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Overview of Invited Talks and Sessions

Invited Talks

DY 4.1	Mon	9:00– 9:30	DYc	**X-ray tomography investigation of cyclically sheared granular materials** — •Yujie Wang
DY 7.1	Mon	10:00–10:30	DYa	**Can convective heat transport be more efficient than the so-called 'ultimate' regime?** — •Basile Gallet
DY 15.1	Mon	16:00–16:30	DYb	**Glassy physics: from liquids to living cells** — •Liesbeth Janssen
DY 18.1	Tue	9:00– 9:30	DYa	**Reinforcement learning of microswimmer chemotaxis using genetic algorithms** — •Andreas Zöttl, Benedikt Hartl, Maximilian Hübl, Gerhard Kahl
DY 22.1	Tue	10:00–10:30	DYc	**Stability and dynamics of convection in dry salt lakes** — •Lucas Goehring, Jana Lasser, Marcel Ernst, Matthew Threadgold, Cédric Beaume, Steven Tobias
DY 27.1	Tue	14:00–14:30	DYa	**Human exhaled particles from nanometres to millimetres** — •Gholamhossein Bagheri
DY 29.1	Tue	14:00–14:30	DYc	**Fingers, fractals, and flow in liquid metals** — •Karen Daniels
DY 31.1	Tue	15:40–16:10	DYb	**Fixation and ancestry of competing species growing on a rugged front** — •Mehran Kardar
DY 35.4	Wed	10:00–10:30	DYa	**When surface viscosities rule: Bubble relaxation and thin film wrinkling** — •Kirsten Harth
DY 37.1	Wed	9:00– 9:30	DYc	**Physical properties of ultrastable computer-generated glasses** — •Ludovic Berthier
DY 44.1	Wed	14:00–14:30	DYb	**Life in a tight spot: How bacteria swim in complex spaces** — •Sujit Datta
DY 45.1	Wed	14:00–14:30	DYc	**Small diffusive systems warm up faster than they cool down** — Alessio Lapolla, •Aljaz Godec

Sessions

DY 1.1–1.14	Mon	9:00–16:30	CPPb	**Wetting - organized by Stefan Karpitschka (Max Planck Institute for Dynamics and Self-Organization, Göttingen) (joint session CPP/DY)**
DY 2.1–2.3	Mon	9:00–10:00	DYa	**Fluid Physics 1 - organized by Stephan Weiss and Michael Wilczek (Göttingen)**
DY 3.1–3.5	Mon	9:00–10:40	DYb	**Statistical Physics 1 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)**
DY 4.1–4.1	Mon	9:00– 9:30	DYc	**Invited Talk: Yujie Wang (Shanghai)**
DY 5.1–5.4	Mon	9:00–11:00	BPb	**Active Biological Matter I (joint session BP/DY/CPP)**
DY 6.1–6.3	Mon	9:30–10:30	DYc	**Granular Physics 1 - organized by Matthias Sperl (Köln)**
DY 7.1–7.1	Mon	10:00–10:30	DYa	**Invited Talk: Basile Gallet (Saclay)**
DY 8.1–8.6	Mon	11:00–13:00	DYa	**Fluid Physics 2 - organized by Stephan Weiss and Michael Wilczek (Göttingen)**
DY 9.1–9.6	Mon	11:00–13:00	DYb	**Statistical Physics 2 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) und Thomas Speck (Mainz)**
DY 10.1–10.6	Mon	11:00–13:00	DYc	**Granular Physics 2 - organized by Matthias Sperl (Köln)**
DY 11.1–11.6	Mon	11:00–13:30	BPb	**Active Biological Matter II (joint session BP/CPP/DY)**

DY 12.1–12.22	Mon	14:00–16:30	DYp	**Posters DY - Fluid Physics, Active Matter, Complex Fluids, Soft Matter and Glasses (joint session DY/BP)**
DY 13.1–13.7	Mon	15:00–17:20	DYc	**Granular Physics 3 - organized by Matthias Sperl (Köln)**
DY 14.1–14.6	Mon	16:00–18:00	DYa	**Microfluidics and Droplets - organized by Uwe Thiele (Münster)**
DY 15.1–15.1	Mon	16:00–16:30	DYb	**Invited Talk: Liesbeth Janssen (Eindhoven)**
DY 16.1–16.4	Mon	16:30–17:50	DYb	**Statistical Physics 3 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)**
DY 17.1–17.13	Tue	9:00–16:30	CPPb	**Complex Fluids - organized by Christine M. Papadakis (Technical University of Munich, Garching) (joint session CPP/DY)**
DY 18.1–18.1	Tue	9:00– 9:30	DYa	**Invited Talk: Andreas Zöttl (Vienna)**
DY 19.1–19.5	Tue	9:00–10:40	DYb	**Statistical Physics 4 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)**
DY 20.1–20.3	Tue	9:00–10:00	DYc	**Nonlinear Dynamics 1 - organized by Azam Gholami (Göttingen)**
DY 21.1–21.3	Tue	9:30–10:30	DYa	**Active Matter 1 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP/CPP)**
DY 22.1–22.1	Tue	10:00–10:30	DYc	**Invited Talk: Lucas Goehring (Nottingham)**
DY 23.1–23.6	Tue	11:00–13:00	DYa	**Active Matter 2 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP/CPP)**
DY 24.1–24.6	Tue	11:00–13:00	DYb	**Dynamics and Statistical Physics - Open Session**
DY 25.1–25.6	Tue	11:00–13:00	DYc	**Nonlinear Dynamics 2 - organized by Azam Gholami (Göttingen)**
DY 26.1–26.5	Tue	11:00–12:40	SOEa	**Data Analytics for Complex Dynamical Systems (joint SOE/DY Focus Session) (joint session SOE/DY)**
DY 27.1–27.9	Tue	14:00–17:10	DYa	**Fluid Physics 3 - organized by Stephan Weiss and Michael Wilczek (Göttingen)**
DY 28.1–28.5	Tue	14:00–15:40	DYb	**Statistical Physics 5 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)**
DY 29.1–29.1	Tue	14:00–14:30	DYc	**Invited Talk: Karen Daniels (Raleigh)**
DY 30.1–30.6	Tue	14:30–16:30	DYc	**Complex Fluids and Soft Matter 1 - organized by Uwe Thiele (Münster) (joint session DY/CPP)**
DY 31.1–31.1	Tue	15:40–16:10	DYb	**Invited Talk: Mehran Kardar (Boston)**
DY 32.1–32.24	Tue	16:30–19:00	DYp	**Posters DY - Statistical Physics, Brownian Motion and Nonlinear Dynamics**
DY 33	Tue	17:45–18:30	BPb	**Nationale Forschungsdateninfrastruktur (NDFI) (joint session BP/CPP/DY/SOE)**
DY 34.1–34.10	Wed	9:00–14:40	CPPb	**Theorie and Simulation - organized by Jens-Uwe Sommer (Leibniz-Institut für Polymerforschung Dresden, Dresden) (joint session CPP/DY)**
DY 35.1–35.4	Wed	9:00–10:30	DYa	**Complex Fluids and Soft Matter 2 - organized by Uwe Thiele (Münster) (joint session DY/CPP)**
DY 36.1–36.5	Wed	9:00–10:40	DYb	**Active Matter 3 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP)**
DY 37.1–37.1	Wed	9:00– 9:30	DYc	**Invited Talk: Ludovic Berthier (Montpellier)**
DY 38.1–38.3	Wed	9:00–10:00	SOEa	**Partial Synchronization in Networks (Focus Session joint with DY and BP) (joint session SOE/DY)**
DY 39.1–39.3	Wed	9:30–10:30	DYc	**Glasses and Glass Transition 1 - organized by Andreas Heuer (Münster) (joint session DY/CPP)**
DY 40.1–40.6	Wed	11:00–13:00	DYa	**Complex Fluids and Soft Matter 3 - organized by Uwe Thiele (Münster) (joint session DY/CPP)**
DY 41.1–41.6	Wed	11:00–13:00	DYb	**Active Matter 4 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP)**
DY 42.1–42.6	Wed	11:00–13:00	DYc	**Glasses and Glass Transition 2 - organized by Andreas Heuer (Münster) (joint session DY/CPP)**
DY 43.1–43.6	Wed	14:00–16:00	DYa	**Pattern Formation - organized by Azam Gholami (Göttingen)**
DY 44.1–44.1	Wed	14:00–14:30	DYb	**Invited Talk Sujit S. Datta (Princeton)**
DY 45.1–45.7	Wed	14:00–16:30	DYc	**Brownian Motion and Anomalous Transport - organized by Ralf Metzler (Potsdam)**

DY 46.1–46.4	Wed	14:30–15:50	DYb	**Active Matter 5 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP)**

DY 1: Wetting - organized by Stefan Karpitschka (Max Planck Institute for Dynamics and Self-Organization, Göttingen) (joint session CPP/DY)

Time: Monday 9:00–16:30 Location: CPPb

DY 1.1 Mon 9:00 CPPb

Breakup Dynamics of Capillary Bridges on Hydrophobic Stripes — Maximilian Hartmann[1], •Mathis Fricke[2], Lukas Weimar[1], Dirk Gründing[2], Tomislav Maric[2], Dieter Bothe[2], and Steffen Hardt[1] — [1]Nano- and Microfluidics Group, TU Darmstadt, Alarich-Weiss-Straße 10, 64287 Darmstadt, Germany — [2]Mathematical Modeling and Analysis Group, TU Darmstadt, Alarich-Weiss-Straße 10, 64287 Darmstadt, Germany

The breakup dynamics of a capillary bridge on a hydrophobic stripe between two hydrophilic stripes is studied both experimentally and numerically. The capillary bridge is formed from an evaporating water droplet wetting three neighboring stripes of a chemically patterned surface. The simulations are based on the Volume-of-Fluid (VOF) method implemented in Free Surface 3D (FS3D). By considering the breakup process in phase space, the breakup dynamics can be evaluated without the uncertainty in determining the precise breakup time. It is found that within an intermediate inviscid regime, the breakup dynamics follows a $t^{2/3}$-scaling, indicating that the breakup process is dominated by the balance of inertial and capillary forces. For smaller bridge widths, the breakup velocity reaches a plateau, which is due to viscous forces becoming more important. In the final stage of breakup, the capillary bridge forms a liquid thread that breaks up consistent with the Rayleigh-Plateau instability. The existence of satellite droplets in a regular pattern indicates that the primary breakup process is followed by self-similar secondary breakups.

DY 1.2 Mon 9:20 CPPb

Simulating the hydrodynamics of droplets on photo-switchable substrates — •Josua Grawitter and Holger Stark — Technische Universität Berlin, Institute of Theoretical Physics, Hardenbergstr. 36, 10623 Berlin, Germany

Interfaces between fluids and photo-switchable substrates provide a unique mechanism to precisely manipulate liquid droplets by creating and adapting a heterogeneous wettability landscape. Because droplets respond to changes in wettability, such interfaces provide a means to keep the droplets in non-equilibrium and thereby induce new states of dynamic wetting.

We present a boundary element method to determine the Stokes flow inside a droplet with its curved free surface and its flat interface at the substrate, where we apply the Navier boundary condition to permit motion of the contact line. In our approach we use the Cox-Voinov law [1] and introduce the velocity of the contact-line as a side condition. We also implement an iterative domain-splitting integration scheme capable of treating singular integrands, which are typical for the boundary element method. Using the implemented method, we study how droplets respond to specific spatiotemporal wettability patterns that either move or deform the droplet. Here, we present first studies of the spatio-temporal deformation dynamics induced by oscillating wettability along the contact line and of directed motion initiated by traveling wettability patterns. We specifically investigate how to design the patterns in order to maximize droplet speed.

[1] O. V. Voinov, Fluid Dyn. **11**, 714 (1976).

DY 1.3 Mon 9:40 CPPb

Dynamics of liquid droplets on switchable prestructured substrates — •Moritz Stieneker[1] and Svetlana Gurevich[1,2] — [1]Institute for Theoretical Physics, University of Münster, Wilhelm-Klemm-Str. 9, D-48149 Münster, Germany — [2]Center for Nonlinear Science (CeNoS), University of Münster, Corrensstrasse 2, D-48149 Münster, Germany

A mesoscopic continuum model is employed to model a thin, liquid film on a substrate with a spatio-temporal wettability. In particular, the effect of a switchable wettability pattern on the structure formation is analyzed for a one-dimensional case with the help of path-continuation techniques and direct numerical time simulations. It is found that if the periodic switching is introduced, the system reaction depends on the ratio between the time scale given by switching and the reaction time of the liquid. The behaviour of the contact angle during the slow and fast switching is investigated in details. Furthermore it is demonstrated that in the case of the slow switching the droplet solutions corresponding to the local minima of the free energy can be stabilized.

DY 1.4 Mon 10:00 CPPb

Gradient dynamics model for drops spreading on polymer brushes — •Simon Hartmann and Uwe Thiele — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Deutschland

When a liquid drop spreads on an adaptive substrate the latter changes its properties what may result in an intricate coupled dynamics of drop and substrate. We present a generic mesoscale hydrodynamic model for such processes that is written as a gradient dynamics on an underlying energy functional. We specify the model details for the example of a drop spreading on a dry polymer brush. There, liquid absorption into the brush results in swelling of the brush causing changes in the brush topography and wettability. The liquid may also advance within the brush via diffusion (or wicking) resulting in coupled drop and brush dynamics. The specific model accounts for coupled spreading, absorption and wicking dynamics when the underlying energy functional incorporates capillarity, wettability and brush energy. We employ a simple version of such a model to numerically simulate a droplet spreading on a swelling brush and provide an in-depth analysis of the simulation results and some interesting quantities.

40 min. meet the speakers - break

Invited Talk DY 1.5 Mon 11:00 CPPb

Liquid-liquid Dewetting: From Spinodal Breakup to Dewetting Morphologies and Rates — •Ralf Seemann[1], Roghayeh Shiri[1], Stefan Bommer[1], Dirk Peschka[2], Sebastian Jachalski[2], Lenoie Schmeller[2], and Barbara Wagner[2] — [1]Saarland University, Experimental Physics, D-66123 Saarbücken — [2]Weierstrass Institute, Mohrenstr. 39, D-10117 Berlin

The dewetting of liquid polystyrene (PS) from liquid polymethylmethacrylate (PMMA) is studied. At dewetting temperatures, both polymers can be considered as Newtonian fluids with the same viscosity. Provided that the liquid PS layer is below 10 nm, breakup occurs by spinodal dewetting. Due to the low interfacial tension of the buried interface compared to the PS-air interface and the large mobility, a very short spinodal wavelength develops with a larger amplitude of the buried interface than that of the free PS-air interface. The spinodal patterns of PMMA-PS and PS-air interface are anti-correlated and the observed wavelength is within the range predicted from thin film models. For a later dewetting stage, when dewetting rims in the range of the PMMA film thickness have formed, characteristic profiles of both PMMA-PS and PS-air interface develop, which depend on the PMMA/PS thickness ratio. The dewetting rates are approximately linear but do not obey any well-defined scaling behavior. Based on the agreement of experimental results with theoretical predictions, we use the numerical simulations to predict local flow fields and energy dissipation that would otherwise be inaccessible to experiments.

DY 1.6 Mon 11:40 CPPb

Wetting transitions on soft substrates — Marek Napiorkowski[1], •Lothar Schimmele[2], and Siegfried Dietrich[2,3] — [1]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Poland — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [3]IV. Institut für Theoretische Physik, Universität Stuttgart, Stuttgart, Germany

Within mean-field theory we study wetting of elastic substrates. Our analysis is based on a grand canonical free energy functional of the fluid number density and of the substrate displacement field. The substrate is described in terms of the linear theory of elasticity, parametrized by two Lamé coefficients. The fluid contribution is of the van der Waals type. Two potentials characterize the interparticle interactions in the system, the long-ranged attraction between the fluid particles and a potential characterizing the substrate-fluid interaction. By integrating out the elastic degrees of freedom we obtain an effective theory for the fluid number density alone. Its structure is similar to the one for wetting of an inert substrate. However, the long-ranged attraction between the fluid particles is replaced by an effective potential which also contains a term bilinear in the substrate-fluid interaction.

We discuss the corresponding wetting transitions in terms of an ef-

fective interface potential depending on the thickness of the wetting layer. We show that in the case of algebraically decaying interactions the elasticity of the substrate may suppress critical wetting transitions, and may even turn them first order.

DY 1.7 Mon 12:00 CPPb

A Thermodynamic Consistent, Instantaneous Dividing Surface to Study Wetting Phenomena — •Amal Kanta Giri and Marcello Sega — Helmholtz Institute Erlangen-Nürnberg for Renewable Energy, Forschungszentrum Jülich, Fürther Straße 248, 90429 Nürnberg, Germany

A detailed knowledge of the microscopic structure and dynamics in the interfacial region of soft materials is a necessary step on the way to develop novel materials and is also key to a deeper understanding of the statistical mechanics of fluid interfaces out of equilibrium. The presence of thermal capillary waves, however, hinders efforts to investigate the local structure of interfaces by smearing out observable quantities computed in the global reference frame. To recover a detailed picture of the interface neighborhood, one needs to compute observables in the local, instantaneous reference frame located at the interface, although the determination of this frame is, in general, not unique.

Here, we report on the possibility of using computational geometry approaches to determine the set of instantaneous surface atoms in a way which is thermodynamically consistent with the Gibbs (equimolar) dividing surface. We apply these methods to the determination of the instantaneous, fluctuating contact line of droplets on solid substrates, with an outlook on the problem of dynamic wetting of soft, deformable substrates.

DY 1.8 Mon 12:20 CPPb

Core-shell latex colloids as interfaces for tailoring wetting properties — Calvin J. Brett[1,2,3], Joakim Engström[3,4], Volker Körstgens[5], Peter Müller-Buschbaum[5,6], Eva Malmström[4], and •Stephan V. Roth[1,4] — [1]DESY, 22603 Hamburg, Germany — [2]KTH, Dept. Mechanics, SE-10044 Stockholm, Sweden — [3]WWSC, SE-10044 Stockholm, Sweden — [4]KTH, Dept. Fibre and Polymer Technology, SE-10044 Stockholm, Sweden — [5]TUM, Physik Department, 85748 Garching, Germany — [6]MLZ, TUM, 85748 Garching, Germany

Facile surface functionalisation of latex colloids makes them most promising materials for broad thin film applications. However, the effect of these colloids on chemical film and wetting properties is not easily evaluated. Core-shell particles can deform and coalesce on the nanoscale during thermal annealing yielding tailored physical properties. We investigated two different core-shell systems (soft and rigid) with identical shell but with chemically different core polymer and core size. These core-shell colloids are probed during thermal annealing on surfaces in order to investigate their behavior as a function of nanostructure size and rigidity. X-ray scattering allows us to follow the re-arrangement of the colloids and the structural evolution in situ during annealing. Evaluation by real-space imaging techniques reveals a disappearance of the structural integrity and a loss of colloids' boundaries. We present the possibility to tailor and fine-tune the wettability by tuning the core-shell colloid morphology in thin films, thus providing a facile template methodology for repellent surfaces.

DY 1.9 Mon 12:40 CPPb

Drop Impact on Hot Plates: Contact, Lift-Off and the Formation of Holes — •Kirsten Harth[1,2], Sang.Hyeon Lee[3], Maaike Rump[2], Minwoo Kim[3], Detlef Lohse[2], Kamel Fezzaa[4], and Jung Ho Je[3] — [1]Institute of Physics, Otto von Guericke University Magdeburg — [2]Physics of Fluid and Max Planck Center, University of Twente, The Netherlands — [3]X-Ray Imaging Center, Pohang University of Science and Technology, Korea — [4]X-Ray Science Division, Argonne Ntnl. Laboratory, USA

Everyone who poured water into a hot pan has experienced the manifold boiling behaviours of drops impacting on a hot plate, a problem which is of high relevance in many technical applications. When the drop is gently deposited, and the surface temperature is sufficiently high, it hovers on a vapour layer (Leidenfrost effect). For impacting drops, this critical temperature for a contact-less rebound is substantially increased, and much harder to determine. In fact, determining contact times between drops and smooth substrates from side view imaging is impossible for most temperatures above the boiling point.

We combine High-Speed Total Internal Reflection and synchrotron X-Ray measurements to reliably determine contact times and the Leidenfrost temperature for drops impacting on smooth hot surfaces. Furthermore, we study the lift-off characteristics. A local minimum in lift-off times correlates with spontaneous lamella rupture and the morphology of the contact.

60 min. meet the speakers - break

Invited Talk DY 1.10 Mon 14:00 CPPb

Sinking droplet durotaxis and engulfment — •Anne Juel — Department of Physics & Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK

Durotaxis refers to the spontaneous motion of objects along stiffness gradients of the supporting substrate. In droplet durotaxis migration occurs down rigidity gradients towards the softer regions of the substrate due to elasto-capillary interaction. We perform experiments in the limit of very soft PDMS substrates, where the cross-linked matrix of the gel can yield under the capillary stresses exerted by the sessile droplet. We find that the droplet moves towards the softest i.e. deepest parts of the gel layer while also sinking into the gel and that droplet durotaxis is much faster when engulfment is associated with the motion. For comparison, we focus on engulfment of aqueous droplets deposited onto a substrate layer of silicone oil. On substrates with a depth gradient, we observe qualitatively similar behaviour to the sinking durotaxis case. On deep layers, the droplet is ultimately engulfed in the oil layer. This involves rapid submersion of the droplet driven by capillary forces in the oil surface, followed by the much slower peeling of the droplet from the interface to which it is adhered. The later peeling stage is driven by a combination of geometric constraints at the apparent contact line and gravity pulling on the droplet. Gravitational effects are therefore essential to complete engulfment, even for micrometric droplets. Furthermore, the opposing effects of geometry and gravity result in the longest engulfment times for droplets of intermediate size.

DY 1.11 Mon 14:40 CPPb

Droplets fighting contamination — •Abhinav Naga, William Wong, Anke Kaltbeitzel, Maria D'Acunzi, Hans-Jürgen Butt, and Doris Vollmer — Max Planck Institute for Polymer Research, Mainz, Germany

Lubricated surfaces are prone to accumulating contaminants due to their sticky yet slippery nature. The presence of contaminants, such as dust and dirt particles, alters their performance. An understanding of the effect of contaminated particles on the friction of surfaces is important not only from a fundamental perspective whereby further insight can be gained of the underlying mechanisms, but also from an applied perspective to predict the effectiveness of lubricated surfaces in the presence of contaminants.

In this study, we systematically contaminate lubricated silicone surfaces (Sylgard 184) and non-lubricated surfaces with spherical glass microparticles. We place a droplet on each surface and measure the force needed to push the droplet at different speeds towards an individual microparticle. We visualise this process with laser scanning confocal microscopy, focusing on the deformation inflicted by the microparticle on the droplet and its lubricant ridge. We combine these visualisations with our force measurements to suggest a mechanism for the removal of contaminated particles from surfaces using droplets, and we outline the differences between the outcomes on the lubricated and the non-lubricated surfaces. This work will help to understand droplet dynamics on imperfect or dirty lubricated surfaces.

DY 1.12 Mon 15:00 CPPb

Lucas-Washburn equation applies for four phase contact point — •Peyman Rostami[1,2] and Günter Auernhammer[1,2] — [1]Max Planck Institute for Polymer Research, 55128, Mainz, Germany — [2]Leibniz Institute of Polymer Research, 01069, Dresden, Germany

A four-phase contact point, e.g., in merging of immiscible drops, is the point where the liquid-liquid interface advances along the contact line of one drop. The dynamics of drop merging involve various driving and dissipating forces in the dynamics of the four-phase contact point. The viscous friction, i.e. the flow field, within liquids is influenced by the different boundary conditions on the different interfaces (liquid-gas, liquid-liquid, liquid-solid). Additionally, Marangoni stresses between the two liquids and the spreading coefficients along the contact lines play a role. Effectively, these effects lead to a capillary force acting on the four-phase contact point. In total, the situation resembles the capillary flow in open V-shaped groove. The important difference is that, in the classical problem, the grooves are made out of two solid

walls, but in the present case one of the *walls* is liquid, i.e., flowable and deformable. We investigate a range of liquids with different combination of physical properties (viscosity ratio, surface and interfacial tensions). The results show a good qualitative agreement for different liquids of the experimental results with the classical Washburn equation (h˜square root of time), where h is the filled length of the *groove*.

DY 1.13 Mon 15:20 CPPb

Imbibition-Induced Deformation Dynamics in Nanoporous Media — •Juan Sanchz[1], Zhuoqing Li[2], Michael Froeba[3], and Patrick Huber[4] — [1]Institute of Materials Physics, Hamburg University of Technology — [2]Institute of Materials Physics, Hamburg University of Technology — [3]Institute of Anorganic and Applied Chemistry, Hamburg University — [4]Institute of Materials Physics, Hamburg University of Technology

We present time-dependent macroscopic dilatometry experiments on the deformation of nanoporous monoliths (carbon and silica) upon spontaneous, capillarity-driven invasion of water. We find two distinct dynamical regimes. One of them can be quantitatively traced to deformations originating in changes in the surface stress at the inner pore walls (dynamic Bangham's regime) upon water invasion, whereas the second one results from Laplace pressure effects. Our study demonstrates that it is possible to dynamically monitor imbibition dynamics by simple dilatometry measurements.

DY 1.14 Mon 15:40 CPPb

Macroscopic Capillary Number for Characterization of Two-phase Flow in Porous Media — •Hu Guo and Rudolf Hilfer — Institute for Computational Physics, Universität Stuttgart, Stuttgart, Germany

The Capillary number (Ca) defined as the ratio of viscous force to capillary force is widely used to qualitatively characterize multiphase flow in porous media as in carbon dioxide geologic sequestration and chemical enhanced oil recovery (EOR). The main difficulty is to characterize forces porperly. There exists 22 definitions for Ca (Guo et al, IOR 2020). The most concise definition is $Ca = \frac{v\mu}{\sigma}$ with velocity v, viscosity μ and interfacial tension σ (Saffman and Taylor, 1958). It is supported by core flooding tests and most widely used. However, this definition is less sound than the one that involves the wettability parameter (Moore and Slobod, 1955). Meanwhile, the values of these Ca are regarded as too small to reflect the actual force balance (Dullien, 1979). It was shown theoretically, that this Ca is microscopic in nature and incorrectly used (Hilfer and Øren, 1996, Trans. Porous Media).

We study the new macroscopic capillary number $Ca = \frac{\mu\phi vL}{KP_b}$ with viscosity μ, porosity ϕ, velocity v, permeability K, length L and capillary breakthrough pressure P_b (Hilfer et al, 2015, Physical Review E). The new Ca explains some of the latest observations (Doorwar and Mohanty, 2017, SPE J; Qi et al, 2017, SPE J; Rabbani et al, 2018, PNAS; Zhao et al, 2019, PNAS) that contradict predictions obtained from the microscopic Ca. EOR field practice also verified that the macroscopic Ca is more profound.

30 min. meet the speakers - break

DY 2: Fluid Physics 1 - organized by Stephan Weiss and Michael Wilczek (Göttingen)

Time: Monday 9:00–10:00 Location: DYa

DY 2.1 Mon 9:00 DYa

Transition to the ultimate regime in a stochastic model for radiatively driven turbulent convection — •Marten Klein[1], Heiko Schmidt[1], and Alan R. Kerstein[2] — [1]Lehrstuhl Numerische Strömungs- und Gasdynamik, Brandenburgische Technische Universität Cottbus-Senftenberg, Germany — [2]Consultant, Danville, California, USA

Heat transfer in thermal convection is investigated using the stochastic one-dimensional-turbulence model (ODT). A Boussinesq fluid of Prandtl number 1 is confined between two horizontal adiabatic no-slip walls (located at $z = 0$ and H) and exposed to constant gravity that points in vertical ($-z$) direction. A flow is driven by radiative heating from below yielding the local heating rate $Q(z) = (P/\ell)\exp(-z/\ell)$, where P is the prescribed heat flux and ℓ the absorption length. ODT resolves all relevant scales of the flow, including molecular-diffusive scales, along a vertical one-dimensional domain, whereas stochastically sampled eddy events represent the effects of turbulent advection. ODT results reproduce and extrapolate available reference experiments direct numerical simulations of Lepot *et al.* (*Proc. Natl. Acad. Sci. USA*, **115**, 2018, pp. 8937–8941) and Bouillaut *et al.* (*J. Fluid Mech.*, **861**, 2019, R5) in particular capturing the turbulent transition from the classical to the 'ultimate' regime. For these regimes, the exponent values in $Nu \sim Ra^p$ scaling are found to be $p \approx 0.3$ and $p \approx 0.55$, respectively, in agreement with measured values. Joint probabilities of eddy size and location indicate that the regime transition is accompanied by a relative increase of bulk turbulence.

DY 2.2 Mon 9:20 DYa

Reservoir Computing of Dry and Moist Turbulent Rayleigh-Bénard Convection — •Florian Heyder, Sandeep Pandey, and Jörg Schumacher — TU Ilmenau, Ilmenau, Germany

Reservoir Computing (RC) is one efficient implementation of a recurrent neural network that can describe the evolution of a dynamical system by supervised machine learning without solving the underlying nonlinear partial differential equations. We apply such a neural network to approximate the large-scale evolution and the resulting low-order turbulence statistics of two-dimensional dry and moist Rayleigh-Bénard convection. We acquire training and test data by long-term direct numerical simulations (DNS). They are postprocessed by a Proper Orthogonal Decomposition (POD) with the snapshot method. The training data comprise time series of the first 150 POD modes, which are associated with the largest total energy amplitudes and thus the large-scale structure of the flows. Feeding the data to the Reservoir Computing model and optimizing the reservoir parameters results in predictions for the evolution of the dry and moist convection flows. The prediction capabilities of our model are comprehensively tested by a comparison with DNS and test data, the latter of which are reconstructed from the most energetic POD modes. Vertical profiles of mean thermodynamic fields and their mean vertical transport show good agreement. We find that RC is capable to model the large-scale structure and low-order statistics of dry and moist turbulent convection. This shows potential for subgrid-scale turbulence parameterization in large-scale atmospheric circulation models.

DY 2.3 Mon 9:40 DYa

Generation of zonal flows in convective systems by travelling thermal waves — •Philipp Reiter[1], Rodion Stepanov[2], and Olga Shishkina[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Götttingen, DE — [2]Institute of Continuous Media Mechanics, Russian Academy of Science, Perm, RU

In this work we study the effects of travelling thermal waves which are applied at the fluid layer, specifically on the formation of global mean horizontal (zonal) flow. Earlier studies suggest that the periodic heating of the Earth's, due to Earth's rotation, could cause zonal winds in the atmosphere. Additionally, the 4-day retrograde rotation in the Venus' atmosphere might be driven by such a periodic thermal forcing. In this work we revisited an existing theoretical model and validated it by means of direct numerical simulations (DNS). Furthermore, we expanded the analysis above the limits of the theory and studied travelling thermal waves in strongly convective flows.

Our results can be summarized as follows. The 2D simulations show excellent agreement with the theoretical model for low Rayleigh numbers (Ra). For larger Ra, the theory overestimates the magnitude of the zonal flows. However, the asymptotic scalings are still valid. The 3D system shows very similar characteristics than the 2D flows, therefore we provide further evidence for the relevance of this problem to natural systems. Finally, we show that the direction of the induced mean zonal flows can change. While it is always directed opposite to the travelling wave (retrograde) for low Ra flows, as the Ra increases the zonal flow is often found in a prograde state.

DY 3: Statistical Physics 1 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)

Time: Monday 9:00–10:40 Location: DYb

DY 3.1 Mon 9:00 DYb

The Five Problems of Irreversibility* — •Michael te Vrugt — Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149, Münster, Germany

Macroscopic thermodynamics has a clear arrow of time: Systems irreversibly approach equilibrium accompanied by a monotonous increase of entropy. This stands in contrast to the laws of microscopic theories, which are invariant under time-reversal. The question how this difference can be explained has created a long debate, with suggestions involving coarse-graining methods as well as cosmological considerations about the entropy of the early universe. In this talk, I will show that a part of the difficulty in solving the problem of irreversibility arises from the fact that it actually consists of five different sub-problems [1], which are mixed in most discussions. Understanding why these problems have to be distinguished and how they are related to each other then allows to solve them on the basis of modern nonequilibrium statistical mechanics. The general approach is illustrated using the example of dynamical density functional theory (DDFT) [2].

[1] M. te Vrugt, arXiv:2004.01276 (2020)
[2] M. te Vrugt, H. Löwen, and R. Wittkowski, Advances in Physics 69, 121-247 (2020)
**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*

DY 3.2 Mon 9:20 DYb

Thermodynamic Uncertainty Relation for Time-Dependent Driving — •Timur Koyuk and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

Thermodynamic uncertainty relations yield a lower bound on entropy production in terms of the mean and fluctuations of a current. In this talk we will present the general form of the thermodynamic uncertainty relation for systems under arbitrary time-dependent driving from arbitrary initial states [1]. This approach unifies earlier derived relations valid for discrete Markovian systems or continuous overdamped Langevin systems. One powerful application of the TUR is to infer entropy production by observing an arbitrary current and its fluctuations without knowing the details of the interactions or underlying topology of the network. In this context we will extend the TUR beyond currents to state variables, which allows one to estimate entropy production by only observing, e.g., a binary observable. We will illustrate the quality of the bounds for various types of observables for the dynamical unfolding of a small protein, which is based on extant experimental data. As another important application of the TUR we will show how to bound the efficiency of cyclic heat engines by using the TUR for periodically driven systems [2]. This bound on the efficiency involves the output power, its fluctuations as well as its response with respect to the driving frequency. It thus imposes fundamental constraints on every cyclic stochastic heat engine for reaching Carnot efficiency.
[1] T. Koyuk and U. Seifert, Phys. Rev. Lett. 125, 260604 (2020).
[2] T. Koyuk and U. Seifert, Phys. Rev. Lett. 122, 230601 (2019).

DY 3.3 Mon 9:40 DYb

Thermodynamic Uncertainty Relation for a Stochastic Field Theory – KPZ-Equation as a Paradigmatic Example — •Oliver Niggemann and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart

Recently, a thermodynamic uncertainty relation (TUR) for a generic stochastic field theory has been proposed [1]. In this talk, I will first formulate a framework which describes the constituents of the field-theoretic TUR, namely current, entropy production and diffusivity. This general setting is then applied to the $(1+1)$-dimensional Kardar-Parisi-Zhang (KPZ) equation, a paradigmatic example of a non-linear field-theoretic Langevin equation. In particular, I will treat the dimensionless KPZ-equation with an effective coupling parameter, λ_{eff}, measuring the strength of the non-linearity. It will be shown that the field-theoretic TUR holds both in the weak and strong coupling regimes and that its value depends on λ_{eff} [2]. For $\lambda_{\text{eff}} \downarrow 0$, the TUR product is equal to 5, whereas for $\lambda_{\text{eff}} \gg 1$ it grows linearly with λ_{eff}. There is no value for λ_{eff} with the TUR product being saturated. Furthermore, I will present numerical simulations of the TUR constituents and the TUR product itself. These simulations display good agreement with the theoretical results for both the weak and strong coupling regime.
[1] Niggemann, O. and Seifert, U. *J Stat Phys* 178, 1142–1174 (2020). https://doi.org/10.1007/s10955-019-02479-x
[2] Niggemann, O. and Seifert, U. *J Stat Phys* 182, 25 (2021). https://doi.org/10.1007/s10955-020-02692-z

DY 3.4 Mon 10:00 DYb

Entropy Production in Open Systems: The Predominant Role of Intraenvironment Correlations — •Krzysztof Ptaszyński[1] and Massimiliano Esposito[2] — [1]Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland — [2]Complex Systems and Statistical Mechanics, Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg

We show [1] that the entropy production in small open systems coupled to environments made of extended baths is predominantly caused by the displacement of the environment from equilibrium rather than, as often assumed, the mutual information between the system and the environment. The latter contribution is strongly bounded from above by the Araki-Lieb inequality, and therefore is not time-extensive, in contrast to the entropy production itself. Furthermore, we show that in the thermodynamic limit the entropy production is associated mainly with generation of the mutual information between initially uncorrelated environmental degrees of freedom. We confirm our results with exact numerical calculations of the system-environment dynamics.
[1] K. Ptaszyński, M. Esposito, Phys. Rev. Lett. 123, 200603 (2019)

DY 3.5 Mon 10:20 DYb

Negative entropy production rates in Drude-Sommerfeld metals — Marcus V. S. Bonança[1], •Pierre Nazé[1], and Sebastian Deffner[2,1] — [1]Universidade Estadual de Campinas, Campinas, Brazil — [2]University of Maryland, Baltimore County, Baltimore, USA

It is a commonly accepted creed that in typical situations the rate of entropy production is non-negative. We show that this assertion is not entirely correct if a time-dependent, external perturbation is not compensated by a rapid enough decay of the response function. This is demonstrated for three variants of the Drude model to describe electrical conduction in noble metals, namely the classical free electron gas, the Drude-Sommerfeld model, and the Extended Drude-Sommerfeld model. The analysis is concluded with a discussion of potential experimental verifications and ramifications of negative entropy production rates.

References:
[1] Marcus V. S. Bonança, Pierre Nazé, and Sebastian Deffner, Phys. Rev. E 103, 012109 (2021)

DY 4: Invited Talk: Yujie Wang (Shanghai)

Time: Monday 9:00–9:30 Location: DYc

Invited Talk DY 4.1 Mon 9:00 DYc

X-ray tomography investigation of cyclically sheared granular materials — •Yujie Wang — School of Physics and Astronomy, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, China

We perform combined x-ray tomography and shear force measurements on a cyclically sheared granular system with highly transient behaviors, and obtain the evolution of microscopic structures and the macroscopic shear force during the shear cycle.We explain the macroscopic behaviors of the system based on microscopic processes, including the

particle level structural rearrangement and frictional contact variation. Specifically, we show how contact friction can induce large structural fluctuations and cause significant shear dilatancy effect for granular materials, and we also construct an empirical constitutive relationship for the macroscopic shear force.

