CPP 25: Poster: Active Matter, Soft Matter, Fluids (joint session DY/CPP)

Time: Wednesday 10:00–12:00 Location: P3

CPP 25.1 Wed 10:00 P3

Enhanced stability and chaotic condensates in multi-species non-reciprocal mixtures — •Laya Parkavousi[1], Navdeep Rana[1], Ramin Golestanian[1,2], and Suropriya Saha[1] — [1]Max Planck Institute for Dynamics and Self-Organization (MPI-DS), D-37077 Göttingen, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, United Kingdom

Random non-reciprocal interactions between a large number of conserved densities are shown to enhance the stability of the system towards pattern formation. The enhanced stability is an exact result when the number of species approaches infinity and is confirmed numerically by simulations of the multi-species non-reciprocal Cahn-Hilliard model. Furthermore, the diversity in dynamical patterns increases with increasing number of components and novel steady states such as pulsating or spatiotemporally chaotic condensates are observed. Our results may help to unravel the mechanisms by which living systems self-organise via metabolism.

CPP 25.2 Wed 10:00 P3

Non-reciprocal Model B and the role of mobilities and non-reciprocal interfacial forces — •Bibhut Sahoo[1] and Peter Sollich[1,2] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, 37077 Göttingen — [2]Department of Mathematics, King's College London, London

Recently the effects of non-reciprocal interactions have been widely studied in the Cahn-Hilliard model for phase separation, which is based on a magnetic analogy. Here we explore the corresponding nonreciprocal model B, as the continuum theory for non-reciprocal particle mixture. We focus on the effect of mobility matrix on topology of the phase diagram and find that changing mobility can change stability of a homogeneous state, which for reciprocal interactions would be impossible. We study spinodal dynamics in regions of instability, where static or travelling spinodal patterns can occur. This aspect is as in non-reciprocal Cahn-Hilliard but, the transitions between these instabilities are novel: they occur not via exceptional points, but via first order transitions in the length scale of the dominant unstable modes. At transition, a static and a travelling spinodal pattern with two different scales coexist. We show that more complicated transitions involving coexistence of three length scales can also occur. We finally argue, based on a nonreciprocal version of Dean's equation, that coarse graining into a model B description should lead to non-reciprocal interface terms, rather than only in the bulk as assumed in theories to date. We show that such interfacial terms can significantly enlarge the travelling spinodal regions in the phase diagram.

CPP 25.3 Wed 10:00 P3

Mixed active fluids of two kinds — •Astik Haldar — Universität des Saarlandes, Saarbrücken 66123, Germany

We explore here the polar active fluids of two types, characterizing by their different aligning and propulsion strengths. We example here the fluids as the collections of moving living creatures, which could fuel itself through chemical reactions in their body . We called this system as active system, and consider their brilliant interactions. We here try to model those through considering some parameters and physically observable quantities. We find the parameters region where they have their oriented flocking as parallel or antiparallel, ordered rotating phase coherently meaning chiral phase. Our study finds the transition between the phases as saddle node as well as pitchfork bifurcation in mean field theory scheme. We find different kind of pattern formed states appear through the analytical as well as numerical study.

CPP 25.4 Wed 10:00 P3

Verification, efficiency analysis and extension of the kinetic Event-Chain Algorithm — •Nico Schaffrath, Tobias Kampmann, and Jan Kierfeld — TU Dortmund, Dortmund, Germany

The novel cluster kinetic Monte-Carlo algorithm, which is based on the event-chain Monte-Carlo method, is specifically designed to simulate systems of two-dimensional self-propelled hard particles. We verify this algorithm from scratch by analysing various single-, two- and many-body systems, as well as some algorithm-specific quantities. To gain insight about the applicability of the algorithm, we compare its performance to that of an Event-Driven Brownian-Dynamics simulation. Finally, we investigate the possibility to simulate particles with soft interaction energies as well as an extension to three-dimensional systems. Regarding the latter, the phase diagram of self-propelled hard spheres is calculated.

