CPP 5: Active Biological Matter II (joint session BP/CPP/DY)

Time: Monday 11:00–13:30 Location: BPb

CPP 5.1 Mon 11:00 BPb

Chiral stresses in nematic cell monolayers — •Ludwig A. Hoffmann[1], Koen Schakenraad[1,2], Roeland M. H. Merks[2,3], and Luca Giomi[1] — [1]Instituut-Lorentz, Leiden University, The Netherlands — [2]Mathematical Institute, Leiden University, The Netherlands — [3]Institute of Biology, Leiden University, The Netherlands

Recent experiments on monolayers of spindle-like cells have provided a convincing demonstration that certain types of collective phenomena in epithelia are well described by active nematic hydrodynamics. While recovering some of the predictions of this framework, however, these experiments have also revealed unexpected features that could be ascribed to the existence of chirality over length scales larger than the typical size of a cell.

We elaborate on the microscopic origin of chiral stresses in nematic cell monolayers and investigate how chirality affects the motion of topological defects, as well as the collective motion in stripe-shaped domains. We find that chirality introduces a characteristic asymmetry in the collective cellular flow, from which the ratio between chiral and non-chiral active stresses can be measured. Furthermore, we find that chirality changes the nature of the spontaneous flow transition under confinement and that, for specific anchoring conditions, the latter has the structure of an imperfect pitchfork bifurcation.

CPP 5.2 Mon 11:20 BPb

Developmentally driven self-assembly of living chiral crystals — •Alexander Mietke[1], Tzer Han Tan[2], Hugh Higinbotham[2], Yuchao Chen[2], Peter Foster[2], Shreyas Gokhale[2], Jörn Dunkel[1], and Nikta Fakhri[2] — [1]Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA

The emergent dynamics exhibited by self-organizing collections of living organisms often shows signatures of symmetries that are broken at the single-organism level. At the same time, early organism development itself is accompanied by a sequence of symmetry breaking events that eventually establish the body plan. Combining these key aspects of collective phenomena and embryonic development, we describe here the spontaneous formation of hydrodynamically stabilized active crystals made of hundreds of starfish embryos during early development. As development progresses and embryos change morphology, crystals become increasingly disordered and eventually stop forming. We show that these structures exhibit distinct macroscopic chiral features as a direct consequence of the embryo's chiral swimming properties. We introduce a hydrodynamic near-field model that quantitatively describes the formation and rotation of crystals, as well as the emergence of long-lived chiral deformation waves, all of which can be understood as consequences of broken symmetries on the single-embryo level.

CPP 5.3 Mon 11:40 BPb

Thin-Film Model of Resting and Moving Active Droplets — •Fenna Stegemerten[1], Sarah Trinscheck[1,2], Karin John[2], and Uwe Thiele[1,3] — [1]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Münster, Germany — [2]Université Grenoble-Alpes, CNRS Laboratoire Interdisciplinaire de Physique, Grenoble, France — [3]Center for Nonlinear Science (CeNoS), Westfälische Wilhelms-Universität Münster, Münster, Germany

We propose a long-wave model for free-surface drops of polar active liquid on a solid substrate. The coupled evolution equations for the film height and the local polarization profile are written in the form of a gradient dynamics supplemented with active stresses and fluxes. A wetting energy for a partially wetting liquid is incorporated allowing for motion of the liquid-solid-gas contact line. This gives a consistent basis for the description of drops of dense bacterial suspensions or compact aggregates of living cells on solid substrates. As example, we analyze the dynamics of active drops and demonstrate how active forces compete with passive surface forces to shape droplets and drive contact line motion. We perform parameter continuation in the activity parameters discussing both, resting and moving droplets. Additional direct time simulations investigate transitions from non-uniformly to uniformly polarized as well as resting to moving states.

CPP 5.4 Mon 12:00 BPb

Sedimentation and Convection of Bottom-Heavy Squirmers — •Felix Rühle, Jan-Timm Kuhr, and Holger Stark — TU Berlin, Institut für Theoretische Physik, Berlin, Germany

Active particles form appealing patterns, in particular, when hydrodynamic interactions are present [1-3]. A fascinating example known from biology is bioconvection of microswimmers under gravity [4]. In order to study such systems, we simulate bottom-heavy squirmers (neutral squirmers, pushers, and pullers) under different gravitational forces and torques [3]. The relevant parameters are the ratio of swimming to bulk sedimentation velocity α and the normalized torque.

