Dynamics and Statistical Physics Division
Fachverband Dynamik und Statistische Physik (DY)

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Overview of Invited Talks and Sessions

(Lecture rooms ZEU 160, ZEU 147, ZEU 118, and HÜL 186; Poster P1A and P3)

Plenary Talk of DY

PV XVII	Wed	14:00–14:45	HSZ 02	**The Statistical Mechanics of Active Matter** — •Michael Cates

Invited Talks

DY 2.1	Mon	9:30–10:00	HÜL 186	**Stochastic thermodynamics and the thermodynamic uncertainty relation** — •Udo Seifert
DY 7.1	Mon	10:15–10:45	ZEU 160	**Immersed Boundary Methods for Rigid and Deformable Particles in Viscoelastic flows** — •Eric Shaqfeh
DY 7.5	Mon	11:45–12:15	ZEU 160	**Effect of bending on the dynamics of a spherical capsule in shear flow** — •Anne-Virginie Salsac
DY 9.1	Mon	15:00–15:30	ZEU 160	**Particle alignment in microchannels and microjets** — •Stephan Foerster, Mathias Schlenk, Susanne Seibt, Martin Trebbin, Josef Breu, Stephan Roth
DY 14.1	Tue	9:30–10:00	HÜL 186	**Tactic Response of Synthetic Microswimmers in Gravitational and Optical Fields** — •Clemens Bechinger
DY 14.7	Tue	11:30–12:00	HÜL 186	**Emergent structures in actuated magnetic and active colloidal suspensions** — •Ignacio Pagonabarraga
DY 16.1	Tue	9:30–10:00	ZEU 118	**The Geostrophic Branch of Rotating Convection** — •Stephan Stellmach, Meredith Plumley, Keith Julien, Philippe Marti
DY 16.7	Tue	11:30–12:00	ZEU 118	**Convection rolls and fingers in double diffusive convection** — •Andreas Tilgner
DY 20.1	Tue	14:00–14:30	ZEU 160	**Particle based simulations of viscoelastic Soft Matter** — •Wim Briels
DY 30.1	Wed	9:30–10:00	HÜL 186	**Fast quantum processes without excitations: shortcuts to adiabaticity** — •Sebastian Deffner
DY 31.1	Wed	9:30–10:00	ZEU 118	**Magnetocapillary interactions for self-assembling dynamical systems** — •Nicolas Vandewalle, Galien Grosjean, Maxime Hubert
DY 31.2	Wed	10:00–10:30	ZEU 118	**Influences of fluxes in nonequilibrium soft matter** — •Marco G. Mazza
DY 32.6	Wed	11:30–12:00	HÜL 186	**Semiclassical Classification of Periodic Orbits in Quantum Many-Body Systems** — •Daniel Waltner, Maram Akila, Boris Gutkin, Petr Braun, Thomas Guhr
DY 38.1	Wed	15:00–15:30	ZEU 160	**Asymmetry-Induced Synchronization Stability in Power-Grid Networks** — •Adilson Motter
DY 38.7	Wed	17:00–17:30	ZEU 160	**Nonlinear Rerouting and Response in Electric Power Networks** — •Marc Timme, Dirk Witthaut, Xiaozhu Zhang
DY 39.1	Wed	15:00–15:30	ZEU 118	**Granular Materials: From solid to fluid with a variable jamming density** — •Stefan Luding
DY 41.1	Thu	9:30–10:00	HÜL 186	**Rolling, rolling, rolling – a new self-propulsion mechanism** — •Falko Ziebert, Igor Kulic
DY 42.1	Thu	9:30–10:00	ZEU 160	**Equilibration and ensembles in coherent quantum systems** — •Fabian Essler

DY 62.1	Fri	9:30–10:00	HÜL 186	**Liquid Crystals in Microgravity** — •Ralf Stannarius
DY 63.1	Fri	9:30–10:00	ZEU 160	**Influence of network topology on spreading of epileptic seizure** — •Simona Olmi, Spase Petkoski, Fabrice Bartolomei, Maxime Guye, Viktor Jirsa
DY 63.2	Fri	10:00–10:30	ZEU 160	**Chimera patterns induced by complex connectivity in Leaky Integrate-and-Fire Networks** — •Astero Provata, Nefeli Tsigkri-DeSmedt, Johanne Hizanidis, Philipp Hoevel, Eckehard Schoell

Invited talks of the joint symposium SYBM

See SYBM for the full program of the symposium.

SYBM 1.1	Tue	9:30–10:00	HSZ 02	**New twists in biological photonics: circular polarisation and beyond.** — •Pete Vukusic, Luke McDonald, Ewan Finlayson
SYBM 1.2	Tue	10:00–10:30	HSZ 02	**Bio-inspired materials and structures for technology and architecture** — •Thomas Speck
SYBM 1.3	Tue	10:30–11:00	HSZ 02	**Cellulose bio-inspired hierarchical structures** — •Silvia Vignolini
SYBM 1.4	Tue	11:15–11:45	HSZ 02	**Strong Flexible Bioenabled Nanocomposites for Sustainable Sensing** — •Vladimir Tsukuruk
SYBM 1.5	Tue	11:45–12:15	HSZ 02	**3D laser nano-printing of rationally designed materials** — •Martin Wegener

Invited talks of the joint symposium SYCM

See SYCM for the full program of the symposium.

SYCM 1.1	Wed	9:30–10:00	HSZ 02	**Mobility in shareability networks** — •Michael Szell
SYCM 1.2	Wed	10:00–10:30	HSZ 02	**Trail-following bacteria: from single particle dynamics to collective behaviour** — Anatolij Gelimson, Kun Zhao, Calvin K. Lee, W. Till Kranz, Gerard C. L. Wong, •Ramin Golestanian
SYCM 1.3	Wed	10:30–11:00	HSZ 02	**Mobility and Self-Organization in Multi-Layer Networks: A Meta-Foodweb example** — •Thilo Gross, Andreas Brechtel, Philipp Gramlich, Daniel Ritterskamp, Barbara Drossel
SYCM 1.4	Wed	11:15–11:45	HSZ 02	**Temporal Percolation in Critical Collective Mobility Systems** — •Andreas Sorge, Debsankha Manik, Jan Nagler, Marc Timme
SYCM 1.5	Wed	11:45–12:15	HSZ 02	**Modeling the evolution of cities** — •Marc Barthelemy

Sessions

DY 1.1–1.3	Sun	16:00–18:30	HSZ 04	**Patterns in Nature and Materials (DY/BP/CPP)**
DY 2.1–2.10	Mon	9:30–12:30	HÜL 186	**Stochastic thermodynamics and information processing**
DY 3.1–3.12	Mon	9:30–13:00	ZEU 250	**Computational Biophysics (joint BP/DY)**
DY 4.1–4.10	Mon	9:30–13:00	SCH A251	**Mechanics and Dynamics of 3D Tissues - Joint Focus Session (BP/CPP/DY) organized by Peter Loskill**
DY 5.1–5.1	Mon	9:30–10:00	ZEU 222	**Keynote Lecture I**
DY 6.1–6.8	Mon	10:00–12:15	ZEU 118	**Many-Body Quantum Systems (joint session DY/TT)**
DY 7.1–7.9	Mon	10:15–13:15	ZEU 160	**Soft Particles in Flows I (Focus session, joint DY/CPP)**
DY 8.1–8.16	Mon	15:00–19:15	ZEU 118	**Statistical Physics far from Thermal Equilibrium**
DY 9.1–9.10	Mon	15:00–18:00	ZEU 160	**Soft Particles in Flows II (Focus session, joint DY, CPP)**
DY 10.1–10.6	Mon	15:00–16:45	SCH A251	**Cell Mechanics (Joint Session BP/DY)**
DY 11.1–11.9	Mon	15:30–18:00	HÜL 186	**Critical phenomena**
DY 12.1–12.7	Mon	15:30–17:15	ZEU 147	**Delay and Feedback Dynamics**
DY 13.1–13.4	Mon	17:30–18:30	ZEU 147	**Complex Systems**
DY 14.1–14.11	Tue	9:30–13:00	HÜL 186	**Microswimmers I (joint session DY/BP)**
DY 15.1–15.14	Tue	9:30–13:15	ZEU 160	**Quantum Dynamics, Decoherence, Quantum Information**
DY 16.1–16.12	Tue	9:30–13:15	ZEU 118	**Focus: Fundamental aspects of turbulent convection**
DY 17.1–17.10	Tue	9:30–13:00	SCH A251	**Physics of Physarum polycephalum and Other Slime Molds - Joint Focus Session (BP/DY) organized by Hans-Günther Döbereiner**
DY 18.1–18.11	Tue	10:00–13:00	ZEU 147	**Brownian Motion / Noise (joint session DY/TT)**

DY 19.1–19.6	Tue	11:30–13:00	ZEU 255	**Colloids and Complex Fluids I (joint session BP/CPP/DY, organized by CPP)**
DY 20.1–20.6	Tue	14:00–15:45	ZEU 160	**Soft Particles in Flows III (Focus session, joint DY/CPP)**
DY 21.1–21.8	Tue	14:00–16:00	ZEU 118	**Statistical Physics in Biological Systems (joint session DY/BP/CPP)**
DY 22.1–22.10	Tue	14:00–16:00	P1A	**Posters - Statistical Physics of Biological Systems**
DY 23.1–23.5	Tue	14:30–15:45	HÜL 186	**Microswimmers II (joint session DY/BP)**
DY 24.1–24.5	Tue	14:30–15:45	ZEU 147	**Pattern Formation / Reaction-Diffusion I**
DY 25.1–25.16	Tue	18:15–21:00	P3	**Posters - Soft Particles, Microswimmers, Microfluidics**
DY 26.1–26.16	Tue	18:15–21:00	P3	**Posters - Statistical Physics, Stochastic Thermodynamics**
DY 27.1–27.6	Tue	18:15–21:00	P3	**Posters - Statistical Physics Biological Systems**
DY 28.1–28.4	Tue	18:15–21:00	P3	**Posters - Dynamics of Many-Body Systems**
DY 29.1–29.5	Wed	9:30–12:15	HSZ 02	**Physics of Collective Mobility (Symposium SYCM, joint SOE / DY / BP / jDPG)**
DY 30.1–30.1	Wed	9:30–10:00	HÜL 186	**Invited talk**
DY 31.1–31.11	Wed	9:30–13:00	ZEU 118	**Particulate Matter I: From microscopic interactions to collective motion (Focus session)**
DY 32.1–32.10	Wed	10:00–13:00	HÜL 186	**Quantum Chaos**
DY 33.1–33.12	Wed	10:00–13:15	ZEU 160	**Fluid Dynamics and Turbulence**
DY 34.1–34.9	Wed	10:15–13:00	ZEU 260	**Colloids and Complex Fluids II (joint session BP/CPP/DY, organized by CPP)**
DY 35.1–35.1	Wed	14:00–14:45	HSZ 02	**Plenary Talk M. Cates**
DY 36.1–36.5	Wed	15:00–17:45	HSZ 03	**Collective Quantum Dynamics: From Fundamentals to New Phenomena (Focus session joint DY/TT)**
DY 37.1–37.15	Wed	15:00–19:00	HÜL 186	**Aktive Matter I (joint session DY/BP/CPP)**
DY 38.1–38.14	Wed	15:00–19:15	ZEU 160	**The Physics of Power-Grids – Fluctuations, Synchronization and Network Structures (Focus session, joint DY/SOE)**
DY 39.1–39.4	Wed	15:00–16:15	ZEU 118	**Particulate Matter II: From microscopic interactions to collective motion (Focus session)**
DY 40.1–40.4	Wed	16:30–17:30	ZEU 118	**Granular Matter**
DY 41.1–41.12	Thu	9:30–13:00	HÜL 186	**Active Matter II (joint session DY/BP/CPP)**
DY 42.1–42.13	Thu	9:30–13:15	ZEU 160	**Coherent Quantum Dynamics (joint session DY/TT)**
DY 43.1–43.14	Thu	9:30–13:15	ZEU 118	**Nonlinear Dynamics, Synchronizsation and Chaos**
DY 44.1–44.8	Thu	10:00–12:15	ZEU 147	**Statistical Physics (general)**
DY 45.1–45.6	Thu	11:15–12:45	ZEU 250	**Microswimmers (joint session BP/DY)**
DY 46.1–46.4	Thu	15:00–16:00	HÜL 186	**Modelling and Data Analysis**
DY 47.1–47.6	Thu	15:00–16:30	ZEU 160	**Complex Fluids and Soft Matter I (joint session DY/CPP)**
DY 48.1–48.8	Thu	15:00–17:00	ZEU 118	**Pattern Formation / Reaction-Diffusion II (joint session DY/BP)**
DY 49.1–49.5	Thu	15:00–16:15	ZEU 147	**Networks: From Topology to Dynamics (joint session DY/BP/SOE)**
DY 50.1–50.10	Thu	15:00–17:30	ZEU 250	**Statistical Physics of Biological Systems I (Joint Session BP/DY)**
DY 51.1–51.3	Thu	16:15–17:00	HÜL 186	**Extreme Events**
DY 52.1–52.2	Thu	16:30–17:00	ZEU 147	**Chimera states: symmetry-breaking in dynamical networks (joint session DY/BP/SOE)**
DY 53.1–53.10	Thu	17:00–19:30	P1A	**Posters - Active Matter**
DY 54.1–54.13	Thu	17:00–19:30	P1A	**Posters - Pattern Formation, Reaction Diffusion, Chimera**
DY 55.1–55.12	Thu	17:00–19:30	P1A	**Posters - Soft Matter, Glasses**
DY 56.1–56.8	Thu	17:00–19:30	P1A	**Posters - Granular and Particulate Matter**
DY 57.1–57.6	Thu	17:00–19:30	P1A	**Posters - Turbulence**
DY 58.1–58.4	Thu	17:00–19:30	P1A	**Posters - Networks**
DY 59.1–59.4	Thu	17:00–19:30	P1A	**Posters - Nonlinear General**
DY 60.1–60.5	Thu	17:00–19:30	P1A	**Posters - Brownian Motion, Noise**
DY 61.1–61.8	Thu	17:00–19:30	P1A	**Posters - Quantum Systems**
DY 62.1–62.10	Fri	9:30–12:30	HÜL 186	**Complex Fluids and Soft Matter II (joint DY/CPP)**
DY 63.1–63.9	Fri	9:30–12:30	ZEU 160	**Controlling Complex Networks in Nature and Engineering (Focus session, joint DY/SOE/BP)**
DY 64.1–64.6	Fri	9:30–12:15	SCH A251	**Physics of Parasites - Joint Focus Session (BP/DY) organized by Holger Stark**
DY 65.1–65.9	Fri	10:00–12:30	ZEU 118	**Glasses and Glass Transition (joint session DY/CPP/DF)**

Annual General Meeting of the Dynamics and Statistical Physics Division

23.3.2017 19:30–20:30 ZEU 160

- Report
- Spring Meeting 11.3.-16.3.2018 in Berlin
- Miscellaneous

DY 1: Patterns in Nature and Materials (DY/BP/CPP)

Pattern formation and self-organization in nature fascinates both the layman and reseachers from many disciplines. In addition to their aesthetic appeal, the function of the patterns in nature are of central interest. Therefore, function, variability and control of patterns are a focus of current research.

This tutorial is intended to give especially young scientists the opportunity to learn more about the subject of (nonlinear) pattern formation. Besides the introduction of fundamental and universal concepts in the field, examples from various disciplines of natural science and materials research will be presented.

Time: Sunday 16:00–18:30 Location: HSZ 04

Tutorial DY 1.1 Sun 16:00 HSZ 04

The fascination of pattern formation: Basic principles, applications, future directions — •Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

Self-organization and pattern formation are fundamental strategies in nature. In this talk I will give an introduction to the field and explain some main concepts with experiments. Using several examples from physics, biology or material science, I will illustrate that the mechanism driving a spatially extended pattern, like a stripe or traveling wave pattern, are vastly different in diverse systems. However, are there also common features in, for example, cloud streets, Turing patterns, wrinkles or stripes in active matter and fluids? I will explain that each nonlinear pattern has a number of robust and system-independent properties and that the concepts of pattern formation provide a theoretical framework for their generic properties. Why are patterns of different wavenumbers stable in homogeneous systems (variability)? By which generic principles can a pattern be selected or controlled? How do patterns interact with their environment such as boundaries or inhomogenities? Which functions do patterns in nature fulfill? Besides addressing these elementary questions, I will also highlight recent developments in the field, applications in emerging fields and possible future directions of pattern formation.

Tutorial DY 1.2 Sun 16:50 HSZ 04

On growth and forms in nature — •Chaouqi Misbah — Laboratoire Interdisciplinaire de Physique, CNRS and Universite Alpes, Grenoble, France

Atoms and molecules self-assemble into fascinating patterns, such as snowflakes, that even very complex entities, such as biological cells and living micro-organisms, try to mimic despite their internal much higher complexity. This points to the existence of an intricate hierarchy of universality which still escapes today a comprehensive description. This lecture will present the basic rules and principles that lead to diverse non-equilibrium patterns and shapes in nature.

C. Misbah, Complex Dynamics and Morphogenesis: An Introduction to Nonlinear Science (Springer, 2016)

Tutorial DY 1.3 Sun 17:40 HSZ 04

What can pattern formation theory tell us about ecosystem response to climate change? — •Ehud Meron — Ben-Gurion University, Beer-Sheva, Israel

Dryland landscapes show a variety of vegetation pattern-formation phenomena; banded vegetation on hill slopes and nearly hexagonal patterns of bare-soil gaps in grasslands are two striking examples. Vegetation pattern formation is a population-level mechanism to cope with water stress. It couples to other response mechanisms operating at lower and higher organization levels, such as phenotypic changes at the organism level and biodiversity changes at the community level, and plays a crucial role in understanding ecosystem response and ecosystem function in changing environments. In this talk I will present a platform of mathematical models for dryland ecosystems and describe some of the ecological questions we have studied using this platform. I will discuss the mechanisms that destabilize uniform vegetation and lead to periodic vegetation patterns, the variety of extended and localized patterns that can appear along a rainfall gradient, the impact of pattern-forming instabilities and front dynamics on state transitions (regime shifts), and restoration of degraded landscapes as a spatial resonance problem. I will conclude with a discussion of a major problem in our current era, the Anthropocene, namely, how to reconcile human intervention in ecosystems dynamics with ecological integrity.

E. Meron, Nonlinear Physics of Ecosystems, CRC Press 2015.
E. Meron, Pattern formation – A missing link in the study of ecosystem response to environmental changes, Mathematical Biosciences 271, 1 (2016).

DY 2: Stochastic thermodynamics and information processing

Time: Monday 9:30–12:30 Location: HÜL 186

Invited Talk DY 2.1 Mon 9:30 HÜL 186

Stochastic thermodynamics and the thermodynamic uncertainty relation — •Udo Seifert — Universität Stuttgart

Stochastic thermodynamics is a universal framework to describe driven systems in a thermodynamically consistent way. It has lead to universal relations like the Jarzynski relation and the fluctuation theorem. More recently, a new inequality, the thermodynamic uncertainty relation, has been found. It provides a constraint on the dispersion of any current in terms of the overall entropy production and can also be framed as bounding the inevitable cost of precision in any non-equilibrium process. I will discuss the origin of this relation, the generalization to a bound on extreme fluctuations, and show a few of its applications.

DY 2.2 Mon 10:00 HÜL 186

Stochastic thermodynamics based on incomplete information: Generalized Jarzynski equality with measurement errors with or without feedback — •Christopher Wächtler, Philipp Strasberg, and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

In the derivation of fluctuation relations, and in stochastic thermodynamics in general, it is tacitly assumed that we can measure the system perfectly, i.e., without measurement errors. We here demonstrate for a driven system immersed in a single heat bath, for which the classic Jarzynski equality [1] holds, how to relax this assumption. Based on a general measurement model akin to Bayesian inference we derive a general expression for the fluctuation relation of the *measured* work and we study the case of an overdamped Brownian particle in particular. We then generalize our results further and incorporate feedback in our description. We argue that, if measurement errors are fully taken into account by the agent who controls *and* observes the system, the standard Jarzynski-Sagawa-Ueda relation [2] should be formulated differently. We again explicitly demonstrate this for an overdamped Brownian particle where the fluctuation relation of the measured work differs significantly from the efficacy parameter [2]. Instead, the generalized fluctuation relation under feedback control, $\langle e^{-\beta(W-\Delta F)-I}\rangle = 1$, holds only for a superobserver having perfect access to *both* the system and detector degrees of freedom.

[1] C. Jarzynski, PRL 78, 2690 (1997).
[2] T. Sagawa and M. Ueda, PRL 104, 090602 (2010).

DY 2.3 Mon 10:15 HÜL 186

Quantum and Information Thermodynamics: A Unifying Framework based on Repeated Interactions — •Philipp Strasberg[1,2], Gernot Schaller[1], Tobias Brandes[1], and Massimiliano Esposito[2] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany — [2]Complex Systems and Statistical Mechanics, Physics and Materials

Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg

We expand the standard thermodynamic framework of a system coupled to a thermal reservoir by considering a stream of independently prepared units repeatedly put into contact with the system. These units can be in any nonequilibrium state and interact with the system with an arbitrary strength and duration. We show that this stream constitutes an effective resource of nonequilibrium free energy and unifies many previously separately studied phenomena. This includes, e.g., work and information reservoirs, Landauer's principle, Maxwell's demon, the micromaser, extraction of work from quantum coherence and much more. Some of these (but not all) applications are presented in the talk.

Reference: arXiv 1610.01829

DY 2.4 Mon 10:30 HÜL 186

Stochastic Thermodynamics of Learning — •Sebastian Goldt and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Virtually every organism gathers information about its noisy environment and builds models from that data, mostly using neural networks. Here, we use stochastic thermodynamics to analyse the efficiency of neural networks in two learning scenarios. We show that the total entropy production of the network bounds the information that the network can infer from data or learn from a teacher [1]. We introduce a learning efficiency $\eta \leq 1$ and discuss the conditions for optimal learning. Finally, we analyse the efficiency of the Hebbian, Perceptron and AdaTron learning algorithms, well-known from machine learning and statistical physics.

[1] S. Goldt and U. Seifert, Stochastic Thermodynamics of Learning. PRL, in press; arxiv:1611.09428

DY 2.5 Mon 10:45 HÜL 186

Cost and Precision of Brownian Clocks — •Andre C Barato — Max Planck Institute for the Physics of Complex Systems

Brownian clocks are biomolecular networks that can count time. A paradigmatic example are proteins that go through a cycle thus regulating some oscillatory behaviour in a living system. Typically, such a cycle requires free energy often provided by ATP hydrolysis. We investigate the relation between the precision of such a clock and its thermodynamic costs. For clocks driven by a constant thermodynamic force, a given precision requires a minimal cost that diverges as the uncertainty of the clock vanishes. In marked contrast, we show that a clock driven by a periodic variation of an external protocol can achieve arbitrary precision at arbitrarily low cost. This result constitutes a fundamental difference between processes driven by a fixed thermodynamic force and those driven periodically. As a main technical tool, we map a periodically driven system with a deterministic protocol to one subject to an external protocol that changes in stochastic time intervals, which simplifies calculations significantly.

Reference: [1] A. C. Barato and U. Seifert; Cost and precision of Brownian clocks; accepted in Phys. Rev. X, arXiv:1610.07960 (2016).

DY 2.6 Mon 11:00 HÜL 186

Extreme values of mesoscopic currents in physics and biology — •Edgar Roldan[1], Izaak Neri[1,2], Simone Pigolotti[1], and Frank Jülicher[1] — [1]Max Planck Institut fur Physik Komplexer Systeme — [2]Max Planck Institute for Molecular Cell Biology and Genetics

The dynamics of mesoscopic systems driven out of equilibrium often exhibits currents against the external driving, as shown in a plethora of experiments inter alia, colloidal systems trapped with optical tweezers and single molecule experiments with molecular motors. What is the maximal mesoscopic current against the external driving that can be observed in a given time? We show that the extreme-value statistics of active molecular processes are governed by the statistics of entropy production. For example, the infimum the entropy production during the stepping a molecular motor can be related to the maximal excursion of the motor against the direction of an external force. We recently derived the infimum law for entropy production: The negative record of entropy production in a given time cannot be below minus the Boltzmann constant. Using the Infimum Law, we make predictions for the distribution of the maximum backtrack depth of RNA polymerases and for the maximum distance traveled by a colloidal particle in a periodic potential against an external force. Our results are extensively validated with numerical simulations and are in agreement with experimental data.

References [1] I Neri, É Roldán, F Jülicher, arXiv:1604.04159 (2016).

15 min. break

DY 2.7 Mon 11:30 HÜL 186

Universality of Infima and Stopping Time Statistics of Entropy Production in Steady States — •Izaak Neri[1,2], Édgar Roldán[1], Simone Pigolotti[1], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany

We show that the statistics of infima, stopping times and passage probabilities of entropy production in nonequilibrium steady states are universal. Our main results are: (i) the distribution of the global infimum of entropy production is exponential with mean equal to minus Boltzmann's constant; (ii) we find the exact expressions for the passage probabilities of entropy production to reach a given value; (iii) we derive a fluctuation theorem for stopping-time distributions of entropy production. Our work reveals the importance of martingales to nonequilibrium thermodynamics, since all our results follow from the martingality of entropy production.

DY 2.8 Mon 11:45 HÜL 186

Thermodynamics of error correction — •Simone Pigolotti[1] and Pablo Sartori[2] — [1]Max-Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Rockefeller University, New York

Biological systems are able to replicate information with outstanding accuracy. In biochemical reactions, such as DNA duplication, different monomers can be distinguished because of their binding energies or via non-equilibrium kinetic mechanisms. I will show how, in simple copying reactions, these two discrimination modes are mutually exclusive and lead to opposite tradeoffs between error, dissipation and reaction velocity. In multi-step reactions, such as in kinetic proofreading, these different modes can be combined to improve overall accuracy. I will conclude by discussing how the second law of thermodynamics can be used to directly relate copying accuracy with thermodynamic observables.

DY 2.9 Mon 12:00 HÜL 186

Nonequilibrium Thermodynamics of Chemical Networks — •Riccardo Rao and Massimiliano Esposito — University of Luxembourg, Luxembourg, Luxembourg

Chemical Networks (CN) are large sets of coupled chemical reactions where some of the species are externally controlled. Cell metabolism and biochemical signal transduction networks are notable examples of CN. We present a rigorous nonequilibrium thermodynamic description of CN in terms of deterministic rate equations. Our description is inspired by Stochastic Thermodynamics and is based on Chemical Reaction Network Theory. The energy and entropy balances of CN are derived and a nonequilibrium Gibbs free energy is introduced. This latter is related to the chemical work necessary to create nonequilibrium states and to the driving work necessary to control the network far from equilibrium. We finally discuss these different forms of work in the stochastic framework.

R. Rao and M. Esposito, "Nonequilibrium Thermodynamics of Chemical Reaction Networks: Wisdom from Stochastic Thermodynamics", Accepted for publication in Phys. Rev. X, arXiv: 1602.07257.

DY 2.10 Mon 12:15 HÜL 186

Hidden and Emergent Cycles in Biochemical Reaction Networks — •Artur Wachtel, Matteo Polettini, and Massimiliano Esposito — Complex Systems and Statistical Mechanics, University of Luxembourg, Luxembourg

We study biochemical reaction networks which naturally arise in the molecular description of biological systems. On the macroscopic level, one describes the dynamics of these systems by differential rate equations, while on a microscopical level the dynamics is inherently stochastic, giving rise to a Markov jump process.

In this talk we give a classification of different topological cycles in these reaction networks: hidden and emergent cycles. The hidden cycles give rise to interesting dynamics and their absence implies agreement of the stochastic and deterministic descriptions. The emergent cycles on the other hand dictate the thermodynamic properties of the network. We exemplify our classification on real biochemical networks and on a small but illuminating toy model.

[1] Polettini, Esposito. J. Chem. Phys. 141, 024117 (2014)
[2] Polettini, Wachtel, Esposito. J. Chem. Phys. 143, 184103 (2015)

DY 3: Computational Biophysics (joint BP/DY)

Time: Monday 9:30–13:00 Location: ZEU 250

Invited Talk DY 3.1 Mon 9:30 ZEU 250

Conformational Transitions in the Presence of Solvent and Internal Memory Effects — •Roland Netz, Julian Kappler, Jan Daldrop, Bartosz Kowalik, and Florian Brünig — Department of Physics, Free University Berlin, Arnimallee 14, 14195 Berlin, Germany

Conformational transitions of biological molecules are controlled by solvent friction. For fast transitions, such as dihedral-angle flips, the finite solvent memory time plays a role. General scaling laws for the transition time including inertial, friction and memory effects are presented. The interplay between fast molecular reconfigurations and long-time conformational relaxation and the coupling between solvent and internal friction effects is discussed.

DY 3.2 Mon 10:00 ZEU 250

Dynamics and energetics of elongation factor SelB in the ternary complex and the ribosome — •Lars V. Bock, Niels Fischer, Holger Stark, and Helmut Grubmüller — Max Planck Institute for Biophysical Chemistry, Göttingen

SelB is an elongation factor specialized to deliver the selenocysteine (Sec) tRNA to the ribosome by recoding the UGA stop codon on the mRNA. Initially the tRNA is in complex with selB and GTP forming the ternary complex (TC). High-resolution cryo-EM structures of intermediates of the Sec incorporation pathway uncover large-scale conformational changes of the ribosome and the TC. To complement the structural information with energetics and rapid dynamics, we performed extensive all-atom molecular dynamics simulations of the ribosome with bound TC as well as of the free TC in solution. The simulations of the free TC were started after extracting the TC from the ribosome-bound cryo-EM structures. The TC was found to rapidly interconvert between the different conformations allowing us to construct the free-energy landscape of the involved motions. This free-energy landscape indicates that the intrinsic large-scale conformational changes of the tRNA and SelB during the delivery to the ribosome are not rate-limiting to the process. In simulations of the free TC started from the GTPase-acitvated ribosome-bound conformation, the TC rapidly transitions into an inactivated conformation, showing that the GTPase-activated state is strongly stabilized by the ribosome. The simulations of the full ribosome with bound TC in the intermediate states allow us to identify the motions that are rate-limiting to the process of tRNA delivery and to identify the molecular mechanism of the domain closure of small ribosomal subunit upon tRNA decoding.

DY 3.3 Mon 10:15 ZEU 250

Correction of Finite-Size Effects on Diffusion in Lipid Membrane Simulations — •Martin Vögele and Gerhard Hummer — Max-Planck-Institut für Biophysik, Frankfurt am Main

Calculating diffusion coefficients from the mean squared displacement is a common task in evaluating molecular dynamics simulations. However, periodic boundary conditions introduce artifacts caused by the self-interaction with the periodic image. In cubic simulation boxes, the diffusion coefficient converges for large sizes. However, this is not the case if the system size is increased asymmetrically. [1]

We specifically test the effect of box geometry on the diffusion in lipid membranes which are usually simulated in very flat periodic boxes. There we find a logarithmic (and therefore unbounded) increase with growing box width. We discuss consequences of the apparent inability to determine a well-defined lipid diffusion coefficient from simulation and present possible methods to rationalize difficulties in comparing simulation results to each other and to experiment.

[1] M. Vögele and G. Hummer, J. Phys. Chem. B, 2016, 120 (33)

DY 3.4 Mon 10:30 ZEU 250

A Monte Carlo Study of Knots in Long Double-Stranded DNA Chains — Florian Rieger and •Peter Virnau — Johannes Gutenberg-Universität Mainz

We determine knotting probabilities and typical sizes of knots in double-stranded DNA for chains of up to half a million base pairs with computer simulations of a coarse-grained bead-stick model: Single trefoil knots and composite knots which include at least one trefoil as a prime factor are shown to be common in DNA chains exceeding 250,000 base pairs, assuming physiologically relevant salt conditions. The analysis is motivated by the emergence of DNA nanopore sequencing technology, as knots are a potential cause of erroneous nucleotide reads in nanopore sequencing devices and may severely limit read lengths in the foreseeable future. Even though our coarse-grained model is only based on experimental knotting probabilities of short DNA strands, it reproduces the correct persistence length of DNA. This indicates that knots are not only a fine gauge for structural properties, but a promising tool for the design of polymer models.

F. Rieger, P. Virnau, PLoS Comp. Biol. 12(9), e1005029 (2016).

DY 3.5 Mon 10:45 ZEU 250

Interaction of hyperbranched polyglycerol sulfate with proteins: calorimetry versus computer simulations — •Xiao Xu[1,2], Qidi Ran[3], Rainer Haag[3], Matthias Ballauff[1,2], and Joachim Dzubiella[1,2] — [1]Institut für Weiche Materie und funktionale Materialien, Helmholtz-Zentrum Berlin — [2]Institut für Physik, Humboldt-Universität zu Berlin — [3]Institut für Chemie und Biochemie, Freie Universität Berlin

Using Isothermal Titration Calorimetry (ITC) and coarse-grained (implicit solvent/explicit salt) Langevin computer simulations, we study the interaction of hyperbranched polyglycerol sulfate (hPGS) with two oppositely charged serum proteins, i.e. human serum albumin (HSA) (-) and lysozyme (+). The simulation reveals explicitly the structural properties of the complexation. We demonstrate that the driving force of the complexation in both cases originates mainly from the release of condensed counter-ions from the polymer upon binding. The binding constant fitted by single set of identical sites model shows very weak dependence on polymer size for both proteins. By applying an excluded-volume (EV) model to fit the ITC data the explict profile of binding free energy for multi-site binding between lysozyme and hPGS can be obtained. The experimental data coincides with computer simulation quantitatively especially for high generation of hPGS, which makes the simulation a useful tool to predict hPGS binding to targeted proteins such as selectins.

15 min break

DY 3.6 Mon 11:15 ZEU 250

Adsorption, binding motifs and structural change of proteins on silica studied by Molecular Dynamics — •Nils Hildebrand, Monika Michaelis, Susan Köppen, and Lucio Colombi Ciacchi — Bremen Center for Computational Materials Science, Bremen

The physisorption of chymotrypsin and lysozyme on amorphous silica is investigated by classical Molecular Dynamics (MD) methods in comparison to adsorption and circular dichroism (CD) experiments. The long-range protein-surface attraction field is calculated in an implicit solvent based on DLVO theory. These calculations reveal a preferred protein orientation, which could be confirmed in explicit solvent simulations. Driven by its large dipole moment, chymotrypsin adsorbs with its alpha-helical regions pointing towards the surface. Lysozyme adsorbs in a side-on orientation. Positively charged hydrophilic residues form dominant binding motifs by adsorbing in dense water layers around the deprotonated silanol surface groups. The amount of adsorbed proteins found in the experiment can be explained by a combination of the binding motifs stability and protein-protein interactions. No significant conformational changes are observed in MD simulations lasting 300 ns. In order to capture surface-induced conformational changes revealed by CD experiments, parallel tempering in combination with metadynamics is employed. In these simulations, the helical content of chymotrypsin is used as a reaction coordinate, as helical unfolding is believe to strengthen the adhesion to the surface.

DY 3.7 Mon 11:30 ZEU 250

Organic co-solutes in aqueous solution: The effect on local water dynamics — Johannes Zeman, Frank Uhlig, and •Jens Smiatek — Institut für Computerphysik, Universität Stuttgart, D-70569 Stuttgart, Germany

We investigate the effect of the organic co-solutes ectoine, trimethylamine N-oxide (TMAO), urea, and guanidinium chloride by means of classical and ab-initio Molecular Dynamics simulations. Our results reveal distinct effects on the local water structure and the water dy-

namics for the different co-solutes. The analysis of the diffusion coefficients and the dielectric spectra demonstrate that ectoine and TMAO significantly slow down water dynamics by a strongly bound hydration shell whereas urea and guanidinium chloride have a weaker impact. In combination with a sodium chloride solution, our findings for ectoine imply compensatory effects in order to explain the high co-solute and salt concentration in halotolerant bacteriae [1].

[1] M. B. Hahn, F. Uhlig, T. Solomun, J. Smiatek, H. Sturm; Phys. Chem. Chem. Phys. 18, 28398 (2016)

DY 3.8 Mon 11:45 ZEU 250

Determinants of nanoparticle protein corona composition investigated with molecular dynamics simulations — •Giovanni Settanni[1], Jiajia Zhuo[1], Tongchuan Suo[1], Susanne Schöttler[2,3], Katharina Landfester[2], Friederike Schmid[1], and Volker Mailänder[2,3] — [1]Department of Physics, Johannes Gutenberg University Mainz — [2]Max-Planck Institute for Polymer Research — [3]Department of Dermatology, University Medical Center Mainz

Therapeutic nanoparticles in contact with biological fluids (blood, lung surfactant, etc.) are quickly covered by a layer of proteins (corona), which determines the particle's fate in the host organism (circulation half-life, cellular uptake, tissue distribution, immune response, etc.). Nanoparticles' surfaces are often modified (adding polymer coatings, or functionalization groups etc.) to improve their therapeutic efficacy, which involve a modification of the nanoparticle protein corona composition. The molecular factors determining the corona composition of nanoparticles are not very well understood, yet. Here we use molecular dynamics simulations to investigate the non-covalent interactions taking place between several blood proteins and poly(ethylene glycol) (PEG), a hydrophilic polymer commonly used to coat nanoparticles for improved efficacies. The simulations reveal recurring patterns of interaction involving specific amino acids. The latter could be used for the development of coarse grained representations of protein-PEG interactions and may provide the basis for understanding the properties of protein coronas formed around PEGylated nanoparticles.

DY 3.9 Mon 12:00 ZEU 250

Monolayer-Protected Anionic Au Nanoparticles Walk into Lipid Membranes Step by Step — •Federica Simonelli[1], Davide Bochicchio[1], Riccardo Ferrando[2], and Giulia Rossi[1] — [1]Physics Department, University of Genoa, Via Dodecaneso 33, 16146 Genoa, Italy — [2]Chemistry Department, University of Genoa, Via Dodecaneso 31, 16146 Genoa, Italy

The design of ligand-protected metal nano-particles (NPs) with biomedical applications relies on the understanding, at the molecular level, of their interactions with cell membranes. We study, via unbiased coarse grained molecular dynamics simulations, the kinetics and the thermodynamics of the interaction between anionic ligand-protected gold NPs and model lipid membranes. We find that the NP-membrane interaction is a three-step process: electrostatics-driven adhesion to the membrane surface, hydrophobic contact and final embedding in the membrane core via anchoring of the charged ligands to both membrane leaflets. Our free energy calculations show that anchoring is highly favorable and not reversible. Furthermore, the interaction pathway of NPs with random surface arrangement of anionic and hydrophobic ligands is characterized by two metastable configurations: adsorbed at the membrane surface, and membrane-embedded. Patched ligand arrangements, instead, lead to the stabilization of a third, intermediate metastable configuration, resulting in a much slower kinetics of interaction with the membrane.

DY 3.10 Mon 12:15 ZEU 250

Modeling epidemic patterns of multiple diseases with short-term non-specific immunity — •Gorm Gruner Jensen[1], Florian Uekermann[1], Kim Sneppen[1], and Lone Simonsen[2] — [1]Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, Copenhagen 2100-DK, Denmark — [2]Department of public health, University of Copenhagen, Øster Farimagsgade 5, Copenhagen 1014-DK, Denmark

A number of common respiratory viruses cause seasonal epidemics in a particular sequential pattern. Seasonal drivers like reduced immune function in mid-winter have been proposed as a possible cause. While these drivers may be sufficient to explain mid-winter viruses such as influenza, it is not clear whether other viruses require different drivers to explain their occurrence in spring, summer or fall. Here we use a multi-disease model to explore the possibility that a short non-specific immunity explains their seasonal patterns as a consequence of interaction between the diseases rather than requiring multiple seasonal drivers or complex pairwise interaction.

In the presence of a single seasonal driver, working identically on all diseases, our model exhibits a variety of observed epidemic patterns, including ordered peaks of different diseases. As example for application to observed patterns, we show two disease simulations reproducing multiple features of the correlation between annual PIV-3 and biennial PIV-1 epidemic peaks.

DY 3.11 Mon 12:30 ZEU 250

Characterization of coarse-grained helix-coil transition networks — •Joseph Rudzinski, Kurt Kremer, and Tristan Bereau — Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

A variety of models, with widely-varying resolution, have contributed to our interpretation of the protein folding process. While atomically-detailed simulations have emerged as an invaluable tool for describing the subtle details which determine particular folding processes, simple physics- and native structure-based coarse-grained (CG) models laid the foundation for current protein folding theories. Despite the success of the latter in describing the essential features of protein folding, the reduced degrees of freedom in CG models inherently obscures the resulting dynamical properties, generally limiting their utility. In this work, we investigate to what extent CG models can describe the precise network of transition pathways for particular protein folding processes. As a model system, we consider the well-studied problem of helix-coil transition kinetics. To elucidate the generic features of the transition, while retaining an accurate description of the transition pathways, we consider a hybrid model with simple, physically-motivated interactions coupled with atomically-detailed sterics. We compare the resulting transition network to networks generated from both an all-atom model and a more sophisticated, transferable CG model. Our results indicate that many features of the transition network are prescribed by rather generic features of the model, motivating further investigation of protein folding kinetics using this approach.

DY 3.12 Mon 12:45 ZEU 250

Mechanism of rhomboid intramembrane proteolysis — •Ana Nicoleta Bondar — Department of Physics, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany

Intramembrane proteases are membrane-embedded proteins whose substrates are transmembrane protein segments. Reaction mechanisms of intramembrane proteases are important to understand, because these proteins are implicated in essential processes such as cell signalling. A fundamental open question is how specific lipid molecules participate in the reaction coordinate of intramembrane protease. We address this question with extensive all-atom molecular dynamics simulations of the intramembrane rhomboid protease from Escherichia coli, GlpG. The computations indicate coupling between lipid binding at the substrate docking-site region and the composition of the lipid membrane, highlighting the importance of lipid interactions for the reaction coordinate of the protease.

Work supported in part by the Excellence Initiative of the German Federal and State Governments provided via the Freie Universität Berlin, and and allocation of computing time from the North-German Supercomputing Center, HLRN (bec00076).

References

1. A.-N. Bondar. Biophysical mechanism of rhomboid proteolysis: setting a foundation for therapeutics. Seminars in Cell and Developmental Biology 10.1016/j.semcdb.2016.09.006, Accepted (2016).

2. A.-N. Bondar, C. del Val, and S. H. White. Rhomboid protease dynamics and lipid interactions. Structure 17: 395-405 (2009).

DY 4: Mechanics and Dynamics of 3D Tissues - Joint Focus Session (BP/CPP/DY) organized by Peter Loskill

Time: Monday 9:30–13:00 Location: SCH A251

Invited Talk DY 4.1 Mon 9:30 SCH A251

Cilia-based transport networks — •Eberhard Bodenschatz — MPI für Dynamik und Selbstorganisation , Am Fassberg 17, 37077 Goettingen

Cerebrospinal fluid conveys many physiologically important signaling factors through the ventricular cavities of the brain. We investigated the transport of cerebrospinal fluid in the third ventricle of the mouse brain and discovered a highly organized pattern of cilia modules, which collectively give rise to a network of fluid flows that allows for precise transport within this ventricle. Our work suggests that ciliated epithelia can generate and maintain complex, spatiotemporally regulated flow networks. I shall also show results on how to assemble artificial cilia and cilia carpets. This work is in collaboration with Regina Faubel, Gregor Eichele, Christian Westendorf, Azam Gholami, Isabella Guido, Yong Wang, Albert Bae and Marco Tarantola. Support by the Max Planck Society and the BMBF within the MaxSynBio initiative is gratefully acknowledged.

DY 4.2 Mon 10:00 SCH A251

Quantitative structure-function relationships in 3D tissues — •Janna Nawroth — Emulate Inc., Boston, MA, USA

Biological tissues are characterized by an organ-specific three-dimensional, multiscale organization of cells and extracellular matrix components. This organization gives rise to organ-specific functions and dysfunctions. Tissue engineering attempts to recapitulate these structure-function relationships in vitro to provide models of disease, drug toxicity, and patient-specific responses. One major challenge is to identify and implement quantitative metrics that capture the most relevant structure-function relationships to serve for both quality control and experimental readout of the engineered tissue. Here, I present engineering and analysis strategies for recapitulating and quantifying the cellular organization and mechanical functions in engineered cardiac muscle and in ciliated epithelia, with a particular emphasis on organ-on-chip technology.

DY 4.3 Mon 10:30 SCH A251

***In vivo* quantification of spatially-varying mechanical properties in developing tissues** — •Friedhelm Serwane[1,2], Alessandro Mongera[1], Payam Rowghanian[1], David Kealhofer[1], Adam Lucio[1], Zachary Hockenbery[1], and Otger Campas[1] — [1]University of California, Santa Barbara, USA — [2]Max Planck Institute for Medical Research, Heidelberg, Germany

We present a technique that allows quantitative spatiotemporal measurements of mechanical properties *in vivo* using biocompatible ferrofluid droplets as local mechanical actuators [1].

The mechanical properties of the cellular microenvironment and their spatiotemporal variations play a central role in controlling cell behavior, including cell differentiation. However, no direct *in vivo* and *in situ* measurement of mechanical properties within developing 3D tissues has been performed yet.

Using our technique we show that vertebrate body elongation entails spatially varying tissue mechanics along the anteroposterior axis. Specifically, we find that the zebrafish tailbud is viscoelastic: elastic below a few seconds and fluid after just one minute. Furthermore, it displays decreasing stiffness and increasing fluidity towards its posterior elongating region.

This method opens the door to study mechanobiology *in vivo*, both in embryogenesis and in disease processes, including cancer.

[1] F. Serwane, A. Mongera, P. Rowghanian, D. Kealhofer, A. Lucio, Z. Hockenbery, O. Campàs. Nature Methods, in press (2016)

DY 4.4 Mon 10:45 SCH A251

Mechanical spectroscopy of retina explants at the protein level employing nanostructured scaffolds — •Mareike Zink[1] and S. G. Mayr[2] — [1]Soft Matter Physics Division, University of Leipzig, Leipzig, Germany — [2]Leibniz Institute for Surface Modification (IOM), Leipzig, Germany & Division of Surface Physics, Department of Physics and Earth Sciences, University of Leipzig, Germany

The mechanical properties of the retina play a crucial role in function and diseases of the eye. Here we present that nanostructured TiO2 substrates can be employed as vibrating reed to investigate the mechanical properties of adult mammalian retinae at the nanometer. Within a self-designed mechanical spectroscopy setup, the reed with the retina on top is excited to perform free damped oscillations. The detected oscillation parameters represent a fingerprint of the frequency-dependent mechanical tissue properties that are derived in combination with sandwich beam analysis and finite element calculations. We found that the Young's modulus of the retina is of the order of a few GPa, much higher than values obtained from experiments in which tissue response is investigated on micrometer length scales. In our study, polymers and proteins on the photoreceptor side of the retina in contact with the nanostructured reed are stretched and compressed during vibration of the underlying scaffold and the acting intramolecular forces are probed at the protein level. To this end, our mechanical spectroscopy approach offers new perspectives in studying mechanical response of individual proteins within the tissue for investigating tissue mechanics, diseases and the effect of drugs.

15 min break

DY 4.5 Mon 11:15 SCH A251

A simulation study on 3D muscle movement: eigen-frequency and force-coupling to the skeleton change with muscle activity — Daniel F B Haeufle, Daniel Wirtz, •Kevin Kraschewski, Syn Schmitt, and Oliver Röhrle — Stuttgart Research Center for Simulation Technology (SimTech), University of Stuttgart, Germany

The muscles in the human body are soft materials coupled flexibly to the rather rigid bones. Due to this flexible coupling, muscles move relative to the bones during movement. The resulting coupling forces of these so-called wobbling masses depend on the neural stimulation of the muscle tissue. It is experimentally very difficult to study the relation between muscle stimulation and coupling forces. Therefore, we developed a 3D continuum-mechanical model of a muscle-tendon complex considering muscle stimulation, elasticity, viscosity, fiber orientation, and tendon stiffness. This model predicts the interaction forces in response to external oscillatory excitations in dependence on excitation frequency and muscle stimulation level. With this approach, the functional role of wobbling masses in human movement, e.g., energy dissipation and force reduction during the impact in human running, can be studied in more detail.

DY 4.6 Mon 11:45 SCH A251

Electromechanical Turbulence in the Heart — •Jan Christoph and Stefan Luther — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

The self-organizing pattern forming mechanisms underlying highly life-threatening cardiac fibrillation are still insufficiently understood. High-speed fluorescence imaging provides highly detailed visualizations of the spatio-temporal electrophysiological activity of the heart. During ventricular fibrillation, these visualizations depict complex spatio-temporal electrical patterns including rotating vortices or spiral waves on the heart's surface. However, with limited penetration depths of fluorescence imaging the optically mapped surface dynamics reflect only the superficial projection of three-dimensional wave phenomena that evolve within the depths of the cardiac muscle.

We combined fluorescence imaging with ultrasound to study the coupled electrical and mechanical activity of the fibrillating heart on its surface as well as within the heart wall. We found that during fibrillation electrical activity patterns and elasto-mechanical deformations are highly correlated producing co-localized patterns of electrical and mechanical activation. Specifically, we found that electrical spiral wave rotors can be accompanied by rotational elasto-mechanical patterns, which like fingerprints of vortex activity occur as a characteristic feature within the deformations of the fibrillating muscle. Our data highlights the importance of studying the mechanics and dynamics of 3D cardiac tissues to obtain a better understanding of cardiac arrhythmias and to conceptualize novel diagnostic and therapeutical strategies.

DY 4.7 Mon 12:00 SCH A251

Local rules for robust global transport in liver networks —

•Jens Karschau[1], Andre Scholich[2], Marius Asal[1], Hidenori Nonaka[3], Hernan Morales-Navarrete[3], Fabian S Miranda[3], Kirstin Meyer[3], Yannis Kalaidzidis[3], Marino Zerial[3], Frank Jülicher[2], and Benjamin M Friedrich[1] — [1]cfaed / TU Dresden — [2]MPI PKS, Dresden — [3]MPI CBG, Dresden

The liver represents a chemical factory that is characterised by intertwined transport networks for toxins and metabolites. Each hepatocyte cell of the liver tissue interacts with two space-filling networks: bile canaliculi and sinusoids which transport bile and blood, respectively. How these networks establish their distinct architecture to supply all hepatocytes, and dynamically adapt to time-varying load as well as to local perturbations remains elusive.

Here, we elucidate design principles of liver tissue structure and self-organisation based on experimental high-resolution imaging data from mice. First, we characterise and quantify liver tissue with tools from liquid-crystal theory that show lobule level patterns of aligned cell polarity and local network anisotropy. Second, we study a simplified flow model to understand the relationship between the spatial structure of the network and robust transport properties. Third, we compare our flow simulations in reconstructed bile canaliculi networks and simulated self-organised networks. Thereby, we establish a connection between local network geometry and properties of global fluid transport, linking tissue structure with function.

DY 4.8 Mon 12:15 SCH A251

Jamming and liquidity in 3D cancer cell aggregates — •Linda Oswald[1], Steffen Grosser[1], Jürgen Lippoldt[1], Steve Pawlizak[1], Anatol Fritsch[2], and Josef Käs[1] — [1]University of Leipzig — [2]MPI CBG Dresden

Traditionally, tissues are treated as simple liquids, which holds for example for embryonic tissue. However, recent experiments have shown that this picture is insufficient for other tissue types, suggesting possible transitions to solid-like behavior induced by cellular jamming. The coarse-grained self-propelled Voronoi (SPV) model predicts such a transition depending on cell shape which is thought to arise from an interplay of cell-cell adhesion and cortical tension. We observe non-liquid behavior in 3D breast cancer spheroids of varying metastatic potential and correlate single cell shapes, single cell dynamics and collective dynamic behavior of fusion and segregation experiments via the SPV model.

DY 4.9 Mon 12:30 SCH A251

Type IV pili govern the internal dynamics of *Neisseria gonorrhoeae* microcolonies. — •Wolfram Pönisch[1], Christoph Weber[2], Khaled Alzurqa[3], Hadi Nasrollahi[3], Kelly Eckenrode[3], Nicolas Biais[3], and Zaburdaev Vasily[1] — [1]Max Planck Institut für Physik Komplexer Systeme, Dresden — [2]Harvard University, Cambridge — [3]Brooklyn College, New York

An important step in the evolution of biofilms is the formation of microcolonies, agglomerates of cells that can consists of several thousands of cells. For many pathogenic bacteria, i.e. *N. gonorrhoeae* or *P. aeruginosa*, the attractive cell-cell-interactions required for microcolonies to form are mediated by micron-long and thin appendages, the called type IV pili. We are interested in the pili-mediated dynamics of individual bacteria within microcolonies and how they affect the properties of the agglomerates. In experiments, we observe a gradient of motility of cells of *N. gonorrhoeae*, depending on their position within a colony. We will present a computational model of cells interacting via individual pili. It allows us to model microcolonies on biologically relevant temporal and spatial scales and is able to reproduce the differential motility of cells within a colony. Furthermore, it enables us to study quantities that are not yet accessible by experiments, e.g. the cell density within a colony, the pili-mediated cell forces and force fluctuations and the internal structure of the colonies. Finally, we will present how the assembly and morphology of microcolonies is affected by the pili properties, particularly for mixtures of cell populations characterized by mutations of their pilus apparatus.

DY 4.10 Mon 12:45 SCH A251

Growth Dynamics of Biofilms — •Benedikt Sabass[1,2], Jing Yan[2], Howard A. Stone[2], and Ned S. Wingreen[2] — [1]Forschungszentrum Jülich — [2]Princeton University

Bacteria can form tight communities that are called biofilms. Although biofilms are ubiquitous and ecologically important, little is known about the physics of biofilm growth. Here, we focus on rod-shaped V. cholerae bacteria that form hemispherical biofilms when growing on a surface. Using high-resolution microscopy data, we measure cell density, cell orientation, and shape evolution of the biofilm. We quantitatively explain the density and cell orientation inside the biofilm by minimization of elastic energies. The evolution of the whole biofilm shape is governed by apparent viscous relaxation. We find that the shape parameters of biofilms follow rather simple, generic scaling laws.

DY 5: Keynote Lecture I

Time: Monday 9:30–10:00 Location: ZEU 222

Invited Talk DY 5.1 Mon 9:30 ZEU 222

Dynamically Reconfigurable Soft Matter in External Fields: Smart Particle Gels, Shape-Changing Clusters and Self-Propelling Microbots — •Orlin D Velev — Department of Chemical and Biomolecular Engineering, North Carolina State University, Raleigh, NC 27695, USA

This talk will focus on principles of using magnetic and electric fields to manipulate new classes of soft matter assembled from responsive, asymmetric, and motile particles. Metallo-dielectric particles acquire complex polarization patterns in external fields, leading to their multi-directional interactions and assembly. First, we will describe how magnetically responsive Janus microcubes can be assembled into clusters and chains that spontaneously reconfigure when the external magnetic field is turned on and off. The magnetization of the metallic facets leads to directional dipole-dipole and field-dipole interactions. The folding pattern of the clusters is encoded by the orientational sequence of the cubes. Assemblies of specific sequences demonstrate prototypes of new microbot and colloidal origami structures. The dynamically reconfiguring clusters can also be designed to be self-motile in media with non-Newtonian rheology or to serve as microrheometers. In the second part of the talk, we will discuss a new smart gel system of ultra-flexible chains from super-paramagnetic nanoparticles coated by condensed lipid shells. The field collects the nanoparticles into magnetically responsive filaments. The soft, "snappable," capillary interactions also enable the assembly of patchy particles, magnetically self-repairing gel networks and novel inks for 3D printing.

DY 6: Many-Body Quantum Systems (joint session DY/TT)

Time: Monday 10:00–12:15 Location: ZEU 118

DY 6.1 Mon 10:00 ZEU 118

Localization in the non-interacting central site model and logarithmic entanglement growth — •Daniel Hetterich[1], Maksym Serbyn[2], Fernando Domínguez[1], Frank Pollmann[3], and Björn Trauzettel[1] — [1]Institut für Theoretische Physik, Universität Würzburg, D-97074 Würzburg, Germany — [2]Department of Physics, University of California, Berkeley, California 94720, USA — [3]Max-Plank Institute for the Physics of Complex Systems, D-0118 Dresden, Germany

We present both numerical and analytical results on localization features in the non-interacting central site model. Although this model is highly non-local – the central site couples equally to all other sites – we find exponentially localized eigenstates for all strengths of the coupling to the central site. Furthermore, the statistics of the corresponding wave functions show multifractality. Due to the special topology of our model, the entanglement entropy of factorized initial states grows logarithmically in time, which was previously thought to be present only in interacting many-body localized systems. This behavior can be analytically understood by the logarithmic motion of particles through the lattice.

DY 6.2 Mon 10:15 ZEU 118

Necessity of eigenstate thermalization for equilibration towards unique expectation values when starting from generic initial states — •Christian Bartsch and Jochen Gemmer — Fachbereich Physik, Universität Osnabrück, Barbarastraße 7, D-49069 Osnabrück

We investigate dynamical equilibration of expectation values in closed quantum systems for realistic non-equilibrium initial states. Thereby we find that the corresponding long time expectation values depend on the initial expectation values if eigenstate thermalization is violated. An analytical expression for the deviation from the expected ensemble value is derived for small displacements from equilibrium. Additional numerics for magnetization and energy equilibration in an asymmetric anisotropic spin-1/2-ladder demonstrate that the analytical predictions persist beyond the limits of the theory. The results suggest eigenstate thermalization as physically necessary condition for initial state independent equilibration.

DY 6.3 Mon 10:30 ZEU 118

Magnus expansion approach to parametric oscillator systems in a thermal bath — •Beilei Zhu — Zentrum für Optische Quantentechnologien and Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

We develop a Magnus formalism for periodically driven systems which provides an expansion both in the driving term and the inverse driving frequency, applicable to isolated and dissipative systems. We derive explicit formulas for a driving term with a cosine dependence on time, up to fourth order. We apply these to the steady state of a classical parametric oscillator coupled to a thermal bath, which we solve numerically for comparison. Beyond dynamical stabilization at second order, we find that the higher orders further renormalize the oscillator frequency, and additionally create a weakly renormalized effective temperature. The renormalized oscillator frequency is quantitatively accurate almost up to the parametric instability, as we confirm numerically. Additionally, a cut-off dependent term is generated, which indicates the break-down of the hierarchy of time scales of the system, as a precursor to the instability. Finally, we apply this formalism to a parametrically driven chain, as an example for the control of the dispersion of a many-body system.

DY 6.4 Mon 10:45 ZEU 118

Experimentally accessible witnesses of many-body localisation — •Marcel Goihl[1], Mathis Friesdorf[1], Albert H. Werner[2], Winton Brown[1], and Jens Eisert[1] — [1]Freie Universität Berlin — [2]University of Copenhagen

The phenomenon of many-body localised (MBL) systems has attracted significant interest in recent years, for its intriguing implications from a perspective of both condensed-matter and statistical physics: they are insulators even at non-zero temperature and fail to thermalise, violating expectations from quantum statistical mechanics. What is more, recent seminal experimental developments with ultra-cold atoms in optical lattices constituting analog quantum simulators have pushed many-body localised systems into the realm of physical systems that can be measured with high accuracy. In this work, we introduce experimentally accessible witnesses that directly probe distinct features of MBL, distinguishing it from its Anderson counterpart. We insist on building our toolbox from techniques available in the laboratory, including on-site addressing, super-lattices, and time-of-flight measurements, identifying witnesses based on fluctuations, density-density correlators, densities, and entanglement. We build upon the theory of out of equilibrium quantum systems, in conjunction with tensor network and exact simulations, showing the effectiveness of the tools for realistic models.

DY 6.5 Mon 11:00 ZEU 118

Dynamics of correlations in long-range quantum systems following a quantum quench — •Lorenzo Cevolani[1], Giuseppe Carleo[2], and Laurent Sanchez-Palencia[3] — [1]Georg-August-Universität, Göttingen — [2]ETH, Zurich — [3]Laboratoire Charles Fabry. France

We study how and how fast correlations can spread in a quantum system abruptly driven out of equilibrium by a quantum quench. This protocol can be experimentally realized and it allow to address fundamental questions concerning the quasi-locality principle in isolated quantum systems with both short- and long-range interactions. We focus on two different models describing, respectively, lattice bosons, and spins. Our study is based on a combined approach, based on one hand on accurate many-body numerical calculations and on the other hand on a quasi-particle microscopic theory. We find that, for sufficiently fast decaying interaction potential the propagation is ballistic and the Lieb-Robinson bounds for long-range interactions are never attained. When the interactions are really long-range, the scenario is completely different in the two cases. In the bosonic system the locality is preserved and a ballistic propagation is still present while in the spin system an instantaneous propagation of correlations completely destroys locality. Using the microscopic point of view we can quantitatively describe all the different regimes, from instantaneous to ballistic, found in the spin model and we explain how locality is protected in the bosonic model leading to a ballistic propagation.

15 min. break

DY 6.6 Mon 11:30 ZEU 118

Direct observation of electronic, spin and charge separation in the ultrafast dynamics of $LaCoO_3$ — •Manuel Izquierdo[1,2], Alexander Yaroslavtsev[1,2], Robert Carley[1], Michael Karolak[3,2], Alexander Lichtenstein[2,1,4], Andreas Scherz[1], and Serguei Molodtsov[1,5,6] — [1]European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany — [2]Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [3]Theoretical Physics I, University of Würzburg, Am Hubland, 97074 Würzburg — [4]Ural Federal University, 620990 Yekaterinburg, Russia — [5]Institute of Experimental Physics, Technische Universität Bergakademie Freiberg, 09599 Freiberg, Germany — [6]ITMO University, Kronverkskiy pr. 49, 197101 St. Petersburg, Russia

The semiconductor to metal transition of $LaCoO_3$ (LCO) is investigated with all-optical and optical-soft x-ray pump-probe experiments performed with different time resolution. Picosecond studies have demonstrated the formation of a laser-induced transient metallic state. All-optical studies with femtosecond resolution have shown an ultrafast excitation of the system within a few hundred fs. Finally, spectroscopic studies with soft x-ray femtoslicing pulses have unraveled the properties of the transient metallic state, in which the electronic, spin and lattice degrees of freedom are excited on different time scales, demonstrating the relevance of soft x-ray femtosecond sources to investigate correlated systems.

DY 6.7 Mon 11:45 ZEU 118

Dissipation-induced enhancement of quantum fluctuations — •Gianluca Rastelli — University of Konstanz Fachbereich Physik, Fach 703 D-78457 Konstanz

We study a quantum harmonic oscillator linearly coupled through the

position operator q to a first bath and through the momentum operator p to a second bath. We analyse the oscillator's fluctuations as a function of the ratio between the strength of the two couplings, focusing in particular on the situation in which the two dissipative interactions are comparable. Analytic formulas are derived in the low temperature limit [1]. In this regime, each bath operates to suppress the oscillator's ground state quantum fluctuations for q or p, viz. the operator appearing in the corresponding interaction. When one of the two dissipative interactions dominates over the other, the fluctuations for the coupling operator are squeezed. When the two interactions are comparable, the two baths enter in competition as the two conjugate operators do not commute yielding quantum frustration. In this regime, remarkably, the fluctuations of both two quadratures are enhanced by increasing the dissipative coupling. [1] G. Rastelli, New J. Phys. 18, 053033 (2016).

DY 6.8 Mon 12:00 ZEU 118

Dynamics of correlations in strongly interacting systems at finite temperatures — •Friedemann Queisser[1], Konstantin Krutitsky[1], Patrick Navez[2], and Ralf Schützhold[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße, Duisburg 47048, Germany — [2]Department of Physics, University of Crete, 71003 Heraklion, Greece

We discuss equilibrium and non-equilibrium properties of the Bose-Hubbard model in the formal limit of large coordination numbers Z [1]. Via an expansion of the correlation functions in powers of $1/Z$ we establish a hierarchy of correlations which facilitates the analysis of the system in equilibrium and in non-equilibrium. With this method we study the quantum dynamics (starting in a thermal state) after a quantum quench in the Mott (or normal gas) phase. The spread of correlations leads to an effective light-cone structure which depends sensitively on the initial thermal distribution [2].

[1] P. Navez and R. Schützhold, Phys. Rev. A **82**, 063603 (2010)
[2] K. V. Krutitsky, P. Navez, F. Queisser and R. Schützhold, EPJ Quantum Technology **1** (2014)

DY 7: Soft Particles in Flows I (Focus session, joint DY/CPP)

The dynamics and interactions of soft particles suspended in a flowing liquid are a physical problem of unusual complexity and of relevance in technical and biological systems, e.g. blood flow. The close connection between sophisticated numerical simulations and experiments has brought about a wealth of new insights in the recent past. The aim of the session is to review some of these recent advances, both experimental and theoretical/computational.

Organized by S. Gekle, G. Gompper, C. Wagner

Time: Monday 10:15–13:15 Location: ZEU 160

Invited Talk DY 7.1 Mon 10:15 ZEU 160

Immersed Boundary Methods for Rigid and Deformable Particles in Viscoelastic flows — •Eric Shaqfeh — Department of Chemical Engineering, Stanford University

The immersed boundary method will be used with a finite volume fluid solver to develop a unique tool to examine the properties of a viscoelastic suspension of particles. The tool will employ unstructured grids and is massively parallel, thus allowing very complex geometries to be simulated. Since the internal stress of the particles is handled using a finite element solver, nearly arbitrary stress-strain relationships for the particles can be handled and their shape can deform continuously. A number of interesting physical problems will be examined with the code including 1) Sedimentation of particles in orthogonal shear and 2) the rheology of particulate suspensions in a viscoelastic fluid under shear.

DY 7.2 Mon 10:45 ZEU 160

A new look at blood shear-thinning — Luca Lanotte[1], Johannes Mauer[2], Simon Mendez[3], Dmitry Fedosov[2], Jean-Marc Fromental[4], Viviana Claveria[1], Franck Nicoud[3], Gerhard Gompper[2], and •Manouk Abkarian[1] — [1]Centre de Biochimie Structurale, Montpellier, France — [2]Institute of Complex Systems and Institute for Advanced Simulation, Forschungszentrum Jülich, Germany — [3]Institut Montpelliérain Alexander Grothendieck, Montpellier, France — [4]Laboratooire Charles Coulomb, Montpellier, France

Blood viscosity decreases with shear stress, a property essential for an efficient perfusion of the vascular tree. Shear-thinning is intimately related to the dynamics and mutual interactions of red blood cells (RBCs), the major component of blood. Because of the lack of knowledge about their behavior under physiological conditions, the link between RBCs dynamics and blood rheology remains still unsettled. Performing experiments and simulations in microcirculatory flow conditions of viscosity, shear rates and volume fractions, our work reveals how rich RBCs dynamic morphologies govern blood shear thinning, contrary to the current paradigm assuming steady RBC orientation and membrane circulation. Our results suggest that any pathological change in RBCs* local rheology will impact the onset of these morphological transitions and should play a key role in pathological blood flow.

DY 7.3 Mon 11:00 ZEU 160

Clustering of microscopic particles in stenosed blood flow — •Christian Bächer, Lukas Schrack, and Stephan Gekle — Biofluid Simulation and Modeling, University of Bayreuth, Germany

A mixed suspension of red blood cells and microparticles flows through a cylindrical channel with a constriction mimicking a stenosed blood vessel. Our three-dimensional Lattice-Boltzmann simulations show that the red blood cells are depleted right ahead and after the constriction. For the red blood cells the axial concentration profile is very similar to that of isolated tracer particles flowing along the central axis. Most importantly, however, we find that the stiff microparticles exhibit the opposite behavior. Arriving on a marginated position near the channel wall, they can pass through the constriction only if they find a suitable gap to dip into the dense plug of red blood cells occupying the channel center. This leads to a prolonged dwell time and, as a consequence, to a pronounced increase in microparticle concentration right in front of the constriction. Similar clustering events occur for marginated particles in a cylindrical channel branching into two daughter channels.

DY 7.4 Mon 11:15 ZEU 160

Margination of blood cells — •Revaz Chachanidze[1,2], Marc Leonetti[1], and Christian Wagner[2] — [1]Institut de Recherche sur les Phénomènes Hors Equilibre (I.R.P.H.E), Aix-Marseille University, Marseille, France — [2]Saarland University, Saarbruken, Germany

In blood flow erythrocytes migrate to the centre of the vessel creating a *cell-free layer* at the edge while leucocytes, lymphocytes and platelets tend to migrate to vessel walls. This phenomenon is known as margination. Margination of leucocytes and its role in immune response as well as margination of red blood cells in cases of some diseases (such as malaria and sickle cell disease) have been subjects of research for a while. Recent advances in targeted drug delivery arouses interest to margination of micro- and nano-particles.

Our research is dedicated to better understanding of mechanical properties of particles involved in margination and to create conditions for blood flow under which particles manifest tendency to segregation. For this purposes we observe and quantify blood flow consisting of 2 populations of red blood cells * healthy and rigidified with cross-linking agent (glutaraldehyde) * in microfluidic channels in cases of different volumetric flow rate, cells concentration and etc.

15min. break

Invited Talk DY 7.5 Mon 11:45 ZEU 160

Effect of bending on the dynamics of a spherical capsule in shear flow — •Anne-Virginie Salsac — CNRS - Universite de

Technologie de Compiegne, Compiegne, France

Encapsulating liquid droplets within a membrane enables to protect fragile or volatile substances and control their liberation. Typical artificial capsules are quasi*spherical at rest and present a hyperelastic membrane with mechanical and geometrical properties that are function of the fabrication process. When suspended in a simple shear flow, such capsules are elongated in the straining direction by the hydrodynamic stresses, while the membrane rotates around the deformed shape under the flow vorticity. But, for low flow strength, the capsule membrane is compressed in the equatorial region and blucking may occur. Since membrane wrinkling can cause fatigue breakup, it is important to predict it in order to avoid/provoke membrane rupture. The objective of the study is thus to study numerically an initially spherical capsule in shear flow and analyze the influence of the membrane bending rigidity on the capsule dynamics and wrinkle formation. The 3D fluid-structure interactions are modeled coupling a boundary integral method to solve for the internal and external Stokes flows with a thin shell finite element method to solve for the wall deformation [1]. For a given wall material, the capsule deformability strongly decreases when the wall thickness (or bending resistance) increases. We show that the global capsule motion and deformation can, however, be inferred from the ones obtained by a membrane model devoid of bending stiffness, as they are mainly governed by in-plane membrane tensions.

DY 7.6 Mon 12:15 ZEU 160

Hydrodynamic mechanism of shear-induced ordering in weakly confined suspensions of deformable particles — •Alexander Farutin[1,2], Zaiyi Shen[1,2], Thomas Fischer[3], Jens Harting[4,5], and Chaouqi Misbah[1,2] — [1]Univ. Grenoble Alpes, LIPHY, F-38000 Grenoble, France — [2]CNRS, LIPHY, F-38000 Grenoble, France — [3]Laboratory for Red Cell Rheology, 52134 Herzogenrath, Germany — [4]Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Forschungszentrum Jülich, Fürther Strasse 248, 90429, Nürnberg, Germany — [5]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600MB Eindhoven, The Netherlands

It has been shown recently by experiments and numerical simulations that suspensions of red blood cells confined between two walls can undergo ordering when subject to shear flow. In this presentation, we propose a hydrodynamical model that explains this effect. The key ingredients of the model are (1) wall-induced migration, which keeps the cells close to the midplane between the two walls, (2) long-range hydrodynamic interactions in the direction parallel to the walls, which cause cell pairs to align with the flow direction and to get attracted to each other and (3) short-range hydrodynamic interactions perpendicular to the walls, which cause the cells move out of the midplane in such a way that the shear flow pushes them apart. We have verified by solving our model analytically that two cells form a stable stationary pair. The intercell distance given by our model agrees with the experiments and the simulations.

DY 7.7 Mon 12:30 ZEU 160

Ultrasound-triggered margination of microbubbles for targeted drug delivery — •Achim Guckenberger and Stephan Gekle — Biofluid Simulation and Modeling, Universität Bayreuth, Germany

During circulation through the vascular system, drug delivery agents should be preferably located in the low-shear interior of the blood stream. Yet, when they are close to the pathological region, they should attain a near-wall position for the most efficient interaction with the endothelium. Using mesoscopic three-dimensional numerical simulations we show that this apparent contradiction can be resolved by using phospholipid coated microbubbles. Application of an ultrasound pulse triggers the rapid migration of the microbubbles toward the endothelial walls due to the hydrodynamic interactions with the red blood cells. The effect is caused by the oscillations of the bubbles, resulting in alternations between a soft and a stiff state, as induced by the lipid shell. We find that the effect is very robust, being triggered even if the time spent in the stiff state is three times lower than the opposing time in the soft state.

DY 7.8 Mon 12:45 ZEU 160

Inertial migration of elastic capsules in Poiseuille flow — •Christian Schaaf, Kevin Irmer, Christopher Prohm, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany

Deformable particles such as capsules, vesicles and red blood cells assemble at fixed equilibrium positions in a microfluidic channel under Poiseuille flow. This behavior can be used to separate particles with different mechanical properties. For example, softer cancer cells travel closer to the center than healthy ones.

Using the Lattice-Boltzmann method, we study the dynamics of single deformable particles in a microfluidic channel for intermediate Reynolds numbers.

We show that particles move to different equilibrium position depending on their size and deformability. For Reynolds numbers below 100, their equilibrium positions collapse onto a single master curve depending only on the Laplace number. By applying external forces along the channel axis, we are able to control the equilibrium distance from the channel centerline and thereby have a means to enhance the sensitivity of particle separation.

DY 7.9 Mon 13:00 ZEU 160

Migration reversal of soft particles in flows through wavy microchannels — •Matthias Laumann[1], Alexander Farutin[2], Chaouqi Misbah[2], Diego Kienle[1], and Walter Zimmermann[1] — [1]Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Laboratoire Interdisciplinaire de Physique, CNRS Universite Alpes, UMR 5588, BP 87, F-28402 Saint-Martin, d'Heres Cedex, FranceH

We study soft particles in low Reynolds number flows through microchannels with wavy boundaries. In low Reynolds number flows through microchannels with straight boundaries, soft particles often tend via cross-streamline migration to the channel center (see e.g. [1]). We show, that for wavy channel boundaries this centric motion may be reversed once the modulation amplitude exceeds a (parameter dependent) threshold, in which case the soft particles migrate to off-center trajectories. This is shown by semi-analytical and numerical results for flexible dumbbells, models for ring polymers and capsules in microflows. The distance between off-center trajectories and the center of the microchannel depends on the particle's elasticity and flow velocity as well as on the wavelength and the amplitude of the boundary modulation. Moreover, by increasing the flow velocity the migration direction may be reversed from out- to inward. Our insights can be exploited for particle separation with different properties in microchannels.

[1] B. Kaoui, G. H. Ristow, I. Cantat, C. Misbah, W. Zimmermann, Phys. Rev. E **77**, 021903 (2008).

DY 8: Statistical Physics far from Thermal Equilibrium

Time: Monday 15:00–19:15 Location: ZEU 118

DY 8.1 Mon 15:00 ZEU 118

Enhanced nonequilibrium fluctuations of particles driven through a viscoelastic bath — •Johannes Berner[1], Juan Ruben Gomez-Solano[1], and Clemens Bechinger[1,2] — [1]2. Phykalisches Institut, Universität Stuttgart, Germany — [2]MPI for Intelligent Systems, Stuttgart, Germany

Viscoelastic fluids are of great importance in biological systems and in medical and industrial applications. Their flow properties have been extensively studied by bulk rheology [1] and more recently by microrheology [2] using embedded colloidal probes. For instance in passive microrheology the fluctuation-dissipation theorem is used to determine such properties by measuring the thermal fluctuations of the particle position [3]. This is only valid provided that the fluid and the particle are in thermal equilibrium. However this assumption is not trivially satisfied, if the microstructure of the fluid is driven far from equilibrium, e.g. by inducing a local deformation by means of the particle [4, 5]. In this work, we investigate the fluctuations of a colloidal particle driven by optical tweezers at constant velocity through a viscoelastic medium. Unlike in a Newtonian fluid, we observe an enhancement of those fluctuations by driving the fluid out of equilibrium.

[1] Larson R G 1999 The Structure and Rheology of Complex Fluids (New York: Oxford University Press), [2] Squires T. M. and Mason T. G., Annu. Rev. Fluid Mech., 42 (2010) 413, [3] Mason T. G. and Weitz D. A., Phys. Rev. Lett., 74 (1995) 1250, [4] Gomez-Solano J. R. and Bechinger C., EPL, 108 (2014) 54008, [5] Gomez-Solano J. R. and Bechinger C., New J. Physics, 17 (2015) 103032

DY 8.2 Mon 15:15 ZEU 118

Nonequilibrium thermodynamics in the strong coupling and non-Markovian regime based on a reaction coordinate mapping — •Philipp Strasberg[1], Gernot Schaller[1], Neill Lambert[2], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany — [2]CEMS, RIKEN, Saitama, 351-0198, Japan

We propose a method to study the thermodynamic behaviour of small systems beyond the weak coupling and Markovian approximation, which is different in spirit from conventional approaches. The idea is to redefine the system and environment such that the effective, redefined system is again coupled weakly to Markovian residual baths and thus, allows to derive a consistent thermodynamic framework for this new system-environment partition. To achieve this goal we make use of the reaction coordinate mapping, which is a general method in the sense that it can be applied to an arbitrary (quantum or classical and even time-dependent) system coupled linearly to an arbitrary number of harmonic oscillator reservoirs. We demonstrate the power of this concept by showing that non-Markovian effects can significantly enhance the steady state efficiency of a three-level-maser heat engine, even in the regime of weak system-bath coupling.