DY 5: Active Biological Matter I (joint session BP/DY/CPP)

Time: Monday 9:00–11:00 Location: BPb

Invited Talk DY 5.1 Mon 9:00 BPb

The tortoise and hare: how moving slower allows groups of bacteria to spread across surfaces — Oliver Meacock[1,2], Amin Doostmohammadi[3], Kevin Foster[1], Julia Yeomans[1], and •William Durham[1,2] — [1]University of Oxford, United Kingdom — [2]University of Sheffield, United Kingdom — [3]University of Copenhagen, Denmark

Bacteria use tiny grappling hook like appendages called pili to pull themselves across solid surfaces. While pili-based motility has been widely studied in solitary Pseudomonas aeruginosa cells, this species also uses pili to collectively migrate across surfaces when they are densely packed together in a colony. Interestingly, we find genotypes that individually move slower can collectively migrate faster as a group. Using theory developed to study liquid crystals, we demonstrate that this effect is mediated by the physics of topological defects, points where cells with different orientations meet one another. Our analyses reveal that when defects with a topological charge of $+1/2$ collide with one another, the fast-moving mutant cells rotate vertically and become trapped. By moving more slowly, wild-type cells avoid this trapping mechanism, allowing them to collectively migrate faster. Our work suggests that the physics of liquid crystals has played a pivotal role in the evolution of collective bacterial motility by exerting a strong selection for cells that exercise restraint in their movement.

Full paper in Nature Physics available free of charge at: https://rdcu.be/cbcgc

DY 5.2 Mon 9:30 BPb

Light-regulated cell aggregation in confinement — •Alexandros Fragkopoulos[1], Jeremy Vachier[1], Johannes Frey[1], Flora-Maud Le Menn[1], Marco Mazza[1,2], Michael Wilczek[1], David Zwicker[1], and Oliver Bäumchen[1,3] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), D-37077 Göttingen, Germany — [2]Department of Mathematical Sciences, Loughborough University, Loughborough, Leicestershire LE11 3TU, United Kingdom — [3]Experimental Physics V, University of Bayreuth, D-95447 Bayreuth, Germany

Photoactive microbes live in complex environments with spatially and temporally fluctuating light conditions. They survive in such habitats by switching their metabolic activity from photosynthesis to aerobic respiration in unfavorable light conditions. We demonstrate that this adaptation in a suspension of soil-dwelling *Chlamydomonas reinhardtii* cells under confinement leads to a spontaneous separation into regions of high and low cell densities. We show that the inhibition of the photosynthetic machinery is necessary but insufficient to generate the observed aggregation. Microfluidic experiments, simulations, and mean-field theory approaches demonstrate that the emergence of microbial aggregations is governed by the oxygen concentration field inside the microhabitat. In fact, in regions where the energy production is completely arrested by both, the photosynthetic and respiratory systems, the cell speed decreases resulting in an aggregation, which thus takes the form of the underline oxygen field.

DY 5.3 Mon 9:50 BPb

Emergent activity of motile phytoplankton in nutrient landscapes — •Jayabrata Dhar, Francesco Danza, Arkajyoti Ghoshal, and Anupam Sengupta — Physics of Living Matter Group, Department of Physics and Materials Science, University of Luxembourg, 162 A, Avenue de la Faencerie, L-1511, Luxembourg City, Luxembourg

Despite their minuscule size, microbes mediate a range of processes in ecology, medicine, and industrial settings that span orders of nutrient concentrations. Yet, to date, we lack a biophysical framework that could link nutrient availability to phytoplankton behavior and predict the impact of dynamic nutrient conditions on motility. Using a combination of micro-scale imaging, microbiology and fluid dynamic models, we quantify how nutrient availability regulates motility, at both individual and population scales [1]. We extract the time-scales over which phytoplankton actively regulate swimming and morphological characteristics, thus shedding light on the finely tuned biophysical mechanisms that equip cells to tackle spatial and temporal heterogeneity of nutrient landscapes. Our results propose local nutrient levels as a handle to control the activity of motile phytoplankton species, promising an exciting model of tunable motile active matter.

[1] Danza, Dhar, Ghoshal and Sengupta (in prep.)

DY 5.4 Mon 10:10 BPb

Chemotaxis strategies of bacteria with multiple run-modes — Zahra Alirezaeizanjani[1,2], •Robert Grossmann[1], Veronika Pfeifer[1], Marius Hintsche[1], and Carsten Beta[1] — [1]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [2]Max Planck Institute of Colloids and Interfaces, 14476 Potsdam, Germany

Bacterial chemotaxis – a fundamental example of directional navigation in the living world – is key to many biological processes, including the spreading of bacterial infections. Many bacterial species were recently reported to exhibit several distinct swimming modes – the flagella may, for example, push the cell body or wrap around it. How do the different run modes shape the chemotaxis strategy of a multimode swimmer? Here, we investigate chemotactic motion of the soil bacterium *Pseudomonas putida* as a model organism. By simultaneously tracking the position of the cell body and the configuration of its flagella, we demonstrate that individual run modes show different chemotactic responses in nutrition gradients and thus constitute distinct behavioral states. Based on an active particle model, we demonstrate that switching between multiple run states that differ in their speed and responsiveness provide the basis for robust and efficient chemotaxis in complex natural habitats.

30 min. Meet the Speaker

DY 6: Granular Physics 1 - organized by Matthias Sperl (Köln)

Time: Monday 9:30–10:30 Location: DYc

DY 6.1 Mon 9:30 DYc

Flow study for poly-dispersed dense granular suspension in Non-Newtonian media, mimicking concrete flow — •Himanshu P Patel, Peyman Rostami, and Günter K Auernhammer — Leibniz-Institut für Polymerforschung Dresden e. V., Hohe Straße 6, D-01069 Dresden, Germany

The study of internal flow dynamics and associated particle migration for poly-dispersed dense granular suspension, e.g., flowing concrete, still lacks quantification on a single particle level.

We use a macroscopically highly transparent model system for concrete and cement paste [1] that is a dense granular suspension of particles suspended in non-Newtonian media (particle volume fractions of 42% to 48%). The model system mimics the rheology behavior of cement paste (yield stress and plastic viscosity) and is completely index matched. The rheological characteristics of the model system is tunable through its composition of additives.

We analyze gravity-assisted continuous flow for the model system through a cylindrical pipe. Our setup allows tracking of polydisperse tracer particles at different sections of the pipe and near its wall us-

ing diffused back-light illumination. The flow analysis revels a flow profile similar to a plug flow and a migration of larger towards the central region of the flow. Sliding and rolling motion of the particles is observable. The lubrication layer thickness is also evaluated in the study.

[1] Auernhammer, Günter K., et al., Materials & Design (2020): 108673.

DY 6.2 Mon 9:50 DYc

Uncertainty relations for mesoscopic coherent light — •Ohad Shpielberg — University of Haifa, Haifa, Israel

Thermodynamic uncertainty relations unveil useful connections between fluctuations in thermal systems and entropy production. This talk extends these ideas to the disparate field of zero temperature quantum mesoscopic physics where fluctuations are due to coherent effects and entropy production is replaced by a cost function defined using a novel disorder reversal operator. A simple expression is obtained for the average cost function, which depends on the dimensionless conductance g and on a geometrical factor B controlled by boundary conditions. Contrary to thermodynamic machines aimed at minimising fluctuations to increase precision, it is desirable in mesoscopic devices to increase coherent effects. The cost function indicates that increasing coherent effects can be achieved by playing with the geometry and boundary conditions through B and not only by decreasing the bulk conductance g.

DY 6.3 Mon 10:10 DYc

Coupling between rotational and translational motions of a vibrated polygonal disk — •Simeon Voelkel[1] and Kai Huang[1,2] — [1]Experimentalphysik V, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Institute of Applied Physical Sciences and Engineering, Division of Natural and Applied Sciences, Duke Kunshan University, No. 8 Duke Avenue, Kunshan, Jiangsu, China 215316

We investigate experimentally the dynamics of a single polygonal disk (regular n-gon with $3 \leq n \leq 8$) under vertical vibrations against gravity. The disks tend to precess continuously upon vibrations, transferring the mechanical energy injection into the rotational as well as the translational degrees of freedom (DoF) spontaneously. An analysis of the velocity distribution functions in both DoF suggests that the mobility in both DoF are coupled with each other with a preferred angular velocity that depends on the confinement, the geometry of the disk as well as the driving condition. The favored angular velocity can be captured with a model considering sustainable precession due to continuous driving. We also find a regime in the parameter space where the kinetic energy in both DoF agree with each other, despite of the strong energy dissipation and fluctuations in the system upon frequent collisions of the disk with the vibrating plates.

DY 7: Invited Talk: Basile Gallet (Saclay)

Time: Monday 10:00–10:30 Location: DYa

Invited Talk DY 7.1 Mon 10:00 DYa

Can convective heat transport be more efficient than the so-called 'ultimate' regime? — •Basile Gallet — CEA Saclay, Gif-sur-Yvette, France.

Decades of investigation of the Rayleigh-Bénard (RB) thermal convection setup indicate that the heat transport is restricted by boundary layers near the hot and cold solid plates. This prevents the unambiguous observation of the 'ultimate' scaling-regime of thermal convection, where bulk turbulence controls the convective heat flux independently of molecular diffusivities. In contrast to the RB setup, many geophysical and astrophysical convective flows are driven radiatively: absorption of light by a body of fluid induces local internal heating. We have developed a laboratory experiment that reproduces such radiative heating: heat is directly input inside the bulk turbulent flow and away from the boundary layers.

After providing experimental and numerical evidence that this setup leads to the ultimate regime of thermal convection, I will discuss the maximum theoretical Nusselt number that can be achieved by such internally heated and cooled convection. I will show that there exist steady laminar solutions that transport heat more efficiently than the ultimate regime, with a scaling behavior Nu~Ra. These solutions can be stable in 2D, but they are unstable in 3D and quickly evolve into a turbulent state. I will show that a maximization of the heat transport over turbulent flows only leads to an upper bound on the Nusselt number that is proportional to the square root of the Rayleigh number, in line with the experimental data.

DY 8: Fluid Physics 2 - organized by Stephan Weiss and Michael Wilczek (Göttingen)

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

DY 8.1 Mon 11:00 DYa

Interpreted machine learning: Explaining relaminarisation events in wall-bounded shear flows — Martin Lellep[1], Jonathan Prexl[2], Bruno Eckhardt[3], and •Moritz Linkmann[4] — [1]School of Physics and Astronomy, University of Edinburgh, UK — [2]Dept. of Civil, Geo and Environmental Engineering, Technical University of Munich, Germany — [3]Dept. Physics, Philipps-University of Marburg, Germany — [4]School of Mathematics and Maxwell Institute for Mathematical Sciences, University of Edinburgh, UK

Machine Learning (ML) is becoming increasingly popular in fluid dynamics. Powerful ML algorithms such as neural networks or ensemble methods are notoriously difficult to interpret. Here, we use the novel Shapley Additive Explanations (SHAP) algorithm (Lundberg & Lee, 2017), a game-theoretic approach that explains the output of a given ML model, to ascertain which physical processes are significant in the prediction of relaminarisation events in wall-bounded parallel shear flows. The flow is described by an established low-dimensional model whose variables have a clear physical and dynamical interpretation in terms of known representative features of the near-wall dynamics, i.e. streamwise vortices, streaks and linear streak instabilities. We consistently find only three modes to play a major role in the prediction: the laminar profile, the streamwise vortex, and a specific streak instability. SHAP thus distinguishes representative from significant features, hence we demonstrate that it is an explainable AI method which can provide useful and human-interpretable insight for fluid dynamics.

DY 8.2 Mon 11:20 DYa

Small scale structures of turbulence in terms of entropy and fluctuation theorems — André Fuchs[1], •Joachim Peinke[1], Matthias Wächter[1], Silvio M Durate Queiros[2], Alain Girard[3], and Pedro G Lind[4] — [1]ForWind, Inst Physik , University of Oldenburg, — [2]Centro Brasileiro de Pesquisas Fisicas and National Institute of Science and Technology for Complex Systems, Rio de Janeiro - RJ, Brazil — [3]INAC-SBT, UMR CEA-Grenoble, 38054 Grenoble, France — [4]Department of Computer Science, OsloMet - University, N-0130 Oslo, Norway

Experimental evidence that the integral fluctuation theorem as well as a detailed-like fluctuation theorem holds for large entropy values of the turbulent cascade processes. Stochastic equations describing the scale-dependent cascade process are derived. From individual cascade trajectories an entropy term can be determined. The statistical fluctuation theorems set the occurrence of positive and negative entropy events in strict relation, which is consistent with a stochastic description of the turbulence by a Fokker-Planck equation. Most interestingly the entropy concept of cascade trajectories is linked to turbulent structures: Whereas trajectories with entropy- production show expected decreasing behavior; trajectories with entropy-consumption end at small scale at velocity increments with finite size and show a lower bound for small scale increments. This indicates a tendency to local discontinuities in the velocity field. Our current research indicates that the velocity increment dynamics through scales in the cascade process

can be described by applying an instanton approach.

DY 8.3 Mon 11:40 DYa

Statistical geometry of material loops in turbulence — Lukas Bentkamp[1], Theodore D. Drivas[2], Cristian C. Lalescu[3], and •Michael Wilczek[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Stony Brook University, Stony Brook, USA — [3]Max Planck Computing and Data Facility, Garching, Germany

Turbulent mixing is often characterized by the statistics of one- or two-particle dispersion. An even more comprehensive characterization of the complexity of turbulent mixing can be achieved by capturing the evolution of extended material lines and surfaces. Here, we investigate the statistical geometry of material loops, i.e. closed material lines, by combining simulations, statistical turbulence theory, and dynamical systems theory. Tracking these structures in direct numerical simulations of homogeneous isotropic turbulence reveals that, while the loops develop convoluted shapes over time, their statistical geometry approaches a stationary state. In particular, their curvature distribution forms clear power-law tails, which we analytically determine in the framework of the Kraichnan model. Dynamically, we show that the high-curvature regime is dominated by the formation of isolated folds and that the power-law exponent can be related quantitatively to finite-time Lyapunov exponents. Thereby, the statistical geometry of material lines can be traced back to their dynamical evolution.

DY 8.4 Mon 12:00 DYa

Velocity measurements in rotating Rayleigh-Bénard convection and the Boundary Zonal Flow — Marcel Wedi[1], •Denis Funfschilling[2], and Stephan Weiss[1] — [1]Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Université Strasbourg, France

Rotating turbulent thermal convection is of great importance in various astro- and geophysical systems, where the buoyancy driven flow strongly influenced by Coriolis forces due to rotation of the celestial bodies. It has been studied for decades in the so-called Rayleigh-Bénard setup, where a horizontal fluid layer is heated at the bottom and cooled at the top and rotated around the vertical axis. We investigate the horizontal velocity field using 2D-particle image velocimetry (PIV) in a cylindrical cell ($H = 196\,\mathrm{mm}$ high) with aspect ratio $\Gamma = D/H = 1$. We use water and various water-glycerol mixtures as working fluid resulting in a Prandtl number (Pr) in the range $6 \leq Pr \leq 70$ and Rayleigh numbers (Ra) $10^8 < Ra < 2 \times 10^9$. With our rotating table we reach Ek as low as 10^{-5}. We are mainly interested in studying the recently discovered *Boundary Zonal Flow* (BZF, see Zhang et al., Phys.Rev.Lett. 2020). The BZF is observed in a region close to the lateral sidewall with a cyclonic flow, i.e, a positive mean azimuthal velocity that is separated from and anticyclonic bulk, with negative mean azimuthal velocity. We measure the size of the BZF as a function of Ek and Ra, and compare the results with DNS (Zhang and Shishkina, 2020).

DY 8.5 Mon 12:20 DYa

Transport and rotation statistics of self–propelled ellipsoids in turbulence — •Jose-Agustin Arguedas-Leiva and Michael Wilczek — Max Planck Institute for Dynamics and Self–Organisation, Am Fassberg 17, 37077, Goettingen, Germany

Many plankton species are motile. Motility is, for example, key for grazing and evading predation. Apart from the swimming speed, shape is a critical parameter in defining the response to hydrodynamic flows. A comprehensive understanding of the relation between the relevant particle parameters, shape and motility, and their transport properties and encounter rates in turbulent flows is still missing. Here, we study self–propelled ellipsoids in turbulence as a simple model for motile microorganisms in aquatic environments. Using direct numerical simulations we find non–trivial dispersion properties and rotation statistics as a result of a complex interplay between turbulent advection, motility, and particle spinning and tumbling rates. We show that one important aspect is the effect of rotation on particle transport. In contrast to spinning, tumbling constantly changes particle orientation. As tumbling rates are shape–dependent, this leads to intrinsically different transport properties for differently shaped particles. Our investigation thus helps to characterize the intricate dynamics of self–motile ellipsoids in turbulent flows and sheds light on the role played by shape and motility.

DY 8.6 Mon 12:40 DYa

Lagrangian Turbulence at Unprecedented Reynolds Numbers — •Christian Küchler[1,2], Antonio Ibanez Landeta[1,2], Jan Molacek[1], and Eberhard Bodenschatz[1,2,3] — [1]Max-Planck-Institute for Dynamics and Self-Organisation, Göttingen, Germany — [2]Institute for the Dynamics of Complex Systems of the University of Göttingen, Germany — [3]Cornell University, Ithaca, USA

The Lagrangian reference frame, in which turbulence is viewed by tracking fluid elements over time, is the natural framework for studying transport and mixing phenomena (Sawford (2001)) and previously unexplored properties of turbulence (Toschi & Bodenschatz (2009)). Particularly important Lagrangian dynamics occur at large Reynolds numbers, e.g. the formation of clouds and precipitation. To our knowledge, the Variable Density Turbulence Tunnel (Bodenschatz et al. (2014)) is the only apparatus capable of generating turbulence at Taylor-scale Reynolds numbers up to 6000, while permitting Lagrangian measurements. In addition, the turbulence generation is highly adjustable through a uniquely flexible active grid (Griffin et al. (2019)) and by tuning the pressure of the working fluid SF6 up to 15 bar. Here we present the first measurements of Lagrangian particle tracking in this high-pressure environment. We describe the particle injection mechanism, the high-speed camera setup, and the illumination system. We present initial results of particle accelerations at Reynolds numbers greater than 3000, marking the highest Reynolds numbers at which such statistics have ever been recorded. Finally, we provide an outlook on the overall capabilities of the setup.

DY 9: Statistical Physics 2 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) und Thomas Speck (Mainz)

Time: Monday 11:00–13:00 Location: DYb

DY 9.1 Mon 11:00 DYb

Path integral approach to strong fluctuations in chemical reaction network dynamics using the Plefka expansion — •Moshir Harsh and Peter Sollich — Institut für Theoretische Physik, Georg-August-Universität, Göttingen, Germany

Biochemical reaction networks such as *gene* regulation, *protein* interaction and signalling pathways involve the participation of just a few copies of some key molecular species. With the advent of modern capabilities in live quantitative fluorescence microscopy and spectroscopy, the dynamics of a number of molecular species in these networks can be observed experimentally. However, inferring dynamical parameters from such data remains a challenge as the trajectories of low copy number species show large fluctuations, causing approximate approaches like the Fokker-Planck equation and moment closure to fail in this regime, while the in principle exact master equation has no general analytical solution.

Here we present an alternative method based on constructing the path integral for the dynamics of a generic reaction network, which is then treated within a Gaussian approximation by constraining the first and the second order statistics of the field variables using the systematic Plefka expansion of the dynamical free energy. We develop the method to treat any system of reactions in full generality and show its applicability and accuracy across a range of example systems. The approximate path integral can also form the basis for making inferences from experimentally measured dynamics.

DY 9.2 Mon 11:20 DYb

Negative dissipation and instability in systems with distributed delay — •Sarah A.M. Loos[1], Simon Hermann[2], and Sabine H.L. Klapp[3] — [1]Universität Leipzig — [2]Humboldt-Universität zu Berlin — [3]Technische Universität Berlin

Many natural and artificial systems are subject to some sort of delay, which can be in the form of a single discrete delay or distributed over a range of times. Here, we discuss the impact of this distribution on

(thermo-)dynamical properties of time-delayed stochastic systems. To this end, we study a simple model with white and colored noise, and focus on the class of Gamma-distributed delays which includes a variety of distinct delay distributions typical for feedback experiments and biological systems. A physical application is a colloid subject to time-delayed feedback control, which is, in principle, experimentally realizable by co-moving optical traps. We uncover several unexpected phenomena in regard to the system's linear stability and its thermodynamic properties. First, increasing the mean delay time can destabilize, or stabilize the process, depending on the distribution of the delay. Second, for all considered distributions, the heat dissipation of the controlled system (e.g., the colloidal particle) can become negative, which implies that the delay force extracts energy of the heat bath. This refrigerating effect is particularly pronounced for exponential delay. The exponential delay further yields the largest stable parameter regions. In this sense, exponential delay represents the most effective and robust type of delayed feedback.

DY 9.3 Mon 11:40 DYb

On the fluctuation-dissipation theorem of a buckminster fullerene — •Andreas Baer[1], David Smith[2], and Ana-Sunčana Smith[1,2] — [1]PULS Group, Institute for Theoretical Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Division of Physical Chemistry, Ruđer Bošković Institute, Zagreb, Croatia

The fluctuation-dissipation theorem goes back to the first half of the last century with a lot of work in statistical physics sharpening the limits of applicability [1]. The Stokes-Einstein relation is a direct consequence of the fluctuation-dissipation theorem and was recently, within an experimental study, argued to be valid for dissolved buckminster fullerenes [2], while theoretical and simulation studies deny the applicability at such small scales [3]. We perform both equilibrium and constrained molecular dynamics studies of a buckminster fullerene dissolved in toluene. Retrieving velocity and force autocorrelation functions, we can directly show the failure of the fluctuation-dissipation theorem. Additionally, transport coefficients obtained via the Green-Kubo formalism can be compared to the friction coefficient retrieved from the ratio of pulling force and resulting velocity to test the Stokes-Einstein relation. We outline the most important assumptions of the theory not fulfilled and provide a solution to the apparent contradiction with experimental studies.

[1] Zwanzig, R., *Annu. Rev. Phys.* 1965, **16**, 67-102
[2] Pearson, J. et al., *J. Phys. Chem. Lett.* 2018, **9**, 6345-6349
[3] Schmidt J. R. et al., *J. Phys. Chem. B* 2004, **108**, 21, 6767-6771

DY 9.4 Mon 12:00 DYb

Quantifying configurational information for a stochastic particle in a flow-field — •Evelyn Tang[1] and Ramin Golestanian[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, United Kingdom

Flow-fields are ubiquitous systems that are able to transport vital signaling molecules necessary for system function. While information regarding the location and transport of such particles is often crucial, it is not well-understood how to quantify the information in such stochastic systems. Using the framework of nonequilibrium statistical physics, we develop theoretical tools to address this question. We observe that rotation in a flow-field does not explicitly appear in the generalized potential that governs the rate of system entropy production. Specifically, in the neighborhood of a flow-field, rotation contributes to the information content only in the presence of strain – and then with a comparatively weaker contribution than strain and at higher orders in time. Indeed, strain and especially the flow divergence, contribute most strongly to transport properties such as particle residence time and the rate of information change. These results shed light on how information can be analyzed and controlled in complex artificial and living flow-based systems.

DY 9.5 Mon 12:20 DYb

Asymmetric nascent Dirac delta functions and their application to probability and mechanics — •Jens Christian Claussen — Department of Mathematics, Aston University, Birmingham, UK

The Dirac delta distribution is ubiquitious from quantum mechanics and statistical physics to Fourier analysis. In theoretical physics lectures, a commonly presented approach uses a series of nascent delta functions which are normalized and localized and converge point-wise to zero except at the origin. For simplicity, nascent delta functions are usually chosen to be even, i.e. $\delta_n(x) = \delta_n(x)$. However, this is not a necessary assumption, and in physical interactions as the inelastic collision of two rigid bodies, the force between the particles as a function of time may follow an asymmetric profile; nevertheless with the total momentum transferred in a Dirac delta pulse in the limit of an infinesimal short interaction time.

Here I discuss asymmetric nascent Dirac delta functions and their implications in probability and physics. The gross advantage of asymmetric nascent delta functions is found in their application to probability theory. By introduction of totally asymmetric nascent delta functions, the inconsistencies of using the Dirac delta in mixed discrete-continuous probability spaces when arriving at the cumulative distribution function are resolved. It is anticipated that asymmetric nascent delta functions find further applications in mathematical physics and the theory of measurement.

DY 9.6 Mon 12:40 DYb

Hilbert space average of transition probabilities — •Nico Hahn, Thomas Guhr, and Daniel Waltner — Faculty of Physics, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

The typicality approach and the Hilbert space averaging method as its technical manifestation are important concepts of quantum statistical mechanics. Extensively used for expectation values we will extend them to transition probabilities. We find that the transition probability of two random uniformly distributed states is connected to the spectral statistics of the considered operator. We will demonstrate our quite general result for a kicked spin chain.

DY 10: Granular Physics 2 - organized by Matthias Sperl (Köln)

Time: Monday 11:00–13:00 Location: DYc

DY 10.1 Mon 11:00 DYc

Particle shape-dependence of the stability properties of granular piles — •Steffen Richters-Finger and Stefan J. Linz — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Germany

It is well known that the shape of particles has a major influence on the behavior of densely packed granular matter making it an important subject of interest for various applications. Multiple schemes for the numerical simulation of non-spherical particles have previously been proposed in the literature [1].

Applying a discrete function representation (DFR) approach for collision detection, we investigate the shape-dependence of the stability properties (e.g. critical angle of stability) of a granular pile in a two-dimensional discrete element model for a wide range of polar geometries generated by the so-called superformula [2].

[1] G. Lu, J.R. Third, C.R. Müller, Chem. Eng. Sci. **127**, 425-465 (2015).
[2] J. Gielis, Am. J. Bot. **90**, 333-338 (2003).

DY 10.2 Mon 11:20 DYc

Machine learning aided tracking of rod-like particles in 3D microgravity experiments on granular gases — •Dmitry Puzyrev, Kirsten Harth, Torsten Trittel, and Ralf Stannarius — Institute of Physics, Otto von Guericke University, Magdeburg, Germany

Granular gases are nonlinear systems which exhibit fascinating dynamical behavior far from equilibrium, including unusual cooling properties, clustering and violation of energy equipartition. Our investigation is focused on 3D microgravity experiments with dilute ensembles of rod-like particles, where the mean free path is substantially reduced as compared to gases of spherical grains of identical volume fraction [1]. Moreover, elongated particles provide the possibility to efficiently study the energy transfer between the translational and rotational de-

grees of freedom.

One particular problem is the reliable detection and tracking of the rods in 3D, especially at volume fractions beyond the very dilute limit. We have developed a Machine Learning aided approach [2] to the experimental data analysis which allows to recognize and track individual particles in ensemble.

[1] K. Harth et al., Free cooling of a granular gas of rodlike particles in microgravity, Phys. Rev. Lett., 120 (2018), 214301

[2] Puzyrev et al., Machine learning for 3D particle tracking in granular gases, Microgravity Sci. Technol., 32 (2020), 897

DY 10.3 Mon 11:40 DYc

Particle size dynamics in abrading pebble populations — •Janos Török[1,2], Andras Sipos[1,3], and Gabor Domokos[1,3] — [1]MTA-BME Morphodynamics Research Group, Budapest University of Technology and Economics — [2]Department of Theoretical Physics, Budapest University of Technology and Economics — [3]Department of Mechanics, Materials and Structures, Budapest University of Technology and Economics

Abrasion of sedimentary particles in fluvial and aeolian environments is widely associated with collisions encountered by the particle. Although the physics of abrasion is complex, purely geometric models recover the course of mass and shape evolution of individual particles in low and middle energy environments (in the absence of fragmentation) remarkably well. In this paper, utilizing results of this individual, geometric abrasion theory as a collision kernel, following techniques adopted in the statistical theory of coagulation and fragmentation, we construct the corresponding Fokker-Planck equation as the first model for the collision-driven collective mass evolution of sedimentary particles. Our model uncovers a startling fundamental feature of collective particle size dynamics: collisional abrasion may, depending on the energy level, either focus size distributions, thus enhancing the effects of size selective transport or it may act in the opposite direction by dispersing the distribution. This complex behaviour does not contradict existing geological observations on mass distributions.

DY 10.4 Mon 12:00 DYc

Applying Edwards' theory for a $2+\epsilon$ dimensional frustrated granular system — •Sára Lévay[1], David Fischer[2], Ralf Stannarius[2], Ellák Somfai[3], Tamás Börzsönyi[3], Lothar Brendel[4], and János Török[1,5] — [1]Budapest University of Technology and Economics — [2]Otto von Guericke University — [3]Wigner Research Centre for Physics — [4]University of Duisburg-Essen — [5]MTA-BME Morphodynamics Research Group

Despite the inherent athermal features of granular materials, treating jammed granular systems in analogy to thermal equilibrium statistical mechanics was proposed by Edwards by using a volume ensemble of equiprobable jammed states. We introduce a simple system to analyze statistical properties of jammed granular ensembles to test Edwards' theory.

Identical spheres packed in a nearly two-dimensional thin geometrical confinement were studied in experiments and numerical simulations. When tapped, it evolves towards a ground state, but due to incompatible domain structures it gets trapped. Analytical calculations of the Edwards ensemble reproduce well our simulation results, which allows us to test Edwards' theory on a coupled system of two subsystems with different properties. We find that the joint system can only be described by a common compactivity if the stress equilibrium is also taken into account and the system is treated as a whole. The results show some counterintuitive effects, as the side with more order compactifies.

DY 10.5 Mon 12:20 DYc

Can machine learning help to identify variables of a granular theory? — •Ansgar Kühn, Song-Chuan Zhao, and Matthias Schröter — Max Planck Institute for Dynamics and Self-Organization, Göttingen

Presently, the best theory for predicting the number of contacts in a granular packing is using the local package fraction as its independent variable [1]. In order to go beyond this one-parameter approach, a more detailed description of the local geometry is given in the form of Minkowski tensors of the Voronoi cell. With this data as features, machine learning provides a more accurate prediction of contact numbers than [1]. Feature selection can be used to identify new variables most relevant for the prediction in order to expand the theory.

[1] Song et al. Nature, 453, 629–632 (2008)

DY 10.6 Mon 12:40 DYc

Flow in an hourglass: particle friction and stiffness matter — •Tamás Börzsönyi[1], Tivadar Pongó[1,2], Viktória Stiga[1], János Török[3], Sára Lévay[3], Balázs Szabó[1], Raúl Cruz Hidalgo[2], and Ralf Stannarius[4] — [1]Wigner Research Centre for Physics, H-1525 Budapest, Hungary — [2]Universidad de Navarra, Pamplona, Spain — [3]Institute of Physics BME, Budapest, Hungary — [4]Otto-von-Guericke-University, D-39106 Magdeburg, Germany

For usual granular materials the discharge rate from a silo is known to be time independent (constant flow rate). This is opposed to the case of a liquid for which the decreasing height leads to decreasing pressure, resulting in gradually decreasing flow rate during a discharge process. We performed laboratory experiments and numerical simulations with traditional (frictional hard) granular materials and grains with reduced surface friction and hardness. We show, that particle stiffness has a strong effect on the qualitative features of silo discharge. For deformable grains lowering the friction coefficient leads to a gradual change in the discharge curve: the flow rate becomes filling height dependent, it decreases during the discharge process. For hard grains the flow rate is much less sensitive to the value of the friction coefficient. For more details see Pongó et al., New J. Phys., (2021)

DY 11: Active Biological Matter II (joint session BP/CPP/DY)

Time: Monday 11:00–13:30 Location: BPb

DY 11.1 Mon 11:00 BPb

Chiral stresses in nematic cell monolayers — •Ludwig A. Hoffmann[1], Koen Schakenraad[1,2], Roeland M. H. Merks[2,3], and Luca Giomi[1] — [1]Instituut-Lorentz, Leiden University, The Netherlands — [2]Mathematical Institute, Leiden University, The Netherlands — [3]Institute of Biology, Leiden University, The Netherlands

Recent experiments on monolayers of spindle-like cells have provided a convincing demonstration that certain types of collective phenomena in epithelia are well described by active nematic hydrodynamics. While recovering some of the predictions of this framework, however, these experiments have also revealed unexpected features that could be ascribed to the existence of chirality over length scales larger than the typical size of a cell.

We elaborate on the microscopic origin of chiral stresses in nematic cell monolayers and investigate how chirality affects the motion of topological defects, as well as the collective motion in stripe-shaped domains. We find that chirality introduces a characteristic asymmetry in the collective cellular flow, from which the ratio between chiral and non-chiral active stresses can be measured. Furthermore, we find that chirality changes the nature of the spontaneous flow transition under confinement and that, for specific anchoring conditions, the latter has the structure of an imperfect pitchfork bifurcation.

DY 11.2 Mon 11:20 BPb

Developmentally driven self-assembly of living chiral crystals — •Alexander Mietke[1], Tzer Han Tan[2], Hugh Higinbotham[2], Yuchao Chen[2], Peter Foster[2], Shreyas Gokhale[2], Jörn Dunkel[1], and Nikta Fakhri[2] — [1]Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA

The emergent dynamics exhibited by self-organizing collections of living organisms often shows signatures of symmetries that are broken at the single-organism level. At the same time, early organism development itself is accompanied by a sequence of symmetry breaking events that eventually establish the body plan. Combining these key aspects of collective phenomena and embryonic development, we describe here the spontaneous formation of hydrodynamically stabilized active crystals made of hundreds of starfish embryos during early development. As development progresses and embryos change morphology, crystals become increasingly disordered and eventually stop forming. We show

that these structures exhibit distinct macroscopic chiral features as a direct consequence of the embryo's chiral swimming properties. We introduce a hydrodynamic near-field model that quantitatively describes the formation and rotation of crystals, as well as the emergence of long-lived chiral deformation waves, all of which can be understood as consequences of broken symmetries on the single-embryo level.

DY 11.3 Mon 11:40 BPb

Thin-Film Model of Resting and Moving Active Droplets — •Fenna Stegemerten[1], Sarah Trinscheck[1,2], Karin John[2], and Uwe Thiele[1,3] — [1]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Münster, Germany — [2]Université Grenoble-Alpes, CNRS Laboratoire Interdisciplinaire de Physique, Grenoble, France — [3]Center for Nonlinear Science (CeNoS), Westfälische Wilhelms-Universität Münster, Münster, Germany

We propose a long-wave model for free-surface drops of polar active liquid on a solid substrate. The coupled evolution equations for the film height and the local polarization profile are written in the form of a gradient dynamics supplemented with active stresses and fluxes. A wetting energy for a partially wetting liquid is incorporated allowing for motion of the liquid-solid-gas contact line. This gives a consistent basis for the description of drops of dense bacterial suspensions or compact aggregates of living cells on solid substrates. As example, we analyze the dynamics of active drops and demonstrate how active forces compete with passive surface forces to shape droplets and drive contact line motion. We perform parameter continuation in the activity parameters discussing both, resting and moving droplets. Additional direct time simulations investigate transitions from non-uniformly to uniformly polarized as well as resting to moving states.

DY 11.4 Mon 12:00 BPb

Sedimentation and Convection of Bottom-Heavy Squirmers — •Felix Rühle, Jan-Timm Kuhr, and Holger Stark — TU Berlin, Institut für Theoretische Physik, Berlin, Germany

Active particles form appealing patterns, in particular, when hydrodynamic interactions are present [1-3]. A fascinating example known from biology is bioconvection of microswimmers under gravity [4]. In order to study such systems, we simulate bottom-heavy squirmers (neutral squirmers, pushers, and pullers) under different gravitational forces and torques [3]. The relevant parameters are the ratio of swimming to bulk sedimentation velocity α and the normalized torque.

In the state diagram of these parameters, for neutral squirmers at low α we observe sedimentation states, where bottom-heaviness leads to the formation of clusters of different sizes. For high α, finite torques lead to inverted sedimentation. In between, we identify plumes of collectively sinking squirmers that feed convective rolls of circling squirmers at the bottom of the simulation cell. At $\alpha \gtrapprox 1$ and large torques squirmers form a spawning cluster above the wall, from which squirmers occasionally escape. For strong pushers and pullers, we find that the dipolar flow fields weaken the formation of plumes and convective rolls.

[1] M. Hennes, *et al.*, PRL **112**, 238104 (2014)
[2] H. Jeckel, *et al.*, PNAS **116**, 1489 (2019).
[3] F. Rühle, and H. Stark, Eur. Phys. J. E **43**, 26 (2020).
[4] T.J. Pedley, and J.O. Kessler, Annu. Rev. Fluid Mech. **24**, 313 (1992).

DY 11.5 Mon 12:20 BPb

Microscopic scattering of pusher particles in complex environments — •Theresa Jakuszeit[1], Samuel Bell[2], and Ottavio A. Croze[1] — [1]Cavendish Laboratory, JJ Thomson Avenue, CB3 0HE, Cambridge, United Kingdom — [2]Laboratoire Physico Chimie Curie, Institut Curie,PSL Research University, CNRS UMR168, 75005 Paris, France

Active propulsion as performed by bacteria and Janus particles, in combination with hydrodynamic interaction at boundaries, can lead to the breaking of time reversibility. One typical example of this is the accumulation of bacteria on a flat wall. However, in microfluidic devices with cylindrical pillars of sufficiently small radius, self-propelled particles can slide along the surface of a pillar without becoming trapped over long times. This non-equilibrium scattering process can result in large diffusivities even at high obstacle density, unlike particles that undergo classical specular reflection, as in the Lorentz gas. We experimentally study the non-equilibrium scattering as well as the long-term diffusive transport of pusher-like particles by tracking wild-type and smooth-swimming mutants of the model bacterium Escherichia coli in microfluidic obstacle lattices. We relate the determined parameters of the scattering process to previously proposed models and discuss their relevance. Finally, we discuss the potential interpretation of the role of tumbles in the scattering process.

DY 11.6 Mon 12:40 BPb

Swimming behavior of squirmer dumbbells and polymers — •Judit Clopés Llahí, Gerhard Gompper, and Roland G. Winkler — Theoretical Soft Matter and Biophysics, Institute for Advanced Simulation and Institute of Complex Systems, Forschungszentrum Jülich, D-52425 Jülich, Germany

Nature provides a plethora of microswimmers, which can be rather elongated, filament- or polymer-like. Examples are bacteria swarmer cells or marine phytoplankton dinoflagellates assembling in a linear fashion. In order to address the relevance of hydrodynamic interactions for the collective behavior of such organisms, we study the swimming properties of linear polymer-like assemblies by mesoscale hydrodynamic simulations, where an active unit (monomer) is described by a spherical squirmer – which can be a pusher, a neutral swimmer, or a puller. We find that the monomer hydrodynamic flow field leads to correlations in the relative orientation of adjacent monomers, and consequently the swimming efficiency differs from that of active Brownian linear assemblies. In particular, puller dumbbells and chains show a pronounced increase in the rotational diffusion coefficient compared to pushers, while for neutral squirmers, the rotational diffusion coefficient is similar to that of active Brownian particles. Hence, the large-scale conformational and dynamical properties depend on the specific propulsion mechanism. Refs.: J. Elgeti, R. G. Winkler, G. Gompper, Rep. Prog. Phys. 78, (2015). R. G. Winkler, J. Elgeti, G. Gompper, J. Phys. Soc. Jpn. 86, (2017). J. Clopés, G. Gompper, R. G. Winkler, Soft Matter 16, 10676 (2020).