CPP 25.5 Wed 10:00 P3

AMEP: Analyzing Active Matter Simulations in Python — Kay-Robert Dormann[1], Lukas Hecht[1], Kai Luca Spanheimer[2], Aritra K. Mukhopadhyay[1], Mahdieh Ebrahimi[1], Suvendu Mandal[1], and •Benno Liebchen[1] — [1]Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Darmstadt, Germany — [2]Institut für Theoretische Physik II, Heinrich-Heine-Universität, Düsseldorf, Germany

The **A**ctive **M**atter **E**valuation **P**ackage (AMEP)[1] is an easy-to-use Python library for analysing simulation data of particle-based and continuum simulations. It provides a powerful interface for handling complex analysis of large data sets from different simulation software such as LAMMPS, HOOMD-blue, GROMACS and others. A plethora of methods to calculate observables and visualise results make AMEP suitable to calculate complex observables not only for beginners but also for advanced studies of active and soft matter. AMEP is written in pure Python and leverages powerful and well-known libraries such as NumPy, SciPy and Matplotlib. Computationally expensive methods are parallelized to run on laptops and workstations as well as high-performance computing clusters.

The methods range from order parameters, cluster methods, spatial and time correlation functions to thermodynamic properties and coarse-graining methods. More information and examples are available at https://amepproject.de. AMEP can be installed via conda and pip.

[1] L. Hecht et al., arXiv:2404.16533 [cond-mat.soft]

CPP 25.6 Wed 10:00 P3

Fluctuation induced network patterns in spatially correlated noise — •Sebastian Fehlinger[1], Kai Cui[2], Arooj Sajjad[1], Heinz Koeppl[2], and Benno Liebchen[1] — [1]Technische Universität Darmstadt, Institut für Physik Kondensierter Materie, Hochschulstraße 8, 64289 Darmstadt — [2]Technische Universität Darmstadt, Selbstorganisierende Systeme, Merkstraße 25, 64283 Darmstadt

Fluctuations play an important role in many fields of physics, from quantum electrodynamics to statistical mechanics. In active matter physics, so far, most works have focused on active particles that are subject to thermal fluctuations caused by the surrounding solvent. Here, we explore the collective behaviour of active particles under the influence of spatially correlated noise, that can arise, e.g., from fluctuating external fields. Therefore, we introduce a minimal model which describes the dynamics of (chiral) active particles with alignment interactions in a time-dependent Gaussian random field, that features a characteristic spatial correlation length, but no temporal correlations. Using Brownian dynamics simulations, we find, that the active particles aggregate to system spanning, percolated networks. These structures are (i) fluctuation-induced, (ii) feature local alignment of the contained particles, but no global alignment, and (iii) hardly show any coarsening. We systematically characterize the emerging patterns with tools from topological data analysis (persistence diagrams, Vietoris-Rips complexes and Betty numbers).

CPP 25.7 Wed 10:00 P3

Reconfiguring hydrodynamic flow fields of active particles by light — Lisa Rohde, Tom-Hannes Hemann, Gordei Anchutkin, and •Frank Cichos — Molecular Nanophotonics Group, Peter Debye Institute for Soft Matter Physics, University Leipzig, Leipzig, Germany

Microscopic active particles propel themselves via localized energy conversion, generating hydrodynamic flow fields that govern their boundary interactions and collective behaviour. The long-range behaviour of the flow patterns classifies them as either pushers, which expel fluid along their swimming axis, or pullers, which draw fluid inward. In nature, some microorganisms can adaptively switch between pusher and puller modes in response to their environment. However, synthetic active particles are currently limited to a fixed pusher or puller configuration during fabrication, constraining our ability to study their dynamic responses to environmental cues. Here, we present a self-thermophoretic active particle that can reconfigure its flow field on

demand during the experiment. This is achieved by illuminating the particle with an inhomogeneous light field shaped by a spatial light modulator. The illumination patterns create surface temperature fields inducing thermo-osmotic flow fields that propel the particle and shape the hydrodynamic interactions. By using gold nanoparticles, we trace and characterize the hydrodynamic flow field of the active particle. The ability to dynamically alter the propulsion characteristics will enable us to investigate and control their interactions and collective dynamics.

