DY 32: Poster: Active Matter, Soft Matter, Fluids

Time: Wednesday 15:00–18:00 Location: Poster C

DY 32.1 Wed 15:00 Poster C

Modelling electrokinetic two-phase flows applicable to porous media — •Alexander Reinauer and Christian Holm — Institute for Computational Physics, Stuttgart, Germany

The simulation of electrolytic multiphase flow is a highly complex task that requires to simulate a large number of explicit particles or to solve a highly coupled set of non-linear partial differential equations, namely the Navier-Stokes and the Nernst-Planck equations in a continuous picture. At the cost of the molecular details, the continuum scale description enables the investigation of larger-scale systems that are relevant for oil-recovery and biological systems. An application is the electrophoresis of liquid droplets, which displays various complex phenomena including phase separation and transport in biological systems. Several choices of solvers exist for the continuum scale description, our implementation is based on the color-gradient extension to the lattice Boltzmann method to simulate immiscible multiphase flow as well as a custom Nernst-Planck solver to describe the transport of dissolved charged chemical species. By developing a coupling between these two methods, we allow for the inclusion of preferential solubilities of the chemical species. For the implementation, the pystencils/lbmpy framework is used, providing a highly optimized code-generation tool for CPU and GPU that allows for rapid prototyping of stencil-code in Python. In order to assess our model, we conduct a simulation study of freely suspended liquid droplets under the application of an external electric field.

DY 32.2 Wed 15:00 Poster C

Nucleation and Growth of Sessile Chemically Active Droplets — •Noah Ziethen and David Zwicker — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Driven chemical reactions can control the macroscopic properties of droplets, like their size. Moreover, such reactions control their formation from a homogeneous phase, e.g., for structuring biological cells. Inside cells, various organelles coexist and potentially interact with the complex cytoplasm. Understanding how the interaction of droplet material with boundaries modifies the droplet formation of size-controlled droplets is thus crucial.

Our numerical simulations reveal that reactions generally suppress nucleation in the presence of a boundary, as expected from homogeneous nucleation. Intriguingly, we uncover a coupled effect of wall interaction and chemical reactions, leading to shapes that deviate from spherical caps. We establish that these distortions result from anisotropic fluxes responding to the boundary conditions dictated by the Young Dupré equation. These findings demonstrate how the properties of stationary active droplets can deviate from their passive counterparts. In a biological context, such shape deformations may serve as a mechanism for cells to transition from a droplet state to a wetted film along the boundary.

DY 32.3 Wed 15:00 Poster C

Droplets on soft and flexible sheets — •Salik Sultan, Josua Grawitter, and Holger Stark — Technische Universität Berlin, Institute of Theoretical Physics, Hardenbergstr. 36, 10623 Berlin, Germany

Droplets sitting on flexible sheets deform the sheets and assume the shape of a lens. One promising application of this phenomenon is the potential for designing tunable fluidic lenses. In our ongoing research we build on our established droplet model, developed using the boundary element method (BEM), to investigate dynamic wetting on thin flexible sheets. Central to our study is the nuanced interplay between the mechanical attributes of the sheet and droplet behavior, with a particular emphasis on contact angle during wetting. Drawing inspiration from biological membranes, we have integrated the Skalak model for elastic deformations and the Helfrich Hamiltonian for bending mechanics into our approach. This enables us to dissect how tension forces and sheet rigidity impact droplet shape and wetting dynamics, and ultimately allows us to steer droplets along the sheet. While our model has implications in material science, its versatility allows for insights into interfacial biology, illuminating the fascinating interactions between soft substrates and liquid interfaces.

DY 32.4 Wed 15:00 Poster C

Nonreciprocal Model B and the role of nonreciprocal 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 it has been shown that the Cahn-Hilliard model for phase separation with nonreciprocal interaction can give rise to travelling states. While the Cahn-Hilliard description comes from a magnetic analogy, we explore here the corresponding nonreciprocal model B dynamics as the continuum theory for a particle mixture. We explore the topology of the phase diagram for binary mixtures, determining where spinodal instabilities occur and where these lead to travelling states because the relevant eigenvalues are complex. Simulations show that in addition to pure travelling states, coexistence of stable, equilibrium-like domains with strongly fluctuating patterns in the rest of the system can also occur, a feature that has not been observed in the Cahn-Hilliard setting. We argue further, based on a nonreciprocal version of Dean's equation, that coarse graining into a model B description should generically lead to nonreciprocal forces also at interfaces, rather than only in the bulk as assumed in nonreciprocal field theories to date. We explore the effects of such nonreciprocal interfacial forces and find that they can convert conventional spinodal instabilities into ones producing travelling patterns. This indicates that interfacial nonreciprocity can have important implications for the spinodal dynamics of phase separating mixtures, and potentially also for their long-time dynamics.