In the state diagram of these parameters, for neutral squirmers at low α we observe sedimentation states, where bottom-heaviness leads to the formation of clusters of different sizes. For high α, finite torques lead to inverted sedimentation. In between, we identify plumes of collectively sinking squirmers that feed convective rolls of circling squirmers at the bottom of the simulation cell. At $\alpha \gtrapprox 1$ and large torques squirmers form a spawning cluster above the wall, from which squirmers occasionally escape. For strong pushers and pullers, we find that the dipolar flow fields weaken the formation of plumes and convective rolls.

[1] M. Hennes, *et al.*, PRL **112**, 238104 (2014)
[2] H. Jeckel, *et al.*, PNAS **116**, 1489 (2019).
[3] F. Rühle, and H. Stark, Eur. Phys. J. E **43**, 26 (2020).
[4] T.J. Pedley, and J.O. Kessler, Annu. Rev. Fluid Mech. **24**, 313 (1992).

CPP 5.5 Mon 12:20 BPb

Microscopic scattering of pusher particles in complex environments — •Theresa Jakuszeit[1], Samuel Bell[2], and Ottavio A. Croze[1] — [1]Cavendish Laboratory, JJ Thomson Avenue, CB3 0HE, Cambridge, United Kingdom — [2]Laboratoire Physico Chimie Curie, Institut Curie,PSL Research University, CNRS UMR168, 75005 Paris, France

Active propulsion as performed by bacteria and Janus particles, in combination with hydrodynamic interaction at boundaries, can lead to the breaking of time reversibility. One typical example of this is the accumulation of bacteria on a flat wall. However, in microfluidic devices with cylindrical pillars of sufficiently small radius, self-propelled particles can slide along the surface of a pillar without becoming trapped over long times. This non-equilibrium scattering process can result in large diffusivities even at high obstacle density, unlike particles that undergo classical specular reflection, as in the Lorentz gas. We experimentally study the non-equilibrium scattering as well as the long-term diffusive transport of pusher-like particles by tracking wild-type and smooth-swimming mutants of the model bacterium Escherichia coli in microfluidic obstacle lattices. We relate the determined parameters of the scattering process to previously proposed models and discuss their relevance. Finally, we discuss the potential interpretation of the role of tumbles in the scattering process.

CPP 5.6 Mon 12:40 BPb

Swimming behavior of squirmer dumbbells and polymers — •Judit Clopés Llahí, Gerhard Gompper, and Roland G. Winkler — Theoretical Soft Matter and Biophysics, Institute for Advanced Simulation and Institute of Complex Systems, Forschungszentrum Jülich, D-52425 Jülich, Germany

Nature provides a plethora of microswimmers, which can be rather elongated, filament- or polymer-like. Examples are bacteria swarmer cells or marine phytoplankton dinoflagellates assembling in a linear fashion. In order to address the relevance of hydrodynamic interactions for the collective behavior of such organisms, we study the swimming properties of linear polymer-like assemblies by mesoscale hydrodynamic simulations, where an active unit (monomer) is described by a spherical squirmer – which can be a pusher, a neutral swimmer, or a puller. We find that the monomer hydrodynamic flow field leads to correlations in the relative orientation of adjacent monomers, and consequently the swimming efficiency differs from that of active Brownian linear assemblies. In particular, puller dumbbells and chains show a pronounced increase in the rotational diffusion coefficient compared to pushers, while for neutral squirmers, the rotational diffusion coefficient is similar to that of active Brownian particles. Hence, the large-scale conformational and dynamical properties depend on the specific propulsion mechanism. Refs.: J. Elgeti, R. G. Winkler, G. Gompper, Rep. Prog. Phys. 78, (2015). R. G. Winkler, J. Elgeti, G. Gompper, J. Phys. Soc. Jpn. 86, (2017). J. Clopés, G. Gompper, R. G. Winkler, Soft Matter 16, 10676 (2020).

30 min. Meet the Speaker