30 min. Meet the Speaker

DY 12: Posters DY - Fluid Physics, Active Matter, Complex Fluids, Soft Matter and Glasses (joint session DY/BP)

Time: Monday 14:00–16:30 Location: DYp

DY 12.1 Mon 14:00 DYp

Jerky active matter: a phase field crystal model with translational and orientational memory* — •Michael te Vrugt, Julian Jeggle, and Raphael Wittkowski — Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149, Münster, Germany

Most field theories for active matter neglect effects of memory and inertia. However, recent experiments have found inertial delay to be important for the motion of self-propelled particles. A major challenge in the theoretical description of these effects, which makes the application of standard methods very difficult, is the fact that orientable particles have both translational and orientational degrees of freedom which do not necessarily relax on the same time scale. In this work, we combine modern mathematical methods from particle physics and nonlinear dynamics to derive the general mathematical form of a field theory for soft-matter systems with two different time scales. This allows to obtain a phase field crystal model for polar (i.e., nonspherical or active) particles with translational and orientational memory. Notably, this theory is of third order in temporal derivatives and can thus be seen as a spatiotemporal jerky dynamics. An analysis of the model reveals interesting effects of memory on the dynamics of active systems.

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DY 12.2 Mon 14:00 DYp

Dynamic role of coherent structures in two-dimensional Navier-Stokes turbulence — •Jiahan Wang[1], Wolf-Christian Müller[1], and Jörn Sesterhenn[2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Universität Bayreuth, Bayreuth, Germany

Turbulent coherent structures can phenomenologically be described as regions in a flow exhibiting a high level of spatio-temporal correlation. Although these structures are ubiquitously observed in nature, providing a universal and rigorous definition of them is not a straightforward task. Therefore the choice of a suitable structure detection method is generally not unique and problem-dependent. We are interested in structures appearing in statistically isotropic Navier-Stokes turbulence. For this purpose, direct numerical simulations (DNS) of a two-dimensional flow, forced at small spatial scales, are employed to compare different definitions of structural coherence. This setup inherently forms large scale structures due to the inverse cascade of energy. Detection methods such as the identification of Lagrangian coherent structures (LCS), dynamic mode decomposition (DMD) and wavelet denoising are all capable of splitting physical fields into coherent and incoherent contributions. Based on that, the analysis of the scale-to-scale decomposed energy flux yields a physical interpretation for the influence of those structures onto the overall inverse cascade dynamics. As a result, the decomposed fluxes gained from LCS and DMD are related, whereas the wavelet decomposition shows no similarity at all.

DY 12.3 Mon 14:00 DYp

Magnetic helicity inverse transfer in supersonic isothermal MHD turbulence — •Jean-Mathieu Teissier[1,2] and Wolf-Christian Müller[1,2,3] — [1]Technische Universität Berlin, ER3-2, Hardenbergstr. 36a, D-10623 Berlin, Germany — [2]Max-Planck/Princeton Center for Plasma Physics — [3]Berlin International Graduate School in Model and Simulation Based Research

Magnetic helicity is an ideal invariant of the magnetohydrodynamic (MHD) equations which exhibits an inverse transfer in spectral space. Up to the present day, its transport has been studied in direct numerical simulations only in incompressible or in subsonic or transonic flows. Inspired by typical values of the turbulent root mean square (RMS) Mach number in the interstellar medium, this work presents some aspects of the magnetic helicity inverse transfer in high Mach number isothermal compressible turbulence, with RMS Mach numbers up to the order of ten:

1) a clear Mach-number dependence of the spectral magnetic helicity scaling but an invariant scaling exponent of the co-spectrum of the Alfvén velocity and its curl,

2) the approximate validity of a dynamical balance relation found by incompressible turbulence closure theory,

3) a characteristic structuring of helically-decomposed nonlinear shell-to-shell fluxes that can be disentangled into different spectrally local and non-local transfer processes.

DY 12.4 Mon 14:00 DYp

Molecular dynamics of janus polynorbornenes: glass transitions and nanophase separation — •Mohamed A Kolmangadi, Paulina Szymoniak, Martin Böhning, and Andreas Schönhals — Bundesantalt für Materialforschung und -prüfung (BAM), Berlin, Germany

For the first time, dielectric and calorimetric investigations of a homologous series of Janus polynorbornenes with rigid main backbones and flexible Si(OR)3 side groups of differing length alkyl chains (R = propyl, butyl, hexyl, octyl, and decyl) is reported.Two dielectrically active processes are observed at low temperatures, denoted as β- and α-relaxation. The former can be assigned to localized fluctuations, while the latter is related to the glassy dynamics of the flexible Si(OR)3 side groups, creating a nanophase separation in both the alkyl chain-rich and backbone-rich domains. This is confirmed through temperature-modulated differential scanning calorimetry (TMDSC) measurements and X-ray scattering experiments. The glass transition temperatures of the backbone rich domains, which are beyond or near to their degradation temperatures in terms of conventional DSC, are determined for the first time using fast scanning calorimetry employing both fast heating and cooling rates. This is complemented with scattering experiments that show how the size of the alkyl chain-rich domains increases with the side chain length. Alongside these results, a significant conductivity contribution was observed for all poly(tricyclononenes) with Si(OR)3 side groups, which is interpreted in terms of a percolation model

DY 12.5 Mon 14:00 DYp

Classical Density Functional Theory for Particles with Hard Cores and Soft Square Shoulders — •Markus Hoffmann, Robert F. B. Weigel, and Michael Schmiedeberg — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Classical density functional theory is an excellent tool to investigate classical many-body systems from fundamental principles, in particular soft matter systems. We consider particles with hard cores and soft square shoulders in two dimensions. The hard-core is implemented by using a variant of the Fundamental Measure Theory that probably is the best mean field approach to hard particles.

The hard core-square shoulder interaction possesses two independent length scales namely the diameter of the hard core and the diameter of the square shoulders. We observe the expected crystallization transitions into a triangular phase for both very weak shoulders where the hard cores dominate and for strong shoulders effectively leading to a soft sphere system.

However, the most interesting cases are expected when the two length scales of the systems are competing. As a result, not only square patterns are observed but we also want to explore quasicrystals. Note that previous mean field descriptions of quasicrystals (like Phase Field Crystal approaches) usually consider cluster crystals and so far have not been able to explain the formation of quasicrystals for particles with hard cores.

DY 12.6 Mon 14:00 DYp

Organizing bacterial vortex lattices by periodic obstacle arrays — •Henning Reinken[1], Sebastian Heidenreich[2], Markus Bär[2], and Sabine H. L. Klapp[1] — [1]Technische Universität Berlin, Germany — [2]Physikalisch-Technische Bundesanstalt, Berlin, Germany

Recent experimental studies have shown that the turbulent vortex structures emerging in bacterial active fluids can be organized into regular vortex lattices by weak geometrical constraints such as small pillars [1]. Using a continuum-theoretical approach [2,3], we show how these artificial obstacles reorganize self-induced topological defects which guides the flow profile of the active fluid and enables the stabilization of vortex patterns with tunable properties. Beyond the stabilization of square and hexagonal lattices, we also provide a striking example of a chiral, antiferromagnetic lattice induced by arranging the obstacles in a Kagome-like array [3]. In this setup, the interplay of lattice topology, activity and length-scale selection generates a net rotational flow. Further, we explore the connections between the stabilized non-equilibrium vortex patterns and equilibrium phase transitions in classical spin lattice models, e.g., the Ising model.

[1] D. Nishiguchi, I. S. Aranson, A. Snezhko, and A. Sokolov, Nat. Commun. **9**, 4486 (2018)
[2] H. Reinken, S. H. L. Klapp, M. Bär, and S. Heidenreich, Phys. Rev. E **97**, 022613 (2018)
[3] H. Reinken, D. Nishiguchi, S. Heidenreich, A. Sokolov, M. Bär, S. H. L. Klapp, and I. S. Aranson, Commun. Phys. **3**, 76 (2020)

DY 12.7 Mon 14:00 DYp

Active mobile oscillators: Density fluctuations and phase ordering — Astik Haldar[1], •Swarnajit Chatterjee[2], Apurba Sarkar[3], Raja Paul[3], and Abhik Basu[1] — [1]Saha Institute of Nuclear Physics, Kolkata, India — [2]Center for Biophysics & Department for Theoretical Physics, Saarland University, Saarbrücken, Germany — [3]Indian Association for the Cultivation Of Science, Kolkata, India

We consider the collective motion of nearly phase-ordered active oscillators on a substrate. The dynamics include activity-induced couplings between the local phase with the concentration of the mobile oscillators on the interface. We show that such a system can be stable over a wide range of model parameters. When stable, the system can also show a variety of orders. In different regions of the phase space, the system can show phase ordering that is stronger than the conventional quasi long-range order (QLRO) together with hyperuniform number fluctuations, or phase ordering weaker than QLRO together with giant number fluctuations, or even QLRO with uniform density fluctuations. In other parameter regimes, the system becomes unstable with the eventual loss of any phase ordering beyond a finite (small) system size. We have also constructed an appropriate agent-based lattice-gas model. Numerical simulations of this model corroborate the analytical predictions and validate the results on the phase fluctuations.

DY 12.8 Mon 14:00 DYp

Structural and dynamical properties of gel networks —

•Matthias Gimperlein and Michael Schmiedeberg — Institut für theoretische Physik 1, FAU Erlangen-Nürnberg

Gelation is connected to a slow-down in dynamics, the onset of percolation and an increasing number of neighboring particles. The slow-down occurs on different time scales depending on the studied length scales.

Using Brownian Dynamics simulation for a system of colloidal particles interacting due to a modified square well and Yukawa potential we investigate the structural properties of gel networks on different time and length scales depending on system parameters as the strength of attraction or repulsion respectively.

The square well potential is modified by introducing an interaction range α to flatten the walls of the square well. The phase diagram was determined by fitting the vapour-liquid binodal. In the square well limit ($\alpha \to 0$) results from the literature are recovered. Structural properties as node distribution or link lengths are extracted from minimal networks which allow an easier analysis of the underlying network structure.

Further research includes distinguishing dynamic regimes or structures on different length and time scales, investigating the history/protocol dependency of the development (i. e. starting from different initial configuration) and finding stable or metastable structures to describe the evolution of gel networks not on the particle level anymore, but on a coarse grained level.

DY 12.9 Mon 14:00 DYp

Simple model for drops on elastic substrates — •Christopher Henkel[1], Uwe Thiele[1], and Jacco Snoeijer[2] — [1]Institut für Theoretische Physik, WWU-Münster, Germany — [2]Fac. of Science and Technologie, University Twente, Netherlands

The investigation of the wetting behavior on viscoelastic or elastic substrates is of great interest. In this talk we present a simple model for steady liquid drops on fully compressible elastic substrates and show that a double transition of contact angles appears under variation of the substrate softness, similar to the one described in [1]. We further discuss whether these angles agree with the Neumann and Young-Laplace conditions in the liquid-liquid and liquid-solid limit respectively and how the transitions depend on drop size. Finally, we employ a gradient dynamics model in the long-wave limit and show first results of direct time simulations.

[1] Lubbers, L. A., Weijs, J. H., Botto, L., Das, S., Andreotti, B., and Snoeijer, J. H., (2014). Drops on soft solids: free energy and double transition of contact angles. *Journal of fluid mechanics*, 747.

DY 12.10 Mon 14:00 DYp

Flocking and reorientation transition in the q-state active Potts model — •Matthieu Mangeat[1], Swarnajit Chatterjee[1,2], Raja Paul[2], and Heiko Rieger[1] — [1]Saarland University, Saarbrücken, Germany — [2]IACS, Kolkata, India

We study the q-state active Potts model (APM) on a two-dimensional lattice in which active particles have q internal states corresponding to the q directions of motion. A local alignment rule inspired by the ferromagnetic q-state Potts model and self-propulsion via biased diffusion according to the internal particle states leads to a collective motion at high densities and low noise. We formulate a coarse-grained hydrodynamic theory with which we compute the phase diagram of the APM and explore the flocking dynamics in the region, in which the high-density (polar liquid) phase coexists with the low-density (gas) phase and forms a fluctuating band of coherently moving particles. As a function of the particle self-propulsion velocity, a novel reorientation transition of the phase-separated profiles from transversal to longitudinal band motion is found, which is absent in the Vicsek model [1] and the active Ising model [2]. The origin of this reorientation transition is revealed by a stability analysis: for large velocities the transverse diffusion constant approaches zero and then stabilizes longitudinal band motion. Computer simulations corroborate the analytical predictions of the flocking and reorientation transitions and validate the phase diagrams of the APM.

[1] T. Vicsek *et al.*, Phys. Rev. Lett. **75**, 1226 (1995).
[2] A. P. Solon and J. Tailleur, Phys. Rev. Lett. **111**, 078101 (2013).

DY 12.11 Mon 14:00 DYp

Cell fitness in growth driven active matter: decoupling turnover rate and homeostatic pressure predictors — •Yoav G. Pollack[1], Philip Bittihn[1], and Ramin Golestanian[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), Goettingen, 37077, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford, OX1 3PU, UK

In growth-driven dense cellular active matter, cell dynamics and competition are governed by the intricate relations between growth, proliferation, removal (e.g. death, extrusion) and mechanical interactions. Though the rates at which a cell proliferates or dies have already been established as a significant factor for fitness, homeostatic pressure was recently suggested as an equivalent predictor of fitness and one that can be more easily measured. Here we show that this equivalence in not universal and can be broken. By introducing an additional timescale that governs the duration of the single-cell removal process in a simple growing dumbbell model of cells, the homeostatic pressure is partially decoupled from the turnover rate, leading to a distinct prediction for each. When the two factors are modulated in this way in a simulated competition assay of a mixture of two cell species in a closed 1D channel, we show that while the homeostatic pressure does not predict well which species triumphs, the turnover rate does. A good fitness measure is important in studies of tumor growth, bacterial evolution, etc. and this result is a first step in understanding for which scenarios is the homeostatic pressure a valid predictor.

DY 12.12 Mon 14:00 DYp

Unjamming of Active Rotators — •Linda Ravazzano[1], Silvia Bonfanti[1], Maria C. Lionetti[1], Maria R. Fumagalli[1], Roberto Guerra[1], Oleksandr Chepizhko[2], Caterina A. M. La Porta[1], and Stefano Zapperi[1] — [1]Center for Complexity and Biosystems, University of Milan, Italy — [2]Leopold-Franzens-Universität Innsbruck, Austria

Active particles assemblies are of peculiar interest thanks to the richness of dynamical phases they can undergo varying internal parameters such as density, adhesion strength or self-propulsion. Most theoretical studies of active matter consider self-propelled particles driven by active forces. The observation of the motion of Chlamydomonas reinhardtii algae, in which the active particles have also the ability to self-rotate, suggests, however, that active torques may also play an important role. Inspired by this example, we simulate the dynamics of a system of interacting active 2D disks endowed with active torques and self-propulsive forces. We studied this model system of active rotators in different conditions: at low packing fractions, where adhesion causes the formation of small rotating clusters, at higher densities, where our simulations show a jamming to unjamming transition promoted by active torques and hindered by adhesion, and in presence of both self-propulsion and self-rotation, studying the interplay between those quantities and deriving a phase diagram. Our results yield a comprehensive picture of the dynamics of active rotators, highlighting the importance of the internal degrees of freedom of active particles in determining the collective behavior of the system.

DY 12.13 Mon 14:00 DYp

The thermodynamics and kinetics of protein crystallization probed by isothermal microcalorimetry — Lorena Hentschel, •Jan Hansen, Florian Platten, and Stefan U. Egelhaaf — Condensed Matter Physics Laboratory, Heinrich Heine University, Düsseldorf, Germany

During a first-order phase transition, a thermodynamic system releases or absorbs latent heat. Despite their fundamental importance, the heat or enthalpy change occurring during protein crystallization has been directly measured only in a few cases, and the associated entropy change can only be determined indirectly. Here, the thermodynamics and kinetics of tetragonal lysozyme crystallization are studied for various physicochemical solution parameters. Direct microcalorimetric and indirect van't Hoff enthalpy determinations quantitatively agree, suggesting a two-state crystallization process. Assuming that crystals are electrostatically neutral, the weak dependences of the crystallization enthalphy and entropy on salt concentration and pH value are explained by a Poisson-Boltzmann model. Furthermore, the calorimetric signal is related to the concentration change during nucleation and growth, from which the induction time and the growth rate are inferred. Their dependences on the chemical potential are in line with previous findings and can be modelled by classical nucleation theory and 2D growth models, respectively.

DY 12.14 Mon 14:00 DYp

Real-Time Investigations during Sputter Deposition on Polymer Thin Films — •Matthias Schwartzkopf[1], Marc Gensch[1,2], Thomas Strunskus[3], Franz Faupel[3], Peter Müller-Buschbaum[2] und Stephan V. Roth[1,4] — [1]DESY, Notkestr. 85, D-22607 Hamburg — [2]CAU zu Kiel, Kaiserstr.2, 24143 Kiel — [3]TUM,

James-Franck-Str. 1, D-85748 Garching — [4]KTH, Teknikringen 56-58,SE-100 44 Stockholm

The reproducible low-cost fabrication of functional metal-polymer-nanocomposites remains a major issue in applied nanotechnology. In order to obtain full control over the evolution at the nanogranular metal-polymer interface, we employed time-resolved surface sensitive X-ray scattering during sputter deposition of gold on thin polystyrene films [1] and SiOx [2]. We correlate the evolution of the metallic layer morphology with changes in the key scattering features. This enabled us to identify the impact of atomic deposition rate on the growth regimes with their specific thresholds. Our study opens up the opportunity to improve nanofabrication of tailored metal-polymer nanostructures for organic electronics like photovoltaic applications and plasmonic-based technologies. [1] Schwartzkopf et al., ACS Appl. Mater. Interfaces 7, 13547 (2015); [2] Schwartzkopf et al., Nanoscale 5, 5053 (2013).

DY 12.15 Mon 14:00 DYp

Fluid transport by metachronal waves of model cilia — •Albert von Kenne, Thomas Niedermayer, and Markus Bär — Department of Mathematical Modelling and Data Analysis, Physikalisch-Technische Bundesanstalt Berlin, Abbestraße 2-12, Berlin 10587, Germany

Motile cilia are hair-like cell extensions that undergo a cyclic motion with the purpose to transport the extracellular fluid at a low Reynolds number, providing crucial functionality of living matter such as cell locomotion and molecular transport in tissue. A striking feature of populations of cilia is a state of collective motion known as metachronal wave.

To investigate these collective states we generalize a simple phase oscillator model for the elastohydrodynamic coupling in ciliated systems [1], to include the effects due to the confined flow in proximity of a cell substrate. Our model encompasses spontaneous creation of waves as well as directed cycle-average fluid flow, yet it's simple enough to be solved analytically. We obtain analytical results for the linear stability of metachronal waves in presence of long-range hydrodynamic interactions, illustrate their properties by numerical simulations and relate the change in transport efficiency to the specific properties of metachronal waves.

[1] . Niedermayer, B. Eckhardt, and P. Lenz, Chaos **18**, 037128 (2008)

DY 12.16 Mon 14:00 DYp

Athermal Jamming for particles with exponentially decreasing repulsions — •Nicolas Wohlleben and Michael Schmiedeberg — Institut für Theoretische Physik I, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 7, 91058 Erlangen, Germany

We study the jamming of a colloidal system where the particles interact according to a Yukawa potential, i.e., the repulsion decreases exponentially with the distance as expected for screened Coulomb interactions of charged colloids in solution. The decay occurs on a length scale given by the screening length and in addition we consider a cutoff length where the potential is set to zero in a smooth way as often used in simulation.

By determining the athermal jamming transition by trying to remove overlaps we find that the transition packing fraction only depends on the cutoff length but hardly on the screening length. We also explore the radial distribution function and again confirm the importance of the cutoff length.

The picture that emerges is that the influence of a cutoff length on athermal jamming is superior to that of the screening length, although the screening length is expected to control the slowdown of the dynamics (i.e., the dynamical glass transition). As a consequence, athermal jamming (as defined by overlaps) and the glass transition obviously are unrelated in the considered system.

DY 12.17 Mon 14:00 DYp

Detection of defects in soft quasicrystals with neural networks — •Ali Döner and Michael Schmiedeberg — Institut für Theoretische Physik I, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudstr. 7, 91058 Erlangen, Germany

The aim of this work is to construct and employ a neural network for the detection of topological defects in dodecagonal quasicystalline patterns. Even though quasircrystals are aperiodic, they exhibit a longe-range order. Furthermore, in principle any discrete rotational symmetry can occur.

In this work, dodecagonal quasicrystalline patterns in two-dimensions with a built-in dislocation are generated and employed as input images of the neural network. The network then should figure out not only the position but also the type of the Burgers vector of the defect.

Our trained neural network is able to recognize the type of the Burgers vector perfectly. The position of the dislocation is recognized up to a mean deviation from the real position that is much smaller than the small length scale in the quasicrystals. In future, we want to train the network with patterns that contain multiple dislocations as well as phasonic excitations.

DY 12.18 Mon 14:00 DYp

Bistable vortices formed by active particles with retarded interactions - Theory — Xiangzun Wang[1], •Pin-Chuan Chen[2], Viktor Holubec[2,3], Klaus Kroy[2], and Frank Cichos[1] — [1]Molecular Nanophotonics Group, Peter Debye Institute for Soft Matter Physics, University of Leipzig, 04103 Leipzig — [2]Institute for Theoretical Physics, University of Leipzig, 04103 Leipzig, Germany — [3]Department of Macromolecular Physics, Faculty of Mathematics and Physics, Charles University, 18000 Prague, Czech Republic

In a recent experiment (see the companion contribution "Experiment", serial number DY193), thermophoretic microswimmers were observed to self-assemble into a bistable mode of circular collective motion. We explain the underlying mechanism qualitatively by deriving a coarse-grained Langevin model for active Brownian particles with retarded interactions. For a single microswimmer attracted to an immobile attractive sphere, it can be broken down to an effective model for the angular degree of freedom. The reduced one-dimensional overdamped Langevin equation features a virtual potential for the angular velocity, self-generated by the retarded propagation of the interaction. We work out the quantitative analytical predictions for the delay-dependent bifurcation scenario and the Kramers rates and numerical results for spontaneous transitions between the degenerate chiral modes of angular motion, beyond the bifurcation point. Our theoretical predictions are found to agree well with the experimental observations and simulations.

DY 12.19 Mon 14:00 DYp

Bistable vortices formed by active particles with retarded interactions - Experiment — •Xiangzun Wang[1], Pin-Chuan Chen[2], Viktor Holubec[2,3], Klaus Kroy[2], and Frank Cichos[1] — [1]Molecular Nanophotonics Group, Peter Debye Institute for Soft Matter Physics, Universität Leipzig, 04103 Leipzig, Germany — [2]Institute for Theoretical Physics, Universität Leipzig, 04103 Leipzig, Germany — [3]Department of Macromolecular Physics, Faculty of Mathematics and Physics, Charles University, 18000 Prague, Czech Republic

Rotating formations of living species are frequently observed in nature from bacterial systems and insects to larger animals like fish or birds. The ubiquity of this behavior suggests universal underlying principles. One could be related to inevitable delays caused by sensimotoric feedback. We explore experimentally the influence of a delayed interaction between individual self-thermophoretic microswimmers on their collective behaviour. Our microswimmers are gold nanoparticle decorated melamine resin colloids, which are propelled by self-thermophoresis due to a local heating of the gold nanoparticles with a focused laser. Using a feedback algorithm we are able to introduce time-delayed virtual interactions with other particles or targets. We find for a single swimmer attracted to an immobilized particle, a transition from a diffusive to a rotating state with two possible rotation directions. This behavior is captured by a simple theoretical model (see companion contribution). This bifurcation is also observed in ensembles of multiple particles where the rotational phase of the ensemble is synchronized by particle collisions.

DY 12.20 Mon 14:00 DYp

Effect of Alignment Activity on the Collapse Kinetics of a Flexible Polymer — •Subhajit Paul[1], Suman Majumder[1], Subir K Das[2], and Wolfhard Janke[1] — [1]Institut fuer Theoretische Physik, Universitaet Leipzig, Bruederstr. 16, D-04103, Leipzig, Germany — [2]Theoretical Sciences Unit, JNCASR, Bangalore- 560064, India.

Dynamics of various biological filaments can be understood within the framework of active polymer models. Keeping this in mind, we construct a bead-spring flexible polymer chain in which the active interaction among the beads is introduced via an Vicsek-like alignment rule.

Following a quench from the high-temperature coil phase to a low-temperature state, we study the non-equilibrium coarsening kinetics of this model via molecular dynamics (MD) simulations. For the passive polymer case the low-temperature equilibrium state is a compact globule. Results from our MD simulations reveal that though the globular state is also expected to be the typical final state in the active case as well, the non-equilibrium pathways change due to the alignment interaction among the beads. We observe that the probability of deviation from the intermediate *pearl-necklace*-like arrangement and the formation of more elongated dumbbell- like structures increases with increasing activity. Also, there exists nonmonotonicity in coarsening with the variation of the strength of activity. In this work, our focus is on such non-equilibrium dynamics results for which we compare with those of the passive case. These are concerning scaling laws related to collapse time and growth of clusters.

DY 12.21 Mon 14:00 DYp

The parameter space of thermohaline stairs — •Axel Rosenthal and Andreas Tilgner — Institut für Geophysik, Georg-August-Universität Göttingen, Deutschland

Convection and diffusion in water can be observed when a gradient in temperature or in salinity takes effect on density in presence of gravity. Both gradients can force or stabilize the process. We conducted experiments where the salt gradient is the driving force and simultaneously the temperature gradient is stabilizing in opposite direction, observed by particle image velocimetry. The question is at which gradients, expressed by Rayleigh numbers, does the transport occure in stable so called "thermohaline stairs"? Thermohaline stairs are a sequence of two flow systems, a finger regime and a large scale circulation.

DY 12.22 Mon 14:00 DYp

Fluctuations of a driven tracer in a viscoelastic bath — •Juliana Caspers — Institut für Theoretische Physik, Göttingen

Recently, viscoelastic fluids have attracted attention as their large structural relaxation times induce a variety of new phenomena such as nontrivial back reactions of the bath on a driven probe particle. Berner *et al* [1] found particle oscillations in the linear response regime, both in theory and experiment. Moreover, Müller *et al* [2] investigated effects of nonlinear baths in equilibrium. They observed interdependencies entering the coefficients in an effective linear generalized Langevin equation. For example, the friction memory kernel depends on properties of the external trap [3] or on the bare tracer friction in the case of an overdamped setting. In [1,2], the simple model of a confined tracer particle interacting via a stochastic Prandtl-Tomlinson model with a bath particle was found to be a good candidate to mimick the properties of a nonlinear viscoelastic bath. This work focuses on the interplay of the external trap that confines the tracer particle and the nonlinearity of the bath. In a nonequilibrium situation we made a first observation of shear thickening, an increase in the microrheological friciton coefficient for a certain regime of driving velocities.

[1] J. Berner, B. Müller, J. R. Gomez-Solano, M. Krüger, and C. Bechinger. *Nat. Commun.*, 9(1):999, 2018
[2] B. Müller, J. Berner, C. Bechinger, and M. Krüger. *New J. Phys.*, 22:023014, 2020
[3] J. O. Daldrop, B. G. Kowalik, and R. R. Netz. *Phys. Rev. X*, 7:041065, 2017

DY 13: Granular Physics 3 - organized by Matthias Sperl (Köln)

Time: Monday 15:00–17:20 Location: DYc

DY 13.1 Mon 15:00 DYc

Monitoring granular drag with non-invasive particle tracking techniques — •Kai Huang[1,2], Jinchen Zhao[1], Chen Lyu[1], Valentin Dichtl[2], and Simeon Voelkel[2] — [1]Institute of Applied Physical Sciences and Engineering, Division of Natural and Applied Sciences, Duke Kunshan University, No. 8 Duke Avenue, Kunshan, Jiangsu, China 215316 — [2]Experimentalphysik V, Universität Bayreuth, 95440 Bayreuth, Germany

Considering granular materials as a complex fluid with a finite yield stress, an object moving inside has to locally unjam and mobilize the surrounding particles in order to step forward. Consequently, granular drag depends strongly on the local rheological behavior and it is essential to have an 'insider' view on granular dynamics. Experimentally, this is achieved using microwave radar and embedded IMU sensor techniques. Our results are in align with discrete element simulations equipped with coarse-graining techniques, which provide additional information on response of the granular bed. Our results of the intruder dynamics are in congruent with existing phenomenological model on granular drag. Interestingly, we find that the macroscopic profiles of the granular bed ahead of the intruder decays exponentially in the co-moving system of the intruder, giving rise to a characteristic length scale on the order of intruder size. Stepping further, we explore the influence of gravity on granular drag by means of microgravity environment in order to shed light on challenges arising from space exploration.

DY 13.2 Mon 15:20 DYc

Granular Rheology from First Principles — •Till Kranz[1], Olfa Lopez[2], Olivier Coquand[2], and Matthias Sperl[2,1] — [1]Institut für Theoretische Physik, Uni Köln — [2]Institut für Materialphysik im Weltraum, DLR Köln

We have recently demonstrated that the *Granular Integration Through Transients* (GITT) formalism allows to derive a constitutive equation for the shear stress σ as a function of the shear rate $\dot{\gamma}$ for arbitrary shear rates and high densities [1] of a granular fluid. Here we extend the formalism to derive a constitutive equation for the pressure $p(\dot{\gamma})$. This allows us to discuss flow curves at constant pressure and the *effective friction* $\mu = \sigma/p$. The phenomenological $\mu(I)$ rheology [2] relates the friction μ to the dimensionless inertial number I. We will discuss the relation between the GITT expressions and $\mu(I)$ rheology. In addition, we will present experimental stress measurements on fluidised glass beads covering several orders of magnitude in shear rate and displaying all the rheologigcal regimes predicted by GITT, namely, Newtonian rheology, as well as shear thinning and shear thickening behaviour.

[1] W. T. Kranz, F. Frahsa, A. Zippelius, M. Fuchs and M. Sperl, PRL **121**, 148002 (2018); PRF **5** 024305 (2020)
[2] GDR Midi, EPJ E **14**, 341 (2004)

DY 13.3 Mon 15:40 DYc

Aeolian structure formation in a laboratory wind tunnel — •Merve Seckin[1], Philip Born[1], and Matthias Sperl[1,2] — [1]Institut für Materialphysik im Weltraum, DLR Köln — [2]Institut für Theoretische Physik, Uni Köln

Aeolian transport causes structure formation in beds of granular particles. The length scale of structures formed by aeolian transport is fundamentally connected to the saturation length of the particle flux. Achieving structures on length scales suitable for laboratory experiments by minimizing this saturation length is challenging, but would allow testing and calibrating models of aeolian transport.

Here we show results obtained with very fine particles with an additional surface treatment to minimize cohesion. Saturation lengths of a centimeter can be obtained with this particle system. Consequently, we can show that self-initiated and sustained structure formation from particle beds by aeolian transport is possible at ambient conditions in a benchtop wind tunnel. Barchan-like structures emerge from flat particle beds and from particles heaps, which migrate downwind even without particle influx. We compare the experimental results with the existing theory and discuss open questions.

DY 13.4 Mon 16:00 DYc

Numerical investigation of the rheology of elongated particles — •Ellák Somfai[1], Dániel Nagy[1], Philippe Claudin[2], and Tamás Börzsönyi[1] — [1]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Budapest, Hungary — [2]Physique et Mécanique des Milieux Hétérogènes, PMMH UMR 7636 CNRS, ESPCI Paris, PSL University Sorbonne Université, Université de Paris, Paris, France

We performed discrete element model simulations to investigate the rheology of a realistic 3-dimensional frictional granular material consisting of elongated particles. Such systems develop orientational or-

dering when exposed to shear flow. The degree of this ordering depends on the interparticle friction and particle elongation in a non-trivial manner. Namely, the shear induced orientational ordering is in principle increasing with particle elongation, but the characteristics of collisional and frictional interactions between neighbours (which hinder each others rotation) changes with the interparticle friction coefficient. We measured how key rheological quantities, including effective friction and normal stress differences depend on these two key parameters. We found that the aspect ratio dependence of the effective friction is non-monotonic not only for frictionless particles as we saw earlier, but also for frictional particles up to interparticle friction coefficient $\mu_p \lesssim 0.4$, – a range already relevant for every day materials. For higher μ_p the effective friction is monotonically increasing. We can explain the microscopic origins of both the non-monotonic behaviour for small and intermediate μ_p and the monotonic one for large μ_p.

DY 13.5 Mon 16:20 DYc

Migrating shear bands in shaken granular matter — Joelle Claussen[1], Stefan Gerth[1], Jonathan E. Kollmer[2,3,4], Thorsten Pöschel[3], Michael Salamon[1], •Matthias Schröter[3,5], Tara Shreve[3,6], and Norman Uhlmann[1] — [1]Fraunhofer-Entwicklungszentrum Röntgentechnik, Flugplatzstr. 75, 90768 Fürth, Germany — [2]Experimentelle Astrophysik, Universität Duisburg-Essen, Lotharstr. 1-21, 47057 Duisburg, Germany — [3]Institute for Multiscale Simulation of Particulate Systems, Cauerstr. 3, 91058 Erlangen, Germany — [4]Dept. of Physics, 2401 Stinson Drive, North Carolina State University, Raleigh, NC 27695, USA — [5]Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany — [6]Université de Paris, Institut de physique du globe de Paris, CNRS, F-75005, Paris, France

When dense granular matter is sheared, the strain is often localized in shear bands. After some initial transient these shear bands become stationary. Here we introduce a setup that periodically creates horizontally aligned shear bands which then migrate upwards through the sample. Using X-Ray radiography we demonstrate that this effect is caused by dilatancy, the reduction in volume fraction occurring in sheared dense granular media. Further on, we argue that these migrating shear bands are responsible for the previously reported periodic inflating and collapsing of the material.

Ref.: Kollmer *et al.* Phys. Rev. Lett. 125, 048001 (2020)

DY 13.6 Mon 16:40 DYc

Force chains in granular packings visualized by stress-birefringent spheres — •David Fischer[1], Karsten Tell[2], Peidong Yu[2], Matthias Sperl[2], and Ralf Stannarius[1] — [1]Otto-von-Guericke-Universität, Institut für Physik, Abteilung Nichtlineare Phänomene, Magdeburg — [2]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Materialphysik im Weltraum, Köln

Force networks play an important role in the stability of granular packings. These networks are able to redirect part of the particle weight inside a container to the side walls, leading to pressure saturation in a certain depth below the granular surface. We employ monodisperse stress-birefringent spheres embedded in an immersion fluid to visualize the contact forces and force network structure of spheres in a quasi-2D and a nearly-2D cuboid cell. A load at the top prevents floating of the spheres caused by buoyancy. In both cell types, an "inverse" Janssen effect is observed, with the pressure decreasing from the top to the bottom of the container.

DY 13.7 Mon 17:00 DYc

Intermittent flow and transient congestions of soft low-friction spheres in silo discharge — •Jing Wang[1], Kirsten Harth[1], Ralf Stannarius[1], and Tamas Börzsönyi[2] — [1]Institute of Physics, Otto von Guericke University, Magdeburg, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Center for Physics, Budapest, Hungary

During discharge of hard particles from a silo with a small orifice at the bottom, grains flow freely only when the orifice size at least 5 times the particle diameter. The outflow rate is practically independent of the fill level. Below a certain outlet diameter, hard particles reach stable clogs, which can only be destroyed by external forcing. We study soft, low-friction particles (hydrogel beads) that show very different, peculiar features during discharge: They flow freely even when the orifice is only slightly larger than two particle diameters. At small orifice sizes, strong fluctuations of the flow velocity set in. Non-permanent congestions are characteristic that have previously been described only for lifestock or pedestrians passing narrow gates or exits, but never for inanimate hard granular material. We present experimental data recorded in a 2D silo.

This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 812638 and DFG Grant HA8467/2-1. [1] K. Harth et al., Soft Matter 16 8013 (2020).

DY 14: Microfluidics and Droplets - organized by Uwe Thiele (Münster)

Time: Monday 16:00–18:00 Location: DYa

DY 14.1 Mon 16:00 DYa

Near-field acoustic manipulation in a confined evanescent Bessel beam — •Pierre-Yves Gires[1,2] and Cédric Poulain[2,3] — [1]University Grenoble Alpes, CEA LETI — [2]University of Bayreuth, Experimental Physics I — [3]University Grenoble Alpes, CNRS, Grenoble INP, Institut Néel

Microparticles such as cells can be manipulated in a suspension by the application of an ultrasonic acoustic field. Following the path taken in the development of optical tweezers, we demonstrate the potential of working in the evanescent regime, with both sub-wavelength confinements and resonators [1]. We generate an evanescent acoustic Bessel beam in liquid above a thin, circular, axisymmetrically excited plate. In the sub-MHz domain, the resulting radiation force causes the particles to assemble at the pressure antinodes along concentric circles corresponding to the Bessel profile. By imposing an axial confinement in the evanescent region, the sub-wavelength two-plate sandwich system becomes resonant, increasing the radiation force magnitude. Resonances occur for some well-defined gaps for which whole numbers of antinodal circles are observed. Through fine tuning, particles as small as bacteria can be patterned. Further amplification can be obtained by trapping a microbubble in the Bessel beam axis. [1] Pierre-Yves Gires and Cédric Poulain. Near-field acoustic manipulation in a confined evanescent bessel beam. Communications Physics, 2(1):1-8, 2019

DY 14.2 Mon 16:20 DYa

Actuation of soft particles in oscillating Poiseuille flow — •Winfried Schmidt[1], Sebastian W. Krauss[2], Andre Förtsch[1], Matthias Laumann[1], Matthias Weiss[2], and Walter Zimmermann[1] — [1]Theoretische Physik 1, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Experimentalphysik 1, Universität Bayreuth, 95440 Bayreuth, Germany

What is the dynamical behavior of soft particles in oscillatory (pulsating) Poiseuille flow at low Reynolds number? By investigating the overdamped motion of 2D bead-spring models, as well as 3D capsules and red blood cells, we predict particle actuation in the case of vanishing mean flow. This effect is generic as it does not depend on the model. We show that symmetric particles propagate for asymmetric flow oscillations with non-equal flow sections. The mean actuation (swim) velocity of a particle is caused by its varying shape in both parts of the flow period. Since the actuation steps depend also on the size and the rigidity of soft particles, this novel actuation (passive swimming) mechanism is also appropriate for particle sorting.