DY 32.5 Wed 15:00 Poster C

PT Symmetry and Non-Hermitian Band Topology — •Kang Yang[1], Zhi Li[2], Lukas König[3], Lukas Rødland[3], Marcus Stålhammar[4], and Emil Bergholtz[3] — [1]Freie Universität Berlin, Berlin, Germany — [2]Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada — [3]Stockholm University, Stockholm, Sweden — [4]Nordita, Stockholm, Sweden

Non-Hermitian matrices are ubiquitous in the description of nature ranging from classical dissipative systems, including optical, electrical, and mechanical metamaterials, to scattering of waves and open quantum many-body systems. Multiple non-Hermitian bands exhibit intriguing exceptional points, spectral braids and crossings. In this work we develop a topological description based on non-Hermitian band gaps and separation gaps. We provide a unified classification of both gapped and nodal systems in the presence of physically relevant parity-time (PT) and pseudo-Hermitian symmetries using homotopy theory. This uncovers new stable topology stemming from both eigenspectra and wavefunctions, and remarkably also implies distinct fragile topological phases. In particular, we reveal different Abelian and non-Abelian phases in PT-symmetric systems, described by frame and braid topology. The corresponding invariants are robust to symmetry-preserving perturbations that do not induce (exceptional) degeneracy, and they also predict the deformation rules of nodal phases. We further demonstrate that spontaneous PT symmetry breaking is captured by Chern-Euler and Chern-Stiefel-Whitney descriptions, a fingerprint of unprecedented non-Hermitian topology overlooked in previous study.

DY 32.6 Wed 15:00 Poster C

AMEP: Active Matter Evaluation Package — •Kai Luca Spanheimer, Lukas Hecht, Kay-Robert Dormann, Aritra Mukhopadhyay, Mahdieh Ebrahimi, Suvendu Mandal, and Benno Liebchen — Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Hochschulstr. 8, D-64289 Darmstadt, Germany

The Active Matter Evaluation Package (AMEP) is a Python library for analysing simulation data of particle-based and continuum simulations. It provides a powerful and simple interface for handling large data sets based on the HDF5 data format. Main features are various methods for calculating observables, visualising results, and analysing simulation data of molecular dynamics simulations, Brownian-dynamics simulations, and continuum simulations. The methods are developed for analysis of active matter systems but are applicable to passive systems as well. AMEP is written in pure Python and leverages powerful libraries such as NumPy, SciPy, Matplotlib, and scikit-image. Computationally expensive methods are parallelised and optimised to run efficiently on workstations, laptops, and high-performance computing

architectures. AMEP provides the first unified framework for analysing results of both particle-based and continuum simulations. This allows users to easily analyse their data of simulations that combine particle-based and continuum techniques, e.g. as used to study the motion of bacteria in chemical fields or modelling particle motion in a flow field.

DY 32.7 Wed 15:00 Poster C

Consequence of anisotropy on flocking: the truly discretized Vicsek model — •Mintu Karmakar[1], Swarnajit Chatterjee[2], Raja Paul[1], and Heiko Rieger[2,3] — [1]School of Mathematical & Computational Sciences, Indian Association for the Cultivation of Science, Kolkata – 700032, India. — [2]Center for Biophysics & Department for Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany. — [3]INM - Leibniz Institute for New Materials, Campus D2 2, 66123 Saarbrücken, Germany.

We numerically study a "true" discretization of the Vicsek model (TDVM) on an off-lattice two-dimensional domain to probe the transition of collective motion as the system switches its symmetry from discrete to continuous. The TDVM consists of particles able to execute motion on a plane in q discrete angular directions like the active clock model (ACM) and follows dynamical rules of particle alignment and movement inspired by the prototypical Vicsek model (VM). We find a novel cluster phase for small q and noise and observe the formation of microphase and cross-sea in the phase coexistence region as q is increased and the system approaches the VM. We find that although the giant number fluctuations for large q corroborate with the nature of phase separation in the coexistence region, the large length-scale behavior of the direction of the global order and correlations does not correspond with it. We also investigate the stability of the ordered liquid phase and find it metastable to the nucleation of droplets of different polarization.