CPP 25.8 Wed 10:00 P3

Brainbots as smart autonomous active particles with programmable motion — •Isa Mammadli[1], Martial Noirhomme[2], Nathan Vanesse[2], Jayant Pande[3], Ana-Sunčana Smith[1], and Nicolas Vandewalle[2] — [1]PULS, Institute for Theoretical Physics, FAU Erlangen-Nürnberg, 91058, Erlangen, Germany — [2]GRASP, Institute of Physics B5a, University of Liege, B4000 Liege, Belgium — [3]Department of Physical and Natural Sciences, FLAME University, Pune, India

We introduce an innovative robotic device designed to enable controlled motion for the study of active matter. Motion is driven by an internal vibrator, powered by a compact rechargeable battery. The system integrates acoustic and magnetic sensors alongside a programmable microcontroller. Unlike conventional vibrobots, this device employs a motor that generates horizontal vibrations, producing cycloidal trajectories that have been thoroughly characterized and optimized. Specific segments of these trajectories can be harnessed to create tailored motion patterns. As a proof of concept, we demonstrate how this versatile system can be used to develop active particles exhibiting diverse dynamics, ranging from ballistic motion to run-and-tumble diffusive behavior. Based on experimental data, we provide a simulation routine capable of replicating these trajectories, enabling the generation of extended datasets and the exploration of various input velocity configurations. This approach facilitates the determination and prescription of optimized input parameters for applications such as enhanced search strategies and precise path following.

CPP 25.9 Wed 10:00 P3

Fundamental Measure Theory for active hard discs — •Jonas Buba and Michael Schmiedeberg — Theoretical Physics: Lab for Emergent Phenomena, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

The behavior of active soft particles has been studied extensively and provides a good model for many active matter systems [1]. However, some systems might be described more accurately by considering hard particles instead. While active soft particles have been described with a Phase Field Crystal approach (e.g., in [2]), a similar description of active hard particles is still lacking. In our approach we use Fundamental Measure Theory [3] to model hard discs and add activity. We expect to gain further insight into the role that the particle type can play in dynamical pattern formation.

[1] Marchetti M C, Joanny J F, Ramaswamy S, Liverpool T B, Prost J, Rao M and Simha R A. Hydrodynamics of soft active matter. Rev. Mod. Phys. 85 1143, 2013. [2] Arold D and Schmiedeberg M. Mean field approach of dynamical pattern formation in underdamped active matter with short-ranged alignment and distant anti-alignment interactions. J. Phys.: Condens. Matter 32 315403, 2020. [3] Roth R, Mecke K, and Oettel M. Communication: Fundamental measure theory for hard disks: Fluid and solid. The Journal of Chemical Physics, 136(8):081101, 2012.

CPP 25.10 Wed 10:00 P3

Many-Body Dynamics of actively rolling fibers — •Alex Arnhold[1], Falko Ziebert[1,2], and Igor M Kulic[3,4] — [1]Institute for Theoretical Physics, Heidelberg University, Philosophenweg 19, 69120 Heidelberg, Germany — [2]BioQuant, Heidelberg University, Im Neuenheimer Feld 267, 69120 Heidelberg, Germany — [3]Institut Charles Sadron UPR22-CNRS, 67034 Strasbourg, France — [4]Institute Theory of Polymers, Leibniz-Institute of Polymer Research, D-01069 Dresden, Germany

Fiberboids are active filaments, capable of self-propulsion, whose dynamics were recently described in [A. Bazir, A. Baumann, F. Ziebert, I. M. Kulić, Soft Matter 2020]. So far, only single and simple 2-body dynamics of fiberboids were described.

In this work we will take a first look at the many-body dynamics. Specifically, we analyze a system of multiple nylon-rods, which when heated from below display self-propelled rolling motion. Confining the rods to roll on a single axis only, implements a simple realization of an 1D active gas. We analyze the experiments concerning clustering and nonequilibrium fluctuations and rationalize the system by simple lattice models.