DY 14.3 Mon 16:40 DYa

Two orders of magnitude boost in the detection limit of droplet-based micro-magnetofluidics — •Julian Schütt[1], Rico Illing[1], Oleksii Volkov[1], Tobias Kosub[1], Pablo Nicolás Granell[1,2], Hariharan Nhalil[3], Jürgen Fassbender[1], Lior Klein[3], Asaf Grosz[4], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]Escuela de Ciencia y Tecnología, UNSAM, Buenos Aires, Argentina — [3]Department of Physics & Institute of Nanotechnology and Advanced Materials, Bar-Ilan University, Israel — [4]Department of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Israel

The detection of magnetic nanoparticles is of major importance in biomedical and biological applications. Here, the trend goes to-

wards improvements of state-of-the-art methods in the spirit of high-throughput analysis at ultra-low volumes. Microfluidics addresses these requirements as it deals with the control and manipulation of liquids in confined microchannels. Sensor elements utilizing the planar Hall Effect (PHE) are exceptionally suited for this conjunction and were already applied in continuous flow microfluidics. We present a sensing strategy relying on PHE sensors in digital microfluidics for the detection of a multiphase liquid flow. We show the detection of nanoliter-sized superparamagnetic droplets with a concentration of 0.58mg/cm3, biased in a geomagnetic field, down to 0.04mg/cm3 in a magnetic field of 5mT. We are convinced that the tracking of microfluidic droplets can greatly contribute to state-of-the-art magnetoresistive sensing with dramatic downscaling of the analyzed volume.

DY 14.4 Mon 17:00 DYa

Theoretical and numerical investigation of an EWOD-driven micro pump — •Sebastian Bohm and Erich Runge — Technische Universität Ilmenau, Theoretische Physik 1, Weimarer Straße 25, 98693 Ilmenau

We show how the EWOD (electrowetting-on-dielectric) effect can be used to realize a micro pump that uses no moveable components at all, as described in [1]. The flow is generated due to the periodic movement of liquid-vapor interfaces in a large number ($\approx 10^6$) of microcavities ($\Delta V \approx 1pl$ per cavity). The total flow resulting from all microcavities adds up to a few hundred nanolitres per cycle. Tesla-Diodes are used as valves to completely forgo on moving parts.
The theoretical description of the pumping mechanism is a challenge due to the coupling of the fluid- and electrodynamics and the intrinsic multi-scale character of the system. The flow in each microcavity can be modelled as multiphase flow with time-dependent wetting properties as boundary conditions. The optimization of the Tesla diodes is also a challenge, as they must produce a reasonable valve action even at small Reynold numbers, which are typical for microfluidics.
A novel time-efficient simulation method for the calculation of the static interface shapes of a liquid-vapor interface in electric fields is presented. With this method, the voltage-dependent volume stroke can be determined efficiently. Topological optimization methods for the design of the Tesla-Diodes are shown. Finally, possibilities for the time-resolved simulation of the entire pumping system are discussed.
[1] Hoffmann, M., Dittrich, L., Bertko, M.; DE11 2011 104 467 (2012)

DY 14.5 Mon 17:20 DYa

Anchoring-dependent flow bifurcation in nematic microflows within circular capillaries — •Paul Steffen[1], Eric Stellamanns[2], and Anupam Sengupta[1] — [1]Physics of Living Matter, Dept. of Physics and Materials Science, University of Luxembourg, Luxembourg — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany

Capillary microflows of liquid crystal (LC) phases are fundamental to biological and bio-inspired systems. Here we investigate stationary flows of nematic LC within circular capillaries under homeotropic (normal) and uniform planar anchoring conditions, using numerical simulations based on the continuum theory of Leslie, Ericksen and Parodi for the material parameters of 5CB, a single component flow-aligning nematic LC. Instead of the expected unique solution with a director field monotonously approaching the alignment angle for increasing Ericksen numbers, we report a second anomalous solution that emerges above a threshold flow rate, leading to an anchoring-dependent flow bifurcation. For homeotropic surface anchoring, the anomalous director field orients against the alignment angle in the vicinity of the pipe center; while in the uniform planar case, the anomalous director field extends throughout the capillary volume, leading to reduction of the flow speed for increasing pressure gradients. Experimental signatures of the second solutions in each case are found in authors's experimental results, reported previously in Phys. Rev. Lett. 110, 048303, 2013 (homeotropic) and Int. J. Mol. Sci. 14, 22826, 2013 (planar case).

DY 14.6 Mon 17:40 DYa

Characterizing the speed, size and shape of droplets during their flight from an ultrasonic spray coater — •Pieter Verding[1,2], Wim Deferme[1,2], and Werner Steffen[3] — [1]Hasselt University Institute for Materials Research, Diepenbeek, Belgium — [2]IMEC, Diepenbeek,Belgium — [3]Max-Planck-Institut for Polymer research, Mainz, Germany

Ultrasonic spray coating - USSC is a technology offering numerous possibilities, such as depositing ultrathin homogeneous layers up to 20 nm on large scale. However, its application is limited due to the many process parameters which have a large impact on the quality of the coating. For this reason, measuring the droplet size, speed and concentration during the flight from the ultrasonically generated droplet to the substrate, gives insight in how to tune these parameters. Because thousands of droplets are created at the same time, measuring the properties of the droplets during flight is a complicated task. Three different measurement techniques have been developed in and around an USSC setup. Dynamic Light Scattering (DLS) shows, after Fourier transformation, shifted peaks, representing the speed of the droplets. By applying Turbidimetry, it is possible to determine the size of the droplets. Droplets size and speed could be measured and gave comparable results as measured with a High Speed Camera (HSC). Furthermore, it was shown that the size and velocity of the droplets depend on the process parameters. It is therefore concluded from this work that a combination of DLS and Turbidimetry is a valuable alternative to measure droplets during their flight from an USSC.

DY 15: Invited Talk: Liesbeth Janssen (Eindhoven)

Time: Monday 16:00–16:30 Location: DYb

Invited Talk DY 15.1 Mon 16:00 DYb

Glassy physics: from liquids to living cells — •Liesbeth Janssen — Eindhoven University of Technology, The Netherlands

The liquid-to-glass transition is a ubiquitous yet highly complex phenomenon, which still lacks a universal physical understanding. In this talk I will share some recent progress on the development and application of so-called Generalized Mode-Coupling Theory–a framework that aims to predict glassy dynamics purely from first principles. I will demonstrate that the theory can be applied not only to ordinary glass-forming materials, but also to more complex systems such as dense collectives of living cells.

DY 16: Statistical Physics 3 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)

Time: Monday 16:30–17:50 Location: DYb

DY 16.1 Mon 16:30 DYb

Aging in the Long-Range Ising Model — •Henrik Christiansen[1], Suman Majumder[1], Malte Henkel[2,3,4], and Wolfhard Janke[1] — [1]Institut für Theoretische Physik, Universität Leipzig, IPF 231101, 04081 Leipzig, Germany — [2]Laboratoire de Physique et Chimie Théoriques (CNRS UMR 7019), Université de Lorraine Nancy, 54506 Vandœuvre-lès-Nancy Cedex, France — [3]Centro de Física Teórica e Computacional, Universidade de Lisboa, 1749-016 Lisboa, Portugal — [4]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

The current understanding of aging phenomena is mainly confined to the study of systems with short-ranged interactions. Little is known about the aging of long-ranged systems. Here, the aging in the phase-ordering kinetics of the two-dimensional Ising model with power-law long-range interactions is studied via Monte Carlo simulations. The dynamical scaling of the two-time spin-spin autocorrelator is well de-

scribed by simple aging for all interaction ranges studied. The autocorrelation exponents are consistent with $\lambda = 1.25$ in the effectively short-range regime, while for stronger long-range interactions the data are consistent with $\lambda = d/2 = 1$. For very long-ranged interactions, strong finite-size effects are observed. We discuss whether such finite-size effects could be misinterpreted phenomenologically as sub-aging.

[1] H Christiansen, S Majumder, W Janke, Phys. Rev. E 99, 011301(R) (2019)
[2] H Christiansen, S Majumder, M Henkel, W Janke, Phys. Rev. Lett. 125, 180601 (2020)

DY 16.2 Mon 16:50 DYb

Ageing and linear response in a mean field elastoplastic model — •Jack T. Parley[1], Suzanne M. Fielding[2], and Peter Sollich[1,3] — [1]Institut für Theoretische Physik, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Science Laboratories, Department of Physics, Durham University, South Road, Durham DH1 3LE, United Kingdom — [3]Department of Mathematics, King's College London, London WC2R 2LS, United Kingdom

Elastoplastic descriptions, based on the alternating elastic/plastic deformation of mesoscopic regions, provide key insights into the complex dynamics of athermal amorphous solids. These systems have recently also been found to display non-trivial ageing dynamics, driven by plastic events and the ensuing Eshelby (quadrupolar) stress redistribution. Here we construct a mean-field elastoplastic model for studying time-dependent perturbations and ageing dynamics, building on the work of Lin and Wyart (2016) for steady shear. Local stresses are driven by power-law distributed mechanical noise, characterised by the exponent μ. We study the ageing behaviour in the glassy regime, where the form of the yield rate decay varies for different values of the exponent μ, reflecting the relative importance of far-field and near-field events as the range of the stress propagator is varied. Moreover, a comparison of the mean-field predictions with ageing simulations of a lattice elastoplastic model shows excellent agreement. Finally, we obtain expressions for the linear stress response in the ageing regime, which will allow to test the theoretical predictions against stress measurements from experiments or simulations of model athermal systems.

DY 16.3 Mon 17:10 DYb

Evaluation of memory effects at phase transitions — •Hugues Meyer — Department of Theoretical Physics and Center for Biophysics, Universität des Saarlandes, Saarbrücken, Germany

Modeling the dynamics of order parameters at phase transitions is often done in terms of stochastic equations of motion but there is to this day no consensus about a systematic strategy to tackle this problem. In particular, the detailed structure of the equations that needs to be used is still debated. Motivated by recent works on crystal nucleation, we propose to describe the dynamics of phase transitions in terms of a non-stationary Generalized Langevin Equation for the order parameter. By construction, this equation is non-local in time, i.e. it involves memory effects whose intensity is governed by a memory kernel. Here we do not aim at investigating the physical origin of memory effects at phase transitions in general, but rather to relate the extent of the memory kernel to quantities that are experimentally observed such as the induction time and the duration of the phase transformation process. Using a simple kinematic model and a recently developed numerical procedure, we show that the extent of the memory kernel is positively correlated with the duration of the transition and of the same order of magnitude, while the distribution of induction times does not have an effect. This theoretical observation is finally tested at the example of several model systems.

DY 16.4 Mon 17:30 DYb

Emergent memory and kinetic hysteresis in strongly driven networks — •David Hartich and Aljaz Godec — MPI BPC, Göttingen, Germany

Stochastic network-dynamics are typically assumed to be memoryless. Involving prolonged dwells interrupted by instantaneous transitions between nodes such Markov networks stand as a coarse-graining paradigm for chemical reactions, gene expression, molecular machines, spreading of diseases, protein dynamics, diffusion in energy landscapes, epigenetics and many others. However, as soon as transitions cease to be negligibly short, as often observed in experiments, the dynamics develops a memory. That is, state-changes depend not only on the present state but also on the past. Here, we establish the first thermodynamically consistent mapping of continuous dynamics onto a network, which reveals ingrained dynamical symmetries and an unforeseen kinetic hysteresis [1]. These symmetries impose three independent sources of fluctuations in state-to-state kinetics that determine the 'flavor of memory'. The hysteresis between the forward/backward in time coarse-graining of continuous trajectories implies a paradigm shift for the thermodynamics of active molecular processes beyond the assumption of local detailed balance. Our results provide a new understanding of fluctuations in the operation of molecular machines as well as catch-bonds involved in cellular adhesion.

[1] DH, A Godec, arXiv:2011.04628 (2020).

DY 17: Complex Fluids - organized by Christine M. Papadakis (Technical University of Munich, Garching) (joint session CPP/DY)

Time: Tuesday 9:00–16:30 Location: CPPb

Invited Talk DY 17.1 Tue 9:00 CPPb

Polymer Micelles with Crystalline Cores: confinement effects, molecular exchange kinetics and mechanical response — Nico Koenig[1], Lutz Willner[2], and •Reidar Lund[1] — [1]Department of Chemistry, University of Oslo, Postboks 1033 Blindern, 0315 Oslo, Norway. — [2]Jülich Centre for Neutron Science JCNS and Institute for Complex Systems ICS,

Partially crystalline, self-assembling systems with multiple components are omnipresent in nature with living cells as a prominent example. Here we study micelles formed by self-assembly of a series of well-defined n-alkyl-(polyethylene oxide) (Cn-PEO) polymers in aqueous solutions [1]. Using small-angle X-ray/neutron scattering (SAXS/SANS), densiometry and differential scanning calorimetry (DSC), we show that the n-alkane exhibit a first-order phase transition in the micellar cores, but with reduced melting points accurately described by the Gibbs-Thomson equation [2]. The effect of core crystallinity on the molecular exchange kinetics is investigated using time-resolved SANS (TR-SANS) [3-9]. We show that the melting transition is cooperative in the confined micellar core, whereas the exchange process is decoupled and unimeric in nature. [9] Telechelic polymers based on Cn-PEO-Cn forms clustered micelles and hydrogels composed of interconnected micelles at higher concentrations.[10] The results show that, contrary to regular micelles, the kinetics occurs in a multistep process involving a novel collision-induced single-molecule exchange mechanism.[11] Morever exchange kinetics directly controls the mechanical response of hydrogels through the bond life time [12]

DY 17.2 Tue 9:40 CPPb

Foams stabilized by PNIPAM microgels — •Matthias Kühnhammer, Christian Appel, and Regine von Klitzing — Technical University of Darmstadt, Department of Physics, Soft Matter at Interfaces, 64287 Darmstadt, Germany

Cross-linked, short-chained poly-N-isopropylacrylamide (NIPAM) polymers have been in the focus of numerous studies in the past years and are still being discussed very actively in the context of multiple possible applications, because of their ability to respond to external stimuli. Because of their amphiphilic character, PNIPAM microgels can be used to stabilize dispersions like emulsions or foams.

In this contribution microgel stabilized foams are investigated. These foams are very stable at temperatures below the volume phase transition temperature (VPTT) of NIPAM and can be destabilized by increasing the temperature above the VPTT. The structure of the microgels inside the foam lamellae is investigated with neutron scattering. These results are compared to the organization of microgels at a single gas / water interface, which is studied with Langmuir isotherms and X-ray reflectivity.

Finally, these findings are related to macroscopic properties of the foams, namely foamability and foam stability.

DY 17.3 Tue 10:00 CPPb

Functional, responsive microgels enlightened with super-resolution fluorescence microscopy — •Dominik Wöll, Laura Hoppe Alvarez, Eric Siemes, Ashvini Purohit, and Silvia Centeno Benigno — Institut für Physikalische Chemie, RWTH Aachen University, Landoltweg 2, 52074 Aachen

The elucidation of the structure and functionalization of materials in the sub-micron range is a key to their further development and application. Microgels are a class of such soft materials with high potential for multiple fields. Several groups have learnt to functionalize and structure microgels in sophisticated ways, but the evaluation of a successful functionalization or the envisioned properties are often limited by the ways of analysis and visualization. The development of modern super-resolved fluorescence microscopy methods opened up new ways of nanoscopic visualization that had not been possible previously due to the diffraction limit of light prohibiting spatial resolution beyond approx. 200 nm. In my contribution, the possibilities to elucidate shape and functionalization, to visualize single cross-linker positions and to address local polarity in microgels with 3D super-resolution fluorescence imaging will be discussed, and ways presented to address and answer scientific questions in soft matter science.

40 min. meet the speakers - break

Invited Talk DY 17.4 Tue 11:00 CPPb

Dynamic behaviour of anisotropic magnetic particles in suspensions — •Sofia Kantorovich — University of Vienna — Ural Federal University

Stable dispersions of magnetic colloidal particles with sizes ranging from nanometers to couple of microns have been actively studied for several decades and the interest to them seems to keep growing. Such an attention to these systems is paid because of several reasons: they are biocompatible, can be remotely controlled by external magnetic fields and new synthesis techniques enable a rich variety of particle morphologies. In classical magnetic fluids with spherical polydisperse nanoparticles, dominating dipolar interactions typically limit the structural complexity of their aggregates to linear arrangements, namely chains, rings and branched structures. In this contribution I will show, how to either alter the shape of magnetic particles or their internal structure in order to extend dramatically the topology and properties of their suspensions. In particular I will focus on magnetic cubes, magnetic Janus particles, soft magnetic colloids and magnetically anisotropic nanoparticles. I will show how lattices, branched clusters of staggered chains, compact clusters, linear chains, and non aggregated configurations can be formed and interconverted reversibly in a controlled way. I will also discuss how adding an active component to magnetically anisotropic particles leads to unique properties. The results gathered in this presentation demonstrate that fundamentally new possibilities for responsive magnetic materials can arise when we step away from conventional dipolar hard spheres.

DY 17.5 Tue 11:40 CPPb

Graphical Magnetogranulometry — •Ingo Rehberg, Reinhard Richter, and Stefan Hartung — Bayreuth University

The dipole strength of magnetic particles in a colloidal suspension can be obtained by a graphical rectification of the magnetization curves based on the inverse Langevin function. The method [1] yields the arithmetic and the harmonic mean of the particle distribution. It has an advantage compared to the fitting of magnetization curves to some appropriate mathematical model: It does not rely on assuming a particular distribution function of the particles.

[1] Measuring magnetic moments of polydisperse ferrofluids utilizing the inverse Langevin function, Ingo Rehberg, Reinhard Richter, Stefan Hartung, and Niklas Lucht, Birgit Hankiewicz, and Thomas Friedrich, Phys. Rev. B 100, 134425 (2019).

DY 17.6 Tue 12:00 CPPb

Phase Behavior of Charged Magnetic Nanoplatelets — •Margaret Rosenberg[1] and Sofia Kantorovich[1,2] — [1]Department of Physics, University of Vienna, Austria — [2]2Department of Mathematical Physics, Ural Federal University, Russia

Recent decades have seen the emergence of a new branch of science, magnetic soft matter, fueled by the advances in synthesis techniques, which have also made a wide variety of anisotropic magnetic colloidal nanoparticles available. Colloidal anisometry can be used as an effective control parameter to tune both self-assembly scenarios and thermodynamic, rheological and phase behavior of dipolar (magnetic) soft matter. For instance, magnetic nanoplatelets can form macroscopic ferromagnetic phases at room temperature. Although the phase behavior of a system hard-core platelets is well known, the influence of the magnetic dipole moment and electrostatic repulsion on suspensions of magnetic platelets is not yet fully understood. We use MD simulations to recreate such a system. The colloidal particles are modelled by charged soft spheres, with a central dipole possessing a magnetic moment of a constant length, permanently oriented perpendicular to the platelet surface. In order to investigate the self-assembly and structural properties of the platelets, we vary the amplitude of an applied magnetic field and the magnetic dipole. We analyze at which electrostatic conditions the system exhibits self-assembly or/and field alignment, based on RDFs, structure factors parallel and perpendicular to the field and extensive cluster analysis.

DY 17.7 Tue 12:20 CPPb

Magnetically Functionalized Star Polymers in Equilibrium and under Shear — •Gerhard Kahl[1], David Toneian[1], and Christos N. Likos[2] — [1]Institut für Theoretische Physik, TU Wien — [2]Fakultät für Physik, Universität Wien

Star polymers are macromolecules consisting of a central site, attached to which are a number f of linear polymer chains, called arms. Depending on the chemical composition of the arms, the polymer stars exhibit intriguing features, both in isolation and in concentrated solution.

We present star polymers with magnetically functionalized end groups as a novel polymeric system whose morphology, self-aggregation and orientation can easily be tuned by exposing these macromolecules simultaneously to an external magnetic field and to shear forces within a channel. Our investigations are based on a specialized simulation technique which faithfully takes into account the hydrodynamic interactions of the surrounding, Newtonian solvent. We find that the combination of magnetic field (including both strength and direction) and shear rate controls the mean number of magnetic clusters, which in turn is largely responsible for the static and dynamic behavior. While some properties are similar to comparable non-magnetic star polymers, others exhibit novel phenomena; examples of the latter include the breakup and reorganization of the clusters beyond a critical shear rate and a strong dependence of the efficiency with which shear rate is translated into whole-body rotations on the direction of the magnetic field.

DY 17.8 Tue 12:40 CPPb

Structural details of polymer grafted nanoparticles: Insights from coarse-grained molecular dynamics simulations — •Jiarul Midya[1], Michael Rubinstein[2], Sanat K. Kumar[3], and Arash Nikoubashman[1] — [1]Johannes Gutenberg University of Mainz, Mainz, Germany — [2]Duke University, Durham, United States — [3]Columbia University, New York, United States

Polymer grafted nanoparticles (GNPs) are promising materials with a wide range of applications in drug delivery, gas separation, photonic and electric materials. In this work, the structural properties of GNPs are studied via coarse-grained molecular dynamics simulations. We systematically vary the degree of polymerization at fixed grafting density, and study in detail the shape and size of the GNPs, the interpenetration between the grafted polymers and their conformations. We then compare these properties to the ones of pure polymer melts to assess the effect of confinement. We observe that the amount of chain-sections in the interpenetration zone is proportional to the length of the grafted chains, N_g, whereas, the brush height follows a power-law like behavior $h \sim N_g^{\alpha}$, where exponent α decreases from a value close to one to the limiting value of 1/3 with the increase of N_g. To understand the scaling behavior of h we provide an empirical form, involving the length of the grafted polymers and the core size of the GNPs, which explains our simulation results.

60 min. meet the speakers - break

DY 17.9 Tue 14:00 CPPb

Charge regulation radically modifies electrostatics in membrane stacks — •Arghya Majee[1], Markus Bier[1,2], Ralf Blossey[3], and Rudolf Podgornik[4] — [1]MPI for Intelligent Systems, Stuttgart & University of Stuttgart, Germany — [2]University of Applied Sciences, Würzburg-Schweinfurt, Germany — [3]University of Lille, CNRS, UMR8576 UGSF, France — [4]CAS & KAVLI Institute of Theoretical Sciences, Beijing

Motivated by biological membrane-containing organelles in plants and photosynthetic bacteria, we study charge regulation in a model membrane stack [1]. Considering (de)protonation as the simplest mechanism of charge equilibration between the membranes and with the bathing environment [2], we uncover a symmetry-broken charge state in the stack with a quasiperiodic effective charge sequence. In the case of a monovalent bathing salt solution, our model predicts complex, inhomogeneous charge equilibria depending on the strength of the (de)protonation reaction, salt concentration, and membrane size. Our results shed light on the basic reorganization mechanism of thylakoid membrane stacks.

References:

[1] A. Majee, M. Bier, R. Blossey, and R. Podgornik, Phys. Rev. E **100**, 050601(R) (2019).

[2] A. Majee, M. Bier, and R. Podgornik, Soft Matter **14**, 985 (2018).

DY 17.10 Tue 14:20 CPPb

Emulsion destabilisation by squeeze flow — •Riande Dekker, Antoine Deblais, and Daniel Bonn — Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

There is a large debate on the destabilisation mechanism of emulsions. We present a simple technique using mechanical compression to destabilise oil-in-water emulsions while at the same time confocal microscopy allows to visualise the mechanism directly. Upon compression of the emulsion, the continuous aqueous phase is squeezed out, while the dispersed oil phase progressively deforms from spherical to honeycomb-like shapes. The liquid films that separate the oil droplets are observed to thin and break at a critical oil/water ratio, leading to coalescence events that destabilise the emulsion. The destabilisation occurs like an avalanche propagating through the system. Local rearrangements occur after the fist destabilisation due to the fist coalescence event. The films participating in the cascade are the finest ones.

DY 17.11 Tue 14:40 CPPb

Impact of hydrogen bonding strength on the structure and dynamics of supramolecular PEO — •Ana Brás[1], Ana Arizaga[1], Uxue Agirre[1], Marie Dorau[1], Patricia Bach[1], Judith E. Houston[2,3], Aurel Radulescu[3], Margarita Kruteva[4], and Annette M. Schmidt[1] — [1]UzK, Cologne, Germany — [2]ESS, Lund, Sweden — [3]FZJ, Garching, Germany — [4]FZJ, Jülich, Germany

In this work we investigate supramolecular poly(ethylene oxide) (PEO) oligomers at the entanglement molar mass (Me) with different hydrogen bonding end groups, such as diaminotriazine (Dat) and thymine-1- acetic acid (Thy), as well as 2-ureido-4[1H]-pyrimidinone (Upy). Small angle scattering and rheology were combined to study the influence of different end-groups association strength as Upy is highly self-associative in comparison to the heterocomplementary pair Thy/Dat. Results on the structure provide insight into the underlying molecular mechanisms and reveal that while Upy-terminated chains phase segregate, forming network-like systems, the Thy/Dat pair-terminated system self-assemble to linear chains, thereby increasing the effective chain length. Moreover, rheological measurements also reveal differences in the viscoelastic response as Upy-terminated chains exhibit an extended rubbery plateau, typical of networks, and the pair Thy/Dat presents a Newtonian fluid behaviour. Remarkably, albeit both systems show end-group association, different hydrogen bonding species influence the type of associates. Acknowledgements: DFG for a research grant (BR5303) and Prof. Dr. D. Richter, Prof. Dr. R. Strey and Dr. Wim Pyckhout-Hintzen for fruitful discussions.

DY 17.12 Tue 15:00 CPPb

Structural characterization and rheology of biocompatible wormlike micelles - comparing experiment and theory — •Benjamin von Lospichl[1,2], Sabine H. L. Klapp[2], and Michael Gradzielski[1] — [1]Institut für Chemie, Technische Universität Berlin, Straße des 17. Juni 124, D-10623 Berlin — [2]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin

Wormlike micelles exhibit a unique viscoelastic behaviour, which has been investigated intensely in the past decades by experimentalists and theoreticians [1,2]. Within our studies we explore the self-assembled structures and the flow behaviour of biocompatible wormlike micelles, which are a mixture of a short-chained C_8 cationic surfactant and the salts of long-chained C_{18} to C_{22} omega-9 fatty acids. The variation of the omega-9 fatty acids yields a change in thickness of the micelles, which strongly influences the flowing properties of the system. To characterize the size distribution and the relaxation time of the micellar solutions we use neutron scattering, rheology and electric birefringence. The obtained experimental results are then quantitatively compared to an established theoretical model describing the dynamics of micelles under shear. The model links mechanical properties such as stress to structural quantities like alignment or micellar length [3].

[1] C. Dreiss, Soft Matter **3**, 956, (2007)

[2] P. D. Olmsted, Rheo. Acta **47**, 283, (2008)

[3] B. v. Lospichl, S. H. L. Klapp, Phys. Rev. E **98**, 042605, (2018)

DY 17.13 Tue 15:20 CPPb

Light driven passive and active motion of colloidal particles — •Pooja Arya, David Feldmann, and Svetlana Santer — University of Potsdam, Potsdam, Germany

We report on how one can manipulate an ensemble of colloidal particles trapped at a solid/liquid interface during irradiation with light of different wavelengths. The colloids are dispersed in an aqueous solution of photosensitive azobenzene containing cationic surfactant, which can photo-isomerize from trans to cis state under irradiation with light of appropriate wavelength. When focused light is applied, light-driven diffusioosmotic (LDDO) flow1 is generated at the solid/liquid interface resulting in a passive motion of particles within this flow. Utilizing the same LDDO mechanism one can also induce active motion of porous particles. Here the radially directed flow is generated by and around a single porous colloid when it is irradiated with either UV or blue light. This results in either mutual long-range diffusioosmotic repulsion of the particles or in even self-propelled motion when the colloids are turned into a Janus-like shape. Here, we discuss how to extend of passive and active motion of colloidal particles depends on the irradiation conditions such as wavelengths and intensities of light.

1.*Feldmann, D.; Maduar S.R.; Santer, M.; Lomadze, N.; Vinogradova, O.I.; Santer, S., Scientific Reports 6 (2016) 36443

50 min. meet the speakers - break

DY 18: Invited Talk: Andreas Zöttl (Vienna)

Time: Tuesday 9:00–9:30 Location: DYa

Invited Talk DY 18.1 Tue 9:00 DYa

Reinforcement learning of microswimmer chemotaxis using genetic algorithms — •Andreas Zöttl, Benedikt Hartl, Maximilian Hübl, and Gerhard Kahl — TU Wien

Many bacteria and eukaryotic cells are able to move in viscous fluids by performing nonreciprocal body deformations, such as rotating attached flagella or by distorting their entire body. In order to perform chemotaxis, i.e. to move towards and to stay at high concentrations of nutrients, they adapt their swimming gaits in a nontrivial manner.

We propose a model how microswimmers are able to autonomously adapt their shape in order to swim towards high field concentrations using an internal decision making machinery modeled by an artificial neural network. We present two methods to measure chemical gradients, spatial and temporal sensing. Surprisingly simple neural networks evolve by using the NEAT genetic algorithm which control the shape deformations of the microswimmer and allows them to navigate in static and complex time-dependent chemical environments [1]. By including noisy signal transmission in the neural network the well-known biased run-and-tumble motion emerges. Our work demonstrates that the evolution of a simple internal decision-making machinery, which we can fully interpret and is coupled to the environment, allows navigation in diverse chemical landscapes. These findings are of relevance for sensing mechanisms of single cells, or for the simple nervous system of small multicellular organisms such as C. elegans.

[1] B. Hartl, M. Hübl, G. Kahl, and A. Zöttl, under review (2021).

DY 19: Statistical Physics 4 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)

Time: Tuesday 9:00–10:40 Location: DYb

DY 19.1 Tue 9:00 DYb

Universal properties of creep flow — •Marko Popovic[1,2], Tom de Geus[1], Wencheng Ji[1], Alberto Rosso[3], and Matthieu Wyart[1] — [1]Institute of Physics, EPFL, Lausanne — [2]MPI-PKS, Dresden — [3]LPTMS, CNRS, Univ. Paris-Sud, Universite-Saclay, 91405 Orsay, France

Amorphous solids, such as atomic glasses, colloidal suspensions, granular matter or foams, begin to deform plastically when exposed to external stress Σ. Steady state flow of these materials in absence of thermal fluctuations is usually described as $\dot{\epsilon} \sim (\Sigma - \Sigma_c)^\beta$ for stresses above critical stress Σ_c and vanishes below. In presence of thermal fluctuations flow persists below Σ_c but is exponentially suppressed. The transient plastic deformation, called creep flow, is much less understood despite its importance in practical applications. Creep flow often displays a power-law decay in time $\dot{\epsilon} \sim t^{-\mu}$ after which it can either arrest or yield at fluidisation time τ_f. Recently, various numerical values and laws have been suggested for μ and τ_f in experimental or numerical studies. We propose that the creep flow parameters μ and τ can be expressed in terms of the steady state flow parameters, both in athermal and thermally activated systems. We successfully tested all our predictions using different mesoscopic elasto-plastic models of amorphous solids and found them to be consistent with published experimental results.

DY 19.2 Tue 9:20 DYb

Universality of photon counting below a local bifurcation threshold — •Lisa Arndt and Fabian Hassler — JARA-Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany

At a bifurcation point, a small change of a parameter causes a qualitative change in the dynamics of the system. Quantum fluctuations wash out this abrupt transition and enable the emission of photons below the classical bifurcation threshold. Close to the bifurcation point, the resulting photon counting statistics is determined by the instability. This talk discusses a generic method to derive a characteristic function of photon counting close to a bifurcation threshold that only depends on the dynamics and the type of bifurcation, based on the universality of the Martin-Siggia-Rose action. The method is exemplified for the cusp catastrophe without conservation laws, which can be implemented by an experimental setup using driven Josephson junctions.

DY 19.3 Tue 9:40 DYb

Fermionic Criticality Out-of-Equilibrium — •Bernhard Frank and Francesco Piazza — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

Coupling critical bosons to a Fermi surface provides a standard route for the formation of a non-Fermi liquid: Its correlation functions do not show features of Landau quasiparticles but exhibit anomalous power laws, which give rise to substantial deviations from Fermi liquid results. So far these systems have been extensively studied in thermal equilibrium, for instance in the context of strange metals. However, recent experiments combine semi-conductor devices with optical cavities and therefore mandatorily require a theoretical formulation that takes into account the intrinsically open nature of the photonic sector in order to understand the electronic many-body physics. In particular, associating the photon with the critical bosonic mode leads to non-Fermi liquids out-of-equilibrium. Here, we use Keldysh field theory to study the paradigmatic Ising-nematic model in two-dimensions within a simple driven-dissipative setup. Compared to the situation in the ground state one observes increased decay rates in the low-energy sector of the fermionic spectrum as well as a violation of the thermal fluctuation dissipation relation caused by the enhanced bosonic fluctuations generated by the drive.

DY 19.4 Tue 10:00 DYb

On the dynamics of the Forest Fire Model — •Diego Rybski[1,2] and Jan W. Kantelhardt[3] — [1]Potsdam Institute for Climate Impact Research – PIK, Member of Leibniz Association, P.O. Box 601203, 14412 Potsdam, Germany — [2]Department of Environmental Science Policy and Management, University of California Berkeley, 130 Mulford Hall #3114, Berkeley, CA 94720, USA — [3]Institute of Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle, Germany.

We investigate the Forest Fire Model in its version proposed by Henley (PRL 1993). Extracting the time series of shares of trees in the system, we investigate the temporal dynamics. For large tree growth probabilities p we find stable regions in which the system reaches a periodic attractor. With decreasing p the period of the attractor increments and for small values the system enters a chaotic regime as found in a Feigenbaum-Diagram. However, this chaotic regime also exhibits (quasi-)periodic fluctuations where the frequency is equal to p. On larger time-scales we observe a random walk behavior ($\approx 1/f^2$ scaling) which approaches white noise (approximately flat spectrum) for very long simulations, but $1/f$ noise only appears as a transition. The standard deviation of the fluctuations is proportional to $p^{1/2}$. Our results call for a new view on forest fire dynamics.

DY 19.5 Tue 10:20 DYb

Minority games played by arbitrageurs on the energy market — •Tim Ritmeester and Hildegard Meyer-Ortmanns — Jacobs University, Bremen, Germany

Along with the energy transition, the energy markets change their organization toward more decentralized and self-organized structures, striving for locally optimal profits. These tendencies may endanger the physical grid stability. One realistic option is the exhaustion of reserve energy due to an abuse by arbitrageurs. We map the energy market to different versions of a minority game and determine the expected amount of arbitrage as well as its fluctuations as a function of the model parameters. Of particular interest are the impact of heterogeneous contributions of arbitrageurs, the interplay between external stochastic events and nonlinear price functions of reserve power, and the effect of risk aversion due to suspected penalties. As conclusions from our results we propose economic and statutory measures to counteract a detrimental effect of arbitrage.

DY 20: Nonlinear Dynamics 1 - organized by Azam Gholami (Göttingen)

Time: Tuesday 9:00–10:00 Location: DYc

DY 20.1 Tue 9:00 DYc

Discrete light bullets in passively mode-locked semiconductor lasers — •Thomas Seidel[1,2], Svetlana V. Gurevich[2], and Julien Javaloyes[1] — [1]Dpt. de Física, Universitat de les Illes Balears & IAC-3, Campus UIB, E-07122 Palma de Mallorca, Spain — [2]Institute for Theoretical Physics & Center for Nonlinear Science (CeNoS), University of Münster, Schlossplatz 2, 48149 Münster, Germany

We study the emergence and stability of discrete light bullets in the output of a passively mode-locked semiconductor laser array coupled to a distant saturable absorber. First, we investigate the dynamics of the tranverse field which can be modeled by a discretised version of the generalised Rosanov equation and next, we also include the longitudinal direction and thus, show the existence of three-dimensional dissipative localized structures with one discrete (transverse) and two continuous (longitudinal) directions. In both situations, we observe multistability between solution branches consisting of a different number of lasing lasers by numerical time integration. For the transverse case, a detailed bifurcation analysis by means of path continuation was conducted in order to study the transition between different solution branches. Further, the existence of drifting solitons is demonstrated for both bright and dark localized structures.

DY 20.2 Tue 9:20 DYc

Laminar Chaos in Experiments: Nonlinear Systems with

Time-Varying Delays and Noise — •David Müller-Bender[1], Andreas Otto[1], Günter Radons[1], Joseph D. Hart[2,3], and Rajarshi Roy[2,3,4] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Institute for Research in Electronics and Applied Physics, University of Maryland, College Park, Maryland 20742, USA — [3]Department of Physics, University of Maryland, College Park, Maryland 20742, USA — [4]Institute for Physical Science and Technology, University of Maryland, College Park, Maryland 20742, USA

A new type of dynamics called laminar chaos was discovered in systems with time-varying delay [1]. It is a low-dimensional dynamics characterized by laminar phases of nearly constant intensity with periodic durations and a chaotic variation of the intensity from phase to phase. This is in contrast to the typically observed higher-dimensional turbulent chaos, which is characterized by strong fluctuations. In this work [2], we demonstrate experimentally and theoretically that laminar chaos is a robust phenomenon. Therefore, we provide the first experimental observation of laminar chaos by studying an optoelectronic feedback loop with time-varying delay and provide a time-series analysis toolbox for its detection. The toolbox is benchmarked by experimental data and by time-series of a delayed Langevin equation.

[1] Müller, Otto, and Radons, Phys. Rev. Lett. 120, 084102 (2018).

[2] Hart, Roy, Müller-Bender, Otto, and Radons, Phys. Rev. Lett. 123, 154101 (2019).