DY 32.8 Wed 15:00 Poster C

Tuning kinetics of chemically fueled droplets — •Lennard Holschuh and Joachim Dzubiella — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Germany

Membraneless organelles like centrosomes play an essential part in intracellular structuring. A similar behaviour can be mimicked by active droplets resulting from phase separation introduced by a chemical reaction that depends on the available fuel. Recent experiments with synthetic molecules in a chemically fueled reaction cycle explore the non-equilibrium behaviour of these active droplets. In our work, a two-state chemical reaction is modeled with a two-dimensional reactive Brownian dynamics simulation and compared to a macroscopic description with the Fokker-Planck equation. In the simulation, particles with state 0 are soluble and particles in state 1 - which are activated via the consumption of fuel - become attractive and are able to accumulate to droplets. In the case of a saturated system, expected power laws for the radius of the droplets as well as for the number of droplets are recovered. A coordination-dependent distinction of 'internal' and 'external' particles of the droplet gives further control over the deactivation process. The simulation shows that deactivation of only external particles slows down the decay and stabilizes the droplets, whereas the deactivation of only internal particles can lead to a temporary encapsulation of deactivated particles where the chemically active particles serve as shell. Similarities and differences to related experiments are discussed.

DY 32.9 Wed 15:00 Poster C

Collective Hall current in chiral active fluids: Coupling of phase and mass transport through traveling bands — Frank Siebers[1], •Robin Bebon[2], Ashreya Jayaram[2], and Thomas Speck[2] — [1]Institute for Theoretical Physics 4, University of Stuttgart, Heisenbergstraße 3, 70569 Stuttgart, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7-9, 55128 Mainz, Germany

Active fluids, composed of motile entities, have garnered enormous interest owing to the programmability of their collective spatiotemporal behavior that can be controlled by tuning physical properties at the individual level. We report a novel phase exhibited by locally aligning chiral particles – (meta-)stable, dispersionless traveling bands that couple phase and mass transport. Intriguingly, the particle current is neither parallel nor perpendicular to the direction of phase propagation, with magnitudes depending on the self-propulsion and angular speeds of particles. We thus report the first instance of a self-organized Hall (or Magnus) effect in chiral active fluids with a tunable Hall angle. Through particle-based simulations, we reveal the mechanism underlying this phenomenon and corroborate our results using a minimal hydrodynamic theory. Within this framework we show that bands arise as non-dispersive soliton solutions that fully explain the properties observed in simulations.

DY 32.10 Wed 15:00 Poster C

Phase Separation in Cycloactive Matter — •Theo Spornhauer[1], Johannes Zierenberg[1,2], and Benoît Mahault[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for the Dynamics of Complex Systems, University of Göttingen, Göttingen, Germany

Living systems that generate activity from environmental resources are dependent on environmental conditions. In nature, these conditions are typically not static, but have a strong temporal profile, as seen for example in the day-night cycle that affects photosynthesis. Here, we numerically investigate the effect of cyclic activity variations in a minimal model of active Brownian particles, focusing in particular on how they affect the phenomenon of motility-induced phase separation (MIPS). Performing simulations at various driving amplitudes and frequencies, our results show that MIPS is robust to the introduction of cyclic activity. For cycles crossing the transition point, measures of phase separation exhibit a characteristic hysteresis, which we find to be most pronounced when the timescales associated with activity and cyclic driving are comparable. We also discuss how the geometric properties of MIPS clusters are affected by the presence of the cyclic drive.

DY 32.11 Wed 15:00 Poster C

Collective actuation in active elastic solids — •Katherina E. Hemmo, Kim L. Kreienkamp, and Sabine H. L. Klapp — Technische Universität Berlin

Collective motion is ubiquitous in various biological systems consisting of interacting active agents. Many of the coupling mechanisms rely on alignment couplings based on an exchange of heading vector information. However, collective motion can also emerge without explicit alignment interactions, solely through positional information exchange [1]. Building upon previous research on elastically coupled active solids [1-2], we here focus on active particles coupled via springlike interactions, leading to self-alignment in direction of displacement. For large enough activity, collective actuation, characterized by nearly synchronized oscillations of all particles around their equilibrium positions, can be observed [1-2]. Here, we address the question of how stable the collective actuation is when mixed groups include non-conforming members. Specifically, we introduce dissenters into the system, which do not engage in the self-alignment interactions but behave as Brownian particles in the otherwise active elastic sheet. Using particle-based simulations and normal mode analysis we find that an increasing number of dissenters weakens the collective actuation. We examine various geometric configurations of dissenters across different noise strengths to assess the most stable configurations and understand how the presence of dissenters impacts the elastic active solid as a whole.