CPP 25.11 Wed 10:00 P3

Pumping currents and formation of flocks in 1D Ising model — •Adrian Morais Cabral and Achim Rosch — Institute for Theoretical Physics, University of Cologne, Germany

Non equilibrium systems create phenomena that are not observed in equilibrium counterparts, such as long range order in two or less dimensions and breaking of detailed balance.

We use an effective description of coupled Langevin equations to study a 1D system where an Ising order parameter is coupled to a charge density. Our assumption is that the charge current has a contribution proportional to the order parameter for the driven system. The formation of domain walls leads to a source of dynamical frustration for the charge. Driving disallows the formation of domain walls and creates flocking blob like states in addition to constant ordered and disordered states and a non moving spike phase. These solutions are studied numerically in 1D for $T \geq 0$.

At $T = 0$, we characterize existing flocking solutions and compare analytical predictions to numerical simulations which agree well with only one fitting parameter.

At finite temperatures we find new dynamics for the flocking state such as reversals similar to the active Ising model and (quasi) crossings. However, we have not yet been able to answer whether the existing ordered phase is stable in 1D.

CPP 25.12 Wed 10:00 P3

Statistical Field Theory for Vicsek-type models — •Carsten Littek, Falko Ziebert, and Matthias Bartelmann — Institut für Theoretische Physik, Universität Heidelberg, Germany

Dry, aligning, dilute active matter systems display a wide range of emergent phenomena such as collective, orientationally ordered motion and phase separation. The self-propelled particles in such systems undergo noisy aligning interactions with their neighbours, but they do not exchange momentum with their surrounding. While microscopic and hydrodynamic descriptions, whose connection involves approximations, exist, their predicted behaviour - such as scaling exponents - do not match.

Here we present a microscopic statistical field theory for active Brownian particles inspired by Mazenko (2010). In our formulation we interpret the particles' two-dimensional positions and their direction of motion as Martin-Siggia-Rose (MSR) fields to obtain a path integral representation of the N-particle partition function. The MSR action is augmented by a two-particle interaction that aligns particle directions either ferromagnetically as in the Vicsek model or nematically. Similar to quantum many-body theory the benefit of our field theoretic formulation of Vicsek-type models is that it allows for developing a self-consistent perturbation theory and using renormalization techniques. Our aim is the calculation of density and velocity correlation functions in the homogeneous ordered phase and the transition into the ordered phase.

CPP 25.13 Wed 10:00 P3

Coupling reaction-diffusion and locomotion in vegetative cells — •Blaž Ivšić[1], Piotr Nowakowski[2], Igor Weber[2], and Ana Sunčana Smith[3,2] — [1]Institut za fiziku, Zagreb, Croatia — [2]Institut Ruđer Bošković, Zagreb, Croatia — [3]Friedrich-Alexander- Universität, Erlangen, Germany

Cellular locomotion involves the dynamic interplay between signaling molecules, cytoskeletal activity, and membrane deformation. We present a computational model coupling protein Rac1 reactiondiffusion dynamics to cell locomotion to study vegetative state of amoeba Dictyostelium discoideum. Rac1 regulates actin polymerization via effectors like WASP and Arp2/3, while GAP modulates its activity. The model captures Rac1 dynamics on a deforming membrane, reproducing experimentally observed spatiotemporal patterns.

Cell shape is modeled using a Level-set method to track membrane dynamics, driven by forces linked to Rac1 concentration. Specifically, surface tension and normal forces (due to interaction of the cell with the substrate) proportional to Rac1 concentration influence membrane movement. The dynamics are conveyed through a fluid velocity field obtained by solving a time-dependent Stokes equation.

Our model replicates Rac1 activity patterns seen in live-cell imaging and links these patterns to cell motility. By bridging Rac1 reactiondiffusion dynamics with membrane mechanics, the model provides

insights into the mechanisms of actin-driven locomotion in vegetative cells.