DY 20.3 Tue 9:40 DYc

Non-local effects in external cavity passively mode-locked lasers — •Jan Hausen[1], Christian Schelte[2], Julien Javaloyes[2], Svetlana V. Gurevich[2,3], and Kathy Lüdge[1] — [1]TU Berlin, Hardenbergstrasse 36, 10623 Berlin — [2]Universitat de les Illes Balears & Institute of Applied Computing and Community Code, Cra. de Valldemossa, km 7.5. Palma (Illes Balears) — [3]WWU Münster, Wilhelm-Klemm-Strasse 9, 48149 Münster

Asymetrical cavity geometries can improve the performances of passively mode-locked vertical external-cavity surface-emitting lasers and give rise to non-equidistant pulse patterns. We show that these geometries create non-local effects; by analysing a previously developed delay differential equation model, we derive rigorously a master partial differential equation from the pulse evolution that contains such non-local terms. We extend our analysis to the dynamics of non-equidistant pulse patterns in the long cavity regime, in which the pulses become temporal localized structures. We study the influence of the non-locality stemming from the asymmetric position of the elements in the cavity on the pulse distance within these patterns and deduce an analytic framework. By performing a Floquet-analysis, we find that with increasing cavity round-trip times there is a continuous transition from bound pulse patterns to pulses which are globally bound by the non-local effects, but locally independent, similar to catenane molecules.

DY 21: Active Matter 1 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP/CPP)

Time: Tuesday 9:30–10:30 Location: DYa

DY 21.1 Tue 9:30 DYa

Swirl formation of active colloids near criticality — •Robert C. Löffler[1], Tobias Bäuerle[1], Mehran Kardar[2], Christian M. Rohwer[3], and Clemens Bechinger[1] — [1]FB Physik, Universität Konstanz, Germany — [2]Dep. Physics, MIT, Cambridge, MA, USA — [3]Dep. Mathematics, University of Cape Town, South Africa

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. Through the variation of a single parameter in our interaction model based on information about a particles local neighbors, 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 observe a critical point with explicit bifurcation dynamics in the rotational order parameter and critical slowing down, as well as hysteresis in the symmetry-breaking regime of the control parameter. 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.

Bäuerle *et al.*, Nat. Comm. **11**, 2547 (2020); Löffler *et al.* (in review).

DY 21.2 Tue 9:50 DYa

A particle-field approach bridges phase separation and collective motion in active matter — •Robert Grossmann[1], Igor Aranson[2], and Fernando Peruani[3] — [1]Institute of Physics and Astronomy, University of Potsdam, Potsdam, Germany — [2]Department of Chemistry, Pennsylvania State University, University Park (PA), United States of America — [3]Laboratoire de Physique Théorique et Modélisation, CY Cergy Paris Université, Cergy-Pontoise, France

Linking seemingly disconnected realms of active matter – active phase-separation of repulsive discs and collective motion of self-propelled rods – is a major contemporary challenge. We present a theoretical framework based on the representation of active particles by smoothed continuum fields which brings the simplicity of alignment-based models, enabling an analytical analysis, together with more realistic models for self-propelled objects including their steric, repulsive interactions. We demonstrate on the basis of the collision kinetics how nonequilibrium stresses acting among self-driven, anisotropic objects hinder the emergence of motility-induced phase separation and facilitate orientational ordering. Moreover, we report that impenetrable, anisotropic rods are found to form polar, moving clusters, whereas large-scale nematic structures emerge for soft rods, notably separated by a bistable coexistence regime. Thus, the symmetry of the ordered state is not dictated by the symmetry of the interaction potential but is rather a dynamical, emergent property of active systems. This theoretical framework can represent a variety of active systems: cell tissues, bacterial colonies, cytoskeletal extracts or shaken granular media.

DY 21.3 Tue 10:10 DYa

A Quantitative Kinetic Theory of Flocking in Dry Active Matter Including a Three Particle Closure — •Rüdiger Kürsten and Thomas Ihle — Institut für Physik, Universität Greifswald, Germany

We consider aligning self-propelled point particles in two dimensions. Their motion is given by generalized Langevin equations, however, the qualitative behavior is as for the famous Vicsek model. We develop a kinetic theory of flocking beyond mean field. In particular, we take into account the full pair correlation function. We find excellent quantitative agreement of those pair correlations with direct agent-based simulations within the disordered regime. Furthermore we use a closure relation to incorporate the spatial correlations of three particles. In that way we achieve good quantitative agreement of the onset of flocking with direct simulations. Compared to mean field theory, the flocking transition is shifted significantly towards lower noise because angular correlations favor disorder.

DY 22: Invited Talk: Lucas Goehring (Nottingham)

Time: Tuesday 10:00–10:30 Location: DYc

Invited Talk DY 22.1 Tue 10:00 DYc

Stability and dynamics of convection in dry salt lakes — •Lucas Goehring[1], Jana Lasser[2], Marcel Ernst[3], Matthew Threadgold[4], Cédric Beaume[4], and Steven Tobias[4] — [1]Nottingham Trent University — [2]Complexity Science Hub Vienna — [3]University of Kassel — [4]University of Leeds

Dry lakes covered with a salt crust organised into beautifully patterned networks of narrow ridges are common in arid regions. This talk will consider the possible origins of this pattern as the surface expression of buoyancy-driven convection in the porous soil beneath a salt crust. Specifically, we look at convection in a deep porous medium with a constant through-flow boundary condition on a horizontal surface, which resembles the situation found below an evaporating salt lake. Solving the linear stability problem, we show that typical field conditions will be unstable to subsurface convection. Further exploring the nonlinear regime of this model, we demonstrate how the growth of small downwelling plumes is itself unstable to coarsening, as the system develops into a dynamic steady state. Interestingly, a robust length-scale emerges for the pattern wavelength, which is largely independent of the driving parameters, and consistent with the size of typical salt crust patterns (arXiv:2004.10578). Finally, we will show how these results can be extended into three-dimensions and more realistic boundary conditions, and include comparisons to field observations.

DY 23: Active Matter 2 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP/CPP)

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

DY 23.1 Tue 11:00 DYa

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

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

DY 23.2 Tue 11:20 DYa

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

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

DY 23.3 Tue 11:40 DYa

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

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

**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*

DY 23.4 Tue 12:00 DYa

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

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

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

DY 23.5 Tue 12:20 DYa

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

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

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

DY 23.6 Tue 12:40 DYa

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

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

DY 24: Dynamics and Statistical Physics - Open Session

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

DY 24.1 Tue 11:00 DYb

Analysing and Optimizing Nonlinear Memory Capacity of Photonic Reservoir Computing — •Felix Köster[1], Serhiy Yanchuk[2], and Kathy Lüdge[1] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstraße 36, 10623 Berlin — [2]Institut für Mathematik, TU Berlin, Hardenbergstraße 36, 10623 Berlin

Reservoir computing is a neuromorphic inspired machine learning paradigm that utilizes the naturally occurring computational capabilites of dynamical systems. In this work, we investigate the linear and nonlinear memory capacity of a delay-based class-A and class-B-laser reservoir computer via eigenvalue analysis and numerical simulations. We show that these two quantities are deeply connected, and thus the reservoir computing performance is predictable by analyzing the eigenvalue spectrum. We introduce two new quantities to describe the influence of the eigenvalue spectrum on the reservoir computer performance. The insight won by the eigenvalue analysis yields understanding and thus helps applying better performing reservoir systems for a broader range of tasks.

DY 24.2 Tue 11:20 DYb

Dissipative nonequilibrium synchronization of topological edge states via self-oscillation — •Christopher W. Wächtler[1,2,3], Victor M. Bastidas[3], Gernot Schaller[1], and William J. Munro[3,4] — [1]Institut für Theoretische Physik, Berlin, Germany — [2]Max-Planck Institut für Physik komplexer Systeme, Dresden, Germany — [3]NTT Basic Research Laboratories, Atsugi, Japan — [4]National Institute of Informatics, Tokyo, Japan

The interplay of synchronization and topological band structures with symmetry protected midgap states under the influence of driving and dissipation is largely unexplored. Here we consider a trimer chain of electron shuttles, each consisting of a harmonic oscillator coupled to a quantum dot positioned between two electronic leads. Each shuttle is subject to thermal dissipation and undergoes a bifurcation towards self-oscillation with a stable limit cycle if driven by a bias voltage between the leads [1]. By mechanically coupling the oscillators together, we observe synchronized motion at the ends of the chain, which can be explained using a linear stability analysis. Because of the inversion symmetry of the trimer chain, these synchronized states are topologically protected against local disorder [2]. Furthermore, with current experimental feasibility, the synchronized motion can be observed by measuring the dot occupation of each shuttle. Our results open another avenue to enhance the robustness of synchronized motion by exploiting topology.

[1] C. W. Wächtler et al., NJP 21, 073009 (2019).
[2] C. W. Wächtler et al, PRB 102, 014309 (2020).

DY 24.3 Tue 11:40 DYb

Athermal Clustering and Jamming of Active Particles — •Michael Schmiedeberg — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

In simulations of overdamped, repulsive, active particles in two dimensions at zero temperature the formation of clusters is observed. Note that it is not the temperature (as for mobility-induced phase transitions in thermal systems) but the unjamming dynamics that competes with the activity.

To be specific, large clusters that are even jammed in the inside only occur for intermediate activities. Decreasing the activity unjams the system and increasing the activity breaks up the clusters. Our simulations are in agreement with our results in [1], where athermal clustering has been studied in three dimensions in a simplified model system.

Our results demonstrate that even in the absence of thermal fluctuations a complex clustering behavior can be observed in active systems. An interesting task for future works will be to further compare the relation between the athermal clustering and mobility-induced phase transitions in thermal systems to the relation between athermal jamming and thermal jamming.

[1] M. Maiti and M. Schmiedeberg, EPL 126, 46002 (2019).

DY 24.4 Tue 12:00 DYb

Unravel the rotational properties of a squirmer in viscoelastic fluids — •Kai Qi[1], Marco De Corato[2], and Ignacio Pagonabarraga[1] — [1]CECAM, EPFL, Lausanne, Switzerland — [2]IBEC, BIST, Barcelona, Spain

We investigate the rotational motion of a single swimmer in viscoelastic fluids via Lattice Boltzmann (LB) simulations. Here, the generic squirmer model is employed and fluid viscoelasticity is achieved by added flexible polymer chains. The interplay of activity and boundary conditions between the squirmer and polymers on the squirmer's rotational motion is addressed. For Reynolds number close to unity, the rotational diffusion of a pusher/puller that employs the no-split boundary condition is enhanced over an order of magnitude. This is mainly due to the asymmetric torques generated during the heterogeneous collisions between the squirmer and polymers. However, this enhancement is about 5 times weaker when a short-range repulsion between squirmer's surface and monomers is used. By increasing system viscosity, we decrease the Reynolds number by an order of magnitude. Consequently, polymer's motility is suppressed profoundly. We find that the rotational diffusion coefficients of a pusher/neutral swimmer obtained from two boundary conditions are nearly identical. But the rotational enhancement of a puller with a no-slip boundary condition is twice stronger compared with the one exploiting short-range repulsion. This is because collisions occur mainly in the front of a puller due to its special swimming scheme.

DY 24.5 Tue 12:20 DYb

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

The reverse perturbation method [1] for shearing simple liquids is extended to the Vicsek model (VM) of self-propelled particles. The sheared systems exhibit a skin effect: Momentum that is fed into the boundaries of a layer decays mostly exponentially toward the center of the layer. It is shown how the shear viscosity and the momentum amplification coefficient can be obtained by fitting this decay with an analytical solution of the hydrodynamic equations for the VM. The viscosity of the VM consists of two parts, a kinetic and a collisional contribution. Here, a novel expression for the collisional part is derived by an Enskog-like kinetic theory [2]. In agent-based simulations, using several methods to measure transport coefficients, we find excellent agreement between these different methods and also good agreement with the theoretical predictions. In addition, we introduce a response theory that allows us to verify the analytical predictions of kinetic theory and to obtain expressions for non-local transport coefficients. [1] F. Müller-Plathe, Phys. Rev. E 59, 4894 (1999), [2] A. Nikoubashman, T. Ihle, Phys. Rev. E 100, 042603 (2019)

DY 24.6 Tue 12:40 DYb

Long-time diffusion and energy transfer in mixtures of particles with different temperatures — •Efe Ilker[1,2], Michele Castellana[1], and Jean-François Joanny[1,3] — [1]Institut Curie, Paris, France — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [3]Collège de France, Paris, France

In biological systems, crowding and composition are key factors affecting the rates of material transport while nonequilibrium aspects of active systems enrich this dynamics from molecular scales to cell populations. Transport properties of solute particles at long timescales differ from their short-timescale behavior due to interactions between the constituent particles. The collisions generate additional friction on a particle, while on top of that, for nonequilibrium (active) systems, the collisions can also lead to an exchange of energy between different constituents. Thus, the long-time diffusion coefficient of a tagged particle is shaped by the interplay between the effective friction and the energy transfer. Using the multiple temperature model, we probe these effects in dilute solutions and derive long-time friction and self-diffusion coefficients as a function of volume fractions, sizes and temperatures of particles. At these long timescales, we show that the tagged particle experiences a size-dependent "bath" temperature which stems from the interparticle energy transfer.

DY 25: Nonlinear Dynamics 2 - organized by Azam Gholami (Göttingen)

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

DY 25.1 Tue 11:00 DYc

Social distancing in pedestrian dynamics and its effect on disease spreading — Sina Sajjadi, Alireza Hashemi, and •Fakhteh Ghanbarnejad — Physics Department, Sharif University of Technology, Tehran, Iran

Non-pharmaceutical measures such as social distancing, can play an important role to control an epidemic. In this paper, we study the impact of social distancing on epidemics for which it is executable. We use a mathematical model combining human mobility and disease spreading. For the mobility dynamics, we design an agent based model consisting of pedestrian dynamics with a novel type of force to resemble social distancing in crowded sites. For the spreading dynamics, we consider the compartmental SEI dynamics plus an indirect transmission with the footprints of the infectious pedestrians being the contagion factor. We show that the increase in the intensity of social distancing has a significant effect on the exposure risk. By classifying the population into social distancing abiders and non-abiders, we conclude that the practice of social distancing, even by a minority of potentially infectious agents, results in a drastic change on the population exposure risk, but reduces the effectiveness of the protocols when practiced by the rest of the population. Furthermore, we observe that for contagions which the indirect transmission is more significant, the effectiveness of social distancing would be reduced. This study can provide a quantitative guideline for policy-making on exposure risk reduction.

arXiv preprint: arXiv:2010.12839

DY 25.2 Tue 11:20 DYc

Damage-Resilient Computation in Spiking Neural Networks — •Fabio Schittler Neves, Georg Börner, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden, Dresden, Germany

Networks of spiking neurons with inhibitory coupling exhibit reconfigurable k-winner-take-all computations via changes to a single parameter [1], robustly determining the k strongest out of N analog inputs. Such partial rank ordering of signals provides a natural basis for computing arbitrary functions. Moreover, computations are completed within a few spikes ($\tilde{}$k), thus requiring low power. Here we show that such networks are strongly resilient with respect to failure or removal of neural units. We develop strategies for immediate function recovery that work even after damage to an extremely large number of units. These networks exhibit two forms of resilience: first, the loss of less than N-k units do not translate in any change in dynamics, as the N-k neurons receiving the weaker inputs never spike, thus never contribute to any collective network dynamics; second, the systems provide great flexibility through symmetric coupling, because any unit in the network can functionally replace any other. Suitably interacting inhibitory neural networks may provide resilient and flexible analogue computations at low power and offer attractive solutions where unit repair or replacements are economically or practically infeasible, for example in autonomous and remote computing.

[1] F. S. Neves & M. Timme, IEEE Access 8:179648 (2020).

DY 25.3 Tue 11:40 DYc

Localization in the Kicked Ising Chain from a Dual Perspective — •Daniel Waltner[1], Petr Braun[1], Maram Akila[2], Boris Gutkin[3], and Thomas Guhr[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Fraunhofer IAIS, Schloss Birlinghoven, 53757 Sankt Augustin, Germany — [3]Department of Applied Mathematics, Holon Institute of Technology, 58102 Holon, Israel

Determining the border between ergodic and localized behavior is of central interest for interacting many-body systems. We consider here the recently very popular spin-chain model that is periodically excited. A convenient description of such a many-body system is achieved by the dual operator that evolves the system in contrast to the time-evolution operator not in time but in particle direction. We identify by various methods the largest eigenvalue of the dual operator as a convenient tool to identify if the system shows ergodic or many-body localized features.

DY 25.4 Tue 12:00 DYc

Understanding the origin of line defects in heart tissue. — •Marcel Hörning[1], Alessandro Loppini[2], Alessio Gizzi[2], Flavio H Fenton[3], and Simonetta Filippi[2] — [1]Institute of Biomaterials and Biomolecular Systems, University of Stuttgart, Stuttgart, Germany — [2]University Campus Bio-Medico of Rome, Rome, Italy — [3]School of Physics, Georgia Institute of Technology, Atlanta, Georgia, USA

Spatiotemporal patterns are observed in a wide range of excitable systems. They have important and diverse regulatory functions. In the heart, excitable waves can form complex oscillatory and chaotic patterns even at an abnormally higher frequency than normal heart beats, which increase the risk of fatal heart conditions by inhibiting normal blood circulation. Previous studies suggested that the occurrence of line defects in alternans play a critical role in the stabilizion of those undesirable patterns. However, this nonlinear phenomenon is still poorly understood. It remains to be elucidated, how nodal lines form, what their origin is, and how they stabilise. Here we show new insights in the stability of those by observing and analysing nodal line dynamics in spiral waves (in-vitro) and entrained high-frequency waves (ex-vivo).

DY 25.5 Tue 12:20 DYc

Effects of social distancing and isolation modeled via dynamical density functional theory* — •Michael te Vrugt, Jens Bickmann, and Raphael Wittkowski — Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149, Münster, Germany

For preventing the spread of epidemics such as the coronavirus disease COVID-19, social distancing and the isolation of infected persons are crucial. However, existing reaction-diffusion equations for epidemic spreading are incapable of describing these effects. In this talk, we present an extended model for disease spread based on combining a susceptible-infected-recovered model with a dynamical density functional theory where social distancing and isolation of infected persons are explicitly taken into account [1]. We show that the model exhibits interesting transient phase separation associated with a reduction of the number of infections, and provides new insights into the control of pandemics. An extension of the model [2] allows for an investigation of adaptive containment strategies. Here, a variety of phases with different numbers of shutdowns and deaths are found, an effect that is of crucial importance for public health policy.

[1] M. te Vrugt, J. Bickmann and R. Wittkowski, Nature Communications 11, 5576 (2020)

[2] M. te Vrugt, J. Bickmann and R. Wittkowski, arXiv:2010.00962 (2020)

**Funded by the Deutsche Forschungsgemeinschaft (DFG) – WI 4170/3-1*

DY 25.6 Tue 12:40 DYc

Information spread enhanced by criticality in high-responsive groups of fish — •Luis Gómez Nava[1,3], Robert T. Lange[2,3], Pascal P. Klamser[1,2], Henning Sprekeler[2,3], and Pawel Romanczuk[1,3] — [1]Institute for Theoretical Biology, Philippstrasse 13, Humboldt University of Berlin, 10115 Berlin, Germany — [2]Bernstein Center for Computational Neuroscience, 10115 Berlin, Germany — [3]Science of Intelligence (SCIoI), Marchstrasse 23, Technical University of Berlin, 10587 Berlin, Germany

Collective dynamics in animal groups has been studied in recent years intensively. Recent works have suggested that such multi-agent systems should operate in a special parameter region, close to critical points. This is relevant because critical systems exhibit unique properties like maximal responsiveness to external stimuli and optimal propagation of information within the group. In our work, we study a high-density system of sulphur mollies in their natural habitat. We measure the surface activity of the fish and characterize their response to external fluctuations. This surface activity results to be similar to the one observed in critical systems (we observe power law-distributed observables, as well as separation of time scales of the activity). We model the system dynamics using cellular automata and we conclude that this natural system operates indeed in a special parameter region. We provide as well a biological interpretation of the characteristic features of such a critical system.

DY 26: Data Analytics for Complex Dynamical Systems (joint SOE/DY Focus Session) (joint session SOE/DY)

Time: Tuesday 11:00–12:40 Location: SOEa

DY 26.1 Tue 11:00 SOEa

Network inference from event sequences: Disentangling synchrony from serial dependency — •Reik Donner[1,2], Adrian Odenweller[2], Frederik Wolf[2], and Forough Hassanibesheli[2] — [1]Magdeburg-Stendal University of Applied Sciences, Magdeburg, Germany — [2]Potsdam Institute for Climate Impact Research (PIK) - Member of the Leibniz Association, Potsdam, Germany

Inferring coupling among interacting units or quantifying their synchronization based on the timing of discrete events has vast applications in neuroscience, climate, or economics. Here, we focus on two prominent concepts that have been widely used in the past: event synchronization (ES) and event coincidence analysis (ECA). Numerical performance studies for two different types of spreading processes on paradigmatic network architectures reveal that both methods are generally suitable for correctly identifying the unknown links. By further applying both concepts to spatiotemporal climate datasets, we demonstrate that unlike ECA, ES systematically underestimates linkages in the presence of temporal event clustering, which needs to be accounted for in network reconstruction from data. In turn, for spike train data from multi-channel EEG recordings (with relatively narrow inter-event time distributions), the obtained results are practically indistinguishable. Our findings allow deriving practical recommendations for suitable data preprocessing in the context of network inference and synchronization assessment from event data.

DY 26.2 Tue 11:20 SOEa

Identification of Stochastic Differential Equations from Data — •Tobias Wand[1] and Oliver Kamps[2] — [1]Westfälische Wilhelms-Universität Münster — [2]Center for Nonlinear Science Münster

In recent years, methods to identify dynamical systems from experimental or numerical data have been developed [1, 2]. In this context, the construction of sparse models of dynamical systems has been in the focus of interest and has been applied to different problems. These data analysis methods work with hyper-parameters that have to be adjusted to improve the results of the identification procedure. Nondeterministic systems require a refined identification algorithm. In this talk, we will introduce an approach to optimally select hyperparameters for the identification of sparse differential equations from non-deterministic data.

[1] Brunton et al. Proceedings of the National Academy of Sciences, 2016, 113, 3932-3937

[2] Mangan et al. Proceedings of the Royal Society A, 2017, 473, 20170009

DY 26.3 Tue 11:40 SOEa

Data-driven analysis of the power grid frequency — •Benjamin Schäfer[1], Christian Beck[1], Leonardo Rydin Gorjão[2,3], Johannes Kruse[2,3], and Dirk Witthaut[2,3] — [1]School of Mathematical Sciences, Queen Mary University of London, London E1 4NS, United Kingdom — [2]Forschungszentrum Jülich, Institute for Energy and Climate Research-Systems Analysis and Technology Evaluation (IEK-STE), Jülich, Germany — [3]Institute for Theoretical Physics, University of Cologne, Köln, Germany

The Paris conference 2015 set a path to limit climate change to "well below 2°C". To reach this goal greenhouse gas emissions have to be reduced and renewable generators, electrical mobility or smart grids are integrated into the existing power system.

The introduction of these new technologies raises several questions about control, stability and operation and therefore requires a solid understanding of existing and future systems and new conceptional approaches.

Here, we use data-driven approaches to work towards a quantitative understanding of the power grid with a particular focus on the power grid frequency. We analyse time series from various synchronous areas such as Continental Europe, Great Britain but also two US areas and several European islands.

We highlight significant deviations from Gaussianity in several regions, scaling laws and spatio-temporal dynamics. Finally, we discuss how past information may be used to forecast the frequency.

DY 26.4 Tue 12:00 SOEa

Tipping and transition paths in high-dimensional agent-based models — •Luzie Helfmann[1,2,3], Peter Koltai[1], Jobst Heitzig[3], and Christof Schütte[2,1] — [1]Freie Universität Berlin — [2]Zuse Institute Berlin — [3]Potsdam Institute for Climate Impact Research

Agent-based models are a popular choice for modeling complex social systems. Here, we are concerned with studying noise-induced tipping between relevant subsets of the agent state space, e.g., in order to understand drastic opinion changes in a population of agents. Due to the large number of interacting individuals, agent-based models are usually very high-dimensional. We therefore apply Diffusion Maps, a non-linear dimension reduction, to reveal the intrinsic low-dimensional structure of the model dynamics. We will characterize the tipping behavior by means of Transition Path Theory, a theory for gaining statis-

tical understanding of the tipping paths (e.g., their density, flux, rate). We will illustrate our approach on two examples, both exhibiting a multitude of tipping pathways.

DY 26.5 Tue 12:20 SOEa

Quasi-stationary states in temporal correlations for traffic systems: Cologne orbital motorway as an example — •Shanshan Wang, Sebastian Gartzke, Michael Schreckenberg, and Thomas Guhr — Fakultät für Physik, Universität Duisburg–Essen, Lotharstraße 1, 47048 Duisburg, Germany

Traffic systems are complex systems that exhibit non-stationary characteristics. Therefore, the identification of temporary traffic states is significant. In contrast to the usual correlations of time series, here we study those of position series, revealing structures in time, i.e. the rich non-Markovian features of traffic. Considering the traffic system of the Cologne orbital motorway as a whole, we identify five quasi-stationary states by clustering reduced-rank correlation matrices of flows using the k-means method. The five quasi-stationary states with nontrivial features include one holiday state, three workday states and one mixed state of holidays and workdays. In particular, the workday states and the mixed state exhibit strongly correlated time groups shown as diagonal blocks in the correlation matrices. We map the five states onto reduced-rank correlation matrices of velocities and onto traffic states where free or congested states are revealed in both space and time. Our study opens a new perspective for studying traffic systems. This contribution is meant to provide a proof of concept and a basis for further study.

DY 27: Fluid Physics 3 - organized by Stephan Weiss and Michael Wilczek (Göttingen)

Time: Tuesday 14:00–17:10 Location: DYa

Invited Talk DY 27.1 Tue 14:00 DYa

Human exhaled particles from nanometres to millimetres — •Gholamhossein Bagheri — Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany

COVID-19 and other airborne diseases are transmitted to healthy individuals by inhalation of pathogen-containing particles exhaled by infectious persons. Here I provide an overview of the mechanisms involved in formation of these particles and the flow physics of the exhaled air. I will present results of our comprehensive experimental study to characterise the size distribution of exhaled particles from more than 125 subjects aged 5-88 years using aerosol size spectrometers and in-line holography. I will also discuss the physics of the exhalation flows during different respiratory manoeuvres by presenting results from our size-resolved three-dimensional particle tracking imaged at 10-15 kHz, which are furthermore complemented by two-dimensional optical flow measurements. In total, we have collected and analysed 200 h of exhalation samples with the spectrometers, 9000 holograms, and more than three million images from the high-speed cameras. With this database, we are now able to predict risk of infection from human exhaled particles in indoor environments using conventional infection models as shown in our multilingual web application (https://aerosol.ds.mpg.de). Finally, we have further improved risk assessment models to account for particles containing multiple pathogens. This research is funded by the Max Planck Society, Universitätsmedizin Göttingen and Bundesweites Forschungsnetz Angewandte Surveillance und Testung project.

DY 27.2 Tue 14:30 DYa

Emergent transport in growing bacterial colonies — •Anupam Sengupta — Physics of Living Matter, Dept. of Physics and Materials Science, University of Luxembourg

Bacteria are known to mediate vital processes in ecology, medicine and industry. Morphology, a key bacterial trait, has been long studied for its biophysical functions. Yet, only recently we have started to uncover the role of morphology in tuning the emergent properties in active cellular micro-environments[1]. Here, I will present recent results that elucidate how non-motile bacteria harness morphology to regulate transport properties over colony scales. We examine the geometric and mechanical properties of growing colonies, with a particular focus on the emergence of topological defects that act as active hydrodynamic sites. Our experimental results indicate that the number of topological defects depends on the cell geometry and colony dimensions, which in turn regulate the emergent transport properties within the bacterial colonies. Our results are supported by MD simulations and continuous modelling [2, 3], suggesting that defect mediated mechanics can potentially lead to biological functions, owing to the active hydrodynamics at scales that are orders of magnitude larger than individual cells. [1] A. Sengupta, Microbial Active Matter: A Topological Perspective, Front. Phys. 8, 184, 2020; [2] You, Pearce, Sengupta, Giomi, Phys. Rev. X. 8 (2018); [3] You, Pearce, Sengupta, Giomi, Phys. Rev. Lett. 123 (2019).

DY 27.3 Tue 14:50 DYa

Hydrodynamically coupled cilia: synchronization and noise — •Anton Solovev and Benjamin M. Friedrich — TU Dresden, Germany

Motile cilia on ciliated epithelia in mammalian airways, brain ventricles and oviduct can display coordinated beating in the form of metachronal (=traveling) waves [1]. Past research proposed hydrodynamic coupling as a mechanism of synchronization, yet if such synchronization is stable in the presence of noise (corresponding to active fluctuations of cilia beating) has been addressed only for $n = 2$ cilia [2], while the question of multi-stable synchronization in cilia carpets ($n >> 1$) remains open.

Using multi-scale simulations [3] that map hydrodynamic interactions between cilia on a generalized Kuramoto model of phase oscillators with local coupling, we predict many multi-stable metachronal wave states, yet only one or two of them have considerable basins of attraction.

In the presence of noise, we observe stochastic transitions between different waves [4]. Active noise excites long-wavelength perturbations (which take relatively long time to decay). Strong noise impedes global synchronization and causes a break-up into smaller synchronized patches (similar to a chimera state).

[1] W. Gilpin, M.S. Bull, and M. Prakash, Nat Rev Phys 2, 74 (2020)
[2] R. Ma et al., Phys. Rev. Lett. 113, 048101 (2014)
[3] A. Solovev, B.M. Friedrich, preprint arXiv:2010.08111 (2020)
[4] A. Solovev, B.M. Friedrich, preprint arXiv:2012.11741 (2020)

DY 27.4 Tue 15:10 DYa

Boundary conditions for polar active fluids exhibiting mesoscale turbulence — •Sebastian Heidenreich[1], Henning Reinken[2], Daiki Nishiguchi[3], Andrey Sokolov[4], Igor S. Aranson[5], and Sabine H. L. Klapp[2] — [1]Physikalisch Technische Bundesanstalt Braunschweig und Berlin, Germany — [2]Technische Universität Berlin, Germany — [3]University of Tokyo, Japan — [4]Argonne National Laboratory, USA — [5]Pennsylvania State University, USA

Bacterial suspensions are intriguing examples for active polar fluids which exhibit large-scale collective behaviour from mesoscale turbulence to vortex lattices. The bulk collective motion is well described by a continuum equation with derivatives up to the fourth order [1]. That simple model reproduces experimental findings of mesoscale turbulence and was recently derived from a minimal micro-swimmer model. However, the treatment of boundaries to describe the collective motion in a confinement or near walls remains so far unknown. In the talk, we propose boundary conditions for active polar fluids suitable to describe recent experiments of Bacillus subtilis bacteria moving in an array of lithographic designed pillars [2]. Furthermore, we describe the collective motion of bacteria around single pillars of different sizes in experiments and show that the model with the mentioned boundary conditions reproduces this behavior faithfully.

[1] J. Dunkel, S. Heidenreich, M. Bär and R. E. Goldstein, New. J. Phys. 15, 040516 (2013). [2] D. Nishiguchi, I. S. Aranson, A. Snezhko and A. Sokolov Nat. Comm. 9, 4486 (2018).

DY 27.5 Tue 15:30 DYa

Non-equilibrium phase transitions in bacterial vortex lattices — •Henning Reinken[1], Sebastian Heidenreich[2], Markus Bär[2], and Sabine H. L. Klapp[1] — [1]Technische Universität Berlin, Germany — [2]Physikalisch-Technische Bundesanstalt, Berlin, Germany

Recent theoretical and experimental studies have shown that the turbulent vortex structures emerging in bacterial active fluids can be or-

ganized into regular vortex lattices by weak geometrical constraints such as small pillars [1,2].

Using a deterministic continuum-theoretical approach for the effective microswimmer velocity [3], we show that the emergence and disappearance of these non-equilibrium structures shares many similarities with second-order equilibrium phase transitions including critical behavior, e.g., long-range correlations and divergent susceptibility at the critical point. The exponents are very close to those of the 2D Ising model with nearest-neighbor interactions. A mapping to the Onsager solution allows us to identify an effective temperature linear in the strength of nonlinear advection.

[1] D. Nishiguchi, I. S. Aranson, A. Snezhko, and A. Sokolov, Nat. Commun. **9**, 4486 (2018)
[2] H. Reinken, D. Nishiguchi, S. Heidenreich, A. Sokolov, M. Bär, S. H. L. Klapp, and I. S. Aranson, Commun. Phys. **3**, 76 (2020)
[3] H. Reinken, S. H. L. Klapp, M. Bär, and S. Heidenreich, Phys. Rev. E **97**, 022613 (2018)

DY 27.6 Tue 15:50 DYa

Impact of the gut motility on nutrient absorption and bacterial growth — •Agnese Codutti[1,2] and Karen Alim[1,2] — [1]MPIDS, Goettingen, Germany — [2]TUM Physics, Munich, Germany

The small intestine malfunctioning and its microbiome have been linked to serious diseases (from obesity, diabetes, Crohn disease to depression and anxiety). Therefore, the study of the physics underlaying such malfunctioning and the healthy gut behavior is of vital importance. In our work, we aim to theoretically model the tight link between gut motility, fluid flows, nutrients absorption and bacterial growth. We extend the Taylor dispersion approach to the case of an absorbing tube with moving walls, and we use a system of coupled equations to model nutrients and bacteria. We show that the gut motility deeply impacts the nutrient absorption: motility patterns with slow flows such as segmentation increase the nutrient absorption due to the long permanence times, while motility patterns with strong flows such as peristalsis reduce the absorption. On the contrary, segmentation favours the bacterial growth, while peristalsis reduces it. Therefore, we prove that the gut alternates such patterns to maximize nutrient absorption and minimise bacterial growth.

DY 27.7 Tue 16:10 DYa

Wet-tip versus dry-tip regimes of osmotically driven bile flow in the liver — Oleksandr Ostrenko, Michael Kücken, and •Lutz Brusch — Center for Information Services and High Performance Computing (ZIH), Technische Universität Dresden, Germany

The secretion of osmolites into a lumen and thereby caused osmotic water inflow drive fluid flows like saliva, sweat and bile in organs without a mechanical pump, as opposed to the heart in blood circulation. The effects of elevated fluid pressure and the associated mechanical limitations of organ function remain largely unknown. We consider the pressure profile of the coupled osmolite-flow problem with combined velocity and pressure boundary conditions. Notably, the entire lateral boundary acts as a fluid source, the strength of which is determined by feedback from the emergent pressure solution itself. Hence, the pressure difference between the boundaries is not imposed but self-organises. Our theoretical results reveal fundamental parameter dependencies and a phase boundary separating the commonly considered "wet-tip" regime with steady flow out of the very tip of a channel from a "dry-tip" regime suffering stalled flow and a self-organised block of osmotic water inflow [1]. We validate model predictions against intra-vital video microscopy data from mouse liver [2] and propose a relation between the predicted phase boundary and the onset of zonated cholestasis, a pathological liver condition [3].

[1] Ostrenko et al. (2019) Scientific Reports 9, 4528. [2] Meyer et al. (2017) Cell Systems 4, 277. [3] Segovia-Miranda et al. (2019) Nature Medicine 25, 1885.

DY 27.8 Tue 16:30 DYa

Resistive force theory and wave dynamics in swimming flagellar apparatus isolated from C. reinhardtii — Samira Goli Pozveh[1], Albert Bae[2], and •Azam Gholami[1] — [1]MPI for Dynamics and Self-organization, Göttingen, Germany — [2]Department of Biomedical Engineering, University of Rochester, USA

The-biflagellated micro-swimmer Chlamydomonas reinhardtii is a model organism to study dynamics of flagellar synchronization. Hydrodynamic interactions, intracellular mechanical coupling or cell body rocking are believed to play crucial role in synchronization of flag- ellar beating in green algae. Here, we use freely swimming intact flagellar apparatus isolated from wall-less strain of Chlamydomonas to investigate wave dynamics. Our analysis in phase coordinates show that, when the frequency difference between the flagella is high (10-41% of the mean), neither mechanical coupling via basal body nor hydrodynamics interactions are strong enough to synchronize two flagella, indicating that beating frequency is perhaps controlled internally by the cell. We also examined the validity of resistive force theory for a flagellar apparatus swimming freely in the vicinity of a substrate and found a quantitative agreement between experimental data and simulations with drag anisotropy of ratio 2. Finally, using a simplified wave form, we investigated the influence of phase and frequency differences, intrinsic curvature and wave amplitude on the swimming trajectory of flagellar apparatus. Our analysis shows that by controlling phase or frequency differences between two flagella, steering can occur.

DY 27.9 Tue 16:50 DYa

Rectified Diffusion of *E. coli* in Microfluidic Labyrinths — •Ariane Weber[1,2,3], Marco Bahrs[4], Zahra Alirezaeizanjani[4], Xingyu Zhang[1,2], Carsten Beta[4], and Vasily Zaburdaev[1,2] — [1]Department Biologie, Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]Max-Planck-Zentrum für Physik und Medizin, Erlangen — [3]Max-Planck-Institut für Menschheitsgeschichte, Jena — [4]Institut für Physik und Astronomie, Universität Potsdam

In many natural environments such as tissue or soil, bacteria have to orient through and interact with complex surroundings. To describe the bacterial dispersal in such environments, the movement of bacteria in the presence of spatial restrictions has to be understood qualitatively and quantitatively. In the present work, we take a first step in this direction by studying the spreading of *E. coli* in labyrinths of square and hexagonal geometry, both experimentally and theoretically. Using a microscopic tracking system, we first generate experimental data quantifying the dispersal of the bacteria in quasi-two-dimensional microfluidic labyrinths. Second, we formulate a two-dimensional random walk model of the bacterial movement within the labyrinths to (i) find theoretical expressions quantifying the diffusive motion and (ii) produce numerical results by implementing it in computer simulations. We then verify the analytical results by comparing them with the simulation statistics and the experimental data. Taken together, we are able to quantify the bacterial dispersal on short time scales and model it on large time scales, predicting faster dispersal and a prolonged time of non-Gaussian diffusion within the labyrinths.