Reference: New. J. Phys. 18, 073007

DY 8.3 Mon 15:30 ZEU 118

Bridging the gap between atomistic and macroscopic models of homogeneous nucleation — •Bingqing Cheng[1], Gareth Tribello[2], and Michele Ceriotti[1] — [1]EPFL, Lausanne, Switzerland — [2]Queen's University Belfast, Belfast, UK

Nucleation has many implications in science and technology, including metal casting, the assembly of microtubules in cells, and the formation of water droplets in the atmosphere. Because the experimental investigation of dynamical nucleation processes is very difficult, much attention has been paid to atomistic simulation efforts in the last two decades.

However, atomistic simulation studies of nucleation face two major challenges. Firstly, the free energy barrier separating the metastable phase and the stable phase can be very high, making nucleation times much larger than the time scales accessible to molecular dynamics simulations. Secondly, it is highly non-trivial to develop a predictive macroscopic model of nucleation using the microscopic quantities directly obtained from atomistic simulations.

In this talk, I aim to address the aforementioned difficulties. I will first briefly introduce state-of-the-art enhanced sampling methods for atomistic simulations, and their applications to studying homogeneous nucleation. I will then discuss our latest thermodynamic model that links macroscopic theories and atomic-scale simulations and thus provide a simple and elegant framework to verify and extend classical nucleation theory.

DY 8.4 Mon 15:45 ZEU 118

Nonequilibrium thermodynamics by nonlocal quantum kinetic theory — •Klaus Morawetz[1,2,3] and Pavel Lipavsky[4] — [1]Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — [2]International Institute of Physics (IIP) Av. Odilon Gomes de Lima 1722, 59078-400 Natal, Brazil — [3]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [4]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague 2, Czech Republic

The balances for thermodynamic quantities are derived from the nonlocal kinetic quantum kinetic equation. It turns out that the nonlocal collision scenario leads to molecular contributions to the observables and currents. The corresponding observable is multiplied with the rate to form a molecule and the delay time which can be considered as collision duration. Explicit expressions of these molecular contributions are given in terms of the scattering phase shifts. The two-particle form of the entropy is derived. This extends the Landau quasiparticle picture by two-particle molecular contributions. While for energy and momentum there is a continuous exchange of correlation into kinetic parts condensing into the rate of correlated variables. For the entropy an explicit gain remains and Boltzmann's H-theorem is proved including the molecular parts of entropy. The consistency of the theory is shown by obtaining the same expressions from the functional between Wigner and quasiparticle distribution within the extended quasiparticle picture.

DY 8.5 Mon 16:00 ZEU 118

Bethe-ansatz solution for ASEP with reflecting boundaries and its application to polymer dynamics — •Wenwen Huang, YenTing Lin, Daniela Frömberg, Frank Jülicher, and Vasily Zaburdaev — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In this contribution, we show that the exact solution of Asymmetric Simple Exclusion Process (ASEP) with reflecting boundaries can be found using a generalised Bethe-ansatz method. The exact partition function is derived and thus the stationary density profile can be solved exactly. Moreover, we calculate the eigenvalues and eigenfunctions of the system analytically and discuss the slowest relaxation time. In addition, we show how to map the ASEP setting to the dynamics of a pinned polymer loop system. By using this mapping, we can get insights into the equilibrium statistics and dynamics of the polymer system. Furthermore, we show how the generalised Bethe-ansatz method can be applied to the continuous single-file diffusion with reflecting boundaries.

DY 8.6 Mon 16:15 ZEU 118

Quantum thermodynamics with local control — •Rodrigo Gallego[1], Jaqueline Lekscha[1,2,3], Henrik Wilming[1], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany — [3]Department of PHysics, Humboldt-Universität zu Berlin, 12489 Berlin, Germnay

We investigate the limitations that emerge in thermodynamic tasks as a result of having local control only over the components of a thermal machine. These limitations are particularly relevant for devices composed of interacting many-body systems. Specifically, we study protocols of work extraction that employ a many-body system as a working medium whose evolution can be driven by tuning the on-site Hamiltonian terms. This provides a restricted set of thermodynamic operations, giving rise to novel bounds for the performance of engines. Our findings show that those limitations in control render it in general impossible to reach Carnot efficiency; in its extreme ramification it can even forbid to reach a finite efficiency or finite work per particle. We focus on the 1D Ising model in the thermodynamic limit as a case study. We show that in the limit of strong interactions the ferromagnetic case becomes useless for work extraction, while the anti-ferromagnetic improves its performance with the strength of the couplings, reaching Carnot in the limit of arbitrary strong interactions. Our results pro-

vide a promising connection between the study of quantum control and thermodynamics and introduce a more realistic set of physical operations well suited to capture current experimental scenarios.

DY 8.7 Mon 16:30 ZEU 118

Driven open quantum systems and Floquet stroboscopic dynamics — •Sebastian Restrepo[1], Javier Cerrillo[1], Victor M. Bastidas[2], Dimitri Angelakis[2], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore

We provide an analytic solution to the problem of driven open quantum systems at the high-frequency limit that goes beyond the weak coupling and Markovian assumptions. It may be applied for the study of driven-dissipative many-body systems, since it solely relies on discrete symmetries of the system-bath Hamiltonian and provides the time evolution operator of the full Hilbert space, including bath degrees of freedom. This allows us to see both the effects of the driving on the coherent part of the dynamics and also on the environment (dissipation).

We propose an interpretation of the solution for the driven open system in terms of the stroboscopic evolution of a continuous family of observables under the influence of an effective static Hamiltonian. The interpretation constitutes a flexible simulation procedure of non-trivial static Hamiltonians. We instantiate the result with the study of the spin-boson model with time-dependent tunneling amplitude and provide observations of simulated polaron dynamics in the strong coupling limit.

15 min. break

DY 8.8 Mon 17:00 ZEU 118

Driven quantum baths — •Joscha Reichert[1,2], Peter Nalbach[3], Hermann Grabert[4,5], and Michael Thorwart[1,2] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Westfälische Hochschule, Münsterstraße 265, 46397 Bocholt, Germany — [4]Freiburg Institute for Advanced Studies (FRIAS), Universität Freiburg, Albertstr. 19, 79104 Freiburg, Germany — [5]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

The established theoretical framework of quantum dissipation usually neglects the interaction between a probing pulse and the surrounding environment of a central-quantum system to preserve equilibrium conditions. The introduction of a dipolar coupling to the environmental modes gives rise to an additional force-component on the system in question which can be quantified using a simple dielectric solvation model. An investigation for a THz-probed polarizable molecule in water and a quantum-dot metal-nanoparticle setup leads to enhancement and profound changes in the linear response of both systems [1]. A more detailed investigation of the spin-boson model within a master-equation framework and pulse-shaped bath-driving reveals the additional force to capture the non-equilibrium memory effects of the bath and depends on its underlying spectral characteristics [2].

[1] Phys. Chem. Lett. 7, 2015 (2016)
[2] Phys. Rev. A 94, 032127 (2016)

DY 8.9 Mon 17:15 ZEU 118

Jarzynski equality beyond thermal Gibbs states — •Daniel Schmidtke and Jochen Gemmer — Fachbereich Physik, Universität Osnabrück, Germany

The Jarzynski equality allows to derive equilibrium thermodynamical quantities just from irreversible (non-equilibrium) trajectories. It holds in both, the classical and the quantum context. Though settings and approaches indeed differ greatly, they all have in common that the initial state is some thermal Gibbs state. Up to now, no conclusive theory when considering other initial states is presented. Therefore, we numerically investigate work distributions in driven isolated systems, starting off from single energy eigenstates of the initial Hamiltonian. A finite size scaling might allow for statements on whether the Jarzynski equality must require Gibbs states, or other initial states at least will fulfill this relation to good accuracy. Moreover, we point out the close connection between fulfilling the Jarzynski equality and eigenstate thermalization hypothesis.

DY 8.10 Mon 17:30 ZEU 118

Manipulating decoherence and relexation by adding non-commuting noise — •Timo Palm[1,2] and Peter Nalbach[1] — [1]Westfälische Hocheschule ,Münsterstr. 265 , 46397 Bocholt — [2]I. Institut für Theoretische Physik Universität Hamburg Jungiusstraße 9 20355 Hamburg

In recent years the role of coherence in quantum systems has been a field of increasing interests, with applications reaching from quantum dots and quantum computers to solar cell efficiency and the possible use of such mechanisms in artificial light-harvesting complexes. Interaction of such quantum system with environments typically destroys coherence and yields relaxation, with larger coupling strengths to the environment resulting in faster relaxation/decoherence. We show that the relaxation rates can significantly be reduced by adding environmental fluctuations, which couple via non-commuting system bath operators. As a toy model the two level system is studied, its dynamics is simulated via an extended version of the quasi adiabatic path integral and a perturbative theory (RESPET).

DY 8.11 Mon 17:45 ZEU 118

Universality of entropy production in driven diffusions — •Simone Pigolotti, Izaak Neri, Édgar Roldán, and Frank Jülicher — Max-Planck Institute for the Physics of Complex Systems, Dresden, Germany

We study non-equilibrium properties of driven colloidal systems, ranging from simple one-dimensional periodic potentials to two-dimensional incompressible flows. We will show that some statistical properties of the entropy production, such as the distribution of local infima, are universal at steady state. We develop a general theory to account for these findings. We conclude with an example of a system maintained out of steady-state by a time-dependent driving which, surprisingly, shares the same universal properties.

DY 8.12 Mon 18:00 ZEU 118

Reducing the roughness in non-equilibrium surface growth by controlled temperature modulations — •Thomas Martynec and Sabine H.L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

The non-equilibrium crystal growth often leads to undesired rough interfaces which negatively affect the quality of devices. By controlled temperature modulations during the non-equilibrium growth it is possible to overcome this problem and obtain smoother structures. The idea is based on the concept of two mobilities [1] which is realized by using different temperatures T during the growth such that the nucleation length associated with second layer nucleation is changed. Using a low temperature T in the early stage of growth and increasing it during the growth leads to small islands and reduces the rate of second layer nucleation. The goal is to find optimal T-modulations by means of kinetic Monte-Carlo simulations such that coalescence of clusters sets in before it comes to nucleation in the layer above and the structure growths in a layer-by-layer fashion.

[1] G. Rosenfeld, B. Poelsema, G. Comsa, J. Cryst. Growth 151, 230-233 (1995)
[2] R. Kunkel, B. Poelsema, L. K. Verheij, G. Comsa, Phys. Rev. Lett. 65, 733 (1990)
[3] P. Šmilauer, M. R. Wilby, D. D. Vvedensky, Phys. Rev. B 47, 4119(R) (1993)
[4] S. Kowarik et al., unpublished.

DY 8.13 Mon 18:15 ZEU 118

The third law for finite non-equilibrium resources — •Henrik Wilming and Rodrigo Gallego — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

The third law in the form of the unattainability principle states that exact ground-state cooling requires infinite resources. Here we investigate the amount of resources needed for approximate cooling. We consider as resource any system out of equilibrium, allowing for resources beyond the i.i.d. assumption and including the input of work as a particular case. We establish sufficient conditions for cooling in full generality and show that for a vast class of non-equilibrium resources sufficient and necessary conditions for low-temperature cooling can be expressed in terms of a single function. This function plays a similar role for the third law to the one of the free energy for the second law. From a technical point of view we provide new results about concavity/convexity of certain Renyi-divergences, which might be of independent interest.

DY 8.14 Mon 18:30 ZEU 118

Fluctuation-dissipation relations far from equilibrium — •Bernhard Altaner, Matteo Polettini, and Massimiliano Esposito — Complex Systems and Statistical Mechanics, Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg

Near equilibrium, where all currents of a system vanish on average, the fluctuation-dissipation relation (FDR) connects a current's spontaneous fluctuations with its response to perturbations of the conjugate thermodynamic force. Out of equilibrium, fluctuation-response relations generally involve additional nondissipative contributions. Here, in the framework of stochastic thermodynamics, we show that an equilibrium-like FDR holds for internally equilibrated currents, if the perturbing conjugate force only affects the microscopic transitions that contribute to the current. We discuss the physical requirements for the validity of our result and apply it to nano-sized electronic devices.

Reference: Phys. Rev. Lett. 117, 180601

DY 8.15 Mon 18:45 ZEU 118

Solvent Coarsening around a Colloid upon Cooling — •Sutapa Roy[1], S Dietrich[1], and Ania Maciolek[2] — [1]Max-Planck-Institut für Intelligente Systeme, Heisenbergstr. 3, 70569 Stuttgart, Germany and IV. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute of Physical Chemistry, Polish Academy of Sciences, Kasprzaka 44/52, PL-01-224 Warsaw, Poland

We investigate temperature-gradient induced coarsening of a cooling binary solvent around a spherical colloidal particle, using numerical calculations and analytical theory. Our phenomenological model impersonates recent experiments in which, upon laser heating of a Janus colloid, the surrounding binary liquid mixture develops concentration gradient. Evidence of 'non-localized' coarsening is provided around a Janus colloid even if the colloid temperature is above the bulk demixing critical temperature of the solvent.

DY 8.16 Mon 19:00 ZEU 118

Depinning as a coagulation process — •Muhittin Mungan[1], Melih Iseri[1], and David Kaspar[2] — [1]Department of Physics,, Bogazici University, 34342 Istanbul, Turkey — [2]Division of Applied Mathematics, Brown University, Providence, RI 02912, USA

We consider a one-dimensional sandpile model which mimics an elastic string of particles driven through a strongly pinning periodic environment with phase disorder.

The evolution towards depinning occurs by the triggering of avalanches in regions of activity which are at first isolated but later grow and merge. For large system sizes the dynamically critical behavior is dominated by the coagulation of these active regions. The analysis and numerical simulations show that the evolution of the sizes of active regions is well-described by a Smoluchowski coagulation equation, allowing us to predict correlation lengths and avalanche sizes. Moreover, the coagulation process emerges as the macroscopic description of the evolution to depinning.

As our analysis shows, this connection is robust, i.e. it depends little on the details of the underlying microscopic model, providing an example for the emergence of universal features in disordered systems far from equilibrium.

DY 9: Soft Particles in Flows II (Focus session, joint DY, CPP)

Organized by S. Gekle, G. Gompper, C. Wagner

Time: Monday 15:00–18:00 Location: ZEU 160

Invited Talk DY 9.1 Mon 15:00 ZEU 160

Particle alignment in microchannels and microjets — •Stephan Foerster[1], Mathias Schlenk[1], Susanne Seibt[1], Martin Trebbin[3], Josef Breu[1], and Stephan Roth[2] — [1]University of Bayreuth, Bayreuth, Germany — [2]DESY, Hamburg, Germany — [3]University of Hamburg, Hamburg, Germany

The flow orientation of particles in microflows is of high relevance in many areas ranging from synthetic fiber production to streams of cells and proteins in blood capillaries. With current advances in device miniaturization in microfluidics, X-ray optics and high-resolution optical microscopy, it has become possible to study the flow orientation of anisometric colloids in-situ with unprecedented precision.

We investigated the flow orientation of Au-nanorods, wormlike polymer micelles and hectorite nanosheets in curved and tapered microchannels. We sursprisingly find that all anisometric particles align perpendicular to the flow orientation in the widening section of tapered microchannels. This is caused by strong extensional forces that reorient the particles. This phenomenon is even observed during the formation of microdroplets from microjets, resulting in biaxial orientations of particles in the free droplets. These findings have important consequences for the production of high performance fibers and the agglomeration of particles in blood capillary stenoses.

DY 9.2 Mon 15:30 ZEU 160

Intricate dynamics and morphology of red blood cells under physiological flow conditions — Johannes Mauer[1], Luca Lanotte[2], Simon Mendez[3], Viviana Claveria[2], Franck Nicoud[3], Manouk Abkarian[2], Gerhard Gompper[1], and •Dmitry A. Fedosov[1] — [1]Institute of Complex Systems, Forschungszentrum Juelich, 52425 Juelich, Germany — [2]Centre de Biochimie Structurale, CNRS UMR 5048, University of Montpellier, 34090 Montpellier, France — [3]Institut Montpellierain Alexander Grothendieck, UMR5149, University of Montpellier, 34095 Montpellier, France

Red blood cells (RBCs) constitute the major cellular part of blood. They have a biconcave shape with a membrane consisting of a lipid bilayer with an attached cytoskeleton formed by a network of the spectrin proteins. The RBC membrane encloses a viscous cytosol (hemoglobin solution), so that RBCs possess no bulk cytoskeleton and organelles. Despite this simple structure, RBCs exhibit fascinating behavior in flow showing complex deformation and dynamics. Current simplified understanding of RBC behavior in shear flow is that they tumble or roll at low shear rates and tank-tread at high shear rates. This view has been mainly formed by a number of experiments performed on RBCs dispersed in a viscous solution, which is several times more viscous than blood plasma. However, under physiological conditions with increasing shear rates, RBCs successively tumble, roll, deform into rolling stomatocytes, and finally adopt highly-deformed poly-lobed shapes. This behavior is governed by RBC elastic and viscous properties and it is important to consider it under relevant physiological conditions.

DY 9.3 Mon 15:45 ZEU 160

Red blood cells in high shear and strain rates: how numerical simulation can contribute — •Simon Mendez, Etienne Gibaud, and Franck Nicoud — IMAG, UMR CNRS 5149, University of Montpellier. 34095 Montpellier. France

Red blood cells (RBCs) constitute 99 percent of the formed elements present in blood. The dynamics of RBCs controls the complexity and the behavior of blood itself, as red blood cells constitute approximately 40 percent of the whole blood volume. The individual dynamics of a RBC is still a topic of research. This is particularly the case at high shear and strain rates, for which experimental data are scarce, due to the difficulty of visualizing the RBC dynamics in high-speed flows.

Although computing the RBCs dynamics in flows with high shear/strain rates is challenging, numerical simulation does not suffer from the same limitations as in vitro experiments of high-speed flows. This talk will illustrate how computations can be used in this context to gain new insight in the dynamics of red blood cells.

Two examples will be used: the behavior of RBCs at high shear rate in a low-viscosity fluid and the dynamics of RBCs during their counting and sizing in industrial blood analyzers, where strain dominates.

DY 9.4 Mon 16:00 ZEU 160

Structure and dynamics of colloidal short range repulsive interacting suspensions with weak attractive interactions. — Clara Weis and •Norbert Willenbacher — Karlsruhe Institute for Technology, Karlsruhe, Germany

The effect of weak attractive interactions on structure and dynamics of aqueous polymer dispersions is investigated using Multiple Particle

Tracking (MPT) and classical rotational rheology. This allowed us to correlate microstructure, structural heterogeneities and local particle mobility in fluid, fluid/crystalline, glassy and gel like samples with the corresponding macroscopic flow behavior. For volume fractions $\phi < 0.5$ good agreement between micro- and macro-viscosity was found. As weak attractive interactions were induced by adding non-adsorbing polymer, an enormous broadening of the fluid-crystalline co-existence regime was observed. MPT allowed for retrieving the phase composition, i.e. the fraction of the fluid and crystalline regions as well as the respective particle concentration, completely. In addition, the size of the crystals as well as their shear modulus could be determined. Further increasing attraction strength a gel state occurred and MPT disclosed a heterogeneous structure resembling a percolating network. At $\phi > \phi_{glass}$, the introduction of weak attractive interactions leads to a much broader fluid regime than predicted by MCT. At a given ϕ, stronger attractive interaction is required to form an attractive gel than for true hard sphere systems. MPT enables to study particle localization and structural heterogeneities on feasible, short time scales since a large number of dispersed particles are in the field of view.

DY 9.5 Mon 16:15 ZEU 160

An iterative solution algorithm for actively and passively swimming elastic capsules — •Horst-Holger Boltz[1,2] and Jan Kierfeld[2] — [1]Institut für nichtlineare Dynamik, Fakultät Physik, Georg-August-Universität Göttingen, Göttingen, Deutschland — [2]Fakultät Physik, Technische Universität Dortmund, Dortmund, Deutschland

Soft elastic capsules which are subject a viscous fluid flow undergo shape deformation coupled to their motion. We introduce an iterative solution scheme which couples hydrodynamic boundary integral methods and elastic shape equations to find the stationary axisymmetric shape and the velocity of an elastic capsule moving in a viscous fluid at low Reynolds numbers. We use this approach to systematically study dynamical shape transitions of capsules with Hookean stretching and bending energies and spherical rest shape sedimenting under the influence of gravity or centrifugal forces [Phys. Rev. E **92**: 033003 (2015)]. Additionally, we discuss the application to actively swimming ("squirming") capsules.

15 min. break

DY 9.6 Mon 16:45 ZEU 160

Shapes and interaction of microcapillary RBC flow — •Alexander Kihm[1], Achim Guckenberger[2], Stephan Gekle[2], and Christian Wagner[1] — [1]Saarland University, Saarbrücken, Germany — [2]Bayreuth University, Bayreuth, Germany

We try to establish the phase diagram of Red Blood Cells (RBC's) flowing through a capillary, i.e. characterize their shape and position as a function of capillary dimensions and imposed flow rate (pressure drop).

Therefore, we perform microfluidic experiments, either with a simple inverted brightfield microscope or with a recently developed 3-D confocal spinning disk technique. In most cases we find a migration of cells towards the center, but above a critical flow rate off-centered positions are observed as well. In addition, we classify the shapes of flowing cells, and as categories we distinguish between slippers, croissants and other (ambiguous) shapes. The experimental data is compared to predictions obtained from numerical simulations using a boundary-integral method.

DY 9.7 Mon 17:00 ZEU 160

Red blood cells dynamics in biomimetic submicron splenic slits — •Annie Viallat[1], Emmanuele Helfer[1], Anne Charrier[1], Priya Gambhire[1], Scott Atwell[1], Catherine Badens[2], and Cecile Iss[1] — [1]Aix Marseille Univ, CNRS CINAM, Marseille, France — [2]Aix Marseille Univ., INSERM, GMGF, Marseille, France

In drug delivery, cancer cell dissemination and red blood cells (RBCs) splenic filtration, nanoparticles and cells have to deform and pass through the submicron and high aspect ratio gaps between the endothelial cells lining blood vessels. The dynamics of passage of particles/cells remain poorly understood because costly technologies are required to reproduce gaps of physiological dimensions in devices suitable for in-vitro optical-microscopy observations. Here, novel microfluidic PDMS devices containing high aspect ratio slits with submicron width were molded on silicon masters by using a simple, inexpensive, and highly flexible combination of standard UV lithography and anisotropic wet etching. These devices revealed novel modes of deformations of healthy and sick RBCs squeezing through slits replicating splenic slits (0.8x2x5 microns) under physiological interstitial pressures. At the slit exit the cytoskeleton of spherocytic RBCs was spectacularly detached from the lipid membrane whereas RBC shapes from healthy donors and patients with sickle cell disease exhibited peculiar tips at their front. These tips disappeared much slower in patients cells, allowing to estimate a threefold increase in RBC cytoplasmic viscosity in sickle cell disease. Measurements of both time and rate of RBC sequestration in the slits allowed quantifying the massive spherocytic RBCs trapping.

DY 9.8 Mon 17:15 ZEU 160

Non-inertial lift and its application to label-free microfluidic cell separation and sorting — T M Geislinger[1,2], M Stamp[1], B Eggart[1], S Braunmüller[1], L Schmid[1], S Chan[2], M Koll[2], M Wahlgren[2], A Wixforth[1], and •T Franke[1,3] — [1]Experimental Physics I, University of Augsburg, 86159 Augsburg, Germany — [2]Department of Microbiology, Tumor and Cell Biology, Karolinska Institutet, Box 280, S-171 77 Stockholm, Sweden — [3]Chair of Biomedical Engineering, University of Glasgow, Oakfield Avenue, G12 8LT, Glasgow, Scotland

Reliable cell separation and sorting are important tasks in everyday's laboratory work and of increasing importance in various medical diagnoses. Widely used methods like fluorescence or magnetically activated cell sorting (FACS, MACS), however, require labelling of samples with adequate markers and/or the generation of external fields. Apart from the dimensions and the costs of such devices, any unwanted alterations of the cells by the markers potentially interfere with subsequent processes such as genetic analyses. Here, we present a simple and cheap microfluidic approach for continuous, passive and label-free cell sorting that relies on the exploitation of a hydrodynamic effect for separation: the non-inertial lift effect. The non-inertial lift effect is a repulsive cell-wall interaction of purely viscous origin that acts on non-spherical and deformable objects in laminar flow fields. Generally, the lateral drift becomes stronger for larger and more deformable objects. We examine this effect for separation of different cells including circulating tumor cells and malaria infected red blood cells.

DY 9.9 Mon 17:30 ZEU 160

Jammed capsules as a model system for soft glassy matter — •Othmane Aouane[1], Andrea Scagliarini[1], and Jens Harting[1,2] — [1]Forschungszentrum Jülich, Helmholtz Institute Erlangen-Nürnberg, Nürnberg, Germany — [2]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

Soft-glassy materials describe materials exhibiting a solid-like behavior at rest and local yielding when subject to a high enough stress. While systems like foams, emulsions[1], colloidal and polymer gels have been widely studied in the last decades; still a little is known about the flow behavior of deformable microgels. We investigate numerically the rheology of microgels formed by dense suspensions of capsules under mechanical stress in an athermal system. In a first step, the packing of capsules is done by increasing the size of the scaled deformable particles until reaching the desired size meanwhile the dynamical evolution of the system follows a molecular dynamics-like approach. After the initialization stage and the formation of the microgel structure, we use the lattice Boltzmann method to resolve the fluid motion and the immersed boundary method to couple between the finite element capsules and the fluid [2]. We investigate the existence or not of local yield points by varying the concentration of capsules from 60 to 90%. The effect of elasticity and mechanical forcing are also considered in our study.

[1] Benzi, R., *et al.* Europhysics Letters, 104.4 (2013): 48006

[2] Krüger, T., *et al.* Journal of Fluid Mechanics, 751 (2014): 725-745

DY 9.10 Mon 17:45 ZEU 160

Dynamics of microcapsules in elongational and shear flows — •Clement de Loubens[1], Kaili Xie[2], and Marc Leonetti[3] — [1]Laboratoire Rheologie et Procedes, Grenoble, France — [2]M2P2, Marseille, France — [3]IRPHE, Marseille, France

A capsule is a drop bounded by a thin solid membrane providing specific mechanical properties. The interfacial rheological properties of these soft microparticles are deduced from their dynamics of deformation in elongational and shear flows.

In elongational flow, the surface shear modulus of the membrane is measured and related to the kind of biopolymer used and to the main

parameters of the process of fabrication. In the regime of large deformations, the microcapsules can present a non-linear elastic response or plastic deformations. Non-linear elastic constitutive law is deduced by comparison of the evolution of the shape of the microcapsule in the two main planes of deformation of the capsule with numerical simulations.

In shear flow, the rotation of the membrane, i.e. the tank-treading, is visualised and quantified by decorating the membrane of microcapsules with particles. The tracking of the distance between two close microparticles showed membrane contraction at the tips and stretching on the sides. This dynamics of deformation induce viscous dissipation inside the membrane. The order of magnitude of membrane viscosity is determined by comparison with numerical simulations.

We will conclude the talk by some examples of breakdown of microcapsules in elongational flow.

DY 10: Cell Mechanics (Joint Session BP/DY)

Time: Monday 15:00–16:45 Location: SCH A251

Invited Talk DY 10.1 Mon 15:00 SCH A251

Quantifying and modelling active motion in biological systems — •Timo Betz — Institute of Cell Biology, ZMBE, University Münster, Germany

Living biological systems are continuously reorganizing their structure to perform their function. The mechanical activity plays here an important role, as the constant generation of forces drives fluctuations as well as controlled motion of intracellular particles, membranes and cells. From a physical point of view, this active motion drives the system far away from thermodynamic equilibrium, which can be measured as a violation of equilibrium quantities such as the fluctuation dissipation theorem.

Quantifying the out-of-equilibrium components provides the possibility to model the active molecular processes. We measure the energy and the forces actively applied on membranes as well as cellular granules and model these with an active Langevin approach. By comparing the predictions of forces and mechanics with the measurement of the fluctuations and viscoelastic properties we can extract molecular parameters from mesoscopic measurements. This gives timescales and chemical reaction parameters such as forces, binding states and velocities of the underlying proteins using a simple average measurement of the active motion.

DY 10.2 Mon 15:30 SCH A251

Feeling for Phenotype: Real-Time Deformability Cytometry for Label-Free Cell Functional Assays — •Oliver Otto[1,2,3], Philipp Rosendahl[1,3], Maik Herbig[1], Angela Jacobi[1,4], Martin Kräter[1,4], Nicole Töpfner[1], Marta Urbanska[1], Maria Winzi[1], Katarzyna Plak[1], Alexander Mietke[5], Christoph Herold[3], Daniel Klaue[3], Edwin Chilvers[6], Reinhard Berner[4], Martin Bornhäuser[4], and Jochen Guck[1] — [1]Technische Universität Dresden, Dresden, Germany — [2]Universität Greifswald, Greifswald, Germany — [3]Zellmechanik Dresden, Dresden, Germany — [4]Universitätsklinikum Dresden, Dresden, Germany — [5]Max-Planck-Institut für Molekulare Zellbiologie und Genetik, Dresden, Germany — [6]University of Cambridge, Cambridge, United Kingdom

By real-time deformability cytometry (RT-DC), we have introduced a high-throughput method for continuous mechanical single-cell classification of heterogeneous cell populations at rates of several hundred cells per second. Here, we demonstrate the extension of this method towards a multi-parameter biological assay where phenotyping is based on quantitative image analysis. Performing RT-DC on whole blood we highlight its potential to identify subsets in heterogeneous cell populations without any labelling and extensive sample preparation. We also demonstrate its capability to detect lineage-, source- and disease-specific mechanical phenotypes in primary human hematopoietic stem cells and mature blood cells. In summary, RT-DC enables marker-free, quantitative phenotyping of heterogeneous cell populations with a throughput comparable to standard flow cytometry.

DY 10.3 Mon 15:45 SCH A251

Light-driven intracellular flow perturbations to unravel transport processes in cells and developing embryos — •Matthäus Mittasch[1,4], Peter Gross[2], Michael Nestler[3], Mathias Munder[1], Axel Voigt[3,4], Simon Alberti[1], Stephan Grill[2,4], and Moritz Kreysing[1,4] — [1]MPI-CBG, Dresden — [2]Biotechnology Center, Technische Universität Dresden — [3]Department of Mathematics, TU Dresden — [4]Center for Systems Biology Dresden

Throughout the last decades, advances in molecular and cell biology have allowed for a precise control of molecular reactions inside cells. The complex interplay of molecular reactions with physical transport processes was suggested to control the spatiotemporal organization of cells and developing embryos. However, unravelling the function of physical transport during morphogenesis and cellular homeostasis remains a challenge due to the lack of suitable perturbation methods for in vivo systems. Here, we exploit thermoviscous pumping (Weinert & Braun) to perform light-driven intracellular flow perturbations. Thereby, we show the causal implications of intracellular flows during PAR polarization of the C. elegans zygote. Finite element simulations in 3D of the Stokes equation with time-dependent source terms recapitulated the experimental findings nearly identical. Furthermore, we utilize flow perturbations for active and probe-free micro-rheology measurements in yeast cells. Hence, we revealed a fluid-to-solid transition of the cytoplasm in energy-depleted cells. Light-driven intracellular flow perturbations lay the foundation to dissect the design principles of transport-dependent organization of living systems.

DY 10.4 Mon 16:00 SCH A251

Biophysics of neutrophil extracellular trap (NET) formation — •Daniel Meyer[1], Elsa Neubert[1,2], Anja Kwaczala-Tessmann[2], Susanne Senger-Sander[2], Michael P. Schön[2], Luise Erpenbeck[2], and Sebastian Kruss[1] — [1]Institute of Physical Chemistry, Göttingen University, Germany — [2]Dermatology, Venerology and Allergology, University Medical Center Göttingen, Germany

Neutrophils are the most abundant type of immune cells in the human blood system and central for immune defense. Recently, it was found that neutrophils and other cells are able to catch and kill pathogens by expelling a fibril network made from their own DNA (neutrophil extracellular traps, NETs). During this process (NETosis), a massive rearrangement of the materials inside the cell takes place which is still poorly understood. Our results show that NETosis can be divided into three distinct phases. The chromatin decondenses out of the disassembled nucleus until it fills the complete cell lumen. Simultaneously, the cytoskeleton decomposes and the cells become softer. In the final phase the cell body rounds up yet stays adherent to the surface, and the cytoplasmic membrane ruptures releasing the NET to the extracellular space. Using Atomic Force Microscopy (AFM) together with fluorescence microscopy methods, we demonstrate how the NETs-release is temporarily regulated by chromatin swelling, changes within the cytoskeletal components as well as the mechanical properties of the cell.

DY 10.5 Mon 16:15 SCH A251

Building up and force probing the microtubule cytoskeleton from scratch — •Matthias Koch[1,2] and Alexander Rohrbach[1] — [1]IMTEK, University of Freiburg, Germany — [2]Lewis-Sigler Institute, Princeton University, USA

Eukaryotic cells are exposed to and driven by a large variety of forces or mechanical stimuli on a brought range of times scales. Due to their mechanical rigidity, microtubules are able to transport such stimuli enabling instantaneous mechanical integration of distant regions of a cell. However, only equilibrium mechanical properties of single microtubules have been characterized so far. We fill this void by using an in vitro bottom-up approach to determine the frequency response of single microtubules and small networks thereof that mimic the basic cytoskeletal structure. We combine a new scanned darkfield imaging technique with multiple time-shared optical tweezers to flexibly construct and force probe such networks with a well-defined, user-selected geometry over a broad frequency range. We report on a length dependent stiffening of individual microtubules above a physiologically relevant transition frequency between 1-30Hz due to the excitation of higher order bending modes which displays a mechanical high-pass filter with a tunable cutoff frequency. Furthermore, we identify and relate different mechanical responses of different network geometries to different functions inside the cell. The mechanistic comparison of basic network geometries to the known cytoskeletal topologies and the

general function of different cell lines will substantially strengthen our understanding of the function and structure of the cytoskeleton.

DY 10.6 Mon 16:30 SCH A251

Theory for forces that slide k-fibers and bridging microtubules to move chromosomes — •Agneza Bosilj[1], Kruno Vukusic[2], Renata Buda[2], Ana Milas[2], Iva Tolic[2], and Nenad Pavin[1] — [1]Department of Physics, Faculty of Science, University of Zagreb, Bijenicka cesta 32, 10000 Zagreb, Croatia — [2]Division of Molecular Biology, Ruder Boskovic Institute, Bijenicka cesta 54, 10000 Zagreb, Croatia

During cell division forces on chromosomes are exerted by k-fibers, bundles of microtubules which extend from the opposite spindle poles and attach to chromosomes. Recently we have shown that in metaphase microtubules which extend between sister chromatids, termed bridging fibers, bridge sister k-fibers and balance the tension between sister chromatids [Kajtez et al, Nat Commun 2016]. However, a theoretical description of forces driving chromosome segregation in anaphase is still missing. Here we introduce a theoretical model which includes motor proteins that connect antiparallel microtubules, as well as passive cross-linkers that connect parallel microtubules. Our model shows that motor proteins generate forces that slide antiparallel bridging microtubules apart, thereby sliding sister k-fibers apart. This implies that forces at chromosomes are balanced by bridging fibers, which we confirmed experimentally by laser ablation of (i) k-fibers close to the spindle pole and (ii) bridging fibers. Our model also predicts that non-motor cross-linkers in regions of parallel overlap allow for movement of k-fibers and chromosomes together with the bridging fiber.

DY 11: Critical phenomena

Time: Monday 15:30–18:00 Location: HÜL 186

DY 11.1 Mon 15:30 HÜL 186

Temperatures are not useful to characterise bright-soliton experiments for ultra-cold atoms — •Christoph Weiss[1], Simon Gardiner[1], and Bettina Gertjerenken[2] — [1]Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, UK — [2]Department of Mathematics and Statistics, University of Massachusetts, Amherst, MA 01003-4515, USA

Contrary to many other translationally invariant one-dimensional models, the low-temperature phase for an attractively interacting one-dimensional Bose-gas (a quantum bright soliton) is stable against thermal fluctuations [1,2]. However, treating the thermal properties of quantum bright solitons within the canonical ensemble leads to anomalous fluctuations of the total energy that indicate that canonical and micro-canonical ensembles are not equivalent. State-of-the-art experiments are best described by the micro-canonical ensemble, within which we predict a co-existence between single atoms and solitons even in the thermodynamic limit - contrary to strong predictions based on both the Landau hypothesis and the canonical ensemble. This questions the use of temperatures to describe state-of-the-art bright soliton experiments that currently load Bose-Einstein condensates into quasi-one-dimensional wave guides without adding contact to a heat bath. [3]

[1] C. Weiss, arXiv:1610.09070

[2] C. Herzog, M. Olshanii, and Y. Castin, Comptes Rendus Physique 15, 285 (2014), arXiv:1311.3857.

[3] C. Weiss, S. A. Gardiner, B. Gertjerenken, arXiv:1610.09074

DY 11.2 Mon 15:45 HÜL 186

Testing conformal invariance in near-critical colloidal suspensions — •Hendrik Hobrecht and Fred Hucht — Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg

Both the critical Casimir interaction between two colloids immersed in a critical medium as well as the according interaction between two plates confining such a fluctuating medium are governed by the scaling functions known from conformal field theory. They are two special cases of a vast variety of possible geometries which are all connected via conformal mappings. However, near criticality conformal invariance no longer holds true and the geometry of the system has an effect on the form of the according scaling functions. Assuming that the geometric scaling variable from conformal field theory is nevertheless sufficient in the scaling regime of a near-critical system, we use the exact critical Casimir interaction scaling function of the Ising universality class in cylinder geometry with variable aspect ratio and open boundaries to expand the predictions to colloidal suspensions. Therefore we discuss which length scale is suitable for the temperature scaling variable and compare our results with Monte Carlo studies of two-dimensional systems of colloidal particles with according boundary conditions.

DY 11.3 Mon 16:00 HÜL 186

The square lattice Ising model on the rectangle — •Fred Hucht — Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg

The partition function of the square lattice Ising model on the rectangle is calculated exactly for arbitrary system size $L \times M$ and temperature. We start with the dimer method of Kasteleyn, McCoy & Wu, construct a highly symmetric block transfer matrix and derive a factorization of the involved determinant, effectively decomposing the free energy of the system into two parts, $F(L,M) = F_{\text{strip}}(L,M) + F^{\text{res}}_{\text{strip}}(L,M)$, where the residual part $F^{\text{res}}_{\text{strip}}(L,M)$ contains the nontrivial finite-L contributions for fixed M. It is given by the determinant of a $M/2 \times M/2$ matrix and can be mapped onto an effective spin model with M Ising spins and long-range interactions. While $F^{\text{res}}_{\text{strip}}(L,M)$ becomes exponentially small for large L/M or off-critical temperatures, it leads to important finite-size effects such as the critical Casimir force near criticality.

In the finite-size scaling limit, the involved expressions simplify and lead to the scaling functions of the Casimir potential and of the Casimir force. At criticality, a prediction from conformal field theory is confirmed.

Alfred Hucht, "The square lattice Ising model on the rectangle I: Finite systems", J Phys A: Math. Theo., 2016, arXiv:1609.01963, accepted

Alfred Hucht, "The square lattice Ising model on the rectangle II: Finite-size scaling limit", in preparation

DY 11.4 Mon 16:15 HÜL 186

Ensemble dependence of the critical Casimir force — •Markus Gross[1,2], Oleg Vasilyev[1,2], Andrea Gambassi[3], and Siegfried Dietrich[1,2] — [1]Max-Planck-Institut für Intelligente Systeme, Heisenbergstraße 3, 70569 Stuttgart, Germany — [2]IV. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]SISSA – International School for Advanced Studies and INFN, via Bonomea 265, 34136 Trieste, Italy

Confining a near-critical fluid leads to critical Casimir forces acting on the boundaries. Critical Casimir forces have been studied so far in the grand canonical ensemble, in which the confined fluid exchanges particles with the surroundings. However, the canonical ensemble, in which the total number of particles in the confined fluid is fixed, is also relevant in certain circumstances. It is well-known that these ensembles are not equivalent in finite systems. This carries over to the critical Casimir force, which behaves significantly different in the two cases: for instance, for so-called (++) boundary conditions, the canonical force is repulsive instead of attractive and it decays algebraically instead of exponentially upon increasing the temperature scaling variable in the supercritical regime [1]. While these features can be rationalized within mean field theory, additional differences emerge upon accounting for fluctuations. These latter aspects are discussed within a statistical field theory in the canonical ensemble.

[1] M. Gross, O. Vasilyev, A. Gambassi, S. Dietrich, Phys. Rev. E 94, 022103 (2016)

15 min. break

DY 11.5 Mon 16:45 HÜL 186

Dynamical crossovers in prethermal critical states — •Alessio Chiocchetta[1], Andrea Gambassi[2], Sebastian Diehl[1], and Jamir Marino[1] — [1]University of Cologne, Cologne, Germany — [2]International School for Advanced Studies, Trieste, Italy

We study the prethermal dynamics of an interacting field theory with a N-component order parameter and O(N) symmetry, suddenly

quenched in the vicinity of a dynamical critical point. Depending on the initial conditions, the evolution of the order parameter, as well as of response and correlation functions, can exhibit a temporal crossover between universal dynamical scaling regimes governed, respectively, by a quantum and a classical prethermal fixed point, as well as a crossover from Gaussian to prethermal dynamical scaling. Together with a recent experiment, this suggests that quenches can be used in order to explore the rich variety of dynamical critical points occurring in the non-equilibrium dynamics of a quantum many-body system. We illustrate this fact by using a combination of functional renormalization group techniques and a non-perturbative large-N limit.

DY 11.6 Mon 17:00 HÜL 186

Integer quantum Hall transitions in random Voronoi-Delaunay lattices — •Martin Puschmann[1,2], Philipp Cain[1], Michael Schreiber[1], and Thomas Vojta[2] — [1]Institute of Physics, Technische Universität Chemnitz, Chemnitz, Germany — [2]Department of Physics, Missouri University of Science and Technology, Rolla, Missouri, USA

The random Voronoi-Delaunay lattice (VDL) is a prototypical model for amorphous solids and foams. Bonds between randomly positioned sites are obtained by Delaunay triangulation. The resulting topologically disordered lattice features strong anticorrelations between the coordination numbers of neighboring sites. This modifies the Harris and Imry-Ma criteria and leads to qualitative changes of the scaling behavior at magnetic phase transitions [1]. We have recently shown that for non-interacting electrons on two-dimensional random VDLs all states are still localized and thus this correlated topological disorder is not sufficient to induce a phase transition [2]. Now, we investigate the behavior in presence of a magnetic field. Landau bands are formed by the field and hence phase transitions occur. Based on a recursive Green function approach and the multifractal analysis, we analyze the critical behavior of the lowest Landau level on random VDLs. [1] Barghathi el al., Phys. Rev. Lett. 113, 120602 (2014); [2] Puschmann et al., Eur. Phys. J. B 88, 314 (2015)

DY 11.7 Mon 17:15 HÜL 186

Understanding population Monte Carlo simulations — •Martin Weigel[1], Lev Yu. Barash[2,3], Lev N. Shchur[2,3,4], and Wolfhard Janke[5] — [1]Applied Mathematics Research Centre, Coventry University, Coventry, CV1 5FB, England — [2]Landau Institute for Theoretical Physics, 142432 Chernogolovka, Russia — [3]Science Center in Chenogolovka,142432 Chernogolovka, Russia — [4]National Research University Higher School of Economics, 101000 Moscow, Russia — [5]Institut für Theoretische Physik, Universität Leipzig, Postfach 100920 04009, Leipzig, Germany

Population annealing is a sequential Monte Carlo scheme that is potentially able to make use of highly parallel computational resources. Additionally, it promises to allow for the accelerated simulation of systems with complex free-energy landscapes, much alike to the much more well known replica-exchange or parallel tempering approach. The relative performance with respect to such more traditional techniques, the appropriate choice of population sizes temperature protocols and other parameters, the estimation of statistical and systematic errors and many other features, however, are essentially uncharted territory. Here, we use a systematic comparison of population annealing to Metropolis as well as parallel tempering simulations for the Ising model to gauge the potential of this new approach, and we suggest a range of heuristics for its application in more general circumstances.

DY 11.8 Mon 17:30 HÜL 186

Scaling theory of the Anderson transition in random graphs: ergodicity and universality — •Remy Dubertrand[1], Ignacio Garcia-Mata[2], Olivier Giraud[3], Bertrand Georgeot[4], John Martin[1], and Gabriel Lemarie[4] — [1]IPNAS CESAM Université de Liège, Liège, Belgium — [2]IFIMAR CONICET-UNMdP, Mar del Plata, Argentina — [3]LPTMS CNRS Université Paris-Sud, Orsay, France — [4]LPT IRSAMC Université de Toulouse CNRS, Toulouse, France

We study the Anderson transition on a generic model of random graphs with a tunable branching parameter $1 < K \leq 2$, through large scale numerical simulations and finite-size scaling analysis. This problem has attracted a renewed attractivity and is currently hotly debated [1,2,3].

We find that a single transition separates a localized phase from an unusual delocalized phase which is ergodic at large scales but strongly non-ergodic at smaller scales. The critical scalings and exponents are independent of the branching parameter, which strongly supports the universality of our results. During the talk I will describe the results presented in [4] and stress the unusual features of the Anderson transition we find on these random graphs.

[1] B. Altshuler et al., arXiv:1605.02295 (2016)
[2] K. Tikhonov et al., arXiv:1604.05353 (2016)
[3] D. Facoetti et al., arXiv:1607.05942 (2016)
[4] I. Garcia-Mata et al., arXiv:1609.05857 (2016)

DY 11.9 Mon 17:45 HÜL 186

Approximate ground states of the random-field Potts model from graph cuts and parallel tempering — Manoj Kumar[1], •Ravinder Kumar[2,3], Varsha Banerjee[4], Sanjay Puri[1], Martin Weigel[2], and Wolfhard Janke[3] — [1]School of Physical Sciences, Jawaharlal Nehru University,New Delhi-110067, India — [2]Applied Mathematics Research Centre, Coventry University, Coventry, UK. — [3]Institut für Theoretische Physik, Leipzig University, Leipzig, Germany. — [4]Department of Physics, Indian Institute of Technology, Hauz Khas, New Delhi - 110016, India.

While the ground-state problem for the random-field Ising model is polynomial, and can be solved using a number of well known algorithms for maximum flow, the analogue random-field Potts model corresponds to a multi-terminal flow problem that is known to be NP hard. Hence an efficient exact algorithm is extremely unlikely to exist. Still, it is possible to employ embedding of binary degrees of freedom into the Potts spins to use graph-cut methods to solve the corresponding ground-state problem approximately with polynomial methods. It is shown here that this works relatively well. We compare results produced by this heuristic algorithm to energy minima found by an appropriately tuned parallel tempering method that is configured to find ground states for the considered system sizes with high probability. The method based on graph cuts finds the same states in a fraction of the time. The new method is used for a first exploratory study of the random-field Potts model in two dimensions.

DY 12: Delay and Feedback Dynamics

Time: Monday 15:30–17:15 Location: ZEU 147

DY 12.1 Mon 15:30 ZEU 147

Delayed feedback control of localized states in a broad area vertical cavity surface emitting laser with saturable absorbtion — •Svetlana Gurevich[1], Christian Schelte[1], Mustapha Tlidi[2], and Krassimir Panajotov[3] — [1]University of Münster, Germany — [2]Université libre de Bruxelles, Belgium — [3]Vrije Universiteit Brussel, Belgium

We are interested in spatio-temporal dynamics of localized solitons in a transverse section of a broad area vertical cavity surface emitting laser (VCSEL) with saturable absorbtion subjected to time-delayed optical feedback. In the absence of delayed feedback, a single branch of localized solutions appears. However, in the presence of the feedback term, the branches of localized solutions fill the surface of the "solution tube" in the parameter space, which is filled densely with increasing delay time. Further, our study reveals that the multistability of stationary solutions is caused by a delayed-induced phase bifurcation. In addition, the thresholds of the drift and phase bifurcations as well as corresponding bifurcation diagrams are obtained using a combination of analytical and numerical continuation methods. It turns out that both thresholds tend to zero in the limit of large delay times. In addition, we demonstrate that the delayed feedback can induce Andronov-Hopf bifurcations and a period doubling route to chaos. A coupling between this bifurcation scenario with the delay-induced multistability leads to a complex spatio-temporal behavior of the system in question.

DY 12.2 Mon 15:45 ZEU 147

Lyapunov vectors of dynamical systems with time-varying delay — •David Müller, Andreas Otto, and Günter Radons —

Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

Time-delay systems arise in many fields such as life science, control theory, synchronization of networks, climate dynamics and engineering. Time-varying delays are introduced for example to take into account environmental fluctuations, for improving control and synchronization strategies and lead to interesting dynamical properties.

We have identified two classes of systems with time-varying delay, whereby the classification depends only on the functional structure of the delay. Systems with *conservative* delay are equivalent to systems with constant delay in the sense that they are connected by a timescale transformation under which dynamical quantities as the Lyapunov spectrum are invariant. Contrarily, systems with *dissipative* delay are not equivalent to systems with constant delay which leads to fundamental differences in the dynamics and characteristic dynamical quantities as the asymptotic scaling behavior of the Lyapunov spectrum.

In this talk we focus on the influence of the delay class on the characteristic properties of the covariant Lyapunov vectors.

DY 12.3 Mon 16:00 ZEU 147

Steering quantum feedback via a dielectric medium of resonant two-level systems — •Fabian Faulstich, Nicolas Naumann, Andreas Knorr, and Alexander Carmele — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Recently, feedback effects have become accessible in quantum optical few emitter systems [1, 2] and theoretical investigations of the feedback delay time have become necessary to reveal the underlying physics [3, 4]. To model quantum delayed feedback, a frequency dependent coupling element in the light-matter interaction is assumed. Here, we derive this light-coupling element by considering a dielectric of identical two-state atoms coupled by the radiation field to an atom outside the dielectric [5].

The Heisenberg equation yields a delay differential operator equation describing the interaction of the atom with the dielectric via photon exchanges. In the macroscopic limit of a continuous distribution of atoms in the dielectric, we derive a more compact delay differential operator equation in which a Fresnel reflection coefficient appears. These equations allow the simulation of the many-photon limit including additional dynamics within the dielectric.

[1] C. Hopfmann, New J. Phys., 15, 025030 (2013).
[2] F. Schulze, et al. Phys. Rev. A, 89.4 (2014): 041801.
[3] H. Pichler and P. Zoller, Phys. Rev. Lett., 116, 093601 (2016).
[4] A. Carmele et al., JOSA B 33.7 (2016): C10-C16.
[5] P. W. Milonni et al. Phys. Rev. A ,35.12 (1987): 5081.

DY 12.4 Mon 16:15 ZEU 147

Solution of delay differential equations via path integrals — •Andreas Otto, Nico Gehre, and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

In many dynamical systems in engineering and nature the effects of time delays are important. Such systems are described by delay differential equations. They can be found, for example, in models for the description of metal cutting vibrations, population growth, El Nino phenomenon and interaction in networks.

In this talk a new approach for the solution of delay differential equations is presented, which is related to the known path integral formulation for the solution of partial differential equations. It is shown how path integrals can be used for the construction of analytical solutions of autonomous as well as non-autonomous delay differential equations. The path integral method is applied to concrete examples and the results are compared with the solution obtained from existing analytical and numerical techniques.

DY 12.5 Mon 16:30 ZEU 147

Quantum-dot lasers with optical feedback: Autocorrelation function and rescaling properties — •David Schicke, André Röhm, Benjamin Lingnau, and Kathy Lüdge — Institut für Theoretische Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The dynamics of a semiconductor laser with feedback can be characterised by the autocorrelation function of the electric field. Experiments using quantum well lasers have shown that the qualitative dynamics do not change for different delay times and pump currents. By rescaling the system variables one can even achieve quantitative agreement [1]. Whether the same rescaling properties hold in quantum dot lasers with feedback is an open problem. We present numerical simulations for a quantum dot laser model as described in [2], extended by an extra delay term for the electric field describing feedback. The laser exhibits mostly stable behaviour for low delay times, i.e. several hundred picoseconds. Accordingly we concentrate on intermediate to long delay times (tens of nanoseconds), where chaotic dynamics can be observed and compared for different operating parameters.

[1] Porte, X., Soriano, M. C., Fischer, I., *Similarity properties in the dynamics of delayed-feedback semiconductor lasers*, Phys. Rev. A **89**, 023822 (2014).
[2] Lingnau, B., Chow, W. W., Lüdge, K., *Amplitude-phase coupling and chirp in quantum-dot lasers: influence of charge carrier scattering dynamics*, Opt. Express **22**, 4867-4879 (2014).

DY 12.6 Mon 16:45 ZEU 147

Quantum coherent time-delayed feedback in cavity and waveguide QED — •Manuel Kraft, Fabian Faulstich, Sven M. Hein, Andreas Knorr, and Alexander Carmele — Technische Universität Berlin, Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Hardenbergstr. 36, 10623 Berlin, Germany

Quantum coherent control schemes provide efficient methods to control open quantum systems [1]. In this talk we focus specifically on quantum coherent self-feedback [2] in a cavity and waveguide QED geometry, where time-delayed quantum signals are fed back directly into system dynamics. In the cQED case, we present how time-delayed quantum coherent self-feedback control can be used to tailor the squeezing spectrum of the output fields of an externally pumped cavity containing a second order nonlinear crystal [3]. Extending the study to a half open waveguide, we investigate the impact of time-delayed feedback on the atom and photon bound states. Thereby we employ a Greens function method [4] based on the Lippmann Schwinger equation to approach the N-photon non-markovian feedback case.

[1] Lloyd, Phys. Rev. A **62**, 022108 (2000)
[2] Carmele, *et al.* Phys. Rev. Lett. **110**, 013601 (2013)
[3] Kraft, *et al.* Phys. Rev. A **94**, 023806 (2016)
[4] Zheng, *et al.* Phys. Rev. Lett. **110**, 113601 (2013)

DY 12.7 Mon 17:00 ZEU 147

Approximating the non-Markovian dynamics of classical noisy systems with time-delay — •Sarah A. M. Loos and Sabine H. L. Klapp — Institut für Theoretische Physik, TU Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany

We investigate the probabilistic treatment of classical overdamped noisy systems with time-delayed forces (that depend on the system state at one earlier time $t-\tau$) in the steady state. Due to the non-Markovianity, there is no standard Fokker-Planck (FP) equation that corresponds to the delayed Langevin equation for such systems. On the contrary, the FP approach yields an infinite hierarchy of coupled differential equations [1].

We investigate approaches to truncate this hierarchy by approximating the two-time probability density. An according first-order perturbation-theoretical approach was developed by Frank [2], starting from the corresponding system without delay force. Here we present a novel approach, starting from the corresponding linearized delayed system. We discuss the application of both approaches to a 1D system consisting of a Brownian particle in a static periodic potential subject to a time-delayed feedback force. Comparing with results from numerical simulations, we demonstrate advantages of the novel approach compared to the perturbation theory.

[1] M. L. Rosinberg et al., Phys. Rev. E **91**, 042114 (2015).
[2] T. D. Frank, Phys. Rev. E **71**, 031106 (2005).

DY 13: Complex Systems

Time: Monday 17:30–18:30 Location: ZEU 147

DY 13.1 Mon 17:30 ZEU 147

Sufficient conditions for the existence of solutions for two phase flow in porous media — •Pradeep Kumar, Rouven Steinle, Tillmann Kleiner, and Rudolf Hilfer — Institute for Computational Physics, University of Stuttgart, Germany

In this talk, we consider a jump-type hysteresis model for two phase flow in porous media. It is shown that, after abstract formulation of the hysteresis model into a Cauchy problem on a Hilbert space $X = L^2(0,1)$, the solutions of the corresponding model are governed by an analytic semigroup defined on X.

[1] Steinle, R. and Hilfer, R.; Transp. Porous Media, (2016) (DOI 10.1007/s11242-015-0598-2)

[2] Hilfer, R. and Steinle, R.; Eur. Phy. J., 223, (2014)

[3] Pazy, A.; Semigroups of Linear Operators and Applications to Partial Differential Equations, Springer-Verlag, (1983)

DY 13.2 Mon 17:45 ZEU 147

Eigenvalue Outliers of Sparse non-Hermitian Random Matrices — •Izaak Neri[1,2] and Fernando Metz[3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany — [3]Universidade Federal de Santa Maria

Spectra of sparse non-Hermitian random matrices determine the dynamics of complex processes on graphs. Eigenvalue outliers in the spectrum are of particular interest, since they determine the stationary state and the stability of dynamical processes. We present a general and exact theory for the eigenvalue outliers of random matrices with a local tree structure. For adjacency and Laplacian matrices of oriented random graphs, we derive analytical expressions for the eigenvalue outliers, the first moments of the distribution of eigenvector elements associated with an outlier, the support of the spectral density, and the spectral gap. We show that these spectral observables obey universal expressions, which hold for a broad class of oriented random matrices.

DY 13.3 Mon 18:00 ZEU 147

An Equal Space: Data-driven Embedding of Complex Dynamics — •Felix Kemeth[1,2], Sindre W. Haugland[1,2], Yannis Kevrekidis[2,3], and Katharina Krischer[1] — [1]Physik-Department, Nonequilibrium Chemical Physics, Technische Universität München, James-Franck-Str. 1, D-85748 Garching, Germany — [2]Institute for Advanced Study - Technische Universität München, Lichtenbergstr. 2a, D-85748 Garching, Germany — [3]The Department of Chemical and Biological Engineering - Princeton University, Princeton, NJ 08544, USA

We present a way to embed nonlinear phenomena in a meaningful and low-dimensional space. In particular we apply diffusion maps, a nonlinear dimensionality reduction method, to extract useful axes from measurements or simulation data of different non-linear phenomena. Useful hereby refers to the degree of coarsening in which we want to observe our system, with this degree being specified by appropriately tuning the kernel scale in the diffusion maps approach. In addition, we demonstrate that these axes are, provided we have sufficient data, independent of the particular nature of the measurement entity. As illustrative examples, we apply our method on spatio-temporal chaotic dynamics apparent in the complex Ginzburg-Landau equation, on modulated traveling waves in the Kuramoto-Sivashinksy equation and on chimera states, states of coexisting coherence and incoherence. For the latter, we show that it is possible to extract insightful order parameters, allowing further understanding of these intricate dynamics.

DY 13.4 Mon 18:15 ZEU 147

Opinion Spreading in the Adaptive Voter Model by Zealots with Excess Degree — •Pascal Klamser[1,2], Marc Wiedermann[1,2], Jonathan Donges[2,3], and Reik Donner[2] — [1]Humboldt Universität, Berlin — [2]Potsdam Institut für Klimafolgenforschung, Potsdam — [3]Stockholm Universität, Stockholm

The (adaptive) voter model is widely studied as a benchmarking toy model for opinion formation processes on time evolving networks. Past studies on the effect of zealots only considered the voter model on a static network. Here, we extend the idea of zealotry to the case of a temporal network and investigate the opinion spreading by the zealots depending on their initial fraction and degree. Numerical simulations reveal that the spreading efficiency is strongly coupled with the fragmentation transition. An analytical representation of the model verifies the numerical findings. In order to avoid a dominance of the zealots opinion, voters must adjust their rate of rewiring as well as the number of connections with other voters, respectively.

DY 14: Microswimmers I (joint session DY/BP)

Time: Tuesday 9:30–13:00 Location: HÜL 186

Invited Talk DY 14.1 Tue 9:30 HÜL 186

Tactic Response of Synthetic Microswimmers in Gravitational and Optical Fields — •Clemens Bechinger — 2. Physikalisches Institut, Universität Stuttgart

Numerous motile organisms have developed intriguing steering mechanisms allowing them to orientate and navigate within gravitational, chemical or light fields. Such tactic response strongly promotes e.g., the search for food, reproduction and/or escape from unfavorable ambient conditions and is therefore an essential aspect of life. Unlike living systems, where tactic behavior is typically achieved by complex internal signal pathways, it is not obvious how this can be imposed on synthetic microswimmers which are distinguished by rather simple internal structures. Using light-activated self-propelled particles, we demonstrate that autonomous steering in gravitational fields and light gradients can be achieved without invoking a complex internal machinery but simply by the combination of viscous forces and torques which naturally arise during self-propulsion in liquids. These findings, which are confirmed by theory and simulations, make the use of artificial swimmers as micro-shuttles for targeted drug delivery to appear promising.

1. Lozano, Hagen, Löwen, Bechinger, Nat. Comm. 7, 12828 (2016).

2. Hagen, Kümmel, Wittkowski, Takagi, Löwen, Bechinger, Nat. Comm. 5, 4829 (2014).

DY 14.2 Tue 10:00 HÜL 186

Fission and fusion of microswimmer clusters — •Andreas Kaiser[1], Francisca Guzmán-Lastra[2], and Hartmut Löwen[2] — [1]Materials Science Division, Argonne National Laboratory, 9700 South Cass Ave, Argonne, Illinois 60439, USA — [2]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

Fission and fusion processes of particles clusters occur in many areas of physics and chemistry from subnuclear to astronomic length scales. Here we study fission and fusion of magnetic microswimmer clusters [1] as governed by their hydrodynamic and dipolar interactions. Rich scenarios are found which depend crucially on whether the swimmer is a pusher or a puller.

A linear magnetic chain of pullers is stable while a pusher chain shows a cascade of fission processes as the self-propulsion velocity is increased. Contrarily, magnetic ring clusters show fission for any type of swimmer. Moreover, we find a plethora of possible fusion scenarios if a single swimmer collides with a ringlike cluster and two rings spontaneously collide [2].

[1] A. Kaiser, K. Popowa, and H. Löwen, Phys. Rev. E 92, 012301 (2015)

[2] F. Guzmán-Lastra, A. Kaiser, and H. Löwen, Nature Commun. 7, 13519 (2016)

DY 14.3 Tue 10:15 HÜL 186

Optimal decision making in sperm chemotaxis — •Justus A. Kromer and Benjamin M. Friedrich — cfaed, TU Dresden

Sperm cells follow dilute chemical gradients to find the egg in a process

termed chemotaxis. To evaluate local concentrations of chemoattractant, sperm detect single attractant molecules, while moving along helical paths. This noisy chemical input signal regulates the flagellar beat to steer the cell up-gradient. Recent experiments showed that sperm cells can switch between two distinct steering modes in a situation-specific manner [1]. While swimming up-gradient, cells employ a mode of conservative steering, characterized by slow bending of the helical swimming path towards the direction of the concentration gradient. In contrast, if a cell accidentally swims down-gradient, it responds with a vigorous steering maneuver, characterized by fast helix bending.

Here, we present a theoretical description of this cellular decision making, formulated as a Markov decision process in the framework of a stochastic single-player game. We predict that decision making would provide no benefit in a hypothetical noise-free world, but substantially increases the chances to find the egg at physiological levels of sensing noise. Our work exemplifies the fundamental trade-off choice between responding accurately or responding fast for navigating cells.

[1] JF. Jikeli et al. Nature Communications **6**, 7985 (2015)

DY 14.4 Tue 10:30 HÜL 186

Lattice Boltzmann study of magnetocapillary microswimmers — •Alexander Sukhov[1], Qingguang Xie[2], and Jens Harting[1,2] — [1]Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Forschungszentrum Jülich GmbH, Fürther Straße 248, 90429 Nürnberg, Germany — [2]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, NL-5600MB Eindhoven, The Netherlands

Magnetocapillary swimmers - a system of three or more paramagnetic beads trapped at a fluid-gas interface - attracted recently considerable theoretical [1] and experimental attention [2]. Due to an interplay of attractive capillary and repulsive magnetic dipole-dipole interactions the swimmer can be stabilized. By applying a set of a static and a time-dependent magnetic field its position and the velocity direction can also be well manipulated. The last makes the swimmers potentially interesting for multiple applications ranging from a controlled cleaning of liquid interfaces to even a drug delivery or other medical applications *in vivo*.
Using a hybrid lattice Boltzmann and discrete element method we show a sharp dependence of the average speed of the swimmer on the frequency of the time-dependent magnetic field, demonstrate the control of the direction of the swimmer motion using B-fields and also analyze the obtained results analytically. [1] R. Chinomona, J. Lajeunesse, W.H. Mitchell, Y. Yao and S.E. Spagnolie, Soft Matter **11**, 1828 (2015). [2] G. Grosjean, G. Lagubeau, A. Darras, M. Hubert, G. Lumay and N. Vanderwalle, Sci. Rep. **5**, 16035 (2015).

DY 14.5 Tue 10:45 HÜL 186

Swimming *Bacillus subtilis* with different number of flagella — •Javad Najafi[1], Florian Altegoer[2], Thomas John[1], Gert Bange[2], and Christian Wagner[1] — [1]Experimental Physics, Saarland University, 66123 Saarbruecken, Germany — [2]LOEWE Center for Synthetic Microbiology (Synmikro), Philipps-University Marburg, Marburg, Germany

Microorganisms generally use so called flexible appendages known as flagella to swim in aqueous media. Different species have various flagellar number and while single flagellum is enough for swimming, it is not understood well why some bacteria synthesize several flagella. We statistically investigate the swimming of multi-flagellated bacteria by characterizing the influence of flagellar number of genetically manipulated strains of *Bacillus subtilis* on diverse swimming parameters. We find that while numerous flagella are not significantly advantageous in terms of propulsion speed, it slightly changes running time and angular quantities. In a homogeneous medium, the strain with more flagella has an increased rotational diffusion and turning angle after tumbling. Consequently, the cells with more flagella tend to turn in larger angles that causes smaller translational diffusion coefficient and localized motion. We use Langevin simulation based on experimental parameters which enables us to disentangle the effect of turning angle and rotational diffusion on translational diffusion.

DY 14.6 Tue 11:00 HÜL 186

Intermediate scattering function of an anisotropic circle swimmer — •Christina Kurzthaler and Thomas Franosch — Institut für theoretische Physik, Universität Innsbruck, Technikerstraße 21A, 6020 Innsbruck, Austria

A plethora of active agents ranging from biological microswimmers to artificially synthesized self-propelled particles exhibit peculiar dynamical behavior while moving in aqueous media at low Reynolds number. These active particles are intrinsically out of equilibrium and their transport properties are highly sensitive to their body shape, the symmetry of the propulsion mechansim, and also interactions with interfaces, which all have shown to induce a chiral swimming pattern. Here, we theoretically characterize the oscillatory dynamics of these Brownian circle swimmers in terms of the directly measurable intermediate scattering function (ISF), i.e. the characteristic function of the random displacements [1]. We identify different spatiotemporal regimes reflecting the bare translational diffusion at large wavenumbers, the persistent circular motion at intermediate wavenumbers and an enhanced effective diffusion at small wavenumbers. In particular, the circular motion of the particle manifests in characteristic oscillations of the ISF away from zero in contrast to oscillations around zero that can be traced back to the persistent swimming motion only. Furthermore, we obtain an exact expression for the non-Gaussian parameter, which displays oscillations at intermediate times mirroring the chiral swimming pattern of these active agents. [1] C. Kurzthaler, S. Leitmann, T. Franosch, Scientific Reports 6, 36702 (2016).

15min. break

Invited Talk DY 14.7 Tue 11:30 HÜL 186

Emergent structures in actuated magnetic and active colloidal suspensions — •Ignacio Pagonabarraga — University of Barcelona, Barcelona, Spain

Actuated and autocatalytic colloids constitute systems that are intrisically out of equilibrium. As a result fo their dynamic interactions, they can show a rich variety of self assembly scenarios. The observed self assembled structures make these systems very sensitive to external forcing, hence making actuated and active matter a fertile ground to explore and develop mechanically tunable materials.

I will analyze the basic physical mechanisms that control the collective behavior of two kinds of colloidal particles that move in a liquid medium. Confined magnetic colloids can rectify their motion when actuated with a rotating magnetic field, acting as a hydrodynamic conveyor belt. Self assembled chains of rotors propel faster than individual ones, reaching a saturation speed at distances where induced-flow additivity vanishes. The development of Janus colloids has opened the possibility to create synthetic microrobots that can move due to the chemical reacions they catalyze on their heterogeneous surfaces. The motion of chemically powered colloids is intricate because of the interplay between chemical and hydrodynamic interactions. These dynamic interactions have a strong impact in the collective behavior of these suspensions. I will describe the analogies and specificities in the hydrodynamic coupling that characterize these two types of systems.

DY 14.8 Tue 12:00 HÜL 186

Phase diagram of microswimmers in bulk — •Fabian Jan Schwarzendahl, Stephan Herminghaus, and Marco G. Mazza — Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen, Germany

The hydrodynamic flow field of microswimmers such as bacteria or algae can be classified into two categories: pushers and pullers. Bacteria like *E. coli* create a force dipole pushing the fluid away at their front and rear. On the other hand algae like *Chlamydomonas reinhartii* create a force dipole that pulls the fluid towards them at the front and rear. We study the bulk behaviour of both types using a combination of molecular dynamic (MD) and stochastic rotational dynamic (SRD) simulations. Here, we use a minimal model for the swimmers accounting for hydrodynamic (SRD) as well as steric (MD) interactions. We find a rich phase diagram showing clustering as well as nematic states.

DY 14.9 Tue 12:15 HÜL 186

Collective migration under hydrodynamic interactions - a computational approach — •Axel Voigt and Wieland Marth — Institut für Wissenschaftliches Rechnen, TU Dresden, Germany

Substrate-based cell motility is essential for fundamental biological processes, such as tissue growth, wound healing and immune response. Even if a comprehensive understanding of this motility mode remains elusive, progress has been achieved in its modeling using a whole cell physical model. The model takes into account the main mechanisms of cell motility - actin polymerization, substrate mediated adhesion and actin-myosin dynamics and combines it with steric cell-cell and hydrodynamic interactions. The model predicts the onset of collective cell

migration, which emerges spontaneously as a result of inelastic collisions of neighboring cells. Each cell here modeled as an active polar gel, is accomplished with two vortices if it moves. Open collision of two cells the two vortices which come close to each other annihilate. This leads to a rotation of the cells and together with the deformation and the reorientation of the actin laments in each cell induces alignment of these cells and leads to persistent translational collective migration. The effect for low Reynolds numbers is as strong as in the non-hydrodynamic model, but it decreases with increasing Reynolds number.

DY 14.10 Tue 12:30 HÜL 186

Swimming by buckling: low Reynolds number swimming by shape hysteresis — •Horst-Holger Boltz[1,2] and Jan Kierfeld[2] — [1]Institut für nichtlineare Dynamik, Fakultät Physik, Georg-August-Universität Göttingen, Göttingen, Deutschland — [2]Fakultät Physik, Technische Universität Dortmund, Dortmund, Deutschland

We present a low Reynolds number swimming concept based on an oscillatory change in a parameter controlling a hysteretic shape transition, which converts the time-reversible parameter changes into non-time-reversible shape changes leading to a net swimming motion. As realization of this general concept we propose and investigate the swimming locomotion of a spherical elastic capsule that undergoes repeated hysteretic buckling under a time-reversible periodic volume change. We show analytically and by numerical simulation based on the boundary integral method that the hysteretic switching gives rise to net locomotion at low Reynolds numbers. We characterize the swimming mechanism and its efficiency in dependence on the elastic properties capsule and derive the characteristic behaviour of the net swimming velocity.

DY 14.11 Tue 12:45 HÜL 186

A kinetic theory for dynamics of self-propelled magnetic suspensions — •Fabian Rouven Kössel and Sara Jabbari-Farouji — Johannes Gutenberg-Universität - Institut für Physik

Inspired by novel dynamical behaviour of magnetotactic bacteria, we present a minimal kinetic model for dilute suspensions of magnetic self-propelled particles. Our kinetic theory couples a Fokker-Planck equation of active particles in an external magnetic field to a Stokes-flow equation. Including the hydrodynamic stress contributions due to self-propulsion and magnetic torque in the Stokes flow we investigate the interplay between internal and external drives on the dynamics and effective viscosity of active suspensions. Through the linear stability analysis and full numerical simulations of our model, we examine the role of the external magnetic field on stability of aligned suspensions and their complex flow patterns.

DY 15: Quantum Dynamics, Decoherence, Quantum Information

Time: Tuesday 9:30–13:15 Location: ZEU 160

DY 15.1 Tue 9:30 ZEU 160

Application of a Discrete Bessel Transform on Wave Packet Dynamics in Jacobian Coordinates — •Jan-Erik Oest and Thorsten Klüner — Institute of Chemistry, Carl von Ossietzky University Oldenburg, 26111 Oldenburg, Germany

Accurate and efficient high-dimensional wave packet dynamics is a goal that has yet to be reached, since this approach is crucial for understanding quantum mechanical phenomena and receiving state resolved expectation values. In spherical coordinates the radial part poses a difficult challenge albeit its superiority to alternative cartesian coordinates with respect to memory requirements due to reduced dimensionality in a restricted coordinate space. In the present work, we try to use the fact that Bessel functions of the first kind are radial eigenfunctions of the Laplacian as a means to construct a basis for expanding the wave function, which allows for an elegant and efficient transformation of the radial coordinate between position- and momentum-space in a Jacobian coordinate system.

This method has been implemented into our current code DYN7D, which allows for an efficient treatment of seven-dimensional quantum dynamics on surfaces, and a comparison of the performance and accuracy of this approach to conventional FFT-methods has been made. The system of particular interest is water on TiO_2 and its photocatalytic activity considering its potential for the generation of solar fuels.

DY 15.2 Tue 9:45 ZEU 160

Dissipative Floquet dynamics of a laser-driven quantum optical system — •Daniel Pagel, Andreas Alvermann, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

A laser-driven quantum system is described by a Hamiltonian with a periodic time-dependence. In order to compute the dynamics of such a system, the simultaneous consideration of this periodicity and also of the coupling to environmental degrees of freedom is necessary. Then, the description is based on a Markovian master equation with time-dependent coefficients. To obtain a simpler differential equation with constant coefficients, the Floquet states have to be chosen as the computational basis. This procedure will be demonstrated in this talk for the example of few emitters strongly coupled to a cavity mode and driven by an external laser. As an evidence for the dynamic Stark effect, shifted peaks are observed in the emission spectra for different laser intensities. Analyzing the emission of nonclassical light with the Glauber function, we explain the additional features appearing for finite laser intensity in terms of the quasienergy spectrum of the driven emitter-cavity system. Finally, we study the generation of entanglement among two emitters, and show that the laser-excitation leads to a decrease of entanglement.

DY 15.3 Tue 10:00 ZEU 160

Reservoir engineering using Rydberg atoms — •David W. Schönleber, Christopher D. B. Bentley, and Alexander Eisfeld — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden

We apply reservoir engineering to construct a thermal environment with controllable temperature in an ultracold atomic Rydberg system [1]. A Boltzmann distribution of the system's eigenstates is produced by optically driving a small environment of ultracold atoms, which is coupled to a photonic continuum through spontaneous emission. This technique provides a useful tool for quantum simulation of both equilibrium dynamics and dynamics coupled to a thermal environment. Additionally, we demonstrate that pure eigenstates, such as Bell states, can be prepared in the Rydberg atomic system using this method.

[1] D. W. Schönleber et al., arXiv:1611.02914 (2016)

DY 15.4 Tue 10:15 ZEU 160

Stroboscopic simulation of environmental dynamics: driven systems and full counting statistics — •Javier Cerrillo and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Modern non-equilibrium transport experiments provide full-counting statistics of environmental observables. We show that the effect of fast periodic driving on an open quantum system can be exploited to obtain additional environmental statistics corresponding to effective static Hamiltonians. The combination of both strategies facilitates investigation of a large portion of the environmental degrees of freedom in such form that dynamical correlations between the system and the environment can be probed. In the case of the strong-coupling, non-Markovian spin-boson model, evidence of polaron dynamics can be directly derived from the population inversion of the spin, and its role in energy transport between two baths can thus be explored. In particular, it can be put in terms of transient deviations from fluctuation-dissipation theorems associated to non-linear transport coefficients.

DY 15.5 Tue 10:30 ZEU 160

Long-lived resonances at mirrors — •Friedemann Queisser[1] and William Unruh[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße, Duisburg 47048, Germany — [2]Department of Physics, University of British Columbia, Vancouver, V6T 1Z1 Canada

Motivated by realistic scattering processes of composite systems, we study the dynamics of a two-particle bound system which is scattered at a mirror [1]. We consider two different scenarios: In the first case we assume that only one particle interacts directly with the mirror whereas in the second case both particles are scattered. The coherence between the transmitted and the reflected wave-packet is reduced

when the internal degree of freedom (the relative coordinate) of the bound system becomes excited. If both particles interact with the mirror, it is possible that the composite system is trapped at the mirror for a finite time. These long-lived resonances occur although the interaction of the bound system with the mirror is purely repulsive.

