CPP 11: Active Matter 2 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP/CPP)

Time: Tuesday 11:00–13:00 Location: DYa

CPP 11.1 Tue 11:00 DYa

Mesoscale turbulence and dynamical clustering in active polar fluids — •Vasco Marius Worlitzer[1], Gil Ariel[2], Avraham Be'er[3], Holger Stark[4], Markus Bär[1], and Sebastian Heidenreich[1] — [1]Department of Mathematical Modelling and Data Analysis, Physikalisch-Technische Bundesanstalt, Abbestrasse 2-12, 10587 Berlin — [2]Department of Mathematics, Bar-Illan University, Ramat Gan 52000, Israel — [3]Zuckerberg Institute for Water Research of the Negev, Sede Boqer Campus 84900 Midreshet Ben-Gurion, Israel — [4]Institute of Theoretical Physics, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin

Bacterial suspensions are fascinating examples for active polar fluids which exhibit large scale collective behavior ranging from polar and disordered states to so-called mesoscale turbulence and vortex lattices. Previous approaches take into account the self-propulsion of bacteria and an effective polar-alignment interaction but assume for simplicity a constant density. Comparison with experiments showed that this modelling approach is successful, to some extent, in a relatively narrow regime corresponding to wild-type swarms in which density is indeed approximately constant and velocity distributions are Gaussian. We seek a unified model that can explain the observed phenomena across the entire phase space of swarming bacteria. To this end, we present a continuum model that allows variations in density. The model predicts new dynamical regimes, such as mixed states with coexisting vortex patterns and dynamical clusters, obeying anomalous statistics, similar to experimental observations.

CPP 11.2 Tue 11:20 DYa

Rewarding cargo-carrier interactions: cell-mediated particle transport — •Valentino Lepro[1,2], Robert Grossmann[1], Oliver Nagel[1], Stefan Klumpp[3], Reinhard Lipowsky[2], and Carsten Beta[1] — [1]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [2]Max Planck Institute of Colloids and Interfaces, 14476 Potsdam, Germany — [3]Institute for the Dynamics of Complex Systems, University of Göttingen, 37077 Göttingen, Germany

As society paves its way towards devices miniaturization and precision medicine, micro-scale actuation and guided transport become increasingly prominent research fields, with high potential impact in both technological and clinical contexts. To accomplish directed motion of micron-sized cargos towards specific target sites, a promising strategy is the usage of living cells as smart biochemically-powered carriers, developing so-called bio-hybrid systems. In this talk, we discuss eukaryotic active particle transport, using Dictyostelium discoideum as a model organism. We shed light on the underlying mechanics and the emerging dynamics governing such cell-mediated transport. A simple yet powerful model is proposed which reproduces the observed phenomenology and, moreover, elucidates the role of cell-cargo interactions for the long-time mass transport efficiency.

CPP 11.3 Tue 11:40 DYa

Predictive local field theories for interacting active Brownian spheres* — Jens Bickmann and •Raphael Wittkowski — Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany

We present predictive local field theories for the dynamics of interacting spherical active Brownian particles in two and three spatial dimensions. Alongside the general theories, which include configurational order parameters and derivatives up to infinite order, we present reduced models that are easier to apply. We show that our theories contain popular models such as Active Model B + as special cases and that they provide explicit expressions for the coefficients occurring in these models. As further outcomes, the theories yield analytical expressions, e.g., for the density-dependent mean swimming speed and the spinodal corresponding to motility-induced phase separation of the particles. The analytical predictions are found to be in very good agreement with results of Brownian dynamics simulations and results from the literature.

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CPP 11.4 Tue 12:00 DYa

Dynamical States in Underdamped Active Matter with Anti-alignment Interaction — •Dominic Arold[1] and Michael Schmiedeberg[2] — [1]TransDeNLab, UKD, Dresden, Germany — [2]Institut für Theoretische Physik 1, FAU, Erlangen, Germany

Many active matter systems, especially on the microscopic scale, are well approximated as overdamped, meaning that any inertial momentum is immediately dissipated by the environment. On the other hand, for macroscopic active systems, the time scale of inertial motion can become large enough to be relevant for the dynamics already on the single-particle level [1]. This raises the question of how collective dynamics and the resulting states in active matter are influenced by inertia. We propose a coarse-grained continuum model for underdamped active matter based on a dynamical density functional theory for passive systems [2]. Further, we apply the model to a system with short-range alignment and distant anti-alignment interaction known from the context of pattern formation. Our simulations of under- and overdamped dynamics both predict a structured laning state. However, activity-induced convective flows only present in the underdamped model destabilize this state when the anti-alignment is weakened, leading to a collective motion state which is not predicted in the overdamped limit. A turbulent transition regime between the two states is distinguished by strong density fluctuations and the absence of global ordering.

[1] Scholz C *et al.* 2018 *Nature communications* **9** 5156
[2] Archer A J 2009 *The Journal of chemical physics* **130** 014509

CPP 11.5 Tue 12:20 DYa

Chemokinesis causes trapping and avoidance by dynamic scattering — •Justus Kromer[1] and Benjamin Friedrich[2,3] — [1]Stanford University, Stanford, United States of America — [2]cfaed TU Dresden, Dresden, Germany — [3]PoL TU Dresden, Dresden, Germany

A minimal control strategy for artificial microswimmers with limited information processing capabilities is chemokinesis: the regulation of random directional fluctuations or speed as function of local, nondirectional cues. In contrast to chemotaxis, it is not well understood whether chemokinesis is beneficial for the search for hidden targets.

We present a general theory of chemokinetic search agents that regulate directional fluctuations according to distance to a target. We characterize a dynamic scattering effect that reduces the probability to penetrate regions with strong directional fluctuations. If the target is surrounded by such a region, dynamic scattering causes beneficial inward-scattering of agents that had just missed the target, but also disadvantageous outward-scattering of agents approaching the target for the first time. If agents respond instantaneously to positional cues, outward-scattering dominates and chemokinetic agents perform worse than simple ballistic search. Yet, agents with just two internal states can decouple both effects and increase the probability to find the target significantly. We apply our analytical theory to the biological example of sperm chemotaxis of marine invertebrates. Sperm cells need to pass a 'noise zone' surrounding the egg, where chemokinesis masks chemotaxis. Kromer et al., PRL 124, 118101 (2020)

CPP 11.6 Tue 12:40 DYa

Magnetic microswimmers exhibit Bose-Einstein-like condensation — Fanlong Meng[1], Daiki Matsunaga[2], •Benoît Mahault[3], and Ramin Golestanian[3] — [1]CAS Key Laboratory for Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences — [2]Graduate School of Engineering Science, Osaka University — [3]Max Planck Institute for Dynamics and Self-Organization

We study an active matter system comprised of magnetic microswimmers confined in a microfluidic channel and show that it exhibits a new type of self-organized behavior. Combining analytical techniques and Brownian dynamics simulations, we demonstrate how the interplay of non-equilibrium activity, external driving, and magnetic interactions leads to the condensation of swimmers at the center of the channel via a non-equilibrium phase transition that is formally akin to Bose-Einstein condensation. We find that the effective dynamics of the microswimmers can be mapped onto a diffusivity-edge problem, and use the mapping to build a generalized thermodynamic framework, which is verified by a parameter-free comparison with our simulations. Our work reveals how driven active matter has the potential to generate exotic classical non-equilibrium phases of matter with traits that are analogous to those observed in quantum systems.