DY 28: Statistical Physics 5 - organized by Barbara Drossel (Darmstadt), Sabine Klapp (Berlin) and Thomas Speck (Mainz)

Time: Tuesday 14:00–15:40 Location: DYb

DY 28.1 Tue 14:00 DYb

Non-Reversible Monte Carlo Simulations of Long-Range Interacting Molecular Systems — •Philipp Höllmer[1], Liang Qin[2], Michael F. Faulkner[3], A. C. Maggs[4], and Werner Krauth[2] — [1]University of Bonn, Germany — [2]École normale supérieure de Paris, France — [3]University of Bristol, United Kingdom — [4]ESPCI Paris, France

We present current progress of developing non-reversible Markov-chain Monte Carlo (MCMC) algorithms for efficient simulations of atom-based models of molecules that include long-ranged interactions. The event-chain Monte Carlo (ECMC) algorithm samples the Boltzmann distribution exactly without computing energy changes, which removes the computational bottleneck of traditional reversible MCMC simulations. Also, in contrast to molecular dynamics, the mixing and autocorrelation times of MCMC are not locked to the physical dynamics.

We introduce our open-source JeLLyFysh (JF) application that im-

plements ECMC in a general way by demonstrating number of worked out molecular-simulation examples that include, e.g., liquid water. We then highlight recent improvements of the application and ECMC itself. This includes, in particular, the concept of fast sequential Markov chains where ECMC's direction of motion is sequentially chosen from a set. Choosing a large direction set leads to much shorter mixing times of the rotational degree of freedom, and may thus greatly accelerate ECMC simulations of molecular systems.

DY 28.2 Tue 14:20 DYb

What can kinetic Monte Carlo do for active Matter? — •Juliane U. Klamser[1], Olivier Dauchot[1], and Julien Tailleur[2] — [1]Gulliver UMR CNRS 7083, ESPCI Paris, Université PSL, 75005 Paris, France — [2]Laboratoire Matiere et Systemes Complexes, UMR 7057 CNRS/P7, Université Paris Diderot, 10 rue Alice Domon et Leonie Duquet, 75205 Paris cedex 13, France

As an efficient numerical method, discrete-time, continuous-space Monte Carlo (MC) is wildly used in physics. While constructing an active matter version is straightforward, the question remains to what extent it faithfully captures real-world active systems. We focus on a kinetic MC version for the simplest kind of active matter: persistently moving, non-polar, interacting particles. On the multi-particle level, the MC dynamics captures not only Motility-induced phase separation but also features a non-equilibrium extension of the celebrated two-dimensional melting. An attempt to characterize these phases and their transitions relies on the existence of a thermodynamic pressure, which is not guaranteed outside equilibrium. For a soundly chosen version of the MC dynamics, we show that pressure is a thermodynamic state variable over a robust parameter range. This is demonstrated by deriving the corresponding Langevin description and the associated expression for pressure, which is confirmed by large scale many-particle simulations. Last but not least, our work culminates in a prescription for extending kinetic MC to the standard active matter models, namely active Brownian particles and active Ornstein-Uhlenbeck particles.

DY 28.3 Tue 14:40 DYb

General solution to the one-dimensional connectivity problem — •Fabian Coupette, Andreas Härtel, and Tanja Schilling — Institut of Physics, University of Freiburg, Germany

We present a general method to obtain the connectivity properties of an arbitrary one-dimensional pairwise interacting n-body system in thermal equilibrium. As input, solely the pair density distribution associated to the equilibrium state is required. Accordingly, if exact analytic results exist for the pair density distribution, the pair connectivity can be determined equally exactly. This is illustrated for fully penetrable and impenetrable rods as well as a repulsive $1/r^2$ nearest-neighbor interaction potential. We also discuss implications of our work for long-ranged interactions, systems in external fields and higher dimensions.

DY 28.4 Tue 15:00 DYb

Criticality in the mechanical regulation of cell adhesion — •Kristian Blom and Aljaz Godec — Max Planck Institute for Biophysical Chemistry, Göttingen, Germany

Cell adhesion, the process by which cells physically attach to their environment, is established through binding of cellular adhesion molecules located at the outer cell membrane. While on the single molecule level adhesive strength is set by the intrinsic-binding affinity alone, on the many-body level an effective interaction between neighboring adhesion molecules arises through fluctuations of the anchoring cell membrane. Changes in the membrane stiffness, observed in e.g. tumor and muscle cells, alter the effective interaction strength and in turn facilitate mechanical regulation of adhesion. In this talk we will explain how mechanical regulation affects the equilibrium binding state and (un)binding kinetics of adhesion clusters. Ranging from small to large clusters, we show that there always exists an optimal membrane stiffness at which the (un)binding rates are largest. In the thermodynamic limit we observe a dynamical phase transition at which the dominant (un)binding pathway undergoes a qualitative change.

[1] K. Blom, A. Godec, arXiv:2011.05310 (2020)

DY 28.5 Tue 15:20 DYb

Complex routes towards a fully-grown monolayer of "sticky" hard rods — •Miriam Klopotek, Hans Joachim Schöpe, and Martin Oettel — University of Tübingen, Tübingen, Germany

We study "sticky" hard rods confined to maximally one monolayer, i.e. "(2+1)D" confinement, in a basic, on-lattice model system for thin film growth with anisotropic particles at early stages [1]. We execute a large array of kinetic Monte Carlo (KMC) simulations of the nonequilibrium dynamics [2]. The physics of monolayer growth with "sticky" hard rods is extremely rich. The bounty of phenomena on metastable phases and complex phase transition kinetics we find has not been addressed before by comparable simulation or analytical models. We identify at least five different phase transition scenarios; the different dynamical regimes are traceable in the 2D plane ("map") spanned by the reduced temperature (or attraction strength) and deposition-flux–to–diffusion ratio. The rod-length as well as simple substrate potentials further shift these regimes and alter the topology of the "map", i.e. the set of phase transition scenarios. The specific model choice for microscopic rotational dynamics of rods is another, surprisingly important factor altering the kinetics and, therewith, the morphological evolution.

[1] G. Hlawacek and C. Teichert, *J. Phys.: Condens. Matter* 25 (2013), p. 143202.
[2] M. Klopotek *et al.*, *J. Chem. Phys.* 146.8 (2017), p. 084903.

DY 29: Invited Talk: Karen Daniels (Raleigh)

Time: Tuesday 14:00–14:30 Location: DYc

Invited Talk DY 29.1 Tue 14:00 DYc

Fingers, fractals, and flow in liquid metals — •Karen Daniels — North Carolina State University, USA

A droplet of pure water placed on a clean glass surface will spread axisymmetrically, and a droplet of mercury will bead up into a spherical droplet. In both cases, the droplet is minimizing its surface energy – creating an object with a minimized surface area – and there is nothing to break the symmetry. Remarkably, droplets of the room-temperature liquid gallium-indium (EGaIn), which like all metals have an enormous surface tension, can nonetheless undergo fingering instabilities in the presence of an oxidizing voltage. I will describe how this oxide acts like a reversible surfactant, generating fingering instabilities, tip-splitting, and even fractals, through Marangoni instabilities. Remarkably, we find that EGaIn droplets placed in an electrolyte under an applied voltage can achieve near-zero surface tension. This effect can in turn be used to suppress the Rayleigh-Plateau instability in falling streams. Quantitative control of these effects provides a new route for the development of reconfigurable electronic, electromagnetic, and optical devices that take advantage of the metallic properties of liquid metals.

DY 30: Complex Fluids and Soft Matter 1 - organized by Uwe Thiele (Münster) (joint session DY/CPP)

Time: Tuesday 14:30–16:30 Location: DYc

DY 30.1 Tue 14:30 DYc

How Frost Forms and Grows on Lubricant Impregnated Surfaces — •Lukas Hauer[1], William S.Y. Wong[1], Lou Kondic[2], and Doris Vollmer[1] — [1]Max Planck Institute for Polymer Research, Mainz, Germany — [2]Department of Mathematical Sciences, NJIT, Newark, USA

In many technical applications the formation of frost and ice displays a hazard to the steady functionality of devices. This motivates the

development of new materials to tackle the reduction of frosting and icing on surfaces. While icing on surfaces is commonly studied by localized nucleation mechanisms, the formation of frost is comparable more complicated: Formation of condensate droplets, freezing, and frost front propagation are multi-physical processes on multiple time and length scales. Lubricant impregnated surfaces are known for improved anti-icing properties. They experience lower ice drop adhesion and allegedly delayed surface frost formation. We show that frost formation can induce immensely strong capillary forces that could result in surface damage, lubricant depletion and the loss of anti-icing properties. Laser scanning confocal microscopy enables us to monitor the dynamic lubricant migration during condensation frosting on microstructured surfaces. We present a quantitative model of the lubricant migration, utilizing lubrication theory. This work serves to improve understanding of lubricant dynamics during condensation frosting, providing roadmaps towards the future design of anti-icing surfaces.

DY 30.2 Tue 14:50 DYc

Hydraulic and electric control of cell spheroids — •Charlie Duclut[1], Jacques Prost[2], and Frank Jülicher[1,3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Laboratoire Physico Chimie Curie, Institut Curie, Paris, France — [3]Center for Systems Biology Dresden, Germany

In addition to generating forces and reacting to mechanical cues, tissues are capable to actively pump fluid and create electric current. In this talk, we will discuss how a hydraulic or electrical perturbation, imposed for instance by a drain of micrometric diameter, can be used to perturb tissue growth dynamics. We address this issue in a continuum description of a spherical cell assembly that includes the mechanical, electrical and hydraulic properties of the tissue. This approach allows us to discuss and quantify the effect of electrohydraulic perturbations on the long-time states of the tissue. We highlight that a sufficiently strong external flow or electric current can drive a proliferating spheroid to decay. We propose that this could have applications in medicine.

DY 30.3 Tue 15:10 DYc

Controlling Elastic Turbulence — •Reinier van Buel and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Controlling the flow patterns of viscoelastic fluids is extremely challenging due to their inherent non-linear and time-dependent properties. These complex fluids exhibit transitions from laminar to turbulent flows, which is useful for heat and mass transport in liquids at the micron scale [1], whereas in Newtonian fluids transport is dominated by diffusion. Turbulent viscoelastic flows show similar properties as their counterparts in Newtonian fluids [1,2] and consequently the observed flow pattern is called *elastic turbulence* [1]. It occurs in shear flow for increasing Weissenberg number Wi, the product of polymer relaxation time and shear rate.

Numerically solving the Oldroyd-B model in a two-dimensional Taylor-Couette geometry, we have identified and described the supercritical transition to turbulent flow at a critical Weissenberg number [2]. Here, we demonstrate that elastic turbulence can be controlled by a time-modulated shear rate. The order parameter measuring the strength of turbulence continuously goes to zero with increasing modulation frequency or Deborah number De. It ultimately vanishes via a supercritical transition, where flow then becomes laminar. Moving closer to the critical Weissenberg number, smaller modulation frequencies are sufficient to induce laminar flow.

[1] A. Groisman and V. Steinberg, Nature **405**, 53 (2000).
[2] R. Buel, C. Schaaf, H. Stark, Europhys. Lett. **124**, 14001 (2018).

DY 30.4 Tue 15:30 DYc

Hydrodynamics of a Pair of Soft Capsules in Inertial Microfluidics — •Kuntal Patel and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany

In recent years, inertial microfluidics has emerged as a robust technique to precisely manipulate solid particles and biological cells. Also, the fact that inertial microfluidics operates at finite Reynolds numbers enables to achieve high throughput. In the present work, we perform 3D numerical simulations to study the hydrodynamic interaction and inertial migration of two soft capsules in a microchannel with quadratic cross section. We employ the lattice Boltzmann method to determine fluid flow and the finite element method to model capsule dynamics. The coupling between bulk fluid and capsules is realized using the immersed boundary method.

We investigate the effect of different starting positions for mono- and bi-dispersed pairs of varying softness and capsule shape. Based on the temporal evolution of interparticle distance, we characterize the dynamics of various mono- and bi-dispersed pairs into four types: stable pair, stable pair with damped oscillations, stable pair with bounded oscillations, and unstable pair. We observe that stable pairs become unstable when increasing the particle stiffness. Furthermore, a pair with both capsules in the same channel half is more prone to become unstable than a pair with capsules in the opposite channel halves.

DY 30.5 Tue 15:50 DYc

Hydrodynamics of immiscible binary fluids with viscosity contrast: A Multiparticle Collision Dynamics approach — •Zihan Tan[1], Vania Calandrini[2], Jan Dhont[1], Gerhard Nägele[1], and Roland Winkler[3] — [1]Biomacromolecular Systems and Processes, Institute of Biological Information Processing, Forschungszentrum Jülich, 52428 Jülich, Germany — [2]Computational Biomedicine, Institute for Advanced Simulation, Forschungszentrum Jülich, 52428 Jülich, Germany — [3]Theoretical Physics of Living Matter, Institute for Advanced Simulation, Forschungszentrum Jülich, 52428 Jülich, Germany

By coupling distinct collision steps in each fluid domain, immiscible binary fluids with different viscosities connected by coarse-grained planer interfaces are realized by multiparticle collision dynamics (MPC). The flow and the stress-viscosity relation of the system are investigated under shear flow, excellently agree with continuum hydrodynamics solution and the analytical theory of MPC. Later, the hydrodynamic mobility coefficients of an embedded colloid close to the fluid-fluid interface are measured, which coincide with hydrodynamic multipole expansion calculations. To validate the length and time scales of hydrodynamics in this model, we explore the corresponding transverse velocity correlations. It is found that the correlations for the fluid regions occupied by one phase are identical to single-phase MPC fluid. In contrast, the transverse modes at the interfacial region can be interpreted by the superposition of both viscous components.

DY 30.6 Tue 16:10 DYc

Optimal hematocrit for ATP release by red blood cell in microcirculation — •Zhe Gou and Chaouqi Misbah — Laboratoire Interdisciplinaire de Physique, Grenoble, France

ATP release by red blood cells (RBCs) acts as an important signaling molecule for various physiological functions, such as vasodilation. When flowing in microcirculation, RBCs experience a cascade of branching vessels, from arterioles to capillaries, and finally to venules, which affects not just flow behavior of blood but also ATP release. In a previous study, we have proposed a model of ATP release by RBCs through two pathways of cell membrane: pannexin 1 channel (Px1), sensitive to shear stress, and cystic fibrosis transmembrane conductance regulator (CFTR) which responds to cell deformation. As a continuation, present work further investigates the effect of flow strength, hematocrit, and vascular diameter by numerical simulations. We found a nontrivial spatial RBC organization and ATP patterns due to application of shear stress on the RBC suspension. Conditions for optimal ATP release per cell are identified, which depend on vessel size and hematocrit Ht. Increasing further Ht beyond optimum enhances the total ATP release but should degrade oxygen transport capacity, a compromise between an efficient ATP release and minimal blood dissipation. Moreover, ATP is boosted in capillaries suggesting a vasomotor activity coordination throughout the resistance network. Further studies of vascular network may help to explore the whole signaling cascade of ATP.

DY 31: Invited Talk: Mehran Kardar (Boston)

Time: Tuesday 15:40–16:10 Location: DYb

Invited Talk DY 31.1 Tue 15:40 DYb

Fixation and ancestry of competing species growing on a rugged front — •Mehran Kardar — Physics Department, MIT, Cambridge, MA 02139, USA

When competing species expand into new territory the population is dominated by descendants of a few successful ancestors at the expansion front. Successful ancestry is stochastic, but biased by fitness of the individual, as well as favorable geographic location. We consider a simple model of range expansion of competing bacteria, in which reproduction and competition only take place at the growing front. Based on symmetry considerations we construct a pair of nonlinear stochastic partial differential equations that describe the coevolution of the profile of the growing surface and the composition of the bacterial species on the front. Macroscopic manifestations (phenomenology) of these equations on growth patterns and genealogical tracks of range expansion will be presented.

DY 32: Posters DY - Statistical Physics, Brownian Motion and Nonlinear Dynamics

Time: Tuesday 16:30–19:00 Location: DYp

DY 32.1 Tue 16:30 DYp

Jarzynski equality for conditional stochastic work — •Akira Sone[1] and Sebastian Deffner[2] — [1]Aliro Technologies, Inc, Boston, MA 02135, USA — [2]University of Maryland, Baltimore County, Baltimore, Maryland 21250, USA

We present our recent work on the fluctuation theorems of conditional stochastic work for classical Hamiltonian dynamics. The notion of conditional stochastic work is inspired by the one-time measurement paradigm, and built upon the change of energy expectation value, which is conditioned on the surface of the initial energy. This notion leads to the generalized Jarzynski equality and a modified second law of thermodynamics, whose sharper bound characterizes the adiabaticity of the thermodynamic process of interest.

DY 32.2 Tue 16:30 DYp

Anharmonic lattice dynamics in large thermodynamic ensembles with machine-learning force fields: the breakdown of the phonon quasipartic le picture in CsPbBr3 — •Jonathan Lahnsteiner and Menno Bokdam — University of Twente, Enschede, Netherlands

The harmonic approximation is a very powerful method for describing phonon dispersion relations. However, when the temperature is raised and the potential energy landscape exhibits more anharmonicity, the approximation fails to capture all crystal lattice dynamics properly. Here we study, for the first time, the phonon dispersion of a complex "Dynamic Solid" with machine-learning force fields, by simulating the dynamic structure factor (DSF) S(q,omega) and the projected velocity autocorrelation function (PVACF) trough large-scale molecular dynamics. These force fields have near first-principles accuracy and the linear scaling computational cost of classical potentials. To asses the strengths and weaknesses of the three methods we start with an analysis based on the classical Morse potential. Hereafter, the methods are applied to the inorganic perovskite: CsPbBr3. This perovskite serves as an archetypal example of a wider class of novel perovskite solar-cell materials. Imaginary modes in the harmonic picture of the CsPbBr3 structure are absent in the calculated DSF and PVACF, indicating a dynamic stabilization of the crystal. The anharmonic nature of the potential and the presence of rattling Cs+ cations, result in the breakdown of the phonon quasi-particle picture.

DY 32.3 Tue 16:30 DYp

Long-range correlations in musical time-series? — •Corentin Nelias and Theo Geisel — MPI for Dynamics and Self-Organization, Goettingen, Germany

Musical pitch time-series seem to present long-range correlations reflected in 1/f-type power-spectral densities. The existence, nature, and shape of these correlations have remained unclear as conflicting results were reported in the literature. The present work is clarifying the existing controversy by a careful analysis of power-spectral densities on a corpus 256 compositions and improvised pieces. Generally we do find 1/f-type spectra, but they show up on limited spectral scales only, corresponding to time scales typically up to a few musical bars.

DY 32.4 Tue 16:30 DYp

Voltage Dynamics in Power Grids — •Hannes Vogel — Stockholm University, Stockholm, Sweden

Understanding the stability of voltage dynamics in power grids is essential to the development of decentralized power networks for renewable energy sources. Current voltage dynamics models are motivated by physics and control theory. We formulate the power grid dynamics in terms of complex voltages, which combine the dynamics of rotor angle, frequency and voltage amplitude. To get a better overview of the properties of different models and to find criteria for classification, a common general formulation is needed.

Indeed, such a formulation is obtained by writing the differential equations in a complex power series. Therefore, the mathematical structure of the Stuart-Landau equation functions as a prototype.

DY 32.5 Tue 16:30 DYp

Satellite instability in Passively Mode-Locked Integrated External-Cavity Surface Emitting Lasers — Christian Schelte[1,2], •Denis Hessel[2], Julien Javaloyes[1], and Svetlana Gurevich[2,3] — [1]Departament de Física, Universitat de les Illes Balears & Institute of Applied Computing and Community Code (IAC-3), Cra. de Valldemossa, km 7.5, E-07122 Palma de Mallorca, Spain — [2]Institute for Theoretical Physics, University of Münster, Wilhelm-Klemm-Str. 9, D-48149 Münster, Germany — [3]Center for Nonlinear Science (CeNoS), University of Münster, Corrensstrasse 2, D-48149 Münster, Germany

We are interested in a pulse instability appearing in passively mode-locked integrated external-cavity surface-emitting lasers (MIXSELs) modelled by delayed algebraic differential equations (DADEs). The micro-cavity geometry induces third order dispersion (TOD) that can lead to a train of satellites on the leading edge of a pulse. We show that those can become unstable due to carrier interaction. The resulting limit cycle is born in a global bifurcation of the saddle-node infinite period (SNIPER) type and exhibits behavior characteristic of excitable systems.

DY 32.6 Tue 16:30 DYp

Spectral theory of fluctuations in time-average statistical mechanics of reversible and driven systems — •Alessio Lapolla, David Hartich, and Aljaz Godec — Mathematical BioPhysics group, Max Plack Institute for Biophysical Chemistry, Goettingen, Germany

Time-averaged observables are one of the building blocks for the analysis of both theoretical and experimental systems. We present a spectral-theoretic approach to derive exact results for the mean, fluctuations, and correlations of time-average observables for ergodic stochastic processes, with continuous or discrete dynamics and with reversible or irreversible dynamics. The emergence of the universal central limit law is shown explicitly on large- deviation timescales. Our results are directly applicable to a diverse range of phenomena underpinned by time-average observables and additive functionals in physical, chemical, biological, and economical systems.

[1] Alessio Lapolla, David Hartich, and Aljaž Godec Phys. Rev. Research 2, 043084 (2020)

DY 32.7 Tue 16:30 DYp

Near and far field of coupled microresonators — •Julia Unterhinninghofen and Lasse Rosskamp — Hochschule Koblenz, Konradd-Zuse-Str. 1, 56075 Koblenz

Wavelength-scale microresonators have various applications as sensors, in nonlinear optics, as filters and micro-laser cavities. Multiple interfer-

ence effects can be seen in microresonator ensembles, both concerning the far (change in far field emission directions, directional emission [1]) and the near field (formation of new cavity modes [2,3]). We compare microresonator arrays of different geometries and their far field emission properties both in a wave and a ray model as well as the near field of strongly coupled ensembles. The effects of surface roughness on the near and far fields is also investigated.

[1] J. Kreismann et al., Superdirectional light emission and emission reversal from microcavity arrays, Phys. Rev. Research 1 (2019) [2] J. Unterhinninghofen et al., Interplay of Goos-Hänchen shift and boundary curvature in deformed microdisks, Phys. Rev. E 82 (2010) [3] J.-W. Ryu et al., Abnormal high-Q modes of coupled stadium-shaped microcavities, Opt. Lett. 39 (2014)

DY 32.8 Tue 16:30 DYp

Critical exponent ν of the Ising model in three dimensions with long-range correlated site disorder analyzed with Monte Carlo techniques — •Stanislav Kazmin[1,2] and Wolfhard Janke[2] — [1]Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany — [2]Universität Leipzig, Institute for Theoretical Physics, Leipzig, Germany

We study the critical behavior of the Ising model in three dimensions on a lattice with site disorder by using Monte Carlo simulations [1]. The disorder is either uncorrelated or long-range correlated with correlation function that decays according to a power law r^{-a}. We derive the critical exponent of the correlation length ν and the confluent correction exponent ω in dependence of a by combining different concentrations of defects $0.05 \leq p_d \leq 0.4$ into one global fit ansatz and applying finite-size scaling techniques. We simulate and study a wide range of different correlation exponents $1.5 \leq a \leq 3.5$ as well as the uncorrelated case $a = \infty$ and are able to provide a comprehensive picture not yet known from previous works. Additionally, we perform a dedicated analysis of our long-range correlated disorder ensembles and provide estimates for the critical temperatures of the system in dependence of the correlation exponent a and the concentrations of defects p_d. We compare our results to known results from other works and to the conjecture of Weinrib and Halperin: $\nu = 2/a$ and discuss the occurring deviations.

[1] S. Kazmin and W. Janke, Phys. Rev. B 102, 174206 (2020)

DY 32.9 Tue 16:30 DYp

Haldane Insulator in the 1D Nearest-Neighbor Extended Bose-Hubbard Model with Cavity-Mediated Long-Range Interactions — •Johannes Sicks and Heiko Rieger — Theoretical Physics, Saarland University, Campus E2.6, 66123 Saarbrücken, Germany

In the one-dimensional Bose-Hubbard model with on-site and nearest neighbor interactions, a gapped phase characterized by an exotic nonlocal order parameter emerges, the Haldane insulator. Bose- Hubbard models with cavity-mediated global range interactions display phase diagrams, which are very similar to those with nearest neighbor repulsive interactions, but the Haldane phase remains elusive there. Here we study the one-dimensional Bose-Hubbard model with nearest-neighbor and cavity-mediated global- range interactions and scrutinize the existence of a Haldane Insulator phase. With the help of extensive quantum Monte-Carlo simulations we find that in the Bose-Hubbard model with only cavity-mediated global-range interactions no Haldane phase exists. For a combination of both interactions, the Haldane Insulator phase shrinks rapidly with increasing strength of the cavity-mediated global-range interactions. Thus, in spite of the otherwise very similar behavior the mean-field like cavity-mediated interactions strongly suppress the non-local order favored by nearest neighbor repulsion in some regions of the phase diagram.

DY 32.10 Tue 16:30 DYp

Depinning of confined colloidal dispersions under oscillatory shear — •Marcel Hülsberg and Sabine H.L. Klapp — ITP, Technische Universität Berlin, Germany

Strongly confined colloidal dispersions under shear exhibit a variety of dynamical phenomena, including a depinning transition similar to single particles that are driven over a periodic substrate potential [1]. Here, we investigate the depinning behavior of these systems under pure oscillatory shearing with shear rate $\dot{\gamma}(t) = \dot{\gamma}_0 \cos(\omega t)$, as it is a common scenario in rheological experiments [2]. The colloid's depinning behavior is assessed from a microscopic level based on particle trajectories, which are obtained from overdamped Brownian Dynamics simulations. The numerical approach is complemented by an analytic one based on a single-particle model in the limit of weak driving. We determine the frequency-dependent critical shear rate amplitude $\dot{\gamma}_{0,crit}(\omega)$, which marks the onset of the depinning transition. Furthermore, we identify the dominant system-intrinsic time scale that dictates the scaling behavior of $\dot{\gamma}_{0,crit}$ with driving frequency ω. Finally, we discuss potential consequences of the depinning behavior on the system's rheological properties [2].

[1] S. Gerloff and S.H.L. Klapp, Phys. Rev. E **94**(6), 062605 (2016)
[2] J.M. Brader, et al., Phys. Rev. E **82**(6), 061401 (2010)

DY 32.11 Tue 16:30 DYp

Subharmonic oscillations in stochastic systems under periodic driving — •Lukas Oberreiter[1], Andre Cardoso Barato[2], and Udo Seifert[1] — [1]II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany — [2]Department of Physics, University of Houston, Houston, Texas 77204, USA

We investigate the conditions under which subharmonic oscillations can persist for a long time in open systems with stochastic dynamics due to thermal fluctuations. In contrast to stochastic autonomous systems in a stationary state, for which the number of coherent oscillations is fundamentally bounded by the number of states in the underlying network [1], we demonstrate that in periodically driven systems, subharmonic oscillations can in principle remain coherent forever, even in networks with a small number of states [2]. By interpreting our finite state model as a single subharmonically oscillating spin, we construct an interacting spin system [3]. The mean-field model displays the phenomenon of subharmonic synchronization, which corresponds to collective subharmonic oscillations of the individual units. The 2D model does not display synchronization but it does show a time-crystalline phase, which is characterized by a power-law behavior of the number of coherent subharmonic oscillations with system size.

[1] A. C. Barato and U. Seifert *Phys. Rev. E* **95**, 062409, (2017)
[2] L. Oberreiter, U. Seifert, and A. C. Barato *Phys. Rev. E* **100**, 012135, (2019)
[3] L. Oberreiter, U. Seifert, and A. C. Barato *Phys. Rev. Lett.* **126**, 020603, (2021)

DY 32.12 Tue 16:30 DYp

Propagator for a driven Brownian particle in step potentials — •Volker Weissmann, Matthias Uhl, and Udo Seifert — II. Institute for Theoretical Physics , University of Stuttgart

Although driven Brownian particles are ubiquitous in stochastic dynamics and often serve as paradigmatic model systems for many aspects of stochastic thermodynamics, fully analytically solvable models are few and far between. In [1], we introduce an iterative calculation scheme, similar to the method of images in electrostatics, that enables one to obtain the propagator if the potential consists of a finite number of steps. For the special case of a single potential step, this method con- verges after one iteration, thus providing an expression for the prop- agator in closed form. In all other cases, the iteration results in an approximation that holds for times smaller than some characteristic timescale that depends on the number of iterations performed. This method can also be applied to a related class of systems like Brownian ratchets, which do not formally contain step potentials in their definition, but impose the same kind of boundary conditions that are caused by potential steps.

[1]: Matthias Uhl et al 2021 J. Phys. A: Math. Theor. 54 065002 https://doi.org/10.1088/1751-8121/abc21f

DY 32.13 Tue 16:30 DYp

Phase separation: from colloids to biological mixtures — •Filipe C. Thewes — Institute for Theoretical Physics, Georg-August-Universität Göttingen, 37077 Göttingen, Germany

Understanding the dynamics of phase separation in complex mixtures remains a profound challenge. In this work, we aim to build a bridge between the well-studied area of phase separation in colloidal systems and its intriguing and complex biological counterpart. We first introduce a model that interpolates between the two limiting cases and investigate the phase diagram using techniques of random matrix theory. Second, in order to understand the competing mechanisms leading to phase separation, we perform lattice simulations within a mean-field approximation and analyse the time evolution of the system in different regions of the parameter space. In the colloidal limit the model reproduces known results from the existing literature. On the biological side, our simulations provide new insights into the competing scaling obtained by early and late time analysis in the random interaction model. The intermediate regime shows new crossovers between

condensation and demixing-dominated kinetics. Time permitting, results will be shown from further exploration of the model with a focus on crowding effects.

DY 32.14 Tue 16:30 DYp

The narrow escape problem in two-shell circular domains — •Matthieu Mangeat and Heiko Rieger — Saarland University, Saarbrücken, Germany

The stochastic motion of particles in living cells is often spatially inhomogeneous with a higher effective diffusivity in a region close to the cell boundary due to active transport along actin filaments [1,2]. As a first step to understand the consequence of the existence of two compartments for stochastic search problems we consider here a Brownian particle in a circular domain with different diffusivities and potentials in the inner and the outer shell. We focus on the narrow escape problem and compute the mean first passage time (MFPT) for Brownian particles starting at some pre-defined position to find a small region on the outer reflecting boundary (cell membrane). We find that the MFPT can be minimized for a specific value of the width of the outer shell only if the particle is sufficiently attracted in the outer shell whereas the MFPT depends monotonously on all model parameters without attraction. A criterion on the difference of potential between the two shells can be calculated analytically with respect to the escape region size and the ratio of diffusivities. Moreover we show that the limit of small width of the outer shell is equivalent to the surface-mediated diffusion problem [3].

[1] K. Schwarz *et al.*, Phys. Rev. Lett. **117**, 068101 (2016).
[2] A. E. Hafner and H. Rieger, Phys. Biol. **13**, 066003 (2016); Biophys. J **114**, 1420-1432 (2018).
[3] J.-F. Rupprecht *et al.*, Phys. Rev. E **86**, 041135 (2012).

DY 32.15 Tue 16:30 DYp

Clustering and emergence of collective motion in two dimensional colloidal systems with delayed feedback — •Robin A. Kopp and Sabine H. L. Klapp — ITP, TU Berlin, Berlin, Germany

In recent years, delayed feedback in colloidal systems has become an active and promising field of study [1,2], key topics being history dependence and the manipulation of transport properties.

Here we study the dynamics of a two-dimensional colloidal suspension, subject to time-delayed feedback. To this end we perform overdamped Brownian dynamics simulations, where the particles interact through a Weeks-Chandler-Andersen (WCA) potential. Furthermore, each particle is subject to a Gaussian, repulsive feedback potential [1], that depends on the difference of the particle position at the current time, $x(t)$ and the particle position at an earlier time, $x(t-\tau_{\mathrm{delay}})$.

We show that the introduction of this type of delayed feedback leads to clustering and the emergence of collective motion in Brownian WCA systems. Depending on the particle density, the cluster size and the propagation speed can be tuned by adjusting the delay time, the strength and the range of the repulsive feedback potential.

We also analyze the effects of time-delayed feedback on the mean-squared displacement (MSD) and, thus, the diffusion of one particle, as well as the effects on the MSD in the two-dimensional many-particle system described above.

[1] S. Tarama, S. U. Egelhaaf, and H. Löwen, Phys. Rev. E 100, 022609 (2019).
[2] R. Gernert and S. H. L. Klapp, Phys. Rev. E 92, 022132 (2015).

DY 32.16 Tue 16:30 DYp

The Role of Resampling in Population Annealing — •Denis Gessert[1,2] and Martin Weigel[1,3] — [1]Applied Mathematics Research Centre, Coventry University, Coventry, CV1 5FB, United Kingdom — [2]Institut für Theoretische Physik, Leipzig University, Postfach 100920, D-04009 Leipzig, Germany — [3]Institut für Physik, Technische Universität Chemnitz, D-09107 Chemnitz, Germany

Population Annealing (PA) is a population-based Monte Carlo algorithm that can be used for equilibrium simulations of thermodynamic systems with a rough free energy landscape. The algorithm has a number of parameters that can be fine-tuned to improve performance. While there is some theoretical and numerical work relating the parameters, little is known to date about the effect of choosing specific resampling protocols.

The 2d Ising model is used as a benchmarking system for this study. At first various resampling methods are implemented and numerically compared using a PA implementation on GPUs. In a second part the exact solution of the Ising model is utilized to create an artificial PA setting with effectively infinite Monte Carlo updates at each temperature as well as an infinite population. This allows one to look at resampling in isolation from other parameters and draw some general conclusions about the effects of the choice of resampling scheme.

DY 32.17 Tue 16:30 DYp

A Mapping between the Spin and Fermion Algebra — •Felix Meier, Daniel Waltner, Petr Braun, and Thomas Guhr — University Duisburg-Essen, Duisburg, Germany

We derive a formalism to express the spin algebra $\mathfrak{su}(2)$ in a spin s representation in terms of the algebra of L fermionic operators that obey the Canonical Anti-commutation Relations. We also give the reverse direction expressing the fermionic operators of many-body systems as non-linear expressions in the spin operators of a single spin. We extend here to further spin values the previous investigations by Dobrov [J.Phys.A: Math. Gen 36 L503, (2003)] who in turn clarified on an inconsistency within a similar formalism in the works of Batista and Ortiz [Phys. Rev. Lett. 86, 1082 (2001)]. Then we consider a system of L fermion flavors and apply our mapping in order to express it in terms of the spin algebra. Furthermore we investigate a possibility to simplify certain Hamiltonian operators by means of the mapping [1].

[1] arXiv:2101.10119 (2021)

DY 32.18 Tue 16:30 DYp

Percolation Properties of Spin Glasses — •Lambert Münster and Martin Weigel — TU Chemnitz, Institute of Physics, Chemnitz, Germany

In the Ising model there exists a direct interrelation between percolation of Fortuin-Kasteleyn clusters and the ferromagnetic phase transition. Percolation of Fortuin-Kasteleyn clusters in spin glasses occurs at a higher temperature than the spin-glass transition [1,2]. Even when looking at the Fortuin-Kasteleyn percolation in two replicas simultaneously the percolation temperature remains above the critical one [3].

In this work we consider Fortuin-Kasteleyn percolation also in more than two replicas. Since the utilization of multiple replicas shifts the percolation transition to lower temperatures this can possibly provide an Ansatz to develop new cluster algorithms for spin glasses. To adress the question of how the percolation threshold behaves as a function of the number of replicas we perform Monte Carlo simulations of the two-dimensional Ising spin glass.

[1] L. de Arcangelis, A. Coniglio, and F. Peruggi, Europhys. Lett. **14** 515 (1991).
[2] H. Fajen, A. K. Hartmann, and A. P. Young, Phys. Rev. E **102**, 012131 (2020).
[3] J. Machta, C. M. Newman, and D. L. Stein, J. Stat. Phys. **130**, 113 (2008).

DY 32.19 Tue 16:30 DYp

How to control a cooperative co-infection dynamics — Adib Khazaee[1] and •Fakhteh Ghanbarnejad[1,2] — [1]Sharif University of Technology, Tehran, Iran — [2]Technische Universität Dresden, Dresden, Germany

In previous studies, it has been shown that the cooperation between pathogens in co-infection spreading dynamics may lead to a discontinuous transition. Here, we are investigating how interventions like quarantine or vaccination with certain rates can turn the discontinuous transitions into continuous ones while increasing the threshold. We have used symmetric coupled Susceptible-Infectious-Recovered (SIR) equations to model the dynamics of co-infection spreading in a well-mixed population. Then we have intervened the epidemic dynamics by decreasing the susceptible population at a given rate, which means that the decreased susceptible compartment will be either quarantined or immunized at the same rate. Firstly, we have solved the equations numerically for a wide range of parameters and different initial conditions. We have illustrated how these interventions can change the type of the transition when the outflow rate gets large enough. Secondly, we have also solved the equations analytically for a special case in which the outflow rate varies with the size of the infectious compartment. Using the exact results for this special case, we can show how the characteristics of the fixed points change when the parameters change. Thirdly, we have explored the same dynamics on metapopulations and also agent based networks to examine how the topology of networks affects the effectiveness of interventions on the co-infection spread.

DY 32.20 Tue 16:30 DYp

In search for defining structural measures of real-world com-

plex networks — •Máté Józsa[1], Alpár Sándor Lázár[2], and Zsolt Iosif Lázár[1] — [1]Department of Physics, Babeş-Bolyai University, M. Kogălniceanu nr. 1, 400084, Cluj-Napoca, Romania — [2]Faculty of Medicine and Health Sciences, University of East Anglia, NR4 7TJ, Norwich, UK

Based on a large dataset containing thousands of real-world networks ranging from genetic, protein interaction, and metabolic networks to brain, language, ecology, and social networks we search for defining structural measures of the different complex network domains (CND). We calculate 208 measures for all networks and investigate the limitations and possibilities of identifying the key graph measures of CNDs. Relevant features are identified based on their role in classifying CNDs by machine learning algorithms. The approach presented here managed to identify well distinguishable groups of network domains and confer their relevant features. Instead of being universal these feature spaces turn out to be specific to each CND and not unique, i.e., depeding on the CND several network measures can be substituted for another. Based on: Józsa et al. Opportunities and challenges in partitioning the graph measure space of real-world networks. accepted for publication in Journal of Complex Networks.