[1] E. Ferrante, et al., New J. Phys. 15.9, 095011 (2013).
[2] P. Baconnier, et al., Nature 18.10, 1234 (2022).

DY 32.12 Wed 15:00 Poster C

Active fractalytes — •Sebastian Fehlinger and Benno Liebchen — Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Hochschulstraße 8, D-64289 Darmstadt, Germany

Non-reciprocal interactions occur widely in nature. For the specific case of a binary mixture of passive particles, where one species non-reciprocally attracts the other one, the breaking of the action reaction principle can lead to formation of active colloidal molecules which are capable of self-propulsion. For small systems, such active molecules have already been realized in experiments [1,2]. The focus of the present work is to understand the collective behavior of many active molecules. Using particle based simulations, in a wide range of the parameter space, we find that active molecules self-organize into ballistically moving structures that feature holes, gaps and a fractal dimension. We call them active fractalytes [3]. Besides structural properties, which clearly distinguish them from aggregates emerging from diffusion-limited aggregation, we analyze the dynamics and the scaling properties of active fractalytes and complement our work with a continuum theory.

[1] F. Schmidt et al. J. Chem. Phys. 150, 094905 (2019).
[2] J. Grauer et al. Nat. Commun. 12, 6005 (2021)
[3] S. Fehlinger, B. Liebchen. Phys. Rev. Res. 5, L032038 (2023).

DY 32.13 Wed 15:00 Poster C

Flocking of two unfriendly species — •Matthieu Mangeat[1], Swarnajit Chatterjee[1], Chul-Ung Woo[2], Jae Dong Noh[2], and Heiko Rieger[1] — [1]Saarland University, Saarbrücken, Germany — [2]University of Seoul, Seoul, Korea

Complex systems are typically heterogeneous as individuals vary in their properties, their response to the external environment and to each other. In particular, many biological systems that show flocking involve self-propelled particles with heterogeneous interactions, which motivates the study of populations with multiple species. In this work, we consider the two-species variant of the Vicsek model (TSVM) and the active Ising model (TSAIM), consisting of two kinds of self-propelled particles that tend to align with particles from the same species and to antialign with the other. These two-species models show a flocking transition that is reminiscent of the original one-species model, as a liquid-gas phase transition, and display phase-separation in the coexistence region where dense liquid bands of each species propagate in a gaseous background. The interesting feature of these models is the appearance of two dynamical states in the coexistence region: the PF (parallel flocking) state in which all bands of the two species propagate in the same direction, and the APF (antiparallel flocking) state in which the bands of two different species move in opposite directions. PF and APF states perform stochastic transitions from one to the other only in TSVM, and the APF liquid phase of the TSVM is replaced by a high density PF state in the TSAIM. We also study the impact of particle switching from one species to another.

DY 32.14 Wed 15:00 Poster C

Controlling the self aggregation of active triblock Janus colloids — •Juri Schubert, Salman Fariz Navas, and Sabine H. L. Klapp — ITP, Technische Universität Berlin, Germany

Triblock Janus colloids belong to the family of patchy particles, interacting with hydrophobic attraction at opposite poles and electrostatic repulsion in the equatorial region. They are known to self assemble into a colloidal kagome crystal from experiments [1] and theory [2]. Such structures are of particular interest owing to their novel optical and mechanical properties. However, the self-assembly of open-cell lattices is a multistep process involving the formation of intermediate competing structures resulting in long time-scales. Recently, it has been shown that introducing activity can significantly accelerate the self assembly and enhance the kagome yield [3].

Here, we study the model introduced in [3] and build upon the results to compare with prior research on Janus particles [2]. Investigating the aggregation pathway, we show preliminary results on the use of time dependent activity protocols to gain better control of the aggregation process.

[1] Q. Chen, S. C. Bae, S. Granick, Nature 469, 7330 (2011).
[2] F. Romano, F. Sciortino, Soft Matter 7, 12 (2011).
[3] S. A. Mallory, A. Cacciuto, JACS 141, 6 (2019).