CPP 25.14 Wed 10:00 P3

Numerical Simulation of Microplastic Permeation in Soil: from Solutes to Particles — •Hao Liu[1], Yifan Lu[2], Christina Bogner[2], Martin Lörder[1], and Stephan Gekle[1] — [1]University of Bayreuth, Bayreuth, Germany — [2]University of Cologne, Cologne, Germany

Microplastics have become significant environmental pollutants, raising concerns about their accumulation and distribution across ecosystems. Although terrestrial environments, particularly soils, often exhibit high levels of microplastic contamination, they remain relatively understudied. Microplastic transport in soil involves complex interactions among particle properties, soil structure, and fluid dynamics. Understanding mechanisms such as permeation, aggregation, and degradation is essential for effective environmental risk assessments and strategies to control microplastic pollution.

This study aims to simulate and predict soil hydraulic conductivity in microplastic-laden flows. Challenges include modeling behaviors of microplastic particles as they transport in soil with complex porous structures. High-resolution μCT scans of soil samples will provide the necessary porous media data, and simulations will be conducted using FluidX3D software. The research progresses in two phases: first, disregarding particle size and shape to analyze solute transport mechanisms; second, incorporating detailed particle properties to study transport and accumulation in pores. The goal is to model microplastic dynamics for accurate predictions of microplastic distribution in soil systems.

CPP 25.15 Wed 10:00 P3

Thermo-Osmotic Flows via Anti-Stokes Cooling — •akshay kallikkunnath[1], kamil bruchal[2], pawel karpinski[2], and frank cichos[1] — [1]Molecular Nanophotonics, Peter Debye Institute for Soft Matter Physics, Faculty of Physics and Earth System Sciences, Leipzig University, Germany — [2]Faculty of Chemistry, Institute of Advanced Materials, Wroclaw University of Science and Technology, Poland

Fluidic manipulation has gained huge interest over time especially with the studies on metal nanoparticles as optically controlled heat sources generating temperature gradients. With recent developments in the synthesis of lanthanide doped crystals which can be cooled by anti-stokes cooling, we try to bring laser cooling of microcrystals to the field of fluidics. In this work, we optically trap and cool ytterbium doped NaYF4 crystals by means of anti-stokes cooling. Temperature measurements for such microscale cooled crystals are done using a technique which utilizes the phase transition of liquid crystals. With such a thermal gradient created using cold sinks in liquid, we study and provide for the first time experimental and numerical results for flows generated at solid-liquid boundary, i.e., thermo-osmotic flows. The results will provide further scope for studying dipolar thermo-osmotic and corresponding thermo-electric fields in an electrolyte solution generated by arranging optically heated and cooled particles together. Our findings can have direct implications on the study of temperature-dependent biochemical processes which inhibit with lower temperature or on response of a biological specimen to low temperature stress or may even find application in local cryotherapy.

CPP 25.16 Wed 10:00 P3

Thermodynamically consistent coarsening model of crossover placement in meiosis — •Marcel Ernst[1,2] and David Zwicker[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Universität Göttingen, Germany

Crossovers play an important role in meiosis, ensuring correct segregation of homologous chromosomes and increasing genetic variability. A recently proposed model suggests that crossover placement is determined by biomolecular condensates that coarsen by exchange and diffusion of a protein along chromosomes, consistent with experiments. We here present an extended model including exchange with the nucleoplasm based on thermodynamic principles. We study theoretically and numerically the initial protein loading onto the chromosome, the droplet growth regime, the coarsening regime, and the final equilibrium. We derive scaling laws for the number of crossovers analogous to Lifshitz-Slyozov-Wagner theory in different limits. Finally, we investigate the effect of protein exchange with the nucleoplasm on crossover placement and compare the results with empirical data from several species. In conclusion, our model allows us to explain key features of meiotic crossover placement in wild type and several mutants.

CPP 25.17 Wed 10:00 P3

A lattice Boltzmann approach to electrolytic multiphase flows — •Alexander Reinauer and Christian Holm — Institute for Computational Physics, Stuttgart, Germany

Simulating electrolytic multiphase flow presents significant challenges, often requiring either the detailed modeling of large numbers of particles or solving complex, nonlinear partial differential equations, such as the Navier-Stokes and Nernst-Planck equations. While particle-based simulations provide molecular details, continuum-scale approaches, including the Navier-Stokes and Nernst-Planck equations, enable the study of larger systems relevant to applications in oil recovery, biological processes, and waste treatment.

