BP 30.5 Fri 11:00 TOE 317

Chlamydomonas axonemes twist during the beat — •Martin Striegler[1,2], Benjamin M. Friedrich[3], Stefan Diez[1,2,3], and Veikko F. Geyer[1] — [1]B CUBE - Center for Molecular Bioengineering, TU Dresden, Dresden, Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [3]Cluster of Excellence Physics of Life, TU Dresden, Dresden, Germany

Motile cilia are slender cell appendages that drive single cell locomotion and fluid transport across surfaces. The motility of cilia is generated by its inner core, the axoneme, which bends by the activity of dynein motor proteins. Generation of bending requires antagonistic dynein activity on opposing sides of the axoneme. How dyneins are activated antagonistically is unknown. Theoretical models propose dynein regulation by mechanical feedback, which entails structural deformations of the axoneme, but direct experimental evidence is missing. To study axonemal deformations during the beat, we purify and reactivate Chlamydomonas reinhardtii axonemes. Using defocused-high-speed-darkfield microscopy, we resolve the 3D waveforms with nanometer resolution on millisecond timescales. We find that asymmetric waveforms have a non-planar component, which is most pronounced during the recovery stroke. To generate non-planarity within the geometric constraints of the axoneme, twist is thought to be required. Using gold-nano-particles as probes attached to the outside of reactivated axonemes, we, for the first time, measure dynamic twisting deformations in reactivated axonemes. We hypothesize that these deformations are involved in controlling dynein motors generating the axonemal beat.

BP 30.6 Fri 11:15 TOE 317

Curvotaxis - the effect of curvature on cells and tissue — Lea Hppel, Jan Sischka, and •Axel Voigt — Institute of Scientific Computing, Technische Universität Dresden, Germany

How do cells respond to curvature? Does curvature has an influence on cell shape and movement? What are the consequences for collective behaviour of interacting cells in tissue? We address these questions using a multiphase field model on different curved surfaces and compare the results with experimental data on pillars, in tubes and other surfaces. The results show a significant influence of curvature and the possibility to effectively model the observed phenomena with classical models and additional curvature terms.

BP 30.7 Fri 11:30 TOE 317

Onset of Homochirality in Cell Monolayers — •Ludwig A. Hoffmann and Luca Giomi — Universiteit Leiden, Leiden, Netherlands

Chirality is a feature of many biological systems and much research has been focused on understanding the origin and implications of this

property. Most famously, sugars and amino acids that are found in nature are homochiral, meaning that chiral symmetry is broken and only one of the two possible chiral states is ever observed. Perhaps less well-know, something similar is the case for certain types of cells too. They show chiral behavior and only one of the two possible chiral states is observed in nature. Understanding the origin of cellular chirality and what, if any, use or function it has in tissues and cellular dynamics is still an open problem and subject to much (recent) research. For example, cell chirality has already been shown to play an important role in drosophila morphogenesis.

BP 30.8 Fri 11:45 TOE 317

Dynamic instability of cytoplasmic compartments — •Melissa Rinaldin[1,2] and Jan Brugués[1,2] — [1]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [2]Cluster of Excellence Physics of Life, TU Dresden, Dresden, Germany

Early embryos are the epitome of self-organization. Following the cell cycle oscillator, their internal structure is continuously reorganized into precise patterns at remarkable speeds. For example, the mm-sized egg of the frog Xenopus Laevis divides every 30 minutes into equally-sized cells. Physical processes such as autocatalytic growth, active transport, and reaction-diffusion can allow these embryos to keep up with fast cell cycle times, however, their understanding in early development remains largely elusive. Here, we present recent data from experiments of in vitro cytoplasmic extract obtained from frog eggs and exhibiting cell-free division. We show that the properties of the cell cycle oscillator regulate the pattern of cytoplasmic compartments. Specifically, by perturbing the oscillator, we establish that the interface of cytoplasmic compartments is unstable. We demonstrate that such instability arises from competing waves of autocatalytic microtubule growth, and can generate compartment fusion, strongly affecting the early embryonic pattern formation. Altogether, our results propose that the cell cycle oscillator plays a critical role in partitioning the cytoplasm of early embryos, keeping the dynamic instability of cytoplasmic compartments at bay.