DY 32.15 Wed 15:00 Poster C

Thermodynamics and coarse graining of colloidal heat engines with active baths — •Roland Wiese[1], Klaus Kroy[1], and Viktor Holubec[2] — [1]Institute for Theoretical Physics, Leipzig University, 04103 Leipzig, Germany — [2]Faculty of Mathematics and Physics, Charles University, CZ-180 00 Prague, Czech Republic

We review the applicability of effective temperatures to describe the thermodynamics of a colloidal probe particle in a bath of active Brownian particles - a prototypical example of a non-equilibrium Brownian system. Using Brownian dynamics simulations, we realise a microscopic Stirling cycle by modulating the probe's trapping potential and the bath particles' swim speed. In contrast to claims for recent experimental studies of colloids in bacterial baths, we show that Carnot's limit for the thermodynamic efficiency cannot be broken, even for a strongly non-Gaussian active bath, by reproducing and rationalising the average performance reported for the experimental system. The probe-in-active-bath setup is coarse-grained to a single active Brownian particle (ABP) and to a single active Ornstein-Uhlenbeck particle (AOUP), with their respective noise correlations determined by the underlying probe-bath interactions. Not only thermodynamic averages but even the stochastic fluctuations of the exchanged work and heat are faithfully preserved for the AOUP.

DY 32.16 Wed 15:00 Poster C

Kinetic Event-Chain Algorithm: Exploring mixtures of hard active and passive particles — •Nico Schaffrath, Thevashangar Sathiyanesan, Tobias Kampmann, and Jan Kierfeld — Physics Department, TU Dortmund, 44221 Dortmund, Germany

The novel cluster kinetic Monte-Carlo algorithm for active matter systems, which is based on the event-chain Monte-Carlo method, efficiently simulates systems of self-propelled hard particles. We extend this algorithm to various mixtures of active and passive particles. In doing so, we uncover the microscopic mechanism behind the enhanced diffusion of a completely symmetric passive tracer disk in a bath of active hard disks. Furthermore, our study includes a systematic exploration of the effective interaction between two large passive disks in a bath of active hard disks, along with an examination of the phase behavior of binary mixtures of active and passive hard disks.

DY 32.17 Wed 15:00 Poster C

Harnessing synthetic active particles for physical reservoir computing — •Xiangzun Wang[1,2] and Frank Cichos[1] — [1]Peter Debye Institute for Soft Matter Physics, Leipzig University, 04103 Leipzig, Germany — [2]Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI) Dresden/Leipzig, 04105 Leipzig, Germany

The processing of information is an indispensable property of living systems realized by networks of active processes with enormous complexity. They have inspired many variants of modern machine learning, one of them being reservoir computing, in which stimulating a network of nodes with fading memory enables computations and complex predictions. Reservoirs are implemented on computer hardware, but also on unconventional physical substrates such as mechanical oscillators, spins, or bacteria often summarized as physical reservoir computing. Here we demonstrate physical reservoir computing with a synthetic active microparticle system that self-organizes from an active and passive component into inherently noisy nonlinear dynamical units. The self-organization and dynamical response of the unit are the results of a delayed propulsion of the microswimmer to a passive target. A reservoir of such units with a self-coupling via the delayed response can perform predictive tasks despite the strong noise resulting from the Brownian motion of the microswimmers. To achieve efficient noise suppression, we introduce a special architecture that uses historical reservoir states for output. Our results pave the way for the study of information processing in synthetic self-organized active particle systems.

DY 32.18 Wed 15:00 Poster C

Spontaneous Symmetry Breaking in Microdroplets Filled with Heat Releasing Particles — •Akshay Kallikkunnath, Arthur Markus Anton, and Frank Cichos — Molecular Nanophotonics, Peter Debye Institute for Soft Matter Physics, Faculty of Physics and Earth System Sciences, Leipzig University, Linnéstraße 5, 04103 Leipzig, Germany

Self-propulsion of microscopic objects require symmetry breaking, which is often achieved by preparing geometrically asymmetric particles, e.g., Janus particles. Self-propulsion can, however, also be achieved with symmetric particles like droplets, where the symmetry is broken dynamically, e.g., by a chemical reaction that induces Marangoni fluxes at the interface to the surrounding medium. Here, we show the self-propulsion of water-in-oil microdroplets encapsulated with symmetric iron oxide particles upon widefield laser illumination. The heat released by the particles close to the boundary of the droplet induces strong Marangoni flows that reshape the distribution of particles inside the droplet. The dynamics of the particles and hydrodynamic flow fields also couple to other particles to create collective motion and cohesive behavior. Our results provide insight into complex collective behavior of micro-particles in confinements and provide new directions for future research in the engineering of such actively propelled micromachines.

