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

Time: Tuesday 14:00–16:00 Location: ZEU 160

DY 30.1 Tue 14:00 ZEU 160

Uncovering novel phase transitions in dense dry polar active fluids using a lattice Boltzmann method — David Nesbitt, Gunnar Pruessner, and •Chiu Fan Lee — Imperial College, London, U.K.

The dynamics of dry active matter have implications for a diverse collection of biological phenomena spanning a range of length and time scales, such as animal flocking, cell tissue dynamics, and swarming of inserts and bacteria. Uniting these systems are a common set of symmetries and conservation laws, defining dry active fluids as a class of physical system. Many interesting behaviors have been observed at high densities, which remain difficult to simulate due to the computational demand. Here, we devise a new method to study dry active fluids in a dense regime using a simple modification of the lattice Boltzmann method. We apply our method to an active model with contact inhibition of locomotion, which has relevance to collective cell migration, and uncover multiple novel phase transitions: two first-order and one potentially critical. We further support our simulation results with an analytical treatment of the hydrodynamic equations.

Reference: D Nesbitt, G Pruessner, and CF Lee. Preprint: arXiv:1902.00530.

DY 30.2 Tue 14:15 ZEU 160

Irreversibility in Active Matter Systems: Fluctuation Theorem and Mutual Information — Lennart Dabelow[2], •Stefano Bo[1], and Ralf Eichhorn[3] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Universität Bielefeld — [3]Nordita, Royal Institute of Technology and Stockholm University

We consider a Brownian particle, which, in addition to being in contact with a thermal bath, is driven by active fluctuations. These active fluctuations do not fulfill a fluctuation-dissipation relation and therefore play the role of a non-equilibrium environment. Using an Ornstein-Uhlenbeck process as a model for the active fluctuations, we derive the path probability of the Brownian particle subject to both, thermal and active noise. From the case of passive Brownian motion, it is well-known that the log-ratio of path probabilities for observing a certain particle trajectory forward in time versus observing its time-reserved twin trajectory quantifies the entropy production in the thermal environment. We calculate this path probability ratio for active Brownian motion and derive a generalized “entropy production”, which fulfills an integral fluctuation theorem. We show that those parts of this “entropy production”, which are different from the usual dissipation of heat in the thermal environment, can be associated with the mutual information between the particle trajectory and the history of the non-equilibrium environment.

DY 30.3 Tue 14:30 ZEU 160

Rheotaxis of active drops in confinements — •Ranabir Dey[1], Carola M. Buness[1,2], Chenyu Jin[1], and Corinna C. Maass[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Goettingen — [2]Institute for the Dynamics of Complex Systems, Georg August Universitaet Goettingen

Biological microswimmers commonly navigate confinements having liquid flows, e.g. locomotions of spermatozoa through the reproductive tract and bacteria in the gut or in blood vessels. The directed motion of the microorganisms in response to the gradients in external flow velocity is classically called ‘rheotaxis’. Recently, rigorous efforts have been made to understand the rheotaxis of microorganims, specifically bacteria. In contrast, there is very little quantitative understanding of rheotaxis of artificial microswimmers. It must be noted that artificial microswimmers, e.g. those designed for drug delivery, are often required to navigate confinements having external flows. Here, we elucidate the swimming dynamics of a common type of artificial microswimmer, i.e. active drops, in micro-confinements having Poiseuille flow. We experimentally quantify the rheotaxis of these droplet microswimmers, intrinsically undergoing Marangoni stress dominated ‘self-propulsion’, in response to velocity gradients of varying strength. We try to understand the observed rheotaxis of the active drops in confinements in the context of a hydrodynamic model– the active Jeffery-Bretherton model. We strongly feel that detailed understanding of artificial active matter rheotaxis will make significant contributions towards better design optimization for practical applications.

DY 30.4 Tue 14:45 ZEU 160

Multiple Particle Correlation Analysis of Many-Particle Systems: Formalism and Application to Active Matter — •Rüdiger Kürsten[1], Sven Stroteich[1], Martín Zumaya Hérnandez[2], and Thomas Ihle[1] — [1]Universität Greifswald, Institut für Physik, Felix-Hausdorff-Str.6 — [2]Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, Apartado Postal 48-3, Código Postal 62251, Cuernavaca, Morelos, México

We introduce a fast spatial point pattern analysis technique which is suitable for systems of many identical particles giving rise to multi-particle correlations up to arbitrary order. The obtained correlation parameters allow to quantify the quality of mean field assumptions or theories that incorporate correlations of limited order. We study the Vicsek model [1] of self-propelled particles and create a correlation map marking the required correlation order for each point in phase space incorporating up to ten-particle correlations. We find that multi-particle correlations are important even in a large part of the disordered phase. Furthermore, the two-particle correlation parameter serves as an excellent order parameter to locate both phase transitions of the system, whereas two different order parameters were required before [2].

[1] Phys. Rev. Lett. 75, 1226 (1995). [2] Phys. Rev. Lett. 92, 025702 (2004); Phys. Rev. E 77, 046113 (2008).