The findings should be of relevance for the state preparation of mesoscopic objects and for double-slit experiments with composite systems.

[1] F. Queisser and W. G. Unruh, arXiv:1503.08814

DY 15.6 Tue 10:45 ZEU 160

A control theory approach to the Schrödinger equation — •Jeanette Köppe[1], Wolfgang Paul[1], and Wilfried Grecksch[2] — [1]Institut für Physik, MLU Halle-Wittenberg, Germany — [2]Institut für Mathematik, MLU Halle-Wittenberg, Germany

Non-relativistic quantum systems are analyzed theoretically or by numerical approaches using the Schrödinger equation. Compared to the options available to treat classical mechanical systems this is limited, both in methods and in scope. However, based on Nelson's stochastic mechanics, the mathematical structure of quantum mechanics has in some aspects been developed into a form analogous to classical analytical mechanics.

We show that finding the Nash equilibrium for a stochastic optimal control problem, which is the quantum equivalent to Hamilton's principle of least action, allows to derive two things: i) the Schrödinger equation as the Hamilton- Jacobi-Bellman equation of this optimal control problem and ii) a set of quantum dynamical equations which are the generalization of Hamilton's equations of motion to the quantum world. We derive their general form for the non-stationary and the stationary case and establish a numerical procedure to solve for the ground state properties without using the Schrödinger equation. Using this method, systems without an exact known wave function, e.g. one-dimensional double-well potential, can be analyzed and an approximation to the wave function can be found.

DY 15.7 Tue 11:00 ZEU 160

Disentangling Fubini-Study geodesics in bipartite Hilbert spaces — •Kristof Harms and Stefan Kehrein — Institut für Theoretische Physik, Göttingen, Germany

In classical statistics, the Fisher information metric gives rise to a notion of distance between probability distributions which is proportional to relative entropy on an infinitesimal scale. This notion is carried over to pure quantum states, where squared probability amplitudes with respect to an observable replace classical probabilities, by the Fubini-Study metric. We study the shape of geodesics with respect to this metric between arbitrary states in pure state spaces. In particular, we show that the geodesic from an entangled state to its closest separable state in a bipartite Hilbert space entirely remains in a subspace determined by its Schmidt decomposition, where the length of the geodesic depends only on the greatest Schmidt coefficient.

15 min break

DY 15.8 Tue 11:30 ZEU 160

Driven open quantum systems and Floquet stroboscopic dynamics — •Sebastian Restrepo[1], Javier Cerrillo[1], Victor M. Bastidas[2], Dimitri Angelakis[2], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore

We provide an analytic solution to the problem of driven open quantum systems at the high-frequency limit that goes beyond the weak coupling and Markovian assumptions. It may be applied to a large class of driven-dissipative many-body systems, since it solely relies on discrete symmetries of the system-bath Hamiltonian and provides the time evolution operator of the full Hilbert space, including bath degrees of freedom. This facilitates exploration of the effects of the driving both on the coherent part of the dynamics and also on the environment (dissipation). Due to the possibility to address strong-coupling and non-Markovian regimes, the latter may involve largely unexplored, highly complex effects. They may be interpreted in terms of the stroboscopic evolution of a continuous family of observables under the influence of an effective static Hamiltonian, which can in turn be regarded as a flexible simulation procedure of non-trivial static Hamiltonians. We instantiate the result with the study of the spin-boson model with time-dependent tunneling amplitude and provide observations of simulated polaron dynamics in the strong coupling limit.

DY 15.9 Tue 11:45 ZEU 160

An operational derivation of Jaynes' Principle — •Paul Boes, Rodrigo Gallego, Henrik Wilming, and Jens Eisert — Dahlem Center for Complex Quantum systems, Freie Universität Berlin

Jaynes principle states that a system should be assigned that state which has the largest entropy of those that are compatible with the available knowledge. Jaynes himself argued for the principle based on information theoretic least bias considerations.

Here, we prove an operational version of Jaynes' Principle: We show that there exists an equivalence relation between resource theories whose states are "macroscopic", based on partial information about a system's state, and resource theories whose states are just the corresponding maximum entropy states, in the sense that state transitions in one theory are possible iff they are possible in the other.

This equivalence arguably provides a better-suited operational justification for the application of Jaynes' Principles in a discipline like quantum thermodynamics than Jaynes' own argument.

DY 15.10 Tue 12:00 ZEU 160

High-Fidelity Hot Gates for Generic Spin-Resonator Systems — •Martin J. A. Schuetz[1], Geza Giedke[2,3], Lieven M. K. Vandersypen[4], and Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastián, Spain — [3]Ikerbasque Foundation for Science, Maria Diaz de Haro 3, E-48013 Bilbao, Spain — [4]Kavli Institute of NanoScience, TU Delft, P.O. Box 5046, 2600 GA Delft, The Netherlands

We propose and analyze a high-fidelity hot gate for generic spin-resonator systems which allows for coherent spin-spin coupling, in the presence of a thermally populated resonator mode. Our scheme is non-perturbative in the spin-resonator coupling strength, applies to a broad class of physical systems, including for example spins coupled to circuit-QED and surface acoustic wave resonators as well as nanomechanical oscillators, and can be implemented readily with state-of-the-art experimental setups. We provide and numerically verify simple expressions for the fidelity of creating maximally entangled states under realistic conditions.

DY 15.11 Tue 12:15 ZEU 160

Quantum simulation with acoustic lattices — •Johannes Knörzer[1], Martin Schuetz[1,2], Eric Kessler[2], Geza Giedke[1,3], Lieven Vandersypen[4], Mikhail Lukin[2] und Juan Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Deutschland — [2]Harvard University, Cambridge, USA — [3]DIPC, San Sebastian, Spanien — [4]TU Delft, Delft, Niederlande

We propose and analyze a solid-state platform for quantum simulation based on high-frequency surface acoustic waves (SAWs). We develop a general theoretical framework demonstrating the emergence of an effective time-independent acoustic lattice for charge carriers in two-dimensional quantum wells and one-dimensional wires; with lattice parameters that are reconfigurable in real time. We discuss potential experimental platforms for a faithful implementation of such an acoustic lattice, and provide estimates for typical system parameters. With a projected lattice spacing on the scale of 100nm, this approach allows for relatively large energy scales in the realization of the fermionic Hubbard model, with the ultimate goal to enter regimes where the antiferromagnetic spin-spin interaction strength exceeds cryostatic temperatures. Implementation and read-out schemes are discussed.

DY 15.12 Tue 12:30 ZEU 160

Understanding errors in digital quantum simulation of fermionic systems — •Jan-Michael Reiner, Sebastian Zanker, Iris Schwenk, Juha Leppäkangas, and Michael Marthaler — Institut für Theoretische Festörperphysik, Karlsruhe Institute of Technology (KIT)

The simulation of complex fermionic systems is one of the most anticipated applications of quantum computing. Various properties of such systems can be described by time-dependent correlation functions of two fermionic operators. Fermions can be mapped onto qubits, e.g., via the Jordan-Wigner transformation. We discuss how (anti-)time sorted correlation functions can be measured in the qubit system. Deploying Keldish formalism, we investigate the effects of relaxation, and dephasing of the qubits, as well as gate errors in an quantum algorithm using the Trotter expansion. We analyze how this translates to a simulated fermionic system, allowing for qualitative understanding of errors of a

quantum simulation.

DY 15.13 Tue 12:45 ZEU 160

Untersuchung der Stabilität von Quantendynamiken — •Lars Knipschild und Jochen Gemmer — Universität Osnabrück, Deutschland

Viele Prozesse im Bereich der linearen Nichtgleichgewichtsthermodynamik können in Form von Mastergleichungen oder Fokker-Plank-Gleichungen formuliert werden. Beispiele sind neben zahlreichen alltäglichen Prozessen auch Ausgleichsprozesse der Magnetisierung oder der Energie in abgeschlossenen Spinsystemen mittlerer Größe (16-32 Spins). Um zu untersuchen, wieso diese Art der Beschreibung auch in abgeschlossenen Quantensystemen häufig gute Resultate liefert, werden verschiedene Testsysteme (Hamiltonians) so generiert, dass der Erwartungswert einer Observablen dem Verlauf ausgewählter Referenzdynamiken entspricht. Unter diesen befinden sich Dynamiken, die nicht durch einen stochastischen Prozess beschreibbar sind. Es wird untersucht, wie sich zufällige Störungen auf die verschiedenen Dynamiken auswirken und ob sich qualitative Unterschiede in der Stabilität der Testsysteme zeigen.

DY 15.14 Tue 13:00 ZEU 160

Topological pumping of photons in nonlinear resonator arrays — Jirawat Tangpanitanon[1], •Victor Manuel Bastidas[1], Sarah Al-Assam[2], Pedram Roushan[3], Dieter Jaksch[2,1], and Dimitris G. Angelakis[1,4] — [1]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543 — [2]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom — [3]Google Inc., Santa Barbara, California 93117, USA — [4]School of Electrical and Computer Engineering, Technical University of Crete, Chania, Crete, Greece, 73100

We show how to implement topological or Thouless pumping of interacting photons in one dimensional nonlinear resonator arrays, by simply modulating the frequency of the resonators periodically in space and time[1]. The interplay between interactions and the adiabatic modulations enables robust transport of Fock states with few photons per site. We analyze the transport mechanism via an effective analytic model and study its topological properties and its protection to noise. We conclude by a detailed study of an implementation with existing circuit QED architectures.

[1] J. Tangpanitanon, V. M. Bastidas, S. Al-Assam, P. Roushan, D. Jaksch, and D. G. Angelakis, Phys. Rev. Lett **117**, 213603 (2016)

DY 16: Focus: Fundamental aspects of turbulent convection

Thermal convection, i.e. a flow driven by a thermal gradient, is frequently encountered in nature and technological applications. It is a fundamental mechanism to effectively transport heat. Convection flows in nature are usually highly turbulent and as such challenging to measure experimentally, simulate numerically, and model theoretically. In this session we discuss current developments and open questions from different branches of turbulent convection research. Experimentalists, theoreticians and, numericists will come together in order to discuss recent results covering the range from large-scale geo- and astrophysical systems down to laboratory size model systems.

Organized by M. Wilczek, S. Weiss and J. Schumacher

Time: Tuesday 9:30–13:15 Location: ZEU 118

Invited Talk DY 16.1 Tue 9:30 ZEU 118

The Geostrophic Branch of Rotating Convection — •Stephan Stellmach[1], Meredith Plumley[2], Keith Julien[2], and Philippe Marti[2] — [1]Institut für Geophysik, Westfälische Wilhelms-Universität, Münster, Germany — [2]Department of Applied Mathematics, University of Colorado, Boulder, USA

Rotating convective flows are ubiquitous in nature. They generate planetary magnetic fields, cause deep mixing in the Mediterranean Sea and possibly drive the zonal winds observed on Jupiter. Unfortunately, laboratory experiments and direct numerical simulations (DNS) fail to reach a dynamical regime in which the convection is strongly turbulent but still dominated by Coriolis forces on all scales of interest. This so-called geostrophic branch of rotating convection is thought to be relevant in many natural systems. A possible way to explore this regime are simulations based on asymptotically reduced model equations that are expected to hold in the limit of rapid rotation. In this talk, I will discuss the predictive power of these models in detail, with a particular focus on the role of boundary layers, inverse energy cascades and the possibility to numerically simulate flows in parameter regimes beyond what can be reached in laboratory experiments and direct numerical simulations today.

DY 16.2 Tue 10:00 ZEU 118

Turbulent convection in planetary interiors — •Ulrich Hansen and Claudia Stein — Institut für Geophysik, Unii Münster, Correnstrasse 24, 48149 MuensterGermany

The dynamics of planetary mantles is largely governed by convection. The Earth's mantle for example, extends from 100 km to about 3000 km depth and consists mostly of silicate rocks. Phenomena like plate tectonics and hot-spot volcanism are intimately coupled to processes within the boundary layers of the convective system. Due to the high viscosity of the material, mantle convection is characterized by a virtually infinite Prandtl number, i.e. mechanical inertia is unimportant for the flow. At the same time the Rayleigh number is high (Ra $>$ 107) , such that thermal advection dominates by far the transport of heat. Under such conditions numerical experiments reveal typical features of turbulent convection. For constant material properties a large scale flow (l.s.c) typically evolves, stipulated with instabilities of smaller scales. These instabilities develop within the thermal boundary layer of the l.s.c. and their interaction with the large scale wind give rise to chaotic fluctuations. In particular, we observe reversals of the l..s.c. without any external triggering Since the experiments are performed under stress free conditions, also counter-flows can be excluded to trigger the reversals. In planetary interiors non-Boussinesq effects complicate the dynamics, especially the strong dependence of the viscosity on temperature.At large viscosity contrasts a viscous lid self consistently develops, which overlies a region of turbulent convection.

DY 16.3 Tue 10:15 ZEU 118

Stellar convection models with Kramers-type opacity law — •Petri Käpylä — Leibniz-Institut für Astrophysik, Potsdam, Germany — ReSoLVE Centre of Excellence, Department of Computer Science, Aalto University, Finland

We present first results from three-dimensional hydrodynamic simulations of stratified convection in a slab geometry applying a Kramers-type opacity law. We show that in such models the depth of the convection zone is not a priori fixed as the opacity law is sensitive to temperature and density. This is in contrast to the overwhelming majority of models presented in the literature where either a fixed profile of the heat conductivity or the boundary conditions dictate the depth of the convective layer.

Furthermore, we also show that a substantial portion of the mixed layer is stably stratified according to the Schwarzschild criterion. In particular, we find an extended layer where both the enthalpy flux and the vertical gradient of specific entropy are positive which cannot be explained by the usual counter-gradient parametrization. Such weakly sub-adiabatic layers are also potentially crucial for solving some of the current issues in stellar differential rotation and dynamo modeling.

DY 16.4 Tue 10:30 ZEU 118

The effect of a horizontal magnetic field on weakly turbulent Rayleigh-Benard convection — Vogt Tobias[1], Ishimi Wataru[2],

Tasaka Yuji[2], Yanagisawa Takatoshi[3], and •Eckert Sven[1] — [1]Helmholtz Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [2]Laboratory for Flow Control, Hokkaido University, Sapporo, Japan — [3]Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan

MHD Rayleigh-Bénard convection was studied experimentally using the eutectic metal alloy GaInSn inside a box having a square horizontal cross section and an aspect ratio of length/height = 5/1. Systematic flow measurements were performed by means of ultrasound Doppler velocimetry that can capture time variations of instantaneous velocity profiles. Applying a horizontal magnetic field organizes the convective motion into a flow pattern of quasi-two dimensional rolls arranged parallel to the magnetic field. If the Rayleigh number (Ra) is increased over a certain threshold Ra/Q, whereby Q is the Chandrasekhar number, the convection flow undergoes a transition to turbulence. Besides the primary convection rolls the flow measurements reveal regular flow oscillations arising from 2D and 3D deformations of the rolls, Ekman-pumping induced flow as well as smaller side vortices that develop around the convection rolls. The experiments are accompanied by direct numerical simulations. The comparison between the DNS and the flow measurements shows a very good agreement.

DY 16.5 Tue 10:45 ZEU 118

Numerical studies of turbulent convection in liquid mercury and sodium — •Jörg Schumacher[1] and Janet D. Scheel[2] — [1]TU Ilmenau, Germany — [2]Occidental College Los Angeles, USA

Statistical properties of turbulent Rayleigh-Bénard convection at low Prandtl numbers Pr, which are typical for liquid metals such as mercury or gallium at Pr=0.021 and liquid sodium at Pr=0.005, are investigated in high-resolution, three-dimensional and massively parallel spectral element simulations in a closed cylindrical cell with an aspect ratio of one. These results are compared to previous turbulent convection simulations in air. In detail, we compare the scaling of global momentum and heat transfer with existing experiments or other simulations. Low-Prandtl-number flows are characterized by a significantly enhanced momentum transfer compared to convection in air. Thus we also investigate the dynamics of near-wall structures in the transient velocity boundary layers of this class of convection flows and their connection to critical points of the skin friction field. These findings are related to turbulent boundary layers in channel flows without temperature differences.

DY 16.6 Tue 11:00 ZEU 118

Turbulent heat transport in low-Pr number fluids — •Lukas Zwirner and Olga Shishkina — MPI Dynamik und Selbstorganisation, Göttingen

Turbulent convective heat transport is ubiquitous in nature. Rayleigh-Benard convection (RBC), where a fluid layer is confined between a lower heated plate and an upper cooled plate, is a classical model system to investigate turbulent convective heat transport. With any tilt of a RBC cell against gravity, the global flow structure in the convection cell changes, which leads to a change of the heat transport.

The purpose of the present work is to investigate by means of direct numerical simulations how heat and momentum transport, represented, respectively, by the Nusselt number and Reynolds number, depend on the main input parameters of the convective system. Those are the Rayleigh number Ra, Prandtl number Pr and the inclination angle of the convection cell. Thereby, the focus is set on convective flows in cylindrical containers of a small diameter-to-height aspect ratio Γ, $\Gamma = 1/5$, and $Pr \leq 1$. For each studied combination of Ra, Pr and Γ, an optimal inclination angle of the convection cell, providing maximal heat flux is determined. Furthermore, for the particular case of RBC (with zero inclination angle of the cell), different possible (e.g. single- or double-roll) states of the large scale circulation are studied in detail, including their influence on global heat transport in the system.

15 min. break

Invited Talk DY 16.7 Tue 11:30 ZEU 118

Convection rolls and fingers in double diffusive convection — •Andreas Tilgner — Institute of Geophysics, Göttingen

Double diffusive convection with a stabilizing temperature and a destabilizing salt gradient occurs in large areas in the oceans. Convection is possible even if the net density stratification is stable owing to the very different diffusivities of heat and salt. The typical flow pattern in this case are so called salt fingers. According to some observations, they can organize into layers separated by standard convection rolls. The transport of heat and salt greatly depends on whether fingers form. This contribution will present experiments which used an electrodeposition cell to sustain a destabilizing concentration difference of copper ions in aqueous solution between the top and bottom boundaries of the cell. The resulting convecting motion is analogous to Rayleigh- Bénard convection at high Prandtl numbers if the cell is kept at spatially uniform temperature. However, if a stabilizing temperature gradient is imposed across the cell, double diffusive fingers appear even for thermal buoyancy two orders of magnitude smaller than chemical buoyancy. It is found that the fingers obey several simple scaling laws. The control parameters can also be chosen such that fingers and convection rolls coexist in vertically stacked layers.

DY 16.8 Tue 12:00 ZEU 118

Droplet nucleation in two-phase thermal convection: A laboratory study — •Prasanth Prabhakaran[1], Stephan Weiss[1], Alexei Krekhov[1] und Eberhard Bodenschatz[1,2,3] — [1]Max Planck Institute f. Dynamics and Self-Organisation — [2]Institute f. Nonlinear Dynamics, University Göttingen — [3]Laboratory of Atomic and Solid-State Physics and Sibley School of Mechanical Aerospace Engineering, Cornell University, Ithaca (USA)

We investigate the nucleation and growth of liquid droplets in a Rayleigh-Bénard convection system, i.e., a horizontal fluid layer heated from below and cooled from above. The fluid consists of a mixture of sulfur hexafluoride (SF_6) and helium (He). Temperature and pressure are such that SF_6 exists in both, the vapor and the liquid phase while He is in the gas phase. Hot SF_6 vapor that rises from the bottom condenses inside the colder gaseous He/SF_6 mixture by homogeneous nucleation and forms small droplets that form clouds. We study the condensation process, as well as the dynamics of the droplet motion inside the gas phase visually using a high-speed camera. We found several instances, where droplet condensation occurs in the cold wake of larger falling droplets. This observation may suggest an additional mechanism for nucleation of droplets in atmospheric clouds.

DY 16.9 Tue 12:15 ZEU 118

Prediction of the temperature profiles in Rayleigh-Bénard convection. — •Mohammad Emran and Olga Shishkina — Max-Planck Institute for Dynamics and Self-Organization, Göttingen, Germany.

Experiments and numerical simulations of Rayleigh-Bénard convection (RBC) show that the temperature profiles in RBC systematically deviate from those obtained as solutions of the classical Prandtl-Blasius or Falkner-Skan boundary layer equations. The deviations persist even after rescaling of the profiles in a fixed or dynamical frame. Some improvements have been made by adapting the pressure gradients and buoyancy effects in the classical boundary layer equations. Those improvements mostly influence the prediction of the viscous boundary layer structure, but not the structure of the thermal boundary layer, in particular at large Prandtl number. Here we report a recipe to predict the mean vertical temperature profiles in turbulent Rayleigh-Bénard convection for Prandtl numbers larger than one. It is based on the thermal boundary layer equation from Shishkina et al., Phys. Rev. Lett. 114, 114302 (2015), which incorporates the effect of turbulent fluctuations, and new Direct Numerical Simulations (DNS) of RBC in a cylindrical cell of the aspect ratio 1, for the Prandtl number variation of several orders of magnitude. Our modeled temperature profiles are found to agree with the DNS much better than those obtained with the classical Prandtl–Blasius or Falkner–Skan approaches.

DY 16.10 Tue 12:30 ZEU 118

Horizontal velocity fields in square large aspect ratio turbulent convection cells: comparison between experiment and simulation — •Christian Kästner, Anastasiya Kolchinskaya, Christian Resagk, and Jörg Schumacher — Institute of Thermodynamics and Fluid Mechanics, Technische Universität Ilmenau, Postfach 100565, 98684 Ilmenau

We report a one-to-one comparison of an experimental and numerical analysis of turbulent velocity fields in a square Rayleigh-Bénard convection cell at an aspect ratio ten and air as working fluid. Horizontal cuts through the convective flow were obtained from planar particle image velocimetry (PIV) measurements. Optical access for laser light sheet and PIV camera was provided by transparent side-walls and a transparent heating plate. The application of a transparent heating plate, a glass plate coated with a transparent and electrically conductive metal oxide (TCO), allowed first time experimental observation

of horizontal velocity fields in turbulent thermal convection at large aspect ratios. The horizontal cuts were taken in mid-plane of the convection cell and below the cooling plate at a Rayleigh number Ra= 500,000. Numerical and experimental results show good agreement and provide new insights into large-scale coherent flow pattern formation in turbulent thermal convection.

DY 16.11 Tue 12:45 ZEU 118

Nonlinear mode decomposition of reversal dynamics in Rayleigh-Bénard convection — •Oliver Kamps[1] and Tim Kroll[2] — [1]Center for Nonlinear Science, WWU Münster, Germany — [2]Institut für Theoretische Physik, WWU Münster, Germany

Complex systems composed of a large number of degrees of freedom can often be described on the macroscopic level by only a few interacting modes or coherent structures. A paradigmatic example for this behaviour is Rayleigh-Bénard convection. In general many turbulent flows seem to be composed of a few coherent structures and it might be possible to find a low dimensional representation of the flow. This has to be done in most cases by means of data analysis methods since it is not possible to derive the low dimensional model from the basic equations of the complex system.

Based on ideas developed in [1,2] we present a nonlinear decomposition method that is able to extract coherent structures and their dynamics from data of turbulent flow fields. We apply this method to reversal dynamics in Rayleigh-Bénard convection in order to derive a low dimensional representation of the system. We also show the relation to other decomposition methods like dynamic mode decomposition.

[1] C. Uhl, R. Friedrich, and H. Haken, Zeitschrift für Physik B, 92, 1993

[2] F. Kwasniok, Physica D: Nonlinear Phenomena, 92, 1996

DY 16.12 Tue 13:00 ZEU 118

Heat and momentum transport scalings in horizontal convection — •Olga Shishkina[1], Siegfried Grossmann[2], and Detlef Lohse[3] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Fachbereich Physik der Philipps-Universität, Marburg, Germany, — [3]Department of Science and Technology, Mesa+ Institute, and J. M. Burgers Centre for Fluid Dynamics, University of Twente, Enschede, Netherlands

In horizontal convection heat exchange takes place exclusively through a single (bottom) horizontal surface of a fluid layer. For this type of convective flow configuration in Shishkina, Grossmann and Lohse, Geophys. Res. Lett. 43 (2016) a theoretical model for the heat and momentum transport scaling with the Rayleigh number (Ra) has been suggested, which is an extension of the Grossmann and Lohse theory (2000) to the case of horizontal convection. The model suggests various different scaling regimes, including in particular the Rossby scaling (with the scaling exponent 1/5 in the Nusselt number versus Rayleigh number scaling) and the ultimate scaling (with the scaling exponent 1/3). In the present talk we discuss the Prandtl-number (Pr) dependences of the Nusselt and of the Reynolds numbers for all derived scaling regimes in horizontal convection and also the locations in the Pr-Ra plane of the (smooth) transitions between different scaling regimes.

DY 17: Physics of Physarum polycephalum and Other Slime Molds - Joint Focus Session (BP/DY) organized by Hans-Günther Döbereiner

Time: Tuesday 9:30–13:00 Location: SCH A251

Invited Talk DY 17.1 Tue 9:30 SCH A251

Laminar mixing in tubular networks of plasmodial slime moulds — •Marcus Hauser — Otto-von-Guericke-Universität Magdeburg, Institut für Biometrie und Medizinische Informatik, Magdeburg, Germany

The plasmodium of the unicellular slime mould *Physarum polycephalum* forms an extended, at times giant, vascular network which is used for transportation of protoplasm through the cell. The transport is driven by pressure gradients generated by peristaltic pumping, leading to a flow that reverses its direction periodically. Although the flow in the veins of *P. polycephalum* is always parabolic, protoplasm and particles suspended in it are effectively and rapidly distributed within the cell. To elucidate how an effective mixing is achieved in such a microfluidic system with Womersley flow (at low Womersley and Reynolds numbers), we performed micro-PIV experiments and advect virtual tracers in the determined time-dependent flow fields. Flow splitting and flow reversals at branchings of veins, as well as small fluctuations in the flow patterns at the branchings of veins play key roles in providing for an efficient mixing of protoplasm in the cell.

DY 17.2 Tue 10:00 SCH A251

Calcium dynamics in *Physarum polycephalum* — •Mirna Kramar and Karen Alim — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Calcium is a known regulator of myosin across all living organisms, as well as a key player in cell signalling. We study the effects of calcium on morphogenesis, locomotion and healing in the plasmodium of *Physarum polycephalum*. *Physarum* is a giant multinucleate and unicellular organism. The organism uses peristaltic contractions of the actomyosin layer to create shuttle streaming of the cytoplasm throughout its network of tubes. Upon a change of environmental conditions, the contractions change and cause a reorganization of the network. The mechanism that propagates information within the body and results in the network reorganization is not yet clear. We hypothesise that calcium plays the key role in this process by directly influencing the myosin and thus causing a local change in the contractions. Using an approach with two fluorescent dyes, we label free calcium ions and show the response of calcium upon the application of various stimuli to the plasmodium.

DY 17.3 Tue 10:15 SCH A251

Light stimuli trigger local and global cellular response in *Physarum polycephalum* — •Felix Bäuerle and Karen Alim — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

The slime mold *Physarum polycephalum* excels in adapting its network-like morphology to its environment. As a giant, single cell it is able to collect localised cues and form a complex organism-wide response. For example, *Physarum* can find the shortest path in a maze and connect sparse food sources to choose a balanced diet. How are localised cues collected, integrated and mediated over the whole organism to perform theses complex tasks? To tackle these questions we study *Physarum*'s pruning reaction to light stimuli. *Physarum*'s body consists of protoplasmic tubes which contract rhythmically. These contractions show distinct temporal patterns until pruning is completed. We found that *Physarum* shows a whole-cell response shortly after light application and then gradually transforms the illuminated region into an autonomous domain. Identifying the interplay between such global and local reactions may advance our understanding of more general processes like wound healing or cell signalling.

DY 17.4 Tue 10:30 SCH A251

Scaling of foraging patterns under starvation in *Physarum polycephalum* — •Jonghyun Lee, Christina Oettmeier, and Hans-Günther Döbereiner — Institut für Biophysik, Universität Bremen

Physarum polycephalum is garnering attention as a model organism for primitive intelligence and decision-making. We utilize microplasmodia, quasi-spherical fragments on the micrometer range, to investigate the reconstitution of the macroplasmodium from smaller components.

Generally, *Physarum* grows as an extended network, of which the transition from micro- to macroplasmodia occurs via percolation [1]. However, under starvation conditions, this transition does not occur. Instead, several bodies on the millimeter scale form and migrate radially away from the site of inoculation. We term these motile mesoplasmodia *satellites*. Satellite growth mode has defined phases of motility and rest, and their behaviour is spatio-temporally correlated. Satellites also have a stable and defined morphology, as well as a constant direction of movement.

Here, we present a description of this growth mode with simplified geometrical shapes. We describe scaling relationships of the number of satellites produced and their size based on initial conditions. The model predicts the size to increase and the number to decrease as the initial biomass increases, which fits well with the data. We discuss implications of assumptions and limitations of our scaling model.

[1] Fessel, A. et al. (2012), *Physical Review Letters* 109, 078103.

DY 17.5 Tue 10:45 SCH A251

Hydrodynamic Mechanism of Information Processing in *Physarum polycephalum* — •Christina Oettmeier, Jonghyun Lee, and Hans-Günther Döbereiner — Institut für Biophysik, Universität Bremen

P. polycephalum exhibits rich spatiotemporal oscillatory behaviour. The organism's size spans orders of magnitude, from meter-sized networks to micrometer-sized amoebae. All morphotypes show actomyosin-based contraction-relaxation cycles resulting in protoplasmic streaming. When a food source is encountered, oscillations at the stimulated site increase in frequency. If repellents are encountered, the local oscillation frequency decreases [1]. This either leads to movement towards the attractant or away from the repellent. We study hydrodynamic information processing in amoeboid locomotion. Autonomous foraging units (mesoplasmodia) maintain their shape over hours while moving in straight trajectories at constant mean speed. Oscillations in the back of the mesoplasmodium cause endoplasm flows through the internal vein system and expand the frontal membrane. Frequencies at the back are higher than those at the front due to filtering. We use the electronic-hydraulic analogy to investigate this case of information processing. A vein segment can be described as a flexible tube, possessing a fluidic resistance (R) and fluidic capacitance (C). The electronic equivalent is a passive RC low pass filter. We use SPICE to simulate vein behaviour. Light- and EM data of mesoplasmodia and other morphotypes provide geometrical and elastic parameters.

[1] Durham, A.C.H. & Ridgway, E.B. (1976), *J.Cell Biol.* 69, 218-223

15 min break

DY 17.6 Tue 11:15 SCH A251

Control of Pattern Formation in *Dictyostelium discoideum* — •Torsten Eckstein, Albert Bae, Vladimir Zykov, Eberhard Bodenschatz, and Azam Gholami — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

We performed experiments to study pattern formation in colonies of *Dictyostelium discoideum* cells under the influence of a regular array of pillars in a petri dish.

We observed a new phenomenon: In the presence of caffeine, synchronized circular waves center on the pillars and dominate the wave dynamics. In a periodic arrangement of pillars, this results in regular macroscopic streaming patterns reminiscent of Voronoi domains centered around the pillars. The shape of these Voronoi domains is based on the underlying shape of the array of pillars. Thus, the macroscopic pattern can be tuned by changing the geometry of the array. We have shown that this phenomenon is found for different geometries, like a rectangular grid of pillars, a hexagonal grid of pillars and long walls as obstacles. It seems the defining characteristic in the system is the presence of a wall. Indeed, the phenomenon persists for pillars of a small height and shallow holes. Additionally, we varied the initial starvation times of the cells, finding that cells stream to the pillars for starvation times from 40 minutes to 7 hours. However, for starvation times of at least 5 hours the macroscopic pattern was lost.

DY 17.7 Tue 11:30 SCH A251

***Physarum polycephalum* single cells proceed through variable trajectories of gene expression to commitment and differentiation** — •Wolfgang Marwan — Magdeburg Centre for Systems Biology, Otto-von-Guericke University, Magdeburg

Physarum polycephalum multinucleate giant plasmodial cells with their naturally synchronous population of nuclei provide ample homogeneous biological material for the analysis of signaling and gene expression dynamics at the single cell level. The developmental program of sporulation was triggered by a brief pulse of far-red light. By taking samples at different time points after the stimulus pulse, we followed how the gene expression pattern changes during commitment and differentiation. Time-dependent patterns of differential gene regulation showed that developmental trajectories were highly variable between individual cells. Differentiation control mutants that are locked in the proliferative state responded to the stimulus pulse by taking altered trajectories of gene expression that did not lead to sporulation. The results are discussed in the context of a Waddington-type quasipotential landscape of cell differentiation and the impact of mutations on its topology. We further discuss how *Physarum polycephalum* can contribute to a data-driven theoretically sound dynamic systems approach to the regulatory control of eukaryotic cell differentiation at genome-wide scale.

DY 17.8 Tue 11:55 SCH A251

Evolutionary experiments with slime molds — •Martin Grube — Institute of Plant Science, University Graz, 8010 Graz, Austria

Acclimatisation describes adaptive physiological or behavioural changes of an organism, whereas adaptation is a process that involves heredity of selected traits. Slime molds seem to use information about past experiences for optimal decision-making, which is a simple form of learning. Yet it is still unclear to what extent this type of learning is mediated by acclimatization, habituation, or by hereditary adaptation. If slime molds can adapt by hereditary mechanisms to a wider range of growth conditions, and modify their growth features and foraging patterns accordingly, the diverged strains should then consistently differ by these properties, even when grown under the same conditions. We use serial transfers of plasmodia to select the best performing plasmodium after each transfer. By using microplasmodia initially we generate a genetic bottleneck to increase genetic drift. In our work we encountered several challenges, including the size variation of microplasmodia, which may cause a bias in the selection procedure, and which need to be addressed.

DY 17.9 Tue 12:20 SCH A251

Mechanochemical pattern formation in simple models of active viscoelastic fluids and solids with application to *Physarum polycephalum* — Sergio Alonso[1], Markus Radszuweit[2], Harald Engel[3], and •Markus Bär[4] — [1]Department of Physics, UPC Barcelona, Spain — [2]Weierstrass Institute Berlin, Germany — [3]Theoretische Physik, Technische Universitaet Berlin, Germany — [4]Physikalisch-Technische Bundesanstalt, Abbestrasse 2-12, 10587 Berlin, Germany

A simple description for active stress generation is coupled to different model of passive viscoelasticity. Specifically, two models for viscoelastic fluids (Maxwell and Jeffrey model) and two models for viscoelastic solids (Kelvin-Voigt and Standard model) are investigated. Our focus is on the onset of mechano-chemical waves and patterns. We carry out linear stability analysis and numerical simulations in one spatial dimension. The primary instability is stationary for all active fluids considered, whereas all active solids exhibit an oscillatory instability. All instabilities found are of long-wavelength nature. The special case of a poroelastic two-phase model, where the active solid represents the cytoskeleton and is described by a Kelvin-Voigt model is coupled to a viscous fluid (cytosol) in which the free calcium concentrations obeys a potentially oscillatory reaction-diffusion dynamics. M. Radszuweit, H. Engel, M. Bär, PLoS One 2014; S. Alonso et al. Physica D 2016.

DY 17.10 Tue 12:45 SCH A251

Poroelastic two-phase model for droplets of *Physarum polycephalum* with free boundaries — •Dirk Alexander Kulawiak[1], Jakob Löber[1], Markus Bär[2], and Harald Engel[1] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Physikalisch-Technische Bundesanstalt, Abbestrasse 2-12, 10587 Berlin, Germany

The model describes the cytoskeleton as an active viscoelastic solid phase coupled to a passive viscous fluid representing the cytosol. The active tension in the solid phase depends on the concentration of a regulating agent that is advected by the fluid phase. In [1] it was shown that under rigid boundary conditions that impose a fixed shape, this model reproduces a large variety of mechano-chemical patterns; these include traveling and standing waves, turbulent patterns, rotating spirals and antiphase oscillations in line with experimental observations of contraction patterns in protoplasmic droplets of *Physarum polycephalum*. Here we present a free-boundary approach to the model of the moving droplet. We find deformations of the droplet boundary as well as oscillatory and chaotic changes in the droplets position.

DY 18: Brownian Motion / Noise (joint session DY/TT)

Time: Tuesday 10:00–13:00 Location: ZEU 147

DY 18.1 Tue 10:00 ZEU 147

Convex Hulls of Random Walks in High Dimensions: A Large-Deviation Study — •Hendrik Schawe[1], Alexander K. Hartmann[1], and Satya N. Majumdar[2] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg — [2]Laboratoire de Physique Théorique et Modèles Statistiques, Université de Paris-Sud

We study the convex hulls of random walks in high dimensions, i.e., the smallest convex polytope enclosing the trajectory of a random walk with T steps. While the convex hulls of two-dimensional random walks are decently studied [1, 2], very little is known about the convex hulls of random walks in $d \geq 3$. Using Markov chain Monte Carlo sampling-techniques, we can study a large part of the support of the distributions of the volume V of the convex hulls or its surface ∂V. This enables us to reach probability densities below $P(A) = 10^{-800}$ and scrutinize large-deviation properties. Similar to two-dimensional random walks, the probability densities show a universal scaling behavior dependent on the exponent $\nu = 0.5$ and the *effective* dimension of the observable, i.e., $d_{\text{eff}} = d$ for V and $d_{\text{eff}} = d-1$ for ∂V. Further, we determined the rate function $\Phi(\cdot) = -\frac{1}{T}\log P(\cdot)$ which shows convergence to a limit shape for $T \to \infty$, which seems to be a power law with an exponent only dependent on d_{eff} and ν.

[1] G. Claussen, A. K. Hartmann, and S. N. Majumdar, Phys. Rev. E **91**, 052104 (2015); [2] T. Dewenter, G. Claussen, A. K. Hartmann, and S. N. Majumdar, Phys. Rev. E **94**, 052120 (2016)

DY 18.2 Tue 10:15 ZEU 147

The transient subdiffusive behavior of particles in mucus — •Thomas John[1], Matthias Ernst[2], Marco Günther[2], Ulrich Schäfer[3], Christian Wagner[1], and Claus-Michael Lehr[4] — [1]Experimental Physics, University of Saarland — [2]Faculty of Engineering, University of Applied Sciences, Saarbrücken — [3]Helmholtz Institute for Pharmaceutical Research Saarland — [4]Biopharmaceutics and Pharmaceutical Technology, University of Saarland

Biological barriers are crucial in protecting our body from environmental influences. Well-known outer barriers are intestinal, pulmonary, nasal, buccal, cervico-vaginal and dermal barriers. Except for the dermal barrier, all these are covered by a mucus layer, providing an additional barrier to the epithelial cell layer.

We have applied a model to explain the reported subdiffusion of particles in mucus, based on the measured mean squared displacements (MSD). The model considers Brownian diffusion of particles in a confined geometry, made from permeable membranes. The applied model predicts a normal diffusive behavior at very short and long time lags, as observed in several experiments. In between these time scales, we find that the "subdiffusive" regime is only a transient effect, $MSD \propto \tau^{\alpha}$, $\alpha < 1$. The only parameters in the model are the diffusion-coefficients at the limits of very short and long times, and the distance between the permeable membranes L. Our numerical results are in agreement with published experimental data for realistic assumptions of these parameters.

This work was submitted and accepted in the Biophysical Journal.

DY 18.3 Tue 10:30 ZEU 147

Non-Gaussian Statistics of Tracer Positions in Fluids Stirred by Microswimmers — •Thomas John[1], Levke Ortlieb[1], Philippe Peyla[2], Salima Rafaï[2], and Christian Wagner[1] — [1]Experimental physics University of Saarland — [2]Laboratoire Interdisciplinaire de Physique, Grenoble

We performed statistical analyses on the measured positions of μm-sized tracer particles in liquids stirred by the microswimmer *Chlamydomonas reinhardtii*. Various tracer diameters, swimmer concentrations and mean swimmer velocities were examined. The statistical characteristics are compared with predictions from various models. Our observed mean squared displacement of the tracer is linear over more than two order of magnitudes in time. The underlying probability density function ($pdf(\Delta t)$) of the displacements has a Gaussian core from the Brownian motion and non-Gaussian tails from the interactions with the flow field from the swimmers. The *pdf* shows a transient diffusive scaling behavior at short times. This scaling breaks down at times longer than few seconds. Our results are in very good agreement with the predictions of the microscopic model by Thiffeault, PRE **92** 023023(2015).

DY 18.4 Tue 10:45 ZEU 147

Dynamically Crowded Solutions of Brownian Needles — •Sebastian Leitmann[1], Felix Höfling[2], and Thomas Franosch[1] — [1]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21A, A-6020 Innsbruck, Austria — [2]Fachbereich Mathematik und Informatik, Freie Universität Berlin, Arnimallee 6, 14195 Berlin, Germany

We perform Brownian dynamics simulations of solutions of infinitely thin needles up to densities n deep in the semidilute regime. With increasing density, the motion of a needle becomes increasingly restricted to a sliding back-and-forth movement in a tube composed of the surrounding needles. From the density-dependent behavior of the rotation and the translation we extract the corresponding longtime transport coefficients and corroborate the scaling behavior of $\sim n^{-2}$. The characteristic algebraic decay of $\sim t^{-1/2}$ in the intermediate scattering function and a plateau over many decades in time in the non-Gaussian parameter represent a fingerprint of the sliding motion of the needle within the tube. We show that on coarse-grained time and length scales, the dynamics of a needle in solution is captured by a single needle (phantom needle) with the extracted transport coefficients as input parameters [1] as anticipated from the tube theory of Doi and Edwards [2]. We also compare the dynamics to needle Lorentz systems where a single tracer needle explores a quenched array of other needles.

[1] S. Leitmann, F. Höfling, and T. Franosch, Phys. Rev. Lett. 117, 097801 (2016). [2] M. Doi and S. F. Edwards, J. Chem. Soc., Faraday Trans. 2 74, 560 (1978).

DY 18.5 Tue 11:00 ZEU 147

Electronic and photonic counting statistics as probes of non-equilibrium quantum dynamics — •Björn Kubala[1], Joachim Ankerhold[1], and Andrew D. Armour[2] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, UK

The emission of radiation generated by the flow of charges through a mesoscopic conductor depends not just on the properties of the conductor itself, but also on those of its electromagnetic environment. Coupling a conductor to a high-quality electromagnetic cavity generates strong mutual feedback which can lead to novel far-from-equilibrium regimes where the charge current and the photon flux leaking out of the cavity are both determined by the nonlinear behavior of the combined system. Using a voltage-biased Josephson junction as an example, we investigate how the photonic and charge current statistics are related to each other and to the underlying coupled dynamics in the non-equilibrium regime. We demonstrate that there is a simple connection between the full counting statistics of the charges and the photons in the long time limit. We also show that measurements of photon statistics would signal the crossover from linear to nonlinear dynamics in the conductor-cavity hybrid through the emergence of highly coherent charge transport.

[1] B. Kubala, J. Ankerhold, and A. D. Armour, arXiv:1606.02200

15 min. break

DY 18.6 Tue 11:30 ZEU 147

Anomalous statistics and ergodicity breaking in a semi-classical electron transfer dynamics — •Igor Goychuk — Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str. 24/25, 14476 Potsdam-Golm, Germany

Can statistical properties of single-electron transfer events be correctly predicted within a common equilibrium ensemble description? This fundamental in nanoworld question of ergodic behavior is scrutinized within a very basic semi-classical model of electron transfer. It is shown that in the limit of non-adiabatic electron transfer (weak tunneling) well-described by the Marcus-Levich-Dogonadze (MLD) rate the answer is yes. However, in the limit of the so-called solvent-controlled adiabatic electron transfer, a profound breaking of ergodicity occurs. Namely, for sufficiently large activation barriers, the ensemble survival probability in a state remains always nearly exponential with the inverse rate given by the sum of the adiabatic curve crossing (Kramers) time and the inverse MLD rate. In contrast, near to adiabatic regime, the single-electron survival probability is clearly non-exponential, even

though it possesses an exponential tail which agrees well with the ensemble description. Initially, it is well described by a Mittag-Leffler distribution with a fractional rate. Paradoxically, the mean transfer time in this classical on the ensemble level regime is well described by the inverse of nonadiabatic quantum tunneling rate on a single particle level. An analytical theory is developed which perfectly agrees with stochastic simulations and explains our findings.

DY 18.7 Tue 11:45 ZEU 147

Strong coupling, non-Markovian transport: Transient deviations from fluctuation-dissipation theorems — •Javier Cerrillo, Maximilian Buser, and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Transient dynamics of transport settings in the strong coupling and non-Markovian regimes are expected to exhibit deviations from steady state fluctuation-dissipation theorems. We show that these may be exactly quantified in terms of equilibration dynamics under alternative measurement schemes. This relation holds far from equilibrium and extends to high-order transport cumulants. In order to explore the strong-coupling, non-Markovian regime where these deviations are expected to be strongest, a new simulation method based in a hierarchy of equations of motion has been developed for the computation of arbitrary cumulants in transport settings. We instantiate our proposal with the study of deviations of high-order cumulants of energetic transport between two baths connected via a few level system.

DY 18.8 Tue 12:00 ZEU 147

Full counting statistics in the non-Markovian, strong-coupling regime - a hierarchy of equations of motion approach — •Maximilian Buser, Javier Cerrillo, and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Within the framework of open quantum systems, we present a new numerical approach to full-counting statistics (FCS) of environmental observables. It is based on the hierarchy of equations of motion (HEOM) technique, a well-established method for the simulation of general multilevel open systems. Thereby, our method directly inherits the key advantages from the HEOM. It faithfully represents non-Markovian effects of the environment and is non-perturbative in the open system-environment coupling strength. Additionally, arbitrary time dependencies of the system Hamiltonian are correctly treated. Here, we focus on usual two-point measurement statistics and show how the back-effect accompanying the initial measurement becomes especially relevant within the now accessible regime. We exemplify our method with a discussion of energetic fluxes trough open systems which are subject to environmental far from equilibrium constraints and study the effect of time-dependent control on the system.

DY 18.9 Tue 12:15 ZEU 147

Ratchet with tunable asymmetry based on φ Josephson junction: operation, loading & efficiency. — •Edward Goldobin[1], Rosina Menditto[1], Martin Weides[2], Hermann Kohlstedt[3], Dieter Koelle[1], and Reinhold Kleiner[1] — [1]Physikalische Institut, Universität Tübingen, Auf der Morgenstelle 14, 72076, Tübingen, Germany — [2]Physikalisches Institut, Karlsruher Institut für Technologie, 76128 Karlsruhe, Germany — [3]Nanoelektronik, Technische Fakultät, Christian-Albrechts-Universität zu Kiel, D-24143 Kiel, Germany

We demonstrate experimentally the operation of a deterministic Josephson ratchet with tunable asymmetry [1]. The ratchet is based on a φ Josephson junction with a ferromagnetic barrier [2] operating in the underdamped regime. The ratchet operation with a load, i.e. in the presence of the additional dc counter current trying to stop the ratchet, is also demonstrated. Under these conditions the ratchet produces a non-zero output power. We estimate the efficiency of the ratchet using a general model for Josephson ratchets with hysteresis [3].

[1] R. Menditto, et al. Phys. Rev. E **94**, 042202 (2016).
[2] H. Sickinger, et al. Phys. Rev. Lett. **109**, 107002 (2012).
[3] E. Goldobin, et al., Phys. Rev. E **94**, 032203 (2016).

DY 18.10 Tue 12:30 ZEU 147

Particle transport using rocking Brownian motors — •Christian Schwemmer[1], Stefan Fringes[1,2], Colin Rawlings[1], and Armin Knoll[1] — [1]IBM Research - Zurich, Switzerland — [2]Institute of Physical Chemistry, University of Zurich, Switzerland

Inspired by how intracellular transport is achieved in nature [1], artificial Brownian motors have been designed to allow for particle transport in fluids [2]. The two main requirements are a spatially asymmetric potential and an external driving force. For our implementation, we utilize a novel approach to transport 60 nm gold particles inside a nanofluidic slit. In detail, we use the electrostatic interaction between the gold particles and surfaces to define, similar to geometry induced trapping [4], a potential landscape. Therefore, one of the confining surfaces is patterned with a 3D ratchet topography by thermal scanning probe lithography [3] which then directly translates to a potential landscape. In contrast to most previous experiments which used flashing ratchets, we realized a rocking ratchet by applying a zero-mean AC electric field across the slit delivering high particle drift speeds of up to 100 μm/s. Experimentally, we could further show that the potential landscape and thus the transport properties strongly depend on the particle size and the gap distance of the slit. By exploiting this property, we plan to develop a fast and highly selective nanoparticle sorting device.

[1] Vale et al., Science, **288**, 88, (2000)
[2] Hänggi et al., Rev. Mod. Phys, **81**, 387, (2009)
[3] Pires et al., Science, **328**, 732, (2010)
[4] Krishnan et al., Nature, **467**, 692, (2010)

DY 18.11 Tue 12:45 ZEU 147

Brownian Carnot Engine — •Edgar Roldan[1], Ignacio A. Martinez[2,3], Luis Dinis[3], Juan MR Parrondo[3], Raul A. Rica[4,5], and Dmitry Petrov[4] — [1]Max Planck Institut fur Physik Komplexer Systeme — [2]Ecole Normale Superieure de Lyon — [3]Universidad Complutense de Madrid and GISC — [4]ICFO The Institute of Photonic Sciences — [5]Universidad de Granada

The Carnot cycle imposes a fundamental upper limit to the efficiency of a macroscopic motor operating between two thermal baths. However, this bound needs to be reinterpreted at microscopic scales, where molecular motors and some artificial micro-engines, operate. Energy transfers in microscopic systems are random and thermal fluctuations induce transient decreases of entropy, allowing for possible violations of the Carnot limit. Nearly two centuries after Carnot's work, we report an experimental realization of a Carnot engine with a single optically trapped Brownian particle as the working substance. We present an exhaustive study of the energetics of the engine and analyse the fluctuations of the finite-time efficiency, showing that the Carnot bound can be surpassed for a small number of non-equilibrium cycles. As its macroscopic counterpart, the energetics of our Carnot machine exhibits basic properties that one would expect to observe in any microscopic energy transducer operating with baths at different temperatures. Our results characterize the sources of irreversibility in the engine and the statistical properties of the efficiency, an insight that could inspire new strategies in the design of efficient nano-motors.

DY 19: Colloids and Complex Fluids I (joint session BP/CPP/DY, organized by CPP)

Time: Tuesday 11:30–13:00 Location: ZEU 255

DY 19.1 Tue 11:30 ZEU 255

Small activity differences drive phase separation in polymers — •Jan Smrek and Kurt Kremer — Max Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany

Recent theoretical studies found that mixtures of active and passive colloidal particles phase separate but only at very high activity ratio. The high value poses serious obstacles for experimental exploration of this phenomenon. Here we show using simulations that when the active and passive particles are *polymers*, the critical activity ratio decreases with the polymer length. This not only facilitates the experiments but also has implications on the DNA organization in living cell nuclei. Entropy production can be used as an accurate indicator of this non-equilibrium phase transition.

DY 19.2 Tue 11:45 ZEU 255

Corresponding States Law For Protein Solutions — •Florian Platten and Stefan U. Egelhaaf — Heinrich Heine University, Condensed Matter Physics Laboratory, Duesseldorf, Germany

The extended law of corresponding states, as proposed by Noro and Frenkel, involves a mapping of the phase behavior of systems with short-ranged attractions. We test its applicability to protein solutions with their complex interactions. We successfully map the experimentally determined metastable gas-liquid binodals to the binodals of short-ranged square-well fluids. This is achieved by representing the binodals as a function of the temperature scaled with the critical temperature (or as a function of the reduced second virial coefficient) and the concentration scaled by the cube of an effective particle diameter, where the scalings take into account the attractive and repulsive contributions to the interaction potential, respectively. The scaled binodals of the protein solutions coincide with simulation data of the adhesive hard-sphere fluid. Furthermore, once the repulsive contributions are taken into account by the effective particle diameter, the temperature dependence of the reduced second virial coefficients follows a master curve that corresponds to a linear temperature dependence of the depth of the square-well potential. We moreover demonstrate that, based on this approach and cloud-point measurements only, second virial coefficients can be estimated, which we show to agree with values determined by light scattering or by Derjaguin-Landau-Verwey-Overbeek (DLVO)-based calculations.

Platten et al., J. Chem. Phys. 142, 174905 (2015).

DY 19.3 Tue 12:00 ZEU 255

Critical Casimir interactions between Janus particles — •Marcel Labbé-Laurent and Siegfried Dietrich — Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany

Critical fluctuations in binary liquid mixtures give rise to forces acting on immersed colloidal particles. Experiments have demonstrated a remarkable agreement with theoretical predictions for spherical colloids close to a (chemically patterned) substrate [1,2]. At the same time, there has been strong experimental and theoretical interest in studying the self-assembly and the phase behavior of patchy and Janus particles. Although a variety of effective interactions have been proposed to drive the self-assembly, the critical Casimir effect stands out as being particularly suitable because it provides both attractive and repulsive interactions depending on the chemical surface properties, as well as a sensitive control of their strength via minute temperature changes. We present theoretical calculations for the interaction between a single Janus particle and a chemically structured substrate and the effective pair potential between two Janus cylinders as well as between two Janus spheres [3].

[1] C. Hertlein, L. Helden, A. Gambassi, S. Dietrich, and C. Bechinger, *Nature* **451**, 172 (2008).

[2] M. Tröndle, O. Zvyagolskaya, A. Gambassi, D. Vogt, L. Harnau, C. Bechinger, and S. Dietrich, *Mol. Phys.* **109**, 1169 (2011).

[3] M. Labbé-Laurent, and S. Dietrich, *Soft Matter* **12**, 6621 (2016).

DY 19.4 Tue 12:15 ZEU 255

From criticality to gelation in sticky spheres — David Richard[1,2], Thomas Speck[1], and •Cristopher Patrick Royall[2] — [1]Institut fur Physik, Johannes Gutenberg-Universitat, Mainz, Germany — [2]HH Wills Physics Laboratory, Tyndall Avenue, Brisol, United Kingdom

Understanding the mechanism of dynamical arrest in liquids is a long standing challenge. Even for simple fluids, such as sticky spheres, an arrested gel can occur when the system is quenched sufficiently fast such that it cannot relax to equilibrium. For many systems the gelation arises at the gas-liquid phase boundary, forming a rigid but dilute network of bonded particles. In this study, we look at the critical behavior of sticky spheres combining confocal microscopy of colloid-polymer mixtures and Monte Carlo simulations of the square-well model. The mapping between those two is achieved via tracking colloids at the single-particle level and fitting pair distribution functions to the simulation data. We then compare the local structure via the topological cluster classification (TCC) method to identify locally favored structures (LFSs) along the critical path. We observe a very good agreement between experiments and simulations, where the growth of highly ordered structures are triggered even far away from the phase boundary. We discuss the link of those LFSs to the global percolating bond network.

DY 19.5 Tue 12:30 ZEU 255

Determination of crystal nucleation barriers for colloidal crystals from computer simulations — •Peter Koss[1,2], Antonia Statt[3], Peter Virnau[1], and Kurt Binder[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudinger Weg 9, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Staudinger Weg 9, 55128 Mainz, Germany — [3]Princeton University, Princeton, NJ 08544, USA

A fluid in equilibrium, confined in a finite volume, with a density exceeding the onset of freezing, may exhibit phase coexistence with a crystal nucleus surrounded by liquid or a gas. Classical nucleation theory predicts that the barrier of homogeneous nucleation is given by two contributions, the free energy gained by the creation of a crystal droplet and the free energy loss due to surface tension of the newly created interface. We obtain the excess free energy due to the surface of the crystalline nucleus by using a computational method suitable for the estimation of the chemical potential of dense fluids. Our analysis method is appropriate for crystal nuclei of all shapes, without suffering from ambiguities occurring when one needs a microscopic identification of the crystalline droplet. We present a novel analysis method to determine the coexistence pressure between fluid and crystal, and report that the nucleation barrier for a soft version of the effective Asakura-Oosawa model is compatible with a spherical shape, and consistent with classical nucleation theory [1].

[1] A. Statt, P. Virnau, and K. Binder, Phys. Rev. Lett. 114, 026101 (2015).

DY 19.6 Tue 12:45 ZEU 255

Phonons and Elasticity in Disordered binary Crystals — •Tadeus Ras and Matthias Fuchs — FB Physik, Univ. Konstanz

The "method of long waves" is a well-established tool for the study of elastic constants [1]. However, until recently, it had been lacking in crystals with point defects due to an unclear definition of the displacement field.

We present a generalization of the projection-operator approach employed in [2]. It yields expressions for the elastic constants valid in binary crystals with arbitrary amounts of point defects and up to the melting temperature. Further, both acoustic and optical phonon eigenfrequencies can be computed in linear response.

While density functionals from classical DFT serve as an input parameter to the approach it can also be employed experimentally to process measurement data. For demonstration, dispersion relations will be shown as obtained from molecular dynamics data of a hard sphere model crystal [3].

[1] D. C. Wallace, Thermodynamics of Crystals (Wiley, NY 1972).
[2] C. Walz and M. Fuchs, Phys. Rev. B **81**, 134110 (2010).
[3] L. Filion et. al., Phys. Rev. Lett. **107**, 168302 (2011).

DY 20: Soft Particles in Flows III (Focus session, joint DY/CPP)

Organized by S. Gekle, G. Gompper, C. Wagner

Time: Tuesday 14:00–15:45 Location: ZEU 160

Invited Talk DY 20.1 Tue 14:00 ZEU 160

Particle based simulations of viscoelastic Soft Matter — •Wim Briels — University of Twente, Enschede, The Netherlands

In order to describe flow of soft matter in complex geometries detailed information is needed about how stresses depend on velocity gradients and concentration. Besides this, often compressible flow equations must be solved concomitantly with diffusion equations.

Since it is difficult to collect the appropriate information and to accurately represent it with a constitutive model, it is natural to develop particle based methods that can be applied to large portions of matter. In order to achieve this goal, large mesoscale objects must be represented by single particles, which move such that both the thermodynamic and the viscoelastic properties of the system are recovered.

The rheological response of Soft Matter usually results from a strong interplay between processes at all time and length scales, including the ones that have been removed by coarse graining. I will discuss a model in which the internal dynamics of the particles is reinstated through the introduction of a few structural parameters. I will apply our approach to describe the rheology of pressure sensitive adhesives and telechelic polymers. If time permits I will address some issues concerning the application of Brownian dynamics simulations of flowing soft matter in complex geometries.

DY 20.2 Tue 14:30 ZEU 160

Telechelic star polymers under shear. — •Diego Jaramillo-Cano[1], Manuel Camargo[2], and Christos N. Likos[1] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria. — [2]CICBA, Universidad Antonio Nariño Campus Farallones, Km 18 via Cali-Jamundí, 760030 Santiago de Cali, Colombia.

Telechelic star polymers(TPSs) are macromolecules formed by a number of diblock copolymers(arms) anchored to a common central core, being the internal monomers solvophilic and the end monomers solvophobic. Recent studies have demonstrated that TPSs constitute self-assembling building blocks with specific softness, functionalisation, shape and flexibility: depending on different physical and chemical parameters, e.g. number of arms f, solvophobic-to-solvophilic ratio α and solvent quality λ, the conformation of TSPs features a well defined number of attractive spots on the surface(patches). In this work, we exhaustively study the conformation of isolated TSPs under shear by means of a combination of MPCD for the solvent and standard MD for the monomers. By employing the Lees-Edwards boundary condition, we systematically evaluate star shape descriptors, patches distinctive features and star rotation frequency as a function of the Weissenberg number Wi for low functionality of the TPSs. We cover a wide range of parameters for representative systems given by f=18, α=0.3,0.5,0.7, λ=1.0,1.1 and Wi=1-1400. Since the conformation of single stars is expected to be preserved in low-density bulk phases, the presented results are a first step in understanding and predicting the rheological properties of semi-dilute suspensions of this kind of polymers.

DY 20.3 Tue 14:45 ZEU 160

Soft colloid suspensions in external flow fields — •Roland G. Winkler and Gerhard Gompper — ICS and IAS, Forschungszentrum Jülich, 52428 Jülich, Germany

Soft colloids, like linear polymers as well as more complex polymeric structures such as star polymers or polymer networks exhibit large conformational changes and an intriguing dynamics when exposed to, e.g., a shear flow [1]. The flow field leads to polymer stretching, associated with a shape change of the soft colloids, and alignment, which depend on the specific structure of the particle. The particular structure even more determines the nonequilibrium dynamics. We will present simulation results of the nonequilibrium properties of such polymeric structures obtained by combining the multiparticle collision dynamics method, a mesoscale simulation approach for fluids [2], with molecular dynamics simulations for embedded polymeric objects. Moreover, the rheological characteristics of semidilute suspensions of linear [3] and star polymers [4] as well as end-functionalized semiflexible polymers [5] will be discussed.

[1] R.G. Winkler *et al.*, Curr. Opin. Colloid Interface Sci. **19**, 594 (2014)
[2] G. Gompper *et al.*, Adv. Polym. Sci. **221**, 1 (2009)
[3] C.-C. Huang *et al.*, Macromolecules **43**, 10107 (2010)
[4] S. P. Singh *et al.*, J. Chem. Phys. **141**, 084901 (2014)
[5] J. S. Myung *et al.*, J. Chem. Phys. **143**, 243117 (2015)

DY 20.4 Tue 15:00 ZEU 160

Soft particles at a fluid interface — •Jens Harting[1,2,3], Hadi Mehrabian[2,3], and Jacco Snoeijer[3,2] — [1]Helmholtz Institute Erlangen-Nürnberg for Renewable Energy, Forschungszentrum Jülich, Fürther Str. 248, 90429 Nürnberg, Germany — [2]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands — [3]Physics of Fluids Group, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands.

Particles added to a fluid interface can be used as a surface stabilizer in the food, oil and cosmetic industries. As an alternative to rigid particles, it is promising to consider highly deformable particles that can adapt their conformation at the interface. In this study we compute the shapes of soft elastic particles using molecular dynamics simulations of a cross-linked polymer gel, complemented by continuum calculations based on linear elasticity. It is shown that the particle shape is not only affected by the Young's modulus of the particle, but also strongly depends on whether the gel is partially or completely wetting the fluid interface. We find that the molecular simulations for the partially wetting case are very accurately described by the continuum theory. By contrast, when the gel is completely wetting the fluid interface the linear theory breaks down and we reveal that molecular details have a strong influence on the equilibrium shape. See: Soft Matter 12, 1062-1073 (2016)

DY 20.5 Tue 15:15 ZEU 160

Migration-transition of sedimenting soft particles in vertical flows — •Andre Förtsch, Matthias Laumann, Diego Kienle, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth

The dynamics of soft, heavy (light) particles is investigated in plane Poiseuille flows between two vertical walls and in the limit of a vanishing Reynolds number. We observe, that heavy (light) soft particles migrate to (away from) the center of a parabolic Poiseuille flow profile with the flow direction parallel to the gravitational force, similar as for buoyant particles. If the flow direction is reversed and antiparallel to gravitation, we find a surprising reversal of the migration direction and heavier (lighter) particles migrate away from (to) the center of a parabolic flow profile. This transition of the migration direction is determined numerically by the Stokesian particle dynamics and the Lattice-Boltzmann-Method as well as analytically in case of small deformations of a ring polymer. The migration away from the center is slowed down due to hydrodynamic particle-wall interactions. The parameter dependence of the final off center particle position may be used for separating different particles.

DY 20.6 Tue 15:30 ZEU 160

Synthesis and characterization of asymmetric, viscoelastic micro-swimmers with a propulsion mechanism based on chemical reactions — •Monika Pella and Heinz Rehage — Physikalische Chemie II, Technische Universität Dortmund, D-44227 Dortmund, Deutschland

Analyzing the movement and self-organization of living cells, it is generally difficult to distinguish between physical interactions and biological processes. More detailed insights into the basic mechanisms of the swimming motions of living cells can by enabled by the investigation of artificial model swimmers. Hydrogel capsules are especially suitable for this purpose because they have similar mechanical properties as biological cells. Active chemical compounds can be stored as fuel in the core of these capsules, serving as an energy source for the propulsion of these particles. Accordingly, each swimmer has its own impellent and can move independently from each other. We investigated in different types of capsule swimmers using oxygen formation as backstroke that pushed the particles forward. Particularly the trajectories, the velocities, the attachments at solid walls, the physical-chemical properties

and the typical swarming behavior of these artificial capsule swimmers are interesting. In addition to these experiments, we also analyzed the capsule swimming motion in the regime of small and large Reynold numbers.

DY 21: Statistical Physics in Biological Systems (joint session DY/ BP/CPP)

Time: Tuesday 14:00–16:00 Location: ZEU 118

DY 21.1 Tue 14:00 ZEU 118

Epidemic spread in heterogeneous populations - Propagation of uncertainty and linear-noise approximation — •Francisco Herrerías-Azcué and Tobias Galla — School of Physics and Astronomy, The University of Manchester, Manchester, UK

The assumption of homogeneity in classic epidemic models is known to be far from realistic; Different susceptibilities may arise from gene expression and strain mutation. We explore the effects of heterogeneity in susceptibility and infectivity on the stochastic susceptible-infective-recovered (SIR) model of epidemic spread. Our focus is on understanding how these heterogeneities and uncertainties propagate to long-term periodic outbreaks. To do so, we study a structured population consisting of sub-classes with different susceptibilities and infectivities. These are assigned at birth, drawn from underlying fixed distributions.

We show how the system can be reduced to a four dimensional set of equations at the fixed point in the deterministic limit, independent of the number of sub-classes, and we derive the Langevin dynamics characterising fluctuations about this fixed point. To characterise the resulting noise-induced cycles we calculate the power spectra of fluctuations, and determine the features of the distributions of susceptibilities and infectivities shaping the quasi-cycles. In particular we explore how the mean or spread of susceptibilities affect the magnitude of the epidemic, and the period of outbreak cycles. We also investigate the dynamic behaviour and relative phase lag of different sub-populations during the outbreaks.

DY 21.2 Tue 14:15 ZEU 118

Impact of stochastic migration on species diversity in metafoodwebs consisting of several patches — •Tatjana Thiel and Barbara Drossel — Technische Universität Darmstadt, Germany

The structure of space has an appreciable influence on the diversity of ecosystems. So far, there are only few theoretical studies investigating the population dynamics of foodwebs consisting of many species that can migrate between several patches, and in most of these models migration is a continuous, deterministic process. However, when migration events are rare (for instance because the patches are far apart), migration is a stochastic process and should be modelled accordingly.

For this purpose, we place a foodweb model consisting of many species on a spatial network of several patches and evaluate the stable configurations and long-time patterns that arise due to the population dynamics. This dynamics has a deterministic contribution from the processes within a patch, and a stochastic contribution due to migration events, which are implemented using the Gillespie algorithm.

We will discuss how the frequency of migration events impacts species diversity on local and regional scales. Furthermore, we investigate in particular the adiabatic limit in which population dynamics always reaches an equilibrium before the next migration event and we will discuss which long-term scenarios are possible.

DY 21.3 Tue 14:30 ZEU 118

The Evolution of Network Structure and Species Diversity in an Evolutionary Meta-Foodweb Model — •Tobias Rogge[1], Korinna T. Allhoff[2], and Barbara Drossel[1] — [1]Technische Universität Darmstadt, Germany — [2]Université Pierre et Marie Curie, Paris, France

Evolutionary foodweb models provide important insights into the stability and the functioning of ecosystems on long time scales, since the network structure is a highly nontrivial outcome of the ongoing processes of species addition and species deletion. Here, we present and investigate an evolutionary food web model that includes no population dynamics but generates nevertheless a large variety of complex, multi-trophic networks. In this model, species are characterized by a few traits that are based on their body mass and that determine the connections to other species in the network. The system evolves due to the addition of new species, which are modifications of existing species. Species survival depends on the predators, the prey, and the competitors of the new species. We investigate this model on one habitat as well as on many habitats coupled by migration. Depending on the parameters, the long-term dynamics of the network can show layered structures, highly dynamical configurations with frequent extinctions, or frozen configurations that allow no mutant to survive. We identify the conditions under which the different types of dynamical and structural patterns emerge. Furthermore, we evaluate local and regional species diversities in the spatial model as well as species lifetime distributions, and we discuss them in an ecological context.

DY 21.4 Tue 14:45 ZEU 118

Mixed Percolation as a Model for Intra-Cellular Transport — •Andreas Koher[1], Patrick Hu[1], Igor M. Sokolov[2], and Philipp Hövel[1] — [1]TU Berlin — [2]HU Berlin

Intra-cellular diffusion is driven by a complex interplay between passively moving particles and a highly disordered, time-varying environment. To understand transport properties on a microscopical scale we propose a (mixed) percolation model that allows to reproduce a wide range of experimental observations analytically. The novel approach places a random walker on a lattice with *dynamic and static bonds*, i.e. parts of the lattice fluctuate with a given relaxation rate. Similar to static percolation problems, we find that the mean squared displacement undergoes a phase transition from a locally confined to a globally diffusing phase. However, unlike previous models the relaxation rate allows to fit short- and long-term transport properties to experimental observations. Finally, we validate our analytical results with Monte-Carlo simulations.

DY 21.5 Tue 15:00 ZEU 118

Entanglement of knotted DNA ring and an entwined DNA loop — •Saeed Najafi and Raffaello Potestio — MPIP, Mainz, Germany

Self-entanglement and knotting can play a crucial role in the mechanical and functional properties of bio-polymers such as DNA and RNA strands and fibers. By means of computer simulations of model DNA systems, we demonstrate that the crossing pattern of a braid of entwined DNA rings has a large impact on its structural and dynamical properties. In particular, we identify under which conditions the braid crossing pattern enforces a positive and stronger correlation between the entangled rings.

DY 21.6 Tue 15:15 ZEU 118

Chirality-mediated interaction between knots on tensioned polymers — •Raffaello Potestio — Max Planck Institute for Polymer Research, Mainz, Germany

Knots appear frequently in semiflexible (bio)polymers, including double-stranded DNA, and their presence can affect the polymers' physical and functional properties. It is possible and indeed often the case that multiple knots appear on a single chain, with effects which are under scrutiny since only a few years. In this talk I will discuss the equilibrium properties of two knots on a stretched semiflexible polymer, an idealization of a typical optical tweezer experiment. Specifically, I will focus on how the knots' relative chirality affects their interaction, rationalizing some of their pertinent features by means of simple effective models. The implications of the chirality-dependent knot-knot interaction will be discussed, in particular with respect to their consequences for the characterization and manipulation of these systems -be they artificial or of biological origin- and for their technological application.

DY 21.7 Tue 15:30 ZEU 118

Phenotypic switching as a strategy for persistence in stochastic environments — •Peter Hufton, Yen Ting Lin, and Tobias Galla — School of Physics and Astronomy, The University of Manchester, Manchester, UK

Bet-hedging constitutes a strategy for life to survive in demanding, fluctuating environments. The ideal example is found in bacterial populations: switching stochastically between phenotypes conveys a fitness advantage when exposed to episodes of antibiotics. But what

does the optimum switching strategy look like when, as in nature, the environment is itself unpredictable? Here, we present a theoretical study of the dynamics of growing populations subject to stochastic environmental switching, and provide a general framework for the analytic study of the fitness of such populations. Our original approach utilises the piecewise-deterministic Markov process, a technique which has seen increasing use in modelling biochemical process. Our results reveal significantly different behaviours to those found in periodic environmental conditions. We report that stochastic environments produce globally fitter populations, and that the optimum switching regimes in each case are markedly different.

DY 21.8 Tue 15:45 ZEU 118

Effect of slow-switching genetic states in gene regulatory network governing stem cell pluripotency — •Yen Ting Lin[1], Peter Hufton[2], Esther Lee[3], and Davit Potoyan[4] — [1]T-6 and CNLS, Los Alamos National Laboratory, USA — [2]School of Physics and Astronomy, The University of Manchester, UK — [3]Department of Bioengineering, Rice University, USA — [4]Center for Theoretical Biological Physics, Rice University, USA

Construction of the gene regulatory network (GRN) from experimental data requires a post-experimental analysis which established the pairwise correlations between the measured dynamical quantities. Then as a coarse description, each gene controls and/or is controlled by another gene(s), forming a network (GRN). Form another perspective of a single gene, the expression mechanism is encapsulated by the central dogma: the mRNA transcribes the sequence, and then the mRNA left the chromatin and synthesize proteins.

We present a detailed model combining these two approaches. Utilizing an analytic approximation we previously proposed, we show that the computational efficiency is dramatically increased on a GRN governing stem-cell differentiation. At different switching rates between the genetic states we inferred a unique parameter space which reproduces experimental results. Moreover, we found a unique space for the switching rates reproducing features from single-molecule experiments. Interestingly, the information entropy was maximized in this space. We argue that the consequence may be utilized to cell differentiations as an maximal information is encoded in the dynamics.

DY 22: Posters - Statistical Physics of Biological Systems

Time: Tuesday 14:00–16:00 Location: P1A

DY 22.1 Tue 14:00 P1A

Generic transport mechanisms for molecular traffic in cellular protrusions — •Isabella Krämer and Erwin Frey — Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität, München, Deutschland

Transport of molecular motors along protein filaments in a half-closed geometry is a common feature of biologically relevant processes in cellular protrusions. Using a lattice-gas model we study how the interplay between active and diffusive transport and mass conservation leads to localised domain walls and tip-localisation of the motors. We identify a mechanism for task sharing between the active motors (maintaining a gradient) and the diffusive motion (transport to the tip), which ensures that energy consumption is low and motor exchange mostly happens at the tip. These features are attributed to strong nearest-neighbour correlations that lead to a substantial reduction of active currents, which we calculate analytically using an exact moment-identity.

DY 22.2 Tue 14:00 P1A

The architecture of bacterial biofilms depends on biofilm age and active force generation — •Anton Welker, Nadzeya Kouzel, and Berenike Maier — Biophysik, Köln, Deutschland

Many bacterial species aggregate in communities, called biofilms. In contrast to individual bacteria, bacterial biofilms show a complex structure, which makes them resistant against a variety of environmental factors and causes environmental, industrial and medical problems. Bacteria can adjust the three dimensional structure of their biofilms to varying environmental conditions. However, the molecular mechanisms governing biofilm structure are unclear. Here, we characterized the three-dimensional structure of biofilms formed by the human pathogen *Neisseria gonorrhoeae* at cellular resolution. In particular, the local density distribution, radial distribution function and parameters describing ordering and defects were implemented. We found that force-generating and force-defective bacterial microcolonies show significant differences in microcolony shape and density. The radial distribution function showed a significant difference in local ordering dependent on biofilm age, indicating that the density and the fraction of diplococci increased with biofilm age.

DY 22.3 Tue 14:00 P1A

Interference of deleterious and beneficial mutations in spatial habitats — •Philipp Klatt and Joachim Krug — Institute for Theoretical Physics, Cologne, Germany

One of the fundamental questions of population genetics is that of the rate at which beneficial or deleterious mutations are generated and incorporated into asexual populations. The quantity which describes this process is the speed of evolution. We here study a spatially structured model in which individuals of a population only compete locally on the time scale of a generation. In contrast to well-mixed models, where individuals compete with the whole population, the speed of evolution tends to a finite value in the limit of infinite habitat size when all mutations are either beneficial or deleterious [1,2]. We consider the general case where both types of mutations are present and map out the dependence of the speed of evolution on several parameters by interpreting analytical and numerical results. In contrast to the well-mixed case, we find that large populations undergoing a fitness decline caused by the accumulation of deleterious mutations (Muller's ratchet) cannot be rescued by a small rate of beneficial mutations. Moreover, the effects of deleterious and beneficial mutations on the speed of evolution are generally not additive, suggesting a nontrivial interference between the two types of mutational effects.

[1] Martens, E.A. and Hallatschek, O. (2011). Interfering waves of adaptation promote spatial mixing. Genetics 189:1045-60.
[2] Otwinowski, J. and Krug, J. (2014). Clonal interference and Muller's ratchet in spatial habitats. Physical Biology 11:056003.

DY 22.4 Tue 14:00 P1A

Recombination and Speciation on Fitness Landscapes — •Alexander Klug and Joachim Krug — Institut für Theoretische Physik, Universität zu Köln, Germany

Deterministic evolution models with selection, mutation and recombination display multiple stable stationary states in one realisation of a fitness landscape [1]. These distinct stationary states are mostly sharply peaked, which implies that the major part of the population of one stationary state has the same genotype, even in the presence of mutation. The populated genotypes of different stationary states can then be thought of as different species, because they differ in a number of loci and are stable. We are investigating various aspects of these stationary states, such as the number of distinct stationary states that exist in different landscapes models (House-of-Cards model, percolation model [2]) and the properties of their basins of attraction under the deterministic dynamics. The results are interpreted in the context of the concepts of Dobzhansky-Muller incompatibility [1] and mutational robustness [3].