DY 32.19 Wed 15:00 Poster C

Phase ordering kinetics in discretized flocking — •Sayam Bandyopadhyay[1], Aditya Kumar Dutta[1], Swarnajit Chatterjee[2], Mintu Karmakar[1], Heiko Rieger[2], and Raja Paul[1] — [1]School of Mathematical & Computational Sciences, Indian Association for the Cultivation of Science, Kolkata – 700032, India — [2]Center for Biophysics & Department for Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

We undertake a numerical study of the ordering kinetics in the two-dimensional (2d) active Ising model (AIM), a discrete flocking model with a non-conserved scalar order parameter. For a quench into the liquid-gas coexistence region and in the ordered liquid region, the char-

acteristic length scale of both the density and magnetization domains follows the Lifshitz-Cahn-Allen (LCA) growth law: $R(t) \sim t^{1/2}$, consistent with the growth law of passive systems with scalar order parameter and non-conserved dynamics. The system morphology is analyzed with the two-point correlation function and its Fourier transform, the structure factor, which conforms to the well-known Porod's law, a manifestation of the coarsening of compact domains with smooth boundaries. We also find the domain growth exponent unaffected by the noise and the self-propulsion velocity of the active particles. However, transverse diffusion is found to play the most significant role in the growth kinetics of the AIM.

DY 32.20 Wed 15:00 Poster C

Hydrodynamic Interaction of a Microswimmer with a Deformable Membrane — •Sagnik Garai, Akhil Varma, and Christina Kurzthaler — Max Planck Institute for the Physics of Complex Systems, Dresden

We study the dynamics of microswimmers, such as bacteria, when they encounter elastic surfaces, like biological membranes, in their environment. In an unbounded domain, the far-field flow signature of a microswimmer is described by a combination of a force and a rotlet dipole. The presence of the membrane creates a non-linear coupling of this flow with the elastic deformation, thereby modifying the microswimmer's velocity. Using the Lorentz reciprocal theorem, we obtain a leading-order correction to the swimming velocity for small membrane deformations. The elastic deformations produce microswimmer trajectories that differ from those observed near rigid surfaces. We characterize them by identifying scattering and bound swimming states near the membrane. Our far-field results are compared to the analytical solution of an axisymmetric squirmer near the membrane.

DY 32.21 Wed 15:00 Poster C

Force-Free and Autonomous Active Brownian Ratchets — •Constantin Rein[1], Klaus Kroy[1], and Viktor Holubec[2] — [1]Universität Leipzig, Institut für theoretische Physik, Brüderstraße 16, 04109 Leipzig — [2]Charles University Prague, Department of Macromolecular Physics, V Holešovičkách 747/2, Praha 8

We present the recently found force-free activity ratchet, that rectifies active Brownian motion using solely time-independent activity landscapes (Rein2023,doi.org/10.1209/0295-5075/accca5). In one dimension, spatially asymmetric activity does not suffice to induce directed transport, unless the activity is modulated in time or an additional potential is used, whereas, in higher dimensions, static activity landscapes alone can induce ratcheting. The underlying principle is similar to the ratcheting induced by asymmetric obstacles in microswimmer baths: swimmers with suitable orientations get channeled, while the others get trapped in low-activity regions until they lost their orientation. The poster presents a full exploration of the properties and working mechanism of the ratchet and its response to external forcing, with an outlook on similarities to transport phenomena in rarefied gases.

DY 32.22 Wed 15:00 Poster C

Investigation in microfiltration for water purification — •Tim R. Baumann, Dario Anselmetti, and Martina Viefhues — Experimental Biophysics, Bielefeld University, Bielefeld, Germany

Fresh water and oceans' pollution due to contamination by plastics is a global endangerment and a highly discussed topic in politics and socioeconomics. Over the last years many restrictions on handling plastics were made specific in the European Union focussing mainly on reducing plastic waste production. Nevertheless, due to mechanical and photo-/chemical wear and tear macroplastics degrade to microplastics or even smaller nanoplastics. Particles of that size are able to migrate in organic tissue and therefore becoming part of the food chain. Filtering plastics of this size is a difficult effort. Thus, this work aims to develop a microfluidic device to be used for removing microplastics from water. Clark et al. proposed a bioinspired mechanism for purification mimicking the feeding mechanism of ray species. The device consists of two rows of tilted posts, splitting the volume. At high Reynolds numbers, i.e. high flow rates, filtration occurs due to position dependent shear and wall induced lift forces. This led to filtration of spherical beads down to 10 μm. In our work, we aim on recreating those results and gaining better understanding of the underlining mechanisms to improve the filter system. Our measurements revealed that the ratio of filtered volume, increased with flow rate up to 50%. Additionally, we were able to filtrate 82% of microparticles. Further, we gain insides of the geometric impact on the systems filtration throughput and efficiency.