DY 30.5 Tue 15:00 ZEU 160

Nonuniversality in scalar active matter with diffusivity edge under periodic confinement — •Benoît Mahault[1] and Ramin Golestanian[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Germany — [2]University of Oxford, United Kingdom

Scalar active matter is often described at the mean field level by non-linear Fokker-Planck equations with density-dependent diffusion coefficients integrating fast degrees of freedom, as well as various equilibrium and/or nonequilibrium processes. A generic class, characterized by a diffusivity vanishing above some threshold density, was recently introduced [Golestanian, Phys. Rev. E 100, 010601(R)]. In presence of harmonic confinement, such ‘diffusivity edge’ was shown to lead to condensation in the ground state, with the associated transition exhibiting formal similarities with Bose-Einstein condensation (BEC).

Many active systems, such as self-propelled Janus particles, can however self-assemble into finite-size coexisting clusters. To account for such feature in the diffusivity edge framework, a periodic egg-crate confinement, that provides multiple sites for condensation, is considered in arbitrary dimensions. While for high barriers separating two minima the system essentially behaves as in the single harmonic trap case, for shallow potentials the transition is qualitatively different as the exponent associated to the scaling of the condensate fraction with an effective temperature is found to be nonuniversal. We nevertheless show from a generalized thermodynamic description that the overall phenomenology of BEC, such as the divergence of the isothermal compressibility at the transition, holds in both cases.

DY 30.6 Tue 15:15 ZEU 160

Anomalous fluctuations accompany dynamical arrest in a cluster of chemically active colloids — •Suropriya Saha, Prathyusha K R, and Ramin Golestanian — Max Planck Institute for Dynamics and Self Organisation

Recent years have seen enormous scientific activity exploring the ability of catalytic colloids to collectively form patterns and clusters. However, fluctuations of individual colloids within a cluster remains unstudied, and is the focus of our work. Using the simplest example of active colloids, hard spheres that generate an isotropic chemical field, we find that an interplay of non-local interactions and finite system size results in the formation of a core and a surface layer in the cluster, both of which exhibit dynamics distinct from one another. The simplicity of our model suggests that aspects of the fluctuations revealed here are generic to matter driven phoretically, including enzymes.

DY 30.7 Tue 15:30 ZEU 160

Transport coefficients of active particles: Reverse perturbations and response theory — •Thomas Ihle[1], Arash Nikoubashman[2], Alexander Unruh[1], Sven Stroteich[1], and Rüdiger Kürsten[1] — [1]Institute for Physics, Greifswald University — [2]Institute of Physics, Johannes-Gutenberg-University Mainz

Müller-Plathe's reverse perturbation method [Phys. Rev. E 59, 4894 (1999)] for shearing simple liquids is extended to the Vicsek model (VM) of self-propelled particles. It is shown how the shear viscosity ν and the momentum amplification coefficient λ, can be extracted from simulations by fitting to an analytical solution of the hydrodynamic equations for the VM. The viscosity consists of two parts, a kinetic and a collisional contribution. While analytical predictions already exist for the former [T. Ihle, J. Stat. Mech. 2016, 083205], a novel expression for the collisional part is derived by an Enskog-like kinetic theory [A. Nikoubahsman, T. Ihle, Phys. Rev. E 100, 042603 (2019)]. Using several methods to measure transport coefficients such as reverse perturbations, Green-Kubo relations and transverse current correlations, we find excellent agreement between the different methods and good agreement with theory. We introduce a novel kind of response theory that allows us to not only verify the analytical predictions of kinetic theory but also to efficiently obtain expressions for nonlocal (wavevector dependent) transport coefficients of active systems, avoiding tedious multiple-scale methods like the Chapman-Enskog expansion. The method is applied to the VM with metric and topological interactions as well as to a model with continuous time dynamics.

DY 30.8 Tue 15:45 ZEU 160

Effect of Vicsek-like Activity on the collapse of a Flexible Polymer — •Subhajit Paul[1], Suman Majumder[1], Subir K Das[2], and Wolfhard Janke[1] — [1]Institüt für Theoretische Physik, Universität Leipzig, IPF 231101, 04081 Leipzig, Germany — [2]JNCASR, Jakkur P.O., Bangalore- 560064, India.

Dynamics of various biological filaments can be understood within the framework of active polymer models. In this context, we construct a bead-spring model for a flexible polymer chain in which the activity or self-propulsion of the beads has been defined in the Vicsek-like manner. Following a quench from a high-temperature coil phase to the low-temperature state we have studied the nonequilibrium dynamics of this model by solving the Langevin equation via molecular dynamics (MD) simulations. The low-T equilibrium state for the passive polymer in which the interaction among the beads modeled via standard LJ potential, is a compact globular one. Results from our MD simulations reveal that the globular state is also likely to be the final equilibrium in the active case also, the nonequilibrium dynamics is quite different than the passive case. We observe that the deviation from the intermediate 'pearl-necklace' arrangement and the formation of elongated structures for the polymer increases with activity. Also, it appears that whether smaller values of the activity makes the coarsening faster, activity beyond a certain value makes it slower. On this nonequilibrium front we also compare various results with that of the passive case, viz., scaling laws related to collapse time, cluster coarsening, etc.