CPP 63: Active Matter IV (joint session DY/CPP/BP)

Time: Wednesday 10:00–12:30 Location: ZEU 160

CPP 63.1 Wed 10:00 ZEU 160

Quantitative Assessment of the Toner and Tu Theory of Polar Flocks — •Benoît Mahault[1,2], Francesco Ginelli[3,4], and Hugues Chaté[1,5,6] — [1]Service de Physique de l'Etat Condensé, CEA, CNRS, Université Paris-Saclay, CEA-Saclay, France — [2]Max Planck Institute for Dynamics and Self-Organization (MPIDS), Germany — [3]University of Aberdeen, United Kingdom — [4]Università degli Studi dell'Insubria, Italy — [5]Beijing Computational Science Research Center, China — [6]LPTMC, CNRS UMR 7600, Université Pierre et Marie Curie, France

We present a quantitative assessment of the Toner and Tu theory describing the universal scaling of space-time correlations functions in polar phases of dry active matter. Using large-scale simulations of the Vicsek model in two and three dimensions, we find the overall phenomenology and generic algebraic scaling predicted by Toner and Tu, but our data on density correlations reveal some qualitative discrepancies. The values of the associated scaling exponents we estimate differ significantly from those conjectured in 1995. In particular, we identify a large crossover scale beyond which flocks are only weakly anisotropic. We discuss the meaning and consequences of these results.

CPP 63.2 Wed 10:15 ZEU 160

Swirl formation of active colloids near criticality — •Robert C. Löffler, Tobias Bäuerle, and Clemens Bechinger — Fachbereich Physik, Universität Konstanz, Konstanz D-78464, Germany

Animal groups like flocks of birds or schools of fish normally show a high degree of order. Yet they are also responsive to external factors in order to optimize nutrition and avoid predation. Various observations of such responsiveness have let to the assumption that those systems represent a state of order close to a critical point. In our experiments, we use light-responsive active Brownian particles (ABPs) to which we can apply individual torques in a feedback controlled system to study such behavioral rules. The propulsion applied to each ABP is thereby calculated based on information about its local neighbors. Through the variation of a single parameter in our interaction model, which is related to zonal models used in theoretical biology, we observe a continuous phase transition in the collective motion of the group: The ABPs transition from a disordered swarm to a stable swirl (i.e. milling, vortex-like state). Being able to continuously change our control parameter we can also measure the susceptibility of the collective motion, peaking at a critical point within the transition. Observation of such critical behavior in simple models not only allows for more insight in complex animal behavior but also helps with designing future rules for collective tasks in robotic or other autonomous systems.

T. Bäuerle *et al., Nat. Comm.* **9**, 3232 (2018); F. A. Lavergne *et al., Science* **364**, 70-74 (2019).

CPP 63.3 Wed 10:30 ZEU 160

Probing mechanical properties of rod-shaped colloidal suspensions with active particles — •N Narinder and Clemens Bechinger — Fachbereich Physik, Universität Konstanz, Konstanz, Germany

Recently self-propelled colloidal particles have been shown to provide a novel tool to probe the mechanical properties of colloidal glassy states of spherical particles [1]. Unlike conventional micro-rheology, where one studies the coupling between the translational motion of a driven probe particle to a background, here the coupling of the host medium to the rotational dynamics of the self-propelled particle contains information about the mechanical properties of the host medium. Here, we apply this method to study the mechanical properties of assemblies of rod-shaped particles with a mean aspect ratio of 15. Such anisotropic colloidal suspensions exhibit a rather rich phase behavior including a two-step glass transition at the aspect ratio considered here [2]. Our first results demonstrate a strong variation of the rotational dynamics of the active particle with increasing area fraction of the rods.

[1] C. Lozano, J.R. Gomez-Solano, & C. Bechinger Nature Materials 18, 1118-1123 (2019).

[2] Z. Zheng, F. Wang, & Y. Han PRL 107, 065702 (2011).

CPP 63.4 Wed 10:45 ZEU 160

Statistical mechanical sum rules for active colloids at surfaces - a touch of equilibrium — •René Wittmann[1,2], Frank Smallenburg[3], and Joseph Brader[2] — [1]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, Germany — [2]Soft Matter Theory, Université de Fribourg, Switzerland — [3]Laboratoire de Physique des Solides, Université Paris Sud, France

We study the mechanical properties of active particles in the presence of curved walls by computer simulation of Active Brownian Particles (ABPs), Active Ornstein-Uhlenbeck Particles (AOUPs) and a passive system with effective interactions [R. Wittmann, F. Smallenburg and J. M. Brader, J. Chem. Phys. 150, 174908 (2019)]. The effective theory admits analytic results for pressure, surface tension and adsorption of an active ideal gas at a two-dimensional circular wall. It further predicts that an equilibrium sum rule also holds for active fluids, which we confirm numerically for both ABPs and AOUPs in the limit of small curvature.

More precisely, we find within each model that the slope of the pressure as a function of the curvature equals the surface tension and adsorption (up to an effective temperature scale) on a planar wall. Intriguingly, the explicit value of these coefficients is model-dependent, which can be explained by the different velocity distributions. We also discuss the influence of interactions and find that the effect of curvature on the wall pressure is reduced when increasing the density. Within numerical accuracy, the equality of the slope of the pressure and the planar surface tension appears to hold at finite density.