DY 32.23 Wed 15:00 Poster C

Deep geothermal fluid flow in complex confinements — •Carola M. Buness, Fabian Nitschke, and Thomas Kohl — Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Deep geothermal projects often reach into hard rocks with low permeability. In these rock formations, the geothermal fluid flows through fracture voids, whose surface roughness varies significantly depending on the type of rock. The complex geometry of the fracture void plays a crucial role in the fluid dynamics as well as the flow rate, which depends highly on the distance to the borehole. However, the detailed description of roughness and fluid dynamics within fractures remains an open research challenge. Since these fluid dynamics define the fracture pressure field, understanding them is one key for the safe operation of deep geothermal power plants in low-porous rock formations. To address this issue, we investigate the fluid dynamics experimentally and numerically in various rough confinements. We measure and analyze the rock surface roughness of different rocks to identify the most appropriate parameters to describe the roughness. Utilizing these parameters, we are recreating rough surfaces to investigate the fluid dynamics within flow-through experiments across a broad range of flow rates, spanning from laminar flow (Re $<<$ 1) to intermediate flow regimes (Re $>$ 1). The research aims to investigate the onset of non-laminar flow and its associated rapid increase in the pressure gradient depending on the wall roughness.

DY 32.24 Wed 15:00 Poster C

A variational approach to the gradient statistics of passive scalar turbulence — •David Aderbauer, Gabriel B. Apolinário, and Michael Wilczek — Universität Bayreuth, Universitätsstr. 30, 95447 Bayreuth

Intermittent non-Gaussian statistics are a common characteristic of turbulent flows. Various approaches exist that use a superposition of Gaussian PDFs (probability density functions) to model these statistics.

This raises the question of how to systematically construct such superpositions. Here, we address this at the example of the Kraichnan model for passive scalar turbulence, which features heavy-tailed gradient statistics.

We derive the Fokker-Planck equation for the gradient PDF and construct a solution based on a superposition of Gaussian PDFs. To this effect, we develop an optimization method to iteratively determine the weight of each Gaussian in the superposition. We compare the PDF resulting from this procedure to the one directly estimated from simulation data, as well as to the stationary solution of the Fokker-Planck equation. We briefly discuss possible extensions to statistical field theories of turbulence.

DY 32.25 Wed 15:00 Poster C

Spatio-temporal correlation in MHD turbulence — •Raquel Mäusle and Wolf-Christian Müller — Technische Universität Berlin, Berlin, Germany

Turbulent flows are ubiquitous on Earth and throughout the universe. They can be understood as the superposition of turbulent fluctuations on various spatial and temporal scales. Energy is transferred between these scales through non-linear interactions, a process known in 3D as the direct energy cascade. We study this energy transfer process by computing the spatio-temporal correlation between fluctuations in magnetohydrodynamic turbulence. To this end, we employ direct numerical simulations, in which the fluctuations are measured in a quasi-Lagrangian manner to avoid the sweeping effect. This framework was used in previous studies of Navier-Stokes turbulence [Physics of Fluids 23.8 (2011):085107], which we extended to account for the anisotropy introduced by the presence of the magnetic field. We present the resulting correlation time scale, strength and direction of the cross-scale energy transfer in the directions parallel and perpendicular to the local magnetic field and relate them to phenomenological models of MHD turbulence. Furthermore, the limitations of the quasi-Lagrangian framework are discussed.

DY 32.26 Wed 15:00 Poster C

High-order finite volume numerics to achieve low numerical diffusivity — •Jean-Mathieu Teissier[1], Raquel Mäusle[1], and Wolf-Christian Müller[1,2] — [1]Technische Universität, Berlin, Germany — [2]Max-Planck/Princeton Center for Plasma Physics

Natural systems typically present turbulent dynamics at Reynolds numbers not yet achievable with current computing facilities. The discretization of the governing equations leads to a loss of energy over time, which can be partially modelled by a so-called "numerical viscosity", which gives an upper bound to the achievable Reynolds number for a given solver at a given numerical grid-size. Hence, finding ways to (*i*) minimize this loss of energy and (*ii*) quantify the dissipation of numerical nature is crucial to perform more realistic simulations. We present high-order dimension-by-dimension finite-volume solvers for the Navier-Stokes and magnetohydrodynamics equations, with discretization orders up to ten. Although higher-order schemes are more costly at a given grid-size, they allow results of similar quality on significantly coarser grids as compared to, e.g. second-order schemes. This leads to an overall gain in computing efficiency, typically a factor of order 10–100. In order to quantify the improvement of the numerical viscosity and magnetic diffusivity of the solvers with discretization order, we present simulations of the tearing mode instability, whose growth rate is a function of (physical) viscosity and magnetic diffusivity.