DY 32.21 Tue 16:30 DYp

Kauffman NK models interpolated between K=2 and K=3 — •James Sullivan, Dmitry Nerukh, and Jens Christian Claussen — Department of Mathematics, Aston University, Birmingham, UK

The NK model was introduced by Stuart Kauffman and coworkers [1] as a model for fitness landscapes with tunable ruggedness, to understand epistasis and pleiotropy in evolutionary biology. In the original formulation, fitness is defined as a sum of fitness functions for each locus, each depending on the locus itself and K other loci. Varying K from $K = 0$ to $K = N - 1$ leads to different ruggedness of the landscape. In previous work we introduced a generalization that allows to interpolate between integer values of K by allowing K_i to assume different values for each locus. We focus on the interpolation between the most widely studied cases of $K = 2$ and $K = 3$ and characterize the landscapes by study of their local minima. Here we transfer this approach to Random Boolean Networks and investigate attractor basins and limit cycles where the average K assumes integer and noninteger values. Relaxing the assumption of degree-homogeneity is an important step towards more realistic boolean network models, relevant to a broad range of applications in the dynamics of social systems and in systems biology.
[1] Kauffman, S.; Levin, S., Journal of Theoretical Biology. 128, 11 (1987); Kauffman, S.; Weinberger, E., Journal of Theoretical Biology. 141, 211 (1989).

DY 32.22 Tue 16:30 DYp

Multiple Singularities of the Equilibrium Free Energy in a One-Dimensional Model of Soft Rods — •Juliane U. Klamser[1], Sushant Saryal[2], Tridib Sadhu[3], and Deepak Dhar[2] — [1]Gulliver UMR CNRS 7083, ESPCI Paris, Université PSL, 75005 Paris, France — [2]Indian Institute of Science Research and Education, Pashan, Pune 411008, India — [3]Tata Institute of Fundamental Research, Mumbai 400005, India

The Landau-Peierls argument and the Perron-Frobenius theorem are frequently used to argue against the existence of equilibrium phase transitions in one dimension. We present a new mechanism for the emergence of singularities in the thermodynamic free energy even in one dimension. This mechanism is observed in an instructive model of thin, rigid, linear rods of equal length 2ℓ whose centers lie on a one-dimensional lattice, of lattice spacing a. The interaction between rods is a soft-core interaction, having a finite energy U per overlap of rods. By solving the model analytically, we show that the equilibrium free energy per rod $\mathcal{F}(\frac{\ell}{a}, \beta)$, at inverse temperature β, has an infinite number of singularities, as a function of $\frac{\ell}{a}$. A two-dimensional extension of this model shows an interesting combination of two kinds of phase transitions, which we understand by an exact solution on the Bethe lattice.

DY 32.23 Tue 16:30 DYp

Interfaces beyond the elastic approximation — •Nirvana Caballero and Thierry Giamarchi — Department of Quantum Matter Physics, University of Geneva, 24 Quai Ernest-Ansermet, CH-1211 Geneva, Switzerland

The framework of disordered elastic systems is widely used to describe the physics of very diverse systems with typical scales ranging from nanometers to kilometers. However, this approach has the limitation that is only applicable to univalued and smooth interfaces, thus inducing uncontrolled approximations. Solving interface dynamics and statics in more realistic systems beyond the elastic approximation is still a largely open theoretical/analytical problem. We propose to address this problem by analyzing a Ginzburg-Landau model that allows us to extend the theory of disordered elastic systems. We show the connection of our approach with the disordered elastic systems theory [1]. In addition, we show how through this connection it is possible to explain otherwise not-understood experimental results in ferromagnetic interfaces [2]. [1] N. Caballero, E. Agoritsas, V. Lecomte, T. Giamarchi. PRB 102, 104204 (2020) [2] N.Caballero. arXiv:2009.14205 (cond-mat).

DY 32.24 Tue 16:30 DYp

Dynamical Casimir interactions with a body in uniform motion and the connection to nonreciprocal media — •Philip Rauch and Matthias Krüger — Institute for Theoretical Physics, Georg-August-Universität, 37077 Göttingen, Germany

The field of the dynamical Casimir effect opened up with the discovery of the phenomenon of vacuum friction acting on accelerated objects in a quantum electrodynamic vacuum. It was later shown that a cold body in vacuum, rotating along it's axis of symmetry, experiences a frictional force and spontaneously radiates energy.

However, the dynamical Casimir effect is not limited to setups with accelerated bodies. Even two parallel plates in relative lateral constant motion experience a frictional force without being in direct contact. The described phenomenas can be explained through the appearance of fluctuating electromagnetic fields, of thermal and quantum nature, in the respective system.

In the context of this work, we intend to extend and generalize the configuration of two parallel plates in relative motion. We study the setup of a translationally invariant body in uniform motion, relative to a body of arbitrary geometry and of reciprocal or nonreciprocal media. The goal is to compute the frictional force between the bodies, which is of relevance for recently developed Casimir engines [1]. As a framework we choose the Rytov formalism, complemented with scattering theory.

[1] David Gelbwaser-Klimovsky, Noah Graham, Mehran Kardar and Matthias Krüger, arXiv preprint arXiv:2012.12768 (2020)

DY 33: Nationale Forschungsdateninfrastruktur (NDFI) (joint session BP/CPP/DY/SOE)

Time: Tuesday 17:45–18:30 Location: BPb

Details will be published in a programme update.

DY 34: Theorie and Simulation - organized by Jens-Uwe Sommer (Leibniz-Institut für Polymerforschung Dresden, Dresden) (joint session CPP/DY)

Time: Wednesday 9:00–14:40 Location: CPPb

Invited Talk DY 34.1 Wed 9:00 CPPb

Data-driven methods in polymer physics: exploring the sequence space of copolymers — •Marco Werner — Institut Theorie der Polymere, Leibniz-Institut für Polymerforschung Dresden, Germany

Automated experiments and computer simulation on highly parallel

machines push the limits of available data in the field of soft matter. For long polymer chains, however, any data set can cover only a marginal fraction of the giant chemical space and conformation space involved. In this talk, data-driven strategies are discussed that allow to trace hidden physical patterns in both giant spaces by machine learning algorithms. The discussion is centered on the example of hydrophilic / hydrophobic copolymers and their interaction with lipid membranes. A neural network has been trained to predict the free energy landscape near a membrane as a function of the copolymer sequence. The information learned in the hidden neural layers showed that the neural network compressed the sequence space into physically meaningful latent variables. The learned semantics was transferable between simulation data with different levels of coarse-graining, and allowed for a physics-informed inverse search for the copolymer sequence leading to the smallest translocation time through the membrane.

DY 34.2 Wed 9:40 CPPb

Prediction of iSCFT chemical potentials via machine learning — •Lucia Milena Wesenberg, Ludwig Schneider, and Marcus Müller — Institute for Theoretical Physics, Georg-August University Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

We explore the use of machine learning to enhance the simulation of polymeric nanostructures. Self-assembly of symmetric diblock copolymers is the chosen testing system for this purpose. Such polymers consist of two equally long blocks of different monomer types. As the two monomer types are incompatible but linked in the center of each polymer, microphase separation occurs.

Simulations of such systems often pose a challenge for particle-based models as large systems and concomitantly long time scales need to be simulated. Thus, continuum models are employed, where the dynamics can be conceived as the relaxation towards the local minimum of a free-energy basin and jumps between such basins. These models reduce the degrees of freedom by integrating out the molecular degrees of freedom. The most detailed continuum model investigated here is the Self-Consistent Field Theory (SCFT). Unfortunately, dynamic SCFT requires the chemical potential of a non-equilibrium morphology that is computationally expensive to obtain. The SCFT potential calculation is an iterative process, and the stability of the algorithm depends heavily on the starting conditions. Our machine learning approach provides suitable initial conditions for the algorithm. The predicted starting conditions reduce the computational effort considerably.

DY 34.3 Wed 10:00 CPPb

Machine Learning Inter-Atomic Potentials Generation Driven by Active Learning: A Case Study for Amorphous and Liquid Hafnium dioxide — •Anand Narayanan Krishnamoorthy[1,2], Ganesh Sivaraman[3], Matthias Baur[1], Christian Holm[1], Chris Benmore[6], Marius Stan[4], Gabor Csanyi[5], and Álvaro Vázquez–Mayagoitia[7] — [1]Institute for Computational Physics, University of Stuttgart — [2]Helmholtz Institute Muenster — [3]Leadership Computing Facility, Argonne National Laboratory - USA — [4]Applied Materials Division, Argonne National Laboratory, USA — [5]Department of Engineering, University of Cambridge, UK — [6]X-ray Science Division, Argonne National Laboratory, USA — [7]Computational Science Division, Argonne National Laboratory, USA

We propose a novel active learning scheme for automatically sampling a minimum number of uncorrelated configurations for fitting the Gaussian Approximation Potential (GAP). We apply this scheme to a Hafnium dioxide (HfO2) dataset generated from a melt-quench ab initio molecular dynamics (AIMD) protocol. Our results show that the active learning scheme, with no prior knowledge of the dataset is able to extract a configuration that reaches the required energy fit tolerance. Further, molecular dynamics (MD) simulations performed using this active learned GAP model on 6144-atom systems of amorphous and liquid state elucidate the structural properties of HfO2 with near ab initio precision and quench rates (ie 1.0 K/ps) not accessible via AIMD.

40 min. meet the speakers - break

DY 34.4 Wed 11:00 CPPb

BoltzmaNN: Heuristic inverse design of pair potentials using neural networks — •Fabian Berressem, Mihir Khadilkar, and Arash Nikoubashman — Institute of Physics, Johannes Gutenberg University Mainz, Germany

In this work, we investigate the use of neural networks (NNs) to devise effective equations of state from a given isotropic pair potential using the virial expansion of the pressure. We train the NNs with data from molecular dynamics simulations, sampled in the NVT ensemble at densities covering both the gas- and liquid-like regime. We find that the NNs provide much more accurate results compared to the analytic estimate of the second virial coefficient derived in the low density limit. Further, we design and train NNs for computing the potential of mean force from the radial pair distribution function, g(r), a procedure which is often performed for coarse-graining applications. Here, we find that a good choice for the loss function is crucial for an accurate prediction of the pair potentials. In both use cases, we study in detail how providing additional information about forces and the density impacts the performance of the NNs. We find that including this additional information greatly increases the quality of the predictions, since more correlations are taken into account. Further, the predicted potentials become smoother and are in general much closer to the target potential.

DY 34.5 Wed 11:20 CPPb

PolyEC - an event-chain framework — •Tobias A. Kampmann, David Müller, and Jan Kierfeld — TU Dortmund University, Germany

PolyEC is a MC event chain framework suitable for simulation of various colloidal systems. We focus on modularity and extensibility to simulate heterogenous systems. In event-chain simulations only one particle is active and interactions can be treated independently by factorization, which allows for a highly modular approach for particlebased simulations. Albeit ECMC is a monte-carlo method, a single event-chain is deterministic (although there are modifications where this is not true). One crucial feature of this method is that each state a piece-wise deterministic event-chain visits between events are properly (Boltzmann-) weighted. This opens the possibility to measure observables like pressure or the distribution of energy on the fly. As examples we show needle-colloid mixtures and an active particle system.

Invited Talk DY 34.6 Wed 11:40 CPPb

Structure formation in drying films and droplets — •Arash Nikoubashman[1], Michael Howard[2], Michael Kappl[3], and Hans-Jürgen Butt[3] — [1]Johannes Gutenberg University Mainz, Mainz, Germany — [2]Auburn University, Auburn (AL), USA — [3]Max Planck Institute for Polymer Research, Mainz, Germany

Drying complex liquids are encountered in many technologies, including painting, manufacturing polymer LED displays, and spraying pesticides. Here, colloids and/or polymers are typically initially dispersed in a solvent such as water, which then evaporates, leaving behind a dried residue. Our recent simulations and experiments of drying bidisperse suspensions revealed that sufficiently fast evaporation could induce spatial segregation of the two species, with the smaller ones accumulating at the liquid-air interface followed by a homogeneously mixed region of small and big particles. To understand this counterintuitive behavior, we conducted particle-based simulations and dynamic density functional theory calculations, with and without hydrodynamic interactions. According to our model calculations, this drying-induced segregation occurs due to a local increase of the solute concentration near the film-air interface, resulting in a chemical potential gradient for both species; typically, this gradient is steeper for the larger particles, leading to a stronger force pushing them away from the liquid-air interface. Segregation then occurs if the mobility of the larger particles decreases slower than the driving force increases. Comparing the various simulations and experiments, we found that including hydrodynamics can decrease or even completely suppress the segregation.

DY 34.7 Wed 12:20 CPPb

Structure of bottlebrush polymers end-grafted to a planar surface — •Jaroslaw Paturej[1], Paul Jungmann[2], Jens-Uwe Sommer[3], and Torsten Kreer[2] — [1]University of Silesia, Katowice, Poland — [2]IPF, Dresden, Germany — [3]Johannes Gutenberg Universität, Mainz, Germany

Polymer brush is a hybrid material composed of a solid substrate coated with end-grafted polymers. We conducted coarse-grained molecular dynamics simulations and scaling theory of the equilibrium structure of planar brushes formed by bottlebrush polymers. Bottlebrushes are branched macromolecules consisting of densely spaced linear side chains grafted along a central (linear) backbone. We elucidate the relationship between bottlebrush architecture, surface coverage σ and polymer brush thickness H. We study the impact of three

length scales on the brush height H: D_0 , the cross-section radius of bottlebrushes determined by the degree of polymerization of side chains N_{sc} , R_0 the (overall) size of bottlebrushes controlled by the degree of polymerization of backbone N_{bb} and d the distance between nearest-neighbor tethering sites. The latter quantity provides a measure of molecular coverage σ of a substrate defined as the number of bottlebrush polymers per unit surface area $\sigma \propto 1/d^2$. Our theoretical analysis identifies three conformational regimes for the height H, which gradually establish upon increasing substrate coverage and stem from interplay between relevant length scales: d, D_0 and R_0.

DY 34.8 Wed 12:40 CPPb

Thermal conductivity of commodity plastics: From conventional to smart polymers — •Debashish Mukherji — Stewart Blusson Quantum Matter Institute, University of British Columbia, Vancouver Canada

Polymers are an important class of soft matter whose properties are dictated by large fluctuations. Because of this reason commodity polymers are ideal for the flexible design of advanced materials. However, applications of polymers are often hindered by their low thermal conductivity κ. While low κ values are desirable for thermoelectric materials, they create severe problems when used under the high temperature conditions. Going from the polymers dictated by weak Van der Waals to hydrogen-bonded interactions, κ varies between 0.1-0.4 W/Km. Using molecular dynamics simulations we study thermal transport and its links to the elastic response of polymers. We find that there exists a maximum attainable stiffness, thus limiting an upper bound of κ. The specific chemical details and the glass transition temperature play no role in controlling κ, especially when the microscopic interaction is hydrogen bonded. These results are consistent with the minimum thermal conductivity model and experiments.

[1] D. Mukherji, C. M. Marques, K. Kremer, Annual Review of Condensed Matter Physics 11, 271 (2020). [2] D. Bruns, T. E. de Oliveira, J. Rottler, D. Mukherji, Macromolecules 52, 5510 (2019). [3] C. Ruscher, J. Rottler, C. Boott, M. J. MacLachlan, D. Mukherji, Physical Review Materials (accepted) (2019).

60 min. meet the speakers - break

DY 34.9 Wed 14:00 CPPb

Polymer Architectures by Chain Walking Catalysis - Theory, Simulations, and Experiments — •Ron Dockhorn[1], Laura Plüschke[1,2], Albena Lederer[1,2], Jan Merna[3], and Jens-Uwe Sommer[1,2] — [1]Leibniz-Institut für Polymerforschung Dresden e.V., D-01069 Dresden, Germany — [2]Technische Universität Dresden, Institute for Theoretical Physics, D-01069 Dresden, Germany — [3]University of Chemistry and Technology Prague, CZ-16628 Praha, Czech Republic

Recently developed chain walking catalysis is an elegant approach to synthesize branched polyethylenes (CWPE) with controllable structure and properties. The catalyst is able to walk along the polymer and to polymerize ethylene and α-olefines into complex topologies depending on pressure, temperature, and olefine concentration introducing branch-on-branch structures. Coarse-grained Monte Carlo simulations utilizing the bond fluctuation model of the CWPE are performed to investigate the influence of the walking mechanism on the polymer architecture. For slow walking rates the structure growths with linear chain extensions, whereas fast walking rates promote dendritic growth of the polymer. The crossover regime is characterized by linear global features and dendritic local substructures contrary to randomly hyperbranched systems. Indeed, the obtained CWPE systems have characteristics of dendritic bottle brushes and the degree of branching can be adjusted by the walking rate of the catalyst. These findings are aimed to understand the physical properties of the CWPE structures and to improve the synthesis of a new class of hyperbranched molecules.

DY 34.10 Wed 14:20 CPPb

Mechanics of shape-shifting droplets — •Ireth Garcia-Aguilar[1], Piermarco Fonda[1], Eli Sloutskin[2], and Luca Giomi[1] — [1]Instituut-Lorentz, Universiteit Leiden, The Netherlands — [2]Department of Physics and Institute of Nanotechnology & Advanced Materials, Bar-Ilan University, Ramat-Gan, Israel

It has been long understood that dispersed liquid droplets are spherical in order to minimize the tension at their interface. Surprisingly, oil emulsion droplets in water have been observed to spontaneously deform into polyhedral shapes when cooling down the system. The equilibrium shape of a droplet at some temperature depends on its initial volume but all deformations take place below the freezing point of the surfactant monolayer, while the bulk oil and water remain liquid. The frozen interface forms an hexagonal lattice which is topologically constrained to accommodate defects. These produce large stresses that induce in and out-of-plane deformations in the crystal which in turn are opposed by the interfacial tension between oil and water. Initially, it was thought that this competition determines the droplet shape; however, this alone can not explain the size dependence of the deformations. By modeling the interface as a 2D elastic surface and studying its equilibrium geometry, we found a mechanism that explains the size-scaling behaviour. Interestingly, crystalline defects are not the only peculiarity playing a role in shaping the droplets.

DY 35: Complex Fluids and Soft Matter 2 - organized by Uwe Thiele (Münster) (joint session DY/CPP)

Time: Wednesday 9:00–10:30 Location: DYa

DY 35.1 Wed 9:00 DYa

Flow structure of marangoni-contracted sessile droplets — O. Ramirez[1], M.A. Hack[2], W. Kwiecinski[3], E.S. Kooij[3], T.J. Seegers[2], J.H. Snoeijer[2], and •S. Karpitschka[1] — [1]MPI for Dynamics and Self-Organization, Göttingen, Germany — [2]Physics of Fluids Group, University of Twente, Enschede, Netherlands — [3]Physics of Interfaces Group, University of Twente, Enschede, Netherlands

A droplet of two miscible liquids should spread over a high-energy surface until complete wetting. However, if one component is more volatile and has a higher surface tension, a quasi-stationary non-vanishing apparent contact angle can be observed. This is caused by the enrichment of the residual component near the contact line and the associated surface tension gradient. A hydrodynamic-evaporative model, using a long-wave approximation for the droplet coupled to diffusion limited evaporation predicts a balance between Marangoni and capillary flows and a power law between the apparent contact angle and the ambient humidity [Karpitschka et al., Langmuir (2017)]. This explanation differs from a recent model, where the low surface tension of a precursor around the droplet is held responsible [Benusiglio et al., Soft Matter (2018)]. A discrimination between possible mechanisms requires experimental resolution of the flow in the drop. We present uPIV measurements and relate them to the apparent shape of the drop, for aqueous solutions of various short chain carbon diols. Depending on the surface activity of the diol, its concentration, and the ambient humidity, we observe different regimes, indicating that multiple mechanisms lead to the observed angles.

DY 35.2 Wed 9:20 DYa

Coalescence of liquid droplets in a quasi 2D liquid film — •Christoph Klopp, Ralf Stannarius, and Eremin Alexey — Institute of Physics, Otto von Guericke University, Department of Nonlinear Phenomena, 39106 Magdeburg

Coalescence of droplets plays a crucial role in nature and modern technology. Various experimental and theoretical studies explored droplet dynamics in 3D and on 2D solid or liquid substrates [1-3].

Here, we demonstrate coalescence of isotropic droplets in thin quasi 2D liquids, an overheated smectic A films. We investigated their dynamics experimentally and measured the shape deformation during the whole merging process using high-speed imaging. This system is a unique example, where the lubrication approximation can be directly applied, and the smectic membrane plays the role of the precursor film. Our studies reveal the scaling laws of the coalescence time depending on the droplet size and the material parameters. We also compared our results with existing models for liquid lens coalescence on liquid and solid surfaces.

[1] J. D. Paulsen et al., Coalescence of bubbles and drops in an outer

fluid, Nat. Commun. 5, 3182 (2014)

[2] D. G. A. L Aarts et al., Hydrodynamics of Droplet Coalescence, Phys. Rev. Lett. 95, 164503 (2005)

[3] N. S. Shuravin et al., Coalescence of viscous two-dimensional smectic islands, Phys. Rev. E 99, 062702 (2019)

DY 35.3 Wed 9:40 DYa

Designing Pickering Emulsions for Catalysis: Influence of Nanoscale Particle Properties on Microscale Droplets — •Sebastian Stock[1], Annika Schlander[1], Kai Spanheimer[1], Maresa Kempin[2], Ariane Weber[3], Reinhard Schomäcker[3], Anja Drews[2], Marcus Gallei[4], and Regine von Klitzing[1] — [1]TU Darmstadt, Darmstadt, Germany — [2]HTW Berlin, Berlin, Germany — [3]TU Berlin, Berlin, Germany — [4]Saarland University, Saarbrücken, Germany

Pickering Emulsions (PEs) describe emulsions stabilized by (nano) particles. The aim of the work was to design PEs as a reaction environment for catalytic reactions. As a model reaction the hydroformylation of 1-dodecene was investigated. Due to the PEs high stability separation methods with outstanding energy efficiency are applicable e. g. the separation of the oil phase by nanofiltration. Many microscopic and macroscopic PE properties are determined in a large degree by the nanoscale properties of the particles. In order to distinguish the impact of particle surface charge both positively and negatively charged silica spheres were produced. This was achieved by adequate surface modification. The resulting nanoscale particle properties concerning size, shape, charge, and hydrophobicity were investigated via Transmission Electron Microscopy (TEM), ζ-potential and sessile drop measurements, the effect on the microscopic emulsion properties were studied with microscopy and the PEs reaction behavior including yield and stability was evaluated.

Invited Talk DY 35.4 Wed 10:00 DYa

When surface viscosities rule: Bubble relaxation and thin film wrinkling — •Kirsten Harth — Institut für Physik, Otto von Guericke Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg

The dynamics of liquid drops and gas bubbles in a surrounding fluid is a classic field of fluid mechanics, studied for over a century. The mathematical problem can be complex already for the case of clean fluid-fluid interfaces, characterized solely by a constant surface tension. However, applications such as ink-jet printing, emulsion characterization or typical biologically inspired systems usually deal with more complex interfacial properties, e.g., adsorbed fluid or contaminant films. Those can completely dominate the overall shape dynamics.

Merged centimeter-sized soap bubbles or rupturing micrometer-thick soap films are a simple yet ideal model system for surface-tension based relaxation. Replacing the soap film by a more complex membrane, nanometer-thin liquid crystalline films in our case, introduces qualitatively new effects due to reorganization of the membrane upon surface area reduction. The talk highlights two aspects: First, the consequences of an effective interfacial viscosity for the relaxation dynamics, known also from interfacial fluid films or adsorbed surfactant layers. Second, out-of-plane bulging and dynamic wrinkling of the interfacial membrane in response to external stress. Experiments will be accompanied by a theoretical / numerical analysis.

DY 36: Active Matter 3 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP)

Time: Wednesday 9:00–10:40 Location: DYb

DY 36.1 Wed 9:00 DYb

Localized States in active Phase-Field-Crystal models — •Max Philipp Holl[1], Lukas Ophaus[1,2], Svetlana Gurevich[1,2], and Uwe Thiele[1,2] — [1]Institut für Theoretische Physik, Münster, Germany — [2]Center for Nonlinear Science, Münster, Germany

The phase-field-crystal (PFC) model represents a gradient dynamics of a single order parameter field related to density and is able to describe crystallisation processes. The model describes a variety of spatially extended periodic and localized steady structures. In an active PFC model, encoding for instance the active motion of self-propelled colloidal particles, the PFC model's gradient dynamics structure is broken by a nonreciprocal coupling of density and an additional polarization field. Then, resting and traveling localized states exist with transitions characterized by parity-breaking drift bifurcations. We briefly review the snaking behavior of localized states in passive and active PFC models before discussing the bifurcation behaviour of localized states in systems of (i) two passive PFC with nonreciprocal coupling and (ii) coupled passive and active PFCs.

DY 36.2 Wed 9:20 DYb

Cooling by Heating in Inertial Active Brownian Particles — •Lukas Hecht and Benno Liebchen — Institut für Physik kondensierter Materie, Technische Universität Darmstadt, Hochschulstraße 8, D-64289 Darmstadt, Germany

The active Brownian particle (ABP) model is commonly used to model active matter consisting of particles which extract energy from their environment to generate directed motion. For both overdamped and inertial ABPs, motility-induced phase separation occurs in a certain parameter regime. Remarkably, inertial ABPs show a coexistence of different effective temperatures of the dilute and the dense phase whereas overdamped ABPs have a uniform effective temperature even in the phase-separated state [1].

The coexistence of different temperatures brings us to the cooling-by-heating idea: Increasing the self-propulsion speed locally could lead to a locally decreased temperature. We investigate the cooling-by-heating idea with numerical simulations of ABPs with translational and rotational inertia. Since a locally increased self-propulsion speed causes a decrease of the local particle density, detailed knowledge about the phase diagram is essential to determine appropriate parameters for which cooling by heating is possible. Therefore, we analyze the phase transition behavior of inertial ABPs and the corresponding phase diagram.

[1] S. Mandal, B. Liebchen, and H. Löwen, "Motility-Induced Temperature Difference in Coexisting Phases", Phys. Rev. Lett. 123, 228001 (2019).

DY 36.3 Wed 9:40 DYb

Active dynamics of microalgae in an anisotropic porous environment — •Florian von Rüling and Alexey Eremin — Otto von Guericke University Magdeburg

Understanding the motion of active colloids in porous media is essential for fundamental physics and a wide range of biological and medical applications. Cell growth and motion is often restricted by complex environments such as the cytoskeleton. Here, we report experimental studies on the motion of the unicellular microalgae Chlamydomonas reinhardtii through a flexible anisotropic lattice of chains formed by magnetic particles. In a thin cell or capillary, the microalgae interact with chain-like aggregates that form in a magnetic field. Shape-anisotropic structures guide the swimmers or initiate tumbling. They affect the persistence time of the microswimmer's motion. As the chains of magnetic particles disintegrate quickly after turning off the magnetic field, the system transforms into an unperturbed state. We investigate the effect of the chains on the orientational velocity correlations in the active dynamics of the algae.

DY 36.4 Wed 10:00 DYb

Effective Langevin equations for a polar tracer in an active bath — •Milos Knezevic and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany

We study the motion of a polar tracer, having a concave surface, immersed in a two-dimensional suspension of active particles. Using Brownian dynamics simulations, we measure the distributions and auto-correlation functions of force and torque exerted by active particles on the tracer.The tracer experiences a finite average force along its polar axis, while all the correlation functions show exponential decay in time. Using these insights we construct the full coarse-grained Langevin description for tracer position and orientation, where the active particles are subsumed into an effective self-propulsion force and exponentially correlated noise for both translations and rotations. The

ensuing mesoscopic dynamics can be described in terms of five dimensionless parameters. We perform a thorough parameter study of the mean squared displacement, which illustrates how the different parameters influence the tracer dynamics, which crosses over from a ballistic to diffusive motion. We also demonstrate that the distribution of tracer displacements evolves from a non-Gaussian shape at early stages to a Gaussian behavior for sufficiently long times. Finally, for a given set of microscopic parameters, we establish a procedure to estimate the matching parameters of our effective model, and show that the resulting dynamics is in a very good quantitative agreement with the one obtained in Brownian dynamics simulations.

DY 36.5 Wed 10:20 DYb

Collective behaviour of self-propelled elliptical particles — •Ashreya Jayaram, Andreas Fischer, and Thomas Speck — Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7-9, 55128 Mainz, Germany

Ensembles of anisotropic self-propelled particles exhibit a rich variety of emergent phases. A combination of short-ranged excluded volume interactions, which induce inter-particle forces and torques, and self-propulsion determines the resulting macroscopic structure. Starting from a point in parameter-space which displays motility-induced phase separation (MIPS) for isotropic particles, we systematically increase the aspect ratio of the constituent ellipses. On doing so, first, MIPS breaks down paving way to a spatially homogeneous state comprising polar domains. Secondly, at sufficiently large aspect ratios, particles aggregate into polar bands. We rationalize these observations from simulations by extracting two effective parameters, *viz.*, the force imbalance coefficient and the coupling to the local polarization, that enter the mean-field description of the system.

DY 37: Invited Talk: Ludovic Berthier (Montpellier)

Time: Wednesday 9:00–9:30 Location: DYc

Invited Talk DY 37.1 Wed 9:00 DYc

Physical properties of ultrastable computer-generated glasses — •Ludovic Berthier — Laboratoire Charles Coulomb, University of Montpellier and CNRS

Computer simulations give unique insights into the microscopic behavior of amorphous materials. It became recently possible to generate ultrastable glass configurations using a simple Monte Carlo algorithm for a broad variety of model glass-formers. In this talk, I will show that this discovery has allowed a deeper understanding of the rheological, thermodynamic and dynamic aspects of glasses and supercooled liquids.

DY 38: Partial Synchronization in Networks (Focus Session joint with DY and BP) (joint session SOE/DY)

Time: Wednesday 9:00–10:00 Location: SOEa

DY 38.1 Wed 9:00 SOEa

Partial synchronization as a model for uni-hemispheric sleep — •Jakub Sawicki[1], Lukas Ramlow[1,2], and Eckehard Schöll[1,3] — [1]Institute of Theoretical Physics, Technische Universität Berlin, Germany — [2]Humboldt University of Berlin, Berlin, Germany — [3]Potsdam Institute for Climate Impact Research, Potsdam, Germany

Uni-hemispheric slow-wave sleep is a dynamical state of the brain where one hemisphere is asleep while the other remains awake. This state can also be characterized by simultaneous but spatially separated occurrence of high and low degree of synchronization in the sleeping and the awake hemisphere, respectively. Therefore, this real world phenomenon can be described in terms of partial synchronization characterizing patterns of coexistence of synchronized and desynchronized parts of a network. Here we investigate the occurrence of partial synchronization patterns in empirical structural connectivities of the human brain. The connectivities consist of ninety regions of interest using the Automated Anatomical Labeling (AAL) Atlas, and were derived by magnetic resonance imaging (MRI) based probabilistic diffusion tractography. The local dynamics is modeled by FitzHugh-Nagumo oscillators. We demonstrate under which conditions partial synchronization patterns with respect to the brain hemispheres can be found.

DY 38.2 Wed 9:20 SOEa

Effect of Topology upon Relay Synchronization in Triplex Neuronal Networks — •Fenja Drauschke, Iryna Omelchenko, Rico Berner, Jakub Sawicki, and Eckehard Schöll — Institute of Theoretical Physics, Technische Universität Berlin

Complex networks consisting of several interacting layers allow for remote synchronization of distant layers via an intermediate relay layer. We investigate relay synchronization in a three-layer neuronal network and study the effect of the topology of the layers upon the synchronization scenarios. Introducing random topologies either in the outer layers or in the middle (relay) layer leads to an increase of the range of inter-layer coupling strength for which the relay-synchronized state is preserved, compared with regular nonlocal coupling topologies.

DY 38.3 Wed 9:40 SOEa

Complexified Kuramoto model – synchrony in the weak coupling regime — •Moritz Thümler, Sheshagobal Srinivas, Malte Schroeder, and Marc Timme — TU Dresden, Dresden, Germany

Networks of Kuramoto oscillators constitute paradigmatic models for the emergence of temporal patterns – foremost synchrony – across oscillatory systems. Here we extend the Kuramoto model to complex dynamical variables. We uncover a transition from traditional synchrony emerging for sufficiently large coupling strengths to a second type of synchrony that exists in the weak coupling regime, i.e. below the coupling required for the real-variable model to synchronize. The new type of synchrony state is known from systems that are not dissipative but conservative, compare [1,2] for relations of the two system types. We introduce a novel, two dimensional order parameter for networks of N oscillators that enables us to consistently quantify synchrony.

[1] D. Witthaut and M Timme, Phys. Rev. E 90:032917 (2014)
[2] D. Witthaut et al., Nature Comm. 8:14829 (2017)

DY 39: Glasses and Glass Transition 1 - organized by Andreas Heuer (Münster) (joint session DY/CPP)

Time: Wednesday 9:30–10:30 Location: DYc

DY 39.1 Wed 9:30 DYc

Molecular dynamics study of 1,4-polybutadiene supported films — •Fedir Demydiuk[1], Hendrik Meyer[1], Joerg Baschnagel[1], Mathieu Solar[1], and Wolfgang Paul[2] — [1]Institute Charles Sadron, University of Strasbourg, UPR22 CNRS 67034 Strasbourg, France — [2]Institut für Physik, University of Halle,

06120 Halle (Saale), Germany

Our work is dedicated to studying the influence of realistic intrachain constraints imposed due to the presence of torsional barriers on the glass transition in thin polymer films of supported geometry by means of classical molecular dynamics simulations. In order to do so, we use the well-established united-atom model of 1,4-polybutadiene, that has been developed by W. Paul and coworkers (G. D. Smith and W. Paul, *J. Phys. Chem. A*, 102, 1200 (1998)) and studied in confined systems (M. Solar, K. Binder and W. Paul, *J. Chem. Phys*, 146, 203308 (2017)). In our case, the model had to be adapted for usage in systems with free surface.

Focusing on dynamics of united atoms and shear-stress relaxation, we first discuss our results for bulk polybutadiene and then present first extensions of bulk simulations to supported films. First analysis of the supported films shows that dynamics is enhanced at the free surface and slowed down at the substrate.

DY 39.2 Wed 9:50 DYc

Glassy dynamics, glass transition and electrical conductivity of Guanidinium based ILCs: Influence of the cation headgroup configuration — •Mohamed A Kolmangadi, Arda Yildirim, and Andreas Schönhals — Bundesantalt für Materialforschung und -prüfung (BAM), Berlin, Germany

Molecular mobility and conductivity of four bent shaped tetramethylated guanidinium based ionic liquid crystals (ILCs) with varying head group configuration (cyclic or acyclic) and alkyl chain length is investigated by a combination of broadband dielectric spectroscopy (BDS) and specific heat spectroscopy (SHS). BDS investigation reveals two relaxation processes: a localized γ process and $\alpha 1$ process corresponding to the glassy dynamics. SHS investigations show one calorimetrically active $\alpha 2$ relaxation process also corresponding to the glassy dynamics of the system. The temperature dependencies of the relaxation rates of two different glassy dynamics are similar for the cyclic ILC while for the acyclic counterpart they are different. Possible molecular assignments for the $\alpha 1$ and $\alpha 2$ relaxation are discussed in detail. Alongside relaxation processes, a significant conductivity contribution was observed for all ILCs, where the absolute value of DC conductivity increases by 4 orders of magnitude at the transition from the crystalline to the hexagonal columnar phase. The increase is traced to the change in the underlying conduction mechanism from the delocalized electrical conduction in the Cry phase to ionic conduction in the quasi 1D ion columns formed in the hexagonal columnar mesophase.

DY 39.3 Wed 10:10 DYc

A new approach to probe the plastic rearrangements inside a shear band. — •Moumita Maiti and Andreas Heuer — University of Münster, Münster, Germany

We follow a single particle trajectory of a system subjected to a uniform shear by calculating it's instantaneous displacement with time. There are intermittent hops in the trajectory, which are treated as plastic events, and the particles which have performed hops, are called active. In the steady state, the number of events per particle of the whole system increases initially by increasing system size, and by further increment the number almost saturates. The onset of saturation is the onset of shear banding. Interestingly, above the onset, we observe a system size scaling in the number of plastic events only inside the shear band. The scaling is explained from the intervals between two consecutive hops of a particle, which decreases on an average with increasing size. We further show that there is a stronger coupling between active particles with increasing system size which helps to understand the smaller value of the intervals, so our approach captures the collective nature of plastic events. Additionally, we observe a system spanning avalanches for these sizes which exhibit shear banding, and the distribution of avalanche sizes have a different exponent from the mean field theory.

DY 40: Complex Fluids and Soft Matter 3 - organized by Uwe Thiele (Münster) (joint session DY/CPP)

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

DY 40.1 Wed 11:00 DYa

Thermally driven material transport in thin freestanding films — •Torsten Trittel, Kirsten Harth, Christoph Klopp, and Ralf Stannarius — Otto-von-Guericke Universität, 39106 Magdeburg, Germany

In addition to their important role in display applications, liquid crystals are attractive in the field of fundamental physics. Smectics can form thin free-standing films with aspect ratios exceeding one million to one (width/thickness). These homogeneously thin films serve as an ideal model system for the study of two-dimensional hydrodynamics. We investigate thermally driven material transport within the film plane under microgravity conditions. Temperature differences in the film lead to thermocapillary (Marangoni) flow. In materials with a normal (negative) temperature coefficient of the surface tension $d\sigma/dT < 0$, temperature inhomogeneities lead to material transport from the warm to the cold film edge. In materials with $d\sigma/dT > 0$, flow is reversed. We present a quantitative model, which predicts that the temperature difference between the hot and cold film edge is the relevant parameter, not the gradient as in conventional thermoconvection.

DY 40.2 Wed 11:20 DYa

Phase Field Crystal Model of patchy colloids in two dimensions — •Robert F. B. Weigel and Michael Schmiedeberg — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Motivated by our recent simulation studies of quasicrystals that occur in systems of patchy colloids [1,2], we develop a Phase Field Crystal Model for such particles. We consider two-dimensional patchy colloids with symmetrically placed attractive sites on their surface, such that they interact with preferred binding angles. We construct a free energy functional that is similar to the free energy used for liquid crystals [3], but obeys the symmetry of the patchy colloids. The functional depends on both a density field and an orientation field. Free numerical minimization of the free energy yields a rich phase behavior of complex structures.

[1] Gemeinhardt et al., Eur. Phys. J. E 41, 126 (2018).
[2] Gemeinhardt et al., EPL 126, 38001 (2019).
[3] Achim et al., Phys. Rev. E 83, 061712 (2011).