[1] T. Paixao, K. E. Bassler, R. B. R. Azevedo, bioRxiv 008268
[2] S. Gavrilets, Trends Ecol. Evol. 12:307-12 (1997)
[3] E. van Nimwegen, J. P. Crutchfield, M. Huynen, PNAS 96:9716-9720 (1999)

DY 22.5 Tue 14:00 P1A

Non-equilibrium dynamics of heterogeneous biological systems — •Federica Mura and Chase Broedersz — Department of Physics, Ludwig-Maximiliams-University Munich, Theresienstrasse 37, 80333 Munich, Germany

Recent experiments indicate that many biological systems, including the cytoplasm, actin-myosin networks, and chromosomal loci can be driven out of thermodynamic equilibrium. The active dynamics of these systems is governed by local stochastic forces resulting from enzymatic processes. To provide insight into the non-equilibrium dynamics of such systems, we propose a simple stochastic model of a d-dimensional bead-spring network subject to a heterogeneous distri-

bution of random driving forces. By using a combination of numerical simulations and analytical results we investigate how this non-equilibrium setting affects the system's steady state dynamics. We discuss how detailed balance is broken in the stochastic dynamics of different degrees of freedom and use this to quantify the rate of entropy production. Ultimately, this model could help to establish a systematic and more general method to extract information from a trajectory analysis of the stochastic dynamics of biological systems.

DY 22.6 Tue 14:00 P1A

Quantification of polymer loop shapes in application to chromosome oscillations — •Wenwen Huang and Vasily Zaburdaev — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In this contribution, we model the chromosomes in meiotic fission yeast by pinned bead-rod loops in external force field. The 3D gyration tensor containing information of all beads positions is calculated. Based on the gyration tensor, the shape of polymer loops is quantified under different strength of the external force field. We show that the resulting shape is more rod-like and prolate under strong force and more sphere-like and oblate under weak force. Our study provides a quantitative description of the shape of pinned polymer loops under external field and may help us to describe the relevant biological processes in fission yeast such as chromosome oscillations and their alignment during meiosis.

DY 22.7 Tue 14:00 P1A

From flexible to stiff: a homopolymer model state diagram and its morphologies — •Benno Werlich and Wolfgang Paul — Institut für Physik, MLU Halle-Wittenberg, Germany

A hard-sphere homopolymer model with attractive interaction potential can be varied in its stiffness by modification the bondlength. According to this variation, thermodynamic functions and geometric observables undergo changes which are presented in a state-diagram for a chain length of N=40. The morphologies, e.g. in the low temperature range, show peculiar changes in monomer ordering towards stiffer chains. We use a Stochastic-Approximation Monte-Carlo (SAMC) method for our off-lattice model simulations and generate an estimation to the microcanonical entropy S(E). This entropy is our statistical weight for canonical production runs.

DY 22.8 Tue 14:00 P1A

Predictability of mutational trajectories in evolutionary rescue — •Jan Schmidt and Joachim Krug — THP, Cologne

Predictability of evolutionary pathways has been considered in terms of the strong selection weak mutation model (SSWM), where the whole population moves monomorphically along pathways with increasing fitness while maintaining a constant population size [1,2]. We compare these trajectories to pathways that are taken by a population which is on the verge of extinction. Here, conceptually, the assumption of SSWM is no longer valid. Dropping the constraint of fixed population size, where the population does not fixate the intermediate types before the rescuing type is reached, this process is described in terms of a branching process [3].

[1] D.M. Weinreich et. al., Science 312, 111 (2006)
[2] J. Franke et. al., PLoS Comput Biol 7, e1002134 (2011)
[3] B. Bauer and C. Gokhale, Scientific Reports 5, 9607 (2015)

DY 22.9 Tue 14:00 P1A

Local optima in NK fitness landscapes — •Benjamin Schmiegelt, Sungmin Hwang, and Joachim Krug — Institute for Theoretical Physics, University of Cologne

Fitness landscapes, the assigment of fitness values to genotypes, determine the structural impact of selection on population dynamics. Populations will, especially under strong selection pressure, cluster around local optima. The number of local optima is also considered a measure of ruggedness, complexity and difficulty for a population to move on the landscape. The NK model models landscapes with parameter-controlled ruggedness and many possible interaction schemes between loci, sharinf similarities with p-spin glass models. For a quasi-one dimensional circular interaction layout the expected number of local optima is well established. We consider instead the case of random interaction networks, mean field and other variations and find, contrary to traditional assumptions, quantitatively different asymptotics for the expected numbers of local optima from the circular case.

[1] Weinberger, E. D. (1991). Local properties of Kauffman's N-k model: A tunably rugged energy landscape. Physical Review A, 44(10), 6399.
[2] Limic, V., & Pemantle, R. (2004). More rigorous results on the Kauffman-Levin model of evolution. The Annals of Probability, 32(3), 2149-2178.
[3] Schmiegelt, B., & Krug, J. (2014). Evolutionary accessibility of modular fitness landscapes. Journal of Statistical Physics, 154(1-2), 334-355.

DY 22.10 Tue 14:00 P1A

Stochastic switching of of Min proteins in short Escherichia coli cells — •Lukas Wettmann[1] and Karsten Kruse[2] — [1]Theoretische Physik, Saarland University, Saarbrücken, Germany — [2]NCCR Chemical Biology, Department of Biochemistry, Department of Theoretical Physics, University of Geneva, Geneva, Switzerland

Intracellular processes are subjected to noise, be it through thermal fluctuations or, for example, molecular noise. The latter case is especially true when the total number of involved molecules inside the cell is low. More interesting than the, for the case of gene expression, local changes in protein number is the stochastic behavior of spatially inhomogeneous protein distributions inside the cell.

To this end, we study the influence of noise on the dynamics of the Min system. The Min proteins are a family of proteins which through self-organization are able to exert spatial pole-to-pole oscillations in rod-shaped E. coli cells. These oscillations cause the division site to be located along the symmetry axis of the cell, ensuring equal-sized daughter cells. In contrast, for short cells, the oscillations are replaced by stochastic switching of the proteins between two stable polar configurations. This behaviour can cause the emergence of mini cells if the residence times are sufficiently long.

We developed a mechanism based on the underlying molecular processes to study the dynamics of the Min proteins. With this mechanism, we are able to use a framework developed in earlier work to analyze the behaviour of the Min proteins in the limit of weak noise and calculate the residence times as a function of the cell length.

DY 23: Microswimmers II (joint session DY/BP)

Time: Tuesday 14:30–15:45 Location: HÜL 186

DY 23.1 Tue 14:30 HÜL 186

Self-propelled Janus Droplets: Properties and Applications — •Leonard Li[1], Mahmoud Hosseinzadeh[1], Martin Brinkmann[1], Ignacio Pagonabarraga[2], Ralf Seemann[1], and Jean-Baptiste Fleury[1] — [1]Saarland University, 66123 Saarbrücken, Germany — [2]University of Barcelona, 08028 Barcelona, Spain

We report the existence of a new type of self-propelling Janus droplets in a continuous oil/surfactant solution. At start, the self-propulsion originates from a Marangoni flow generated by the solvent solubilization into the oily phase. During active motion, the droplets absorb a large amount of surfactant, which is preferentially soluble in the solvent phase. This surfactant adsorption into the droplet and the loss of solvent from the droplet lead, after some time, to spontaneous water/solvent phase separation and the formation of Janus droplet. In the Janus state, the solvent-rich droplet acts as a sink for the surfactant molecules, which get transported to and dissolved in the trailing droplet and thus drive the locomotion. Depending on initial solvent concentration the time before phase separation and thus the duration in the different propulsion regimes and with it different delivery modes can be programmed. After describing the properties of these active janus droplets, we will present their possible applications.

DY 23.2 Tue 14:45 HÜL 186

Collective dynamics of active emulsions under light sheet microscopy — •Babak Vajdi Hokmabad, Carsten Krüger, and Corinna Maass — MPI for Dynamics and Self Organization, Göttingen

Liquid crystal droplets exhibit Marangoni-flow-induced self-propulsion in an aqueous surfactant solution well above the critical micelle concentration. We can mass produce identical droplets with biomimetic properties, rendering these artificial swimmers promising experimental models to investigate the collective dynamics of biological microswimmers. We have previously shown that dimensional confinement plays a crucial role in the collective behavior of such active emulsions.

We study the collective dynamics of dense droplets ensembles in various conditions of number density, swimmer speed and buoyancy, resulting in effects like clustering and caging, using a custom built light sheet fluorescence microscope. A macroscopic sample volume, containing several hundred swimmers, is scanned via a system of a synchronized thin laser sheet and selective plane microscope, and individual trajectories for multiple swimmers can be recorded over long time scales.

DY 23.3 Tue 15:00 HÜL 186

Chemotaxis and auto-chemotaxis of self-propelling droplets — Chenyu Jin, Carsten Krüger, and •Corinna Maass — MPI for Dynamics and Self Organization, Göttingen

Chemotaxis and auto-chemotaxis are key mechanisms in the dynamics of micro-organisms. However, chemical signalling and the natural environment of biological swimmers are generally complex, making them hard to access analytically. Simple artificial systems showing biomimetic features can provide vital insights. We present self-propelling droplet swimmers with both chemotactic and autochemotactic properties, as well as microfluidic assays to study them quantitatively and reproducibly.

We demonstrate chemotaxis by guiding droplets through mazes in the presence of a chemical gradient.

To study auto-chemotaxis, we let swimmers pass through bifurcating microfluidic channels and record anticorrelations between the branch choices of consecutive droplets. We present an analytical model balancing a Brownian process versus a diffusion-governed gradient force able to explain our experimental findings.

DY 23.4 Tue 15:15 HÜL 186

Extreme fluctuations of active Brownian motion — •Patrick Pietzonka, Kevin Kleinbeck, and Udo Seifert — II. Institut für theoretische Physik, Universität Stuttgart

In active Brownian motion, an internal propulsion mechanism interacts with translational and rotational thermal noise and other internal fluctuations to produce directed motion. We derive the distribution of its extreme fluctuations and identify its universal properties using large deviation theory [1]. The limits of slow and fast internal dynamics give rise to a kink-like and parabolic behavior of the corresponding rate functions, respectively. For dipolar Janus particles in two- and three-dimensions interacting with a field, we predict a novel symmetry akin to, but different from, the one related to entropy production. Measurements of these extreme fluctuations could thus be used to infer properties of the underlying, often hidden, network of states.

[1] P. Pietzonka, K. Kleinbeck, U. Seifert, New. J. Phys. **18**, 052001 (2016)

DY 23.5 Tue 15:30 HÜL 186

Collective Sedimentation of Squirmers under Gravity — •Jan-Timm Kuhr, Felix Rühle, Johannes Blaschke, and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Biological microswimmers such as algae or plankton experience gravity. Recent theoretical studies on the sedimentation of microswimmers often explore the dilute case, where hydrodynamic and steric interactions between them can be neglected [1,2]. We apply parallelized MPCD simulations to study sedimentation of spherical squirmers under gravity and thereby explicitly include long-ranged hydrodynamic interactions also with bounding surfaces. We measure density profiles for systems of thousands of microswimmers and analyze how the ratio of active velocity to passive sedimentation velocity as well as the squirmer type (neutral, pusher, and puller) affect sedimentation.

Lower regions of the system are dominated by incomplete hexagonal layer formation with distinct orientation, whereas we recover an exponential density profile in the upper, less dense region. The average vertical orientation of the squirmers depends strongly on their vertical position as well as their type. Furthermore, we find that hydrodynamics organizes the microswimmers into convection cells, the strength of which changes with squirmer type and influences the sedimentation length.

[1] M. Enculescu and H. Stark, Phys. Rev. Lett. **107**, 058301 (2011).
[2] K. Wolff, A. Hahn, and H. Stark, Eur. Phys. J. E **36**, 43 (2013).

DY 24: Pattern Formation / Reaction-Diffusion I

Time: Tuesday 14:30–15:45 Location: ZEU 147

DY 24.1 Tue 14:30 ZEU 147

Control of traveling localized spots — •Steffen Martens[1], Christopher Ryll[2], Jakob Löber[1], Fredi Tröltzsch[2], and Harald Engel[1] — [1]Technische Universität Berlin, Institut für Theoretische Physik, 10623 Berlin, Deutschland — [2]Technische Universität Berlin, Institut für Mathematik, 10623 Berlin, Deutschland

Besides traveling waves, moving localized spots represent yet another important class of self-organized spatio-temporal structures in non-equilibrium dissipative systems. In this talk, we present two different approaches to guide localized spots along a pre-given trajectory. First, an analytical solution for the control – being an open-loop control – is proposed which attempts to shift the spot's "center of mass" according to a given protocol of movement without disturbing its profile [J. Löber and H. Engel, PRL **112**, 148305; J. Löber, PRE **89**, 62904]. The control signal is expressed in terms of the uncontrolled spot profile and its propagation velocity; rendering detailed informations about the reaction kinetics unnecessary. Secondly, optimal control with Tikhonov regularization is used. Noteworthy, both control schemes coincide for vanishing regularization term. In particular, our analytic control is an excellent initial guess for the numerical solution of optimal control problems; thereby achieving a substantial computational speedup [C. Ryll et al., *Control of Self-Organizing Nonlinear Systems* (Springer, Berlin-Heidelberg, 2016)].

DY 24.2 Tue 14:45 ZEU 147

Periodic sequence of stabilized wave segments in excitable media — •Vladimir Zykov and Eberhard Bodenschatz — Max-Planck-Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany

Wave segments represent an interesting and important example of spatio-temporal pattern formation in a broad class of nonlinear dynamic systems, so-called excitable media. They have been observed, for instance, in cardiac and cortex tissue, catalytic surface reactions, concentration waves in thin layers of the Belousov-Zhabotinsky reaction or during cell aggregation of Dictyostelium discoideum. For a given excitability a medium supports propagation of a wave segment with a selected size and shape, which is intrinsically unstable. In order to make this solution observable it has to be stabilized by an adequate noninvasive feedback control. For the case of a solitary propagating wave segments a universal selection rules have been found by use a free-boundary approach. The main aim of our study is to generalize these results on a case of a periodic sequence of wave segments. To this aim the translational motion of a stabilized wave segment in an excitable medium is numerically studied by use of a generic reaction-diffusion model with nonlinear activator-inhibitor kinetic. In addition, the free-boundary approach is applied to determine the wave segment shape and the speed as functions of the medium parameters. We hope that the results obtained in this study are also applicable to the spiral wave dynamics.

DY 24.3 Tue 15:00 ZEU 147

Propagation and Boundary Mediated Control of Reaction-Diffusion Waves in Modulated Tubes — •Alexander Ziepke, Steffen Martens, and Harald Engel — Institut für Theoretische Physik, Technische Universität Berlin, Germany

Propagation of traveling front and pulse solutions to reaction-diffusion equations within periodically modulated tubes is investigated. In the fashion of our recent paper [1], we apply asymptotic analysis for a small changing rate of the tube's cross-section to reduce the dimensionality

of the problem. Within this approach, the no-flux condition at the tube's boundary translates into a boundary-induced advection term. Treating the latter as a weak perturbation, we derive an equation of motion for the wave position [2]. Numerical simulations demonstrate that our analytical results predict properly the nonlinear dependence of the propagation velocity on the ratio of the period of the cross-section's spatial modulation to the intrinsic width of the wave solution. As a main feature, we observe finite intervals of propagation failure of waves induced by the tube's modulation. Further, using the derived equation of motion, the inverse problem of calculating the cross-section profile for a given protocol of motion is treated. This allows a geometry based control of chemical wave propagation. Additionally, we discuss the effects of a single bottleneck on periodic pulse trains.

[1] A. Ziepke, S. Martens, and H. Engel, *J. Chem. Phys.*, **145**, 094108 (2016).
[2] J. Löber and H. Engel, *Phys. Rev. Lett.*, **112**, 148305 (2014).

DY 24.4 Tue 15:15 ZEU 147

Hydrodynamic instabilities driven by complex chemical reactions — •Dario M. Escala[1], Jorge Carballido-Landeira[1], Anne DeWit[2], and Alberto P. Munuzuri[1] — [1]Nonlinear Physics Group, Univ. of Santiago de Compostela, Spain — [2]Nonlinear Physical Chemistry Unit, Univ. Libre de 6 Bruxelles (ULB), Belgium

Classical hydrodynamic instabilities in Hele-Shaw cells (like those produced by buoyancy or differences in viscosity) have been extensively studied during decades. The potential applications have aroused major interest in a variety of research fields with the aim of understanding the physics behind it and thus, find ways to control and model these systems. During the past years, researchers have increased the complexity of these investigations proposing interesting couplings between hydrodynamic instabilities and chemical systems. From simple neutralization reactions to more complicated autocatalytic reactions, a broad horizon has been opened where these coupled systems were also extensively analyzed and modeled seeking the description of new instabilities. Here, two setups will be analyzed that clearly demonstrate the constructive role played by the coupling of chemical and hydrodynamic instabilities. First, buoyancy-driven instability is generated due to the oscillatory Belousov-Zhabotinsky reaction. Second, a pH-shifting reaction which produces a new type of viscous finger instability. In both cases, the control parameters are varied. We use advanced optics techniques and numerical simulations as a complementary source of information in order to unveil the mechanisms underlying behind the observed phenomena.

DY 24.5 Tue 15:30 ZEU 147

Transition to chaos: From small to large systems in the Nikolaevskiy model — •Steffen Finger and Stefan Jakob Linz — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

The Nikolaevskiy equation originally introduced as a model for seismic waves [1] also appears in many different contexts ranging from instabilities of fronts over electroconvection to reaction-diffusion-systems and serves as a paradigmatic minimal model for the appearance of soft-mode turbulence in most parameter ranges. Extending the work by Tanaka [2] and using numerical simulations and Lyapunov exponent methods, we detect and classify the highly elaborate scenario of different transitions from regular dynamics to spatiotemporal chaos that appears when the system size is varied and periodic boundary conditions are applied.

[1] V. N. Nikolaevskii, Lecture Notes in Engineering 39, 210 (1989).
[2] D. Tanaka, J. Phys. Soc. Jpn. 74, 2223 (2005).

DY 25: Posters - Soft Particles, Microswimmers, Microfluidics

Time: Tuesday 18:15–21:00 Location: P3

DY 25.1 Tue 18:15 P3

2D simulation of Red Blood Cells in Capillaries. — •Zakaria Boujja[1], Chaouqi Misbah[2], and Christian Wagner[1] — [1]Saarland University, Experimental Physics, Saarbrücken, Germany — [2]Grenoble Alpes University, LIPHY, Grenoble, France

Blood at physiologic conditions is a dense suspension of cells, dominated in terms of its dynamics by red blood cells, they make up over approximately 40% of the blood volume, they are the blood component principally responsible for its rheology. RBCs are made of a two dimensional fluid bilayer of phospholipids, having underneath a network of proteins conferring to them shear elasticity. Simplified systems, like vesicles (made of a pure bilayer of phospholipid) and capsules (made of an extensible polymer shell) are used as models for RBCs, both systems reproduce several features known for RBCs under flow, the general problem is to understand the movement of cells under different flows and geometries.
The model used in our 2D simulation is the Giant Unilamellar Vesicle (GUV) model, the membrane curvature force will be calculated with the Helfrich elasticity theory. The numerical resolution will give us the vesicle shape as function of two carasteristic numbers the Capillary number (C_k) and the Confinement (C_n). A large number of studies were devoted to finding the equilibrium shapes of a RBCs in Poiseuille flow. We focused our study in a particularly interesting shape which has a motion like flagella, and called "Snaking Shape".

DY 25.2 Tue 18:15 P3

Tracking of PEG nanoparticles flowing around red blood cells inside microchannels — •François Yaya, Thomas John, and Christian Wagner — Experimental Physics, University of Saarland

During their life span in our body, red blood cells (RBC) travel through capilaries within a few microns in diameter. In this study, we reproduce these conditions using microfluidic chips with microchannels. Microchannels of 10 μm are built in polydimethylsiloxane (PDMS). Blood was drawn from a single donor from the fingertip and RBC were washed by standard protocol in a solution of Phosphate Buffered Saline (PBS) in which they were resuspended. Nanoparticles of polyethylene glycol (PEG) with a diameter of 250 nm were added at different concentrations. We use a high speed camera to record the particles flow at different pressure drops, flow velocities respectively, to monitor the particles displacements. We track these particles by image processing and we analyse the particles' trajectory. We show the behaviour of PEG nanoparticles around the RBC in different reference frames and different conditions (e.g. concentration, pressure). We give an overview on the parameters having an influence on the flow, vorticity and the nanoparticles distribution around the RBC.

DY 25.3 Tue 18:15 P3

Reduced-order hybrid multiscale method combining the regularized data from MD simulations with the macroscopic flow solver — Nehzat Emamy[1], Leonid Yelash[1], Mária Lukácová[1], •Stefanie Stalter[2], and Peter Virnau[2] — [1]Institut für Physik, JGU Mainz, Staudingerweg 7, 55128 Mainz — [2]Institut für Mathematik, JGU Mainz, Staudingerweg 9, 55128 Mainz

We introduce a reduced-order method to simulate the dynamics of complex materials (e.g. polymer/colloid systems) combining the continuum and atomistic descriptions. We follow the framework of heterogenuous multi-scale method (HMM), separating the scales to macro- and micro-levels. On the macro-level, the governing equations of the incompressible flow are the continuity and momentum equations, which are solved using a high-order accurate discontinuous Galerkin Finite Element Method (dG) and implemented in the BoSSS code. The missing information on the macro-level to solve the momentum equation is the stress tensor, which is computed from molecular Dynamics (MD) simulations on the micro-level. The data obtained from the MD simulations underlie relatively large stochastic errors, which can be controlled by means of the least square approximation. In order to reduce a large number of MD runs for the coupled simulations, we split the computations into an offline phase of expensive training and an online phase of fast multiple queries. In the training phase, we use the Greedy sampling algorithm as a model reduction technique to replace the nonlinear functionality of the stress tensor on the strain by a smooth low-dimensional reliable approximation.

DY 25.4 Tue 18:15 P3

blood crystal: shear-induced ordering in confined suspensions of red blood cells — •zaiyi shen[1], thomas m fischer[2], alexander farutin[1], jens harting[3,4], and chaouqi

MISBAH[1] — [1]Universite Grenoble Alpes/CNRS, Laboratoire Interdisciplinaire de Physique/UMR5588, Grenoble F-38041, France — [2]Laboratory for Red Cell Rheology, 52134 Herzogenrath, Germany — [3]Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Forschungszentrum Jülich, Fürther Strasse 248, 90429 Nürnberg — [4]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600MB Eindhoven, The Netherlands

We report on numerical simulations and experiments which reveal that red blood cells (RBCs) submitted to a shear flow between two parallel walls spontaneously show order, in the Stokes regime, in the form of a 2D crystalline pattern of purely hydrodynamic origin. Order appears as a subtle interplay between (i) the wall-induced migration requiring RBCs deformability, and driving cells away from walls towards the mid-plane and (ii) the intercellular hydrodynamic interaction which has both attractive and repulsive contributions depending on RBC interdistance. Various crystal-like orders arise depending on RBC concentration and confinement. The equilibrium distance between RBCs is shown to be a linear and universal function of confinement. Hardened RBCs in experiments, and rigid particles in simulations adopt a disordered pattern, highlighting the intimate link between particle deformability and the emergence of order.

DY 25.5 Tue 18:15 P3

blood crystal: shear-induced ordering in confined suspensions of red blood cells — •ZAIYI SHEN[1], THOMAS M FISCHER[2], ALEXANDER FARUTIN[1], JENS HARTING[3,4], and CHAOUQI MISBAH[1] — [1]Universite Grenoble Alpes/CNRS, Laboratoire Interdisciplinaire de Physique/UMR5588, Grenoble F-38041, France — [2]Laboratory for Red Cell Rheology, 52134 Herzogenrath, Germany — [3]Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Forschungszentrum Jülich, Fürther Strasse 248, 90429 Nürnberg, Germany — [4]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600MB Eindhoven, The Netherlands

We report on numerical simulations and experiments which reveal that red blood cells (RBCs) submitted to a shear flow between two parallel walls spontaneously show order, in the Stokes regime, in the form of a 2D crystalline pattern of purely hydrodynamic origin. Order appears as a subtle interplay between (i) the wall-induced migration requiring RBCs deformability, and driving cells away from walls towards the mid-plane and (ii) the intercellular hydrodynamic interaction which has both attractive and repulsive contributions depending on RBC interdistance. Various crystal-like orders arise depending on RBC concentration and confinement. The equilibrium distance between RBCs is shown to be a linear and universal function of confinement. Hardened RBCs in experiments, and rigid particles in simulations adopt a disordered pattern, highlighting the intimate link between particle deformability and the emergence of order.

DY 25.6 Tue 18:15 P3

Transport of ring polymers in microfluidic channels: A comparison to their linear counterparts — •LISA WEISS[1], ARASH NIKOUBASHMAN[2], and CHRISTOS N. LIKOS[1] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Institute of Physics, Johannes Gutenberg University, Mainz, Staudingerweg 7, 55128 Mainz, Germany

Ring polymers are an important class of biological and synthetic macromolecules. Due to the lack of free ends, they are expected to show distinct behaviour compared to their linear counterparts, as for example with respect to migration mechanisms, rheology or disentanglement. This simulation study aims at addressing the question, whether those two are transported distinctly in microfluidic devices. Since many biological ring polymers are in aqueous solution hydrodynamics is taken into account by a simulation method called Multi-Particle Collision Dynamics while the polymer itself is treated via Molecular Dynamics. We establish the existene of marked differences in the density profiles between linear chains and their cyclic counterpart in a Hagen-Poiseuille flow profile. In addition, we investigate the effects of polymer rigidity on their transport properties, which lead to a pronounced difference regarding depletion close to walls. On this basis we suggest possibilities to utilise these features as a means to separate the two architectures in microfluidic devices.

DY 25.7 Tue 18:15 P3

Cross-stream transport of asymmetric particles driven by oscillating shear — •M. LAUMANN[1], P. BAUKNECHT[2], A. FÖRTSCH[1], S. GEKLE[2], D. KIENLE[1], and W. ZIMMERMANN[1] — [1]Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Biofluid Simulation, Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth, Germany

We study the dynamics of asymmetric, deformable particles in oscillatory, linear shear flow. By simulating the motion of a dumbbell, a ring polymer, and a capsule we show that cross-stream migration occurs for asymmetric elastic particles even in linear shear flow if the shear rate varies in time. The migration is generic as it does not depend on the particle dimension. Importantly, the migration velocity and migration direction are robust to variations of the initial particle orientation, making our proposed scheme suitable for sorting particles with asymmetric material properties.

DY 25.8 Tue 18:15 P3

Active Brownian particles moving in a random Lorentz gas — •MARIA ZEITZ and HOLGER STARK — Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany

Biological microswimmers often inhabit a porous or crowded environment such as soil. In order to understand how such a complex environment influences their spreading, we numerically study noninteracting active Brownian particles (ABPs) in a two-dimensional random Lorentz gas. Close to the percolation transition in the Lorentz gas, they perform the same subdiffusive motion as ballistic and diffusive particles. However, due to their persistent motion they reach their long-time dynamics faster than passive particles and also show superdiffusive motion at intermediate times. While above the critical obstacle density η_c the ABPs are trapped, their long-time diffusion below η_c is strongly influenced by the propulsion speed v_0. With increasing v_0, ABPs are stuck at the obstacles for longer times. Thus, for large propulsion speed, the long-time diffusion constant decreases more strongly in a denser obstacle environment than for passive particles.

Moreover, we present first results how a constant gradient in obstacle density influences the dynamics of the system. We expect an induced drift along the gradient, similar to the *durotaxis* of motile cells which move along the stiffness gradient of the substrate.

DY 25.9 Tue 18:15 P3

Active Swimmers and convection — •JÉRÉMY VACHIER, STEPHAN HERMINGHAUS, and MARCO G. MAZZA — Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany

Active matter systems are driven out of thermodynamic equilibrium because the particles are able to convert energy into motion. Suspensions of self-propelled microscopic particles, such as swimming bacteria (*E. Coli*) or swimming algae (*Chlamydomonas*), exhibit collective motion. Describing the motion of these swimmers has an august place in the history of fluid mechanics. The small scale of our system implies that the hydrodynamics governing the motion are at low Reynolds numbers. We use the Stokes equation to describe the fluid, and we describe the swimmers as force dipoles, the swimmers are represented as spheroids, under Weeks-Chandler-Anderson (WCA) potential. We investigate the collective behaviour under mass convection due to a density mismatch. In order to simulate our system numerically, we use a hybrid method composed to Molecular Dynamics and Stochastic Rotation Dynamics. In this approach the fluid and the particles are represented with a particle based, coarse grained description. We study the dimensionless numbers, such as Péclet, Galilei and Sherwood numbers, characterizing the dynamics.

DY 25.10 Tue 18:15 P3

Controlled motion of L-shaped microswimmers — •TOBIAS BÄUERLE[1], JULIA RIEDE[1], DANIEL HÄUFLE[2], JAKOB STEINER[1], KEYAN GHAZI-ZAHEDI[3], SYN SCHMITT[1], CHRISTIAN HOLM[1], and CLEMENS BECHINGER[1,4] — [1]Universität Stuttgart, Deutschland — [2]Eberhard Karls Universität, Tübingen, Deutschland — [3]Max-Planck-Insitut für Mathematik in den Naturwissenschaften, Leipzig, Deutschland — [4]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Deutschland

Microswimmers can be steered by controlling the propulsion velocity depending on their orientation and position with respect to a target [1]. For spherical particles the orientation and, hence, the direction of motion changes only due to rotational diffusion. However, L-shaped particles, subjected to a gravitational force field, reorient depending on their orientation and swimming velocity [2]. In this sense, the shape of the particle, i.e. its morphology, significantly influences the swimming behavior. We investigate, numerically and experimentally, how this behavior can be exploited for steering these particles to reach a target position or follow a desired path. The resulting strategies are

quantitatively compared by different figures of merit, such as energy expenditure, time to reach the target, deviation from an ideal path, or morphological computation [3].

1 D. Haeufle et al., Physical Review E, 94, 012617 (2016)
2 Ten Hagen et al., Nature Communications, 5, 4829 (2014)
3 K. Ghazi-Zahedi et al., Frontiers in Robotics and AI, 3, 1 (2016)

DY 25.11 Tue 18:15 P3

Random Shaped Magnetic Micropropellers — •Felix Bachmann[1], Peter Vach[1], Agnese Codutti[1], Stefan Klumpp[2], Peter Fratzl[1], and Damien Faivre[1] — [1]Department of Biomaterials, Max Planck Institute of Colloids and Interfaces, Science Park Golm — [2]Theoretical Biophysics, Georg-August-University Göttingen

Swimming at low Reynolds number is a difficult task that diverges from our day by day experience. At the micrometer scale viscous forces play a dominant role and inertia can be neglected. Nature provides us with fascinating solutions for motion at low Reynolds numbers, e.g. swimming *E.coli* bacteria: moving their flagella in a cork screw manner, they overcome the hindrance of symmetry. Trying to mimic this mechanism, many achievements in designing and producing micro swimmers have been made over the last couple of years. Now the task is to optimize the motion process in this regime: moving fast and being able to control the moving pattern precisely.

In a step towards these goals, experiments with random shaped micropropellers allow exploring new avenues [1]. The characteristics and understanding of those random shaped micropropellers is subject of this work. Of particular interest are the very fast propellers and their morphology visualized through optical microscopy and tomography. Together with propelling characteristics like velocity-frequency dependence and direction pattern, this will help to create design guidelines for future task specific micropropellers.

[1] Vach PJ, Fratzl P, Klumpp S, Faivre D., Fast Magnetic Micropropellers with Random Shapes. Nano Letters. 2015;15(10):7064-7070.

DY 25.12 Tue 18:15 P3

Collective Dynamics of Squirmers in Poiseuille Flow — •Shahajhan Sorathiya and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin,Germany.

For their immense importance and impact on human health and ecology, we aim at understanding the collective behaviour of organisms like sperms, bacteria, and algae using the squirmer model. We present numerical simulations of a large number of squirmers confined in a channel and subjected to Poiseuille flow using multi-particle collision dynamics (MPCD). Building upon our understanding how a single microswimmer behaves near the wall and in Poiseuille flow [1,2], we report on results of a parametric study varying squirmer concentration, swimming speed, and strength of background flow.

We first verified the single-squirmer motion of tumbling and swinging trajectories as derived in Ref. [1]. Increasing density we then observe different types of clustering patterns formed by pushers and pullers in Poiseuille flow. We also report on the lateral density profile, which shows a depletion in the channel center according to experiments [3]. Finally, we investigate the average squirmer orientation close to walls, which heavily depends on concentration and background flow.

[1] A. Zöttl and H. Stark, Phys. Rev. Lett **108**, 218104 (2012).
[2] K. Schaar, A. Zöttl, and H. Stark, Phys. Rev. Lett **115**, 038101 (2015).
[3] R. Rusconi, J. S. Guasto, and R. Stocker, Nature Phys. **10**, 212 (2014).

DY 25.13 Tue 18:15 P3

Self-Chemotactic Properties of Active Droplets — •Mahmoud Hosseinzadeh[1], Leonard Li[1], Martin Brinkmann[1], Ignacio Pagonabarraga[2], Ralf Seemann[1], and Jean-Baptiste Fleury[1] — [1]Saarland University, 66123 Saarbrücken, Germany — [2]University of Barcelona, 08028 Barcelona, Spain

We explore the self-chemotactic properties of a new type of water/solvent emulsion droplets, which self-propel in a continuous oil/surfactant solution. Depending on solvent concentration the droplets evolve in up to three stages finally forming Janus droplets. We concentrate on the first stage, where the propulsion is generated by a Marangoni flow originating from the solvent solubilization into the oily phase. During active motion, the droplets additionally absorb a large amount of surfactant, which is preferentially soluble in the solvent phase. An increasing ethanol concentration in the continuous phase and a decreasing surfactant concentrations leads to repulsive chemotactic interactions. By adjusting the initial ethanol and surfactant concentration in the continuous phase we vary the chemotactic interactions of the droplets. In particular, we explore the consequences of the self-chemotactic properties in terms of flow properties (squirmer modes).

DY 25.14 Tue 18:15 P3

Active microrheology of dense microswimmer suspensions — •Alexander Liluashvili[1] and Thomas Voigtmann[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Köln, Germany — [2]Heinrich-Heine-Universität, Düsseldorf, Germany

The dynamics of self-propelled particles like microswimmers in dense environments are studied using the mode coupling theory of the glass transition. The theory is developed to investigate the glassy dynamics of active suspensions out-of-equilibrium, violating the fluctuation-dissipation-theorem relations.

As starting point of mathematical calculations the Mori-Zwanzig equations with orientational degrees of freedom in two dimensions are used. The final equations for the density two-point function in the time domain are solved numerically for the full model including the orientational degrees of freedom, as well as the spatial fluctuations.

DY 25.15 Tue 18:15 P3

Particle inertia induced passive swimming in oscillatory flows — •M. Laumann[1], I. Jo[2], Y. Huang[3], E. Kanso[3], D. Kienle[1], and W. Zimmermann[1] — [1]Theoretische Physik I, University of Bayreuth, 95440 Bayreuth, Germany — [2]Electrical Eng., University of Southern California, Los Angeles, California 90089, USA — [3]Aerospace and Mechanical Eng., University of Southern California, Los Angeles, California 90089, USA

Microswimmers are often actuted via active shape deformations. Here we describe a mechanism of passive swimming of soft particles in oscillatory homogenous flows, that is based on an interplay between their inertia and elasticity. This actuation strategy is demonstrated by analyzing a simple Λ shaped model analogous to Purcell's scallop, but passively deformed in homogeneous oscillatory flows [1]. In addition this actuation strategy is investigated for asymmetric bead-spring models in oscillatory flow by using a established hydrodynamic description of accelerated particles in flows [2]. We determine optimal parameters which maximize passive swimming. We also examine the stability of swimming motions and observe a transition from stable to unstable swimming. These results suggest that one can tune the background flow properties to control the swimmer motion, and thus, they may have profound implications on design and employment of artificial swimmers in oscillatory flows.

[1] I. Jo, Y. Huang, W. Zimmermann, E. Kanso, Phys. Rev. E **94**, 063116 (2016); [2] M.R. Maxey, J.J. Riley, Phys. Fluids **26**, 883 (1983).

DY 25.16 Tue 18:15 P3

Hydrodynamic ratchet — •František Slanina — Institute of Physics ASCR, Na Slovance 2, CZ-18221 Prague, Czech Republic

We investigate analytically a microfluidic device consisting of a tube with a nonuniform but spatially periodic diameter, where a fluid driven back and forth by a pump carries colloidal particles. Although the net flow of the fluid is zero, the particles move preferentially in one direction due to the ratchet mechanism, which occurs due to the simultaneous effect of inertial hydrodynamics and Brownian motion. We show that the average current is strongly sensitive to particle size, thus facilitating colloidal particle sorting.

DY 26: Posters - Statistical Physics, Stochastic Thermodynamics

Time: Tuesday 18:15–21:00 Location: P3

DY 26.1 Tue 18:15 P3

Investigating crystal-liquid interface by using fundamental measurement theory — •Shang-Chun Lin and Martin Oettel — Institut für Angewandte Physik, Universität Tübingen, 72076 Tübingen, Germany

The crystal-liquid interface is important in material science. To investigate crystal-liquid interface, fundamental measurement theory (FMT) within density functional theory (DFT) provides the almost accurate properties for the hard-sphere like system. In FMT, the equilibrium crystal-liquid interface has been done within DFT, but has not been tackled within dynamic density functional theory (DDFT). The dynamics play a crucial role in non-equilibrium systems, such as nucleation; however, so far only the bulk liquid phase has been done within DDFT. Thus, I attempt to model the crystal phase and crystal-liquid interface by using FMT within DDFT, and compare results with FMT within DFT.

DY 26.2 Tue 18:15 P3

Importance of many-body dispersion and temperature effects on gas-phase gold cluster (meta)stability — •Bryan R. Goldsmith, Philipp Gruene, Jonathan T. Lyon, David M. Rayner, André Fielicke, Matthias Scheffler, and Luca Ghiringhelli — Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6, 14195 Berlin, Germany

Gold clusters in the gas phase exhibit many structural isomers that are shown to intercovert frequently, even at room temperature. We performed ab initio replica-exchange molecular dynamics (REMD) calculations on gold clusters (of sizes 5-14 atoms) to identify metastable states and their relative populations at finite temperature, as well as to examine the importance of temperature and van der Waals (vdW) on their isomer energetic ordering. Free energies of the gold cluster isomers are optimally estimated using the Multistate Bennett Acceptance Ratio. The distribution of bond coordination numbers and radius of gyration are used to address the challenge of discriminating isomers along their dynamical trajectories. Dispersion effects are important for stabilizing three-dimensional structures relative to planar structures and brings isomer energetic predictions to closer quantitative agreement compared with RPA@PBE calculations. We find that higher temperatures typically stabilize metastable three-dimensional structures relative to planar/quasiplanar structures. Computed IR spectra of low free energy Au9, Au10, and Au12 isomers are in agreement with experimental spectra obtained by far-IR multiple photon dissociation in a molecular beam at 100 K.

DY 26.3 Tue 18:15 P3

Determination of elastic constants in the isothermal-isobaric ensemble — •Dominik Lips and Philipp Maass — Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, 49076 Osnabrück, Germany

The calculation of local elastic constants in heterogeneous materials from computer simulations is an important task for applications in materials science on the nanoscale and for a better understanding of biological processes involving elastic deformations. By combining Irving and Kirkwood's definition of a continuum stress field in terms of averages over phase space functions [1], and the work of Ray and Rahman on the calculation of bulk elastic constants by equilibrium stress fluctuations [2], Lutsko succeeded to derive a stress fluctuation formula to cope with the problem of local elastic constants in heterogeneous materials [3]. This approach has been worked out in the canonical ensemble and cannot be applied in constant pressure simulations, as they are nowadays often conducted in soft matter and biological systems. We present new stress fluctuation formulas valid in the isothermal-isobaric ensemble, for both local and bulk elastic constants [4]. Useful applications of these fluctuation formulas to complex heterogeneous soft matter systems subject to external pressure will be discussed.
[1] J. H. Irving and J. G. Kirkwood, J. Chem. Phys. **18**, 817 (1950).
[2] J. R. Ray and A. Rahman, J. Chem. Phys. **80**, 4424 (1984).
[3] J. F. Lutsko, J. Appl. Phys. **64**, 1152 (1988).
[4] D. Lips and P. Maass, preprint.

DY 26.4 Tue 18:15 P3

Impact of heterogeneities in power generation and transmission line admittances on power grid stability — •Matthias Wolff, Pedro Lind, and Philipp Maass — Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, 49076 Osnabrück, Germany

In theoretical studies, power grids are often investigated assuming topological simplifications, namely neglecting the heterogeneous features of transmission lines and generators. These grid heterogeneities, however, play an important role and need to be taken into account to predict critical states for failure. We analyze their impact on the grid stability based on the dynamical equations for the voltage phase angles and frequencies in the synchronous machine model [1], which we apply to an IEEE test grid. It is shown that disregarding heterogeneities can lead to biased estimates of the grid stability [2]. This conclusion is drawn by comparing the stability of the heterogeneous IEEE test grid with a partially and fully homogenized version of this network.

[1] T. Nishikawa and A. E. Motter, New J. Phys. 17, 015012 (2015).
[2] M. Wolff, P. Lind and P. Maass, preprint.

DY 26.5 Tue 18:15 P3

Machine learning quantum phases of matter beyond the fermion sign problem — •Peter Broecker[1], Simon Trebst[1], Juan Carrasquilla[2], and Roger Melko[2,3] — [1]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany — [2]Perimeter Institute for Theoretical Physics, Waterloo, Ontario N2L 2Y5, Canada — [3]Department of Physics and Astronomy, University of Waterloo, Ontario, N2L 3G1, Canada

Many-fermion systems exhibit some of the most intriguing physical phenomena in condensed matter physics such as the formation of non-Fermi liquids, superconductivity, or Mott insulators with fractionalized excitations. Exact analytical methods for the study of such fascinating phenomena are scarce and numerical tools are called for. However, one of the most powerful methods at our disposal - quantum Monte Carlo sampling - is often hampered by the fermion sign problem, which manifests itself most strikingly in the exponential growth of statistical errors and thus an exponential slowdown of the sampling. Here, we present the use of artificial neural networks as a powerful approach that is able to learn and distinguish quantum phases of matter despite the sign problem.

DY 26.6 Tue 18:15 P3

Nonequilibrium thermodynamics in the strong coupling and non-Markovian regime based on a redefined system-environment partition — •Philipp Strasberg — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany — Complex Systems and Statistical Mechanics, Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg

I propose a method to study the thermodynamic behaviour of small systems beyond the weak coupling and Markovian approximation, which is different in spirit from conventional approaches. The idea is to redefine the system and environment such that the effective, redefined system is again coupled weakly to Markovian residual baths and thus, allows to derive a consistent thermodynamic framework for this new system-environment partition. Besides general conclusions, I will also present particular model systems demonstrating the feasibility of this approach.

DY 26.7 Tue 18:15 P3

Apparent Entropy Production in Networks with Hidden Degrees of Freedom — •Matthias Uhl, Patrick Pietzonka, and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

The fluctuation theorem for entropy production is a remarkable symmetry relation for the distribution of produced entropy that holds universally in non-equilibrium steady states of Markovian systems. However, in systems with degrees of freedom that are hidden from the observer, it is not possible to infer the amount of produced entropy exactly. Previous work [1] suggested that a relation similar to the fluctuation theorem may hold at least approximately for such systems if one considers the apparent entropy production. By extending the notion of apparent entropy production to discrete bipartite systems we investigate which criteria have to be met for such a modified fluctuation theorem to hold in the large deviation limit and how the deviations

from the regular fluctuation theorem can be used to infer information on the hidden degree of freedom.
[1] J. Mehl, B. Lander, C. Bechinger, and U. Seifert, Phys. Rev. Lett. **108**, 220601 (2012)

DY 26.8 Tue 18:15 P3

Dissipationless precision by counting the time spent in a state — •Somrita Ray and Andre C Barato — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany.

We analyze the relation between precision and dissipation for a random variable that is the time a stochastic trajectory spends in a state. We find that for this random variable, precision can be obtained with an arbitrarily low energetic cost. This result is in contrast with the thermodynamic uncertainty relation for the currents, which establishes a minimal energetic cost for precision in a current like random variable. On the technical side, we obtain a general analytic expression for the dispersion of the time that a stochastic trajectory spends in a cluster of states for a unicyclic network.

DY 26.9 Tue 18:15 P3

Work and Power in the Strong Coupling Regime — Martí Perarnau-Llobet[1,3], •Henrik Wilming[2], Arnau Riera[3], Rodrigo Gallego[2], and Jens Eisert[2] — [1]Max-Planck-Institut fur Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [3]Institut de Ciencies Fotoniques (ICFO), The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain

We combine recent results in thermodynamics and the theory of equilibration in closed quantum systems to discuss work extraction of a quantum thermal machine strongly coupled to a heat bath. Giving the corrections to the weak-coupling limit, in particular we show that a finite coupling strength necessarily leads to irreversibility due to built-up of correlations. We then discuss the power of such strongly coupled thermal machines, showing that optimal power is reached for intermediate coupling strengths where the work per cycle is not optimal. Finally we exemplify all our results in the Caldeira-Leggett model. To analyze power in this model we also present new results regarding equilibration times in the Caldeira-Leggett model which might be of independent interest.

DY 26.10 Tue 18:15 P3

On the Role of Latent Variables in Stochastic Thermodynamics — •Jannik Ehrich and Andreas Engel — Institut für Physik, Carl von Ossietzky Universität, 26111 Oldenburg, Germany

Hidden variables play an important role for the entropy balance in stochastic thermodynamics. By constructing a general bipartite Markov chain we elaborate on several limiting cases including the setup of a sensor, a measurement-feedback-loop and a hidden Markov model. We derive and explain fluctuation theorems relevant to each of these setups. This view promises a unified approach for the understanding of the role of latent variables in stochastic thermodynamics.

DY 26.11 Tue 18:15 P3

Percolation transition of Fortuin-Kasteleyn clusters for the three-dimensional $\pm J$ random-bond-Ising model — •Hauke Fajen and Alexander K. Hartmann — Institute of Physics, University of Oldenburg

We investigated the behavior of the Wolff algorithm for the $\pm J$ Random-Bond-Ising model on a three-dimensional lattice. We studied the percolation transition of the Fortuin-Kasteleyn clusters. Our motivation is that the Wolff algorithm works best when the percolation transition temperature T_p and the phase transition temperatureT_c coincide. Fortuin-Kasteleyn clusters are constructed be randomly drawing subsets of bonds from all satisfied bonds of a given spin configuration. Each satisfied bond is considered with a possibility of $1-e^{-2J/T}$. Therefore we studied the percolation temperature T_p as a function of the fraction p of antiferromagnetic ($-J$) bonds. To measure the percolation probability we used the Swendsen-Wang algorithm to construct the Fortuin-Kasteleyn clusters. It's already known that the Wolff algorithm doesn't work efficiently for $p = 0.5$. Our results show that $T_p > T_c$ for most values of p, only near $p = 0$ T_p is equal T_c. We also studied an effective cluster size near p_c (ferromagnet-spin-glass transition) in the spin-glass phase. Nevertheless, close to T_c the effective cluster sizes remain small, showing that the Wolff algorithm is not efficient for all values $p > p_c$.

DY 26.12 Tue 18:15 P3

Phase diagram and critical phase transitions of driven granular matter in quasi 2d — •Thomas Schindler and Sebastian Kapfer — Theorie 1, FAU Erlangen

Driven granular matter exhibits a rich variety of nonequilibrium phases [1,2]. Recently, a critical transition to a state with quadratic order has been reported, with several critical exponents measurable [3]. We study this set-up by computer simulations, which consists of spherical particles between two horizontal plates. The particles are agitated by vibrating the plates in vertical direction. The energy injection is balanced by energy loss through inelastic collisions of the granular particles. Thus, the system reaches a steady state which exhibits phase behavior similar to equilibrium systems. The gap between the plates is about two particle diameters allowing the particles to form - besides fluid-like states - hexagonal and quadratic bilayers. We determine the relevant parameters for formation of ordered states, present a numerical phase diagram for this system, and study phase coexistence and criticality.
[1] Melby et al, J.Phys. Condens. Matter **17**, S2689 (2005)
[2] Reyes and Urbach, Phys. Rev. E **78**, 051301 (2008)
[3] Castillo et al, Phys. Rev. Lett. **109**, 095701 (2012)

DY 26.13 Tue 18:15 P3

A Linear Programming Approach to Graph-Coloring — •Daniel Grujic and Alexander K. Hartmann — Institut of Physics, University of Oldenburg

We study phase transitions in the combinatorial optimimization problem [1] in particular Graph-Coloring for Erdős-Rényi random graphs with N nodes and M edges. Graph coloring is an assignment of q colors to vertices in a way that no two adjacent vertices share the same color. To find such a solution we use the simplex algorithm known from linear programming (LP). Similiar studies were performed previously for other NP-hard problems like the Vertex-Cover problem [2] and the Travelling-Salesman problem [3]. We use a LP relaxation, which can lead to incomplete solutions where a node has multiple colors. We find that the LP is able to find complete solutions for small connectivities $c = \frac{2M}{N}$ which means the problem is "easy" there. At the critical connectivity c_{crit} a phase transition occurs. Beyond the critical point we find incomplete solutions with high probability. We try different methods to eliminate such incomplete solutions such as different types of *cutting planes*. We also try a pseudo-optimization, where we assign specific colors to specific nodes in advance and let the LP try to retain the colors. Both approaches lead to different critical thresholds c_{crit}.
[1] A. K. Hartmann, M. Weight, *Phase Transitions in Combinatorial Optimization Problems*, Wiley-VCH, Weinheim (2005)
[2] T. Dewenter, A. K. Hartmann, Phys. Rev. E **86**, 041128 (2012)
[3] Hendrik Schawe, Alexander K. Hartmann, EPL **113**, 30004 (2016)

DY 26.14 Tue 18:15 P3

Multifractal finite-size scaling at the Anderson transition in the unitary symmetry class — Jakob Lindinger, Andreas Buchleitner, and •Alberto Rodríguez — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

We carry out a full characterisation of the Anderson transition in the unitary symmetry class. We apply multifractal finite-size scaling [A. Rodriguez, L. J. Vasquez, K. Slevin, R. A. Römer, Phys. Rev. B 84, 134209 (2011)] to the 3-D Anderson model subjected to a random magnetic field, and estimate the critical parameters as well as the multifractal exponents with high precision using wavefunction data of systems up to $L^3 = 150^3$. We also examine the scaling of the probability density function and the spatial correlations of the wavefunctions intensities as the system undergoes the transition.

DY 26.15 Tue 18:15 P3

Characterisation of the superfluid to Mott insulator transition from multifractal fluctuations in Hilbert space — •Jakob Lindinger, Andreas Buchleitner, and Alberto Rodríguez — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

Recent theoretical work has revealed multifractality in Hilbert space as a generic feature of certain many-body systems even in the absence of disorder. The study of multifractal fluctuations in Fock space is particularly significant in the context of many-body localisation and

Anderson localisation in random graphs, where the potential existence of an extensive non-ergodic multifractal phase is currently under an intense debate which has led to a controversy. Inspired by these results, we explore the possibility of identifying fingerprints of the superfluid to Mott insulator transition in the fluctuations of the many-body wavefunction in Hilbert space. We present preliminary numerical and analytical results obtained for the Bose-Hubbard model.

DY 26.16 Tue 18:15 P3

Analysis of bifurcations in stochastic biological networks with few nodes — •Marc Mendler, Johannes Falk, and Barbara Drossel — Technische Universität Darmstadt, Institut für Festkörperphysik

We investigate how intrinsic noise, which is due to small molecule numbers, influences the occurrence, position and critical parameter values of saddle-node and hopf bifurcations in reaction networks with few nodes.

In recent years new experimental techniques have enabled researchers to observe and analyse biological systems at the single cell level. At those scales intrinsic noise can play a significant role and alter the system's behaviour. In order to describe such systems correctly, one has to utilize stochastic methods.

Based on the Fokker Planck equation we investigate how the number and position of local maxima of the stationary distribution changes and relates to the position of fixed points and bifurcations in the deterministic description. We apply these methods to stochastic saddle-node and hopf bifurcations. Using simple example systems, we also compare our analytical results with numerical simulations.

DY 27: Posters - Statistical Physics Biological Systems

Time: Tuesday 18:15–21:00 Location: P3

DY 27.1 Tue 18:15 P3

Effects of migration on an evolutionary food-web model without explicit population dynamics — •David Jones, Tobias Rogge, and Barbara Drossel — Hochschulstraße 6, 62489 Darmstadt

Given the complexity of the structure of ecosystems and the interactions of the multitude of species therein, modeling of food-webs can prove to be a crucial tool in understanding the patterns that can be observed in nature. Here we present an evolutionary model to generate a network of complex, multi-trophic food-webs on a grid of habitats without a need for population dynamics. The individual species are defined by a small number of body mass based traits. These traits in turn define the links between the species within the food-web. After the initiation of a simple food-web on each node of the grid, mutations of existing species lead to the addition of species to a food-web, whereas migration allows a species to invade a neighboring food-web on the grid. Random extinction events are additionally implemented to prevent frozen configurations of the food-web network. After each mutation, migration or extinction event, the survival criterion is evaluated for the altered food-web structure. Species that do not fulfill the survival criterion within a food-web die out of the respective food-web. We explore the effect of migration on the network of food-webs and evaluate quantities that are of ecological interest, in particular species area laws.

DY 27.2 Tue 18:15 P3

Thermodynamic bounds on the ultra- and infra-affinity of Hsp70 for its substrates — •Basile Nguyen[1,2], David Hartich[1], Paolo De Los Rios[2], and Udo Seifert[1] — [1]II. Institut für Theoretische Physik, Universität Stuttgart, Stuttgart, Germany — [2]Laboratory of Statistical Biophysics, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Heat shock proteins 70 (Hsp70s) have essential functions in living systems, such as protecting proteins against aggregation and assisting protein folding. They are ATP-driven machines which rely on allosteric regulation to optimally tune their affinity to specific substrates (e.g., misfolded or partially folded proteins). Hsp70s use the chemical free energy from an ATP hydrolysis to show affinity to their substrates beyond the equilibrium bounds, these regimes are called ultra- and infra-affinity. We derive a thermodynamic relation which quantifies how far the affinity can be tuned using the finite energy budget of hydrolysing one ATP. We find that an optimal tuning requires fast hydrolysis and nucleotide exchange reactions with respect to substrate binding and unbinding. Most remarkably, Hsp70s work with cofactors which are observed to catalyze these key reactions. Therefore, we show that the Hsp70 system is optimally tuned to achieve ultra-affinity, thus explaining how it prevents aggregation and refolds efficiently. Finally, we consider small GTPases which can benefit from infra-affinity to optimize intracellular signal transduction.

DY 27.3 Tue 18:15 P3

Giant Acceleration of Diffusion for Molecular Motors — •Lukas P. Fischer, Patrick Pietzonka, and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, Germany

Recent experimental studies have shown the existence of giant acceleration of diffusion for molecular motors [1]. Typically, such an effect is observed for driven continuous motion in a periodic potential [2]. The existence of giant acceleration for molecular motors gives rise to new characteristics for probing the underlying molecular mechanism. We examine the hybrid model, consisting of a bead harmonically coupled to a discretely jumping motor, under the effect of an external force [3]. We present the force-dependence of the velocity and the diffusion coefficient which is comparable to the diffusion in periodic potentials. This allows us generalize the giant diffusion to more complex models. By considering different system parameters we reveal a rich structure of the dependence of the velocity and diffusion coefficient. For very large jump rates of the motor the hybrid system can be effectively mapped to a probe particle diffusing in a periodic potential. The general behavior, however, depends crucially on the complete set of parameters.

[1] R. Hayashi *et al.*, Phys. Rev. Lett. **114**, 248101 (2015)
[2] P. Reimann *et al.*, Phys. Rev. Lett. **87**, 010602 (2001)
[3] E. Zimmermann *et al.*, Neq J. Phys. **14**, 103023 (2012)

DY 27.4 Tue 18:15 P3

Can one hear the length of an axon? — •Frederic Folz[1], Lukas Wettmann[1], Karsten Kruse[2], and Giovanna Morigi[1] — [1]Department of Theoretical Physics, Saarland University, Saarbrücken, Germany — [2]NCCR Chemical Biology, Department of Biochemistry, Department of Theoretical Physics, University of Geneva, Geneva, Switzerland

Axons are linear processes of nerve cells that can range from a few tens of micrometers up to meters in length. In addition to external cues, the length of an axon is also regulated by unknown internal mechanisms. Molecular motors have been suggested to generate oscillations with a length-dependent frequency that could be used to measure an axon's extension. Here, we present a mechanism that uses the oscillatory signal to regulate the axon length. We show that in addition to the frequency also the form of the oscillations contribute significantly to determining the steady state length.

DY 27.5 Tue 18:15 P3

Receptor activation — •Cheng-Yu Sun[1] and Hsuan-Yi Chen[1,2] — [1]Department of Physics, Nation Central University, Taoyuan 32001, Taiwan — [2]Institute of Physics, Academia Sinica, Taipei 11520, Taiwan

To effectively detect external environment, receptors in biological cells have to be sensitive and efficient. In this study, we consider a general receptor activation model. In our model, a binding site can bind to a ligand, it can also be activated by an activator. Depending on its binding and activation state, a binding site has four states. We allow couplings between sites through their binding states and activation states. The equilibrium study reveals that strong switch-like behavior can be achieved by strong coupling of the activation states between the sites, while the additional coupling of the binding state helps to strengthen this effect. We also study the dynamics of coupled sites. The results show the important role played by the ratio between binding rate and activation rate. The regions where the behavior of this system becomes similar to classical MWC and Pauling models are discussed.

DY 27.6 Tue 18:15 P3

A minimal spatial cell lineage model of epithelium exhibits tissue stratification and multi-stability — Wei-Ting Yeh[1] and •Hsuan-Yi Chen[1,2] — [1]Department of Physics, National Central University, Jhongli, 32001, Taiwan — [2]Institute of Physics, Academia Sinica, Taipei, 11529, Taiwan

In this work, we consider stratified epithelium, which is a multi-layered self-renewal tissue, and build up a minimal model which includes the spatial information and cell lineage dynamics. We numerically and analytically solve the steady state and discuss how different differentiation models can lead to different tissue functionality and stratification. Thus, we provide a possible way to deduce the unknown cell differentiation mechanism by fitting the observed degree of stratification with our model.

The minimal model also shows other properties. For example, we find that there is no stratified steady state if there is only short-range interaction between cells. In other word, we need long-range interaction like coupling with morphogen dynamics to avoid the trivial homogeneous state. Interestingly, our model in general permits the existence of multiple steady states if both long- and short-range interaction between cells are present, and the degree of functionality and stratification is different for each steady state. In the future, it is possible to study the transition between these states and discuss its biological relevance to tissue morphogenesis and cancer invasion.

DY 28: Posters - Dynamics of Many-Body Systems

Time: Tuesday 18:15–21:00 Location: P3

DY 28.1 Tue 18:15 P3

Typical relaxation dynamics to equilibrium, thermal or non-thermal, of isolated many-body quantum systems — •Ben Niklas Balz and Peter Reimann — Fakultät für Physik, Universität Bielefeld, Germany

In the recent past, typicality arguments were used extensively to corroborate that isolated quantum many-body systems equilibrate and that the associated steady state is naturally given by the microcanonical ensemble. These statements are usually derived making use of uniformly distributed unitary transformations (Haar measure) and therefore do not take conserved quantities into account. In the following we are going to present an adapted typicality technique, employ it to derive the corresponding relaxation dynamics and present numerical as well as experimental data in its support.

DY 28.2 Tue 18:15 P3

Pinned-to-sliding transition and structural crossovers for helically confined charges — •Alexandra Zampetaki[1], Jan Stockhofe[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

We explore the non-equilibrium dissipative dynamics of a system of identical charged particles trapped on a closed helix. The particles are subject to an external force accelerating them along the underlying structure. The effective interactions between the charges induce a coupling of the center-of-mass to the relative motion which in turn gives rise to a pinned-to-sliding transition with increasing magnitude of the external force. In the sliding regime we observe an Ohmic behaviour signified by a constant mobility. Within the same regime a structural transition of the helical particle chain takes place with increasing the helix radius leading to a global change of the crystalline arrangement. The resulting crystal is characterized by the existence of multiple defects whose number increases with the helix radius.

DY 28.3 Tue 18:15 P3

Theory of quantum scattering for quantum scatterers — •Ankita Bhattacharya[1,2] and Shyamal Biswas[2] — [1]Institute of Theoretical Physics, TU Dresden, Germany — [2]School of Physics, University of Hyderabad, India

We have analytically explored the phenomenon of quantum scattering for unfixed quantum scatterer(s) in quantized bound states in different types of box geometry and potential-trapped geometry. We have considered short ranged (Fermi-Huang δ_p^3) interaction between the incident particle and the scatterer(s) with no interactions among the scatterers, and the scatterer(s) as (i) particle(s) in a 1-D box, (ii) particle(s) in a 1-D double box, (iii) particle(s) in a 1-D grating, (iv) particle(s) in a 2-D rectangular box, (v) particle(s) in a 3-D harmonic trap, (vi) Bose-Einstein condensates in a double well, (vii) Bose-Einstein condensates in an optical lattice, etc. Coherent scattering from all possible positions of the quantum scatterers in the finite geometry gives rise to rich physics specially for the interference between the scattering due to the aperture and that due to the scatterer(s) in the aperture. We have predicted differential scattering cross-section for particle scattering, not only for the above cases, but also for 3-D harmonically trapped Bose and Fermi gases in thermodynamic equilibrium. We also have explored temperature dependence of the quantum scattering even for 3-D ideal quantum gases in the restricted geometries. Our predictions can be tested within the present day experimental setups.

DY 28.4 Tue 18:15 P3

The role of particle (in-)distinguishability for many-particle dynamics in optical lattices — Tobias Brünner, Gabriel Dufour, •Alberto Rodríguez, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

Much attention has been dedicated so far to the dynamical impact of interactions —which often can be associated with the progressive suppression of coherence phenomena. On the other hand, little is known on the fundamental role of the interacting particles' degree of mutual (in-)distinguishability in such experiments. We have learnt from a new generation of photonic interference experiments and theory that controlling the degree of (in-)distinguishability unveils novel many-particle interference phenomena. We import this program into the realm of controlled, interacting many-particle quantum systems, specifically for cold atoms in optical lattices, and identify statistical, experimentally readily accessible quantifiers to infer the particles' degree of distinguishability.

DY 29: Physics of Collective Mobility (Symposium SYCM, joint SOE / DY / BP / jDPG)

Time: Wednesday 9:30–12:15 Location: HSZ 02

Invited Talk DY 29.1 Wed 9:30 HSZ 02

Mobility in shareability networks — •Michael Szell — Centre for Social Sciences, Hungarian Academy of Sciences, Országház utca 30, 1014 Budapest, Hungary — Center for Network Science, Central European University, Nador utca 11, 1051 Budapest, Hungary — Center for Complex Network Research, Northeastern University, 177 Huntington Avenue, 02115 Boston, USA — moovel lab, Haupstätter Straße 149, 70178 Stuttgart, Germany — Senseable City Lab, MIT, 77 Massachusetts Ave, 02139 Cambridge, USA

We introduce the notion of shareability network, which allows us to model the collective benefits of sharing trips as a function of passenger inconvenience, and to efficiently compute optimal sharing strategies on massive datasets. We apply this framework to a dataset of millions of taxi trips taken in New York City, showing that cumulative trip length can be cut by 40%. This benefit comes with reductions in emissions and split fares, hinting toward a wide passenger acceptance. Shareability as a function of trip density saturates fast, suggesting effectiveness of the taxi sharing system also in cities with much sparser taxi fleets. We compute the shareability curves in several further world cities, and find that a natural rescaling collapses them onto a single, universal curve. We explain this scaling law with a simple model that predicts the potential for ride sharing in any city, using a few basic urban quantities and no adjustable parameters. Finally, we demonstrate how interactive data visualizations of re-ordered city spaces can effectively inform relevant stakeholders and the public about large-scale reductions of parking spaces in future scenarios of wide-spread car-sharing.

Invited Talk DY 29.2 Wed 10:00 HSZ 02

Trail-following bacteria: from single particle dynamics to collective behaviour — Anatolij Gelimson[1], Kun Zhao[2,3], Calvin K. Lee[3], W. Till Kranz[1], Gerard C. L. Wong[3], and •Ramin Golestanian[1] — [1]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3NP, United Kingdom — [2]Key Laboratory of Systems Bioengineering, Ministry of Education, School of Chemical Engineering and Technology, Tianjin University, Tianjin, 300072, People's Republic of China — [3]Bioengineering Department, Chemistry & Biochemistry Department, California Nano Systems Institute, UCLA, 90095-1600, Los Angeles, CA, USA

Can we learn from bacteria how to coordinate our mobility, and navigate our way towards mutually beneficial collective states? Trail-following bacteria leave behind precious exopolysaccharides as marker of where they been, and use it to accelerate the formation of colonies. We study this phenomenon, by building a stochastic microscopic model for the pili-driven motility of bacteria that interact with trails which could be laid by themselves and others. We discuss its phenomenology both at the level of single bacterium dynamics and collective self-organization into colonies. We validate the model using Pseudomonas aeruginosa trajectories, and show that fitting the parameters at the single bacterium level leads to a good quantitative agreement between the predictions of the model for the collective behaviour of the colony and the corresponding experimental observations.

Invited Talk DY 29.3 Wed 10:30 HSZ 02

Mobility and Self-Organization in Multi-Layer Networks: A Meta-Foodweb example — •Thilo Gross[1], Andreas Brechtel[2], Philipp Gramlich[2], Daniel Ritterskamp[1], and Barbara Drossel[2] — [1]Department of Engineering Mathematics, University of Bristol, Bristol, UK — [2]Institut für Festkörperphysik, TU Darmstadt, Darmstadt, Germany

The emergence of structures and patterns from diffusive motion has long fascinated scientists. This phenomenon is best known from systems in continuous space. In this talk I will propose a general approach for the study of such phenomena in certain multi-layer networks.

I focus on the example of ecological meta-foodwebs, which describe the dispersal of animals across a fragmented landscape. Each individual undergoes diffusive motion on a network where the nodes are habitats and the links are routes of potential migration. Furthermore, the individuals are subject to predator-prey interactions with other individuals, described by a complex food web. The meta-foodweb thus constitutes a large multiplex network-on-network system.

To study the onset of self-organized pattern formation I consider the dynamical stability of steady states. By exploiting the structure of the system it is possible to separate the effects of the food-web and the geographical network and write a master stability function for the system. The result is a reduced system that bears a remarkable resemblance to pattern forming systems in continuous space, but has much richer behaviour.

15 min. break

Invited Talk DY 29.4 Wed 11:15 HSZ 02

Temporal Percolation in Critical Collective Mobility Systems — •Andreas Sorge[1,2,4], Debsankha Manik[1,2], Jan Nagler[3,4], and Marc Timme[1,2,4] — [1]MPI for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität, Göttingen, Germany — [3]Computational & Theoretical Physics, IfB, ETH Zürich, Switzerland — [4]Organization for Research on Complex Adaptive Systems (or-cas), Göttingen, Germany

A collective mobility system is a stochastic dynamical system that operates under opposing objectives. Its function is to both satisfy individual mobility demand in a timely fashion and make efficient use of the available transport vehicles. To understand and design such a system, one must study, devise and assess dispatching rules that bundle individual requests and assign them to vehicles. If overall mobility demand exceeds capacity, the system congests and ceases to function. Determining the capacity is henceforth crucial to assess any given dispatching rule and inform system design for optimized system performance and individual utility. Intriguingly, the brink to congestion constitutes a critical transition reminiscent of percolation in time. We develop a dynamic notion of criticality of such stochastic processes, mapping return times to spatial clusters of percolation theory. We present a method to algorithmically determine the critical point and exponents and its application to collective mobility systems in this temporal percolation paradigm.

Invited Talk DY 29.5 Wed 11:45 HSZ 02

Modeling the evolution of cities — •Marc Barthelemy — IPhT/CEA, Saclay, France — CAMS/EHESS, Paris, France

The recent availability of data about cities and urban systems opens the exciting possibility of a 'new Science of Cities'. Urban morphogenesis, activity and residence location choice, mobility, urban sprawl and the evolution of urban networks are just a few of the important processes that can be discussed now from a quantitative point of view. In this talk, I will discuss how a data-informed approached can elaborate on urban economics models in order to get predictions in agreement with empirical observations. I will illustrate this approach on the growth of cities and the emergence of a polycentric structure of activity centers. I will conclude by highlighting some important challenges and possible research directions.

DY 30: Invited talk

Time: Wednesday 9:30–10:00 Location: HÜL 186

Invited Talk DY 30.1 Wed 9:30 HÜL 186
Fast quantum processes without excitations: shortcuts to adiabaticity — •Sebastian Deffner — University of Maryland Baltimore County (UMBC), Baltimore, USA

Achieving effectively adiabatic dynamics in finite time is a ubiquitous goal in virtually all areas of modern physics. So-called "shortcuts to adiabaticity" refer to a set of methods and techniques that allow to produce in a short time the same final state that would result from an adiabatic, infinitely slow process. After briefly reviewing the major techniques to achieve such shortcuts to adiabaticity, we discuss two recent developments: (i) We generalize the "fast-forward technique" to driven Dirac dynamics. As a main result we find that shortcuts to adiabaticity for the (1+1)-dimensional Dirac equation are facilitated by a combination of both scalar and pseudoscalar potentials. (ii) In a second part of the talk, we focus on how to thermodynamically quantify the cost of implementing "transitionless quantum driving". We find that there is a trade-off between speed and cost, i.e., the faster such a shortcut shall be implemented, the higher the corresponding thermodynamic cost.

DY 31: Particulate Matter I: From microscopic interactions to collective motion (Focus session)

Particulate systems, such as colloids, foams, granular as well as active matter, share common features such as jamming, non-locality and intermittency. However, the daily life experience of building a sand sculpture tells us that tuning slightly the particle-particle interactions may lead to a dramatically different collective behaviour. This focus session shall discuss how properties at the microscopic particle level, such as form, softness and interactions, influence the collective behaviour of particulate systems: From static problems such as jamming and glass transition to dynamic ones such as pattern formation and phase transitions, from thermally driven colloids to granular and self-propelled particles driven far from thermodynamic equilibrium. The goal is to identify universal laws for a better understanding, controlling and eventually designing the collective behaviour of particulate systems that widely spread in nature, industry and our daily lives.

Organized by K. Huang and S. Herminghaus

Time: Wednesday 9:30–13:00 Location: ZEU 118

Invited Talk DY 31.1 Wed 9:30 ZEU 118
Magnetocapillary interactions for self-assembling dynamical systems — •Nicolas Vandewalle, Galien Grosjean, and Maxime Hubert — GRASP, Institute of Physics B5a, Sart Tilman, University of Liege, B4000 Liege, Belgium

When soft ferromagnetic particles are suspended at air-water interfaces in the presence of a vertical magnetic field, dipole-dipole repulsion competes with capillary attraction such that 2d structures are self-assembling. The complex arrangements of such floating bodies are emphasized. The equilibrium distance between particles exhibits hysteresis when the applied magnetic field is modified. Irreversible processes are evidenced. By adding a horizontal and oscillating magnetic field, periodic deformations of the assembly are induced. We show herein that collective particle motions induce locomotion at low Reynolds number. The physical mechanisms and geometrical ingredients behind this cooperative locomotion are identified. These physical mechanisms can be exploited to much smaller scales, offering the possibility to create artificial and versatile microscopic swimmers. Moreover, we show that it is possible to generate complex structures that are able to capture particles, perform cargo transport, fluid mixing, etc...

Invited Talk DY 31.2 Wed 10:00 ZEU 118
Influences of fluxes in nonequilibrium soft matter — •Marco G. Mazza — Max Planck Institute for Dynamics and Self-Organization, Göttingen

The world contains structures at every scale that are produced by nonequilibrium processes. We investigate how fluxes of matter or energy can create states with structural and dynamical properties completely absent in equilibrium systems. We will discuss two recent results in soft matter systems. Firstly, we will show with computer simulations and theory how deformations in the liquid crystals' orientational fields lead to colloidal self-assembly. Secondly, we discuss by means of experiments and simulations how to rationalize an intriguing nonequilibrium phase separation in driven granular materials without invoking *ad hoc* equilibrium-like assumptions.

DY 31.3 Wed 10:30 ZEU 118
How does a magnetic snake swim in a pool billiard? — Florian Johannes Maier, Markus Sesselmann, Ingo Rehberg, and •Reinhard Richter — Experimentalphysik 5, Universität Bayreuth, 95440 Bayreuth, Germany

We experimentally investigate magnetic surface swimmers on water. Those are moving objects, which self-assemble from ferromagnetic micro-particles, floating on the liquid surface due to interface tension, under the influence of an harmonically oscillating homogeneous magnetic field oriented vertically and a non-magnetic disc. The magnetic field is distinguished by its amplitude and frequency. The speed of the surface swimmers strongly depends on these parameters. We observe the swimmers by means of a camera from above. Via object-tracking, the position of the disc can be protocolled as a function of time, allowing us to reproduce trajectories and to calculate the speed.

The functional dependencies between speed and amplitude and between speed and frequency are investigated by independently varying both control parameters. In the first case, the data obtained are in good agreement with the predicted scaling whilst there are some deviations in the latter case.

Moreover, due to the interplay between the surface bound swimmers and the liquid meniscus at the edge of the experimental vessel different dynamics can be realized. We observe periodic and quasiperiodic trajectories in a circular vessel and aperiodic trajectories in a vessel shaped like a Bunimovich-stadium.

DY 31.4 Wed 10:45 ZEU 118
Shear-induced dynamics in colloidal nanoclutches — •Sascha Gerloff and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Dense colloidal suspensions in strong spatial confinement under shear display complex non-equilibrium dynamics [1-3]. Understanding the shear stress response of these soft materials at the nanoscale is key from a fundamental point of view as well as for applications [3,4].

Here, we discuss results from Brownian dynamic (BD) simulations of strongly confined suspensions of charged colloids under shear in two different set-ups. First, the colloids are confined to a narrow slitpore, which induces the formation of well-defined layers with crystalline in-plane structure [2]. We find that the response of this system is dictated by the frictional dynamics between the crystalline layers. In the sec-

ond set-up, we consider a system consisting of two individually driven rings, confining additional particles between the inner- and the outer ring (Taylor-Couette geometry). We focus on the impact of hydrodynamic interactions on the dynamics and the shear stress response. The overall goal is to identify the dominating transport mechanisms, determining the rheological response.

[1] W. Fornari et al., Phys. Rev. Lett. 116, 018301 (2016).
[2] S. Gerloff and S. H. L. Klapp, Phys. Rev. E (2016) in press.
[3] I. Williams et al., Nat. Phys. 12, 98-U134 (2016).
[4] F. M. Pedrero et al., Phys. Rev. Lett. 115, 138301 (2015).

DY 31.5 Wed 11:00 ZEU 118

Dynamics of particles in self-generated flow — Ran Niu, Thomas Palberg, and •Thomas Speck — Institut für Physik, Johannes Gutenberg-Universität Mainz

Colloidal particles are an established model system for a range of microscopic processes in condensed matter. While interactions can be tuned, truly long-range attractions so far have not been possible. Here we report on experiments using ion exchange particles, whereby the release of ions generates a flow above a substrate. We show that this flow leads to effective forces over hundreds of microns and discuss ramifications.

15 min. break

DY 31.6 Wed 11:30 ZEU 118

Shear-driven segregation of dry granular materials with different friction coefficients — •Tamás Börzsönyi, Katalin Gillemot, and Elláк Somfai — Wigner Research Centre for Physics, Budapest, Hungary

We present experimental and numerical results about bulk segregation in a shear-driven dry granular mixture, where the particles only differ in their surface friction coefficients. We show that the smoother particles tend to sink to the bottom of the shear zone, while rough particles migrate to the top of the sample. This phenomenon is similar to the well known kinetic sieving in particle mixtures with size heterogeneity. In the present case the smooth particles have a higher probability to penetrate into voids created by the shearing than the rough ones. The experimentally observed patterns were reproduced by discrete element simulations. Moreover, simulations performed in the absence of gravity revealed, that rough particles tend to stay in the shear zone, while the smooth particles are being expelled from it. We propose a mechanism, in which the smooth particles are driven towards regions of lower shear rate.

[1] K. A. Gillemot, E. Somfai, T. Börzsönyi, Soft Matter, 2016, DOI: 10.1039/C6SM01946C

DY 31.7 Wed 11:45 ZEU 118

Outflow and clogging of shape-anisotropic grains in hoppers with small apertures — •Ahmed Ashour[1], Tamás Börzsönyi[2], and Ralf Stannarius[1] — [1]Institute of Experimental Physics, Otto von Guericke University, Magdeburg, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Center for Physics, Hungarian Academy of Sciences, Budapest, Hungary

Outflow of granular material through a small orifice is a fundamental process in many industrial fields, for example in silo discharge, and in everyday's life. Most experimental studies of the dynamics have been performed so far with monodisperse disks in two-dimensional (2D) hoppers or spherical grains in 3D. We investigate this process for shape-anisotropic grains in 3D hoppers and discuss the influence of size and shape parameters on avalanche statistics, clogging states, and mean flow velocities. Increasing the aspect ratio of the grains leads to lower flow rates and higher clogging probabilities compared to spherical grains. The number of grains forming the clog is larger for elongated grains of comparable volumes, and the long axis of these blocking grains is preferentially aligned towards the center of the orifice. At still higher aspect ratio, the outflowing material leaves long vertical rat-holes in the hopper that can even reach the surface of the granular bed.