DY 32.27 Wed 15:00 Poster C

Reduced order network model of incompressible magnetohydrodynamic turbulent flows — •Maria Mathew and Wolf-Christian Müller — ZAA, Technische Universität Berlin, Germany

Plasma turbulence is a widespread phenomenon in astrophysical systems. However, three-dimensional simulations of these systems with realistic parameter values present a significant challenge due to the extensive spectral bandwidth of nonlinearly interacting fluctuations within turbulent flows.

To address this, model reduction techniques have been employed to facilitate a more cost-effective approximative representation of the flow. We extend the network model ansatz newly proposed in a reduced scalar model for the energy dynamics in magnetohydrodynamic flows [Beck, Müller; arXiv:2203.11536 (physics.flu-dyn)], to encompass the dynamics of magnetic helicity, in order to obtain an easily modifiable, reduced representation of plasma turbulence. Our approach involves selecting an inherently minimal subsystem that conservatively transports energy and other quadratic invariants across wavenumber space. This network-based representation of energy-exchanging interconnected agents adeptly captures the intricate dynamics of the flow while simultaneously reducing computational complexity. Within this framework, the spectral scaling is studied, comparing it to the established phenomenological models. Additionally, the impact of various geometric constraints on our transfer function is investigated, particularly on the spectrum of magnetic helicity. We discuss our findings as well as the associated limitations.

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Numerical simulations of subsonic magnetized plasma-jets — •Thomas Christian Vandamme[1], David Kube[1], Jean-Mathieu Teissier[1], and Wolf-Christian Müller[1,2] — [1]Technische Universität Berlin, ER 3-2, Hardenbergstr. 36a, 10623 Berlin, Germany — [2]Max-Planck/Princeton Center for Plasma Physics

In astrophysical processes such as star formation and accretion of material around compact objects free starting jets that travel huge distances, more than 10^5 or 10^7 times their initial radius, can be generated. This is in contrast to hydrodynamic jets, observed e.g. on earth, that suffer from Kelvin-Helmholtz-instabilities leading to disruption of their shear-layer and to turbulent mixing with the environment. Thus, astrophysical jets are subject to stability enhancing processes. Most of all the presence of a magnetic field has a significant impact on the jet's stability.

In order to study the stabilizing effects of magnetic fields, we perform fourth-order accurate numerical simulations of isothermal subsonic jets, both in the hydrodynamic and magnetohydrodynamic case, for different magnetic field configurations in the interior of the jet.

Setups with a helical field topology dominated by axial field components show the most stabilizing effects. Simulations with purely axial or purely azimuthal fields tend to destabilize the jet through current driven instabilities or can not suppress the Kelvin-Helmholtz-modes effectively.

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A basic structure of 2D Boussinesq-Convection — •Lukas Moczarski and Wolf-Christian Müller — Plasma-Astrophysik, TU Berlin, Deutschland

In thermally driven turbulence, heat is mainly carried by buoyant structures, so called thermal plumes. We show that in DNS of 2D homogeneous Boussinesq-convection these plumes condensate on a characteristic scale, on which their mutual interaction induces a large-scale vorticity to the flow. This plume-induced vorticity is proposed as a basis for flow structuring. It is shown that the zero-vorticity level set takes shape as a grid of intersecting lines, whose structure changes slowly on the scale of the large-eddy buoyancy time. A Lagrangian tracer diffusion analysis indicates that the grid lines and their intersection points are paths of enhanced convective transport, whereas the centres of large-scale vortices in between them entrap tracers and lead to reduced transport. A subsequent investigation of the energy cascade in physical space, obtained by Gaussian filtering in spectral space, reveals a strong correlation of the cross-scale energy flux with the grid lines. We show that this is due to the (mis-)alignment of large-scale strain and small scales stress which is strongly modulated by the motion of individual thermal plumes on the grid.