In this work, we extend the Lattice Boltzmann Method using a Color-Gradient approach to simulate immiscible two-phase flow, coupled with a custom Nernst-Planck solver for the transport of dissolved charged species. This coupling allows to incorporate the preferential solubilities of chemical species.

Our implementation, based on the pystencils/lbmpy framework, generates highly optimized code for both CPU and GPU architectures. To validate the model, we performed simulations of freely suspended liquid droplets subjected to an external electric field. Additionally, we explored contact angle models and initiated studies on applying the approach to porous media under varying conditions.

CPP 25.18 Wed 10:00 P3

Coarsening of chemically active droplets — •Stefan Köstler[1,2], Yicheng Qiang[1], and David Zwicker[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany — [2]University of Göttingen, Institute for the Dynamics of Complex Systems, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Droplets formed by phase separation play an important role in cellular organization and are widely used in the design of synthetic cells and lab-on-chip devices. Droplet emulsions typically coarsen due to surface tension and hydrodynamic effects, which generally prevents precise control over droplet sizes. While coarsening can be suppressed by active chemical reactions, it is unclear how these reactions affect the coarsening dynamics and control droplet sizes. To elucidate this, we numerically simulate a binary mixture that phase separates and undergoes reactions. We find three different dynamical regimes: Small droplets are dominated by coalescence due to hydrodynamic advection, then transition to an Ostwald ripening regime dominated by diffusion, and finally exhibit size control by active chemical reactions. We predict the transition from ripening to size control analytically, and we validate our analytical estimate of the final size using a numerical minimization of a surrogate equilibrium free energy. Our theory provides an improved understanding of coarsening mechanisms, allowing to achieve greater control of emulsions.

CPP 25.19 Wed 10:00 P3

Zetapotential of Gold Surfaces in a Flow Cell — •Mattis Rasenat, Peter Vogel, Marcus Witt, and Thomas Palberg — Johannes gutenberg Universität Mainz

We present a case study on the zeta-potential of gold surfaces in a continuous flow cell. The charge of dielectric surfaces is of high interest for technological applications. Therefore, we measure the zeta potential of polymer particles in a custom-made electrokinetic flowthrough cell with exchangeable sidewall. The zeta potential is measured with a super-heterodyne light scattering setup.

CPP 25.20 Wed 10:00 P3

Use of molecular CO_2 for surface charge regulation — Peter Vogel[1], Markus U. Witt[1], David Beyer[2], Christian Holm[2], Muhammad Navaz Qaisrani[3], Marialore Sulpizi[4], and •Thomas Palberg[1] — [1]Inst. of Physics, JGU, Mainz, Germany — [2]Inst. of Computational Physics (ICP), U Stuttgart, Stuttgart, Germany — [3]MPI for Polymer Research, Mainz, Germany — [4]Dept. of Physics, RU Bochum, Bochum, Germany

In deionized water CO_2 forms carbonic acid which partially dissociates. Such 'realistic' salt free systems contain a significant background electrolyte concentration and a pH of 5.5. Both lowers the effective charge of dielectric surfaces. Surprisingly, the remaining molecular CO_2 causes an additional drastic decharging effect, even to complete decharging in water equilibrated against pure CO_2. Molecular CO_2 acts directly on the degree of dissociation and thus lowers the bare charge, while effective charges merely follow suit. MD simulations

show the formation of a diffusely adsorbed monolayer of CO_2, which locally lowers the dielectric constant. Based on this we suggested dielectric charge regulation as novel decharging mechanism. If then salts are added to the carbonized surfaces, one finds recharging by co-ion adsorption. This process is favoured by hydrophobicity, by co-ion size and, most important, also by the amount of adsorbed CO_2. Given the ubiquity of dielectric surfaces in contact with aqueous electrolytes, this very general charge regulation processes appear to be of great fundamental and practical importance.