DY 31.8 Wed 12:00 ZEU 118

Dancing screw nuts: collective behaviour under vertical vibrations — •Simeon Völkel, Manuel Baur, and Kai Huang — Experimentalphysik V, Universität Bayreuth, 95440 Bayreuth, Germany

The collective behaviour of vertically vibrated hexagonal disks confined in a horizontal monolayer is investigated experimentally. Unlike spheres or circular disks, hexagonal disks prefer to rotate upon sufficiently strong driving due to the broken circular symmetry. As wetting liquid is added, the rotating disks self-organize into a hexagonal structure, reminiscent of a rotator crystal in equilibrium systems. The bond length of the ordered structure is slightly smaller than the circumdiameter of a hexagon, indicating geometric frustration. At the "microscopic" level, we propose an analytical model to predict the rotation speed of individual disks. At the "macroscopic" level, we quantify the influence of cohesive particle-particle interactions on the collective behaviour through characterizing the pair correlation and angular distribution functions in the ordered state. Finally we explore the transitions into and out of the rotator crystal state.

DY 31.9 Wed 12:15 ZEU 118

The effect of particle shape on the flow field in a quasi-2D hopper — •Balázs Szabó[1], Zsolt Kovács[1], Sandra Wegner[2], Ahmed Ashour[2], David Fischer[2], Ralf Stannarius[2], and Tamás Börzsönyi[1] — [1]Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, Hungary — [2]Otto-von-Guericke-University, D-39106 Magdeburg, Germany

We study the outflow and the clogged states of spherical and non-spherical particles in a quasi-2D hopper setup by means of optical measurements. For spherical grains, the vertical velocity profile along a horizontal line is close to Gaussian, as suggested by most of the existing theories. However, for prolate particles, this curve clearly deviates from a Gaussian profile, indicating that the alignment of the grains has a strong effect on the velocity field. The plug-like flow profile suggests a fitting function that is the sum of two error functions, with two characteristic length scales instead of one. One parameter is the displacement of the two error functions, which appears to be related to the geometry of the setup. The other parameter is the width of the error functions, which is more sensitive to the particle shape.

DY 31.10 Wed 12:30 ZEU 118

Pattern formation on the brink of granular liquid-gas-like transition — •Andreas Zippelius and Kai Huang — Universität Bayreuth, 95440 Bayreuth, Germany

Granular materials driven far from thermodynamic equilibrium are a rich pattern forming system. For instance, a thin layer of sand grains under vertical vibrations yields Faraday's crispations (stripes, squares, circular rings, etc.). If the particles are slightly wet, so that cohesive particle-particle interactions start to play a role, a different pattern forming scenario arises: Propagating kink-wave fronts and rotating spirals emerge as the granular layer is fluidized.

Here, we report a new class of patterns observed in the vicinity of the liquid-gas-like transition in a cohesive granular layer. It is composed of ordered density-wave fronts propagating continuously along the rim of the container. We quantify the rotation speed and the shape of the fronts by means of high speed photography and discuss the influence of particle-particle interactions and driving parameters on the pattern selection. Finally, we analyze the dynamics of the propagating fronts from the mobility of individual particles to shed light on the pattern forming mechanism.

DY 31.11 Wed 12:45 ZEU 118

Particle-based model for the coating of complex-shaped, cohesive powder particles in additive manufacturing — •Eric Parteli[1] and Thorsten Pöschel[2] — [1]University of Cologne — [2]Friedrich-Alexander-University of Erlangen-Nuremberg

The development of reliable strategies to optimize part production in additive manufacturing technologies hinges, to a large extent, on the quantitative understanding of the mechanical behavior of the powder particles during the application process. In the present work, we develop a numerical tool for the particle-based simulations of powder application in additive manufacturing devices. Our simulations take into account an accurate description for the attractive particle interaction forces as well as the complex geometric shapes of the applied powder particles. To verify our numerical tool, we compute packing density of polydisperse powder systems of different materials, covering a broad range of size distributions, thereby finding excellent quantitative agreement with measurements. From simulations of powder coating in additive manufacturing, we find that the mechanical behavior of the bulk is fundamentally influenced by the dynamics of the powder at the microscopic level, in particular the formation of complex-shaped particle agglomerates and the concatenated suppression of pore filling by smallest particles in the distribution. We show that this behavior is

responsible for one surprising result, namely that broader size distributions lead to coated powder beds of lower solid fractions. Moreover, an increase in surface roughness of the powder bed with process speed is found, thus suggesting decrease in part quality with production speed.

DY 32: Quantum Chaos

Time: Wednesday 10:00–13:00 Location: HÜL 186

DY 32.1 Wed 10:00 HÜL 186

Spectral two-point correlation functions in microwave graphs with symplectic symmetry — •Aimaiti Rehemanjiang[1], Ulrich Kuhl[2,1], and Hans-Jürgen Stöckmann[1] — [1]Fachbereich Physik der Philipps-Universität Marburg, D-35032 Marburg, Germany — [2]Université Côte d'Azur, CNRS, LPMC, France

In a recent experiment we succeeded in a microwave realization of the Gaussian symplectic ensemble (GSE) in a microwave graph [1,2] obeying an antiunitary symmetry T with $T^2 = -1$. The Kramers doublets, expected in such a system, were clearly observed and showed a level spacing distribution in full agreement with the Wigner GSE prediction. In the present talk results on the two-point correlation function, the spectral form factor, the number variance and the spectral rigidity are presented. Furthermore we discuss the transition from GSE to GOE statistics by continuously changing T from $T^2 = -1$ to $T^2 = 1$.

[1] A. Rehemanjiang, M. Allgaier, C. H. Joyner, S. Müller, M. Sieber, U. Kuhl, and H.-J. Stöckmann. Phys. Rev. Lett. 117, 064101 (2001).
[2] C. H. Joyner, S. Müller, and M. Sieber. Europhys. Lett. 107, 50004 (2014).

DY 32.2 Wed 10:15 HÜL 186

Phase-space dynamics of van der Waals dissociation — •Tom Schilling[1] and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden

An effective description of the dissociation of van der Waals complexes, such as He−I_2, can be obtained in terms of 4D symplectic maps. The escape dynamics is governed by a mixed phase space where invariant manifolds are attached to a family of fixed points at infinity. We use frequency space plots, escape time plots, and 3D phase-space slices to visualize the dynamics. Together with an analysis of the escape time statistics this allows for an understanding of the higher-dimensional chaotic transport leading to dissociation.

DY 32.3 Wed 10:30 HÜL 186

Exceptional points in the elliptical three-disk scatterer using semiclassical periodic orbit quantization — •Niklas Liebermann, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

The three-disk scatterer has served as a paradigm for semiclassical periodic orbit quantization of classical chaotic systems using Gutzwiller's trace formula. It represents an open quantum system, thus leading to spectra of complex eigenenergies. An interesting general feature of open quantum systems described by non-Hermitian operators is the possible existence of exceptional points where not only the complex eigenvalues but also their respective eigenvectors coincide.

Using Gutzwiller's periodic orbit theory we show that exceptional points exist in a three-disk scatterer as well if the system's geometry is modified by extending the system from circular to elliptical disks. The extension is implemented in such a way that the system's characteristic C_{3v} symmetry is conserved. The two-dimensional parameter plane of the system is then spanned by the distance and the excentricity of the elliptical disks. As characteristic features of exceptional points we observe the permutation of two resonances when an exceptional point is encircled in parameter space and the non-exponential decay of the periodic orbit signal. This non-exponential behaviour is related to a non-Lorentzian shape of resonances in the density of states.

DY 32.4 Wed 10:45 HÜL 186

Complex-Path Prediction of Resonance-Assisted Tunneling in MixedSystems — •Felix Fritzsch[1,2], Arnd Bäcker[1,2], Roland Ketzmerick[1,2], and Normann Mertig[1,2,3] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden — [3]Department of Physics, Tokyo Metropolitan University, Tokyo

Dynamical tunneling occurs between regular and chaotic regions of a system with a mixed phase space. We present a semiclassical theory for regular-to-chaotic tunneling, which also describes the resonance-assisted enhancement due to a nonlinear resonance chain in the classical phase space. Based on an integrable approximation with one nonlinear resonance chain we derive a complex-path prediction based on just a few phase-space properties [1]. We illustrate our approach with the paradigmatic model of the standard map where excellent agreement with numerically determined tunneling rates is observed.

[1] arXiv:1609.09276 [nlin.CD] (2016)

DY 32.5 Wed 11:00 HÜL 186

Ballistic Transport in graphene antidot lattices — •George Datseris, Ragnar Fleischmann, and Theo Geisel — Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Goettingen, Germany

Recent experiments have demonstrated ballistic transport effects in graphene antidot super-lattices. In the two-dimensional electron gas of semiconductor heterostructures, antidot systems have long been established as a prime example of ballistic transport, showing fingerprints of nonlinear resonances and chaos in magneto-transport measurements. We study quasi-classical electron dynamics in graphene using different models of the antidot lattice and calculate their magneto-transport properties, in overall very good agreement with the experiments. In particular, we study the effects of imperfections in lithographically fabricated antidots and show that even significant perturbations of the potential landscape have little effect on most resonances, leaving the structure of resistance curves surprisingly robust to this disorder.

15 min. break

Invited Talk DY 32.6 Wed 11:30 HÜL 186

Semiclassical Classification of Periodic Orbits in Quantum Many-Body Systems — •Daniel Waltner, Maram Akila, Boris Gutkin, Petr Braun, and Thomas Guhr — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg

Classical periodic orbits on the one side and the quantum energy spectrum on the other are related in semiclassical theories by trace formulae. In the past, there has been huge interest in obtaining periodic orbit spectra for one-particle quantum systems (for example for the hydrogen atom in a strong magnetic field [1]). Here, the Fourier transformation of the trace formula was compared with the periodic orbits calculated by the classical equations of motion. In this talk, I demonstrate how to generalize this comparison to a many-particle system considering a kicked spin chain with nearest neighbor Ising coupling and on-site kicked magnetic field. Here, we face the problem that the dimension of the quantum Hilbert space and the number of periodic orbits is too large to apply the conventional methods used in [1]. We show how to overcome the problem arising from the large Hilbert space dimension by a duality relation and identify dominant contributions to the quantum spectrum arising from collective classical motion of the spins.

[1] D. Wintgen, Phys. Rev. Lett. **58**, 1589 (1987).
[2] M. Akila, D. Waltner, B. Gutkin, P. Braun, T. Guhr, `arXiv1611.05749`.

DY 32.7 Wed 12:00 HÜL 186

Berry-Tabor Trace Formula for the Lieb-Liniger Model — •Christian Scharf, Juan-Diego Urbina, and Klaus Richter — Universität Regensburg

We report our progress in constructing a trace formula for the semiclassical density of states of the Lieb-Liniger model, describing a gas of one-dimensional bosons interacting via a repulsive δ-potential.

We combine the methods of Berry and Tabor used in [1] for any integrable Hamiltonian and apply them to this system by making use of the Bethe-Ansatz equations expressing the quantization of the momenta. Further, using Poisson summation and applying a stationary phase approximation we get perfect agreement between semiclassical and numerical calculation for the oscillatory part of the density of states for the two-particle case while extending the results to arbitrary number of particles is work in progress. We show how this method can be used to obtain a trace formula for other systems like the Fermi- or the Bose-Hubbard models.

[1] Berry, M. V.,Tabor, M., Proc. R. Soc. Lond. A. 349, 101-123 (1976)

DY 32.8 Wed 12:15 HÜL 186

Polarization evolution in 3D micro-cavities — •Jakob Kreismann and Martina Hentschel — TU Ilmenau, Institut für Physik, Theoretische Physik II / Computational Physics, Weimarer Straße 25, 98693 Ilmenau

We investigate electromagnetic propagation in three-dimensional cone-shaped microtube cavities. In such a geometry, the polarization state of resonant whispering gallery modes may differ strongly from the reference case of homogeneous cylinders. In particular, we study how breaking of symmetries influences the morphology of resonances that can be associated with inclined trajectories. This is accompanied by the transition from linear to elliptical polarization. Eventually, we discuss the results from the point of view of spin-orbit interaction of light and its interpretation in terms of Berry phases.

DY 32.9 Wed 12:30 HÜL 186

Stationary waves on nonlinear quantum graphs: Canonical perturbation theory — •Daniel Waltner[1] and Sven Gnutzmann[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg — [2]School of Mathematical Sciences, University of Nottingham, Nottingham NG7 2RD, UK

We present a general framework for solving the stationary nonlinear Schrödinger equation on a network of one-dimensional wires modelled by a metric graph with suitable matching conditions at the vertices. For sufficiently small intensities we use canonical perturbation theory that allows to reproduce characteristic effects of nonlinear equations like bifurcations and multistabilities. Simple closed and scattering graphs serve as examples.

DY 32.10 Wed 12:45 HÜL 186

Angular deflection on transmission: From planar to curved dielectric interfaces — •Daniel Kotik — Technische Universität Dresden

Optical beams of finite spatial extent show deviations from the classical laws of reflection and refraction when incident upon a dielectric interface. The resulting spatial and angular beam shifts are well understood on reflection (Goos-Hänchen shift and Fresnel filtering effect) and are typically small compared to the width and divergence of the incident beam. In this respect the angular deflection on transmission is different: even in the short wavelength limit this effect is in its most pronounced form on the order of several degrees.

Our objective is to clarify the deflection mechanism and to reveal the different contributing parts. We identify two partly opposing processes—a refraction induced weighting as well as an accompanying deformation of the incident angular spectrum and show that the angular shift at critical incidence is primarily determined by a displacement of the whole spectrum due to its weighting, and that the deflection caused by Fresnel's transmission coefficients is comparably small and actually *weakens* the effect.

An extended theory for curved interfaces is presented and compared with independent numerical studies. We conclude with a discussion of the prediction capability of our amended ray optics theory concerning the emission properties of *ultrasmall* optical microcavities.

DY 33: Fluid Dynamics and Turbulence

Time: Wednesday 10:00–13:15 Location: ZEU 160

DY 33.1 Wed 10:00 ZEU 160

Characterization and optimization of devices for active flow control — •Max Huber[1,3], Andreas Zienert[2], Hans-Reinhard Berger[1], and Jörg Schuster[3] — [1]Institute of Physics, Technische Universität Chemnitz, Chemnitz, Germany — [2]Center for Microtechnologies, Technische Universität Chemnitz, Chemnitz, Germany — [3]Fraunhofer Institute for Electronic Nano Systems, Chemnitz, Germany

Synthetic jet actuators (SJAs) are used for active flow control to achieve reduction of drag and noise as well as lift enhancement for airplane wings. The devices consist of a movable piezoelectric diaphragm and a closed cavity with a small orifice. The synthetic (i.e. zero net mass flux) jet is generated by the oscillation of the diaphragm and transfers momentum to the surrounding medium.

The present work studies a one dimensional analytical model for SJAs. The single parts of the actuator are described by a coupled set of mechanical and hydrodynamical equations. The model is used to analyse quantitatively the measured relation between diaphragm vibration and fluid flow through the orifice for different SJAs. In addition, an optimization of the cavity volume with respect to the resonance frequency of the diaphragm was carried out to maximize the performance of the device.

DY 33.2 Wed 10:15 ZEU 160

Unsteady dynamics of the flow around an adaptive chamber profile visualized by high speed PIV — •Tom T. B. Wester, Gerd Gülker, Michael Hölling, and Joachim Peinke — ForWind - Center for Wind Energy Research, Institute of Physics, University of Oldenburg, Germany

Wind turbines are subjected to severe inflow fluctuations during their operation. These dynamics lead to high load changes and can result in defects of single components within the system (e.g. pitch actuator, generator or airfoils).
In order to minimize these loads a chambered airfoil could be used. This airfoil is designed to alleviate high loads and is therefore expected to be less susceptible to defects caused by a turbulent inflow. This is done by a coupled moving leading and trailing edge of the airfoil. A segment of such an airfoil is investigated in a defined and reproducible turbulent inflow. This inflow is generated in our wind tunnel by an active grid and is based on statistics of measured atmospheric wind fields.
To visualize the aerodynamics around the airfoil segment, high speed PIV is used. With this technique it is possible to measure the occurring flow dynamics in a highly spatial and temporal resolved manner. This makes it possible to connect the known inflow conditions directly to flow situations (e.g. flow separation) around the airfoil.
In our presentation we will show first PIV results of the flow around the airfoil and characteristics of the modulated inflow conditions.

DY 33.3 Wed 10:30 ZEU 160

Generation of reproducible 2D atmospheric turbulence in a closed wind tunnel test section — •Johannes Krauss, Tom Wester, Michael Hölling, Joachim Peinke, and Gerd Gülker — ForWind - Center for Wind Energy Research, Institute of Physics, University of Oldenburg, Germany

Changes in the inflow conditions of wind turbines cause fatigue loads and they have an important influence on the turbines lifetime. Important aspects are variations of the angle of attack and gusts that lead to aerodynamic effects such as dynamic stall and sudden changing moments and forces.

We will present a technique which makes it possible to reproduce wind speed time series measured in the turbulent atmospheric boundary layer in a closed test section of a wind tunnel. With this technique, we can generate quasi-2D flows which mimic the real atmospheric inflow acting on an outside wind energy converter. The quasi-2D properties of the wind flow are meant to enable its usage for flow analysis at airfoil segments and to simplify the identification of complex aerodynamic phenomena. The technique is based on independently moving vanes affecting the laminar inflow of the wind tunnel in a controllable and reproducible manner. For flow modulation, different situations are modelled and characterized. To capture the entire temporal and spatial dynamic of the system high speed PIV and hotwire measurements

are used. In this presentation, first measurements and conclusions are shown.

DY 33.4 Wed 10:45 ZEU 160

Multi-Scale Analysis of Lagrangian Properties of Turbulence — •Michael Wilczek and Cristian Lalescu — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Deutschland

Turbulence is a multi-scale problem in space and time with a broad range of strongly interacting degrees of freedom. Lagrangian tracer particles advected with the flow sample this spatio-temporal complexity. This naturally leads to the question of how Lagrangian properties are affected by the scales of turbulence. We attempt to answer this question numerically and theoretically adopting a filtering approach. In an extensive DNS (direct numerical simulation) study, we track tracer particles advected by spatially filtered velocity fields. This allows to distinguish the impact of large-scale sweeping effects and small-scale intermittency on Lagrangian aspects of turbulence. In this presentation we will present results on Lagrangian particle dispersion and velocity fluctuations for various filtering scales. The results will furthermore be discussed in the context of Eulerian-Lagrangian bridging relations.

DY 33.5 Wed 11:00 ZEU 160

Discrete exterior calculus for the surface Navier-Stokes equation - the interplay of topology, geometry and flow properties — •Axel Voigt, Ingo Nitschke, and Sebastian Reuther — Institut für Wissenschaftliches Rechnen, TU Dresden, Germany

We consider a numerical approach for the incompressible surface Navier-Stokes equation. The approach is based on the covariant form and uses discrete exterior calculus (DEC) in space and a semi-implicit discretization in time. We compare computational results with a vorticity-stream function approach for surfaces with genus g(S) = 0 and demonstrate the interplay between topology, geometry and flow properties. Our discretization also allows to handle harmonic vector fields, which we demonstrate on a torus.

15 min. break

DY 33.6 Wed 11:30 ZEU 160

An Extended Transfer Operator Approach to Identify Separatrices in Open Flows — •Benedict Johannes Lünsmann and Holger Kantz — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Deutschland

Eddies, mesoscale masses of coherent fluid volume, are considered to have a substantial impact on the transport of heat, nutrition and oxygen in the ocean. Yet, due to their Lagrangian nature detecting these structures is highly nontrivial. In this respect transfer operator approaches have proven to provide useful tools: Approximating a possibly time-dependent flow as a discrete Markov process in space and time, information about coherent structures are contained in the operator's eigenvectors which is usually extracted by employing clustering methods. Here, we propose an extended approach that refrains from machine learning techniques such as clustering and uses physical arguments instead. We show, that this technique is suited to reconstruct separatrices in stationary flows and can be used to probe regions for coherent structures individually.

DY 33.7 Wed 11:45 ZEU 160

Wetting dynamics beneath fluid drops impacting on hot surfaces — •Kirsten Harth[1], Michiel A. J. van Limbeek[1], Minori Shirota[1], Chao Sun[1,2], and Detlef Lohse[1] — [1]Physics of Fluids, Universiteit Twente, Enschede, The Netherlands — [2]Center for Combustion Energy, and Department of Thermal Engineering, Tsinghua University, China

Fluid droplets encountering a phase transition when they impact a target surface are involved in many applications, e.g., spray cooling or painting / coating, ink-jet and 3D printing, soldering, firefighting using sprinklers. Drop impact on hot plates is an emerging topic, involving a complex interplay of hydrodynamics, heat flux and the occurring phase transition, involving large spatial and temporal gradients. Whether and to what extent droplets touch the surface is of immense importance for the overall heat transfer. High-speed total internal reflection imaging allows us to discriminate wetted and vapor-covered regions of the substrate. We study the transient wetting behaviour of the plate by varying the latent heat of the droplet. The characteristic cooling time of the plate is not solely determined by the plate properties. In addition to current literature, we show that in those cases the wetting pattern is both spatially and temporally inhomogeneous.

DY 33.8 Wed 12:00 ZEU 160

Detailed finite element method modeling of evaporating multi-component droplets — •Christian Diddens — Eindhoven University of Technology, The Netherlands

The evaporation of sessile multi-component droplets is modeled with a finite element method. The model comprises the coupled processes of mixture evaporation, multi-component flow with composition-dependent fluid properties and thermal effects. Based on representative examples of water-glycerol and water-ethanol droplets, regular and chaotic examples of solutal Marangoni flows are discussed. Furthermore, the relevance of the substrate thickness for the evaporative cooling of volatile binary mixture droplets is pointed out. It is shown how the evaporation of the more volatile component can drastically decrease the interface temperature, so that ambient vapor of the less volatile component condenses on the droplet.

DY 33.9 Wed 12:15 ZEU 160

Evaporation-triggered microdroplet nucleation and the four life phases of an evaporating Ouzo drop — Huanshu Tan[1], •Christian Diddens[2], Pengyu Lv[1], Hans Kuerten[1,2], Xuehua Zhang[3], and Detlef Lohse[1,4] — [1]University of Twente, The Netherlands — [2]Eindhoven University of Technology, The Netherlands — [3]Royal Melbourne Institute of Technology University — [4]Max Planck Institute for Dynamics and Self-Organization

While the evaporation of pure liquid droplets and binary mixture droplets has been intensively studied, the evaporation of ternary mixture droplets with different volatilities and mutual solubilities has not yet been explored. Here, we show that the evaporation of such ternary mixtures can trigger a phase transition and the nucleation of microdroplets of one of the components of the mixture. As a model system, we pick a sessile Ouzo droplet (as known from daily life) and reveal and theoretically explain its four life phases: In phase I, the spherical cap-shaped droplet remains transparent while the more volatile ethanol is evaporating, preferentially at the rim of the drop because of the singularity there. This leads to a local ethanol concentration reduction and correspondingly to oil droplet nucleation there. This is the beginning of phase II, in which oil microdroplets quickly nucleate in the whole drop, leading to its milky color that typifies the so-called Ouzo effect. Once all ethanol has evaporated, the drop, which now has a characteristic nonspherical cap shape, has become clear again, with a water drop sitting on an oil ring (phase III), finalizing the phase inversion. Finally, all water has evaporated, leaving behind a tiny oil drop.

DY 33.10 Wed 12:30 ZEU 160

intermolecular mode coupling: insight from nonlinear THz spectroscopy of liquids — •mohsen sajadi, martin wolf, and tobias kampfrath — fritz-haber-institute of the max-planck society, berlin, germany

Low-frequency structural dynamics of liquids in the range of 0.1 to 10 THz (3 to 300 cm-1) is believed to strongly contribute to the outcome of chemical processes. The underlying molecular motions are very complex and include reorientations, vibrations and translations. Implemented techniques for gaining microscopic insight to such low-frequency molecular motions have mostly been limited to the off-resonant optical excitation of liquids via Raman processes. Using intense THz fields, we interrogate the structural dynamics of molecular liquids directly. We show that resonant excitation with strong THz pulses is capable of driving librational-reorientational modes of liquids through coupling to the permanent molecular dipole moments. We observe a hallmark of this light-matter interaction as a transient optical birefringence up to one order of magnitude higher than obtained with optical excitation. In light of a simple but generic model and excitation at different THz frequencies we discuss that the enhancement arises from resonantly driven librations and their coupling to reorientational motion, assisted by either the pump field or a cage translational mode.

DY 33.11 Wed 12:45 ZEU 160

Transmission of Ultracold Neutrons Through Cold Deuterium and Hydrogen – The Scattering Cross Sections — •Stefan Döge[1,2,3], Peter Geltenbort[2], Tobias Jenke[2], Christoph Morkel[1], Erwin Gutsmiedl[1], Winfried Petry[3], and Stephan Paul[1] — [1]Physik-Department, Technische Universität

München, Garching, Germany — [2]Institut Laue–Langevin, Grenoble, France — [3]Forschungsneutronenquelle Heinz Maier-Leibnitz, Technische Universität München, Garching, Germany

Ultracold neutrons (UCNs) are a versatile tool for fundamental physics experiments, such as the exact determination of the free neutron lifetime or the search for a possible non-zero neutron EDM.

The precise knowledge of UCN cross sections in deuterium are pivotal to the design and improvement of new UCN sources, which promise to provide higher UCN densities than the current frontrunner – the "turbine" at Institut Laue–Langevin (ILL).

The total UCN cross sections in hydrogen and deuterium were measured in transmission geometry with a time-of-flight (TOF) setup and were corrected for several side effects like UCN scattering on surfaces etc. We present energy-dependent cross section data (σ^{scatt}) for UCNs in liquid and solid deuterium and hydrogen and discuss newly detected phenomena.

[1] S. Döge et al., Phys. Rev. B 91, 214309 (2015) and arXiv:1511.07065 [nucl-ex]

[2] S. Döge et al., ISINN-23 Proceedings, p. 119-130, Dubna/Russia (2016)

DY 33.12 Wed 13:00 ZEU 160

Pattern-fluid interpretation of chemical turbulence — •Gerd E. Schröder-Turk[1,2], Christian Scholz[2], and Klaus Mecke[2] — [1]Murdoch University, Perth, WA, Australien — [2]Friedrich-Alexander Universität Erlangen-Nürnberg Erlangen

The formation of heterogeneous patterns is a hallmark of many nonlinear systems. The standard model for pattern formation in general, and for Turing patterns in chemical reaction-diffusion systems in particular, are deterministic nonlinear partial differential equations where an unstable homogeneous solution gives way to a stable heterogeneous pattern. However, these models fail to explain the experimental observation of turbulent patterns with spatio-temporal disorder in chemical systems. Here we introduce a pattern-fluid model as a concept where turbulence is interpreted as a weakly interacting ensemble obtained by random superposition of stationary solutions to the underlying reaction-diffusion system. The transition from turbulent to stationary patterns is interpreted as a condensation phenomenon, where the nonlinearity forces one single mode to dominate the ensemble. This model leads to better reproduction of the experimental concentration profiles for the 'stationary phases' and reproduces the turbulent chemical patterns observed by in Ouyang and Swinney [1]. This results presented here have been published in ref [2].

[1] Ouyang and Swinney, Chaos 1, 411 (1991)

[2] Scholz et al, Physical Review E 91, 042907 (2015)

DY 34: Colloids and Complex Fluids II (joint session BP/CPP/DY, organized by CPP)

Time: Wednesday 10:15–13:00 Location: ZEU 260

Invited Talk DY 34.1 Wed 10:15 ZEU 260

Computer simulations of colloidal systems under flow — •Arash Nikoubashman — Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany

Colloidal systems under flow are ubiquitous in nature and technology, whether it is the transport of proteins and enzymes in biological systems or the flow of surfactants in enhanced oil recovery. Such microrheological systems are also highly intriguing from a purely scientific point of view due to the intricate interplay between the solute and solvent particles. To better understand the physical properties of these complex systems and to assist the design of microfluidic devices, we performed extensive simulations of both rigid and soft colloidal particles under flow. This computational approach allows for systematic control over the system parameters while also providing microscopic insight. In this presentation, selected systems will be discussed to give an overview of the possibilities and challenges in this field. For example, microfluidic channels can be used to distinguish polymers based on their topology, such as linear, dendritic or ring-shaped macromolecules. Furthermore, non-linear flow effects such as inertia or viscoelasticity can be exploited to control the lateral motion of dispersed particles. Flow can also be used to enhance the growth as well as the breakup of colloidal aggregates, depending on the applied flow strength.

DY 34.2 Wed 10:45 ZEU 260

A temporarily arrested state in protein solutions — •Stefano Da Vela[1], Fajun Zhang[1], Christian Exner[1], Johannes Möller[2], Zhendong Fu[3], and Frank Schreiber[1] — [1]Institut für Angewandte Physik, Universität Tübingen, 72076 Tübingen — [2]ESRF, Grenoble, France — [3]JCNS, Garching, Germany

The interplay of liquid-liquid phase separation (LLPS) with the glass transition is a possible route to the formation of arrested states in colloidal and protein systems. LLPS requires attractive interactions, the microscopic details of which set the temperature dependence of the LLPS phase boundary. We report the kinetics of phase separation and arrest for two protein systems: γ-globulin in the presence of PEG 1000, featuring upper critical solution temperature behavior, and bovine serum albumin in the presence of Y(III), featuring lower critical solution temperature behavior. For both systems, the time evolution of the characteristic length is followed during phase separation by Ultra Small Angle X-ray Scattering (USAXS) and Very Small Angle Neutron Scattering(VSANS). This time evolution corresponds to classical LLPS proceeding by spinodal decomposition for shallow quenches in the two-phase region, and to arrested LLPS for deep enough quenches [1]. For intermediate quenches, we report evidence of an unusual three-stage coarsening process. In this case, a temporary arrest of the kinetics is found, which is overcome at later times. We interpret the finding in the light of simulations and experimental results on colloidal systems.

[1] Da Vela et al. Soft Matter, 2016, 12, 9334 - 9341

DY 34.3 Wed 11:00 ZEU 260

Demixing and clustering in a binary system of long-ranged capillary interactions — •Malte Lütje, Johannes Bleibel, and Martin Oettel — Institut für Angewandte Physik, Universität Tübingen, Deutschland

We consider a binary system of micron-sized spherical colloidal particles trapped at a fluid interface, which induces long-ranged capillary interactions. If one species has positive and one has negative buoyancy, colloids of the same species attract while different species repel. This leads to the demixing of initially uniform densities, and ultimately to the formation of close-packed clusters for each species. Demixing competes with the clustering of each species.

We present static phase diagrams for the system. Brownian Dynamics simulation results illustrate the evolution from a homogeneous state to the demixed and clustered states. The system has unusual phase separation dynamics: The timescales of demixing and clustering can be different, yielding an intermediate stage with halo-like structures.

DY 34.4 Wed 11:15 ZEU 260

Poisson-Boltzmann study of the effective electrostatic interaction between colloids at an electrolyte interface — •Arghya Majee[1,2], Markus Bier[1,2], and S. Dietrich[1,2] — [1]Max-Planck-Institut für Intelligente Systeme, Heisenbergstr. 3, 70569, Stuttgart — [2]IV. Institut für Theoretische Physik, Universität Stuttgart, Pfaffenwaldring 57, 70569, Stuttgart

The effective electrostatic interaction between a pair of colloids, located close to each other at an electrolyte interface, will be discussed by employing the full, nonlinear Poisson-Boltzmann (PB) theory within classical density functional theory. Using a simplified yet appropriate model, all contributions to the effective interaction are obtained exactly, albeit numerically. The comparison between our results [1] and those obtained within linearized PB theory [2] reveals that the latter overestimates these contributions significantly at short inter-particle separations. Whereas the surface contributions to the linear and the nonlinear PB results differ only quantitatively, the line contributions show qualitative differences at short separations. Moreover, a dependence of the line contribution on the solvation properties of the two adjacent fluids is found, which is absent within the linear theory. Our results are expected to enrich the understanding of effective interfacial interactions between colloids.

References:

[1] A. Majee, M. Bier, and S. Dietrich, J. Chem. Phys. **145**, 064707 (2016). [2] A. Majee, M. Bier, and S. Dietrich, J. Chem. Phys. **140**, 164906 (2014).

15 min break

DY 34.5 Wed 11:45 ZEU 260

Entropic Interactions between Dendrimers and Impenetrable Surfaces — •Ron Dockhorn[1,2], Stephan Meschede[3], Martin Wengenmayr[1,2], and Jens-Uwe Sommer[1,2] — [1]Leibniz Institute of Polymer Research Dresden, D-01069 Dresden, Germany — [2]Technische Universität Dresden, Institute for Theoretical Physics, D-01069 Dresden, Germany — [3]Institute for Physics, Humboldt-Universität zu Berlin, D-12489 Berlin, Germany

Monte Carlo simulations are performed to investigate depletion effects on dendrimers using the bond fluctuation model. Two different situations are investigated: The interaction between a single dendrimer against a hard wall and the interaction between two dendrimers. The simulations of the dendrimers are performed with implicit solvent as well as in a linear polymer matrix. The free energy landscape along the particular reaction coordinate is determined by Umbrella Sampling (WHAM algorithm) and compared to a mean-field approach. Both systems immersed in a polymer matrix show entropic attraction (depletion forces) depending on the length of the surrounding linear chains. Additionally, a spontaneous conformational change and rapid mixing caused by the strong interaction in the two dendrimers' system can be noticed. These findings are aimed to understand the agglomeration and the coagulation processes of hyperbranched structures in drug-delivery systems in medical applications.

DY 34.6 Wed 12:00 ZEU 260

Liquid-state theory of the interactions between colloids mediated by attractive reversibly adsorbed polymers. — •A.I. Chervanyov — Institute for Nano- and Microfluidics, TU Darmstadt

By making use of the liquid state theory, we analytically study the effect of attractive polymer-colloid (P-C) and polymer-polymer (P-P) interactions on the effective forces acting between colloids immersed in a polymer system. The performed theoretical analysis has no restrictions with respect to the polymer density and relative sizes of the colloids and polymers. The polymer mediated (PM) potential acting between fillers is shown [1,2] to significantly depend on the strength and range of the P-P and P-C interactions. In the nano-particle limit, where the colloid radius is much smaller than the polymer gyration radius, the presence of attractive P-P interactions causes significant, but only quantitative changes to the PM potential. In the opposite limit of relatively large colloids, the P-P interactions revert the sign of the total effective force acting between colloids so that this force becomes attractive at sufficiently large polymer densities. The effect of the C-P interactions on the PM potential is found to be most pronounced in the case of large polymer densities and small colloid-to-polymer size ratios. The dependence of the second virial coefficient of the effective PM potential on the polymer density is discussed in detail, revealing several novel features of the PM forces caused by the presence of attractive P-P and P-C interactions.

[1] A.I. Chervanyov, Soft Matter 11,1038-1053 (2015).
[2] A.I. Chervanyov, J. Chem. Phys. 141, 244902(2014).

DY 34.7 Wed 12:15 ZEU 260

Determing helicity modulus in systems with orientational order from microscopic properties through Zwanzig-Mori formalism — •Johannes Häring and Matthias Fuchs — FB Physik, Universität Konstanz, 78457 Konstanz, Germany

Up to now, we have studied crystals with point disorder and applied the theory to crystals of soft core particles, so-called cluster crystals [1]. Now, systems with orientational order like nematic liquid crystals are considered. With the Zwanzig-Mori formalism it is possible to calculate the helicity modulus for all temperatures in the ordered phase, even near the critical point.

The Zwanzig-Mori formalism is a way to treat many-body systems systematically. Projection Operators are used to focus on the dominant variables of the system and their correlation functions. Simulations of the three dimensional XY model are done to test the accuracy of the approach. The XY model consists of particles with one orientational degree of freedom which are fixed on a lattice.

It is known from the Mermin-Wagner theorem that two dimensional systems show no conventional long range order, i.e have vanishing order parameters. That leads to problems in calculating the helicity modulus. We discuss how it is still possible to obtain a solution.

[1] J. M. Häring, C. Walz, G. Szamel, and M. Fuchs, Phys. Rev. B 92, 184103 (2015)

DY 34.8 Wed 12:30 ZEU 260

Clusters in dipolar fluids — •Michela Ronti[1], Alexey O. Ivanov[2], Lorenzo Rovigatti[3], Jose M. Tavares[4], Francesco Sciortino[5], and Sofia S. Kantorovich[1,2] — [1]Computational Physics, University of Vienna, Sensengasse 8, 1090 Vienna, Austria — [2]Ural Federal University, 3 Ural Federal University, Lenin av. 51, Ekaterinburg, 620000, Russia — [3]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, 1 Keble Road, Oxford, OX1 4 NP, United Kingdom — [4]Instituto Superior de Engenharia de Lisboa-ISEL, Rua Conselheiro Emidio Navarro 1, 1950-062 Lisboa, Portugal — [5]University of Rome La Sapienza, Piazzale Aldo Moro 2, I-00185, Roma, Italy

We describe the self-assembly in magnetic nanocolloids by using a dipolar hard sphere (DHS) model. The phase diagram of this system at low temperature remains debatable regardless the expected simplicity of the model. At low temperature DHS particles self-assemble into complex structures, with primary structures composed by rings and chains. The latter form the building blocks for further aggregation. To elucidate the formation of branched structures analytically, we need to calculate accurately partition functions of various clusters. For that we introduce grand-canonical single cluster Monte Carlo simulations.

DY 34.9 Wed 12:45 ZEU 260

Ferromagnetic phases in colloidal suspensions — •Grigorii Zarubin[1,2] and Markus Bier[1,2] — [1]Max Planck Institute Int. Sys. — [2]University of Stuttgart, Germany

A ferromagnetic phase of anisotropic particles suspended in a nematic liquid crystal (NLC) was predicted as early as 1970 [1]. A recent experimental realization [2] confirmed that a dilute suspension of magnetic platelets in NLC forms ferromagnetic phase which is susceptible to weak magnetic fields. In this work we describe such a suspension of plate-like particles using density functional theory. The influence of the NLC is taken into account implicitly through the introduction of the effective elastic interaction between platelets. Following approach of Lev and Tomchuk [3], the effective potential was derived under the assumption of weak anchoring of the NLC at the surface of the platelets. An ordered phase was identified with help of the orientational distribution function, and the dependence of the ferromagnetic phase on the strength of the magnetic and the elastic coupling was studied.

References: [1] F. Brochard and P.G. de Gennes, J. Physique 31, 691 (1970). [2] A. Mertelj, D. Lisjak, M. Drofenik and M. Copic, Nature 504, 237 (2013). [3] B.I. Lev and P.M. Tomchuk, Phys. Rev. E 59, 1 (1998).

DY 35: Plenary Talk M. Cates

Time: Wednesday 14:00–14:45 Location: HSZ 02

Plenary Talk DY 35.1 Wed 14:00 HSZ 02
The Statistical Mechanics of Active Matter — •Michael Cates — DAMTP, University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, UK

In active matter, the local dynamics of individual particles is maintained far from equilibrium by a continuous conversion of fuel into motion. Examples include swimming bacteria and a class of synthetic colloidal swimmers in which a fuel bath and/or light field maintains self-propulsion. Such systems can show new forms of collective behaviour arising from the absence of microscopic Time Reversal Symmetry (TRS). An example is the motility-induced phase separation (MIPS) into dense and dilute phases for swimmers whose only interaction is a hard-core repulsion. (This contrasts with equilibrium systems which only phase-separate when attractions are present). In cases where swimming is light-activated, these collective effects might be exploitable in the directed assembly of swimming colloids into functional microfluidic devices.

I will discuss the above phenomena, and then describe how the physics of broken TRS can be incorporated into stochastic field theories of the Cahn-Hilliard type. An important question is whether the entropy production of individual particles survives coarse-graining, or whether it ceases to have any important effects at large length scales, so that the system is equivalent to an equilibrium one with shifted parameters (e.g., an effective attraction in the case of MIPS). This is a difficult question: I will describe some first steps towards answering it.

DY 36: Collective Quantum Dynamics: From Fundamentals to New Phenomena (Focus session joint DY/TT)

This session covers recent experimental and theoretical advances both in condensed mater physics as well as in cold atomic systems in the field of dynamical and nonequilibrium properties of quantum many-body systems. Collective quantum dynamics plays a central role in a number of different physical systems. First, dynamical systems will exhibit a rich set of phenomena which lie beyond static ground state properties, e.g. in non-thermal many-body localised systems. Second, dynamical properties of many-body systems can serve as experimentally accessible probes to detect characteristic fingerprints of otherwise featureless phases of matter, such as topologically ordered and fractionalized states of matter. Recent technological advances have had an impact on all of these aspects of the field, while continuing experimental progress in AMO and materials physics is valuable in providing access to new phenomena, as well as testing new theoretical findings.

Organization: Frank Pollmann, MPI-PKS, Dresden; Roderich Moessner, MPI-PKS, Dresden

Time: Wednesday 15:00–17:45 Location: HSZ 03

Invited Talk DY 36.1 Wed 15:00 HSZ 03
Many-Body Localization and Glassiness in Quantum Spin Systems — •Antonello Scardicchio — Abdus Salam ICTP, Trieste, Italy — INFN, Sezione di Trieste, Trieste, Italy

I will discuss the interplay of two phenomena arising in disordered quantum spin systems: the appearance of a glassy phase, and the complete suppression of transport due to many-body localization. I will review work done on some models, under various approximations (analytical and numerical), and summarize a universal physical picture for how the two dynamical phases can interplay. I will also comment on the implications for the performance of quantum computers.

Invited Talk DY 36.2 Wed 15:30 HSZ 03
Exploring Many-Body Localization in Two Dimensions — •Christian Gross — Max-Planck-Institut für Quantenoptik, Garching

The question of thermalization in closed quantum systems is currently a topic of intense research and ultracold atoms are an almost ideal experimental system for its study. In this context it is particularly interesting to study systems that do not thermalize. Many-body localized systems form a generic class of such systems, which is largely unexplored in higher dimensions and at high energy densities. Here we report on recent experiments with single site resolved ultracold lattice bosons in two dimensions subject to random disorder. Our data indicates a transition from thermalizing behavior at low disorder to localization at higher disorder and a diverging length scale at the transition. Finally we discuss ongoing experimental effort and possibilities to characterize the MBL phase close to the transition point.

Invited Talk DY 36.3 Wed 16:00 HSZ 03
Floquet Engineering and Control of Topology in Solid State Systems — •Takashi Oka[1,2], Leda Bucciantini[1,2], Sthitadhi Roy[2], and Sota Kitamura[3] — [1]Max Planck institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck institute for Chemical Physics of Solids, Dresden, Germany — [3]The university of Tokyo, Department of Tokyo, Tokyo, Japan

Periodically driven quantum system is attacting interest as a way to create new state of matter with exotic topological and dynamical properties.

1. Emergent Weyl points and Fermis arcs in a Floquet Weyl semimetal [1]: We find that a series of infinite numbers of Weyl points emerges, moves and annihilates in a Floquet Weyl semimetal that can be realized by applying circularly polarized laser to a three dimensional Dirac mateiral.

2. Landau quantization in an oscillating magnetic field [2]: We find that Landau quantization is not restricted to a static magnetic field but can be realized in oscillating fields and find a state that is analogous to the integer quantum Hall effect (QHE) when the ratio between the cyclotron frequency and the laser frequency is given by magic numbers.

[1] L. Bucciantini, S. Roy, S. Kitamura, and T. Oka, in prep.
[2] T. Oka, and L. Bucciantini, Phys. Rev. B 94, 155133 (2016)

15 min. break.

Invited Talk DY 36.4 Wed 16:45 HSZ 03
Hydrodynamic Regimes of Electron Transport — •Andrew Mackenzie — Max Planck Institute for Chemical Physics of Solids, Nöthnitzerstr 40, Dresden

In this talk I will discuss recent experiments showing that in some ultra-pure metals, it is possible to reach a regime of transport in which the viscosity of the electronic fluid plays a significant role in determining its flow. The conditions for this to happen are rather stringent, but there is some prospect of achieving them in a broader range of materials than those so far studied, so I will also try to give a sense of the future directions that the field might take.

Invited Talk DY 36.5 Wed 17:15 HSZ 03
Dynamical Phase Transitions — •Stefan Kehrein — Univ. Göttingen

Phase transitions play a central role in the theory of equilibrium statistical mechanics. They are indicated by non-analytic behavior of the free energy in the thermodynamic limit, for example at a critical

temperature. The goal to understand and classify equilibrium phase transitions led to the fundamental concept of universality with its far-reaching implications in many different fields of physics.

Interestingly, similar non-analytic behavior of the dynamical free energy at certain critical times has been found in the real time evolution of the quantum Ising model [1]. This behavior has been denoted dynamical phase transition and has since been theoretically investigated in numerous other non-equilibrium quantum many-body models. Recently, the first experimental observation of dynamical phase transitions was reported in an ultracold fermionic quantum gas that was quenched between a static and a Floquet Hamiltonian [2].

This talk will give an overview over the current theoretical understanding of such dynamical phase transitions, the role of non-zero temperature and non-integrable perturbations, and possible experimental verifications.

[1] M. Heyl, A. Polkovnikov, and S. Kehrein, Phys. Rev. Lett. 110, 135704 (2013)

[2] N. Fläschner, D. Vogel, M. Tarnowski, B. S Rem, D.-S. Lühmann, M. Heyl, J. C. Budich, L. Mathey, K. Sengstock, and C. Weitenberg, arXiv:1608.05616

DY 37: Aktive Matter I (joint session DY/BP/CPP)

Time: Wednesday 15:00–19:00 Location: HÜL 186

DY 37.1 Wed 15:00 HÜL 186

Flocking ferromagnetic particles — •Andreas Kaiser, Alexey Snezhko, and Igor S. Aranson — Materials Science Division, Argonne National Laboratory, 9700 South Cass Ave, Argonne, Illinois 60439, USA

Suspensions of microswimmers, show fascinating collective behaviours like clustering, flocking and turbulence [1]. Here, we demonstrate the discovery of ferromagnetic flocking colloids. The self-propulsion is an outcome of the spontaneous rotation of a ferromagnetic colloidal sphere in a vertical alternating (AC) magnetic field [2]. Depending on the frequency of this magnetic field, a sequence of transitions can be observed: from gas-like motion of individual particles to the onset of flocking and global rotation followed by a reentrant flocking and gas-like state for increasing frequency [3]. We also emphasize a subtle role of rotational noise: While the low-frequency flocking appears to be noise-insensitive, the reentrant flocking happens to be noise-activated. Moreover, we uncover a new relation between collective motion and synchronisation.

[1] T. Vicsek, A. Zafeiris, Physics Reports 517, 71 (2012)

[2] G. Kokot, D. Piet, G.M. Whitesides, I.S. Aranson, A. Snezkho, Scientific Reports 5, 9528 (2015)

[3] A. Kaiser, A. Snezkho, I.S. Aranson, Science Advances (submitted)

DY 37.2 Wed 15:15 HÜL 186

Unexpected enhancement of rotational dynamics of self-propelled particles in a colloidal glass — •CELIA LOZANO[1,2], JUAN RUBEN GOMEZ-SOLANO[1], and CLEMENS BECHINGER[1,2] — [1]2. Physikalisches Institut, Universitaet Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max-Planck-Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany

It has been recently demonstrated that the glass transition of dense colloidal suspensions is progressively shifted by increasing activity of embedded self-propelled particles (SPP) [1]. However, it is not clear yet how the dynamics of such SPP becomes affected by the surrounding glassy environment. We experimentally investigate the active motion of spherical Janus particles within a cage created by a binary mixture of colloidal particles. We observe a dramatic enhancement of the rotational diffusion of active particles with increasing particle velocity and the density, in a similar fashion as SPP in semi-dilute polymer solutions [2]. This experimental approach allows us to measure, in parallel, the temporal evolution of the active particle and the passive colloidal suspension. Our findings suggest that these effects originate from the coupling between the thermal fluctuations of the particle and the surrounding heterogeneities, which displays large relaxation times of several seconds.

[1] Ni, R., Stuart, M. A. C. & Dijkstra, M. Nature communications 4, 2704 (2013). [2] Gomez-Solano, J. R., Blokhuis, A. & Bechinger, C. Phys. Rev. Lett. 116, 138301 (2016).

DY 37.3 Wed 15:30 HÜL 186

Motility-Induced Phase-Separation of Microswimmers: Hydrodynamics and Phase-Equilibria — •Johannes Blaschke and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenberg Str. 36, 10623 Berlin, Germany

Active motion of microorganisms and artificial microswimmers is relevant both to real world applications as well as for posing fundamental questions in non-equilibrium statistical physics. Microswimmers are often modelled as active Brownian particles, neglecting hydrodynamic interactions between them. However, real microswimmers, such as ciliated microorganisms, catalytic Janus particles, or active emulsion droplets, employ propulsion mechanisms reliant on hydrodynamics. Therefore, we use multi-particle collision dynamics to explore the influence of hydrodynamics on the collective behavior of spherical microswimmers in quasi-two-dimensional geometry [1].

A striking feature of the collective motion of microswimmers is that for sufficiently strong self-propulsion they phase-separate into dense clusters coexisting with a low-density gas phase. Here we examine the influence of hydrodynamic interactions on this motility-induced phase separation. The most striking difference with the phase diagram of active Brownian particles is that a larger mean density results in a lower density of the coexisting dilute phase, which is a clear signature of hydrodynamics. Furthermore, we find that pushers or pullers suppress phase separation by increasing the critical Péclet number.

[1] J. Blaschke, M. Maurer, K. Menon, A. Zöttl, and H. Stark, *Soft Matter* (2016), DOI:10.1039/C6SM02042A.

DY 37.4 Wed 15:45 HÜL 186

Synthetic Janus microswimmers moving under confinement in viscoelastic media — •Juan Ruben Gomez Solano[1], Mahsa Sahebdivani[1], and Clemens Bechinger[1,2] — [1]2. Physikalisches Institut, Universitaet Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Max-Planck-Institut fuer Intelligente Systeme, Heisenbergstrasse 3, 70569 Stuttgart, Germany

The motion of many natural microswimmers, e.g. bacteria and spermatozoa, commonly takes place in viscoelastic media and under confinement close to solid walls. Recent experiments demonstrate that active colloids in Newtonian liquids can be hydrodynamically and phoretically trapped or guided by solid walls depending on the surrounding flow field and on the geometry of the confinement [1-3]. In our work, using spherical Janus microswimmers activated by light in a semidilute polymer solution [4], we experimentally investigate how viscoelasticity affects the motion of such self-propelled particles when approaching or leaving a flat wall. Unlike self-propulsion in Newtonian fluids, we find a strong particle-wall repulsion induced by the surrounding viscoelastic liquid over large distances from the wall. We show that this phenomenon has dramatic consequences for the particle translational and rotational dynamics in more complex confined geometries, as well as for collective motion in crowded environments.

[1] G. Volpe et al., Soft Matter 7, 8810 (2011). [2] D. Takagi et al., Soft Matter 10, 1784 (2014). [3] J. Simmchen, Nat. Comm. 7, 10598 (2016). [4] J. R. Gomez-Solano, A. Blokhuis, and C. Bechinger, Phys. Rev. Lett. 116, 138301 (2016).

DY 37.5 Wed 16:00 HÜL 186

Dynamics of microswimmer molecules — Sonja Babel, Niklas Küchler, Hartmut Löwen, and •Andreas M. Menzel — Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany

In recent years, the dynamical properties of individual microswimmers have been investigated intensively. The same applies for their collective dynamical behavior in dilute and dense suspensions. Here we address an intermediate level. We study the dynamics of compound objects of coupled swimmers that we term "microswimmer molecules" [1,2].

First, we address three spherical magnetic microswimmers connected by elastic springs to a straight object [1]. The magnetic interactions support the straight arrangement. However, with increasing active drive, hydrodynamic interactions destabilize the straight shape. Technically, this occurs via a subcritical Hopf bifurcation. The oscillatory feature of this bifurcation is connected to a cork-screw-like motion of

the molecule.

Second, we consider an active microswimmer coupled by elastic springs to one or more passive swimmers [2]. The dynamics of this type of molecule in an external planar swirl flow is investigated, while hydrodynamic interactions are neglected to lowest order. Because of the finite extension and deformability of these molecules, interesting dynamical features arise. They comprise an expulsion from or undertow into the swirl, rotations of the deformed trajectories, and changes in the sense of the trajectory rotations.

[1] Babel et al., *EPL (Europhys. Lett.)* **113**, 58003 (2016).
[2] Küchler et al., *Phys. Rev. E* **93**, 022610 (2016).

DY 37.6 Wed 16:15 HÜL 186

Microscopic derivation of the hydrodynamics of active-Brownian-particle suspensions — Stefano Steffenoni[1], •Gianmaria Falasco[2], and Klaus Kroy[2] — [1]Max planck for the mathematics in the science, leipzig — [2]Institute for theoretical physics, leipzig

We derive the hydrodynamic equations of motion for a fluid of active particles described by under- damped Langevin equations that reduce to the Active-Brownian-Particle model, in the overdamped limit. The contraction into the hydrodynamic description is performed by locally averaging the particle dynamics with the non-equilibrium many-particle probability density, whose formal expres- sion is found in the physically relevant limit of high-friction through a multiple-time-scale analysis. This approach permits to identify the conditions under which self-propulsion can be subsumed into the fluid stress tensor and thus to define systematically and unambiguously the local pressure and surface tension of the active fluid.

15 min. break

DY 37.7 Wed 16:45 HÜL 186

Determination of the phase behavior and the critical point in systems of active particles in depletants — •Jonathan Tammo Siebert[1], Benjamin Trefz[1,2], Thomas Speck[1], Kurt Binder[1], and Peter Virnau[1] — [1]Department of Physics, Johannes Gutenberg University of Mainz, D-55128 Mainz, Germany — [2]Graduate School Materials Science in Mainz, D-55128 Mainz, Germany

We study a modified, active variant of the well-known Asakura-Oosawa model for colloid-polymer mixtures. Activity is introduced as Vicsek-like self-propulsion. This system already undergoes phase separation in case of zero propulsion. In the driven case, the binodal lines are shifted towards lower densities.

Building on earlier results for the binodal line, we completed the phase diagram by determination of the critical point, using a subsystem-block-density distribution analysis. In addition to understanding critical phenomena in this specific system far from equilibrium, the proposed method can serve as a recipe to find critical points and the associated exponents for other types of active particles.

DY 37.8 Wed 17:00 HÜL 186

Clustering of nematic active particles in low Reynolds number Navier-Stokes flow — •Rebekka Breier, Cristian C. Lalescu, Devin Waas, Michael Wilczek, and Marco G. Mazza — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen

Large groups of self-propelled particles are ubiquitous in nature, from flocks of starlings and herds of wildebeests down to schools of fish and groups of bacteria or algae. Many of these creatures exist in (possibly mildly) turbulent habitats, like motile plankton in the pycnocline of the ocean. We study large systems of self-propelled, nematically aligning, hard core particles by means of molecular dynamic simulations which inhabit a turbulent environment. We investigate the active dynamics and compare the results from kinematic simulations ("synthetic turbulence") with direct numerical simulations of the turbulent background field. We find a "sweet spot" for clustering, that is, an optimal strength of turbulence leads to very dense small-scale clusters. We explain the mechanism that induces clustering. Moreover, we investigate the effect of hard cores compared to point particles, and also give the appropriate dimensionless numbers to describe the dynamic transitions.

DY 37.9 Wed 17:15 HÜL 186

Reinforcement learning of artificial microswimmers — •Santiago Muiños-Landin[1], Keyan Ghazi-Zahedi[2], and Frank Cichos[1] — [1]Molecular Nanophotonics. University of Leipzig. Institut for Experimental Physics I — [2]Information Theory of Cognitive Systems, Max Planck Institute for Mathematics in the Sciences

Reinforcement Learning (RL) is a special area of the Machine Learning discipline which consist in the search of an optimal policy in the context of Markovian Decision Processes (MDP). Learning is based on the interaction of the system with its environment and is guided by sparse rewards. In RL a policy is a function that connects the available actions that an agent can execute with the states where this agent can be located at. MDPs were already proposed as a model for the navigation of natural microswimmers. Here we present now a method that uses this RL in order to achieve an autonomous explorative behavior from a self-thermophoretic microswimmer. We implement it experimentally by photon nudging to reach reinforcement learning of a symmetric microswimmer.

DY 37.10 Wed 17:30 HÜL 186

Self-propelled motion of an extra particle in a two-dimensional plasma crystal — •Ingo Laut, Christoph Räth, Sergey K. Zhdanov, Volodymyr Nosenko, Gregor E. Morfill, and Hubertus M. Thomas — Deutsches Zentrum für Luft- und Raumfahrt, Forschungsgruppe Komplexe Plasmen, 82234 Weßling, Germany

Plasma crystals consist of charged microparticles that levitate in a weakly ionized gas. In these nonequilibrium systems the particle interaction is nonreciprocal due to flowing ions. Plasma crystals were successfully used to study dynamical effects in liquids and solids at the kinetic level and have the potential to also enable the study of active particles.

Here, we analyze in simulations and theory the self-propelled motion of an "extra" particle in a two-dimensional plasma crystal. Experimental observations [1] showed that the extra particle is confined in a channel of two neighboring rows of particles and moves persistently through the crystal. We use the simple model of a pointlike ion wake charge to reproduce this intriguing effect in simulations. We show that the nonreciprocity of the particle interaction, owing to the plasma flow, is responsible for a broken symmetry of the channel that enables the self-propelled motion of the extra particle [2].

[1] C.-R. Du, V. Nosenko, S. Zhdanov, H. M. Thomas, and G. E. Morfill, Phys. Rev. E **89**, 021101(R) (2014)
[2] I. Laut, C. Räth, S. K. Zhdanov, V. Nosenko, G. E. Morfill, and H. M. Thomas, accepted for publication in Phys. Rev. Lett.

DY 37.11 Wed 17:45 HÜL 186

Dynamics of model bacteria in dense polymer suspensions and networks — •Andreas Zöttl and Julia M Yeomans — Rudolf Peierls Centre for Theoretical Physics, University of Oxford, UK

Swimming bacteria, such as Helicobacter pylori, Pseudomonas aeruginosa and sperm cells, move through viscoelastic fluids, such as mucus, in vivo. Theoretical models for these complex fluids are typically based on continuum equations which assume a constant density of sufficiently small polymers, homogeneously embedded in a Newtonian fluid. However, real viscoelastic fluids are more structured when considered on the length scale of a microswimmer: they can consist of heterogeneously distributed, up to micrometer long, macromolecules such as mucin polymers.

Here we present results of coarse-grained hydrodynamic simulations of a flagellated bacterium swimming in explicitly modeled macromolecular polymer solutions and cross-linked networks. We find a remarkable increase in the bacterium's swimming speed at high polymer density. We further discuss the effect of polymer properties such as length, stiffness and cross-linking. We also report the flow fields and the local polymer properties in the vicinity of the bacterium, which can be strongly influenced by its motion.

DY 37.12 Wed 18:00 HÜL 186

Rheology and shear-induced dynamics of passive and active anisotropic colloids — •Henning Reinken and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate the rheology of passive and active fluids focusing on shear-induced instabilites and emerging spatiotemporal structures. Prominent examples of active matter, which is composed of self-driven units converting energy into motion on the microscopic scale, are anisotropic colloidal particles with polar or nematic interactions. Al-

ready in the passive case, these systems show very interesting rheological properties including oscillatory orientational states and shear banding [1]. Introducing activity into the system modifies the rheology and leads to additional instabilities [2].

We study the rheological properties via the Doi-Hess theory [1], a continuum theoretical approach. In this framework, the orientational order parameter is coupled to the flow via the stress tensor, which can be extended to include an active stress [2]. In particular, we focus on parameter regimes where interesting spatiotemporal structures like banded states or active turbulence [3] emerge and discuss the differences between active and passive systems.

[1] R. Lugo-Frías, H. Reinken, S. H. L. Klapp, Eur. Phys. J. E **39**: 88 (2016).
[2] M. C. Marchetti et al. Rev. Mod. Phys. **85**, 1143 (2013).
[3] S. Heidenreich, J. Dunkel, S. H. L. Klapp, M. Bär, Phys. Rev. E **94**, 020601(R) (2016).

DY 37.13 Wed 18:15 HÜL 186

Effective interactions of active particles: interfacial phase behavior and swim pressure — •René Wittmann, Abhinav Sharma, and Joseph Brader — Departement für Physik, Universität Fribourg, 1700 Fribourg, Schweiz

We employ classical density functional theory to study the self-organization in active systems. Using a first-principles approach, we map the self-propulsion onto an effective pair interaction potential, which has been shown [1] to account for the motility-induced phase separation (MIPS) observed for active Brownian particles. We further introduce an effective external potential and investigate inhomogeneous situations.

Solely as a result of their activity, we predict [2] that active (Brownian) particles undergo a variety of interfacial phase transitions, e.g., wetting and capillary condensation in purely repulsive systems or drying and capillary evaporation of attractive colloids. We explain why the effective thermodynamic pressure and interfacial tension do not coincide with the mechanical results, which we recover by embedding the presented effective-potential approach within a more general (dynamical) framework. Finally, we comment on situations with a non-vanishing particle current [3].

[1] T. F. F. Farage, P. Krinninger and J. M. Brader, Phys. Rev. E **91**, 042310 (2015).
[2] R. Wittmann and J. M. Brader, Europhys. Lett. **114**, 68004 (2016).
[3] A. Sharma, R. Wittmann, J. M. Brader, arXiv:1611.03897 (2016).

DY 37.14 Wed 18:30 HÜL 186

Patterns in chemically interacting microswimmers: Do they really exist? — •Benno Liebchen[1], Davide Marenduzzo[1], and Michael E. Cates[2] — [1]SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom — [2]DAMTP, Centre for Mathematical Sciences, University of Cambridge, Cambridge CB3 0WA, United Kingdom

Chemotaxis is the directed motion of particles in response to a gradient in a chemical signal. It allows micro-organisms, like bacteria, to find food and to escape from toxins. Some micro-organisms can produce the species to which they respond themselves and use chemotaxis for signalling. Remarkably, artificial Janus colloids that swim by catalysing reactions in a bath naturally feature chemical interactions and thereby provide a synthetic analogue to signalling micro-organisms. While, it is well known that cases where these interactions are attractive lead to clustering and phase separation, we have recently demonstrated that the purely repulsive case does not simply stabilize the uniform phase but creates a versatile new route to pattern formation in active systems.

In this talk, I will briefly review our work on chemorepulsive pattern formation and will focus the question on how generic and realistic these patterns are for Janus colloids. Our work unveils a fundamental link between autophoresis and chemotaxis leading to a massive collapse of parameter space and generic instability criteria which we confirm using particle based simulations.

DY 37.15 Wed 18:45 HÜL 186

Kinetic theory of self-propelled particles: von Mises distribution and Chapman-Enskog expansion — •Rüdiger Kürsten and Thomas Ihle — Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald

We consider Vicsek-type models [1] with multi-particle interactions and discrete time dynamics. Starting from the exact evolution equation for the N-particle probability distribution, an Enskog-like kinetic equation is derived. Recently, the von Mises distribution and an geometric series ansatz were proposed to treat this nonlinear integral equation [2,3]. We critically assess them for a Vicsek-model with bounded-confidence interactions. Both approaches recover the qualitative behavior of the system but the von Mises distribution causes large deviations in certain parameter regions [4]. We extend the von Mises approximation by an additional term that leads to much better agreement. The geometric series ansatz for the Fourier modes of the probability density is typically very accurate but fails for very weak noise. We therefore suggest an alternative approach – a Gaussian ansatz – for the higher modes, which is robust at all noises. Furthermore, we present a non-standard Chapman-Enskog expansion with a fast time scale. This expansion is used to derive the macroscopic transport equations from the microscopic collision rules. We discuss the expressions for the transport coefficients, which become simple in the limit of infinite density.

[1] Phys. Rev. Lett. 75 (1995) 1226 [2] J. Stat. Mech. (2015) P10017
[3] Phys. Rev. E 90 (2014) 063315 [4] arXiv:1611.00624

DY 38: The Physics of Power-Grids – Fluctuations, Synchronization and Network Structures (Focus session, joint DY/SOE)

The resilient and sustainable energy supply via power grids is one of the main future challenges for science and technology. Since the dynamics of power grids can be described by models that resemble the structure of Kuramoto's famous model for synchronization, power grid modeling is a topic where nonlinear dynamics, statistical physics and network science meet an important topic from engineering. Especially the integration of renewable energy sources accompanied by grid decentralization and fluctuating power feed-in from wind and solar power generation raises novel challenges for power system stability and design which can be addressed from the viewpoint of physics. In this focus session we will cover different aspects of the question how fluctuations and network structure influence the stability of the power grid.

Organized by Oliver Kamps, Joachim Peinke, Philipp Maass

Time: Wednesday 15:00–19:15 Location: ZEU 160

Invited Talk DY 38.1 Wed 15:00 ZEU 160

Asymmetry-Induced Synchronization Stability in Power-Grid Networks — •Adilson Motter — Northwestern University, Evanston, IL, USA

Synchronization is a paradigm for behavioral uniformity that can emerge from interactions and a necessary condition for the operation of coupled generators in power-grid networks. When the interacting entities are identical and their coupling patterns are also identical, the complete synchronization of the entire network is the state inheriting the system symmetry. As in other systems subject to symmetry breaking, such symmetric states are not always stable. Here, I will discuss the discovery of the converse of symmetry breaking—the scenario in which complete synchronization is not stable for identically

coupled identical oscillators but becomes stable when, and only when, the oscillator parameters are judiciously tuned to nonidentical values. This corresponds to breaking the symmetry of the system to preserve the symmetry of the state. I will discuss how this implies that heterogeneity of dynamical units can facilitate and even be required for the stability of synchronous states in power grids and other oscillator networks. (Joint work with Takashi Nishikawa and Ferenc Molnar.)

DY 38.2 Wed 15:30 ZEU 160

The benefit of cooperation in a simplified highly renewable European electricity infrastructure — Leon Schwenk-Nebbe[1], Jonas Hörsch[2], Mirko Schäfer[1], and •Martin Greiner[1] — [1]Department of Engineering, Aarhus University, Denmark — [2]Frankfurt Institute for Advanced Studies, Germany

We consider a simplified model of a future European electricity network with a high share of renewable generation. In a cost optimal design of such a system, most of the renewable generation capacity is placed at locations with favorable weather conditions, that is for instance onshore wind in countries bordering the North Sea and solar PV in South European countries. Countries with less favorable renewable generation conditions benefit from this capacity by importing the respective electricity as power flows through the transmission grid. Using flow tracing techniques, which are related to directed diffusion processes on networks, we disentangle the emerging pattern of imports and exports and assign shares of the distributed generation capacity in the European system to the countries which actually make use of them. This procedures yields nodal levelized costs, which incorporate both internal and external generation as well as transmission costs associated with the electricity consumption in a country. Compared to a scenario without transmission, these nodal levelized costs are reduced by about 15% and represent the benefit of cooperation.

DY 38.3 Wed 15:45 ZEU 160

Scaling of transmission capacities in aggregated renewable electricity networks — Simon Bugge Siggaard[1], Chris Risager Poulsen[1], Jonas Hörsch[2], Mirko Schäfer[1], and •Martin Greiner[1] — [1]Department of Engineering, Aarhus University, Denmark — [2]Frankfurt Institute for Advanced Studies, Germany

Models of the electricity system often feature only a reduced spatial resolution, either due to lack of data or in order to reduce the complexity of the problem with respect to numerical calculations. For the determination of power flows in the respective electricity grid model, this reduced spatial resolution is connected to an aggregation procedure, which concerns both the network topology as well as the pattern of power imports and exports at the network nodes. The resulting flow patterns and transmission capacities of the system thus depend on the spatial resolution of the aggregated network. In this contribution, we investigate the scaling properties of aggregated power flows and transmission capacities on synthetic complex networks and a model of the European power grid, both including a high share of fluctuating renewable generation. The numerical findings are supported by analytical results for the scaling of power flows on aggregated two-dimensional lattices.

DY 38.4 Wed 16:00 ZEU 160

Probabilistic methods for deterministic systems (on networks) — •Frank Hellmann — Potsdam-Institut für Klimafolgenforschung (PIK), Potsdam, Detuschland

I discuss how we use probabilistic, sampling based methods to understand and uncover dynamic properties of complex systems on networks. The motivating example are Kuramoto oscillators with inertia, which we interpret as a simple example of power grids.

Concretely I show how the underlying network topology leaves a quantifiable imprint on the dynamical properties of the overall system, in particular its ability to return to or stay close to synchronization, and how we can identify novel asymptotic states that are only accessible by perturbations at specific nodes.

DY 38.5 Wed 16:15 ZEU 160

From conventional to renewable power: the role of grid heterogeneities — •Pedro Lind, Philipp Maass, Christoph Schiel, and Matthias Wolff — Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, 49076 Osnabrück, Germany

The influence of heterogeneities characterizing transmission lines and generators on the functioning of power grids is investigated, focusing on the situation where conventional power plants are replaced by renewable power sources.Two problems are addressed.

First, we study the probability of single line failure [1], showing that it is necessary to consider the maximum power at the generator where renewable power is injected into the grid, the mean injected power and operating time scales of human intervention. We derive a formula for the failure probability that incorporates all these three aspects as well as simple parameters characterizing the wind statistics at the envisaged injection node. Our derivation is based on empirical sets taken at the North Sea.

Secondly, we report on simulations of the time-dependent power flow in grids [2], where power input from a fraction of the generator nodes is fluctuating and follows stochastic dynamics mimicking statistical features of wind and solar power injection. Different measures of the grid stability are discussed, as, for example, frequency stability and phase synchronization.

[1] S. Backhaus and M. Chertkov, Phys. Today 66, 42-48 (2013).
[2] T. Nishikawa and A. E. Motter, New J. Phys. 17, 015012 (2015).

DY 38.6 Wed 16:30 ZEU 160

Complex statistics of regenerative power feed-in — •Matthias Wächter, Mehrnaz Anvari, Patrick Milan, and Joachim Peinke — Instute of Physics and ForWind, Carl von Ossietzky University, 26111 Oldenburg, Germany

Future power grids are expected to experience a high share of renewable power generation. These renewable sources present pronounced statistical features stemming from the turbulent and intermittent nature of the wind and solar resources. Such features include strongly intermittent power fluctuations as well as long-range and higher-order correlations in time and space. Moreover, photovoltaic power feed-in is characterized by jump-like behavior due to cloud borders. We will give an overview on the current knowledge of these complex statistics specific for renewable power, which will pose significant challenges for future power grids.

15 min. break

Invited Talk DY 38.7 Wed 17:00 ZEU 160

Nonlinear Rerouting and Response in Electric Power Networks — •Marc Timme[1,2], Dirk Witthaut[3], and Xiaozhu Zhang[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization and Technical University of Darmstadt — [2]http://networkdynamics.info — [3]FZ Julich

Networks dominate our daily life – and most of them are dynamic. For instance, almost all of the infrastructure we use today, from simple lights to hospital treatment, from communication to transport systems, crucially depend on electric energy reliably supplied via power grids. The ongoing integration of renewable energy sources, being smaller, more heterogeneous, decentralized and more fluctuating, implies more strongly networked systems with more distributed operation states. In our research group we aim to understand fundamental principles underlying the collective nonlinear dynamics of networked systems in general. This talk highlights recent developments and provide two examples of collective phenomena in decentrally organized power grids. First, we offer a theory of non-local rerouting of electricity upon line failure, providing an accurate prediction of flow redistribution that goes beyond local predictors. Second, we analyze patterns of dynamic responses to distributed fluctations across time scales and demonstrate under which conditions the notion of a "variation in the grid frequency" breaks down.

See also: Phys. Rev. Lett. 109:064101 (2012); Phys. Rev. Lett. 116:138701 (2016); Zhang et al., DPG talk (2017); New J. Phys. 14:083036 (2012); Nature Comm. 7:11061 (2016).

DY 38.8 Wed 17:30 ZEU 160

Impact of Wind Feed-in on Power System Stability and Quality — •Katrin Schmietendorf[1], Joachim Peinke[1], and Oliver Kamps[2] — [1]Universität Oldenburg, ForWind — [2]Universität Münster, Center for Nonlinear Science

Feed-in fluctuations are one of the major challenges for future electrical power grids. Short-term fluctuations on the second and sub-second scale are not counteracted by standard load balancing mechanisms. Moreover, on these time scales feed-in fluctuations are strongly non-Gaussian with intermittent increment statistics. We focus on short-term wind power fluctuations with realistic properties: temporal correlation, power spectrum, and intermittent increments. We discuss the implications on power system stability in terms of noise-induced

desynchronization. Furthermore, we show that the turbulent nature of wind significantly reduces power quality as it is directly transferred into the fluctuations of frequency and voltage.

DY 38.9 Wed 17:45 ZEU 160

Collective Network Dynamics of Electric Power Grids — Xiaozhu Zhang[1,2], Dirk Witthaut[3], and •Marc Timme[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization and Technical University of Darmstadt — [2]http://networkdynamics.info — [3]FZ Julich

Networks dominate our daily life – and most of them are dynamic. For instance, almost all of the infrastructure we use today, from simple lights to hospital treatment, from communication to transport systems, crucially depend on electric energy reliably supplied via power grids. The ongoing integration of renewable energy sources, being smaller, more heterogeneous, decentralized and more fluctuating, implies more strongly networked systems with more distributed operation states. In our research group we aim to understand fundamental principles underlying the collective nonlinear dynamics of networked systems in general. This talk highlights recent developments and provide two examples of collective phenomena in decentrally organized power grids. First, we offer a theory of non-local rerouting of electricity upon line failure, providing an accurate prediction of flow redistribution that goes beyond local predictors. Second, we analyze patterns of dynamic responses to distributed fluctations across time scales and demonstrate under which conditions the notion of a "variation in the grid frequency" breaks down.

This is work with various other colleagues. see also: Phys. Rev. Lett. 109:064101 (2012); Phys. Rev. Lett. 116:138701 (2016); New J. Phys. 14:083036 (2012); Nature Comm. 7:11061 (2016).

DY 38.10 Wed 18:00 ZEU 160

Topology related Instabilities driven by Intermittent Fluctuations in Distribution Grids — •Sabine Auer[1,2], Frank Hellmann[1], and Jürgen Kurths[1,2,3,4] — [1]Potsdam Institute for Climate Impact Research, 14412 Potsdam, Germany — [2]Department of Physics, Humboldt University Berlin, 12489 Berlin, Germany — [3]Institute of Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen AB24 3FX, UK — [4]Department of Control Theory, Nizhny Novgorod State University, 606950 Nizhny Novgorod, Russia

The impact of increased shares in variable renewable energy sources on the power system is subject to a controversial public debate. The question to what extent grid stability is influenced, especially the effect on distribution grids, is not well-understood but has come into focus, recently.

Thus, we investigated the influence of intermittent fluctuations from renewables on frequency stability with respect to network topology. Here, single node fluctuations are exerted onto each node of a typical distribution grid and the reaction in network frequency is quantified studying the frequency tail distributions.

We chose two prominent model cases which stand for today's Mid-Voltage distribution and potential future micro grids. Results and potential balancing measures as decentral smart grid control with the help from electric vehicles will be discussed.

DY 38.11 Wed 18:15 ZEU 160

Power Grid Resilience: Short-term Fluctuations and Intermittency — •Hauke Haehne, Matthias Waechter, and Joachim Peinke — Carl von Ossietzky University Oldenburg, Institute of Physics and ForWind, 26111 Oldenburg, Germany

Future power grids will be fed by a high share of renewable generation with strongly intermittent fluctuation patterns of produced power. This poses new challenges for resilient grid operation. From a physical perspective, the frequency of the alternating current in a power grid provides information on the instantaneous ratio of demand to production. We use high-resolution frequency measurements of the continental European power grid to analyze resilience regimes of the electric transport and actor system. We characterize fluctuations on different time scales and compare our findings to prior results from renewable power systems analysis. We combine stochastic methods and network dynamics, data analysis and simulations.

DY 38.12 Wed 18:30 ZEU 160

Frequency Fluctuations in Power Grids: From Observed Data to Lévy-stable Laws — •Benjamin Schäfer[1], Kazuyuki Aihara[2], Dirk Witthaut[3,4], and Marc Timme[1,5] — [1]Network Dynamics, Max Planck Institute for Dynamics and Selforganization (MPIDS), Göttingen — [2]Institute of Industrial Science, The University of Tokyo, Komaba, Meguro-ku, Tokyo, Japan — [3]Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), Jülich — [4]Institute for Theoretical Physics, University of Cologne, Köln — [5]Department of Physics, Technical University of Darmstadt, Darmstadt

The ongoing energy transition (*Energiewende*) to replace fossil by renewable energy sources raises new challenges for power grid design and control, because renewables do not supply a constant power but introduce fluctuations to the grid. Here, we analyze fundamental dynamics of power grid frequency fluctuations. We analyze specific frequency data for the continental European grid, the British grid, the Japanese power grids as well as for the Eastern Interconnection in North America. We model the underlying stochastic process using (generalized) Fokker-Planck equations and validate our analytical predictions by Monte-Carlo simulations. We conclude that dominant contributions to the frequency fluctuations in a grid may be approximated by a single variable, the average frequency deviation, modeled as a random variable following a Lévy-stable distribution.