CPP 63.5 Wed 11:00 ZEU 160

Lorentz forces induce inhomogeneity and flux in active systems — •Hidde Vuijk[1], Jens-Uwe Sommer[1,2], Holger Merlitz[1], Joseph Brader[3], and Abhinav Sharma[1,2] — [1]Leibniz Institute of Polymer Research, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Universite de Fribourg, Fribourg, Switserland

We consider the dynamics of a charged active Brownian particle in three dimensions subjected to the Lorentz force due to an external magnetic field. We show that in the presence of a field gradient, a macroscopic flux emerges from a flux-free system and the density distribution becomes inhomogeneous. The flux is induced by the gradient of the magnetic field only and does not require additional symmetry breaking such as density or potential gradients, which stands in marked contrast to similar phenomena in condensed matter such as the classical Hall effect. We further demonstrate that passive tracer particles can be used to measure the essential effects caused by the Lorentz force on the active particle bath, and we discuss under which conditions this diffusive Hall-like effect might be observed experimentally. Lastly, we show that similar effects arise in case of inhomogeneous activity in combination with a constant magnetic field.

15 min. break.

CPP 63.6 Wed 11:30 ZEU 160

Interaction of Active Crystallites within the Active Phase-Field-Crystal Model — •Lukas Ophaus[1], Johannes Kirchner[2], and Uwe Thiele[1,2] — [1]Center for Nonlinear Science, Münster, Germany — [2]Institut für Theoretische Physik, Münster, Germany

We use the active phase-field-crystal (PFC) model, developed by Menzel and Löwen as a model for crystallizing self-propelled particles [1], to study the interaction of traveling crystalline patches. Within the active PFC model, these localized states exist besides periodic states, i.e., spatially extended crystals [2]. Due to the activity, crystalline states undergo a drift instability and start to travel while keeping their spatial structure. Using results for the parameter ranges where the individual states exist, we explore how two and more traveling localized states interact by performing numerical collision experiments. We show that a critical minimal free path is necessary to preserve the number of colliding localized states and that the active PFC model fails to exhibit dynamical clustering and motility induced phase separation.

[1] A.M. Menzel and H. Löwen, Phys. Rev. Lett. 110, 055702 (2013)

[2] L. Ophaus, S.V. Gurevich and U. Thiele, Phys. Rev. E 98, 022608 (2018)

CPP 63.7 Wed 11:45 ZEU 160

Continuum model for bacterial suspensions with density variations — •Vasco Marius Worlitzer[1], Avraham Be'er[2], Gil Ariel[3], Markus Bär[1], Holger Stark[4], and Sebastian Heidenreich[1] — [1]Physikalisch-Technische Bundesanstalt — [2]Ben-Gurion University — [3]Bar-Ilan University — [4]Technical University of Berlin

The various dynamical states found in bacterial suspensions are a fascinating illustration of the rich dynamics exhibited by active polar fluids. A recent study explored the phase space experimentally, identifying three major states: single-cell motion, collective swarming, biofilm formation and mixtures between them [1]. While a continuum model presented in [2] has been proven to describe the statistical features of the swarming phase quite successfully, it is not applicable outside this regime as a constant density is assumed. We show that new dynamical states are accessible by relaxing this assumption. In particular a regime similar to the mixed state of swarming and biofilm formation is covered, showing the same anomalous statistics as found experimentally. The new model is inspired by work on scalar active matter [3] and consist of a generic continuity equation for the density. The density is coupled to a local polar order parameter through a density dependent self-propulsion speed and an active pressure.

[1] H Jeckel et al., PNAS 116 (5) (2019) [2] J Dunkel et al., Phys. Rev. Lett. 110 (2013) 228102. [3] J Bialké et al., EPL 103 (2013) 30008.

CPP 63.8 Wed 12:00 ZEU 160

A minimal model for dynamical symmetry breaking in active matter — Matt Davison and •Patrick Pietzonka — Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK

It is well known that asymmetrically shaped passive particles immersed in active matter move in a persistent direction. Recent work provides a thermodynamic framework and design principles for engines exploiting this mechanism [1]. We build on these results and reveal that symmetric passive particles in contact with active matter perform such a persistent motion as well. Its direction is determined through spontaneous symmetry breaking and remains fixed in time in the limit of a large number of active particles. We present an analytically solvable one-dimensional model for a single passive particle interacting with many active particles, which provides a physical understanding of these effects.

[1] P. Pietzonka *et al.*, Phys Rev. X **9**, 041032 (2019)

CPP 63.9 Wed 12:15 ZEU 160

Self-propelled thermophoretic colloidal swimmers — •Sergi Roca-Bonet and Marisol Ripoll — Theoretical Soft Matter and Biophysics, Institute of Complex Physics, Forschungszentrum Jülich, Germany

Self-propelled phoretic colloids have recently emerged as a promising avenue for the design of artificial microswimmers. We employ a hydrodynamic fluctuating mesoscale simulation approach to study both single and collective swimming. We investigate self-propelled colloidal multimers in which one monomer can eventually get higher temperature, and it is linked with one or more other monomers which induce the multimer motion. Single colloid swimming properties are varied by changing the number of the constituting monomers (here two or three), their spatial arrangement (rod-like or v-like) and the relative sizes of such monomers. We have investigated the effect of slid confinement in comparison to the 3d-bulk motion of these dimeric and trimeric colloids. The collective system properties are determined by the competition between hydrodynamic and phoretic interactions which vary as a function of the density, the colloid geometry, and the monomers phoretic affinity (philic or phobic). Examples of the resulting behaviour are clustering, swarming, or rotational motions.