DY 40.3 Wed 11:40 DYa

Orientational order parameters for arbitrary classical and quantum liquid crystals — •Michael te Vrugt and Raphael Wittkowski — Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149, Münster, Germany

The orientational order of liquid crystals is measured using orientational order parameters such as the polarization vector and the nematic tensor. These are obtained from an angular or Cartesian multipole expansion of the one-body distribution function of the liquid crystal. In recent years, there has been an increase of interest in particles with general shapes, as well as in so-called "quantum liquid crystals" which are relevant, e.g., in superconductors. However, the standard methods for defining order parameters are not applicable to biaxial particles or quantum systems. In this talk, we discuss how the orientational expansion method can be generalized to particles with arbitrary shape [1] and to quantum soft matter [2]. This provides a unified framework for general classical and quantum liquid crystals.

[1] M. te Vrugt and R. Wittkowski, AIP Advances 10, 035106 (2020)

[2] M. te Vrugt and R. Wittkowski, Annalen der Physik 532, 2000266 (2020)

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DY 40.4 Wed 12:00 DYa

Analytical classical density functionals from an equation learning network — •ShangChun Lin[1], Georg Martius[2], and

Martin Oettel[1] — [1]Institut für Angewandte Physik, Universität Tübingen, Tübingen, Germany — [2]Max Planck Institute for Intelligent Systems, Tübingen, Germany

We explore the feasibility of using machine learning methods to obtain an analytic form of the classical free energy functional for two model fluids, hard rods and Lennard Jones, in one dimension. The Equation Learning Network proposed in Ref.[1] is suitably modified to construct free energy densities which are functions of a set of weighted densities and which are built from a small number of basis functions with flexible combination rules. This setup considerably enlarges the functional space used in machine learning optimization. As a result in Ref [2], we find a good approximation for the exact hard rod functional. For the Lennard Jones fluid, we let the network learn the full excess free energy functional and the excess free energy functional related to interparticle attractions. Both functionals show a good agreement with simulated density profiles inside and outside the training region.

[1]G. Martius and C. H. Lampert, arXiv:1610.02995 (2016).
[2]S.-C. Lin, G. Martius and M. Oettel, JCP 152.2 (2020): 021102.

DY 40.5 Wed 12:20 DYa

Particle-resolved topological defects of smectic colloidal liquid crystals in extreme confinement — •René Wittmann[1], Louis Cortes[2], Hartmut Löwen[1], and Dirk Aarts[2] — [1]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, Germany — [2]Department of Chemistry, University of Oxford, UK

Hard particles are a standard model for colloidal systems and can be effectively studied within classical density functional theory (DFT). Fundamental mixed measure theory (FMMT) allows to predict the phase behavior of a hard-body fluid solely from the shape of individual particles. Recent experimental advances allow for the synthesis of colloids with a nearly hard interaction that can be analyzed on the single-particle level. Slices of such silica rods confined in a three-dimensional chamber under gravity can be considered a quasi-two-dimensional fluid that exhibits typical liquid-crystal behavior in confinement.

Applying FMMT to hard discorectangles in two dimensions, we study a smectic fluid in extreme complex confinement, where the optimal bulk layer spacing competes with the extrinsic geometric and topological constraints. As a result, we characterize a variety of topologically different states in an annular geometry, also observed in particle-resolved experiments with silica rods. By further comparing the free energy of the different states, naturally provided by our DFT, we map out a topological phase diagram, indicating the stable topology depending on the details of the annular geometry.

Publication: R. Wittmann et al., Nat Commun 12, 623 (2021).

DY 40.6 Wed 12:40 DYa

Full phase diagram of continuous-time self-propelled particle models with alignment interaction — •Yinong Zhao[1], Pawel Romanczuk[1], and Cristian Huepe[2,3] — [1]Institute of Theoretical Biology, Department of Biology, Humboldt Universität zu Berlin — [2]CHuepe Labs, 2713 West Haddon Ave #1, Chicago, IL 60622, USA — [3]Northwestern Institute on Complex Systems and ESAM, Northwestern University, Evanston, IL 60208, USA

Self-propelled particle (SPP) models are widely used for exploring emergence of collective motion in nature. Despite the significant advances over the past decades in understanding self-organized active matter, many questions remain open about the general phase space of Vicsek-like alignment models and the regions of validity of corresponding analytical theories. We investigate a set of different continuous-time SPP-models with alignment interactions. We find that all these models share qualitatively the same phase diagram. Focusing on one of them, we identify three homogeneous states with long-range orientational order, that can be distinguished using statistical approaches. We tested the predictions of the Toner-Tu theory on these states and show that they do not hold for all three of them. Furthermore, we also phenomenologically explore the role of positional repulsion on the emergent spatial structure. Our study provides a broad, over-arching perspective on continuous-time alignment-based SPP model.

DY 41: Active Matter 4 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP)

Time: Wednesday 11:00–13:00 Location: DYb

DY 41.1 Wed 11:00 DYb

Wrinkling instability in 3D active nematics — Tobias Struebing, Amir Khosravanizadeh, Andrej Vilfan, Eberhard Bodenschatz, Ramin Golestanian, and •Isabella Guido — Max Planck Institute for Dynamics and Self-Organization, Goettigen, Germany

Networks of biopolymers and motor proteins are useful model systems for the understanding of emergent behaviour of active matter. An interesting class of such systems comprises active nematics, fluids constituted by self-organising elongated particles that in-vitro assemble in dynamical structures at length scales larger than those of their components by several orders of magnitude. In the last years the active nematic behaviour of biopolymer-motor networks confined on a 2D substrate was reported. Here we present an experimental and theoretical study on 3D active nematics made of microtubules, kinesin-1 motor proteins and a depleting agent. The network is subjected to the force exerted by the motors that crosslinked the filaments and let them slide against each other. In this way the system evolves toward a flattened and contracted 2D sheet that undergoes a wrinkling instability in the third dimension and subsequently transitions into an active turbulent state. We observe that the wrinkle wavelength is independent of the ATP concentration. A theoretical model describes its relation with the appearance time and a numerical simulation confirms the key role of kinesin motors in the contraction and extension of the network. Finally, we show how motor concentration and environmental cues influence the network properties

DY 41.2 Wed 11:20 DYb

A minimal model for dynamical symmetry breaking in active matter — Matthew 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)

DY 41.3 Wed 11:40 DYb

Boundary-interior principle for microbial navigation in complex geometries — •Jan Cammann[1,2], Fabian Jan Schwarzendahl[2,3], Tanya Ostapenko[2], Danylo Lavrentovich[2], Oliver Bäumchen[2,4], and Marco G. Mazza[1,2] — [1]Loughborough University, UK — [2]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [3]Heinrich-Heine-Universität, Düsseldorf, Germany — [4]University of Bayreuth, Germany

Microswimmers have attracted considerable interest due to the biological and ecological implications of understanding the mechanisms governing their dynamics. The motion of a motile cell appears erratic, and yet the combination of nonequilibrium forces and surfaces can produce striking examples of organization in microbial systems. While our current understanding is based on bulk systems or idealized geometries, it remains elusive how self-organization emerges in complex geometries. In this talk I will describe experiments, analytical and numerical calculations [1] to study the motion of motile cells in complex geometries, and demonstrate that a robust topology of probability flux loops organizes active motion even at the level of a single cell in an isolated habitat. Accounting for the interplay of activity and interfacial forces, we find that the boundary's curvature determines the nonequilibrium probability fluxes. We predict a universal relation

between fluxes and global geometric properties that is confirmed by experiments.

[1] J. Cammann, et al. "Boundary-interior principle for microbial navigation in geometric confinement." arXiv:2011.02811 (2020).

DY 41.4 Wed 12:00 DYb

The role of inertia in active nematic turbulence — •Colin-Marius Koch and Michael Wilczek — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Suspensions of active agents with nematic interactions can exhibit complex spatio-temporal dynamics such as mesoscale turbulence. Continuum descriptions for such systems are inspired by the hydrodynamic theory of liquid crystals and introduce additional effects of active stresses. The resulting equations feature an advective nonlinearity which represents inertial effects. The typically low Reynolds number of such active flows raises the question of the importance of the inertial effects. To address this question, we investigate mesoscale turbulence in a two-dimensional dense suspension of active nematic liquid crystals. We compare numerical simulations with and without nonlinear advection of the flow field. We find that for sufficiently high activity, the simulations including nonlinear advection exhibit large-scale motion which is not observed when excluding advection. Performing a spectral analysis of the energy budget, we identify an inverse energy transfer to the largest scales highlighting the importance of inertial effects in this model. We additionally show that surface friction, mimicked by a linear friction term, dissipates the transported energy and suppresses the large-scale motion.

DY 41.5 Wed 12:20 DYb

Rheotaxis of active droplets in confinements — •Ranabir Dey[1,2], Carola M. Buness[1,3], Babak Vajdi Hokmabad[1], Chenyu Jin[1,4], and Corinna C. Maass[1,3,5] — [1]Max Planck Institute for Dynamics and Self-Organization, Germany — [2]Indian Institute of Technology Hyderabad, India — [3]Georg August Universitat Goettingen — [4]University of Bayreuth, Germany — [5]University of Twente, the Netherlands

Biological microswimmers commonly navigate confined spaces having liquid flows, e.g. locomotions of spermatozoa through the reproductive tract and bacteria in the gut. The directed motion of the microorganisms in response to the external velocity gradients is classically referred to as 'rheotaxis'. Over the last few years, 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 cargo 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 droplets, in micro-confinements having Poiseuille flow. We experimentally quantify the the swimming characteristics of these droplet microswimmers in response to velocity gradients of varying strength. We also try to understand the observed rheotaxis in confinements by considering the long range hydrodynamic interactions with the confining walls.

DY 41.6 Wed 12:40 DYb

Collective search strategies — •Adam Wysocki and Heiko Rieger — Department of Theoretical Physics and Center for Biophysics, Universität des Saarlandes, Saarbrücken, Germany

How long does it take to find N targets by M searchers? This question arises, for example, if animals search for food or immune cells chase for pathogens (our main motivation). The usual goal is to minimize the time needed to catch all targets. One obvious possibility would be to increase the number of ideal searchers another to search collectively by utilizing communication between the searchers. It is known, that cells of the immune system talk to and influence one another by secreting small proteins that bind to and activate each other. For instance, T cells (a type of lymphocyte) are chemotactic, i.e. they move in response to a chemical stimulus, however, it is unknown if chemotaxis is important in the coordination of the search for pathogens. We use a simulation model of chemotactic active particles together with a self-generated chemorepellent in order to test the possibility and the benefit of collective search strategies in microbiological systems.

DY 42: Glasses and Glass Transition 2 - organized by Andreas Heuer (Münster) (joint session DY/CPP)

Time: Wednesday 11:00–13:00 Location: DYc

DY 42.1 Wed 11:00 DYc

Residual stress distributions and mechanical noise in athermally deformed amorphous solids — •Céline Ruscher[1,2], Daniel Korchinski[2], and Joerg Rottler[2] — [1]Institut Charles Sadron, Strasbourg, France — [2]Department of Physics and Astronomy and Stewart Blusson Quantum Matter Institute, University of British Columbia, Vancouver, Canada

Amorphous solids are yield stress materials whose flow consists of periods of elastic loading interrupted by rapid stress drops, or avalanches, coming from microscopic rearrangements known as shear transformations (STs). From the microscopic point of view, the density of STs, or density of local residual stresses, $P(x)$, governs the statistical properties of global collective failure events at the yielding transition.

Using atomistic simulations, we reveal the evolution of $P(x)$ upon deformation. A pseudogap form $P(x) \sim x^\theta$ is observed in the freshly quenched state and in the early stages of deformation. After a few percent strain, however, $P(x)$ starts to develop a system size dependent plateau in the small x limit. To explain the origin of the plateau we consider a mesoscopic elastoplastic approach. Our results show how the spatial extent of avalanches in the stationary regime has a profound effect on the distribution of local residual stresses x. While the entrance into the plateau is set by the lower cutoff of the mechanical noise produced by individual STs, the departure from the usually assumed power-law pseudogap form comes from stress fluctuations induced by collective avalanches.

DY 42.2 Wed 11:20 DYc

Evaluation of Local Atomic Structural Changes in $Cu_{50}Zr_{50}$ Cluster Assembled Metallic Glasses through Molecular Dynamics Simulations — •Syamal Praneeth Chilakalapudi[1], Shyam Katnagallu[1], Wolfgang Wenzel[1], Penghui Cao[2], and Horst Hahn[1,2,3] — [1]Institute Nanotechnology, Karlsruhe Institute of Technology, Germany — [2]Dept. Mat. Sci. & Engg., University of California-Irvine, USA — [3]KIT-TUD Joint Research Laboratory Nanomaterials, Technische Universität Darmstadt, Germany

Cluster assembled metallic glasses (CAMGs), synthesized by cluster (amorphous) ion beam deposition (CIBD), are a prominent bottom-up approach to tailor amorphous structures. Experimental control of amorphous structure and magnetic properties [1] was demonstrated with a custom-made apparatus which offers precise control on the size and the deposition energy of the clusters under ultra high vacuum [2].

To understand the underlying mechanisms of these structural changes in CAMGs, we performed atomistic molecular dynamics simulations of $Cu_{50}Zr_{50}$ cluster assembly using LAMMPS. Our simulations model the CIBD process and evaluate changes in the local short-range order in CAMGs as a function of the deposition energy of the clusters. We notice the presence of interfacial regions, formed between every adjacent cluster. The interfaces are most prominent in soft-landing cases. We also investigate the effect of quenching rate used to generate the amorphous clusters on CAMGs.

[1] C. Benel et al., Mat. Horizons, (2019) 6, 727
[2] A. Fischer et al., Rev. Sci. Instr. (2015) 86, 023304

DY 42.3 Wed 11:40 DYc

X-ray computed tomography of glass foams with tailored hierarchical pore structure — •Cristine Santos de Oliveira[1], Richard Kohns[2], Felix Meyerhoefer[2], Simon Carstens[2], Dirk Enke[2], Ralf Boris Wehrspohn[1,3], and Juliana Martins de Souza e Silva[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]Institut für Technische Chemie, Universität Leipzig, Germany — [3]Fraunhofer Gesellschaft, München, Germany

Glass foams are materials consisting of a light-weight porous glass structure of special importance in the fields of civil engineering and

bio-implants. Typically, their synthesis involves the thermal foaming of a powder mixture of glass with a foaming agent that decomposes at the foaming temperature, resulting in a solid glass skeleton permeated by empty pores. In our work, we synthesized a series of glass foams with a hierarchical pore structure, obtained by combining pores generated through the foaming of a powdered mixture of silica-based glass, MnO_2 and C at 815 °C, with pores obtained by phase-separation (performed at circa 500 °C) followed by acid leaching and washing. Using a combination of mercury intrusion porosimetry, N_2 sorption and X-ray CT at the micro and nanometer scales we observed that slight changes in the preparation procedure resulted in foams with different porosity, surface area, pore size and pore volume. Furthermore, by applying machine learning segmentation to the X-ray CT data it was possible to map inhomogeneities, residues and cracks inside the foam walls.

DY 42.4 Wed 12:00 DYc

Decelerated aging in metallic glasses by low temperature thermal cycling — •Fathollah Varnik — ICAMS, Ruhr-University Bochum, Germany

It has been recently proposed that deep temperature cycling of metallic glasses may lead to a rejuvenation and improve their ductility. Here, we investigate this issue via extensive molecular dynamics simulations of a generic model glass former. We disentangle the effects of aging from those of thermal treatment and show that aging is slowed down but not stopped – neither reversed – during thermal cycling. These observations are corroborated further by a survey of energy distribution, which continues narrowing, albeit with a smaller rate. Our results are in qualitative agreement with recent differential scanning calorimetry measurements on different bulk metallic glasses, which show no measurable rejuvenation upon deeply cooled (cryogenic) thermal cycling. This applies both to as-quenched and well-annealed samples.

DY 42.5 Wed 12:20 DYc

Glassy dynamics in viscous liquids - Prospects of broadband NMR relaxometry — •Manuel Becher[1,2], Michael Vogel[2], and Ernst Rössler[1] — [1]Nordbayerisches NMR-Zentrum, Universität Bayreuth, Germany — [2]Institute of Condensed Matter Physics, TU Darmstadt, Germany

As the molecular dynamics of a liquid undergoing a glass transition features a wide range of timescales over many decades, it is beneficial to study these viscous liquids with broadband spectroscopic techniques. Besides well established methods such as dielectric spectroscopy (DS) and depolarized dynamic light scattering (DDLS) covering many decades in time/frequency, also nuclear magnetic resonance (NMR) offers detailed insights in molecular motion ranging from the boiling point of a liquid to its glassy arrest. However, in most recent publications the spectral shape of the main relaxation peak between DS, DDLS and NMR was readressed and the question of universality arised, rendering the prospect of broadband NMR experiments to a new importance. As NMR experiments can provide single-particle correlation functions of the probed molecular moieties, but are usually carried out at a single Larmor-frequency, interest lies in 'broadening' their frequency range. In this talk, ways to access the relaxation spectrum are presented, focussing on field-cycling (FC) NMR. Here, recent advances allow us to evaluate the concept of frequency-time superposition in molecular glass formers. Moreover, making use of NMR's isotope sensitivity, molecular site-dependent measurements are shown to reveal the impact of molecular flexibility on structural relaxation.

DY 42.6 Wed 12:40 DYc

The dynamics of a glassforming Lennard-Jones system below the critical mode-coupling temperature — •Juergen Horbach — Heinrich Heine-Universitaet, Duesseldorf, Germany

We present molecular dynamics (MD) computer simulations of a polydisperse glassforming Lennard-Jones model. The equation of state of this model is very similar to that of the Kob-Andersen binary Lennard-Jones (KABLJ) mixture. At a comparable density, also the critical mode coupling temperature is similar as in the KABLJ mixture. Using the swap Monte Carlo technique in combination with MD, we are able to equilibrate supercooled liquids far below the critical mode coupling temperature. We analyze the properties of these deeply supercooled samples with respect to their dynamics in the beta relaxation regime and their response to external shear. In particular, we find the formation of shear bands at sufficiently low shear rates.

DY 43: Pattern Formation - organized by Azam Gholami (Göttingen)

Time: Wednesday 14:00–16:00 Location: DYa

DY 43.1 Wed 14:00 DYa

Suppression of coarsening in a Cahn-Hilliard model with nonreciprocal coupling — •Tobias Frohoff-Hülsmann[1] and Uwe Thiele[1,2] — [1]Institute of theoretical physics, WWU Münster — [2]Center of Nonlinear Science (CeNoS), WWU Münster

When coarsening occurs, an initial patterned state develops into a fully phase-separated state. This is standard for passive mixtures and is now also frequently discussed in the field of active matter. The Cahn-Hilliard equation is the paradigmatic description for a passive system characterized by a single conserved order parameter field, e.g., concentration for a mixture. Here, we study a two-field Cahn-Hilliard system (e.g. representing a ternary mixture). The chosen couplings maintain both conservation laws and consist of passive (reciprocal) and active (nonreciprocal) contributions. Our particular focus is the suppression of coarsening that occurs when going from the passive to the active case. We distinguish three mechanisms of suppression: Linear and nonlinear complete, and nonlinear partial suppression. They differ from the suppression of coarsening due to broken mass conservation observed in other systems.

DY 43.2 Wed 14:20 DYa

Pattern selection in reaction-diffusion systems — •Srikanth Subramanian and Seán M. Murray — Max Planck Institute for Terrestrial Microbiology, Marburg, Germany

Turing's theory of pattern formation has been used to describe the formation of self-organized periodic patterns in many biological, chemical, and physical systems. However, the use of such models is hindered by our inability to predict, in general, which pattern is obtained from a given set of model parameters. While much is known near the onset of the spatial instability, the mechanisms underlying pattern selection and dynamics away from onset are much less understood. Here, we provide physical insight into the dynamics of these systems. We find that peaks in a Turing pattern behave as point sinks, the dynamics of which is determined by the diffusive fluxes into them. As a result, peaks move toward a periodic steady-state configuration that minimizes the mass of the diffusive species. We also show that the preferred number of peaks at the final steady state is such that this mass is minimized. Our work presents mass minimization as a potential general principle for understanding pattern formation in reaction diffusion systems far from onset.

DY 43.3 Wed 14:40 DYa

Periodic patterns displace active phase separation — •Frederik Thomsen and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth

In this work we identify and investigate a novel bifurcation in conserved systems on one- and two-dimensional spatial domains. This secondary bifurcation stops active phase separation in its nonlinear regime. It is then either replaced by an extended, system-filling, spatially periodic stripe pattern in one spatial dimension or by a hexagonal pattern in two dimensions. In complementary parameter regions phase separation is replaced by a novel hybrid state with spatially alternating homogeneous and periodic states. The transition from phase separation to extended spatially periodic patterns is hysteretic. We show that the resulting patterns are multistable, as they show stability beyond the bifurcation for different wavenumbers belonging to a wavenumber band. Both transition scenarios are systems-spanning phenomena in particle conserving systems. They are predicted with a generic dissipative model as described by this contribution. Candidates for specific systems in which these generic secondary transitions are likely to occur are, for example, generalized models for motility-induced phase separation in active Brownian particles, models for cell division or chemotactic systems with conserved particle dynamics.

DY 43.4 Wed 15:00 DYa

Chimera solitons and soliton turbulence in oscillatory media — •Arkady Pikovsky[1], Lev Smirnov[2], Maxim Bolotov[3], Dmitry Bolotov[3], and Grigory Osipov[3] — [1]University of Potsdam, Germany — [2]Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Russia — [3]Department of Control Theory, Nizhny Novgorod State University, Nizhny Novgorod, Russia

Chimera states are coexisting patterns of synchrony and asynchrony in oscillatory media. Here we report on stable solitary chimera states in an infinite medium: a finite region of synchrony coexists with an infinite asynchronous background. When this state becomes unstable, soliton turbulence appears, where solitons merge and reappear randomly. With a further change of parameters, this regime evolves into a spatial-temporal intermittency, where the synchronous state is absorbing. Close to the transition point, where the spatial-temporal intermittency disappears, it is dominated by traveling dark solitons: moving patches of asynchrony on a synchronous background.

DY 43.5 Wed 15:20 DYa

A hierarchy of protein patterns robustly decodes cell shape information — •Tzer Han Tan[1,4], Manon C. Wigbers[2], Fridtjof Brauns[2], Jinghui Liu[1], Zak Swartz[3], Erwin Frey[2], and Nikta Fakhri[1] — [1]MIT, Cambridge, USA — [2]LMU, Munich, Germany — [3]Whitehead Institute, Cambridge, USA — [4]MPI-CBG, Dresden, Germany

Many cellular processes rely on precise positioning of proteins on the membrane. Such protein patterns emerge from a combination of protein interactions, transport, conformational state changes, and chemical reactions at the molecular level. Recent experimental and theoretical work clearly demonstrates the role of geometry and advective cortical flow in modulating membrane protein patterns. How can regulatory proteins form a robust spatiotemporal organization on the membrane in the face of dynamic cell-shape changes during physiological processes? Here, we use the oocytes of the starfish *Patiria miniata* as a model system and elucidate a shape-adaptation mechanism that robustly controls spatiotemporal protein dynamics on the membrane despite cell-shape deformations. By combining experiments with biophysical theory, we show how cell-shape information contained in a cytosolic gradient can be decoded by a bistable regulator of Rho. In turn, this bistable front precisely controls a mechanochemical response by locally triggering excitable dynamics of Rho. We posit that such a shape-adaptation mechanism based on a hierarchy of protein patterns may constitute a general physical principle for cell-shape sensing and control.

DY 43.6 Wed 15:40 DYa

Wavelength selection by interrupted coarsening in reaction–diffusion systems — Fridtjof Brauns[1], •Henrik Weyer[1], Jacob Halatek[2], Junghoon Yoon[1], and Erwin Frey[1] — [1]Arnold Sommerfeld Center for Theoretical Physics and Center for NanoScience, Department of Physics, Ludwig-Maximilians-Universität München, Theresienstraße 37, D-80333 München, Germany — [2]Biological Computation Group, Microsoft Research, Cambridge CB1 2FB, UK

Intracellular pattern formation may be described by (nearly) mass-conserving reaction–diffusion systems. Of these, two-component mass-conserving reaction–diffusion systems are paradigmatic models, also used to describe for example precipitation patterns or granular media systems. We will discuss that these mass-conserving models generically show uninterrupted coarsening because of positive feedback in the mass transport between neighbouring pattern domains. From this, a general coarsening criterion follows and the coarsening law may be determined.

We use this understanding to explain the arrest of coarsening due to weak source terms and predict the wavelength thereby selected. This analysis will exemplify how the phase-space structure of pattern-forming systems may be used to study wavelength selection far from equilibrium.

DY 44: Invited Talk Sujit S. Datta (Princeton)

Time: Wednesday 14:00–14:30 Location: DYb

Invited Talk DY 44.1 Wed 14:00 DYb

Life in a tight spot: How bacteria swim in complex spaces — •Sujit Datta — Princeton University, Princeton NJ, USA

Bacterial motility is central to processes in agriculture, the environment, and medicine. While motility is typically studied in bulk liquid or on flat surfaces, many bacterial habitats – e.g., soils, sediments, and biological gels/tissues – are complex porous media. Here, we use studies of E. coli in transparent 3D porous media to demonstrate how confinement in a heterogenous medium fundamentally alters motility. In particular, we show how the paradigm of run-and-tumble motility is dramatically altered by pore-scale confinement, both for cells performing undirected motion and those performing chemotaxis, directed motion in response to a chemical stimulus. Our porous media also enable precisely structured multi-cellular communities to be 3D printed. Using this capability, we show how spatial variations in the ability of cells to perform chemotaxis enable populations to autonomously stabilize large-scale perturbations in their overall morphology. Together, our work thus reveals new principles to predict and control the behavior of bacteria, and active matter in general, in complex environments.

DY 45: Brownian Motion and Anomalous Transport - organized by Ralf Metzler (Potsdam)

Time: Wednesday 14:00–16:30 Location: DYc

Invited Talk DY 45.1 Wed 14:00 DYc

Small diffusive systems warm up faster than they cool down — Alessio Lapolla and •Aljaz Godec — Mathematical bioPhysics Group, Max Planck Institute for Biophysical Chemistry, Göttingen

The celebrated laws of linear irreversible thermodynamics dictate that the relaxation of an extensive thermodynamic observable to its equilibrium value depends linearly on the departure from equilibrium, and is therefore independent of the direction of the departure. However, these linear laws rely on the assumption of "local thermodynamic equilibrium" which is expected to break down when systems become sufficiently small. It turns out that the relaxation of nano-scale systems driven out of equilibrium by a rapid change in temperature depends not only on the distance but also on the direction of the displacement from thermodynamic equilibrium. Contrary to intuition nano-scale systems in fact warm up faster than they cool down. This asymmetry is a general feature of reversible overdamped diffusive systems with smooth single-well potentials and also occurs in multi-well landscapes when quenches disturb predominantly intra-well equilibria. In the talk we will explain the physical origin of this intriguing asymmetry in relaxation to equilibrium.

[1] A. Lapolla, A. Godec, *Phys. Rev. Lett* **125**, 110602 (2020) with focus article in *Physics* **13**, 144 (2020)

DY 45.2 Wed 14:30 DYc

Cooperatively enhanced reactivity and stabilitaxis of dissociating oligomeric proteins — •Jaime Agudo-Canalejo[1], Pierre Illien[2], and Ramin Golestanian[1] — [1]Department of Living Matter Physics, Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Sorbonne Universite, CNRS, Laboratoire PHENIX, UMR CNRS 8234, Paris, France

Many functional units in biology, such as enzymes or molecular motors, are composed of several subunits that can reversibly assemble and disassemble. This includes oligomeric proteins composed of several smaller monomers, as well as protein complexes assembled from a few proteins. By studying the generic spatial transport properties of such proteins, we investigate here whether their ability to reversibly

associate and dissociate may confer on them a functional advantage with respect to non-dissociating proteins [1]. In uniform environments with position-independent association-dissociation, we find that enhanced diffusion in the monomeric state coupled to reassociation into the functional oligomeric form leads to enhanced reactivity with localized targets. In non-uniform environments with position-dependent association-dissociation, caused by, for example, spatial gradients of an inhibiting chemical, we find that dissociating proteins generically tend to accumulate in regions where they are most stable, a process that we term "stabilitaxis."

[1] Agudo-Canalejo, J., Illien, P., & Golestanian, R. (2020). Proceedings of the National Academy of Sciences, 117(22), 11894-11900.

DY 45.3 Wed 14:50 DYc

Hot Brownian Motion in the Ballistic Timescale — •Xiaoya Su[1], Alexander Fischer[1], Frank Cichos[1], and Klaus Kroy[2] — [1]Peter Debye Institute for Soft Matter Physics, University Leipzig, Leipzig, Germany — [2]Institute of Theoretical Physics, University Leipzig, Leipzig, Germany

Brownian motion is the erratic motion of particles in a fluid due to the bombardment of the particle with solvent molecules providing thermal energy and viscous friction. It is fundamental for the dynamics of soft matter and defines the prototype of a fluctuation dissipation relation. While at long timescales the motion is purely stochastic, it is at shorter times influenced by hydrodynamic effects and even ballistic at ultrashort times. Yet, the ballistic motion is still determined by the temperature of the system. Here we explore the transition to the ballistic regime for a hot Brownian particle, i.e. a microparticle which is heated by a laser in an optical trap. In this case the particle temperature is different from the solvent temperature and so far, only theoretical predictions exist for the relevant temperature determining the particle velocity.

We report the first measurements of the thermal non-equilibrium process in a specially designed optical trap which is able to resolve particle displacements of about 20 pm with a time-resolution of 5ns. We show how the mean squared displacement of the particle from the nanoseconds to the seconds timescale changes as a function of the surface temperature of the particle and discuss the model of a frequency dependent effective temperature of hot Brownian motion.

DY 45.4 Wed 15:10 DYc

Stochastic action for tubes: Connecting path probabilities to measurement — •Julian Kappler[1], Jannes Gladrow[2], Ulrich F. Keyser[2], and Ronojoy Adhikari[1] — [1]Department of Applied Mathematics and Theoretical Physics, Cambridge University, Cambridge, United Kingdom — [2]Cavendish Laboratory, University of Cambridge

The trajectories of diffusion processes are continuous but nondifferentiable, and each occurs with vanishing probability. This introduces a gap between theory, where path probabilities are used in many contexts, and experiment, where only events with nonzero probability are measurable. We bridge this gap by considering the probability of diffusive trajectories to remain within a tube of small but finite radius around a smooth path. This probability can be measured in experiment, via the rate at which trajectories exit the tube for the first time, thereby establishing a link between path probabilities and physical observables. In my talk I will show how this link can be used to both measure ratios of path probabilities [1], and to extend the theoretical stochastic action from individual paths to tubes [2].

[1] J. Gladrow, U. F. Keyser, R. Adhikari, and J. Kappler. Direct experimental measurement of relative path probabilities and stochastic actions. arXiv:2006.16820

[2] J. Kappler and R. Adhikari. Stochastic action for tubes: Connecting path probabilities to measurement. Physical Review Research, 2(2), June 2020.

DY 45.5 Wed 15:30 DYc

Diffusion and random search in (in)homogeneous media — •Trifce Sandev[1,2] and Ralf Metzler[1] — [1]University of Potsdam — [2]Macedonian Academy of Sciences and Arts

Different approaches to diffusion in both homogeneous and heterogeneous media will be discussed. Such processes often become anomalous due to the geometric constraints, random potential effects or variations of the diffusion coefficients. Such problems of heterogeneous diffusion might be closely related to inhomogeneous advection-diffusion processes and geometric Brownian motion used to analyze stock prices in financial markets in the Black-Scholes model. The search strategies of many animals follow similar laws but they often return to their nest or resting place, after some (random) search time. We will give results on the first passage and first hitting times for different random search processes with and without external forces for which we will show that introduction of stochastic resetting in such systems leads to various interesting realizations. The investigation of resetting mechanism in aforementioned systems may also be important for description of experiments of random motion with resetting using optical trap techniques, or economic models of income dynamics.

DY 45.6 Wed 15:50 DYc

Disentangling the origins of anomalous diffusion in data: the Moses/ Noah and Joseph effects — •Erez Aghion[1], Philipp G. Meyer[1], Vidushi Adlakha[2], Holger Kantz[1], and Kevin E. Bassler[2] — [1]Max-Planck Institute for the Physics of complex systems, Dresden, Germany — [2]University of Houston, Houston Texas, USA

We study a method for detecting the precise elements that lead to anomalous diffusion, when it is observed in a experimental data, where we do not have exact knowledge about the underlying dynamics.

The reasons for anomalous diffusion are decomposed into three effects: Increment correlations are expressed by the *Joseph effect*, fat-tails of the increment probability density lead to a *Noah effect*, and non-stationarity, to the *Moses effect*. Telling these three effects apart is crucial when one tries to infer the underlying structure of the system, and build a model to describe it.

We present this decomposition method by analysing the example of a widely-applicable model for coupled Levy walk. We infer the properties of the dynamics from data using methods of time-series analysis, and compare our results with theoretical predictions.

DY 45.7 Wed 16:10 DYc

Dynamics of a point-like colloid in a confined critical fluid — •Markus Gross — MPI for Intelligent Systems, Stuttgart

We study analytically and via simulations a point-like colloidal particle (tracer) immersed in a confined critical fluid. Particle and fluid are governed by a system of coupled stochastic PDEs. In addition to a white noise, the particle experiences a random force due to the coupling to the fluctuating fluid density, which is spatially correlated and strongly non-Markovian. By adiabatically eliminating the fluid degrees of freedom, we obtain an effective Langevin equation for the particle, which entails a fluctuation-induced (Casimir) potential, a spatially dependent Markovian noise, and a spatially dependent mobility. The stochastic interpretation of the noise is found to depend on the type of coupling between particle and fluid.

Reference: M. Gross, arXiv:2101.02072

DY 46: Active Matter 5 - organized by Carsten Beta (Potsdam), Andreas Menzel (Magdeburg) and Holger Stark (Berlin) (joint session DY/BP)

Time: Wednesday 14:30–15:50 Location: DYb

DY 46.1 Wed 14:30 DYb

Barrier-mediated predator-prey dynamics — •Fabian Jan Schwarzendahl and Hartmut Löwen — Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

The survival chance of a prey chased by a predator depends not only on their relative speeds but importantly also on the local environment they have to face. For example, a wolf chasing a deer might no be able to cross a river which can be crossed by the deer. Here, we propose a simple predator-prey model for a situation in which both the escaping prey and the chasing predator have to surmount an energetic barrier. Different barrier-assisted states of catching or final escaping

are classified and suitable scaling laws separating these two states are derived. We discuss the effects of diffusion on the catching times and determine states in which catching or escaping is more likely. Including hydrodynamic and chemotactic interactions, we further identify trapping or escaping states which are determined by hydrodynamics and chemotaxis. Our results are of importance for both microbes and self-propelled unanimous microparticles following each other by non-reciprocal interactions in inhomogeneous landscapes.

DY 46.2 Wed 14:50 DYb

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

The defining feature of active particles is that they locally consume energy, which enables them to self-propel and prevents them from equilibrating with their thermal environment. Within the framework of active Ornstein-Uhlenbeck particles we derive the path probability of a particle subject to both, thermal and active noise. By comparing the path probabilities for observing a particle trajectory forward in time versus observing its time-reserved twin trajectory we obtain a generalized "entropy production" for active Brownian motion, 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. We then investigate the time-reversal properties of steady-state trajectories of a trapped active particle. We find that steady-state trajectories in a harmonic potential fulfill pathwise time-reversal symmetry exactly despite their active nature, while this symmetry is typically broken in anharmonic potentials.

DY 46.3 Wed 15:10 DYb

Shape-anisotropic Microswimmers: Influence of Hydrodynamics — •Arne W. Zantop and Holger Stark — Institute of Theoretical Physics, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Constituents of active matter, e.g. bacteria or active filaments, are often elongated in shape. The shape and the stiffness of the active components clearly influence their individual dynamics and collective pattern formation. On length scales much larger than the size of the constituents, active materials exhibit many fascinating phenomena such as the formation of vortices or turbulent structures [1,2]. To identify how steric and hydrodynamic interactions as well as thermal fluctuations influence collective behavior is subject of current research. In this context, we model shape-anisotropic microswimmers with rod shape by composing them of overlapping spherical squirmers. We simulate their hydrodynamic flow fields using the method of multi-particle collision dynamics. With increasing aspect ratio of the rods, we find that a force quadrupole moment dominates the hydrodynamic flow field, whereas in quasi-2D confinement between two parallel plates (Hele-Shaw geometry) the far field is determined by a two-dimensional source dipole moment [3]. Investigating the collective dynamics of the squirmer rods, we identify with increasing density and aspect ratio of the rods a disordered, a swarming, and a jamming state.

[1] Dunkel *et al.*, Phys. Rev. Lett. **110**, 228102 (2013)
[2] Wensink *et al.*, Proc. Natl. Acad. Sci. **109**, 14308-14313 (2012)
[3] A. W. Zantop and H. Stark, Soft Matter **16**, 6400-6412 (2020)

DY 46.4 Wed 15:30 DYb

Feedback Control of Multiple Active Microswimmers — •Alexander Fischer[1], Giovanni Volpe[2], and Frank Cichos[1] — [1]Peter Debye Institute for Soft Matter Physics, Universität Leipzig — [2]Physics Department, Gothenburg University

Sensing and reacting to signals is a fundamental component of life. The exchange of information is used to organize ensembles of active objects into collective states that appear as flocks, swarms or even tissue. Here we explore the emergent collective behavior as a result of an information exchange between synthetic microswimmers by computer-controlled feedback processes. We have created a setup where multiple active microswimmers can respond to local signals in space or their distance to other microswimmers [1]. Our system consists of symmetric self-thermophoretic swimmers that are propelled by light-to-heat conversion allowing us to implement almost arbitrary control of propulsion speed and direction. Using this system, we study in particular the delayed response of the swimmers to environmental signals, where the swimmers remember previous information on a signaling landscape or infers future signals from experience. We find that this type of delayed response is modifying the collective behavior enhancing local swimmer densities depending on delay time, extrapolation or memory and the rotational diffusion time. Our data suggest the existence of optimal delays for the given landscapes.

[1] U. Khadka, V. Holubec, H. Yang, F. Cichos, Nat. Commun. 9, 3864 (2018)