DY 38.13 Wed 18:45 ZEU 160

Mathematical models for the transient stability of conventional power generating stations connected to low inertia systems — •Marios Zarifakis[1], William T Coffey[2], Yuri P Kalmykov[3], and Sergei V Titov[4] — [1]Electricity Supply Board, Generation, Asset Management, Dublin 2, Ireland — [2]Department of Electronic and Electrical Engineering, Trinity College, Dublin 2, Ireland — [3]Laboratoire de Mathématiques et Physique (EA 4217), Université de Perpignan Via Domitia, F-66860, Perpignan, France — [4]Kotelnikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, Vvedenskii Square 1, Fryazino 141120, Russia

Recent experience shows that this increase of power generation sources influences the behaviour of grid connected generating units. One observation is the change in the generated power after a transient disturbance especially its oscillatory behaviour accompanied by similar oscillatory behaviour of the grid frequency. An understanding of such behaviour of generators under various disturbances requires a new modelling technique. Therefore, a mathematical model of a generating station based on a system of coupled nonlinear differential equations and suitable for analysis of its stability is presented. The mathematical model will allow one to highlight limitations to the operational range of synchronous generators and could also be used to identify limits to the amount of total inertia necessary to maximise the usage of grid connected non-synchronous generators such as wind turbines and solar photo-voltaic installations.

DY 38.14 Wed 19:00 ZEU 160

Langevin analysis of large scale power outages - A case study — •Frank Ehebrecht[1] and Oliver Kamps[2] — [1]Institut für Theoretische Physik, WWU Münster, Germany — [2]Center for Nonlinear Science, WWU Münster, Germany

The anticipation of critical transitions in complex systems is a field of active research in such diverse disciplines as ecology, climate research or engineering [1]. In [2] large scale power outages are considered as critical transitions in the operation of power grids. It was shown for the large scale power outage on August 10 in 1996 in the USA that the event could be anticipated from critical fluctuations of the system frequency.

In this talk we present results from the analysis of two different data sets of the system frequency from the same event that have been measured at two different positions in the grid. We show that critical fluctuations seem not to be a reliable indicator for a critical transition in the power grid. In contrast to that, analyzing the data from the viewpoint of Langevin equations by estimating the drift and diffusion coefficients shows to be more reliable to anticipate the outage.

[1] M. Scheffer et. al., Nature, 461, 2009

[2] E. Cotilla-Sanchez et. al., IEEE Transactions on Smart Grid, 3, 2012

DY 39: Particulate Matter II: From microscopic interactions to collective motion (Focus session)

Time: Wednesday 15:00–16:15 Location: ZEU 118

Invited Talk DY 39.1 Wed 15:00 ZEU 118

Granular Materials: From solid to fluid with a variable jamming density — •Stefan Luding — MSM, UTwente, Enschede, NL

Soft, disordered, micro-structured materials are ubiquitous in nature and industry, and are different from ordinary fluids or solids, with unusual, interesting static solid-like and dynamic, fluid-like flow properties.

The transition from fluid to solid (at the so-called jamming density) features a multitude of complex mechanisms, (creep, relaxation, jamming, un-jamming and shear-jamming, or shear-thickening) but there is no unified theoretical framework that explains them all. In this talk, a simple yet quantitative and predictive model is presented, which allows for a variable, changing jamming density, encompassing the memory of the deformation history and explaining a multitude of phenomena at and around jamming.

The jamming density, a new state-variable, changes due to the deformation history and relates the systems macroscopic response to its micro-structure. The packing effciency can increase logarithmically slow under gentle tapping or repeated compression, leading to an increase of the jamming density. In contrast, shear deformations cause anisotropy and change the packing effciency exponentially fast with either dilatancy or compactancy as consequence. The memory of the system near jamming can be explained by a micro-statistical model that involves a multiscale, fractal energy landscape and links the microscopic particle picture to the macroscopic continuum description, providing a unified explanation for different deformation modes.

DY 39.2 Wed 15:30 ZEU 118

Tribo-electric charging in granular matter — •André Schella[1], Stephan Herminghaus[1], and Matthias Schröter[1,2] — [1]Max-Planck Institut für Dynamik und Selbstorganisation (MPIDS), Am Faßberg 17, 37077 Göttingen — [2]Institut für Multiskalensimulation, Nägelsbachstrasse 49b, 91052 Erlangen

If granular particles touch either walls or other beads, they do tribocharge. The charge modifies the way these particles interact, causing e. g. lightnings in dust storms, clogging of pipes or even dust explosions [1]. Despite its ubiquity in nature and technology, little is known about the mechanisms behind tribo-electric charging [2]. In our contribution, we will show that tribo-charging in shaken granular media can be controlled via the ambient humidity [3]. Even though the charging of a single bead is related to microscopic processes, it has consequences for the physics of the entire bed: First, charging in binary mixtures can be strong enough to overcome segregation mechanisms. Second, charges alter the structural properties, like the contact number and Voronoi volumes, of the grains. And third, same-sized binary mixtures form macroscopic, granular crystals. [1] J. Duran, Sands, Powders, and Grains, Springer, New York, 2000 [2] L. McCarty and G. Whitesides; Angew. Chem. Int. Ed. 47 2188 (2008) [3] A. Schella et al., arXiv:1609.04639

DY 39.3 Wed 15:45 ZEU 118

Triboelectric charging of surface treated granular media — •Jan Haeberle[1], André Schella[2], Matthias Schröter[3], Matthias Sperl[1], and Philip Born[1] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft-und Raumfahrt, 51170 Köln, Germany — [2]MPI Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen, Germany — [3]Institute for Multiscale Simulation, Nägelsbachstrasse 49b, 91052 Erlangen, Germany

Triboelectric charging of granular media has important consequences for the bulk behaviour. Effects such as powder flowability or cluster formation due to charging are everyday experiences [1]. Recently, triboelectric charging has also been linked to segregation [2] and suggested as a tool for structure formation in granular media [2,3]. In order to change charging behaviour and contact angle, we applied surface treatments to glass beads (d=0.5mm). We study the effect of these treatments in a custom-made Faraday cup setup, that allows the automated measurement of hundreds of individual particles over time periods of hours. In addition, we can control the humidity in a climate chamber to study the effect of water layers on the charging behaviour. We show that we can indeed measure the charge distribution, which can be tuned by surface treatment.

[1] Duran, J., Sands, Powders, and Grains, Springer, New York (2000)

[2] Schella, A. et al., arXiv:1609.04639 (2016)

[3] Cademartiri, R. et al., Soft Matter 8, 9771 (2012)

DY 39.4 Wed 16:00 ZEU 118

Flow Curves for Granular Matter at Finite Density and Shear Rate — •Till Kranz[1], Fabian Frahsa[2], Annette Zippelius[3], Matthias Fuchs[2], and Matthias Sperl[1] — [1]Institut für Materialphysik im Weltraum, DLR Köln — [2]Theorie der Weichen Materie, Uni Konstanz — [3]Institut für Theoretische Physik, Uni Göttingen

A fundamental understanding of the stress-strain relation is crucial for the rational description of granular flows in nature and industry. Experiments and simulations have shown a nontrivial rheology with a Newtonian-fluid regime at low shear rates and densities, a yield stress at high densities, and both shear thinning and shear thickening away from the linear response regime. At high shear rates the granular fluid displays Bagnold scaling. To describe all these regimes in a unified theoretical framework poses a considerable challenge.

We will discuss a recently developed integration through transients theory for the shear stress in a far from equilibrium granular fluid at high densities and finite shear rates which complements the established low-density, linear response results derived from the Boltzmann equation. We will show that with this theory we cover the full range of rheological regimes introduced above using numerical solutions of the granular mode-coupling equations and we will present kinetic expressions for the transport coefficients. In addition, we will discuss what determines the regimes and the range of validity of our approach.

DY 40: Granular Matter

Time: Wednesday 16:30–17:30 Location: ZEU 118

DY 40.1 Wed 16:30 ZEU 118

Heaping and secondary flows in sheared granular materials — •David Fischer[1], Tamás Börzsönyi[2], and Ralf Stannarius[1] — [1]Institute of Experimental Physics, Otto von Guericke University, Universitätsplatz 2, D-39106 Magdeburg, Germany — [2]Institute for Solid State Physics and Optics, Wigner Research Center for Physics, Hungarian Academy of Sciences, PO Box 49, H-1525 Budapest, Hungary

In granular matter, grain shape may have important consequences on macroscopic physical behaviour. Cylindrical split-bottom containers are well established experimental devices to shear granular materials in a continuous way, and to generate well-defined localized shear bands in the granular bed. In such shear experiments, shape-anisotropic grains develop a "secondary flow" profile in radial direction which leads to the formation of a considerable heap of material in the center of the container. We describe the quantitative influence of geometric and dynamic parameters.

DY 40.2 Wed 16:45 ZEU 118

Axial segregation of shape-anisotropic granular particles — •Tina Hanselka, Tilo Finger, and Ralf Stannarius — Otto-von-Guericke-Universität Magdeburg

When a granular mixture is rotated in a horizontal cylindrical drum, it shows radial and axial segregation. Most experimental observations of these effects were performed with spherical particles. Several models have been proposed to describe the mechanism of axial segregation. In our experiments, we compare the behaviour of a mixture of spherical and elongated particles to mixtures with only spherical grains. We discuss the conformity of the proposed models with our experimental results.

DY 40.3 Wed 17:00 ZEU 118

Energy Partition During Cooling of Granular Gases of Rodlike Grains in Microgravity — •Kirsten Harth[1,2], Torsten Trittel[1], Sandra Wegner[1], and Ralf Stannarius[1] — [1]Otto von Guericke Univesität Magdeburg, Institut für Experimentelle Physik — [2]Univesiteit Twente, Physics of Fluids

Granular gases are loose emsembles of grains interacting by dissipative collisions. They represent one of the simplest and most fundamental granular many-particle systems and thus the topic of manifold theoretical investigations. The collective loss of energy of granular gases from an initially excited state is termed granular cooling, and is probably the most frequently theoretically investigated aspect of granular gases. Experimental realizations minimizing disturbances from the container boundaries and minimal spatial inhomogeneities oft he initial state require microgravity. For 3D granular gases, the use of rodlike grains instead of spheres proves advantageous as rotational as well als translational motions are accessible and the spatial distributions are more uniform than those of spherical grains. Here, we address the granular cooling of gases of rodlike grains in micro-gravity. We focus on the evolution oft he decay and the partition of kinetic energy on the different degrees of freedom. Drop tower experiments offer fundamental insights into the energy equilibration and homogeneous cooling of a 3D granular gas.

DY 40.4 Wed 17:15 ZEU 118

Energy dissipation in sheared wet granular piles — •Anna-Lena Schuhmacher[1], Marc Schaber[1], Somnath Karmakar[1], Mario Scheel[3], Marco DiMichiel[3], Martin Brinkman[1,2], and Ralf Seemann[1,2] — [1]Experimental Physics, Saarland University, 66041 Saarbruecken, Germany — [2]MPI for Dynamics and Self-Organization, 37077 Goettingen, Germany — [3]European Synchrotron Radiation Facility, 38000 Grenoble, France

The resistance of granular bead packs is explored when being sheared with a parabolic profile at constant shear volume. The dissipated energy can be determined from the measured differential pressure and increases about linearly with confining pressure for both dry and wet bead packs. However, the dissipated energy for wet beads has a finite value for vanishing external pressure and increases slower with external pressure compared to dry beads.

Using a downsized version of the shear cell the reorganization of beads and liquid is imaged using ultrafast x-ray micro-tomography. The movement of each bead can be tracked during the shear process. The relative movement of the beads causes the breakup of liquid capillary bridges. The contribution of the breaking capillary bridges to the dissipated energy can be quantified by directly detecting individual rupture events.

DY 41: Active Matter II (joint session DY/BP/CPP)

Time: Thursday 9:30–13:00 Location: HÜL 186

Invited Talk DY 41.1 Thu 9:30 HÜL 186

Rolling, rolling, rolling – a new self-propulsion mechanism — •Falko Ziebert[1,2] and Igor Kulic[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, 79104 Freiburg, Germany — [2]Institut Charles Sadron UPR22-CNRS, 67034 Strasbourg Cedex 2, France

We describe a generic mechanism that induces an instability towards rolling motion of a rod along a heated plate. The mechanism, relying on geometric planar confinement, can be explained by an effective model combining elasticity of a rod with thermal advection-diffusion. We exemplify the versatility of the effect by investigating self-propellers, as well as simple motors and energy storage devices, both experimentally and theoretically.

DY 41.2 Thu 10:00 HÜL 186

Cluster Formation and Deformation of Spherical Circle Swimmers Dispersed on a Monolayer — •Guo-Jun Liao and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Inspired by recent experimental developments in manufacturing "active" colloidal particles with unusual, e.g. curved, modes of motion (such as form-anisotropic particles [1] or decorated metallodielectric Janus spheres [2]), as well as by the proceeding of a theoretical study on the collective behavior of curved polymers with circular paths [3], we computationally investigate models of spherical particles in which the colloids dispersed on a monolayer feel not only a propelling force, but also a propelling torque. In the absence of propulsion torque (without circular motion), we find clustering of "conventional" self-propelled disks, in accordance with Ref. [4]. We show that the motility-induced cluster formation is enhanced by polar interaction, and cumulatively hindered by increasing the propulsion angular velocity ω_0. Different from the model of curved polymers [3], in which the occurrence of stable vortices is attributed to the shape anisotropy, our generic model of isotropic "active" spheres also form clockwise vortices as ω_0 approaches the rotational diffusion coefficient D_r.

[1] F. Kümmel et al., Phys. Rev. Lett. **110**, 198302 (2013)
[2] S. Gangwal et al., Phys. Rev. Lett. **100**, 058302 (2008)
[3] J. Denk et al., Phys. Rev. Lett. **116**, 178301 (2016)
[4] J. Bialke et al., EPL **103**, 30008 (2013)

DY 41.3 Thu 10:15 HÜL 186

Effect of the orientational relaxation on the collective motion of patterns formed by self-propelled particles. — •Alexander Chervanyov[1], Hector Gomez[2], and Uwe Thiele[1] — [1]Institut für Theoretische Physik, WWU Münster, Germany — [2]Universidade da Coruna, A Coruna, Spain

We investigate the collective behavior of self-propelled particles (SPPs) undergoing competitive processes of pattern formation and rotational relaxation of their self-propulsion velocities. As a main result of this study, we quantitatively explain [1] transitions between different steady states of the SPPs caused by the intricate interplay among the involved effects of pattern formation, orientational order, and coupling between the SPP density and orientation fields. Based on rigorous analytical and numerical calculations, we prove that the rate of the orientational relaxation of the SPP velocity field is the main factor determining the steady states of the SPP system. Further, we determine the exact boundaries between domains in the parameter plane that delineate qualitatively different resting and moving states. In addition, we analytically calculate the collective velocity of the SPPs and show that it perfectly agrees with our numerical results. Our results can be effectively used to identify the regimes of collective behavior of SPPs in living systems in relevance to the domains of dominance of the above described effects of the self-propulsion, pattern formation and orientational relaxation of SPPs.

[1] A.I. Chervanyov, H. Gomez, U. Thiele, EPL 115, 68001 (2016).

DY 41.4 Thu 10:30 HÜL 186

Statistical features of active turbulence — •Martin James and Michael Wilczek — Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Dense bacterial suspensions display rich dynamical features including turbulence-like behavior. Recent studies have shown that such turbulent dynamics of active fluids can be modeled by a generalized Navier-Stokes equation (Wensink et al., PNAS 2012). The statistical features of active turbulence, however, differ significantly from classical hydrodynamic turbulence (see, e.g., Bratanov et al., PNAS 2015). We further explore the statistical features of this active turbulence model both, numerically and analytically. In particular, we focus on scale-dependent statistics to characterize deviations from Gaussianity and the occurrence of extreme events. Moreover, we investigate the transport properties of active flow by using Lagrangian tracer techniques. Our results provide insight into mixing of microbial suspensions due to turbulent dynamics.

DY 41.5 Thu 10:45 HÜL 186

Large scale vortex-patterns in dense suspensions of microswimmers — •Sebastian Heidenreich[1], Jörn Dunkel[2], Sabine H. L. Klapp[3], and Markus Bär[1] — [1]Physikalisch-Technische Bundesanstalt — [2]Massachusetts Institute of Technology — [3]Technische Universität Berlin

In this talk we consider a prominent examples of an active biological

fluid - dense suspension of swimming bacteria (e. g. Bacillus subtilis). For dense suspensions of bacterial swimmers, we have proposed a simple phenomenological model that predicts regular and turbulent vortex lattices and reproduces recent experimental findings of mesoscale turbulence in two- and three-dimensional suspensions of Bacillus subtilis in a quantitative manner [1]. A continuum model that couples the orientation of the swimmers with the surrounding velocity field was derived from stochastic equations of motions for individual active swimmers for a realistic hydrodynamical model of swimmers in a fluid [2]. This model contains the simple phenomenological model used in [1] as a special case. Furthermore, the continuum model enables us to understand the mechanism and properties of pattern formation in microswimmer suspensions and relate the physical parameters characterizing the individual swimmers and their interaction to the coefficients for continuum model equations.

[1] Dunkel, S. Heidenreich, K. Drescher, H. H. Wensink, M. Bär & R. E. Goldstein Phys. Rev. Lett. 110; New. J. Phys. (2013).

[2] S. Heidenreich, J. Dunkel, S. L. Klapp, and M. Bär (2016). Phys. Rev. E, 93

DY 41.6 Thu 11:00 HÜL 186

Collective Effects of Active Particles at Fluid-Fluid Interfaces. — •Irina Kistner, Paolo Malgaretti, Mihail Nicolae Popescu, and Siegfried Dietrich — Max-Planck-Institut fuer Intelligente Systeme, Stuttgart, Germany

Micrometer sized particles capable of self-induced motility are of high interest for various applications in medicine, sensing and environmental science. Recent works report of different types of collective motion such as clustering, swarming or fluid-solid phase separation. Moreover different phenomena may arise when active particles are bounded or reside in the proximity of a fluid-fluid interface [1], [2].

The model system we are investigating consists of two or more chemically active, spherical colloidal particles located close to a fluid-fluid interface. Due to the Marangoni stresses self-induced at the interface, the particles experience a repulsive long-ranged effective force field under harmonic confinement. We show that this effective interaction results in a crystal-like pattern formation of collectively rotating particles and define a gas-crystal phase separation governed by the Marangoni force constant.

[1] A. Dominguez, P. Malgaretti, M. N. Popescu, and S. Dietrich: Effective interaction between active colloids and fluid interfaces induced by Marangoni flows, Phys. Rev. Lett. 117, 079902 (2016)

[2] A. Dominguez, P. Malgaretti, M. N. Popescu, and S. Dietrich: Collective dynamics of chemically active particles trapped at a fluid interface, Soft Matter, 12, 8398-8406 (2016)

15 min. break

DY 41.7 Thu 11:30 HÜL 186

Mechanical Instabilities in Active Systems — •Christoph A. Weber and Lakshminarayanan Mahadevan — Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138, USA

Active stress can affect the stability of biological systems and drive macroscopic changes of matter on very short time scales that cannot be explained by the liquid-like transport of the constituents. Examples are contracting active gels or the compaction of cells in tissues. For these systems the solid-like response to active stress is the key to understand the physics underlying the change of matter. Here we study a generic framework to describe mixtures composed of an active solid and a passive liquid phase. We find that such a mixture is unstable for large enough activity and can demix into regions mostly consisting of solid or fluid, respectively. The instability leads to the formation of disintegrated patches of a length scales which arises from the competition between the shear transport in the solid phase versus the solid-liquid momentum transfer. This mechanical instability might be relevant for many very dense active systems where liquid-like particle transport is mostly jammed.

DY 41.8 Thu 11:45 HÜL 186

Defect dynamics in topological active matter — •Axel Voigt and Francesco Alaimo — Institute für Wissenschaftliches rechnen, TU Dresden

If active systems are confined on curved surfaces, topological constraints strongly influence the emerging spatiotemporal patterns. Using these topological constraints to guide collective cell behavior might be a key in morphogenesis and active nematic films on surfaces have been proposed as a promising road to engineer synthetic materials that mimic living organisms. Recent experiments consider an active nematic film of microtubules and molecular motors encapsulated within a lipid vesicle. As in passive systems the mathematical Poincare-Hopf theorem forces topological defects to be present in the nematic film. On a spherical vesicles this leads to an equilibrium defect configuration with four +1/2 disclinations arranged as a tetrahedron. In active systems unbalanced stresses drive this configuration out of equilibrium. But in contrast to planar active nematics with continuous creation and annihilation of defects the creation of additional defect pairs can be suppresses on curved surfaces. This led to the discovery of a tunable periodic state that oscillates between the tetrahedral and a planar defect configuration. We confirm this finding by computer simulations. For non-constant Gaussian curvature constraints local geometric properties can be used to control defect dynamics. We are concerned with a systematic investigation of the impact of such constraints on the emergence of complex patterns and oscillations.

DY 41.9 Thu 12:00 HÜL 186

Dancing disclinations in living fluids — •Amin Doostmohammadi, Tyler Shendruk, Kristian Thijssen, and Julia Yeomans — University of Oxford

The spontaneous emergence of collective flows is a generic property of active fluids and often leads to chaotic flow patterns characterised by swirls, jets, and topological disclinations in their orientation field. However, the ability to achieve structured flows and ordered disclinations is of particular importance in the design and control of active systems. By confining an active nematic fluid within a channel, we find a regular motion of disclinations, in conjunction with a well defined and dynamic vortex lattice. As pairs of moving disclinations travel through the channel, they continually exchange partners producing a dynamic ordered state, reminiscent of Ceilidh dancing. We anticipate that this biomimetic ability to self-assemble organised topological disclinations and dynamically structured flow fields in engineered geometries will pave the road towards establishing new active topological microfluidic devices.

DY 41.10 Thu 12:15 HÜL 186

Effective interactions between catalytic particle and fluid-fluid interfaces — •Paolo Malgaretti, Mihail Nicolae Popescu, and Siegfried Dietrich — Max Planck Institute for Intelligent Systems, Heisenbergstr. 3 70569 Stuttgart Germany

When catalytic particles, such as Janus particles, or enzymes are in the vicinity of a fluid-fluid interface, their is strongly modulated by the pres-ence of the interface and/or by the inhomogeneity in the transport properties of the two fluid phases. Hence, the effective interaction with the interface can lead to novel dynamical regimes absent in homogeneous fluids. For example, if the by-products of the catalysis are surfactants their spatial distribution will affect the local value of the surface tension. In such a scenario, when catalytic particles approache a fluid-fluid interface a Marangoni flow will set up in response to the inhomogeneity in the surface tension induced by the byproducts of the catalysis. The onset of such a flow attracts the catalytic particle towards the interface. Interestingly the strength of such an effective attraction is strongly affected by the affinity of the byproduct to the interface as well as by the transport properties of the two fluid phases. In particular, for water-oil interfaces such an effect overwhelms other means of active transport such as self-diffusiophoresis and makes it suitable to enhance particle accumulation close to fluid-fluid interfaces. Finally I will discuss the onset of collective behavior.

DY 41.11 Thu 12:30 HÜL 186

Active crystals on the sphere — •Simon Praetorius[1], Axel Voigt[1], Raphael Wittkowski[2], and Hartmut Löwen[3] — [1]Institute of Scientific Computing, Technische Universität Dresden, D-01062 Dresden, Germany — [2]Institut für Theoretische Physik Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [3]Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

Two-dimensional crystals on curved manifolds like a sphere exhibit nontrivial defect structures. Here we consider "active" crystals on the sphere which are composed of self-propelled particles. A coarse-grained model is proposed by unifying the Phase-Field Crystal approach with a Toner-Tu-like theory which involves a density and a polarization field on the sphere. Depending on the strength of the self-propulsion, four different dynamical modes are found: a resting crystal, a self-

spinning "vortex-vortex" crystal containing two vortical poles with integer defects of the polarization, a "source-sink" crystal and a travelling/spinning lamellar. We analyze the dependence of orientational and translational defects on the activity of the crystal.

DY 41.12 Thu 12:45 HÜL 186

Green-Kubo approach to active Brownian systems — •ABHINAV SHARMA and JOSEPH BRADER — Universite de Fribourg, Rue du Musee 3, ch 1700, Fribourg

We develop an exact Green-Kubo formula relating nonequilibrium averages in systems of interacting active Brownian particles to equilibrium time-correlation functions. The method is applied to calculate the density-dependent average swim speed, which is a key quantity entering coarse grained theories of active matter. The average swim speed is determined by integrating the equilibrium autocorrelation function of the interaction force acting on a tagged particle. We generalize our approach to a spatially and time varying activity. Analytical results are validated using Brownian dynamics simulations.

DY 42: Coherent Quantum Dynamics (joint session DY/TT)

Time: Thursday 9:30–13:15 Location: ZEU 160

Invited Talk DY 42.1 Thu 9:30 ZEU 160

Equilibration and ensembles in coherent quantum systems — •FABIAN ESSLER — Oxford University

I consider the relaxation after quantum quenches in isolated quantum systems. In the thermodynamic limit local relaxation towards a stationary state occurs. I first discuss the characterization of the stationary state for generic and integrable systems and how this relates to properties of finite energy density eigenstates. In generic systems the stationary state is locally thermal and has a volume-law entanglement entropy, while there is a considerably richer set of possibilities in integrable models. I then turn to the recently proposed "quantum disentangled liquid", in which thermalized and non-thermalized degrees of freedom are postulated to co-exist. I discuss the possible existence of such states in the half-filled Hubbard model with strong repulsive interactions.

DY 42.2 Thu 10:00 ZEU 160

Thermalization and light cones in a model with weak integrability breaking — BRUNO BERTINI[1,2], FABIAN ESSLER[1], •STEFAN GROHA[1], and NEIL ROBINSON[3] — [1]The Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford, OX1 3NP, United Kingdom — [2]SISSA and INFN, Sezione di Trieste, via Bonomea 265, I-34136, Trieste, Italy — [3]Condensed Matter Physics and Materials Science Division, Brookhaven National Laboratory, Upton, New York 11973, USA

We employ equation of motion techniques to study the non-equilibrium dynamics in a lattice model of weakly interacting spinless fermions. Our model provides a simple setting for analyzing the effects of weak integrability breaking perturbations on the time evolution after a quantum quench. For sufficiently weak integrability-breaking interactions we always observe prethermalization plateaux, where local observables relax to non-thermal values at intermediate time scales. At later times a crossover towards thermal behaviour sets in. We determine the associated time scale, which depends on the initial state, the band structure of the non-interacting theory, and the strength of the integrability breaking perturbation. Our method allows us to analyze in some detail the spreading of correlations and in particular the structure of the associated light cones in our model. We find that the interior and exterior of the light cone are separated by an intermediate region, the temporal width of which appears to scale with a universal power-law $t^{1/3}$.

DY 42.3 Thu 10:15 ZEU 160

Non-equilibrium interacting integrable models — •JACOPO DE NARDIS[1], JEAN-SÉBASTIEN CAUX[2], ENEJ ILIEVSKI[2], MICHAEL BROCKMANN[3], and MILOSZ PANFIL[4] — [1]CNRS-Laboratoire de Physique Théorique de l'Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris Cedex, France — [2]Institute for Theoretical Physics, University of Amsterdam, Science Park 904,
Postbus 94485, 1090 GL Amsterdam, The Netherlands — [3]Max Planck Institute for the Physics of Complex Systems, Nothnitzer Str. 38, 01187 Dresden, Germany — [4]Institute of Theoretical Physics, University of Warsaw,
ul. Pasteura 5, 02-093 Warsaw, Poland.

We review the recent progresses in computing the non-equilibrium steady states (often referred as Generalized Gibbs Ensemble states) of interacting integrable models, as the XXZ spin 1/2 chain and the Lieb-Liniger model for interacting bosons on a line. We show how the role of quasi-local charges is fundamental in order to capture the long time limit of the expectation values of simple local observables and how important information regarding the time evolution towards equilibrium can be extracted by such steady states and their thermodynamic quasi-particle excitations. Finally we show how the steady state can be directly computed via experimental observations with cold atoms in a shallow trap or in an optical lattice.

DY 42.4 Thu 10:30 ZEU 160

Quenching a Quantum Critical State by the Order Parameter: Dynamical Quantum Phase Transitions and Quantum Speed Limits — •MARKUS HEYL — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany

Quantum critical states exhibit strong quantum fluctuations and are therefore highly susceptible to perturbations. In this work we study the dynamical stability against a sudden coupling to these strong fluctuations by quenching the order parameter of the underlying transition. We find that such a quench can generate superextensive energy fluctuations. This leads to a dynamical quantum phase transition with nonanalytic real-time behavior in the resulting decay of the initial state. At the corresponding critical time the dynamically-evolved state becomes orthogonal to the initial one yielding an unconventional quantum speed limit. An outlook is given on the implications onto potential restricted thermalization despite of nonintegrability.

DY 42.5 Thu 10:45 ZEU 160

Localization in a disorder-free model after a global quantum quench. — •ADAM SMITH[1], JOHANNES KNOLLE[1], DMITRY KOVRIZHIN[2], and RODERICH MOESSNER[3] — [1]T.C.M. group, Cavendish Laboratory, JJ Thomson Ave, Cambridge CB3 0HE, United Kingdon — [2]Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road, Oxford OX1 3NP, United Kingdom — [3]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany

We consider an interacting, translation invariant one dimensional model in which we observe complete localisation in one of two fermionic subsystems. Its effective disorder is generated dynamically and can be rigorously identified through a set of conserved quantities. To corroborate the emergence of localization after a global quantum quench we show persistence of a density wave in the initial state, absence of domain-wall melting, and suppression of light-cone growth of correlations.

DY 42.6 Thu 11:00 ZEU 160

Transport in Out-of-Equilibrium XXZ Chains: Exact Profiles of Charges and Currents — •BRUNO BERTINI[1], MARIO COLLURA[1,2], JACOPO DE NARDIS[3], and MAURIZIO FAGOTTI[3] — [1]SISSA and INFN, Trieste, Italy — [2]Oxford University, Oxford, United Kingdom — [3]École normale supérieure, Paris, France

We consider the non-equilibrium time evolution of piecewise homogeneous states in the XXZ spin-1/2 chain, a paradigmatic example of an interacting integrable model. The initial state can be thought as the result of joining chains with different global properties. Through dephasing, at late times the state becomes locally equivalent to a stationary state which explicitly depends on position and time. We propose a kinetic theory of elementary excitations and derive a continuity equation which fully characterizes the thermodynamics of the model. We restrict ourselves to the gapless phase and consider cases where the chains are prepared: 1) at different temperatures; 2) in the ground state of two different models; 3) in the "domain wall" state. We find excellent agreement (any discrepancy is within the numerical error) between theoretical predictions and numerical simulations of time evolution based on TEBD algorithms. As a corollary, we unveil an exact

expression for the expectation values of the charge currents in a generic stationary state.

15 min. break

DY 42.7 Thu 11:30 ZEU 160

Unconventional quasienergy bands in tilted optical lattices — •Onno Renke Diermann — Institut für Physik, Carl von Ossietzky Universität Oldenburg

The existence of quasienergy bands in periodically driven lattices under the influence of an additional static force has first been predicted by J.Zak ["Finite Translations in Time and Energy", Phys. Rev. Lett **71**, 2624 (1993)]. Among other things, it was suggested that within a single-band approximation such bands may take the form of cosine bands "modulated with the Bessel function of the shaking amplitude". Considering the experimentally accessible example of ultracold atoms in deep shaken cosine lattices, we show by numerical calculations of the full quasienergy spectrum that the single-band approximation is not reliable, and the quasienergy bands in fact are broken by a multitude of multiphoton resonances. This means that particles prepared in such bands tend to heat up on short time scales, and dynamic localization will be hard to observe.

DY 42.8 Thu 11:45 ZEU 160

iDMRG Study of the Kitaev-Heisenberg Model — •Matthias Gohlke, Ruben Verresen, Frank Pollmann, and Roderich Moessner — MPI-PKS, Dresden, Germany

Quantum spin-liquids represent novel phases of matter that host emergent fractionalized excitations. The Kitaev-Heisenberg model is a two-dimensional model system in this context and relevant for recent experiments on putative quantum spin-liquid materials. We revisit the ground state phase diagram of the Kitaev-Heisenberg model using large scale infinite density-matrix renormalization group method of cylinders with up to twelve sites circumference. In particular, the cylindrical geometry allows to capture the gapless points and to extract its universal critical properties. Furthermore, we observe that the gapless excitations remain stable under perturbation with Heisenberg interaction.

DY 42.9 Thu 12:00 ZEU 160

Dynamics of the Kitaev-Heisenberg Model — •Ruben Verresen, Matthias Gohlke, Roderich Moessner, and Frank Pollmann — MPI for Physics of Complex Systems, Dresden, Germany

Quantum spin-liquids represent novel phases of matter that host emergent fractionalized excitations. The Kitaev-Heisenberg model is a two-dimensional model system in this context and relevant for recent experiments on putative quantum spin-liquid materials. We obtain the dynamical spin-structure factor for this model using a matrix-product state based method. This quantity can be compared to neutron scattering measurements and provides characteristic insights into the dynamics of the fractionalized excitations. We find significant broad high energy features beyond spin-wave theory even in the ordered phases when tuned near the spin-liquid regime. We then focus on the zig-zag phase of the Kitaev-Heisenberg model which is relevant for α-$RuCl_3$ and observe that the high energy part reveals features that were first seen in neutron scattering experiments, displaying proximate spin liquid physics. In particular we are led to the interpretation of the observed broad high energy features as the intersection of remnants of very diffuse spin-wave bands.

DY 42.10 Thu 12:15 ZEU 160

Probing density and spin correlations in two-dimensional Hubbard model with ultracold fermions — •Chun Fai Chan[1], Jan Henning Drewes[1], Marcell Gall[1], Nicola Wurz[1], Eugenio Cocchi[1,2], Luke Miller[1,2], Daniel Pertot[1], Ferdinand Brennecke[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Quantum gases of interacting fermionic atoms in optical lattices is a promising candidate to study strongly correlated quantum phases of the Hubbard model such as the Mott-insulator, spin-ordered phases, or in particular d-wave superconductivity. We experimentally realise the two-dimensional Hubbard model by loading a quantum degenerate Fermi gas of 40K atoms into a three-dimensional optical lattice geometry. High-resolution absorption imaging in combination with radiofrequency spectroscopy is applied to spatially resolve the atomic distribution in a single 2D layer. We investigate in local measurements of spatial correlations in both the density and spin sector as a function of filling, temperature and interaction strength. In the density sector, we compare the local density fluctuations and the global thermodynamic quantities, and in the spin sector, we observe the onset of non-local spin correlation, signalling the emergence of the anti-ferromagnetic phase.

DY 42.11 Thu 12:30 ZEU 160

Adiabatic Dynamics of the Excited States for the Lipkin-Meshkov-Glick Model — •Wassilij Kopylov and Tobias Brandes — Technische Universität Berlin, Institut für Theoretische Physik, Berlin, Deutschland

We theoretically investigate the impact of the excited state quantum phase transition (ESQPT) on the adiabatic dynamics for the Lipkin-Meshkov-Glick model. Using a time dependent protocol, we continuously change a model parameter and discuss then the scaling properties of the system especially close to the ESQPT. On top, we show that the mean-field dynamic with the time dependent protocol gives the correct expectation values in the thermodynamic limit even for the excited states.

1) W. H. Zurek, U. Dorner, and P. Zoller, PRL 95, 105701 (2005) 2) H. J Lipkin, N. Meshkov and A. Glick, Nucl. Phys. 62, 188 (1965) 3)T. Caneva, R. Fazio and G. E. Santoro, PRB 78, 104426 (2008)

DY 42.12 Thu 12:45 ZEU 160

Spectral functions of quantum impurity models in the long-time limit of the time-dependent numerical renormalization group approach — •Theo Costi and Hoa Nghiem — Peter Grünberg Institut (PGI-2) and Institute for Advanced Simulation IAS-3), Forschungszentrum Jülich, Jülich, Germany

We develop a new multiple-quench time dependent numerical renormalization group (TDNRG) approach to study the time-evolution of strongly correlated quantum impurities in response to quantum quenches, pulses and periodic driving fields with potential application to a number of fields, including cold atom systems, non-equilibrium transport in nanoscale devices, and the theory of pump-probe spectroscopies of correlated materials within the non-equilibrium dynamical mean field theory. While the single-quench TDNRG suffers from sizeable errors for spectral functions and thermodynamic observables in the long-time limit, we show that our new multiple-quench TDNRG approach systematically reduces these errors to negligible values. Precise results are presented for local observables of the Anderson model, both static (local occupation and double occupancy) and dynamic (spectral function), in the long-time limit. For finite times and periodic driving, we demostrate a significant improvement for the time evolution of the local occupation as compared to our previous approach [1].

[1] H. T. M. Nghiem, T. A. Costi, Phys. Rev. B90, 035129 (2014).

DY 42.13 Thu 13:00 ZEU 160

Energy exchange in driven open quantum systems at strong coupling — •Matteo Carrega[1], Paolo Solinas[2], Maura Sassetti[2,3], and Ulrich Weiss[4] — [1]Nest, Istituto Nanoscienze and Scuola Normale Superiore (CNR-Pisa) — [2]SPIN-CNR — [3]Università di Genova — [4]Universität Stuttgart

The time-dependent energy transfer in a driven quantum system strongly coupled to a heat bath is studied within an influence functional approach. Exact formal expressions for the statistics of energy dissipation into the different channels are derived. The general method is applied to the driven dissipative two-state system. It is shown that the energy flows obey a balance relation, and that, for strong coupling, the interaction may constitute the major dissipative channel. Results in analytic form are presented for the particular value K = 1/2 strong Ohmic dissipation. The energy flows show interesting behaviors including driving-induced coherences and quantum stochastic resonances. It is found that the general characteristics persists for K near 1/2.

DY 43: Nonlinear Dynamics, Synchronizsation and Chaos

Time: Thursday 9:30–13:15 Location: ZEU 118

DY 43.1 Thu 9:30 ZEU 118

Optical injection in quantum dot micropillar lasers — •Xavier Porte[1], Elisabeth Schlottmann[1], Steffen Holzinger[1], Benjamin Lingnau[2], Kathy Lüdge[2], Christian Schneider[3], Martin Kamp[3], Sven Höfling[3], Janik Wolters[1,4], and Stephan Reitzenstein[1] — [1]Institut für Feskörperphysik, Technische Universität Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Germany — [3]Technische Physik, Julius-Maximilians-Universität Würzburg, Germany — [4]Present address: Department of Physics, University of Basel, Switzerland

Semiconductor lasers are well known to exhibit highly nonlinear behavior when subject to external optical injection and coupling. Particularly interesting nowadays is the case of microlasers, where such nonlinearities can be studied at the edge of cavity quantum electrodynamics (cQED). In the present work, we explore the phenomenon of optical injection applied to quantum dot micropillar lasers. These lasers are based on high-quality micropillar cavities containing a single layer of quantum dots as active medium. In contrast to the classical scenario of optical injection, high-β microlasers can oscillate simultaneously in a state which is synchronized to the external signal and at its solitary natural frequency, a phenomenon that we refer as partial injection locking (Schlottmann, E. et al, Phys. Rev. Applied 6, 044023 (2016)). We extensively investigate the influence of optical injection on the output power, polarization behavior, photon statistics and coherence times of the lasing modes. Our results enable the external control and tailoring of the emission of microlasers in the cQED regime.

DY 43.2 Thu 9:45 ZEU 118

Aging in deterministic classical oscillators — •Darka Labavić and Hildegard Meyer-Ortmanns — Physics and Earth Sciences, Jacobs University Bremen, Bremen, Germany

We study Kuramoto oscillators on small hexagonal lattices with repulsive coupling. Repulsive coupling in combination with the lattice topology makes bonds between individual oscillators frustrated, which induces multistability. In [1] we observe noise-driven migration of oscillatory phases in a rough potential landscape. Upon this migration, a multitude of different escape times from one metastable state to the next is generated. Based on these observations, it does not come as a surprise that the set of oscillators shows physical aging [2]. Here we introduce disorder into the system through a random distribution of natural frequencies, rather than additive or multiplicative Gaussian noise as in [2], so that the system is fully deterministic. Disorder in natural frequencies generates long time scales, observed in transients, and long periods of the order parameter. A typical trajectory of the system consists of a connected set of former (un)stable limit cycles. When our system is quenched from the regime of a unique fixed point towards the regime of multistable solutions, the autocorrelation function depends on the waiting time after the quench, so that time translation invariance is broken. So disorder in the natural frequencies leads to different exploration of the rich attracktor space as compared to noise. [1] F. Ionita, D. Labavić, M. Zaks, and H. Meyer-Ortmanns, Eur. Phys. J. B **86** (12), 511 (2013). [2] F. Ionita and H. Meyer-Ortmanns Phys. Rev. Lett. **112**, 094101 (2014).

DY 43.3 Thu 10:00 ZEU 118

Spontaneous symmetry-breaking in the Bose-Hubbard model — •Christopher D. B. Bentley[1], Alan Celestino[1], Ramy El-Ganainy[1,2], and Alexander Eisfeld[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany — [2]Department of Physics and Henes Center for Quantum Phenomena, Michigan Technological University, Houghton, MI 49931, USA

Spontaneous symmetry-breaking has recently been experimentally observed with low photon numbers in a pair of cavities [1], which can be described by the Bose-Hubbard model. This phenomenon is well understood in the classical regime, and different approaches including quantum trajectories have been used to explore the equivalent quantum regime [2,3]. Here we extend the quantum trajectory approach, and present our results on the stability of spontaneous symmetry-breaking trajectories with symmetric Hamiltonian and control.

[1] P. Hamel et al. 2015, Nature Photonics 9, 311 [2] W. Casteels and C. Ciuti 2016, arXiv:1607.02578 [3] B. Cao, K. W. Mahmud and M. Hafezi 2016, arXiv:1608.07766

DY 43.4 Thu 10:15 ZEU 118

Sliding drops - from individual droplets to droplet ensembles — •Uwe Thiele, Sebastian Engelnkemper, Markus Wilczek, Walter Tewes, and Svetlana V. Gurevich — Institut für Theoretische Physik, Westfälische Wilhelms-Universität, Wilhelm-Klemm Str. 9, 48149 Münster

We study the dynamics of liquid drops on a solid inclined substrate [1] individually and in large ensembles employing a long-wave time evolution equation for partially wetting liquids. First, we discuss bifurcation diagrams that show how an individual sliding drop undergoes various transformations (e.g., a pearling instability) in dependence of driving force or volume. The resulting pearling states show a period-doubling route to chaos [2]. Second, we conduct large-scale numerical simulations and analyse the coarsening behaviour of drop ensembles. Ongoing merging and pearling results in a stationary distribution of drop sizes. We illustrate that aspects of this distribution may be deduced from the single-drop bifurcation diagrams. Finally, we construct a statistical model for the time evolution of the drop size distribution and show that it captures the main features of the full scale simulations.

[1] T. Podgorski, J.-M. Flesselles and L. Limat, Phys. Rev. Lett. 87, 036102 (2001). [2] S. Engelnkemper, M. Wilczek, S. V. Gurevich and U. Thiele, Phys. Rev. Fluids 1, 073901 (2016).

DY 43.5 Thu 10:30 ZEU 118

Wave control by cooperative excitation of cardiac tissue — •Pavel Buran[1], Sergio Alonso[2], Markus Bär[1], and Thomas Niedermayer[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Berlin — [2]Universitat Politècnica de Catalunya, Barcelona

Rotating excitation waves and electrical turbulence in cardiac tissue have been associated with arrhythmias like the life-threatening ventricular fibrillation. The application of an electrical shock (defibrillation) is an effective therapy, as it globally excites the tissue resulting in termination of all excitation waves, but also causes severe side effects. Recent experimental studies have shown that a sequence of electrical pulses is able to terminate fibrillation more gently than a single pulse. Only tissue at major conduction heterogeneities, such as large coronary arteries, may be activated by each of these very weak pulses. Therefore, global tissue activation and wave termination originates from few localized activation sites. In order to decipher the interplay of the individual pulses, we performed extensive simulations of cardiac tissue perforated by blood vessels and tested a variety of cellular models. For models exhibiting a dominant excitation period during fibrillation, the pulses appear to be highly cooperative if the period between these pulses matches the dominant period. These findings are elucidated by the analysis of the dynamical variables, such as the fraction of excited tissue and the number of phase defects, both during the state of electrical turbulence and during cooperative excitation. Moreover, we propose a simple stochastic model which integrates our results in an intuitive way.

DY 43.6 Thu 10:45 ZEU 118

Synchronization of mutually coupled quantum dot high-Q micropillar lasers — •Sören Kreinberg[1], Felix Krüger[1], Steffen Holzinger[1], Elisabeth Schlottmann[1], Martin Kamp[2], Christian Schneider[2], Sven Höfling[2,3], Xavier Porte[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Technische Physik, Julius-Maximilians-Universität Würzburg, Germany — [3]School of Physics and Astronomy, University of St Andrews, Scotland

Mutual coupling and synchronization of semiconductor lasers is an exciting topic in the field of non-linear dynamics with potential applications to secure data communication. In this work, we aim at pushing the phenomenon of synchronization towards the quantum regime of cavity enhanced microlasers. We address this novel regime by experimental studies on mutually coupled quantum dot microcavity lasers with sub-μW emission power.

The structures under study are electrically driven GaAs/AlAs micropillar cavities containing a single layer of In-GaAs quantum dots (QD) as active medium. In contrast to conventional macroscopic lasers, these high-β microcavity lasers exhibit a strong influence of

spontaneous emission on their dynamics. In the field of non-linear dynamics, this peculiarity leads to the effect of partial injection locking as was recently demonstrated [1]. We investigate the pump-dependent detuning range of phase locking, frequency pulling and partial locking, as well as the existence of mutually correlated chaotic intensity fluctuations. [1] E. Schlottmann et al., *Phys. Rev. Applied* 6, 044023 (2016)

DY 43.7 Thu 11:00 ZEU 118

The load-response of the flagellar beat and its implications for synchronization — •Gary Klindt[1], Christian Ruloff[2], Christian Wagner[2,3], and Benjamin Friedrich[4] — [1]MPI PKS, Dresden, Germany — [2]University of the Saarland, Saarbrücken, Germany — [3]University of Luxemburg, Luxemburg — [4]TU Dresden, Germany

Cilia and flagella exhibit regular bending waves that perform mechanical work on the surrounding fluid, to propel cellular swimmers and pump fluids inside organisms. Conversely, hydrodynamic forces feedback on flagellar oscillations, changing speed and shape of the flagellar beat. This flagellar load-response is a prerequisite for self-organized synchronization observed in collections of cilia and flagella.

Here, we combine theory and experiment to comprehensively characterize the load-response of the flagellar beat, including stalling of flagellar oscillations at high load [1]: Our description of the flagellar beat as a limit-cycle oscillations is calibrated by experimental data of flagellated Chlamydomonas cells exposed to controlled microfluidic flows.

Remarkably, in our simulations, two previously suggested mechanisms of flagellar synchronization, (i) flagellar waveform compliance, and (ii) elastic coupling between flagellar bases, each stabilize antiphase synchronization, yet their combination stabilizes in-phase synchrony as observed in experiments.

[1] G.S. Klindt, C. Ruloff, C. Wagner, B.M. Friedrich, Load-response of the flagellar beat, accepted at Phys. Rev. Lett.

15 min. break

DY 43.8 Thu 11:30 ZEU 118

Synchronizing cardiac activity during ventricular fibrillation — •Henrik tom Wörden — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen, Deutschland

Ventricular fibrillation is a lethal condition of the heart which is still not well understood and medicine lacks a suitable treatment. The irregular and fast activation patterns during ventricular fibrillation make it hard to find efficient methods to control the dynamics of the myocardium. In contrast, e.g. monomorphic ventricular tachycardia can often be terminated by local stimulation with a train of uniform electric pulses. While such a local stimulation has a very limited region of influence in ventricular fibrillation, electric far field shocks allow the application of stimuli at many places of the ventricle at once. We demonstrate how the cardiac activity can be synchronized with such pulses and how it modifies the properties of the dynamics in the heterogeneous cardiac tissue.

DY 43.9 Thu 11:45 ZEU 118

Features and Control of Chaotic Transients in Excitable Media — •Thomas Lilienkamp, Stefan Luther, and Ulrich Parlitz — Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany

Cardiac tissue is a prominent example of an excitable medium. Cardiac dysfunctions of the heart like ventricular fibrillation can be associated with a (chaotic) spatio-temporal dynamics, which is mainly determined by spiral or scroll waves. Here we discuss which role chaotic transients play in this context, using numerical simulations of 2D and 3D systems. We investigate which properties of the system have an impact on the lifetime of the transients and how a chaotic transient can be terminated in an efficient way (control).

DY 43.10 Thu 12:00 ZEU 118

Impact of anisotropy on termination of pinned spiral waves using far field pulses — •Edda Boccia[1], Stefan Luther[1,2,3], and Ulrich Parlitz[1,3] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Department of Pharmacology, University Medical Center, Göttingen, Germany — [3]Institute for Nonlinear Dynamics, Georg-August-Universität Goettingen, Göttingen, Germany

Reentrant waves find a critical substrate in the multi-sized heterogeneities of myocardium. Spiral waves pinned to an heterogeneity can self-terminate or be unpinned (and terminated) by electric far field pulses exploiting heterogeneities as virtual electrodes. We implement a 2D bidomain formulation of the phase I of the Luo and Rudy model under acute ischemia. We investigate how anisotropy and size of the ischemic area may affect reentrant dynamics with and without exposing the tissue to far field pacing (FFP). Without FFP, we found that: 1. waves stability is affected more by changes in the intracellular space than by modifications in the extracellular space; 2. not only the size of the heterogeneity, but also the degree of intracellular anisotropy highly affects maintenance or self-termination of pinned spirals. How FFP contributes to unpinning or successful termination of pinned spirals in anisotropic media is much less clear compared to isotropic domains. In this contribution we focus on the impact of anisotropy and compare the success rate for several sequences of FFP pulses in both isotropic and anisotropic domains. Interestingly, anisotropic tissues result to be a more suitable substrate for successful termination of pinned spirals.

DY 43.11 Thu 12:15 ZEU 118

Finite Time Basin Stability and Basin Escape Rates — •Paul Schultz[1,2], Frank Hellmann[1], Kevin Webster[1], and Jürgen Kurths[1,2,3,4] — [1]Potsdam Institute for Climate Impact Research, P.O. Box 601203, 14412 Potsdam, Germany — [2]Department of Physics, Humboldt University of Berlin, Newtonstr. 15, 12489 Berlin, Germany — [3]Institute for Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen AB24 3UE, United Kingdom — [4]Department of Control Theory, Nizhny Novgorod State University, Gagarin Avenue 23, 606950 Nizhny Novgorod, Russia

We define the finite-time basin stability, which is the probability of a system returning closely enough to an equilibrium within a certain time while being subject to random shocks at specified time intervals.

When the frequency of these perturbations becomes low enough for the system to equilibrate between two shocks, subsequent perturbations are independent and the measure yields the conventional basin stability (Menck et al. Nat. Phys. 9, 89-92. 2013).

Using an appropriately defined Lyapunov function, we show that finite-time basin stability reveals information about the maximum frequency of perturbations at which basin stability becomes the escape rate from the basin. As an example, we use Kuramoto oscillators with inertia.

DY 43.12 Thu 12:30 ZEU 118

Stabilization of three-dimensional scroll waves by heterogeneities — •Florian Spreckelsen[1], Daniel Hornung[1], Oliver Steinbock[2], Ulrich Parlitz[1,3,4], and Stefan Luther[1,3,4] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany — [2]Department of Chemistry and Biochemistry, Florida State University, Tallahassee, FL 32306-4390, United States — [3]Institute for Nonlinear Dynamics, Georg-August-Universität Göttingen, Am Faßberg 17, 37077 Göttingen, Germany — [4]German Centre for Cardiovascular Research, partner site Göttingen, 37077 Göttingen, Germany

Scroll waves in a three-dimensional excitable medium with negative filament tension may break up and display spatiotemporal chaos. The presence of non-excitable heterogeneities can influence the evolution of the medium, in particular scroll waves may pin to such heterogeneities. We show [1] thin rodlike heterogeneities suppress otherwise developing spatiotemporal chaos and additionally clear out already existing chaotic excitation patterns.

[1] F. Spreckelsen, D. Hornung, O. Steinbock, U. Parlitz, and S. Luther. Phys. Rev. E 92 (2015): 42920. doi:10.1103/PhysRevE.92.042920.

DY 43.13 Thu 12:45 ZEU 118

Synchronisation Behaviour and the Emergence of Chaotic Dynamics in Systems of Viscoelastically Coupled Van der Pol Oscillators — •Sebastian Stein[1,2], Stefan Luther[1,2,3], and Ulrich Parlitz[1,2] — [1]Biomedical Physics Research Group, Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, D-37077 Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany — [3]Universitätsmedizin Göttingen, Georg-August-Universität Göttingen, Robert-Koch-Straße 40, D-37075 Göttingen, Germany

We investigate a system of viscoelastically coupled, modified Van der Pol oscillators to compare their synchronisation properties due to elastic and viscoelastic coupling. To study the impact of symmetry, the

Van der Pol oscillators are modified to exhibit either a symmetric or asymmetric restoring force. It will be shown that increasing viscosity of the coupling or symmetry breaking of the (harmonic) potential have a strong impact on the stability of synchronised periodic solutions and may lead to the emergence of chaotic behaviour.

DY 43.14 Thu 13:00 ZEU 118

Multi-node basin stability in complex networks of dynamical systems — Chiranjit Mitra[1], Anshul Choudhary[2,3], Sudeshna Sinha[2], Jürgen Kurths[1,4,5,6], and •Reik V. Donner[1] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]IISER Mohali, India — [3]Carl von Ossietzky University of Oldenburg, Germany — [4]Humboldt University, Berlin, Germany — [5]University of Aberdeen, UK — [6]Nizhny Novgorod State University, Russia

In networks of interacting oscillators, the stability of the synchronized state in the presence of large perturbations is critical, with various real-world examples like ecosystems, power grids, the human brain, etc. The study of this problem calls for the development of appropriate quantifiers of stability of multiple stable states of such systems. Motivated by the concept of basin stability (BS) (Menck et al., Nature Physics 9, 89 (2013)), we propose here the general framework of multi-node basin stability for gauging global stability and robustness of networked dynamical systems in response to non-local perturbations simultaneously affecting multiple nodes of a system. The framework of multi-node BS provides an estimate of the critical number of nodes which when simultaneously perturbed significantly reduces the capacity of the system to return to the desired state. We demonstrate the potential of multi-node BS in assessing the stability of the synchronized state in a deterministic scale-free network of Rössler oscillators and a conceptual model of the power grid of the United Kingdom with second-order Kuramoto-type nodal dynamics.

DY 44: Statistical Physics (general)

Time: Thursday 10:00–12:15 Location: ZEU 147

DY 44.1 Thu 10:00 ZEU 147

Measurement of second-order response without perturbation — •Laurent Helden[1], Urna Basu[2], Matthias Krüger[3,4], and Clemens Bechinger[1,4] — [1]2. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart, Germany — [2]SISSA - International School for Advanced Studies and INFN, Trieste, Italy — [3]4th Institute for Theoretical Physics, Universität Stuttgart, Germany — [4]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany

We study the second order response functions of a colloidal particle being subjected to an anharmonic potential. Contrary to typical response measurements which require an external perturbation, here we experimentally demonstrate that the system's susceptibilities up to second order can be obtained from the particle's equilibrium fluctuations as theoretically outlined in [Basu et al. PCCP **17**, 6653 (2015)]. The measured susceptibilities are in quantitative agreement with those obtained from the response to an external perturbation.

DY 44.2 Thu 10:15 ZEU 147

Interface propagation in fiber bundles: Local, mean-field and intermediate range-dependent statistics — •Soumyajyoti Biswas[1] and Lucas Goehring[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany — [2]School of Science and Technology, Nottingham Trent University, Clifton Lane, Nottingham, NG 11 8NS, UK

The fiber bundle model is an array of elements that break when sufficient load is applied on them. With a local loading mechanism, this can serve as a model for a one-dimensional interface separating the broken and unbroken parts of a solid in mode-I fracture. The interface can propagate through the system depending on the loading rate and disorder present in the failure thresholds of the fibers. For quasistatic driving, the intermittent dynamics of the interface mimic front propagation in disordered media. Such situations appear in diverse systems such as crack propagation, magnetic domain walls, charge density waves, contact lines in wetting etc. We study the effect of the range of interaction, i.e. the neighborhood affected following a local perturbation, on the statistics of the intermittent dynamics of the front. There exists a crossover from local to global behavior as the range of interaction grows and a continuously varying universality in the intermediate range, implying that the interaction range is a relevant parameter here. This is interesting in view of the scatter in experimentally observed scaling exponents, in even idealized experiments on fracture fronts, and also a possibility in changing the interaction range in real samples.

DY 44.3 Thu 10:30 ZEU 147

Hyperuniformity of Quasicrystals — •Erdal C. Oğuz — School of Mechanical Engineering and The Sackler Center for Computational Molecular and Materials Science, Tel Aviv University, Israel

Density fluctuations in many-body systems are of fundamental importance throughout various scientific disciplines, including physics, materials science, number theory and biology. Hyperuniform systems, which include crystals and quasicrystals, have density fluctuations that are anomalously suppressed at long wavelengths compared to the fluctuations in typical disordered point distributions such as in ideal gases and liquids. Quantitatively speaking, hyperuniform systems are characterized by a local number variance of points within a spherical window of radius R that grows more slowly than the window volume in the large-R limit.

In this talk, we provide the first rigorous hyperuniformity analyses of quasicrystals by employing a new criterion for hyperuniformity to quantitatively characterize quasicrystalline point sets. We reveal that one-dimensional quasicrystals produced by projection from a two-dimensional lattice fall into two distinct classes with respect to their large-scale density fluctuations. Depending on the width of the projection window, the number variance is either uniformly bounded in the one class for large R, or it scales like $\ln R$ in the other class. This distinction provides a new classification of one-dimensional quasicrystalline systems and suggests that measures of hyperuniformity may define new classes of quasicrystals in higher dimensions as well.

DY 44.4 Thu 10:45 ZEU 147

Event-chain Monte Carlo algorithms for three- and many-particle interactions — •Tobias A. Kampmann[1], Julian Harland[1], Manon Michel[2,3], and Jan Kierfeld[1] — [1]TU Dortmund University, Dortmund, Germany — [2]Orange Labs, Chatillon, France — [3]Laboratoire de Physique Statistique, Paris, France

We generalize the rejection-free event-chain Monte Carlo algorithm from many particle systems with pairwise interactions to systems with arbitrary three- or many-particle interactions. We introduce generalized lifting probabilities between particles and obtain a general set of equations for lifting probabilities, the solution of which guarantees maximal global balance. We validate the resulting three-particle event-chain Monte Carlo algorithms on three different systems by comparison with conventional local Monte Carlo simulations: (i) a test system of three particles with a three-particle interaction that depends on the enclosed triangle area; (ii) a hard-needle system in two dimensions, where needle interactions constitute three-particle interactions of the needle end points; (iii) a semiflexible polymer chain with a bending energy, which constitutes a three-particle interaction of neighboring chain beads. The examples demonstrate that the generalization to many-particle interactions broadens the applicability of event-chain algorithms considerably.

DY 44.5 Thu 11:00 ZEU 147

On the influence of interaction softness on crystallization of soft particles in 2D: A systematic DFT study — •Alexander Kraft and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

We investigate a system of soft particles with varying steepness of the interaction potential in a 2D system within the framework of density functional theory (DFT) and dynamical density functional theory (DDFT). Depending on system parameters, we find a homogeneous fluid phase or crystallization. In contrast to previous studies on 3D systems [1,2], here we focus on a 2D system in order to gain access to the behaviour in flat geometries or on surfaces, which was started in Ref. [3,4]. Furthermore, we systematically study the influence of the steepness of the interaction potential. We compare calculations

based on free minimization within DFT with estimates based on linear stability analysis of the fluid state, which yields good agreements for all steepness values. Furthermore, we investigate the crystal-liquid coexistence and discuss possible control strategies by external potentials or prestructured substrates on crystallization.

[1] A. A. Louis et al. **62**, 7961 (2000)

[2] A. J. Archer and R. Evans, Phys. Rev. E **64** (2001)

[3] S. Prestipino and F. Saija, J. Chem. Phys. **141**, 184502 (2014)

[4] A. J. Archer and A. Malijevský, J. Phys.: Condens. Matter **28**, 244017 (2016)

15 min. break

DY 44.6 Thu 11:30 ZEU 147

The microfoundation of deflation; simulations based on the Ising model in industrial networks — •Kei Murakami, Fujio Toriumi, and Hirotada Ohashi — The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan

Deflation, the phenomenon that the overall price level decreases with the negative inflation rate, is one of the most serious problems in modern economy, especially in Japan in these 20 years. It has been deeply discussed why deflation occurs and price levels fluctuate by using macroeconomic models, which describe macroscopic prices as the integrations of microscopic prices. However, these models generally fail to explain actual price fluctuations so far, and it might need to introduce perspectives of statistical physics including complex systems. This study attempts to reveal mechanisms of macroscopic price fluctuations in the framework of statistical physics considering interactions among microscopic prices. We make networks from actual data of industrial interrelationships in Japan and apply the ferromagnetic Ising model in them to deal with such interactions among price fluctuations of industries and to express the macroeconomic price index as well. The results show that under some parameters the phase transition occurs, and then most prices of industries decrease or increase all together. This phase transition can be considered as the indication of deflation or inflation. This study could provide new insights into the mechanisms of deflation and help make appropriate economic policies.

DY 44.7 Thu 11:45 ZEU 147

Domain wall dimers in a lattice of half vortices — •Beñat Mencia Uranga and Austen Lamacraft — Theory of condensed matter, University of Cambridge, UK

We study the thermodynamics of a lattice of half vortices and strings. The response of a superfluid to mechanical rotation demonstrates one of the most remarkable features of these systems. Rather than rotate like a classical fluid, a superfluid will instead nucleate quantised vortices which carry angular momentum. In the limit of many vortices, a vortex lattice will form. Depending on the type of superfluid and the experimental parameters, different kinds of vortices can be found as the equilibrium configuration of the rotating superfluid: integer vortices and half vortices. In the half vortex lattice with the presence of an easy-axis anisotropy, a state which is phenomenologically equivalent to having strings with finite tension pairing up half vortices arises. Hence, we develop a description of the system based on interacting point vortices and strings.

DY 44.8 Thu 12:00 ZEU 147

Statistics and dynamic in the cosmology — •Norbert Sadler — Wasserburger Str, 25a ; 85540 Haar

To understand and to evaluate the universe in its collective and complex codition methods of the statistic physics, of the exploraive factor analisis and the group theory, especial the exzeptional symmetry group E8 can be applied.

If the universe is considered as a closed thermodynamic system, the accessible Phase space volume and the entropy of the universe can be determined.

Results: The accessible phase space volume is 5/6. The non-accessible phase space volume is therfore 1/6 and corresponds to the dark matter and the dark energy. The entropy of the Universe S(Univ.)=-(5/6)x log(5/6)=0.066.

Further Information: www.cosmology-harmonices-mundi.com

DY 45: Microswimmers (joint session BP/DY)

Time: Thursday 11:15–12:45 Location: ZEU 250

DY 45.1 Thu 11:15 ZEU 250

A single squirmer under gravity — •Felix Rühle and Holger Stark — Inst. für Theor. Physik, TU Berlin, 10623 Berlin

A simple yet versatile model for many microswimmers is the widely studied spherical squirmer [1]. In this contribution we include a gravitational force acting on a single swimmer. In experiments this setup has yielded fascinating non-equilibrium structure formation such as floating rafts formed by active emulsion droplets [2] or dancing *Volvox* algae [3]. While theoretical and numerical studies for microswimmers under gravity do exist [4,5], they usually do not account for full hydrodynamics, which need to be included in the presence of surfaces.

In our study we observe a rich phenomenology depending on gravitational strength and on squirmer type: Swimmers are caught at the wall or completely escape from its influence, or they float at a finite distance from the bottom wall, both permanently and recurrently. We reproduce and explain these findings, which we obtained in MPCD simulations, using analytical calculations, which include wall-induced linear and angular velocities in the near and far field [6].

[1] J. R. Blake, *J. Fluid Mech.* **46**, 199 (1971).
[2] C. Krüger et al., *EPJE* **39**, 64 (2016).
[3] K. Drescher et al., *Phys. Rev. Lett.* **102**, 168101 (2009).
[4] M. Enculescu and H. Stark, *Phys. Rev. Lett.* **107**, 058301 (2011); K. Wolff, A. M. Hahn and H. Stark, *EPJE* **36**(4), 1 (2013).
[5] B. ten Hagen et al. *Nat. Comm.* **5**, 4829 (2014).
[6] J. S. Lintuvuori et al., *Soft Matter* **12**, 7959 (2016)

DY 45.2 Thu 11:30 ZEU 250

Chemotaxis in external fields: magnetotactic bacteria behavior — •Agnese Codutti[1], Stefan Klumpp[2], and Damien Faivre[1] — [1]Max Planck Institute of Colloids and Interfaces, Research Campus Golm, 14476 Potsdam, Germany — [2]Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Microswimmers such as bacteria, algae and artificial swimmers can be described with a three dimensional active brownian particle model. Here, we modify this simple model to better describe bacterial motility. First of all, different states of motion are included: the bacteria can run straight or actively change direction of motion through tumble or reverse. Second, chemotaxis is added to generate a bias towards the preferred concentration of some substance. Finally, the swimmer may be subject to external forces and torques. We show how this modified model can be applied to various scenarios, including the run and tumble chemotactic motion of *E. Coli* and the motion of magnetotactic bacteria in a magnetic field. Magnetotactic bacteria produce an intracellular chain of magnetic nanoparticles that acts like a compass and passively orients the bacterium in the external magnetic field of the earth. The orientation provides an advantage to the bacteria, since it improves chemotaxis. Therefore we explore the interaction between chemotaxis and an external magnetic field. We show that reversing is more advantageous then tumbling, when a magnetic torque is included.

DY 45.3 Thu 11:45 ZEU 250

A microscopic field theoretical approach for active systems — •Francesco Alaimo[1,2], Simon Praetorius[1], and Axel Voigt[1,2,3] — [1]Institut für Wissenschaftliches Rechnen, TU Dresden, Dresden, Germany — [2]Dresden Center for Computational Materials Science (DCMS), TU Dresden, Dresden, Germany — [3]Center for Systems Biology Dresden (CSBD), Dresden, Germany

We consider a microscopic modeling approach for active systems. The approach extends the phase field crystal (PFC) model and allows us to describe generic properties of active systems within a continuum model. The approach is validated by reproducing results obtained with corresponding agent-based and microscopic phase field models. We consider binary collisions, collective motion and vortex formation. For larger numbers of particles we analyze the coarsening process in active crystals and identify giant number fluctuation in a cluster for-

mation process.

DY 45.4 Thu 12:00 ZEU 250

Interface-Controlled Motility of Photoactive Microalgae in Confinement — •Tanya Ostapenko, Christian T. Kreis, and Oliver Bäumchen — Max Planck Institute for Dynamics and Self-Organization (MPIDS), Am Fassberg 17, 37077 Göttingen, Germany

The natural habitats of many biological microorganisms include complex interfaces and varying environmental conditions. For flagellated microalgae swimming in an aqueous medium, we showed that the curvature of the compartment wall governs their motility in geometric confinement [1]. This curvature-guided motility results in long detention times towards highly curved interfaces. We determined this from the analysis of individual cell trajectories, the results of which are supported by simulations and analytics. For puller-type microswimmers, the precise nature of their flagella-surface interactions are important and remain debated to this day. We discovered that the flagella adhesiveness for photoactive microalgae can be controlled by light [2]. Here, we report on the swimming dynamics of single *Chlamydomonas* cells isolated in two-dimensional microfluidic chambers under different light conditions. We find that the cell's motility in confinement can be switched reversibly by light, which could be exploited for application in biological optical traps and wastewater decontamination. [1] T. Ostapenko, et al. (arXiv:1608.00363, 2016), [2] C. T. Kreis, et al. (in review, 2016).

DY 45.5 Thu 12:15 ZEU 250

Dynamics of spheroidal squirmers in Poiseuille flow — •Hemalatha Annepu, Mario Theers, Gerhard Gompper, and Roland G. Winkler — Theoretical Soft Matter and Biophysics, Institute for Advanced Simulation and Institute of Complex Systems, Forschungszentrum Jülich, 52425 Jülich, Germany

Bacteria such as *E. coli* exhibit a remarkable rheological behavior. On the one hand, the viscosity exhibits a Newtonian plateau at low shear rates, which decreases with increasing concentration. On the other hand, the bacteria exhibit positive rheotaxis, i.e., they swim preferentially upstream next to surfaces. This points toward an intriguing interplay between the swimmer flow field with the surface. To analyze the properties of microswimmers in channel flows, we consider spheriodal squirmers with a rotlet dipole embedded in a MPC fluid and study their flow-induced structure and dynamics. The no-slip boundary condition at a surface combined with the swimmer characteristics (puller, pusher) leads to a preferential alignment parallel (pusher) or perpendicular (puller) to the wall. This applies to both, spherical as well as spheroidal squirmers as long as they are not to close to a surface and the hydrodynamics is determined by the far field. We want to shed light on the influence of near-field hydrodynamic interactions on the swimming behavior of spheroidal squirmers close to surfaces. Our simulations reveal a dependence of the swimming behavior under flow on the shape of the microswimmer. We find positive rheotaxis for spheroidal pushers in narrow channels, which disappears in the limit of zero rotlet dipole strength.

DY 45.6 Thu 12:30 ZEU 250

Interaction of 3D amoeboid swimmer with a wall — •Mohd Suhail Rizvi, Alexandr Farutin, and Chaouqi Misbah — Université Grenoble Alpes, LIPHY, CNRS, F-38000 Grenoble, France

Several micro-organisms and eukaryotic cells, including those of immune system, are known to migrate in fluids with the help of the appendages (flagella or cilia) or by deforming their body, known as amoeboid swimming. We performed a numerical study of the interaction of a three dimensional amoeboid swimmer with a plane boundary using boundary integral method. Expectedly, for purely hydrodynamic interactions, the swimmer nature is dependent on its separation and orientation relative to the wall but shows two contrasting behaviors as it either gets attracted towards the wall or moves away from it depending on its configuration. We identify the regions in the phase space associated with these two contrasting behaviors and demonstrate that the navigational motion of an amoeboid swimmer in a confined region observed in 2D also persist in 3D. In the presence of the adhesive interaction (modeled using Lennard-Jones potential) between swimmer and the wall along with hydrodynamic, the swimmer velocity demonstrates a non-monotonic relationship with the adhesion strength by demonstrating fastest migration at moderate adhesion and thus recapitulates experimental observations.

DY 46: Modelling and Data Analysis

Time: Thursday 15:00–16:00 Location: HÜL 186

DY 46.1 Thu 15:00 HÜL 186

Information transfer in gravity waves as identified with mutual information and network measures — David Kittlaus, Christoph Räth, and •Heike Modest — Forschungsgruppe Komplexe Plasmen, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Argelsrieder Feld 1a, 82234 Wessling, Germany

Nonlinear network based analysis of multidimensional meteorological time series have led to new insights in climatology [1]. On the other hand, atmospheric gravity waves, that play a key role in large scale convection, have never been object to this technique. Here we use a method relying on both linear covariance and nonlinear mutual information as well as varying lags between the time series to construct a family of networks from simulated, multidimensional gravity wave data. Specifically, we analyze the vertical component of the wind speed in 137 vertical layers of the atmosphere ranging from the ground level up to an altitude of approximately 40 km. We prove the presence of nonlinear correlations by statistical tests with covariance preserving surrogate time series. Analyzing the degree centrality of a set of networks allows us to extract information propagation velocities varying with height, which can be interpreted by varying densities and temperatures at different levels of the atmosphere leading to varying propagation speed of gravity waves. Our findings give new insights into the processes of momentum and energy transfer into higher layers of the atmosphere.

[1] Donges F., et al. "The backbone of the climate network."EPL(2009)

DY 46.2 Thu 15:15 HÜL 186

A deeper look at time averages in the study of heart rate variability — •Mozhdeh Massah and Holger Kantz — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The fluctuations of human heartbeat of healthy patients, in the sense of convergence of finite sample time averages to a well-defined mean value, are analytically and theoretically studied. The approach for this investigation lies in the theory called large deviations theory, which in it's classical version claims that the large deviations of the identically independently distributed data get suppressed exponentially. It is here shown that long range correlations lead to sub-exponential decay of these deviations. In the case of heart rate variability , data resembles a non-stationary Gaussian process; and hence no convergence at all is found, leading to the conspicuous result of ergodicity breaking.

DY 46.3 Thu 15:30 HÜL 186

MDL based multidimensional step detection in piecewise constant signals — •Marius Bauer[1,2], Gerald Hinze[1], Klaus Müllen[1,3], and Thomas Basché[1,2] — [1]Insitut für Physikalische Chemie, Universität Mainz, Duesbergweg 10-14, 55128 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany — [3]Max-Planck-Insitut für Polymerforschung, Ackermannweg 10, 55128 Mainz, Germany

Recent experimental advances allow tracking single molecule features not easily addressable by ensemble techniques. As a general drawback, low signal intensities compared to ensemble experiments often accompany such experiments, requiring more demanding data evaluation.

Here we present an approach to analyze time dependent single molecule fluorescence data employing a parameter free algorithm based on the minimum description length (MDL) concept. Following single molecule fluorescence, features such as rotational or energy transfer dynamics can be traced. Common models for these processes predict stepwise fluorescence intensity changes, where the identification of steps in the noisy data remains the challenging part of the data analysis.

We introduce a new method for the identification of steps and signal

levels in noisy data for both recurring and nonrecurring signal levels. The method has been tested by Monte Carlo simulation to establish its reliability. As an example we have investigated the rotational dynamics of several organic dye molecules by polarization dependent single molecule measurements, yielding time scales and geometry of the reorientation process.

DY 46.4 Thu 15:45 HÜL 186

Estimability of model parameters and state variables from observed time series — •Ulrich Parlitz[1,2], Jan Schumann-Bischoff[1], and Stefan Luther[1,2,3] — [1]Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [3]Department of Pharmacology, University Medical Center, Robert-Koch-Str. 40, 37075 Göttingen, Germany

For many physical processes a mathematical model exists but not all state variables and parameters can be measured directly. Instead, their values have to be estimated from observed time series and the question arises whether unique results can be expected for the estimates and how reliable the obtained results are. To answer these questions we propose to analyze the null space of the linearized delay coordinates map [1]. This approach to estimability analysis is illustrated and generalized to multivariate time series.

[1] J. Schumann-Bischoff, S. Luther, U. Parlitz, Phys. Rev. E 94, 032221 (2016).

DY 47: Complex Fluids and Soft Matter I (joint session DY/CPP)

Time: Thursday 15:00–16:30 Location: ZEU 160

DY 47.1 Thu 15:00 ZEU 160

All-Atom Molecular Dynamics Simulation of Ionic Liquid films on Silica Surface — •Tamisra Pal and Michael Vogel — Institut für Festkörperphysik,Technische Universität Darmstadt,Hochschulstraße 6 64289 Darmstadt , Germany

Room temperature ionic liquid (RTIL) films in confined geometries have been recognized for their significant interfacial properties in electrochemical and electronic devices. Depending on the hydrophobicity of the anions, we chose IL 1-butyl-3-methylimidazolium cation with hexafluorophosphate ([Bmim][PF6]) and tetrafluoroborate ([Bmim][BF4]) counterparts. Here, the dynamical and structural properties of these ILs confined between amorphous silica slabs have been investigated by all-atom molecular dynamics simulation studies at 300 K. Relative number densities of the ions are calculated near the surface, as well as in the middle of the slit. The more hydrophilic [BF4]- ions tend to stay closer to the slab wall than symmetric [PF6]-, whereas the [Bmim]+ ions always resides in the next layer forming a bi-layered arrangement from the wall. A preferred orientation has been observed for the cations with their methyl groups pointing towards the slab surface and butyl tail projected inwards. The middle of the slit displays more of a bulk behavior in terms of density and ion diffusivities. Spatially-resolved analyses of the mean square displacement (MSD) and incoherent intermediate scattering function (ISF) reveal very sluggish and heterogeneous dynamics of these ILs in the vicinity of the silica surface, which need to be considered when designing applications.

DY 47.2 Thu 15:15 ZEU 160

Kirkwood-Buff integrals in the thermodynamic limit from small-sized molecular dynamics simulations — •Robinson Cortes Huerto, Kurt Kremer, and Raffaello Potestio — Max Planck Institute for Polymer Research, Ackermannweg 10, 55118, Mainz

We present an accurate and efficient method to obtain Kirkwood-Buff (KB) integrals in the thermodynamic limit from small-sized molecular dynamics simulations. By introducing finite size effects into integral equations of statistical mechanics, we derive an analytical expression connecting the KB integrals of the bulk system with the fluctuations of the number of molecules in the corresponding closed system. We validate the method by calculating the activity coefficients of aqueous urea mixtures and the KB integrals of Lennard-Jones fluids. Moreover, our results demonstrate how to identify simulation conditions under which computer simulations reach the thermodynamic limit.

DY 47.3 Thu 15:30 ZEU 160

Reconstruction of phason modes in colloidal quasicrystals — •Johannes Hielscher, Miriam Martinsons, Michael Schmiedeberg, and Sebastian C. Kapfer — FAU Erlangen-Nürnberg, Institut für Theoretische Physik

In colloidal quasicrystals, the idealised positions of the particles can be expressed in higher-dimensional space, accounting for the degrees of freedom of displacements within (phonons), and perpendicular (phasons) to the physical space. Phasonic displacements manifest in "flips", i. e. characteristic particle jumps. Our model systems are two-dimensional intrinsic quasicrystals of decagonal symmetry, which are stabilised by a next-neighbour double-minimum pair potential. Brownian Dynamics and Monte Carlo simulations are conducted to let flip patterns develop at finite temperatures.

We present an method to analyse the flip pattern in a monocrystalline, dislocation-free quasicrystal by decomposition into long-wavelength harmonic phason modes [1]. Thermal flips are only partially accounted for by this approach. We discuss the break-down of the supposed phason-phonon coupling on the atomic scale, in the context of fundamental limitations of extended, collective phasonic distortions in soft quasicrystals with short-range interactions.

[1] J. Hielscher, M. Martinsons, M. Schmiedeberg & S. C. Kapfer: Detection of phonon and phason modes in intrinsic colloidal quasicrystals by reconstructing their structure in hyperspace. *Submitted to J. Phys.: Cond. Matt.*

DY 47.4 Thu 15:45 ZEU 160

Two-step melting in Two Dimensions with Long-ranged forces — •Sebastian Kapfer — Theoretische Physik 1, FAU Erlangen, Germany

Recent progress in global-balance Monte Carlo algorithms has allowed to confirm the essentials of the Halperin-Nelson-Young theory (KTHNY) for the 2D Melting problem with short-range interactions [1]. A key challenge in these simulations are large correlation lengths which could be overcome by a new class of Monte Carlo algorithms [2].

In this talk, I will show that the new Monte Carlo paradigm can be extended to include long-range forces (including periodic images) rigorously, without any truncation effects. The resulting algorithm improves on the scaling of Ewald summation [3].

The new algorithm allows to check the scaling predictions of KTHNY theory in the long-range limit, and complete the phase diagram of inverted power-law potentials, relevant for charged colloids, plasma crystals, and other systems.

[1] S. C. Kapfer & W. Krauth, Phys. Rev. Lett. 114, 035702 (2015). [2] M. Michel et al., J. Chem. Phys. 140, 054116 (2014). [3] S. C. Kapfer & W. Krauth, Phys. Rev. E 94 (R), 031302 (2016).

DY 47.5 Thu 16:00 ZEU 160

Quantised Phase Transition of Confined Discotics forming Concentric Rings: Monte-Carlo and Experimental Studies — •Arne W. Zantop[1], Kathrin Sentker[2], Patrick Huber[2], and Marco G. Mazza[1] — [1]Max-Planck-Institut für Dynamik Komplexer Fluide, Am Faßberg 17, 37077 Göttingen — [2]Institut für Materialphysik und -technologie, Technische Universität Hamburg-Harburg, Eißendorferstr. 42, 21073 Hamburg

Interfaces and geometrical confinement crucially alter the phase transitions of various substances, as those of liquid crystals. We present combined results of a parallel tempering Monte-Carlo study of the discotic Gay-Berne-II fluid model in cylindrical nano-confinement, and an experimental study of the triphenylene derivate HAT6 confined in porous silica pores rendered both hydrophilic and hydrophobic. Here we report a quantised, layer by layer transition of the confined discotic liquid crystals. While the bulk phase shows a discontinuous transition from isotropic to hexagonal columnar phase upon cooling, the confined system forms concentric rings. Starting form the interface these ring develop inwards one after another with a discontinuous increase in local order parameter followed by plateaus with a continuous increase in local order.

DY 47.6 Thu 16:15 ZEU 160

Tracers in complex environments — •Tatjana Sentjabrskaja[1,2], Marco Laurati[3], Viktoria Wollrab[2], Gijsje Koenderink[2], and Stefan Egelhaaf[1] — [1]Condensed Matter Physics Laboratory, Heinrich Heine University, Düsseldorf, Germany — [2]FOM Institute AMOLF, Amsterdam, The Netherlands — [3]Division de Ciencias e Ingenieria, Universidad de Guanajuato, Leon, Mexico

Biological cells are critically dependent on intracellular transport. To understand the flow of proteins, vesicles and organelles, we study the dynamics of tracers in complex environments, which are modeled using 1) a dense quasi-arrested matrix formed by colloidal hard spheres [1] and 2) a network of semi-flexible actin filaments. The dynamics of the tracer particles in both environments display an anomalous behavior. As a most striking feature the intermediate scattering function of the tracer particles dispersed in dense colloidal matrix displays an extended logarithmic decay resulting from the competition between localization and diffusion.

The characterization of tracer dynamics over a wide range of time and length scales relies on differential dynamic microscopy (DDM) [2-3], which is a powerful combination of microscopy and concepts of light scattering. Thanks to the recent successful extension of DDM to dense systems [4], the application to dense, crowded and multi-component biological systems is feasible.

[1] T. Sentjabrskaja et al., Nat. Com. 7 (2016). [2] R. Cerbino et al., Phys. Rev. Lett. 100 (2008). [3] F. Giavazzi et al., Phys. Rev. R 80 (2009). [4] T. Sentjabrskaja, PhD thesis, HHU (2015).

DY 48: Pattern Formation / Reaction-Diffusion II (joint session DY/BP)

Time: Thursday 15:00–17:00 Location: ZEU 118

DY 48.1 Thu 15:00 ZEU 118

Flow Induced Instabilities in an Advected Dictyostelium Discoideum Model — •Estefania Vidal, Azam Gholami, and Eberhard Bodenschatz — Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, D-37077 Göttingen, Germany

The spirals and concentric waves of cAMP appearing during the aggregation process of the social ameba Dictyostelium Discoideum have been widely studied as an example of pattern formation in biological systems, however in the rain forest soil, the natural environment of these amebas, the constant rain washes away the signalling chemical, thus affecting the pattern formation. To simulate these environmental conditions, we studied numerically and theoretically a Reaction Diffusion model in the presence of a constant flow advection. The model, proposed by Martiel and Goldbeter, describes the dynamics of cAMP by taking its concentration as an activator and the ratio of active receptors in the cell membrane as inhibitor. Depending on the election of parameters this system can be in an oscillatory or an excitable state, and has successfully reproduce many of the experimentally observed features. We show how a Dirichlet boundary condition destabilises the system, creating a continuous influx of waves upstream which grow into train waves that fill the entire system. These phenomena, which appear due to the interaction between the Flow Induced Instability and a Hopf Bifurcation provide a novel mechanism for the creation of continuos waves in Advected Reaction Diffusion systems.

DY 48.2 Thu 15:15 ZEU 118

Localized structures in the Kuramoto-Sivashinsky-Verhulst equation in context of ion-beam eroded surfaces — •Christoph Kabelitz and Stefan Jakob Linz — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

Pattern formation of ion-beam eroded semiconductor surfaces has received considerable attraction because of the variety of structures (from flat, rough up to periodically arranged on large scales) being experimentally observed. Besides that, also large area localized hexagonal dot patterns have being experimentally detected [1]. Using a numerically manageable extended Kuramoto-Sivashinsky equation that models the dynamics of the surface morphology of the combined erosion and redeposition processes [2, 3], such localized hexagonal structures are identified, the existence range in the parameter space is determined and the rather involved scenarios of the creation and annihilation of these structures are classified and clarified.

[1] T. Allmers, M. Donath and G. Rangelov, J. Vac. Sci. Technol. B 24, 582 (2006). [2] C. Diddens and S. J. Linz, Europhys. Lett. 104, 17010 (2013). [3] C. Diddens and S. J. Linz, Eur. Phys. J. B 88, 190 (2015).

DY 48.3 Thu 15:30 ZEU 118

Surface instabilities in vibrating thin fluid films — •Sebastian Richter[1] and Michael Bestehorn[2] — [1]Department of Theoretical Physics, BTU, 03044, Cottbus, Germany — [2]Department of Theoretical Physics, BTU, 03044, Cottbus, Germany

We investigate the spatio-temporal evolution of a thin fluid layer, which is located on a horizontal, solid substrate and is either subjected to a constant or to a time-periodic gravitational force field in normal direction. Starting with an appropriate initial state, the behavior of the liquid is simulated numerically considering both the exact problem and a long wave lubrication approximation based model obtained from the incompressible Navier-Stokes equations. The model includes inertia and viscous friction. For the case of a periodic external force, we observe the formation of time-periodic surface waves (Faraday instabilities) if the frequency and amplitude of excitation meet certain critical values. A Floquet analysis is made to determine the exact stability criteria of the linearized system. Both approaches show good agreement in the limit of a thin fluid geometry: Harmonic excitations generate patterns oscillating harmonically with the driver's frequency (ω) for low frequency ranges and subharmonically ($\omega/2$) at higher frequencies.

DY 48.4 Thu 15:45 ZEU 118

Control of competing patterns in anti-symmetrically coupled Swift-Hohenberg equations — •Maximilian Becker[1], Sina Reichelt[2], Thomas Niedermayer[1], Thomas Frenzel[2], Alexander Mielke[2], and Markus Bär[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany — [2]Weierstraß-Institut für Angewandte Analysis und Stochastik (WIAS), Berlin, Germany

The Swift-Hohenberg equation (SHE) provides a generic formulation for non-equilibrium pattern formation at a characteristic length scale. We present analytical and numerical investigations of two anti-symmetrically coupled 1d SHEs with cubic nonlinearities. A linear stability analysis of the homogeneous state reveals a wave instability in addition to the Turing instability of uncoupled SHEs. Weakly nonlinear analysis has been performed in the vicinity of the codimension-2-point of the Turing-wave instability, resulting in a set of coupled amplitude equations for Turing patterns and left- and right-traveling waves. In particular, these complex Ginzburg-Landau-type equations predict a mutual suppression of the amplitudes. In consequence, different patterns can coexist in distinct spatial regions, separated by localized interfaces. We identified specific control mechanisms for these interfaces which allow for global pattern selection. Extensive simulations of the underlying SHEs confirm our results.

DY 48.5 Thu 16:00 ZEU 118

Modeling collective motion and pattern formation of self-propelled rods and application to myxobacteria — Robert Großmann[1,2], Fernando Peruani[1], and •Markus Bär[2] — [1]Universite de Nice, France — [2]Physikalisch-Technische Bundesanstalt, Germany

We study self-propelled particles with nematic velocity-alignment in two dimensions, which reverse their direction of motion repeatedly. The large-scale properties of these point-like self-propelled rods are analyzed within a hydrodynamic theory that can be systematically derived from the microscopic dynamics. Combining analytical methods and numerical continuation, we show that an entire family of elongated high-density regions, called bands, self-segregates spontaneously from a homogeneous background via two subcritical bifurcations. The reduction of the multi-particle system onto the dynamics of bands provides a unified framework to understand aggregation mechanisms and nonequilibrium phase separation in active systems with nematic velocity-alignment, e. g. the collective dynamics of rod-shaped, actively moving myxobacteria. R. Großmann, F. Peruani, and M. Bär, Phys. Rev. E 94, 050602 (2016).

DY 48.6 Thu 16:15 ZEU 118

Pattern formation in polymerizing actin flocks — •Thomas Le Goff, Benno Liebchen, and Davide Marenduzzo — School of Physics and Astronomy, University of Edinburgh, UK

F-Actin is a polymer existing in the cytoskeleton of cells and which is involved in cell motility, cell division or cell signaling. These polymers form a network which can exhibit very interesting dynamics. Particularly, actin waves usually following formation of spots were observed experimentally [1].

We propose a simple physical model based on a minimum number of ingredients to describe the appearance of these waves :(i) treadmilling - i.e. the simultaneous growth and shrinkage at the two ends of the actin fiber, (ii) polymerisation and (iii) a nematic interaction term causing fiber alignment for large concentration of F-actin. With this simple model we obtain very rich dynamics, in particular we can observe formation of spots, spirals and waves resembling the dynamics seen experimentally. Our model also allows us to make definite predictions on the mechanism underlying wave formation in vivo.

[1]T. Bretschneider, K. Anderson, M. Ecke, A. Müller-Taubenberger, B. Schroth-Diez, H. C. Ishikawa-Ankerhold, G. Gerisch, Biophys. J. 96, 2888 (2009).

DY 48.7 Thu 16:30 ZEU 118

Size matters for Nonlinear Waves and Min Protein Patterns — •Fabian Bergmann, Lisa Rapp, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

Self-organization is a fundamental strategy in nature. In E. coli bacteria, for example, self-organized pole-to-pole oscillations of the Min proteins have an important function within the cell division machinery. Such pole-to-pole oscillations in living cells behave like standing waves (SW) in very small (confined) systems. In extended in vitro experiments, Min oscillations develop into nonlinear traveling waves (TW). TW patterns are also known from many other nonequilibrium systems. But is the transition from traveling waves in extended to standing waves in strongly confined systems a specific property of the Min oscillation pattern? Or is it a generic and robust universal principle of all nonlinear traveling waves that just also applies to the Min oscillations in cells?

We address this central question by imposing strong spatial confinement to a generic model for nonlinear traveling waves. Using simulations, analytical and symmetry considerations, we conclude that traveling waves inevitably change into standing waves in sufficiently small confined systems.

DY 48.8 Thu 16:45 ZEU 118

Traveling Waves in Conserved Systems — •Lisa Rapp, Fabian Bergmann, Markus Hilt, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Deutschland

Nonlinear traveling waves are one of the elementary prototype patterns that occur in various systems in nature far from thermal equilibrium. So far, their behavior has mostly been investigated in systems with an unconserved order parameter. In contrast, in systems with conserved order parameter, the Hopf-bifurcation to traveling waves is nearly unexplored (except for a first approach in Ref. [1]). The effects of conservation laws, however, may play a significant role in many pattern forming systems such as the Min protein oscillations during cell division in E.coli bacteria.

In spatially extended conserved systems, there are two distinctly different Hopf-bifurcations from a homogeneous basic state to traveling waves. On the one hand, the transition can occur via a finite wavenumber instability, similar to convection systems. On the other hand, the basic state can also become unstable towards long wavelength modes, comparable to the non-oscillatory Cahn-Hilliard model for potential systems.

We introduce a generalized Swift-Hohenberg model for conserved systems that includes both scenarios as special cases. Exploring this model and its limiting cases, we find interesting types of coarsening behavior and spatio-temporal complexity.

[1] W. Zimmermann, Physica A **237**, 575 (1997).

DY 49: Networks: From Topology to Dynamics (joint session DY/ BP/SOE)

Time: Thursday 15:00–16:15 Location: ZEU 147

DY 49.1 Thu 15:00 ZEU 147

Response Patterns for Fluctuations in Complex Flow Networks — •Xiaozhu Zhang[1], Sarah Hallerberg[1,2], Moritz Moritz Matthiae[3], Dirk Witthaut[3,4], and Marc Timme[1,5] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen — [2]Faculty for Engineering and Computer Science, Hamburg University of Applied Science, 20099 Hamburg — [3]Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), Forschungszentrum Jülich, 52428 Jülich — [4]Institute for Theoretical Physics, University of Cologne, 50937 Köln — [5]Department of Physics, Technical University of Darmstadt, 64289 Darmstadt

Dynamic collective phenomena prevail in networked systems across physics, biology and engineering. How external signals generate distributed responses patterns in such systems fundamentally underlies their function, yet is far from fully understood. Here we analyze the collective response patterns of oscillatory networks to fluctuating input signals. For an arbitrary network topology, we analytically find distinct response patterns to fall into three distinct frequency regimes: homogeneous responses across the network at low frequencies, topology-dependent resonances at intermediate frequencies and are frequency-dependent, localized responses at high frequencies. These results render regime-specific implications for real-world network design and control, in particular for transport and supply networks, e.g. electric power grids.

DY 49.2 Thu 15:15 ZEU 147

Control of chimeras in small networks — Iryna Omelchenko[1], Oleh Omel'chenko[2], Anna Zakharova[1], Matthias Wolfrum[2], and •Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Weierstrass Institute, Mohrenstraße 39, 10117 Berlin, Germany

We propose a control scheme which can stabilize and fix the position of chimera states in small networks [1]. Chimeras consist of coexisting domains of spatially coherent and incoherent dynamics in systems of nonlocally coupled identical oscillators. Chimera states are generally difficult to observe in small networks due to their short lifetime and erratic drifting of the spatial position of the incoherent domain. The control scheme, like a tweezer, might be useful in experiments, where usually only small networks can be realized.

[1] I. Omelchenko, O. E. Omel'chenko, A. Zakharova, M. Wolfrum, and E. Schöll, Phys. Rev. Lett. **116**, 114101 (2016).

DY 49.3 Thu 15:30 ZEU 147

Scaling Laws in Spatial Network Formation — •Nora Molkenthin[1,2] and Marc Timme[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, German — [2]Institute for Nonlinear Dynamics, Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany

Geometric constraints strongly impact the formation of networked systems. Examples range from amino acid chains folding to proteins structures to rearranging particle aggregates. The dynamical self-organization of the interaction network in such systems is far from fully understood. Here, we analyze a class of spatial network formation processes by introducing a mapping from geometric to graph-theoretic constraints. Combining stochastic and mean field analyses yields an algebraic scaling law for the extent (graph diameter) of the resulting networks with system size, in contrast to logarithmic scaling known for networks without constraints. Intriguingly, the exponent falls between that of self-avoiding random walks and that of space filling arrangements, consistent with experimentally observed scaling (of the spatial radius of gyration) for protein tertiary structures.

DY 49.4 Thu 15:45 ZEU 147

Boolean network analysis reveals interaction networks among low-abundance species in the human gut microbiome — •Jens Christian Claussen[1], Jurgita Skieceviciene[2], Jun Wang[3],

Philipp Rausch[6,5], Tom H. Karlsen[4], Wolfgang Lieb[5], John F. Baines[5,6], Andre Franke[5], and Marc-Thorsten Hütt[3] — [1]Computational Systems Biology, Jacobs University Bremen — [2]U Kaunas — [3]KU Leuven — [4]U Oslo — [5]UKSH, U Kiel — [6]MPI Plön

Microbiome compositions in clinical context gained recent interest. Most analyses infer interactions among highly abundant species. The large number of low-abundance species has received less attention. Here we present a novel analysis method based on Boolean operations applied to microbial co-occurrence patterns. We calibrate our approach with simulated data based on a dynamical Boolean network model from which we interpret the statistics of attractor states as a theoretical proxy for microbiome composition. We show that for given fractions of synergistic and competitive interactions in the model our Boolean abundance analysis can reliably detect these interactions. In our human gut microbiome dataset, we find a large number of highly significant synergistic interactions among these low-abundance species, forming a connected network, and a few isolated competitive interactions.

DY 49.5 Thu 16:00 ZEU 147

Complex Contagion and Coordinated Response in Animal Groups — •Winnie Poel[1,6], Bryan Daniels[3], Colin Twomey[2], Iain Couzin[4,5], and Pawel Romanczuk[1,6] — [1]Inst. of Theor. Biol., Dept. of Biol., Humboldt Universität zu Berlin — [2]Dept. of Ecology and Evolutionary Biol., Princeton University, Princeton, US — [3]ASU-SFI Center for Biosocial Complex Systems, Arizona State University, US — [4]Dept. of Collective Behaviour, MPI for Ornithology, Konstanz, Germany — [5]Dept. of Biology, University of Konstanz, Germany — [6]Bernstein Center for Computational Neuroscience Berlin, Germany

Our work focuses on the underlying communication network in animal swarms that enables coordinated movement and collective information processing in large groups while taking into account the limited attention and cognitive ability of each individual. Here, we study the influence of network structure on processes of behavioral complex contagion in fish groups. Specifically, we investigate the spreading of startling behavior in golden shiners on empirically inferred networks built on their individual visual perception of neighbors [1]. Using a simple adapted SIR model [2] we aim to uncover how the spatial configuration of a swarm (and thus its visual interaction network) aid to amplify or dampen out the information send out by a certain individual.

[1] Rosenthal, S., et al., PNAS 112.15 (2015): 4690-4695
[2] Dodds, P., et al., J. Theor. Biol. 232.4 (2005): 587-604

DY 50: Statistical Physics of Biological Systems I (Joint Session BP/DY)

Time: Thursday 15:00–17:30 Location: ZEU 250

DY 50.1 Thu 15:00 ZEU 250

Inference of chemotactic strategies of *E. coli* and *Pseudonomas putida* using Kramers-Moyal coefficients — •Maximilian Seyrich[1], Oliver Pohl[1], Marius Hintsche[2], Zahra Alirezaei[2], Carsten Beta[2], and Holger Stark[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam, Germany

Bacteria like *E. coli* and *Pseudomonas putida* move with alternating runs and tumbles that occur with a mean tumble rate. In the presence of gradients of a chemoattractant, they both perform chemotaxis. We set up a random-walk model that describes runs and tumbles as a stochastic process of the bacterium's swimming direction and speed. The dynamics include rotational Brownian motion and shot noise for the swimming direction to initiate tumbling, while thermal and shot noise together with a mean reverting drift-term analogously to an Ornstein-Uhlenbeck process governs the speed dynamics. In order to infer the parameters of our model, generalized Kramers-Moyal coefficients are calculated for our model and matched to the ones determined from experimental trajectories. In contrast to common tumbling recognition algorithms no free parameters need to be preset. We first show that our method identifies the classical bacterial chemotaxis strategy of *E. coli* and *P. putida*, i.e., the tumble rate decreases along the chemical gradient. We also find evidence that a subpopulation of *E. coli* reduces its mean tumble angle when swimming in this direction.

DY 50.2 Thu 15:15 ZEU 250

Genotypic complexity of Fisher's geometric model — Sungmin Hwang[1], Su-Chan Park[2], and •Joachim Krug[1] — [1]Institute for Theoretical Physics, University of Cologne, Cologne, Germany — [2]Department of Physics, The Catholic University of Korea, Bucheon, Republic of Korea

Biological evolution can be conceptualized as a dynamical process in the space of gene sequences guided by the fitness landscape, a mapping that assigns a measure of reproductive value to each genotype [1]. The relationship between genotype and fitness is generally complex, as it is mediated by the multidimensional organismic phenotype that interacts with the environment and thereby determines reproductive success. A simple mathematical framework for exploring this relationship is provided by Fisher's geometric model, which describes the phenotype as a vector in an n-dimensional Euclidean trait space with a unique optimum located at the origin [2]. Genetic mutations are encoded as random phenotypic displacements, and complex fitness landscapes arise from the projection of the discrete network of genotypes onto the continuous trait space. The talk will discuss the properties of these fitness landscapes from the viewpoint of statistical physics, focusing in particular on the exponential growth of the number of local fitness peaks as a measure of genotypic complexity.

[1] J.A.G.M. de Visser, J. Krug, Nat. Rev. Genet. 15:480 (2014).
[2] R.A. Fisher, The Genetical Theory of Natural Selection. Clarendon Press, Oxford (1930).

DY 50.3 Thu 15:30 ZEU 250

Statistical description of normalized odor representations — •David Zwicker — Harvard University, Cambridge, USA

Natural odors comprise many molecules at different concentrations and it is unclear how such odors are discriminated by relatively few olfactory receptors. One problem is that the correlations present in natural odors cannot be removed by local computations, like center-surround inhibition in vision. Instead, the global inhibition present in the olfactory system leads to normalized odor representations, where the odor intensity is separated from its identity, encoded by the relative concentrations of the odorant molecules. This separation is useful to robustly identify odors at different intensities, but how such global inhibition influences the neural representations of odors is unclear.

In this presentation, I discuss a simple theoretical model of the olfaction system that focuses on global inhibition. The model leads to sparse odor representations and reveals two generic consequences of global inhibition: (i) odors with many molecular species are more difficult to discriminate and (ii) receptor arrays with heterogeneous sensitivities perform badly. Comparing these predictions to experiments will help us to understand the role of global inhibition in shaping normalized odor representations.

DY 50.4 Thu 15:45 ZEU 250

Magnetosensing with ion channels and the origin of anomalous gating kinetics — •Igor Goychuk — Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str. 24/25, 14476 Potsdam-Golm, Germany

It was earlier proposed by J. Kirschvink *et al.* that magnetosensitive ion channels can be involved in sensing weak magnetic fields by various animals, with a magnetic nanoparticle coupled to a gate of an ion channel and serving as sensor. I consider a generalization of this hypothesis, where a magnetic nanorod made of several magnetosomes is elastically coupled to a cluster of ion channels [1]. Magnetic nanorod reorients in viscoelastic cytosol following a Generalized Langevin equation dynamics and a gating spring instability leads to bistable open-shut dynamics in such a hypothetical magnetosensory complex. Is the proposed mechanism feasible for realistic parameters? It is shown that YES, and interestingly enough the open-shut dynamics can exhibit both stretched-exponential and power law features in the residence time distributions. Beyond this particular context of magnetosensing, viscoelasticity of the medium in which the sensory part of ion channel moves is proposed as a generic mechanism to explain the origin of anomalous gating kinetics observed in several naturally occurring ion channels.

[1] I. Goychuk, Phys. Rev. E **92**, 042711 (2015).

DY 50.5 Thu 16:00 ZEU 250

Quorum sensing in stochastic many-particle models of microbial populations — •Johannes Knebel[1], Matthias Bauer[2], Matthias Lechner[1], Peter Pickl[1], and Erwin Frey[1] — [1]Ludwigs-Maximilians Universitity, Munich — [2]Max Planck Institute for Intelligent Systems, Tuebingen

Autoinducers are small signaling molecules that mediate intercellular communication in microbial populations and trigger coordinated gene expression via "quorum sensing". Elucidating the mechanisms that control autoinducer production is pertinent to understanding collective microbial behaviors such as virulence and bioluminescence. Recent experiments indicate that autoinducers can be heterogeneously produced in clonal populations. Here we ask how phenotypic heterogeneity is established and how the autoinducer concentration in the population is regulated at the same time. In our conceptual model, cells synthesize and excrete autoinducers, and replicate and adapt in this environment. The model reveals that heterogeneous autoinducer production is facilitated by the coupling of ecological and evolutionary dynamics through quorum sensing. To capture the emergent dynamics, we derived a macroscopic mean-field equation from the microscopic stochastic many-particle process in the spirit of the kinetic theory in statistical physics. This mean-field equation reduces to the continuous replicator equation when quorum sensing is absent and, notably, admits bimodal stationary distributions when quorum sensing is present. Our analysis explains phenotypic heterogeneity through quorum sensing and the observed phase transitions to homogeneity.

DY 50.6 Thu 16:15 ZEU 250

Dynamics of population fronts in the presence of finite-sized heterogeneities — •Wolfram Möbius[1,3], Kim M. J. Alards[1], Francesca Tesser[1], Roberto Benzi[2], David R. Nelson[3], and Federico Toschi[1] — [1]Technische Universiteit Eindhoven, Eindhoven, The Netherlands — [2]Universita' di Roma "Tor Vergata" and INFN, Rome, Italy — [3]Harvard University, Cambridge, MA, USA

Populations spread on surfaces through the combined effect of dispersal and population growth on a wide range of length and time scales, yet the effect of heterogeneous environments on this spreading process is not well understood. We here investigate the effect of finite-sized features which affect dispersal or growth of the population locally. With an individual-based simulation we investigate the effect of individual features on the population front and identify a regime within which a local front speed is sufficient to predict the resulting front. Using least-time arguments we are able to describe the front dynamics for individual features and characterize how width and length of the features determine front shape at long times. These findings combined with numerical solutions of the Eikonal equation allow us to characterize the resulting effective front speed for dilute to dense random sets of features. The results advance our understanding of population and other fronts in two-dimensional irregular environments.

DY 50.7 Thu 16:30 ZEU 250

Universality in the clonal dynamics in developing tissues — •Steffen Rulands[1,2], Samira Chabab[3], Fabienne Lescroart[3], Cedric Blanpain[3], and Benjamin David Simons[1] — [1]University of Cambridge, Cambridge, United Kingdom — [2]MPI-PKS, Dresden, Germany — [3]Université libre de Bruxelles, Brussels, Belgium

Lineage tracing studies based on transgenic animal models have led to advances in our understanding of cellular identity, hierarchy and function. They provide insights into the development, maintenance and regeneration of tissues, and factors leading to dysregulation in diseased states. However, large-scale cell rearrangements, particularly in growing tissues may render the retrospective analysis of lineages highly problematic. Drawing on studies of heart development, we show how such effects may lead to the emergence of universal scaling distributions. By mapping the problem of clonal evolution onto the theory of aerosols, we elucidate the origin and range of possible scaling behaviors. In generalizing our studies to other tissue types and contexts, we show how the identification of universal scaling dependences allows biological information on cell fate behavior to be distilled.

DY 50.8 Thu 16:45 ZEU 250

Incorporating sleep regulation and thalamocortical interactions in a cortical meanfield model — •Michael Schellenberger Costa[1], Arne Weigenand[1], Hong-Viet V. Ngo[2], Lisa Marshall[3], Jan Born[2], Thomas Martinetz[1], and Jens Christian Claussen[4,1] — [1]INB, U Lübeck — [2]Med. Psych. and Behav. Neurobiol., U Tübingen — [3]Neuroendocrinology, U Lübeck — [4]Comp. Syst. Biol, Jacobs University Bremen

Few models accurately reproduce the complex rhythms of the thalamocortical system, as well as the dynamical patterns of sleep regulation. Here, we build upon previous work on a meanfield (neural mass) model of the sleeping cortex [1] and investigate the effect of neuromodulators on the dynamics of the cortex and the corresponding transition between wakefulness and the sleep stages [2]. We show that our simplified model generates essential features of human EEG over a full day. This approach builds a bridge between sleep regulatory models and EEG generating neural mass models. Based on model [1|, we also suggest a new interpretation of the mechanisms responsible for the generation of KCs and SOs [3]. A KC corresponds to a single excursion along the homoclinic orbit, while SOs are noise-driven oscillations around a stable focus. The model generates both time series and spectra that strikingly resemble real EEG data and points out differences between the stages of natural sleep.

[1] A. Weigenand et al., PloS Comp Biol (2014) [2] M. Schellenberger Costa et al., J. Comp. Neurosci. (2016) [3] M. Schellenberger Costa et al., PloS Comp Biol (2016)

DY 50.9 Thu 17:00 ZEU 250

Modeling the spread of West Nile Virus in Germany — •Suman Bhowmick[1], Philipp Lorenz[2], Philipp Hövel[2], and Hartmut H. K. Lentz[1] — [1]Institute of Epidemiology, Friedrich-Loeffler-Institute, Südufer 10, 17493 Greifswald — [2]Institute of Theoretical Physics, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

West Nile virus (WNV) is an arthropod-borne virus (arbovirus) spreading in transmission cycle between mosquitoes and birds. In addition, horses and human are also the victims of WNV, being infected by blood feeding mosquitoes. In our current endeavour, a dynamic model has been devised to decipher the intricacy of the spreading dynamics of the West Nile virus.

The model which is of SEIR (susceptible-exposed-infected-removed) type, comprises of 19 compartments. In this model, we tried to couple the terrestrial and aqueous stages of mosquitoes through a single ODE, for the simplicity. In addition to the local spreading dynamics, spatial spread through aerial movement (diffusion) and bird migration shall be included in the model.

As results, we will present solutions of the local infection model as well as an analytical expression for the basic reproduction number R_0. The seasonal and environmental impacts are also taken into the considerations. The associated map of the basic reproduction number R_0 will be investigated further along with the ODE coupled with network.

DY 50.10 Thu 17:15 ZEU 250

Burst-Noise induced bifurcations in the Schlögl-Model — •Johannes Falk, Marc Mendler, and Barbara Drossel — TU Darmstadt, Germany

We investigate the influence of intrinsic noise on stable states of a one-dimensional dynamical system that shows in its deterministic version a saddle-node bifurcation between monostable and bistable behaviour. The system is a modified version of the Schlögl model, which is a chemical reaction system with only one type of molecule. The strength of the intrinsic noise is varied without changing the deterministic description by introducing bursts in the autocatalytic production step. We study the transitions between monostable and bistable behavior in this system by evaluating the number of maxima of the stationary probability distribution. We find that changing the size of bursts can destroy and even induce saddle-node bifurcations. This means that a bursty production of molecules can qualitatively change the dynamics of a chemical reaction system even when the deterministic description remains unchanged.

DY 51: Extreme Events

Time: Thursday 16:15–17:00 Location: HÜL 186

DY 51.1 Thu 16:15 HÜL 186

Time to build Noah's ark? Searching for trends in extreme events of river data. — Philipp Müller and •Holger Kantz — MPI for the Physics of Complex Systems, Dresden

Floods are one of the most devastating natural disasters striking Germany and at least at a perceived level one might find them happening more frequently nowadays. In this talk we search for trends in extreme events using the example of the river Elbe in Dresden. We will apply the extreme value theory in a non-stationary setting and discuss difficulties, potentials and limitations of this approach.

DY 51.2 Thu 16:30 HÜL 186

Caustics in nonlinear waves — •Gerrit Green[1,2] and Ragnar Fleischmann[1] — [1]Max-Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Departement of Physics, Georg-August University Göttingen, 37077 Göttingen, Germany

Rogue waves appear suddenly and unpredictably on the ocean surface in otherwise benign conditions and have a large amplitude. Potential formation mechanisms are random focusing as well as modulational instability in nonlinear wave equations. The former leads to branched flow, a universal phenomenon occurring in wave or particle flows that propagate through weakly scattering media, closely connected to the occurrence of random caustics. We investigate caustics in the nonlinear Schrödinger equation which is used as a model for deep water surface waves, as well as Bose-Einstein condensates and for light propagating through a nonlinear medium. We study the impact of small nonlinearities on branched flows and the distance to the onset of random caustics.

DY 51.3 Thu 16:45 HÜL 186

An early warning signal for interior crises in excitable systems — •Stephan Bialonski[1], Rajat Karnatak[2], and Holger Kantz[1] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany — [2]Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany

The ability to reliably predict critical transitions in dynamical systems is a long-standing goal of diverse scientific communities. Previous work focused on early warning signals related to local bifurcations (critical slowing down) and non-bifurcation type transitions. We extend this toolbox and report on a characteristic scaling behavior (critical attractor growth) that is indicative of an impending global bifurcation, an interior crisis in excitable systems. We demonstrate our early warning signal in a model of coupled neurons known to exhibit extreme events.

DY 52: Chimera states: symmetry-breaking in dynamical networks (joint session DY/BP/SOE)

Time: Thursday 16:30–17:00 Location: ZEU 147

DY 52.1 Thu 16:30 ZEU 147

The emergence of chimera states in arrays of cilia — •Thomas Niedermayer and Markus Bär — Physikalisch-Technische Bundesanstalt (PTB), Berlin

Systems of non-locally coupled, identical phase oscillators exhibit the coexistence of coherent and incoherent regions. These intriguing dynamical states, termed chimeras, have been studied theoretically in recent years and their emergence is hypothesized for instance in unihemispheric sleep and ventricular fibrillation. However, observations directly linked to theory were only made in engineered systems.

We have reconsidered our previously published phase oscillator model for hydrodynamic interactions of flagella and cilia, thread-like projections of eukaryotic cells. This simple, yet realistic, minimal model gives rise to the well-established phenomenon of metachronal waves. Here, we show that it additionally comprises all necessary and sufficient conditions for the emergence of chimera states. In particular, the flexibility of cilia might function as a lever between synchronous and asynchronous dynamics, that is a switch between two qualitatively different motility states. Our theoretical predictions provide a testable hypothesis in experimental and computational studies of large cilia arrays.

DY 52.2 Thu 16:45 ZEU 147

Origins of alternating chimeras — •Sindre W. Haugland, Felix P. Kemeth, and Katharina Krischer — Physik-Department, Nonequilibrium Chemical Physics, Technische Universität München, James-Franck-Str. 1, D-85748 Garching, Germany

Oscillatory media can exhibit the coexistence of synchronized and desynchronized regions, so-called chimera states, for uniform parameters and symmetrical coupling. In a phase-balanced chimera state, where the totals of synchronized and desynchronized regions, respectively, are of the same size, the symmetry of the system allows for an alternative solution to the underlying equations, in which the dynamics of the phases are interchanged. Recently, we observed this kind of interchange as a self-emergent, self-sustained phenomenon in simulations of an oscillatory medium governed by a complex Ginzburg-Landau equation with nonlinear global coupling, and classified it as an alternating chimera (Sci. Rep. 5, 9883 (2015)). Here, we present more systematic research on its origin and dynamics, revealing new, related states, notably a form of self-sustained alternating regular subclustering, and providing additional insights into its mechanism of emergence. Working with minimal models, we are able to reproduce important features of the oscillatory medium close to the alternating chimera, and to identify several specific bifurcations in which these features are created and destroyed. Our results broaden the knowledge about self-emergent and self-sustained chimera states, particularly regarding alternating chimeras, and may help improve our understanding of chimera-like phenomena observed in biology.

DY 53: Posters - Active Matter

Time: Thursday 17:00–19:30 Location: P1A

DY 53.1 Thu 17:00 P1A

Modelling the physical origin of bacterial biofilm morphotypes — •Horst-Holger Boltz and Stefan Klumpp — Institut für nichtlineare Dynamik, Fakultät Physik, Georg-August-Universität Göttingen, Göttingen, Deutschland

Microbial biofilms have been an important subject of study in the recent years due to their biological, medical and technological relevance. Biofilms are large multicellular structures of mi- croorganisms adherent to a substrate. The formation of these structures is usually accompanied by the production of an extracellular matrix formed by so-called extra-cellular polymeric substances (EPS). Thus, an elastic film is created that is growing due to the ongoing cell growth and division as well as the continued production of EPS. This growth leads to residual and dynamic stresses that are relieved by a non-planar pattern-formation (wrinkling). We present a reductionist model highlighting the physical origin of the different morphotypes observed.

DY 53.2 Thu 17:00 P1A

Bifurcations in a Model for Active Crystals: The Onset of Motion — •Lukas Ophaus, Svetlana Gurevich, and Uwe Thiele — Institut für Theoretische Physik, WWU, Münster, Germany

The conserved Swift-Hohenberg equation (or Phase-Field-Crystal [PFC] model) provides a simple microscopic description of the thermodynamic transition from a fluid to a crystalline state [1]. The model can be combined with the Toner-Tu theory for self-propelled particles to obtain a model for crystallization (swarm formation) in active systems [2]. Within the resulting active PFC model, resting and traveling crystals can be identified. Above a critical value of activity, crystals migrate with a well-defined velocity while keeping their spatial periodicity.

Like the passive PFC model [3], the active version describes a variety of localized clusters besides spatially extended crystals. We use a 1d model to explore how the bifurcation structure (slanted homoclinic snaking of localized states) is amended by activity. Numerical continuation is applied to follow resting and traveling localized states while varying the activity and mean concentration. In addition, we provide a general analytical criterion for the onset of motion in the nonlinear regime, that corresponds to a drift pitchfork bifurcation.

[1] M.J. Robbins et al., Phys Rev E 85, 061408 (2012)
[2] A.M. Menzel and H. Löwen, Phys. Rev. Lett. 110, 055702 (2013)
[3] U. Thiele et al., Phys Rev E 87, 042915 (2013)

DY 53.3 Thu 17:00 P1A

The growth and structural properties of microbial colonies in microfluidic devices — •Sebastian Mair — Max-Planck-Institut für Dynamik und Selbstorganisation, Am Faßberg 17, 37077 Göttingen, Deutschland

Microbial organisms are ubiquitous in nature. Escherichia coli bacteria serve as a model organism to study many phenomena pertaining to a large class of organisms. It is among the best understood microbes, yet relatively little is known about the colony growth mechanisms on a single-cell level. In the last decade the availability of microfluidic devices opened new pathways to experimental research. This facilitated the development of realistic simulation-schemes and related theory. We perform simulations of a growing microbial colony, where microbes are represented by mechanically interacting discrete elements, that incorporate the principles of reaction-diffusion systems. We study the microscale-growth, the dynamic properties and the emerging morphology of microbial colonies under the presence of convective flows. We compare our findings with experimental evidence.

DY 53.4 Thu 17:00 P1A

Dense Microswimmer Systems in Model Porous Media — •Jonathan Onody — DLR e.V. Köln, Deutschland, AG Prof. Thomas Voigtmann

We model the dynamics of active Brownian particles as model microswimmers in porous media by the mode-coupling theory of the glass transition.

The microswimmers are modeled as hard disks undergoing diffusive motion in both, translational and rotational direction. On top they have a constant velocity in a random direction. The particles are embedded in a porous background which is obtained by introducing a second species of particles that are not allowed to move and thus imitate obstacles for the microswimmers. We extend an approach by V. Krakoviack for passive particles without orientational degrees of freedom. The two-dimensional setting is described within the mode-coupling approach, such that an integro-differential equation for density fluctuations is obtained. The memory-kernel and first numerical results will be presented.

DY 53.5 Thu 17:00 P1A

Hot Brownian Nanoswimmers — •Romy Schachoff[1], Katrin Günther[2], Michael Mertig[2], and Frank Cichos[1] — [1]Universität Leipzig, Germany — [2]Technische Universität Dresden, Germany

Hot Brownian swimmers are thermally anisotropic Brownian particles driven by optical heating. Geometric asymmetry of the swimmers establishes an asymmetric temperature profile in the surrounding solvent upon particle heating. The thermo-osmotic flow along the surface of the swimmer leads to a phoretic self-propulsion. We studied hot Brownian swimmers that are synthesized from a gold nano particle of 50 nm in diameter and a tail of a DNA helix bundle (6HB) of a length of 400 nm. Here, the highly localized optical heating of the nanoparticles creates a steep temperature gradient over the DNA tail. The overall change in the diffusion coefficient for the chosen particle complex will be only in the per mille region, since rotational brownian motion randomizes the direction of propulsion. The ballistic propulsion is retained only for times shorter than the rotational diffusion time that scales with the radius cubed. We use our unique split focus geometry in twin-focus photothermal correlation spectroscopy to detect small flow velocities on small length and time scales (nm/ms) to show a clear swimmer characteristic of the gold nanoparticle DNA complex in dependence of the heating power that is clearly distinguishable from pure hot Brownian motion that is performed by heated gold nanoparticles themselves. Further, the split focus is arranged perpendicular to the optical axis to neglect flow velocities that are exerted by radiation pressure.

DY 53.6 Thu 17:00 P1A

Confined active Brownian particles: A comparison between simulations and analytical results — •Shibananda Das, Gerhard Gompper, and Roland G. Winkler — Theoretical Soft Matter and Biophysics (ICS 2/ IAS 2), Forschungszentrum Jülich, D-52425 Jülich, Germany

A thorough understanding of the relevant physical mechanisms of self-propelled objects, their collective behavior, and their properties in external fields and confinement, has promising applications in technology and health-care. This can be tackled with simplified and generic models of microswimmers such as the active Brownian particle (ABP) description. This model has been exploited to characterize the phase behavior and the non-equilibrium properties of active systems. We analyze the distribution function of active Brownian particles in confinement by computer simulations and analytical approach. We apply the well-known ABP model of a spherical colloid with a given propulsion direction which changes in a diffusive manner by an independent stochastic process. In addition, we study a somewhat more simplified theoretical model with independent stochastic processes along the Cartesian coordinates of the active velocity corresponding to a Gaussian, but non-Markovian, colored-noise process for the active velocity. Especially, we consider an ABP confined in a harmonic potential, which can be solved exactly. For non-harmonic potentials, we apply the Unified Colored Noise Approximation (UCNA) to find an approximate solution. The comparison between the simulation and analytical result reveals the applicability of the applied approximation schemes.

DY 53.7 Thu 17:00 P1A

DNA based molecular force sensors in reconstituted actin networks — •Christina Jayachandran[1], Max Wardetzky[2], Florian Rehfeldt[1], and Christoph Schmidt[2] — [1]Third Institute of Physics, Georg- August Universität — [2]Institute of Numerical and applied Mathematics, Georg- August Universität

Actin, among the other bio-polymers present in cells, is largely responsible for cellular shape and mechanical stability. The actin cytoskeleton which self-assembles into networks of crosslinked filaments and bundles is responsible for active cellular processes ranging from migration, di-

vision and intracellular transport to morphogenesis. Crucial for these processes is the spatial and temporal regulation of the structure and dynamics of the network and of the generation of forces, mostly by myosin motors.

To understand basic phenomena in such active networks, we investigate model networks comprised of semi-flexible actin filaments crosslinked by custom designed dsDNA constructs as flexible cross linkers. We also utilize these DNA constructs as force sensors in order to map stress distributions in the networks. We characterized the FRET-based stress sensors with a spectrophotometer. We study the macro- and micro-rheological properties of the actin/DNA networks, focusing on network failure mechanisms beyond a non-linear response.

DY 53.8 Thu 17:00 P1A

Phase behaviour of active Brownian particles — •Andreas Fischer and Thomas Speck — Institut für Physik, Johannes-Gutenberg-Universität Mainz, Germany

At sufficiently high densities and propulsion speeds, solutions of self-propelled colloidal particles can undergo a phase separation into large clusters and a dilute gas phase even without attractive interactions [1]. The same qualitative behaviour has been observed in simulations of 'active Brownian particles' - a minimal model capturing the main physical ingredients volume exclusion and persistence of motion. This motility induced phase separation is caused by a dynamical instability due to self-trapping of the particles and can be mapped onto that of passive fluids with attractive interactions via an effective free energy [2]. We extend this model to more general interactions and explore the phase behaviour combining analytic theory and numerical simulations.

[1] I. Buttinoni, J. Bialké, F. Kümmel, H. Löwen, C. Bechinger, and T. Speck, *Phys. Rev. Lett.* **110**, 238301 (2013)
[2] T. Speck, A.M. Menzel, J. Bialké, and H. Löwen, *J. Chem. Phys.* **142**, 224109 (2015)

DY 53.9 Thu 17:00 P1A

BD-Simulations on interfacially trapped active particles with long-ranged capillary interactions — •Jonathan Funk, Johannes Bleibel, and Martin Oettel — Institut für Angewandte Physik, Universität Tübingen, Deutschland

We study the dynamics of micron-sized colloidal particles trapped at a fluid interface. The particles deform the surface due to an external force (e.g. gravity), giving rise to long-ranged capillary interactions. Additionally the particles are self-propelled, with a constant velocity and changing direction due to rotational diffusion. In systems with a packing fraction ($\Phi > 0.3$) the active particles self-assemble in clusters even without an attractive potential by simply blocking each others motion. In systems with capillary interaction the ratio between the capillary force and an effective temperature is the determining factor for the clustering behavior. We study the movement in this capillary systems with lower densities, especially the active clustering effect and the diffusive characteristic of the active particles. Important observables of the system are the density distribution, the evolution of the Fourier modes of the density distribution, the average swimming speed and the persistence length of the active motion. With this observables, we can evaluate the phase behavior of the systems and establish a phase diagram.

DY 53.10 Thu 17:00 P1A

Highly Efficient Multivalent 2D Nanosystems for Inhibition of Orthopoxvirus Particles — Benjamin Ziem[1], Hendrik Thien[2,3], Katharina Achazi[1], Constanze Yue[3], Daniel Stern[3], Kim Silberreis[3], •Mohammad Fardin Gholami[4], Fabian Beckert[5], Dominic Gröger[1], Rolf Mülhaupt[5], Jürgen P. Rabe[4], Andreas Nitsche[3], and Rainer Haag[1] — [1]Institute of Chemistry and Biochemistry, Freie Universität Berlin — [2]Institute of Virology, University of Leipzig — [3]Robert Koch Institute, Center for Biological Threats and Special Pathogens, Berlin — [4]Department of Physics & IRIS Adlershof, Humboldt-Universität zu Berlin — [5]Institute for Macromolecular Chemistry, University of Freiburg

Efficient inhibition of cell-pathogen interaction to prevent subsequent infection is an urgent but yet unsolved problem. In this study, we developed a new 2D multivalent surface, functionalized with sulfated dendritic polyglycerol (dPG), to enable virus interaction. A simple "graft from" approach enhances the solubility of thermally reduced graphene oxide (TRGO) and provides a suitable 2D surface for multivalent ligand presentation. Polysulfation is used to mimic the heparan sulfate-containing surface of cells and to compete with this natural binding site of viruses. Here, orthopoxvirus strains are used as model viruses as they use heparan sulfate for cell entry. Scanning force microscopy (SFM) showed that the dPGs were successfully grafted to the TRGO sheets, resulting in abundant presence of dPG on the sheets. The newly designed graphene derivatives demonstrate excellent binding as well as efficient inhibition of orthopoxvirus infection.

DY 54: Posters - Pattern Formation, Reaction Diffusion, Chimera

Time: Thursday 17:00–19:30 Location: P1A

DY 54.1 Thu 17:00 P1A

Magnetic Hills — •Constantin Geier[1] and Thomas Grillenbeck[1,2] — [1]Ignaz-Günther-Gymnasium Rosenheim — [2]Rosenheim University of Applied Sciences

A small amount of a ferrofluid placed in an inhomogeneous magnetic field forms hill-like structures. We investigate how the properties of these structures depend on relevant parameters.

DY 54.2 Thu 17:00 P1A

Stability of amplitude chimeras in oscillator networks — Liudmila Tumash[1], Anna Zakharova[1], Judith Lehnert[1], Wolfram Just[2], and •Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Queen Mary, University of London, London E1 4NS, UK

We show that amplitude chimeras in ring networks of Stuart-Landau oscillators with symmetry-breaking nonlocal coupling represent saddle-states in the underlying phase space of the network [1]. Chimera states are composed of coexisting spatial domains of coherent and of incoherent oscillations. We calculate the Floquet exponents and the corresponding eigenvectors in dependence upon the coupling strength and range, and discuss the implications for the phase space structure. The existence of at least one positive real part of the Floquet exponents indicates an unstable manifold in phase space, which explains the nature of these states as long-living transients. Additionally, we find a Stuart-Landau network of minimum size $N = 12$ exhibiting amplitude chimeras.

[1] L. Tumash, A. Zakharova, J. Lehnert, W. Just, E. Schöll, arXiv:1611.03348 (2016).

DY 54.3 Thu 17:00 P1A

Chimera states in networks of Van der Pol oscillators with hierarchical connectivities — Jakub Sawicki, Stefan Ulonska, Iryna Omelchenko, Anna Zakharova, and •Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin, Germany

Chimera states are complex spatio-temporal patterns that consist of coexisting domains of coherent and incoherent dynamics. We analyse chimera states in networks of Van der Pol oscillators with hierarchical (fractal) connectivities [1]. We investigate the stepwise transition from a nonlocal to a hierarchical topology, and adapt various quantifications to establish a link between the existence of chimera states and the compactness of the initial base pattern of a hierarchical topology; we show that a large clustering coefficient promotes the occurrence of chimeras. Depending on the level of hierarchy and base pattern, we obtain chimera states with different numbers of incoherent domains. We investigate the chimera regimes as a function of coupling strength and nonlinearity parameter of individual oscillators.

[1] S. Ulonska, I. Omelchenko, A. Zakharova, and E. Schöll, Chaos 26, 094825 (2016)

DY 54.4 Thu 17:00 P1A

Numerical simulation of polygonal patterns in salt playa — •Marcel Ernst[1], Jana Lasser[1], and Lucas Goehring[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]School of Science and Technology, Notting-

ham Trent University, Clifton Lane, Nottingham, NG11 8NS, UK

In salt pans and playa we sometimes observe that salt crystallization due to evaporation forms polygonal salt-ridge patterns on the surface. Ridges of crystalized salt surround a flat center with a characteristic length scale of about one meter. We aim to understand the development of those polygonal structures as there is currently no comprensive theory of their formation, and different approaches to describing them range from wrinkling to cracking of the surface; none of these mechanisms reproduce the characteristic length scale of the pattern. Here we investigate a numerical model that includes the subsurface dynamics of the salt water-filled porous medium below the crust: salinity gradients drive convection cells which, in turn, interact with the development of salt ridges at the surface. The typical length scales of those convection rolls is consistent with the observed patterns. We use semi-spectral Fourier Galerkin methods to simulate the convection-diffusion-dynamics in the system and complex boundary conditions on the surface in a simplified 2d-model. We compare our results with similar experiments in Hele-Shaw cells and measurements of salt polygons in the field.

DY 54.5 Thu 17:00 P1A

Formation of Crack Patterns in drying Mud Layers — •Tobias-Emanuel Regenhardt[1], Pawan Nandakishore[1,2], and Lucas Goehring[1,3] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]National Centre for Biological Sciences, Bellary Road, Bangalore 560065, Karnataka, India — [3]School of Science and Technology, Nottingham Trent University, Clifton Lane, Nottingham, NG11 8NS, UK

Formation of crack patterns in drying or cooling layers is controlled by the cracking layer itself and external factors. The geometric structure of any underlying substrate layer can have substantial influence on the pattern evolving above. Cracking phenomena can range from the drying of mud in riverbeds to the cooling of lava resulting in crack networks kilometers across. However, the mathematics behind the modeling of these cooling or drying systems is the same, and scale-free. Inspired by graben systems found on Mercury, of which some show clear circular symmetry, the question arises whether these particular patterns evolved due to craters buried below. We used drying mud slurry to create cracking patterns on various crater shapes, scaled down to lab size. We chose craters from Mars and idealized bowl-shaped craters and collect information on the resulting crack networks. Using image analysis of photos taken from the patterns we show the connection between the orientation of the cracks, enclosed cracked regions and the length scales of the systems (layer height, crater aspect ratio). This opens opportunities in the future to study buried craters and similar structures from satellite imagery, in otherwise inaccessible locations.

DY 54.6 Thu 17:00 P1A

Resonating Glass — •Lisa Kastenhuber[1], Adrian Ebert[2], and Thomas Grillenbeck[1] — [1]Ignaz-Gynther-Gymnasium Rosenheim, Germany — [2]Universität Bayreuth, Fakultät für Physik, Germany,

Everybody knows the phenomenon which can often be seen in movies: A singer sings at a glass with such a high volume that the glass will break. The precondition is that the singer meets the resonance frequency. Shortly before the glass breaks interesting oscillation patterns occure. We study these patterns and the relevant parameters they depend on.

DY 54.7 Thu 17:00 P1A

Modeling and simulation of vascular endothelial calcium waves induced by blood shear stress — •Hengdi Zhang and Chaouqi Misbah — Liphy, Laboratoire Interdisciplinaire de Physique, 140 Rue de la Physique, 38402 Saint-Martin-d Heres, France

Vascular endothelial cells form an inner monolayer in human blood vessel. As they are directly contacting with blood flow, a lot of blood vessel functions are modulated or initiated by them, such as vasodilation / vasoconstriction in blood pressure control and angiogenesis in wound healing. These functions require endothelial cells to be capable of sensing its micro environment changes and signaling to surrounding tissues. One of the most important micro environments is the blood flow induced shear stress on the endothelial surface. Endothelial cells respond to the shear stress change in multiple time scales. But for the very first tens of seconds during and after the shear stress change, a transient increase in cytosolic free calcium ion concentration will take place. This calcium signal involves and triggers signaling cascades in many endothelial functions. To get a further understating to this signal, we analyzed possible candidates of endothelial mechanical sensors from relevant literatures, and integrated them into a convection-diffusion-reaction model coupled with shear / shear-rate dependent complex boundary conditions. A Lattice-Boltzmann method is employed to solve the system numerically. Responses to different flow condition and roles of mechanical sensor candidates are investigated in this research.

DY 54.8 Thu 17:00 P1A

Lamellae and dipolar ordering in fluid mixtures of hard nematic rods and dipolar spheres — •Alice C. von der Heydt and Sabine H. L. Klapp — Inst. of Theoret. Physics, TU Berlin, Secr. EW 7-1, Hardenbergstr. 36, 10623 Berlin, Germany

Suspensions of dipolar, e.g., magnetic particles in a liquid crystal (LC) [1] continue to stimulate scientific activity due to interesting properties such as dipolar chain formation and spontaneous magnetisation induced by the LC [2]. Microdomains coupled to LC order already appear in mixtures of differently shaped particles with hard-body repulsion only [3]. Our study focuses on the even richer phase behaviour in mixtures of hard, parallelly aligned LC rods and dipolar spheres able to display smectic density *and* dipolar orientation patterns. To systematically extract the prerequisites for ordering, we identify and analyse a free-energy functional of suitable collective order parameters. The long-range, anisotropic dipolar interaction is considered with continuous spatial, angular, and strength variables. A stability analysis sheds light on the coupling of smectic, component-density, and dipolar ordering in the control-parameter space of packing fraction, sphere density, and dipolar strength. For rods and spheres of similar size, lamellar phase separation is seen to be the dominant effect.

[1] F. Brochard, P.-G. de Gennes, J. Phys. - Paris **31**, 691 (1970)
[2] S. D. Peroukidis, K. Lichtner, S. H. L. Klapp, Soft Matter **11**, 5999 (2015)
[3] Z. Dogic, D. Frenkel, S. Fraden, Phys. Rev. E **62**, 3925 (2000)

DY 54.9 Thu 17:00 P1A

Membrane Instability Driven by an AC Electric Field — •Mirko Ruppert[1], Walter Zimmermann[1], and Falko Ziebert[1,2] — [1]Theoretische Physik, Universität Bayreuth, Bayreuth, Germany — [2]Physikalisches Institut, Universität Freiburg, Freiburg, Germany

Unilamellar vesicles are important model systems in biophysics. They are typically created by applying a voltage on a stack of flat membrane bilayers, but this so-called electroformation process is still poorly understood. Models exist for the case of a static (dc) electric field, but experimentally typically ac fields of about 10 Hz have to be used. We therefore study the ac field-induced instability of a flat capacitive membrane with respect to spatial modulations, using an effective zero-thickness model developed previously in the dc case. The instability of the membrane is driven by the charge accumulation in the Debye layers and the voltage drop at the membrane. Increasing the driving frequency or reducing the amount of salt reduces the instability. By a full Floquet analysis of the linear, coupled Poisson-Nernst-Planck-Stokes boundary value problem we found that the instability is with respect to finite wavenumber undulations, in contrast to the static case where the instability is long-wavelength.

DY 54.10 Thu 17:00 P1A

Nonlinear patterns shape the domain on which they from — •Mirko Ruppert[1], Fabian Bermann[1], Lisa Rapp[1], Falko Ziebert[2], and Walter Zimmermann[1] — [1]Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Physikalisches Institut, Universität Freiburg, Freiburg, Germany

In recent experiments with liquid drops on vertically vibrated surfaces [1,2] the formation of Faraday surface waves was investigated. By increasing the vibration amplitude, the magnitude of the surface stripe pattern increases and in addition the initially circular drop deforms into an elliptical or even a wormlike shape. We here present a model for stationary stripe patterns within an arbitrarily shaped domain, wherein pattern formation is restricted to a finite domain [3] of fixed area by coupling the Swift-Hohenberg model to a phase field. We investigate the self-consistent interplay between the pattern formation process and the shape of the domain on which it takes place.

[1] G. Pucci, E. Foret, M. Ben Amar, Y. Couder, Phys. Rev. Lett. 106, 024503 (2011)
[2] A. Hemmerle, G. Froehlicher, V. Bergeron, T. Charitat, J. Farago, EPL 111, 24003 (2015)
[3] L. Rapp, F. Bergmann, W. Zimmermann, EPL 113, 28006 (2016)

DY 54.11 Thu 17:00 P1A

Wavenumber Restriction for Traveling Waves via Parameter Variations (Ramps) — •Samuel Grimm, Fabian Bergmann, Lisa Rapp, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Deutschland

We investigate the problem of wavenumber selection of traveling waves (TWs) by spatial variations of the control parameter and the oscillation frequency within a complex Swift-Hohenberg equation [1] and coupled Ginzburg-Landau equations.

As is well known, for a given parameter set, a whole band of stable wavenumbers is possible for both stationary [2] and TW patterns [3]. Additionally, in realistic systems, parameters are often spatially inhomogeneous. These parameter variations further influence pattern formation. In stationary systems, e.g., parameter ramps may lead to wavenumber selection or even an orientational selection of patterns ([4] and references therein). For nonlinear TWs, smooth parameter ramps may lead to wavenumber restriction and interesting spatio-temporal behavior [5].

Here, we determine the influence of slow, as well as non-adiabatic parameter variations on the width of the stable wavenumber band for TWs and their spatio-temporal behavior. Can spatio-temporal chaotic behavior of TWs be tamed by spatial parameter variations?

[1] B. A. Molomed, Z. Physik B **55**, 241 (1984); [2] L. Kramer and W. Zimmermann, Physica A **16** 221 (1985); [3] B. Janiaud et al. Physica D **55**, 269 (1992); [4] L. Rapp, F. Bergmann, W. Zimmermann, EPL **113**, 28006 (2016); [5] B. A. Malomed, Phys. Rev. E **47**, R2257 (1993).

DY 54.12 Thu 17:00 P1A

Rectangular and branched Wrinkle patterns in inhomogeneous film substrate systems — •A. Zippelius, R. Aichele, M. Hilt, B. Kaoui, F. Ziebert, and W. Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

We study wrinkles on thin hard skins supported by elastic substrates under uniaxial (anisotropic case) and biaxial compression. We use generic models and the full elastic equations for the skin substrate system [1,2]. For homogeneous skin layers the preferred wave-vector of wrinkles points along the major compression direction (anisotropy). As recent experimental studies show [2], a spatial variation of the substrate elasticity (bending elasticity of the skin [3]) perpendicular to the anisotropy triggers branched wrinkle patterns. One observes coexistence of many branched wrinkle patterns of different wavenumbers and branching points densities, which are stable at identical parameters. This corresponds to a generalization of the concept (Eckhaus) stability bands to inhomogeneous systems.

For a spatial variation of the skin elasticity along the preferred (load) direction and with the modulation wavenumber of the order of that of the wrinkles, we predict and characterize rectangular wrinkle patterns.

[1] B. Kaoui, A. Guckenberger, A. P. Krekhov, F. Ziebert and W. Zimmermann, New J. Phys. **17**, 103015 (2015); [2] B. A. Glatz, M. Tebbe, B. Kaoui, R. Aichele, C. Kuttner, A. E- Schedl, H. W. Schmidt and W. Zimmermann, A. Fery, Soft Matter **11**, 3332 (2015); [3] J. Wang, B. Li, Y.-P. Cao, X.-Q. Feng, H. Gao, Appl. Phys. Lett. **106**, 021903 (2016)

DY 54.13 Thu 17:00 P1A

Stability of periodic, stationary patterns in conserved systems — •F. Dietl, F. Bergmann, L. Rapp, and W. Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

Pattern formation in systems with conserved fields is considered by studying an extended Cahn-Hilliard model. This model shows either a bifurcation to a stationary periodic pattern or a large scale phase separation. We investigate the stability of nonlinear, stationary periodic patterns, as well as the evolution of the nonlinear patterns, including the transition to a coarsening regime. We also describe possible applications and extensions of the model to vegetation patterns.

DY 55: Posters - Soft Matter, Glasses

Time: Thursday 17:00–19:30 Location: P1A

DY 55.1 Thu 17:00 P1A

Role of surface forces in the spreading of biofilms at solid/gas interfaces — •Sarah Trinschek[1,2], Karin John[2], and Uwe Thiele[1,3] — [1]Westfälische Wilhelms-Universität, Münster, Germany — [2]LiPhy, Université Grenoble Alpes, Grenoble, France — [3]Center for Nonliner Science, Münster, Germany

Biofilms are interface-associated aggregates of bacteria enclosed in a self-produced extracellular matrix. Their widespread occurrence and either detrimental or beneficial function implies that it is highly important to understand the principles underlying their development.

We consider biofilms on moist solid substrates in contact with a gas phase that spread via an osmotic spreading mechanism that is driven by growth processes and the physico-chemical properties of the biofilm and the interfaces. Recent experiments have shown that surface forces are a major determinant of the invasiveness of the colony. We propose a model for the osmotic biofilm spreading that explicitly includes wetting effects. The model is based on a hydrodynamic description for biologically passive liquid suspensions supplemented by bioactive processes. We find a regime where surface forces confine biofilm colonies, which are not able to spread, albeit being biologically active. A small reduction in the surface tension of the biofilm is sufficient to induce lateral spreading of the colony.

DY 55.2 Thu 17:00 P1A

Excitations and defects in colloidal quasicrystals — •Miriam Martinsons and Michael Schmiedeberg — Institut für Theoretische Physik I, FAU Erlangen-Nürnberg, Germany

Quasicrystals are structures with long range order but no translational symmetry. They can have any rotational symmetry including those that are not allowed in periodic crystals. Quasicrystals possess additional degrees of freedom that do not exist in periodic crystals. As a consequence, additional hydrodynamic modes called phasons arise supplemental to the phononic modes known from periodic crystals. Phasonic excitations correspond to correlated rearrangements of the particles.

We study the development of defects close to the melting transition. It has been predicted that dislocations and disclinations cause the melting of the quasicrystal (cf. KTHNY theory [1, 2]). In our studies we reveal the similarities and differences of the melting process of quasicrystals compared to the melting of periodic crystals. Furthermore, we study the influence of phasonic excitations on the formation of defects and their coupling to phononic displacements.

[1] P. De, R. A. Pelcovits, J. Phys. A: Math. Gen. 22, 1167 (1989).
[2] P. De, R. A. Pelcovits, Phys. Rev. B 38, 5042 (1988).

DY 55.3 Thu 17:00 P1A

Supramolecular structure of monohydroxy alcohols at high pressure — Thomas Büning, •Christian Sternemann, Catalin Gainaru, Michael Paulus, Holger Göhring, Susanne Dogan, Julian Schulze, Jennifer Bolle, Roland Böhmer, and Metin Tolan — Fakultät Physik / DELTA, Technische Universität Dortmund, D-44221 Dortmund, Germany

Hydrogen bonds are essential for the structure and dynamics of alcohols, aqueous solutions, and water. Due to their low tendency of crystallization and large variability in molecular configuration, monohydroxy alcohols (MAs) have often been studied as model systems for hydrogen-bonded fluids in general [1]. MAs are supposed to form supramolecular structures via hydrogen bonding in the liquid phase. Tracking the Debye process, dielectric absorption studies suggest ring-like arrangements for 4-methyl-3-heptanol (4M3H) with a sterically hindered hydroxyl group and chainlike structures in 2-ethyl-1-hexanol (2E1H) with the hydroxyl group in a terminal position. Surprisingly, an oppositional behavior of the strength of the Debye process has been observed at increasing pressure for the MAs ponting towards a structural reorganization on the molecular level [2]. We present x-ray diffraction measurements of 2E1H and 4M3H at pressures up to 4500 bar over a temperature range from 273 K to 343 K. The results indicate a breaking of supramolecular structures in both MAs that manifest in significant changes in the first diffraction peak.

[1] R. Böhmer et al., Phys. Reports 545, 125 (2014) and references

therein; [2] S. Pawlus et al., J. Chem. Phys. 139, 064501 (2013).

DY 55.4 Thu 17:00 P1A

Phase Field Crystal Models of Colloidal Quasicrystals — •Benedikt Decker and Michael Schmiedeberg — Institut für Theoretische Physik 1, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen

Phase field crystal models that employ a Swift-Hohenberg-like free energy are widely used to explore periodic pattern formation [1]. Recently, the phase field crystal model has been modified by adding a second preferred length scale, such that stable quasicrystalline structures are obtained [2,3].

In addition, there are other ways to realize colloidal quasicrystals: A large variety of complex self-organized structures are observed in systems with patchy colloids. Patchy colloids usually carry attractive sites, such that the interaction depends on their orientation. In order to study how such preferred binding angles influence the self-assembly, we construct and explore a phase field crystal model for patchy colloids. Similar to the case of liquid crystals [4], the free energy in such a model depends on order parameters that denote the density as well as the degree and angle of orientation of the particles.

[1] K.R. Elder *et al.*, Phys. Rev. Lett. **88**, 245701 (2002).
[2] J. Rottler *et al.*, J. Phys. Condens. Matter **24**,135002 (2012).
[3] C.V. Achim *et al.*, Phys. Rev. Lett. **112**, 255501 (2014).
[4] C.V. Achim *et al.*, Phys. Rev. E **83**, 061712 (2011).

DY 55.5 Thu 17:00 P1A

Phase behavior of a confined classical Heisenberg fluid — •Stefanie Maria Wandrei[1], Martin Schoen[1,2], and Keith E. Gubbins[2] — [1]Technische Universität, Berlin, Deutschland — [2]North Carolina State University, Raleigh, USA

In this work we employ classical density functional theory (DFT) to investigate equilibrium properties of a Heisenberg fluid confined to nanoscopic slit pores of variable width. Within DFT pair correlations are treated at modified mean-field level. We consider three types of walls: hard ones, where the fluid-wall potential becomes infinite upon molecular contact but vanishes otherwise, and hard walls with superimposed short-range attraction with and without explicit orientation dependence.

If the walls are hard or attractive without specific anchoring the results are "quasi-bulk"-like in that they can be linked to a confinement-induced reduction of the bulk mean field. In these cases the precise nature of the walls is completely irrelevant at coexistence. Only for specific anchoring nontrivial features arise, because then the fluid-wall interaction potential affects the orientation distribution function in a nontrivial way, and thus appears explicitly in the Euler-Lagrange equations to be solved for minima of the grand potential of coexisting phases.

DY 55.6 Thu 17:00 P1A

Low temperature dielectric properties of the polymers poly(vinyl acetate) and poly(vinyl chloride) in the frequency range from Hz to MHz — •Marcel Schrodin, Annina Luck, Benedikt Frey, Lennart Singer, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institut für Physik, Universität Heidelberg, 69120 Heidelberg

At low temperatures the behavior of amorphous solids is mainly governed by two level systems and described by the standard tunneling model. In the last years, considerable deviations were observed in dielectric measurements. These deviations are possibly due to the influence of long-range interactions between tunneling systems and the effect of nuclear electric quadrupole moments involved in such tunneling systems.

We show measurements of low temperature dielectric properties of the two amorphous polymers poly(vinyl acetate) and poly(vinyl chloride) in the frequency range from Hz to MHz. As poly(vinyl chloride) contains nuclear electric quadrupole moments due to the presence of the isotopes ^{35}Cl and ^{37}Cl, a possible influence of nuclear quadrupole moments on the dielectric properties can be investigated. In contrast, poly(vinyl acetate) has a similar basic structure but contains only atoms with no nuclear electric quadrupole moment, which enables a direct comparison between both polymers to get a further insight. In addition, both polymers contain large electric dipole moments due to polar side groups, which allows to look for possible effects of long-range interaction between tunneling systems.

DY 55.7 Thu 17:00 P1A

A lattice system of hard rods in three dimensions — •Axel Gschwind, Martin Oettel, and Miriam Klopotek — Eberhard Karls Universität, Institut für Angewandte Physik, Tübingen

Hard rods in contiuum space with discrete orientations (Zwanzig model) make a useful model for the phase behavior of anisotropic particles, and it was already shown in [1] that these undergo a first-order nematic transition.

For hard rods on a lattice and with discrete orientations one would expect similar behavior. We have studied this system with Grand Canonical Monte Carlo simulations for aspect ratios between 5 and 25. A nematic-isotropic transition is visible starting from aspect ratio 6, but it is only very weakly first order for all aspect ratios investigated. This is in sharp contrast to results from density functional theory for the same system and also from the behavior of hard rods in the continuum.

[1] R. Zwanzig, *First-Order Phase Transition in a Gas of Long Thin Rods*, J. Chem. Phys., **39**(7):1714 (1963).

DY 55.8 Thu 17:00 P1A

From glass to supercooled liquid: long-range correlation of shear strain persists — •Muhammad Hassani and Fathollah Varnik — Interdiciplinary center for advanced material Simulations (ICAMS), Ruhr Universität, Bochum, Germany

While the elasticity in glassy materials is shown to be responsible to mediate long-range strain correlations, there are evidences of similar long-range correlations in the supercooled state as well [1], though low frequency shear modulus vanishes for this state. Via molecular dynamics simulations of a 3D binary Lennard-Jones glass former, we study the temporal evolution of these correlations in supercooled and glassy states [2]. Beside the quadropolar symmetry, the supercooled liquid shares with the glass also the $\frac{1}{r^3}$ power-law decay of strain correlations. Interestingly, the evolution of strain amplitude follows a similar pattern as the single-particle mean-square displacement; in the glass, the amplitude comes to arrest in long time intervals, whereas it follows a diffusive growth in the supercooled state. These findings are in quantitative agreement with the mode-coupling theory predictions which suggest that high viscosity in supercooled state facilitates long-range correlations [3].

[1] J. Chattoraj, A. Lemaître, Elastic Signature of Flow Events in Supercooled Liquids Under Shear, Phys. Rew. Lett.,111, 2013
[2] M. Hassani, F. Varnik, Survey of spatio-temporal strain correlations across the glass transition, (in preparation)
[3] B. Illing, S. Fritschi, D. Hajnal, C. Klix, P. Keim,M. Fuchs, Strain Pattern in Supercooled Liquids, Phys. Rev. Lett. 117, 208002

DY 55.9 Thu 17:00 P1A

Theory for the activation energy in mixed glass former glasses — •Mohamad Alhamad and Philipp Maass — Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, 49076 Osnabrück, Germany

Improved physical and electrochemical properties of glassy electrolytes can be achieved by mixing two glass former cat- or anions at constant mole fraction of the mobile cation. This effect is known as the mixed glass former effect. Optimized mixed glass former electrolytes are promising materials for developing next generation solid state batteries. Most important is the optimization of the ionic conductivity and its activation energy. Extending a previous approach [1], we present a theory that allows us to predict the dependence of the activation energy on the glass former mixing ratio based on the charge redistribution in the glassy network. This redistribution is caused by changes in the concentration of the various network forming units associated with the glass formers. The latter are modeled within a thermodynamic model and the resulting change of the activation energy by applying percolation theory. Application of the theory leads to excellent quantitative agreement with measurements for five different types of alkali conducting mixed glass former systems with mixing pairs B_2O_3/P_2O_5, $GeS_2/PO_{5/2}$, B_2O_3/Si_2O_4, B_2O_3/TeO_2, and $PO_{5/2}/TeO_2$.

[1] M. Schuch, C. Trott, P. Maass, RSC Adv. **1**, 1370 (2011).

DY 55.10 Thu 17:00 P1A

Irreversibility transition of colloidal polycrystals under cyclic deformation — •Pritam Kumar Jana[1], Mikko J. Alava[1], and Stefano Zapperi[1,2,3,4] — [1]1COMP Centre of Excellence, Department of Applied physics, Aalto University, P.O. Box 11100, Aalto 00076, Finland — [2]Center for Complexity and Biosystems, Depart-

ment of Physics, University of Milano, via Celoria 16, 20133 Milano, Italy — [3]ISI Foundation, Via Alassio 11/C, 10126 Torino, Italy — [4]CNR-IENI, Via R. Cozzi 53, 20125 Milano, Italy

Recently, Tamborini et al. have investigated plasticity of colloidal polycrystals, which are prepared by crystallizing thermo sensitive block copolymer Pluronics F108 with a small amount of nanoparticles as impurities, under cyclic shear. [1] Guided by their experiment, we perform plastic deformation study on 2D polycrystalline samples using molecular dynamics simulations. Samples are prepared by reducing the temperature of binary Lennard-Jones liquids with a fixed cooling rate. A small amount of bigger particles, which basically acts as an impurity, creates dislocations in the system because of size mismatch. A string of dislocations are defined as grain boundaries and the amount of impurities can control the number of grains. In the next stage, samples are undergone a cyclic deformation where the maximum strain amplitude (γmax) is varied by changing the strain rate. For a small value of γmax, the system becomes quiescent within a few cycles whereas for larger γmax, particles move irreversibly which leads to the grain boundary motion and the annihilation of dislocations.

[1] Tamborini et al. PRL 113, 078301 (2014)

DY 55.11 Thu 17:00 P1A

Aging and Coarsening During Polymer Collapse — •Suman Majumder and Wolfhard Janke — Institute for Theoretical Physics

Using state of the art Monte Carlo simulations of a bead-spring model we investigate both the equilibrium and the nonequilibrium behavior of a homopolymer collapse. The equilibrium properties obtained via multicanonical sampling recover the well-known finite-size scaling behavior of collapse for our model polymer. For the nonequilibrium dynamics we study the collapse by quenching the homopolymer from an expanded coiled state into the globular phase. The sequence of events observed during the collapse is independent of the quenched depth. In particular, we focus on finding out universal scaling behaviors related to the growth or coarsening of clusters of monomers, by drawing phenomenological analogies with ordering kinetics. We distinguish the cluster growth from the initial nucleation stage and show via nonequilibrium finite-size scaling analyses that the clusters grow linearly at all temperatures. In addition, we provide evidence of aging by constructing a suitable autocorrelation function and its corresponding dynamical power-law scaling with respect to the growing cluster sizes. The predicted theoretical bound for the exponent governing such scaling is strictly obeyed by the numerical data irrespective of the quench temperature. The results and methods presented here in general should find application in similar phenomena such as the collapse of a protein molecule preceding its folding.

DY 55.12 Thu 17:00 P1A

Induced anomalous diffusion nearby elastic interfaces — •Abdallah Daddi-Moussa-Ider, Achim Guckenberger, and Stephan Gekle — Biofluid Simulation and Modeling, Universität Bayreuth, Universitätsstraße 30, Bayreuth 95440, Germany

The approach of a small particle to the cell membrane represents the crucial step before active internalization and is governed by thermal diffusion. Using a fully analytical theory, we show that the membrane induces a long-lived subdiffusive behavior on the nearby particle, during which the residence time is increased by up to 50 % for a typical scenario. The corresponding scaling exponent is found to be as low as 0.87 in the perpendicular direction, and as low as 0.92 in the parallel direction. Such behavior is qualitatively different from the normal diffusion near a hard wall or in a bulk fluid. A good agreement is found for the frequency dependent mobility between the analytical predictions and the numerical simulations that we performed using a boundary integral method.

References

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DY 56: Posters - Granular and Particulate Matter

Time: Thursday 17:00–19:30 Location: P1A

DY 56.1 Thu 17:00 P1A

Sound absorption of stratified and blent granulates — •Hannes Pravida[1] and Thomas Grillenbeck[1,2] — [1]Iganz-Günther-Gymnasium Rosenheim — [2]Fakultät für angewandte Natur- und Geisteswissenschaften, Fachhochschule Rosenheim

We examine the sound absorption coefficient of granulates. We are especially interested in how the sound absorption depends on the mixture and the size of the granular materials. Our experiment is implemented by a variant of "Kundt's Tube" which sends an acoustic signal to granulates and appraises the reflected sound wave.With these data we can calculate the sound absorption coefficient. Moreover we analyze how and why the sound absorption coefficient changes when we blend sound-absorbing and sound-reflecting granular materials.

DY 56.2 Thu 17:00 P1A

The magic of staples — •Quirin Koller[1], Barbara Maier[1], Adrian Ebert[2,3], and Thomas Grillenbeck[1,2] — [1]Ignaz-Günther-Gymnasium Rosenheim — [2]Fakultät für angewandte Natur- und Geisteswissenschaften, Fachhochschule Rosenheim — [3]Universität Bayreuth

A qualified, high-grade silo has to have an immaculate bottom and stable, dense walls. If the wall is not built well enough, it might burst.

To avoid such problems, you can explore different kinds of granulates. In my experiments I want to find out which form and kind of granular materials exert the less force to the walls. Therefore, I use different kinds of granulates such as staples, drawing pins or balls made by wood.

DY 56.3 Thu 17:00 P1A

Dropping eggs — •Anna Treffurth[1], Thomas Grillenbeck[1,2], and Adrian Ebert[3] — [1]Ignaz Günther Gymnasium Rosenheim — [2]Rosenheim University Of Applied Sciences — [3]Universität Bayreuth

Eggs will be dropped from a certain height. These eggs should be protected from breaking by developing a device which is as small as possible. However, there are different ways to define *small*. I therefore tested different, after categorising each, designs on their reliability. The certainty and the reproducibility were also investigated.

DY 56.4 Thu 17:00 P1A

Radiography and tomography of fluidized granular beds — •Manuel Baur and Matthias Schröter — MSS, FAU, Germany

We examine fluidized beds using an x-ray tomograph. In a first step we focus on particle trajectories, the mean square displacement (MSD) and fluctuations in the particle density. These parameters are extracted from transmission radiograms. The further aim of the project is to study the translation and rotation of particles simultaneously. Therefore tomograms of a fluidized bed containing Janus particles are taken. A comparison to results obtained by diffusing wave spectroscopy (DWS) will be drawn.

DY 56.5 Thu 17:00 P1A

Densest Local Structures and Packing Properties of Uniaxial Ellipsoids — •Robert F. B. Weigel, Fabian M. Schaller, and Sebastian C. Kapfer — Institut für Theoretische Physik, FAU Erlangen-Nürnberg, 91058 Erlangen, Germany

The relationship between local structure and macroscopic properties is a current research focus in granular matter. We study the distribution of local packing fractions (defined via Voronoi cell volumina) which is a sensitive observable for characterizing these systems. Previously, mainly packings of spherical particles were considered. Here, we focus on packings of uniaxial ellipsoids as an instance of aspherical particles [1]. In particular, we generalize the famous "kissing problem" and report numerical results on the densest local structures of ellipsoids with aspect ratio between 0.7 (oblate) and 1.4 (prolate). Like in the spherical case, these packings locally exceed the density of known ellipsoid crystals. Analogous to results for lattice packings [2], we find that ellipsoids pack denser than spheres, and with more neighbors. In dense disordered packings of ellipsoids, distorted variations of some of

our densest packing motifs can be identified. Our results permit us to generalize and test the k-Gamma model for local packing fraction distributions, previously only applicable to spherical particles [3].

[1] Fabian Schaller *et al.*, Phys. Rev. X 6, 041032 (2016)
[2] Yoav Kallus, Adv. Math. 264, 355–370 (2014)
[3] Tomaso Aste *et al.*, Europhys. Lett. 79, 24003 (2007)

DY 56.6 Thu 17:00 P1A

Shape, Friction and Cohesion in Granular Packings — •Simon Weis[1], Fabian Schaller[1], Gerd Schröder-Turk[1,2], and Matthias Schröter[3] — [1]Theoretische Physik1, FAU Erlangen, Germany — [2]School of Engineering and IT, Murdoch University, Australia — [3]Institute of Multiscale Simulations, FAU Erlangen, Germany

Friction and adhesive forces are important parameters for the stability of granular packings. We analyze packings of wetting and non wetting spheres and triaxial ellipsoids with different aspect ratios. The structural properties of packings are analyzed with respect to friction and adhesive forces. Interparticle friction is changed by grinding the particles with different abrasives and by applying liquid and dry lubricants, which also changes adhesive forces. Adhesive forces are changed by adding water with a surfactant to the packing. Various packings with a range of friction coefficients and liquid contents are prepared at various packing fractions.

To obtain structural properties, the packings are recorded by X-ray tomography and particles as well as liquid clusters are detected. Structural characterization includes mean and local packing fractions, contact numbers as well as Voronoi cell anisotropy by Minkowski tensors.

We show that, although friction has an impact on the mechanical characteristics, the analyzed local structural features remain unchanged.

DY 56.7 Thu 17:00 P1A

The effect of electrostatics on the clustering in granular gas — •Chamkor Singh, Stephan Herminghaus, and Marco G. Mazza — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen

The ubiquity of granular materials around us makes them a subject of fundamental interest. Flows of such large ensembles of particles exhibit a range of peculiar physical behaviors such as spontaneous fluctuations, self-assembly, self-organized shocks and much more. The mechanisms behind are the dissipative collisions, short range cohesive forces and the ones which are still not well understood. One such phenomenon is the local electrostatic charging and discharging in the naturally occurring granular gas flows. We investigate its effects on the dynamics of granular gas by performing direct numerical simulations of hydrodynamic equations coupled with Maxwell equations. We analyze the influence of these long range forces on the clustering in the system. Finally, we compare the formation of clusters with and without the presence of electrostatic charges.

DY 56.8 Thu 17:00 P1A

Coarsening dynamics of ferromagnetic networks: experimental results and simulations — Armin Kögel[1], •Tom Dumont[1], Elena Pyanzina[2], Sofia Kantorovich[3], and Reinhard Richter[1] — [1]Experimentalphysik 5, University of Bayreuth, 95440 Bayreuth, Germany — [2]Ural Federal University, Lenin av. 51, Ekaterinburg, 620000, Russia — [3]University of Vienna, Sensengasse 8, Vienna, 1090, Austria

We investigate the phase separation of a shaken mixture of glass and magnetized steel spheres after a quench of the shaker amplitude. Then transient networks of the magnetic dipoles emerge in the experiment. We characterize the networks by the distribution of its number of neighbours, and its number of loops. For the emerging network clusters we estimate the number of spheres, the gyration radii, and the characteristic path lengths. We find that all three quantities follow a log-normal distribution function. Moreover, we study the temporal evolution of the mean number of neighbours and of the efficiency of the networks. We observe a sudden increase and than a moderate growth of both order parameters. This two distinct time scales are indicating an elastic and an hydrodynamic regime of the viscoelastic phase separation predicted by H. Tanaka (2000) for dynamically asymmetric mixtures. Eventually we use a simple simulation approach to understand the influence of the nonmagnetic spheres on the cluster structures formed by magnetic dipolar particles in quasi 2 dimensions. Not aiming at describing the experimental results we rather use the simulation approach to define the key interactions in the experimental system.

DY 57: Posters - Turbulence

Time: Thursday 17:00–19:30 Location: P1A

DY 57.1 Thu 17:00 P1A

Inclined-layer convection in fluids with small Prandtl number — •Oliver Zier, Werner Pesch, and Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

The onset of thermal convection is strongly modified, if the fluid layer is not perpendicular to gravity and inclined by an angle [1]. In this case the system becomes anisotropic and the basic state is characterized by a cubic shear flow profile. In addition an intricate competition between an buoyancy-driven and a shear-flow driven pattern-forming instability mechanism takes place. The shear-flow driven instability prevails in the case of a small Prandtl number P, on which we focus in this work.

For a finite inclination angle transverse rolls form at threshold with their axes perpendicular to gravity. The secondary instabilities of the rolls with increasing Rayleigh number depend on the inclination angle and are characterized by spatially periodic perturbations along their roll axes. Here we focus on the regime of small inclination angle, where both instabilities compete. As a result, we find in full simulations complex 'heteroclinic orbits' where the system switches periodically between the two pattern types.

[1] P. Subramanian, O. Brausch, E. Bodenschatz, K. Daniels, T. Schneider, W. Pesch, J. Fluid. Mech. **794**, 719 (2016)

DY 57.2 Thu 17:00 P1A

Experimental modeling of gas-liquid horizontal jet flows — •Oleksii Barybin — Donetsk National University, 600-Richchya Str., 21, Vinnytsia, 21021, Ukraine

The behavior of gas-liquid turbulent two-phase jets has been substantially studied over many years, due to their fundamental importance in many multiphase systems. Understanding jet performance is crucial for modeling many effects of practical importance. I discuss some specific non-equilibrium processes in two-phase horizontal jets (dispersion of bubbles, development stages, etc.) as well as possibility to apply single-phase buoyant flow models in order to determine geometrical characteristics of the aeration zone in jet aerators. It has been found that for the high initial gas content above 30% the bubbles dispersion is within 2 mm and thus, the device can be considered middle-size bubbled. Growth of the initial gas content in the gas-liquid jet above 30-35% results in the formation of very large bubbles with diameter above 5 cm. I have compared the proposed and experimentally verified physical model of the horizontal gas-liquid jet with those for buoyant single-phase jets with low (less than 10 %) gas content, obtained an additional stage of the process development, the stage of a single-phase flow with a residual fluid movement without bubbles, and defined specific similarity number.

DY 57.3 Thu 17:00 P1A

Modeling drying mixture droplets on porous substrates — •Christian Diddens[1], Hans Kuerten[1,2], Cees van der Geld[1], and Herman Wijshoff[1,3] — [1]Eindhoven University of Technology, The Netherlands — [2]University of Twente, The Netherlands — [3]Océ Technologies B.V., Venlo, The Netherlands

Inspired by the typical composition of water-based inks in inkjet printing processes, we have developed a numerical model for the drying of sessile multi-component droplets on porous substrates. Due to different volatilities of the components, a composition gradient is induced in the droplet. Since the physical properties of the liquid, i.e. the mass density, viscosity, surface tension and the mutual diffusion coefficient, depend on the local fluid composition and the local temperature, the flow in the droplet is governed by a complicated spatio-temporal

interplay of preferential evaporation, evaporative cooling, solutal and thermal Marangoni flow and absorption of liquid into the pores of the substrate. It is shown how preferential evaporation can drastically influence the absorption speed. Furthermore, colloidal particles and their deposition to the substrate are taken into account, which allows to predict resulting deposition patterns as function on the initial mixture composition.

DY 57.4 Thu 17:00 P1A

Quantum-like approach for a wave-particle system in fluid mechanics — •Remy Dubertrand, Maxime Hubert, Peter Schlagheck, Nicolas Vandewalle, Thierry Bastin, and John Martin — IPNAS CESAM Université de Liège, Liège, Belgium

A droplet bouncing on a vibrating bath can mimic, close to the Faraday instability threshold, a wave-particle system called a walker, see the pioneering experiment in [1]. It reported the observation of a diffraction pattern in a single slit geometry. This wave-like phenomenon can be linked to the coupling of the droplet with the associated bath surface wave. Yet a quantitative model in the presence of boundaries represents a highly difficult question while recent experiments have reported clear effects of the geometry [2, 3].

Here we present a simple model inspired from quantum mechanics for a walker in an arbitrary geometry [4]. We propose to describe its trajectory via a Green function approach. In the case of a single-slit geometry, our model is analytically and explicitly solvable, and reproduces some of the features observed experimentally.

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DY 57.5 Thu 17:00 P1A

Forced oscillations of droplets confined to a stripe — •Martin Brinkmann and Ralf Seemann — Experimentalphysik, Universtität des Saarlands, 66123 Saarbrücken

Sessile droplets confined to a stripe of finite length display a multistability of static shapes above a certain critical liquid volume and stripe length [1,2]. Close to the bifurcation point the energy barrier separating an elongated filamentous morphology from a localized, droplet-like conformation can be resolved using the distance of the center of mass to the substrate as a 'reaction' coordinate. To study the oscillation dynamics of droplets on a stripe in response to vertical vibrations close to the bifurcation point, we propose a fluid mechanical model that is build on small amplitude oscillations around equilibrium shapes under the constraint of a fixed center of mass distance. Numerical computations of the effective mass matrix and spring constants describing the shape oscillations around these constrained equilibria as a function of their center of mass coordinate allow us to describe the temporal evolution of the droplet shape by a coupled system of non-linear equations. Numerical integrations of this low dimensional system comprising a number of 'fast' oscillation amplitudes and the 'slow' center of mass coordinate reveal a rich spectrum of dynamic phenomena, including a fluid mechanical analog to Kapizas pendulum.

[1] M. Brinkmann and R. Lipowsky, J. Appl. Phys. **92**: 4296 (2002)
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DY 57.6 Thu 17:00 P1A

The effect of planetary rotation on early Earth differentiation — •Christian Maas and Ulrich Hansen — Institute for Geophysics, University of Münster, Münster, Germany

Most geophysical systems, e.g. atmospheres and planetary interiors, are crucially influenced by planetary rotation. One of the few systems where it is reasonable to exclude rotation as well as inertia is today's Earth mantle due to its high viscosity. However, during the early evolution of the Earth the mantle was probably largely affected by rotation. About 4.5 billion years ago the proto-Earth was hit by a mars-sized impactor, which led to extensive melting of the early mantle. After the impact the planet was covered by a global layer of molten mantle material with a thickness of about 1000-3000 km. This molten layer is called magma ocean. It is characterized by turbulent convection, high temperatures and pressures and a small magma viscosity. The existence of such a magma ocean is of key importance for the differentiation and chemical evolution of the Earth. It sets the initial conditions for plate tectonics and the habitability on Earth.

After the impact the magma ocean cools and starts to crystallize. Due to asmall magma viscosity and rotation periods of 2-5 h, rotation probably had a profound effect on this crystallization.

With numerical experiments we study the dynamics of crystal settling in a vigorously convecting and strongly rotating magma ocean to gain insight into the influence of planetary rotation on magma ocean crystallization.

DY 58: Posters - Networks

Time: Thursday 17:00–19:30 Location: P1A

DY 58.1 Thu 17:00 P1A

Modelling the regulation of p21 by p53 after DNA damage — •Isabella-Hilda Bodea and Barbara Drossel — TU Darmstadt, Germany

Biological cells must constantly respond to different forms of stress. One of the most common sources of cellular stress is ionizing radiation, which causes DNA double strand breaks and hence threatens the successful division or even the survival of the irradiated cell. For this reason, cells react to DNA damages by upregulating the tumor suppressor protein p53, which shows multiple pulses after the occurrence of the damage and activates numerous target proteins. One of the most important target proteins of p53 is CDKN1A (also known as p21), a potent cyclin-dependent kinase inhibitor that regulates cell-cycle arrest after DNA damage. Studies of the CDKN1A dynamics post-DNA damage in single cells revealed heterogeneity in the timing and rate of CDKN1A induction and showed that the cell-cycle stage plays a crucial role in this context.

We present a minimalistic nonlinear ordinary differential equation model for the regulation of p21 by p53 that reproduces the overall dynamical behavior of p21 in response to the p53 oscillations following DNA damage. The model includes cell-cycle dependence of degradation rates and several inhibition mechanisms and reveals the possible ways in which the observed heterogeneous response of p21 can arise.

DY 58.2 Thu 17:00 P1A

Estimating outage probabilities of electricity grids under wind power injection — •Christoph Schiel, Pedro Lind, and Philipp Maass — Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, 49076 Osnabrück, Germany

Increasing share of generated power by renewable energy sources in power grids, largely wind and photovoltaic, leads to the question how the stochastic nature of these sources and their corresponding fluctuating power production affects the grid stability. We investigate the probability of failures in electricity grid under wind power injection in dependence on the envisaged mean injected power, a critical power threshold for failure, and a time scale of human intervention to prevent outages. The wind power fed into the grid is estimated from empirical data for wind velocities measured at a wind turbine in the North Sea. Based on a statistical analysis of these data, we suggest a simple formula for estimating outage probabilities. To illustrate our findings, we apply the method to the problem of single transmission line outages in an IEEE test grid, where we replace conventional by wind power generators. Correlations of the obtained transmission line outages to the topological features of the injection nodes are discussed.

DY 58.3 Thu 17:00 P1A

Biologically implementable cycles in a Boolean model of gene regulation — •David F. Klosik and Stefan Bornholdt — Institut für Theoretische Physik, Universität Bremen

Gene regulatory networks have to be implemented in an inherently noisy environment, yet have to perform their regulatory tasks in a very reliable fashion. The main dynamical features of a number of biological regulatory networks (e.g., the cell-cycle sequence in yeast) seem to be well captured in terms of Boolean (threshold) networks with a

parallel update scheme. Assuming that the sequence or the underlying network are unknown, we here approach the question of which pairs of cycles and graphs yield reliable results under noisy signal transmission in an autonomous Boolean network model with underlying continuous dynamics, that has previously been applied to simulating biochemical stochasticity in regulatory networks [1].

[1] S. Braunewell and S. Bornholdt, Superstability of the yeast cell-cycle dynamics: Ensuring causality in the presence of biochemical stochasticity, J. Theor. Biol. 245 (2007) 638-643.

DY 58.4 Thu 17:00 P1A

Asymptotic spectrum of multi frequency states in sparse oscillator networks — •Anton Plietzsch — Potsdam-Institut für Klimafolgenforschung — Humboldt-Universität zu Berlin

I discuss various new analytic and numerical results on the structure of asymptotic multi frequency states in sparse oscillator networks.

DY 59: Posters - Nonlinear General

Time: Thursday 17:00–19:30 Location: P1A

DY 59.1 Thu 17:00 P1A

Tests for chaos and partial predictability — •Hendrik Wernecke, Bulcsú Sándor, and Claudius Gros — Goethe-Universität Frankfurt am Main, Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt am Main

For deterministic dynamical systems the exponential divergence of pairs of initially close trajectories on the attracting set is a tell-tale indicator for chaos. This process can lead to a total loss of correlation within the time scale of the Lyapunov prediction time. However, there is a type of chaotic motion, for which the time scale of decorrelation is dominantly determined by a diffusive process on the attractor. This type of chaos stays partially predictable for remarkably long time. However, due to the high level of cross-correlation, the standard tests for chaos either yield ambiguous results or misclassify partially predictable chaos as laminar flow. Therefore we present in this study a novel indicator for chaos based on the cross-distance scaling of pairs of initially close trajectories. This test is capable of robustly and unambiguously distinguishing chaotic dynamics, including partially predictable chaos, from laminar flow in a 0-1 fashion. In combination with the finite-time cross-correlation, we are able to distinguish all three types of motion – chaos, partially predictable chaos and laminar flow – in a 0-1 manner from the time evolution of pairs of trajectories.

DY 59.2 Thu 17:00 P1A

Determining the free energy gain of phase separation via Markov state modelling — •Myra Biedermann and Andreas Heuer — Westfälische Wilhelms-Universität, Institut für Physikalische Chemie, Corrensstr. 28/30, 48149 Münster, Germany

Within the last two decades, Markov state modelling (MSM) has gained increased attention as a sampling method. On this basis a kinetic model can be built that describes the long-time statistical dynamics of a system by systematically collecting simulation data from trajectories that are significantly shorter than the longest relaxation time of the system. The development of MSMs has been largely driven by studies of protein folding and protein functionality. Here, we aim at expanding the application range of MSM towards studies of phase-separating systems such as e.g. raft-forming lipid bilayers. Because of the complexity of these types of systems, we discuss the general procedure for the Ising model with fixed concentration of up- and down-spins in the low-temperature limit.

Here, we present our results from application of MSM to the Ising model, including a study of the difficulties and problems that arise in the estimation process. We will show detailed investigations of the causes for these problems and present possible methods to circumvent, or rather account for them during the estimation process.

DY 59.3 Thu 17:00 P1A

Rodlike Localized States in a Swift-Hohenberg Model — •Felix Tabbert[1], Ignacio Bordeu[2], and Svetlana Gurevich[1] — [1]Institute for Theoretical Physics, Münster — [2]Imperial College, London

We study the existence of localized rodlike solutions in a Swift-Hohenberg model which have been reported in [1]. We provide a linear stability analysis and a bifurcation analysis in two dimensions of rodlike and other stationary solutions which bifurcate by breaking the rotational symmetry of a single localized solution. To this aim, we deploy numerical pathway continuation in two spatial dimensions in combination with direct numerical simulations. Since the Swift-Hohenberg equation possesses the same stationary solutions as the conserved Swift-Hohenberg equation, most of the results can also be applied to phase field crystal models of this type [2][3].

Further analysis includes the destabilization of the aforementioned solutions by time-delayed feedback leading to complex dynamics, e.g. drift or rotations. A stability analysis of the time-delayed system is also performed and shows good agreement with the results from direct numerical simulations.

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DY 59.4 Thu 17:00 P1A

Bifurcation analysis of a passively mode-locked semiconductor laser with optical feedback — •Lina Jaurigue[1] and Kathy Lüdge[1,2] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany — [2]Department of Mathematics, University of Auckland, Auckland, New Zealand

Passively mode-locked semiconductor lasers can exhibit a rich range of pulsed dynamics. The time scales of these dynamics are related to the roundtrip time of the laser cavity and the recovery times of carriers in the gain and absorber sections of the laser. Adding optical self-feedback to such system can strongly influence these dynamics which then depend crucially on the ratio of the internal time scales to the feedback delay time [1,2]. In this contribution we present an analysis of the dynamics and bifurcations of such a system, which we describe using a system of coupled delay differential equations involving multiple delay times [3,4].

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DY 60: Posters - Brownian Motion, Noise

Time: Thursday 17:00–19:30 Location: P1A

DY 60.1 Thu 17:00 P1A

Convex Hulls of Self-Avoiding Random Walks: A Large-Deviation Study — •Hendrik Schawe[1], Alexander K. Hartmann[1], and Satya N. Majumdar[2] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg — [2]Laboratoire de Physique Théorique et Modèles Statistiques, Université de Paris-Sud

We study the convex hulls of different types of random walks, i.e., the smallest convex polygon enclosing the trajectory of a random walk with T steps. While the convex hulls are of interest from a pure mathematical point of view, they are also considered as a model to estimate animal territories. The convex hulls of normal random walks are decently studied [1, 2], but very little is known about the convex hulls of other important types of random walks as the Self-Avoiding Random Walk (SAW) and the Loop-Erased Random Walk (LERW). Using Markov chain Monte Carlo sampling-techniques, we can study a large part of the support of the distributions of the area A or perimeter L of the convex hulls. This enables us to reach probability densities below $P(A) = 10^{-800}$ and scrutinize large-deviation properties. Similar to normal random walks, the probability densities show a universal scaling behavior dependent on the scaling exponent ν and the dimension of the observable (e.g., $d = 2$ for the area A and $d = 1$ for the perimeter L). Further, we determined the rate function $\Phi(\cdot) = -\frac{1}{T}\log P(\cdot)$ which shows convergence to a limit shape for $T \to \infty$.

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DY 60.2 Thu 17:00 P1A

Thermoelectric Charging of a Hot Spot in Electrolyte Solution — •Martin Fränzl and Frank Cichos — Molecular Nanophotonics, Institute for Experimental Physics I, Universität Leipzig, Germany

We discuss the thermoelectric charging of a hot spot in an electrolyte solution. The underlying thermal forces depend on the temperature gradient through different mechanisms. In the last decades thermophoresis of colloids is mainly discussed in terms of thermoosmotic pressure. However, in the recent years it has become clear that, for charged systems in an electrolyte solution the thermoelectric or Seebeck effect provides a non-local driving force that presents remarkable effects. At a non-uniform temperature, positive and negative ions have the tendency to migrate in opposite directions, thus giving rise to a thermoelectric field $E = S\nabla T$ that is proportional to the temperature gradient. This field drives charged particles to the hot or to the cold, depending on the sign Seebeck coefficient S and so on electrolyte. The present work investigates the thermoelectric properties by locally heating a gold film with a focused laser beam within a colloidal suspension and investigates the resulting colloidal transport.

DY 60.3 Thu 17:00 P1A

Weak nonergodicity in a generalized Lévy walk model — •Tony Albers and Günter Radons — Technische Universität Chemnitz, Germany

In this contribution, we investigate the weakly nonergodic behavior of a generalized Lévy walk in which the velocities of the flights depend on the durations of the flights in a nonlinear way. This process essentially depends on two characteristic exponents determining the distribution of flight durations and the deterministic dependence of the flight velocities on the durations of the flights. We compare for this model of anomalous diffusion the temporal behavior of the ensemble-averaged squared displacement with the time-averaged squared displacement and quantify the randomness of the latter with a scatter distribution and the ergodicity breaking parameter. We find regions in the two-dimensional parameter space which show manifestations of weak nonergodicity which have never been observed before in the literature. Moreover, we provide a simple explanation for the observed transitions between different kinds of anomalous diffusion and weak nonergodicity by a divergence of six different characteristic quantities of the random walk.

DY 60.4 Thu 17:00 P1A

Splitting of the Universality Class of Anomalous Transport in Crowded Media — Markus Spanner-Denzer[1], Felix Höfling[2], Sebastian Kapfer[1], Klaus Mecke[1], Gerd Schröder-Turk[3], and •Thomas Franosch[4] — [1]FAU Erlangen, Erlangen, Germany — [2]FU Berlin, Berlin, Germany — [3]Murdoch University, Murdoch, Australia — [4]Universität Innsbruck, Innsbruck, Austria

We investigate the emergence of subdiffusive transport by obstruction in continuum models for molecular crowding [1]. While the underlying percolation transition for the accessible space displays universal behavior, the dynamic properties depend in a subtle nonuniversal way on the transport through narrow channels. At the same time, the different universality classes are robust with respect to introducing correlations in the obstacle matrix as we demonstrate for quenched hard-sphere liquids as underlying structures. Our results confirm that the microscopic dynamics can dominate the relaxational behavior even at long times, in striking contrast to glassy dynamics.

[1] M. Spanner, F. Höfling, S.C. Kapfer, K.R. Mecke, G.E. Schröder-Turk, and T. Franosch, Phys. Rev. Lett. **116**, 060601 (2016).

DY 60.5 Thu 17:00 P1A

Hot Brownian Motion — •Alexander Fischer and Frank Cichos — Molecular Nanophotonics, Institut für Experimentalphysik I, Fakultät für Physik und Geowissenschaften, Universität Leipzig

Hot Brownian motion describes the motion of a heated microsphere in a liquid. A temperature field is created around the heated particle decaying with 1/r. The heat transferred from the particle to the surrounding fluid spreads around three orders of magnitude faster than the particle moves. Therefore a stationary temperature field is moving with the particle through the liquid. The non-equilibrium dynamics of the particle now differs from the unheated particles and an effective temperature and viscosity is introduced to describe the system. With the development of fast detection systems in the recent years and the possibility to restrict the motion of a microscopic object using an optical tweezer, an investigation of hot Brownian motion on short time scales has become possible. Due to the increasing impact of the particle's inertia and the surrounding fluid on short time scales, the motion of the particle is not completely random anymore. The aim of this research is to understand the fundamentals of an effective temperature definition for fluctuation dissipation relations under non-equilibrium conditions.

DY 61: Posters - Quantum Systems

Time: Thursday 17:00–19:30 Location: P1A

DY 61.1 Thu 17:00 P1A

Perturbation theory for asymmetric deformed optical microdisk cavities — •Julius Kullig and Jan Wiersig — Institut für Theoretische Physik, Otto-von-Guericke-Universität Magdeburg, Postfach 4120, D-39016 Magdeburg, Germany

Optical microdisk cavities confine light into very small volumes for long times. Via slight boundary deformations the cavity can be designated for a desired application; e.g. for unidirectional light emission or as sensor device. However, in real experiments slight deformations destroy mirror-reflection symmetry either intended or unintended via production tolerances. Therefore we have generalized the perturbation theory for microdisk cavities to treat such asymmetric deformations. This allows us to describe interesting non-Hermitian phenomena like copropagation of optical modes in the (counter-)clockwise direction inside the cavity. The derived analytic formulas are demonstrated at two generic boundary shapes, the spiral and the double-notched circle where a good agreement to the numerical boundary element method is observed.

DY 61.2 Thu 17:00 P1A

Phase-space localization in absorbing quantum maps — •Konstantin Clauss[1], Martin Körber[1], Tobias Becker[1], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden

In absorbing quantum systems a fundamental question concerns the phase-space localization of resonance states. The semi-classical description of a chaotic resonance state is given by a classical conditionally invariant measure with the same decay rate. We present a construction of such measures that generalizes the classical natural decay to arbitrary decay rates. We investigate (i) quantum mechanical deviations, (ii) the case of partial absorption, and (iii) the applicability to a mixed phase space.

DY 61.3 Thu 17:00 P1A

Separatrix modes in weakly deformed microdisk cavities — •Chang-Hwan Yi[1,2], Jullius Kullig[2], Ji-Won Lee[1], Ji-Hwan Kim[1], Hyeon-Hye Yu[3], Jan Wiersig[2], and Chil-Min Kim[1] — [1]Department of Emerging Materials Science, DGIST, Daegu 711-873, Korea — [2]Institut für Theoretische Physik, Otto-von-Guericke-Universität Magdeburg, Postfach 4120, D-39016 Magdeburg, Germany — [3]Department of Physics, Sogang University, Seoul 121-742, Korea

Quasi stationary modes in deformed dielectric microdisk cavities show an unexpected localization along unstable periodic ray orbits. We reveal a mechanism for this kind of localization in weakly deformed cavities. In such systems the ray dynamics is nearly integrable and its phase space contains small island chains. When increasing the deformation the enlarging islands incorporate more and more modes. Each time a mode comes close to the border of an island chain (separatrix) the mode exhibits a strong localization near the corresponding unstable periodic orbit. Using an Einstein-Brillouin-Keller quantization scheme taking into account the Fresnel coefficients we derive a frequency condition for the localization. Observing far field intensity patterns and tunneling distances, reveals small differences in the emission properties.

DY 61.4 Thu 17:00 P1A

Resonance–assisted tunneling in 4D normal-form systems — •Markus Firmbach[1], Felix Fritzsch[1], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden

Nonlinear resonances are ubiquitous in higher–dimensional systems, however, a quantitative description of their influence on quantum dynamical tunneling is still lacking. To understand resonance–assisted tunneling in higher–dimensional system we use a 4D resonant normal-form system. Focusing on the case of a double resonance, we obtain tunneling rates showing resonance–assisted enhancement as well as suppression. Using quantum perturbation theory we reveal the underlying mechanism for these phenomena.

DY 61.5 Thu 17:00 P1A

Phase space and frequency space of the spatial circular restricted three-body problem — •Martin Langer[1] and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden, Germany — [2]MPI für Physik komplexer Systeme, Dresden, Germany

The spatial circular restricted three-body problem is a Hamiltonian system with three degrees of freedom, describing for example the dynamics of an astroid in the field of two heavy masses moving on circular orbits. By a Poincaré section this can be reduced to a 4D symplectic map. To visualize the dynamics in phase space, in particular around the Lagrangian triangular equilibria $\mathcal{L}_{4,5}$, we use the recently introduced 3D phase space slices and chaos indicators. We relate regular phase-space structures with those in frequency space and explain the organization of phase space using lower-dimensional tori.

DY 61.6 Thu 17:00 P1A

Driven, dissipative dynamics of a Dicke model: relaxation and pumping — •Christos Bokas, Björn Kubala, and Joachim Ankerhold — Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany

A dissipative Dicke model can be realized in a new hybrid architecture, where a cloud of cold atoms is brought close to a superconducting microwave resonator. We establish a description of this hybrid in the quasi-continuum limit of a large number of atoms by deriving a mapping on single-particle motion in a single effective two-dimensional potential, so that the full coherent dynamics far from equilibrium can be investigated. Dissipative dynamics is then incorporated by the quantum jump method.

Within this framework, numerical simulations are feasible even for thousands of atoms in various non-equilibrium scenarios of interest. Exemplary, we study, how the system starting from a highly excited atomic cloud relaxes to equilibrium through a "superradiant burst". Via a time-dependent coupling between atoms and cavity, the system is pumped through the phase transition between normal and superradiant state.

DY 61.7 Thu 17:00 P1A

Amended ray-optical description of dielectric optical microcavities — •Pia Stockschläder and Martina Hentschel — Institut für Physik, Technische Universität Ilmenau, Weimarer Straße 25, 98693 Ilmenau, Germany

Dielectric optical microcavities and microlasers have attracted much attention because of their possible applications in photonics or optoelectronics. It has proven useful to describe these systems based on geometrical optics. In this efficient and easily implemented approach, the dielectric cavities can be considered as open billiards. Using the concept of ray-wave correspondence, much insight can be gained about the mode structure and the emission characteristics. Here, we discuss some aspects of an amended ray description of dielectric optical microcavities focusing on the determination of the far-field emission pattern. Firstly, we examine the differences between the modelling of cavities with predominantly chaotic and with non-chaotic classical billiard dynamics (chaotic and non-chaotic cavities, for short). For chaotic cavities, it is well known that the far-field is determined by the overlap of the unstable manifold of the chaotic saddle with the leaky region. For non-chaotic cavities, on the other hand, the trajectories with the smallest, nonzero decay rates dominate the emission pattern. Secondly, we include wave-inspired corrections to the ray-optics which can be important for the reliable description of small cavities. We discuss the influence of these correction terms for systems with curved and with planar boundaries, as well as for systems with chaotic and non-chaotic dynamics.

DY 61.8 Thu 17:00 P1A

Semi-Classics in many-body spin chains — Maram Akila, •Daniel Waltner, Boris Gutkin, Petr Braun, and Thomas Guhr — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg

Recently, we discovered an exact trace duality for kicked, one dimensional spin chains. It expresses traces of the unitary evolution operator for N spins and T time-steps by traces of an operator whose dimension is determined by T instead of N. This simplification allows us to address large spin systems at practically arbitrary N. With this at

hand, we can perform a semi-classical analysis of a many-body system, determining (action-)spectra and their correspondence to classical periodic orbits. In this initial study we illustrate challenges of mixed classical dynamics, the exponential orbit count proliferation with N, and possible pathways to overcome these obstacles.

DY 62: Complex Fluids and Soft Matter II (joint DY/CPP)

Time: Friday 9:30–12:30 Location: HÜL 186

Invited Talk DY 62.1 Fri 9:30 HÜL 186

Liquid Crystals in Microgravity — •Ralf Stannarius — Otto-von-Guericke-Universität Magdeburg

Experiments under microgravity allow to study dynamic processes in thin freely suspended liquid films in air, as well as freely floating bubbles of smectic liquid crystals. These are representative for quasi-twodimensional liquids. Shape dynamics, film rupture, and mobility and interactions of inclusions in quasi-2D emulsions are topics of scientific interest in these unique fluid structures. Results from parabolic flights, a suborbital rocket flight, and an ISS experiment are presented.

DY 62.2 Fri 10:00 HÜL 186

Temporal evolution of free floating smectic bubbles — •Patricia Dähmlow, Torsten Trittel, Christoph Klopp, Kirsten Harth, and Ralf Stannarius — Otto-von-Guericke University Magdeburg, Germany

Freely floating smectic bubbles are investigated under microgravity conditions, which form a minimal surface, like soap bubbles, in equilibrium. A great advantage of freely floating bubbles is the absence of a meniscus, which acts as a reservoir of smectic material when the surface area of the film changes. In this work, the freely floating bubble must rearrange its internal layer structure without such a reservoir. Bubbles are produced by collapsing catenoids, resulting in an elongated shape after the rupture of the catenoids. With time the bubble shows complex oscillations, which includes the invagination of the film and thus, a temporary increase of the surface area until it relaxes to a sphere. Experiments are performed performed with optical highspeed imaging during parabolic flights.

DY 62.3 Fri 10:15 HÜL 186

Orientational order on surfaces - the coupling of topology, geometry and dynamics — •Axel Voigt, Michael Nestler, Ingo Nitschke, and Simon Praetorius — Institut für Wissenschaftliches Rechnen, TU Dresden, Germany

We consider the numerical investigation of surface bound orientational order using unit tangential vector fields by means of a gradient-flow equation of a weak surface Frank-Oseen energy. The energy is composed of intrinsic and extrinsic contributions, as well as a penalization term to enforce the unity of the vector field. Four different numerical discretizations, namely a discrete exterior calculus approach, a method based on vector spherical harmonics, a surface finite-element method, and an approach utilizing an implicit surface description, the diffuse interface method, are described and compared with each other for surfaces with Euler characteristic 2. We demonstrate the influence of geometric properties on realizations of the Poincare-Hopf theorem and show examples where the energy is decreased by introducing additional orientational defects.

DY 62.4 Fri 10:30 HÜL 186

Microrheology of rod-shaped particles in free standing liquid crystal films of the smectic phase — •Christoph Klopp, Alexey Eremin, and Ralf Stannarius — Institute of Experimental Physics, Otto-von-Guericke University Magdeburg, Germany

Flow phenomena in restricted geometries have been studied in a variety of different physical, chemical and biological systems in the last years. These studies investigate the motion of proteins in lipid membranes and the motion of submicrometer-sized inclusions on thin membranes. Organic liquid crystal materials are able to form very thin, stable free standing films of highly uniform structure and thickness, making them ideal systems for studies of hydrodynamics in two dimensions. We study the mobility of sphere and rod-shaped inclusions in freely-suspended liquid crystal films of the smectic A phase [1]. For the rod-shaped particles we analyze the rotational and translational mobility by measuring Brownian motion. We compare our results with the existing theory of Saffman and Delbrück [2] and analyze the effect of particle anisometry. Measurable effects appear when the length of the particles is comparable to or larger than the hydrodynamic size of the system (Saffman length) and we are able to confirm the theory of Levine et al. with our data [3].

[1] A. Eremin *et al.*, 2011. Pys. Rev. Lett. 107, 268301.
[2] Z. H. Nguyen *et al.*, 2010. Pys. Rev. Lett. 105, 268304.
[3] A. J. Levine *et al.*, 2004. Phys. Rev. Lett. 93, 038102.

DY 62.5 Fri 10:45 HÜL 186

Structure and rheology of suspensions controlled by capillary forces in thin liquid films — •Andrea Scagliarini[1] and Jens Harting[1,2] — [1]Forschungszentrum Jülich GmbH, Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Nürnberg, Germany — [2]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

Commonly, the rheology of suspensions is primarily controlled by the volume fraction of solids, as it is the case, for instance, of colloidal gels. However, it has been recently shown that adding small amounts of a liquid, immiscible with the continuous phase of the suspension, affects strikingly the mechanical response of the system, even at low solid volume fraction, owing to the formation of particle aggregates and networks sustained by capillary forces. Such structures endow the material with elasto-plastic/gel-like properties which make these capillary suspensions particularly suitable for a number of applications. By means of lattice Boltzmann simulations I will address a number of open questions, concerning: i) the dependence of the network structure upon the particle shape and wettability, and, in turn, ii) the dependence of the rhelogical properties on such structure. In particular, I will show that by adding water to an oil-based suspension of strongly hydrophobic particles, the formation of a percolating cluster is observed. The percolation transition occurs at a critical value of the water volume fraction, for which we provide an explicit expression depending of the particle geometry, the solid volume fraction and the contact angle.

DY 62.6 Fri 11:00 HÜL 186

Transient dynamics in the accelerating region of collapsing freely suspended films — •Florian von Rüling and Alexey Eremin — Institute of Experimental Physics, Otto von Guericke University Magdeburg, Universitätsplatz 2, 39016 Magdeburg, Germany

We report experimental studies on collapse dynamics of freely suspended smectic liquid crystal films. In contrast to soap films, whose collapse has been studied in detail, films of thermotropic liquid crystals have a well-defined layer structure and represent a quasi-two-dimensional fluid. The particular inner structure of smectics stabilizes freely suspended films with an extraordinary surface-to-volume-ratio. In our studies, we use tracer particles to visualise the flow in collapsing smectic films, thus enabling us to estimate the size of the dissipation region and to test the predictions of the theory. Using high-speed imaging we show that the advective flow involves the whole film, however, the flow velocity gradually reduces with the distance from the moving edge. The dissipation region is nearly independent of the film thickness.

15 min. break

DY 62.7 Fri 11:30 HÜL 186

A nearly incompressible mesoscopic method for simulating complex fluids and flows — •Davod Alizadehrad and Dmitry A. Fedosov — Institute of Complex Systems and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

Numerical simulation and theoretical modeling of mesoscopic processes are constantly challenged by the large separation of time scales and length scales. We introduce a general mesoscopic framework for simulating complex liquids and flows using the smoothed dissipative particle dynamics [1]. Modifying the equation of state and the course-grained

system, we show that the speed of sound can be controlled, while the radial distribution function (RDF), the mean-square displacement, and the Schmidt number correspond to liquid state, even for low temperatures. Performing reverse-Poiseuille flow simulations, measured viscosity shows only 1-2 percent changes over several orders variation of shear rates. The RDF in equilibrium and in shear flow remains same and independent of shear rates. This is an advantage in modeling of structures and boundaries either rigid or deformable. As a challenging test of incompressibility, we have considered the Poisson ratio, divergence of velocity field, and the number density in elongational flow. Density variation remains smaller than one percent and the velocity field satisfies well the divergence-free condition, indicating that the simulated fluid is nearly incompressible. Finally, we present the applicability and validity of the method in simulating cellular blood flow in irregular geometries as an example of complex mesoscopic fluids flow.

[1] K. Müller, et al., J. Comp. Phys. **281**, 301-315, (2015)

DY 62.8 Fri 11:45 HÜL 186

How to regulate the position of a droplet in a heterogeneous liquid environment? — •Samuel Krüger[1,2], Christoph A. Weber[4], Jens-Uwe Sommer[2,3], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Leibniz Institute of Polymer Research Dresden e.V. — [3]Technische Universität Dresden, Institute of Theoretical Physics, Dresden, Germany — [4]Harvard University, Division of Engineering and Applied Sciences, Cambridge, USA

Cells contain organelles that are not separated from the cytoplasm by a membrane. An example are liquid-like P granules in the *C. elegans* embryo. P Granules consist of RNA and proteins that are segregated from the cytoplasm. During asymmetric cell division, P granules are segregated to one side of the cell and distributed to only one daughter cell. This segregation is guided by the spatial concentration gradient of the protein Mex-5. Motivated by this system, we study the general question of how droplets are positioned in a concentration gradient of a regulator molecule that influences phase separation. We consider a ternary system and study the simplified case, where an external potential establishes the regulator gradient. A mean field Flory-Huggins model reveals a first order phase transition between the droplet position at high and low regulator concentration. We discuss this result in comparison to Monte Carlo simulations. Simulations reveal signatures of the mean field phase transition and give insight into the free energy landscape of the system in the presence of fluctuations.

DY 62.9 Fri 12:00 HÜL 186

Self-Assembly of Rings and Capsids in Hydrodynamic Flow — •Nikolas Schnellbächer[1,2], Fabian Fuchs[1,2], and Ulrich Schwarz[1,2] — [1]Institute for Theoretical Physics, Heidelberg University, Germany — [2]BioQuant, Heidelberg University, Germany

Patchy particle systems have emerged as useful model systems to investigate protein or colloidal self-assembly, but are usually studied under ideal conditions. We study self-assembly of patchy particles in hydrodynamic flow since this is a typical scenario for many applications and represents an important step towards more complex environments. Solute particles are propagated using Molecular Dynamics (MD) with solute-solute reactions being implemented through reactive patches. Solvent flow is simulated with Multi-Particle Collision Dynamics (MPCD). As paradigmatic examples, we study the assembly of pentagonal rings and icosahedral capsids with and without hydrodynamic flow. We find that there is a strong nonlinear relationship between shear rate and assembly yield and observe a multi-pitched interplay between shear rate and frequency of malformed complexes. This leads to optimal regimes both at low and intermediate shear rates, such that a balanced relation of bond association and dissociation prevents kinetic trapping and ensures constant monomer supply. At very high shear assemblies are disrupted by force. Our work highlights how both strong cooperative effects and non-equilibrium conditions are important to understand the intricate dynamics of self-assembly pathways.

DY 62.10 Fri 12:15 HÜL 186

Regulation of liquid phase separation of PGL-3 protein by RNA — •Omar Adame-Arana[1], Christoph A. Weber[1,2], Shambaditya Saha[3], Anthony A. Hyman[3], and Frank Jülicher[1] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138, USA — [3]Max Planck Institute of Molecular Cell Biology and Genetics, 01307 Dresden, Germany

Liquid-liquid phase separation has been proposed as a key mechanism for the assembly and maintenance of membraneless compartments in cells. For example, in the *C. elegans* embryo, liquid-like droplets called P granules, condense and subsequently segregate to one side of the cell prior to cell division. P granules play a key role in the specification of germ cell fate. It has been shown that PGL-3, a key P granule component, is able to form RNA-rich liquid droplets in vitro. We investigate the role of RNA to facilitate phase separation using a Flory-Huggins model. We show that competition for RNA binding by PGL-3 and the regulatory protein Mex-5 can acount for the observed droplet segregation.

DY 63: Controlling Complex Networks in Nature and Engineering (Focus session, joint DY/SOE/BP)

The control of complex dynamical networks is of great current interest, especially in the light of various applications in nature and engineering, e.g., brain, genetic networks, communication, transport and supply networks, power grids. Important issues are the control of networks with complex topologies and heterogeneous components, in particular by making small local perturbations to steer the system to a desired target state or stabilize a desired state.

Organized by Eckehard Schöll and Anna Zakharova

Time: Friday 9:30–12:30 Location: ZEU 160

Invited Talk DY 63.1 Fri 9:30 ZEU 160

Influence of network topology on spreading of epileptic seizure — •Simona Olmi[1], Spase Petkoski[2], Fabrice Bartolomei[2,3], Maxime Guye[4], and Viktor Jirsa[2] — [1]Weierstrass Institute, Berlin, Germany — [2]Aix-Marseille Univ, Inserm, Institut de Neurosciences des Systémes, Marseille, France — [3]Assistance Publique, Hôpitaux de Marseille, Hôpital de la Timone, Service de Neurophysiologie Clinique, Marseille, France — [4]Faculté de Médecine de la Timone, Centre de Résonance Magnétique et Biologique et Médicale, Medical School of Marseille, Aix-Marseille Université, Marseille, France

In partial epilepsy, seizures originate in a local network, the so-called epileptogenic zone, before recruiting other close or distant brain regions. Correctly delineating the epileptogenic and the propagation zone is essential for successful resective surgery. In particular the stereotaxic EEG (SEEG) is used to edge the zone to resect. However the propagation pathways of epileptic seizures are still largely unknown. Using a specific dynamical model for epilepsy [1], we then predict the recruitment network given the seizure origins and we try to understand the role played by the topology in constraining the recruitment process. The identification of the minimal number of connections that allows the seizure to propagate, via the application of linear stability analysis, and the choice of the optimal set of links to be cut in order to stop seizure propagation might reveal an approach to improve the success rate of epilepsy surgery. [1] Jirsa VK, Stacey WC, Quilichini PP, Ivanov AI, Bernard C (2014) 137:2210-2230.

Invited Talk DY 63.2 Fri 10:00 ZEU 160

Chimera patterns induced by complex connectivity in Leaky Integrate-and-Fire Networks — •Astero Provata[1], Nefeli

Tsigkri-DeSmedt[1], Johanne Hizanidis[1], Philipp Hoevel[2], and Eckehard Schoell[2] — [1]Intitute of Nanoscience and Nanotechnology, National Center for Scientific Research "Demokritos", 15310 Athens, Greece — [2]Institut fur Theoretische Physik, Technische Universitaet Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany a

We study synchronization patterns in ring networks of Leaky Integrate-and-Fire(LIF) oscillators under different connectivity schemes. Earlier studies have demonstrated the formation of chimera and multichimera states in LIF networks with nonlocal connectivity and specific ranges of parameters. Because in natural networks the connectivity takes complex schemes we investigate here the modifications in the form of the chimera states under: a) reflecting connectivity and b) diagonal connectivity. In case a) we show numerically that reflecting connectivity induces a novel chimera pattern in which near-threshold elements coexist with oscillating ones. The oscillating elements form arch-shaped mean phase velocity profiles while the potentials of the near-threshold elements never drop to the resting state. In case b) the diagonal connectivity induces multichimera states whose mean phase velocity profile changes its multiplicity as the coupling constant varies, while regimes of classic multichimera states are separated by synchronous regimes.The new synchronization patterns demonstrate the influence of complex connectivity in network synchronization.

DY 63.3 Fri 10:30 ZEU 160

Coherence-Resonance Chimeras in a Neural Network — •Anna Zakharova[1], Nadezhda Semenova[2], Vadim Anishchenko[2], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Department of Physics, Saratov State University, Astrakhanskaya street 83, 410012 Saratov, Russia

We show that chimera patterns can be induced by noise in nonlocally coupled neural networks in the excitable regime. In contrast to classical chimeras, occurring in noise-free oscillatory networks, they have features of two phenomena: coherence resonance and chimera states. Therefore, we call them coherence-resonance chimeras [1]. These patterns demonstrate the constructive role of noise and appear for intermediate values of noise intensity, which is a characteristic feature of coherence resonance. In the coherence-resonance chimera state a neural network of identical elements splits into two coexisting domains with different behavior: spatially coherent and spatially incoherent, a typical property of chimera states. Moreover, these noise-induced chimera states are characterized by alternating behavior: coherent and incoherent domains switch periodically their location. We show that this alternating switching can be explained by analyzing the coupling functions.

[1] N. Semenova, A. Zakharova, V. Anishchenko, E. Schöll, Coherence-resonance chimeras in a network of excitable elements, Phys. Rev. Lett. 117, 014102 (2016)

DY 63.4 Fri 10:45 ZEU 160

Self-controlled latching dynamics in simple models with attractor-ruins — •Diemut Regel and Marc Timme — Network Dynamics, MPI for Dynamics and Self-Organization, 37077 Goettingen, Germany

Standard models of natural computation commonly exhibit attractors as their core concept, with convergence dynamics towards them viewed as the completion of a computational task, e.g. the recognition of an object or the processing of a piece of information [1]. Higher cognitive activities such as free association have been proposed to be representable by latching dynamics [2], a repeated switching between representative system states by dynamical parameter drifting that is intrinsically controlled by the system itself. Yet, how such latching might be achieved and which mechanism may cause latching in dynamical systems is not well understood. Here we propose simple models of latching dynamics and reveal fundamental mechanisms of their self-control options.

[1] J.J. Hopfield, Proc. Natl. Acad. Sci. (1982).
[2] A Treves, Cogn. Neuropsychol. (2005).

DY 63.5 Fri 11:00 ZEU 160

Interaction Control to Synchronize Non-synchronizable Networks — •Malte Schröder[1], Aditya Tandon[2], Sagar Chakraborty[2], Dirk Witthaut[3], Jan Nagler[4], and Marc Timme[1] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]Department of Physics, Indian Institute of Technology Kanpur, Kanpur, Uttar Pradesh 208016, India — [3]Forschungszentrum Jülich, Institute for Energy and Climate Research (IEK-STE), 52428 Jülich, Germany — [4]Computational Physics, IfB, ETH Zurich, 8093 Zurich, Switzerland

Synchronization constitutes one of the most fundamental collective dynamics across networked systems. Whether a system may synchronize depends on the internal unit dynamics as well as the topology and strength of their interactions. For chaotic units with certain interaction topologies synchronization might be impossible across all interaction strengths, meaning that these networks are non-synchronizable.

Here we propose the concept of interaction control, generalizing transient uncoupling, to induce desired collective dynamics in complex networks. Intriguingly, localizing interactions in phase space by a fixed control scheme enables stable synchronization across *all* connected networks regardless of topological constraints. Interaction control may thus ease the design of desired collective dynamics, even without knowledge of the networks exact interaction topology.

15 min break

DY 63.6 Fri 11:30 ZEU 160

Complex communication in automotive networks — •Christian Pigorsch — BMW AG, Hufelandstraße 1, 80788 München

Different types of automotive networks have been used for the communication in BMW vehicles. For communication across such heterogeneous networks, it is important to ensure stability and robustness, especially for safety related use cases. This is accomplished by evaluating the in-car implementation by means of statistical parameters and comparing the results with the specification. This timing analysis approach, and the questions it introduces, will be illustrated in this talk using several examples. The overall goal of the communication design is optimal utilization of communication resources.

DY 63.7 Fri 11:45 ZEU 160

On the Impact of Network Topology on Distributed Constraint-Satisfaction Problems — •Henning Blunck[1], Dieter Armbruster[2], Julia Bendul[1], and Marc-Thorsten Hütt[1] — [1]Jacobs University Bremen, Bremen, Germany — [2]Arizona State University, Tempe, AZ, USA

The scheduling of operations to machines is a core logistic challenge with a multitude of applications in our complex industrialized world. As part of the so called "fourth industrial revolution", distributed, agent-based approaches to this problem are receiving renewed attention, with important questions about the design about such systems still unanswered.

In the light of the above, we investigate the more general question how network structure influences the solution performance of distributed constraint-satisfaction problems, here the problem of finding a k-coloring. In particular, we study the impact of "leader"-nodes, nodes introduced specifically to collect and distribute information from large parts of the network.

The results we find shed light on the role of hubs in coordination processes on networks with direct implications not only on long held beliefs in the domain of agent-based production control, but Multi-Agent system design and organization theory.

DY 63.8 Fri 12:00 ZEU 160

Towards an integrated model for stochastic effects in power system dynamics and control — •Philipp C. Böttcher and David Kleinhans — NEXT ENERGY | EWE Research Centre for Energy Technology, Carl-von-Ossietzky-Straße 15, 26129 Oldenburg

While today's energy system heavily relies on fossil fuels, the energy systems of tomorrow most likely will be realised with a large share of renewable energies. This will have several advantages, but also introduces highly volatile energy sources without inertia into a system designed for conventional energy sources with large rotating generator masses. To cope with the strongly fluctuating energy resources various aspects of the current energy system have to change, such as e.g. modifications to the grid, demand side management, or investment into new technology.

The scope of this work is to investigate the stochastic effects in power system dynamics and control. For this purpose we aim to develop an integrated stochastic model, which reflects the grid codes for power frequency control by the *European Network of Transmission Operators* (ENTSO-E). The power frequency measurements reveal clear signatures of the grid codes. We present these results and outline the

intended stochastic modelling approach.

DY 63.9 Fri 12:15 ZEU 160

Principal Components of the European Power System — •Fabian Hofmann, Jonas Hoersch, and Stefan Schramm — Frankfurt Institute for Advanced Studies, Frankfurt, Germany

The European power system represents a huge network of different nodes, each with a complex time-dependent behaviour. In order to efficiently integrate renewable energy sources, such as wind and solar, it is a major task to understand and handle their additional effects. In particular, the more renewables in the system, the more the power generation will be subject to the weather. We therefore build up a european power system, which is dominated by non-conventional power generators, and extract general time-dependant patterns from it by applying a Principal Component Analysis to the timeseries of the nodes. This reduces the multivariate dimension of the system to a small number of general patterns, which are though uncorrelated but may not necessarily be statistically independent. Furthermore, these dominating patterns determine main flows in the network and can be used to align investments and network design.

DY 64: Physics of Parasites - Joint Focus Session (BP/DY) organized by Holger Stark

Time: Friday 9:30–12:15 Location: SCH A251

Invited Talk DY 64.1 Fri 9:30 SCH A251

Spontaneous curvature and membrane curling for malaria-infected erythrocytes — •Manouk Abkarian[1,2], Octavio Albarran Arriagada[2], Gladys Massiera[2], Cyril Claudet[1,2], Andrew Callan Jones[2], Vladimir Lorman[2], and Catherine Braun Breton[3] — [1]Centre de Biochimie Structurale, Montpellier, France — [2]Laboratoire Charles Coulomb, Monptellier, France — [3]Dynamique des Interactions Membranaires Normales et Pathologiques, Montpellier, France

The culminating step of the intra-erythrocytic development of P. falciparum, the causative agent of malaria, is the spectacular release of multiple invasive merozoites upon rupture and curling of the infected erythrocyte membrane in a split second. We rationalized curling eversion by the acquisition of a high (negative) natural curvature c0 by the iEM, at a moment during parasite development. In this presentation, we will discuss our current investigation on curling both experimentally and theoretically. In particular, we will show with recent data that c0 is acquired several hours before maturation, by inducing a metastable curled and opened pore state in the iEM. I will discuss such stability using a more sophisticated model of the iEM taking into account its axisymmetry, the pore line tension and the iEM shear elasticity. Our model captures such a metastability and predicts the dynamics during egress when considering the internal and external viscous dissipations of the iEM. In particular, our approach underlines the importance of the membrane viscous flow thanks to the study of macroscopic elastic naturally curved ribbons.

DY 64.2 Fri 10:00 SCH A251

Shape and adhesiveness of malaria-infected red blood cells — Anil Kumar Dasanna, Marco Linke, Mailin Waldecker, Christine Lansche, Sirikamol Srismith, Marek Cyrklaff, Cecilia P. Sanchez, Michael Lanzer, and •Ulrich S. Schwarz — Heidelberg University

An infection of a red blood cell by the malaria parasite takes approximately 48 hours and during this time, the host cell is completely remodelled by the parasite. In particular, the parasite induces an adhesive structure on the host cell surface that keeps the infected red blood cell (iRBC) in the vasculature for a longer time and thus avoids clearance by the spleen. At the end of the infectious cycle, the iRBC ruptures and around 20 new parasites are released into the blood stream. Using fluorescence microscopy and image processing, we have found experimentally that during this process, the surface area of the iRBC is relatively constant, while the volume increases by 60 percent due to increased osmotic pressure, leading to a final reduced volume of 1 and thus to a spherical shape. This shape transition becomes apparent at the schizont stage (40 hours after infection). Using flow chamber experiments, we show that at the same time, the movement of iRBC under flow on endothelial monolayers changes from flipping to rolling adhesion. Using adhesive dynamics simulations, we systematically predict the effect of the adhesive structure on the rolling adhesion of schizont-stage iRBC, in good agreement with our experimental results.

DY 64.3 Fri 10:30 SCH A251

Deadly microswimmers - how trypanosomes move in blood and navigate in the tsetse fly — Sarah Schuster, Tim Krüger, and •Markus Engstler — Department of Cell and Developmental Biology, Biocenter, University of Würzburg, Würzburg, Germany

Trypanosomes are flagellate microswimmers and causative agents of deadly human diseases. The parasites swim freely in the blood and tissue fluids of their mammalian hosts, where they employ hydrodynamic drag to escape immune destruction. We found that different trypanosomes species reveal distinct motion patterns, which allows adaptations to diverse infection niches. Cell motility is essential for trypanosome survival, not only in the mammal, but also in the transmitting insect, the blood sucking tsetse fly. Within the tsetse, the parasites pass through different microenvironments and undergo several developmental transitions. This involves crossing various barriers and confined surroundings, concurrent with major morphological changes. This lecture introduces the trypanosome microswimmer system and focuses on the tsetse fly stages. Light sheet fluorescence microscopy is presented as a powerful tool for the 3D analysis of geometries within the tsetse fly's digestive tract. High spatio-temporal resolution microscopic analyses reveal how the different forms of trypanosomes exploit obstacles and borders for navigation in a complex environment. Transitions between solitary swimming and swarming mark the 30 days long journey of the trypanosomes through the fly. The parasites' behaviours range from self-avoidance to collective motion. We suggest that the trypanosome system is well suited for addressing some fundamental questions related to active motion in the world of low Reynolds numbers.

15 min break

DY 64.4 Fri 11:15 SCH A251

An *in silico* model for the African trypanosome — •Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

The African trypanosome is the causative agent of the sleeping sickness and there is tremendous interest in understanding all aspects of how it moves forward and how it interacts with its environment. This includes the blood flow in blood vessels and passing the brain-blood barrier. Therefore, in the past years we have developed an *in silico* model for the African trypanosome, which fairly well captures its swimming motion [1-3]. The trypanosome has a conventional eukaryotic flagellum attached to its body. When a bending wave runs along the flagellum, the whole body deforms and is able to swim in the liquid environment, which me model with a particle-based solver of the Stokes equations called multi-particle collision dynamics.

With the help of the *in silico* model, we are able to demonstrate that the helical attachment of the flagellum optimizes the swimming speed [3], which helps the trypanosome to dispose of antibodies. We also simulate different morphotypes that occur during the parasite's development in the tsetse fly [3]. Finally, we address swimming in confinement and demonstrate that nearby channel walls or obstacles help the trypanosome to move forward.

[1] S. B. Babu and H. Stark, New J. Phys. **14**, 085012 (2012).
[2] N. Heddergott *et al.*, PLoS Pathogen **8**, e1003023 (2012).
[3] D. Alizadehrad, T. Krüger, M. Engstler, and H. Stark, PLoS Comput. Biol. **11**, e1003967 (2015).

DY 64.5 Fri 11:45 SCH A251

The development of a novel malaria diagnostic device — •Agnes Orban[1], Adam Butykai[1], Petra Molnar[1], Maria Pukancsik[1], Tivadar Zelles[2], Stephan Karl[3], and Istvan Kezsmarki[1] — [1]Dept. of Physics, Budapest Uni. of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, 1111 Budapest, HU — [2]Dept. of Oral Biology, Semmelweis University, 1089 Budapest, HU — [3]Infection and Immunity Division, Walter and Eliza Hall Institute of Medical Research,

Parkville, Victoria, AU

Although malaria is the most threatening parasitic disease worldwide and a global health issue, the current standard for its detection still remains the microscopic observation of stained blood smears. A novel cost-effective, automated, yet sensitive diagnostic method is needed for malaria detection both as an in-field instrument and as a laboratory tool for malaria researchers.

Our group aims to design such a device based on the detection of the magnetically induced linear dichroism of the malaria pigment crystals (hemozoin) by replacing the conventional polarization-modulation detection scheme with a rotating magnetic field. This concept enables a very high sensitivity detection of both synthetic and natural malaria pigment crystals as tested on suspensions of synthetic hemozoin; on hemozoin produced by *in vitro Plasmodium falciparum* cultures and on *in vivo* mouse models and human samples.

My brief introduction into the technological background will be followed by the presentations of the test results by my colleagues.

DY 64.6 Fri 12:00 SCH A251

Pre-clinical testing of a novel malaria diagnostic device — •Petra Molnar[1], Agnes Orban[1], Adam Butykai[1], Maria Pukancsik[1], Istvan Kezsmarki[1], Tivadar Zelles[2], Istvan Kucsera[3], Jetsumon Prachumsri[4], and Stephan Karl[5] — [1]Dept of Physics, Budapest Uni. of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, 1111 Budapest, HU — [2]Dept of Oral Biology, Semmelweis Uni.,1089 Budapest, HU — [3]National Center for Epidemiology, 1097 Budapest, HU — [4]Mahidol Vivax Research Center (MVRC) of Mahidol Uni., Bangkok, TH — [5]Infection and Immunity Division, Walter and Eliza Hall Institute of Medical Research, Parkville, Victoria, AU

We have developed a compact and inexpensive rotating-crystal magneto-optical diagnostic (RMOD) device based on the detection of hemozoin crystals, a metabolic byproduct of all *Plasmodium* species. The first step of the in-field validation had been carried out in Thailand. To assess the diagnostic performance of the RMOD technique, 50 field-collected frozen human blood samples were measured at the MVRC. The RMOD method was also tested in collaboration with Dr. Stephan Karl, using field samples (n≈800) previously collected from symptomatic children prior to treatment and following combination therapies at Modilon Hospital in Papua New Guinea. These samples, well characterized by light microscopy and quantitative PCR, have offered an ideal opportunity to i) assess the diagnostic capability of the RMOD method and ii) study the hemozoin clearance kinetics in patient samples.

DY 65: Glasses and Glass Transition (joint session DY/CPP/DF)

Time: Friday 10:00–12:30 Location: ZEU 118

DY 65.1 Fri 10:00 ZEU 118

Molecular Dynamics Simulations of Aqueous Mixtures in Bulk and Nano-Confinement — •Niels Müller, Rebecca Schmitz, and Michael Vogel — Institut für Festkörperphysik, Technische Universität Darmstadt

Binary mixtures of glass forming liquids have complex dynamical properties, leading to shifted time scales of the dynamics or changed temperature dependence compared to the respective behavior of the pure liquids. We performed MD simulations of ethylene-glycol water mixtures in silica-pores, which show unmixing near the pore wall and a change from non-Arrhenius to Arrhenius like temperature dependence. To single out the origin of these unusual behaviors we use binary mixtures composed of two water-like molecules with different polarity as a model system. These systems avoid steric effects from molecules of different size and have the characteristic tetrahedral order of water, but form hydrogen bonds of different strength. Through simulations in a wide temperature range we probe unmixing transitions of these systems. In addition, we confine these model mixtures by walls formed by fixed molecules of one of the water-like species. In this way, we systematically study the effect of the polarity of the confinement on mixtures of hydrogen-bonded liquids. Performing spatially resolved analyses or selecting a subset of the system we can gather detailed insights into the effects of confinement on the dynamics of these systems.

DY 65.2 Fri 10:15 ZEU 118

The glass transition as a mixture of random organization and athermal jamming — Moumita Maiti and •Michael Schmiedeberg — Institut für Theoretische Physik 1, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We explore the properties of the glass transition by employing a model system for a mixture of athermal jamming and random organization. We start with random configurations of soft repulsive spheres. While athermal jamming is realized by heading for the local minimum of the overlap energy without crossing energy barriers, random organization is obtained if we displace overlapping particles randomly in each step [1]. When mixing these protocols, we obtain a transition which is in the universality class of a directed percolation transition in time. Furthermore, we reveal that the limit of a small but nonzero probability of random steps differs from the case without random steps. This limit corresponds to the glass transition at small but non-zero temperatures. As a consequence the glass transition is a directed percolation transition and is fundamentally different from the athermal jamming transition. Finally, we explore the relation to spatial percolation transitions.

[1] L. Milz and M. Schmiedeberg, Connecting the random organization transition and jamming within a unifying model system, Phys. Rev. E 88, 062308 (2013).

DY 65.3 Fri 10:30 ZEU 118

NMR and BDS Experiments on Water confined in MCM-41 — •Edda Klotz, Matthias Sattig, Christina Lederle, and Michael Vogel — TU Darmstadt Solid State Physics, Darmstadt, Germany

The investigation of the dynamics of water in confinement is relevant for various fields of interest, from biological applications to geological ones. It is well established that confined water undergoes a dynamic crossover upon supercooling. However, the origin of the crossover is controversially discussed. To further study this issue, we focus on water im MCM-41 silica nanopores and use por diameters for which well defined partial freezing occurs. Calorimetric studies are performed to characterize this freezing behavior. Moreover, nuclear magnetic resonance (NMR) and broadband dielectric spectroscopy (BDS) are applied to ascertain the dynamics of the non-freezing water fraction cross the freezing transition. The dielectric spectra exhibit several processes that are sensitive to an appearance of a solid water fraction. ^{2}H-NMR allows us to show that one of the processes can be identified with the rotational motion of water, exhibiting a kink in the temperature depenence at the freezing-transition. Moreover, ^{1}H static field gradient NMR yields self-diffusion coefficients of water, which can be linked to freezing-affected polarization processes in BDS. Thus, these combined studies clearly show a dynamic crossover due to formation of a solid water fraction.

DY 65.4 Fri 10:45 ZEU 118

Water Dynamics in Mesoporous Silica Confinement — •Max Schäfer, Edda Klotz, Alexander Hariri, and Michael Vogel — Institut für Festkörperphysik, TU-Darmstadt, Germany

Confinement effects on the dynamics of water are examined using mesoporous silica MCM-41 with various pore diameters. Additionally the size of these pores are systematically modified by atomic layer deposition with Al2O3. To explore rotational motion, we combine different 2H NMR technics that are sensitive to molecular reorientations. Applying spin-lattice-relaxation, line shape analyzes and stimulated echo experiments, we cover the dynamical range down to very slow dynamics in a deeply supercooled temperature regime. 1H diffusion measurements in an ultra high static field gradient were performed also. These experiments were supplemented by broadband dielectric spectroscopy and differential scanning calorimetry. We find that the temperature dependence of the structural alpha-relaxation exhibits a kink, which is strongly related to the pore size. We show that this kink is not associated to a proposed liquid-liquid phase transition of water, but to partial freezing. Furthermore we study confinement effects on dynamics and phase behavior in binary mixtures of water and glycerol for various concentrations. The properties of the hydrogen bond network and an eventually phase separation initiated by the confinement

are of great interest. Glycerol dynamics for confined mixtures show an Arrhenius behavior at low temperatures in contrast to bulk mixtures and to pure glycerol confined in MCM-41. The similarity to water dynamics in confinement suggests a cooperative motion of water and glycerol.

DY 65.5 Fri 11:00 ZEU 118

Dynamical coexistence in a polydisperse hard-sphere liquid — •Matteo Campo[1,2], Christopher Patrick Royall[3], and Thomas Speck[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]H.H. Wills Physics Laboratory, University of Bristol, United Kingdom

The glass transition is a long-standing challenge of condensed matter physics. One of the problems is that no significant change in the global structure seems to arise upon vitrification [1]. Recent studies however have recovered the old idea of Frank according to which geometric motifs which minimise the local free energy, so-called locally favoured structures (LFS), would grow in correlation with the slow regions of the glass and thus play an important role in the transition [2]. Among the key insights is the identification of a non-equilibrium phase transition in trajectory space, which implies phase coexistence between a slow phase rich in LFS and the normal supercooled liquid. Here we present a study of a polydisperse hard-sphere model glassformer and its LFS properties upon crystallization [3] and vitrification. We combine our numerical simulations with experimental observations that support the picture of the non-equilibrium phase transition in trajectory space.

[1] Ludovic Berthier and Giulio Biroli. REV MOD PHYS, 2011.
[2] C Patrick Royall and Stephen R Williams. PHYS REP, 2015.
[3] Matteo Campo and Thomas Speck. JSTAT, 2016.

15 min. break

DY 65.6 Fri 11:30 ZEU 118

Electro-diffusion versus chemical diffusion in alkali calcium phosphate glasses - implication of structural changes — •Anneli Hein, Johannes Martin, Martin Schäfer, and Karl-Michael Weitzel — Philipps-Universität Marburg

A long term transport experiment has been performed on a bioactive calcium phosphate glass of the molar composition 30 CaO *25 NaO *45 P2O5 using the technique of bombardment induced ion transport (BIIT) with potassium as foreign bombarder ion. Ion transport due to gradients of the electrical potential and the concentration lead to incorporation of K+ and depletion of both Na+ and Ca++ by electro-diffusion in forward direction. The resulting concentration profile has been quantitatively analyzed by ToF-SIMS. Further analysis of the P+ and POx+ signals (x = 1-4) shows characteristic changes of the structure of the local glass network. Since the concentration profiles imprinted by the BIIT constitute pronounced concentration gradients, these depletion profiles further evolve on a much longer time scale due to chemical diffusion (absence of electric potential gradients). The former depletion zone is partially refilled by chemical diffusion. At the same time the structural changes of the glass network are demonstrated to be reversible. Numerical simulations on the basis of the coupled Nernst-Planck-Poisson equations allow deriving the diffusion coefficients of sodium, potassium and calcium for both cases, i.e. electro-diffusion and chemical diffusion. The two experiments are sensitive to different aspects of the diffusion coefficients and thus are complementary.

DY 65.7 Fri 11:45 ZEU 118

Confinement effects on the correlation of plasticity in amorphous solids — •Muhammad Hassani, Philipp Engels, and Fathollah Varnik — Interdisciplinary Centre for Advanced Materials Simulation (ICAMS), Ruhr Universität, Bochum, Germany

In amorphous solids, spatio-temporal correlations of plastic deformation are known to be mediated by the elastic medium [1]. Solid walls may strongly alter this elastic propagator and are thus expected to also influence these correlations. We study this issue via large scale molecular dynamics (MD) simulations. Spatial correlations of plastic activity are found to decay more slowly when approaching a wall. This observation is paralleled by a similar trend in the case of the strain field around a spherical inclusion placed at various distances from a wall. Results obtained from MD simulations are in quantitative agreement with numerical solution of continuum mechanics equations in the presence of an inclusion [2,3].

[1] F. Varnik, S. Mandal, V. Chikkadi, D. Denisov, P. Olsson, D. Vagberg, D. Raabe, and P. Schall, Correlations of plasticity in sheared glasses, Phys. Rev. E 89, 040301 (2014)
[2] A. Nicolas and J.-L. Barrat, A mesoscopic model for the rheology of soft amorphous solids, with application to microchannel flows, Faraday Discuss. 167, 567 (2013)
[3] M. Hassani, P. Engels, and F. Varnik, Confinement effects on the correlation of plasticity in amorphous solids (in preparation

DY 65.8 Fri 12:00 ZEU 118

Glass transitions, semiconductor-metal (SC-M) transitions and fragilities in Ge-V-Te (V=As, or Sb) liquid alloys: the difference one element can make — •Shuai Wei[1], Garrett Coleman[2], Pierre Lucas[2], and C.Austen Angell[1] — [1]Arizona State University — [2]University of Arizona

Glass transition temperatures (Tg) and liquid fragilities are measured along a line of constant Ge content in the system Ge-As-Te, and contrasted with the lack of glass-forming ability in the twin system Ge-Sb-Te at the same Ge content. The one composition established as free of crystal contamination in the latter system shows a behavior opposite to that of more covalent system. Comparison of Tg vs bond density in the three systems Ge-As-chalcogen differing in chalcogen i.e. S, Se, or Te, shows that as the chalcogen becomes more metallic, the bond density effect on Tg becomes systematically weaker, with a crossover at <r> = 2.3. When the more metallic Sb replaces As at <r> greater than 2.3, incipient metallicity rather than directional bond covalency apparently gains control of the physics. This leads us to an examination of the electronic conductivity and, then, semiconductor-to-metal (SC-M) transitions, with their associated thermodynamic manifestations, in relevant liquid alloys. The thermodynamic components control liquid fragility and cause fragile-to-strong transitions during cooling. We tentatively conclude that liquid state behavior in phase change materials (PCMs) is controlled by liquid state SC-M transitions that have become submerged below the liquidus surface. The analogy to supercooled water phenomenology is highlighted.

DY 65.9 Fri 12:15 ZEU 118

Glass structure and quantum efficiency of luminescent borate glass — •A. Charlotte Rimbach[1], Bernd Ahrens[1,2], Franziska Steudel[2], and Stefan Schweizer[1,2] — [1]South Westphalia University of Applied Sciences, Luebecker Ring 2, 59494 Soest — [2]Fraunhofer Application Center for Inorganic Phosphors, Branch Lab of Fraunhofer Institute for Microstructure of Materials and Systems IMWS, Luebecker Ring 2, 59494 Soest

Luminescent glasses have gained more importance in the last decades, in particular for lasers, optical fibres, and optical amplifiers. For optical applications, borate glass is very versatile in shape and a suitable host for luminescent lanthanide ions due to its good lanthanide ion solubility. The borate glass system possesses a high transparency, low melting point as well as high mechanical, chemical, and thermal stability. Various luminescent borate glasses using boron oxide as network former and lithium oxide as network modifier are prepared. Here, the ratio between network former and network modifier determines the mechanical and chemical properties of the glass. An important parameter for the evaluation of luminescent materials is the absolute photoluminescence quantum efficiency (QE), i.e. the ratio of emitted to absorbed photons. While the ratio between network former and network modifier affects the QE only slightly, additional doping with aluminium oxide to reduce hygroscopicity results in a significant decrease in QE. Raman and Fourier transform infrared spectroscopy are used to analyze the structure of the glass network; the results are correlated with the QE measurements.