DY 72: Poster: Stoch. and Nonl. Dy., Modeling, Compl. Sys.

Time: Thursday 15:30–18:00 Location: Poster A

DY 72.1 Thu 15:30 Poster A

Stochastic Kuramoto oscillators with discrete phase states — •David J. Jörg — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

We present a generalization of the Kuramoto phase oscillator model in which phases advance in discrete phase increments through Poisson processes, rendering both intrinsic oscillations and coupling inherently stochastic. We study the effects of phase discretization on the synchronization and precision properties of the coupled system both analytically and numerically. Remarkably, many key observables such as the steady-state synchrony and the quality of oscillations show distinct extrema while converging to the classical Kuramoto model in the limit of a continuous phase. The phase-discretized model provides a general framework for coupled oscillations in a Markov chain setting.

DY 72.2 Thu 15:30 Poster A

Analysis of stochastic bifurcations with phase portraits — •Marc Mendler, Johannes Falk, and Barbara Drossel — Technische Universität Darmstadt, Institut für Festkörperphysik

We propose a new method to obtain phase portraits for stochastic systems, which in many cases give a correct picture of the most likely states of the system. To this purpose, we start with the Fokker-Planck-Equation of a reaction network and separate the dynamics into a convection and a diffusion part. This allows us to draw stochastic phase portraits as vector plots of the convection part, which is also the determining equation for the extrema of the stationary probability density of the system. We apply this method to different example systems, for which the attractors of the deterministic and stochastic model version can differ from each other. We show that noise-induced bistability and oscillations are correctly reproduced in the stochastic phase portrait in these examples, as well as the bifurcations between them.

DY 72.3 Thu 15:30 Poster A

The influence of intrinsic noise on the dynamics of small gene regulation modules — •Lara Becker and Barbara Drossel — TU Darmstadt, Germany

We examine how the intrinsic stochasticity associated with small molecule numbers affects the dynamics of simple two-gene modules in gene regulatory networks. To this purpose, we model the module in terms of a set of chemical reactions for the involved mRNA and protein molecules. We compare the dynamics obtained from deterministic rate equations with the stochastic dynamics obtained from the Master equation. For the deterministic version, we use the generalized modelling approach, which is based on a linear stability analysis of fixed points, in order to obtain the stability diagram that shows the saddle-node and Hopf bifurcations of the system. For the stochastic system, we perform stochastic simulations using the Gillespie algorithm. We also perform various analytical studies of the stochastic system. On the one hand, we calculate the power spectral density of the fluctuations based on the Linear Noise Approximation and show that for the two-gene negative feedback loop oscillatory behaviour can occur for the stochastic model while it cannot for the deterministic model. Furthermore, we calculate stochastic phase portraits in order to explore the parameter range that shows bistability in the deterministic model.

DY 72.4 Thu 15:30 Poster A

Using Neural Networks to Obtain the Dynamics on the Normally Hyperbolic Invariant Manifold of Driven Systems — •Martin Tschöpe, Johannes Reiff, Robin Bardakcioglu, Matthias Feldmaier, Jörg Main, and Günter Wunner — Institut für Theoretische Physik 1 Universität Stuttgart, Deutschland

The semi-classical reaction dynamics in Transition State Theory (TST) for periodically driven systems has been solved numerically in the past. It has been shown that the reaction rate can be determined by integrating a large number of trajectories and analyzing phase space structures.

An alternative way to obtain a reaction rate for these systems might be to analyze the dynamics on the Normally Hyperbolic Invariant Manifold (NHIM) itself. This task is especially challenging, due to the critical properties of such trajectories. Our work will tackle this disadvantage by using neural networks as a tool to stabilize the numerical integration on the NHIM.

DY 72.5 Thu 15:30 Poster A

Dynamics and Phase Space Structure for Reactions with Multiple Saddles — •Johannes Reiff, Robin Bardakcioglu, Martin Tschöpe, Matthias Feldmaier, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

In chemical and physical reactions with time-dependent potentials, an important task is to distinguish products from reactants. In Transition State Theory (TST), this task has been successfully tackled semi-classically for a single potential barrier using Dividing Surfaces (DSs) attached to Normally Hyperbolic Invariant Manifolds (NHIMs). However, when considering multiple time-dependent saddles, it is still unknown whether a recrossing-free dividing surface exists.

We use Lagrangian descriptors and variations thereof to analyze the phase space structure of such multi-saddle systems. In doing so, fractal-like structures are revealed which make the search for recrossing-free DSs and therefore time-dependent reaction rates more challenging.

DY 72.6 Thu 15:30 Poster A

On the dynamics of a periodically driven damped harmonic oscillator coupled to Ising spins — •Paul Zech and Günter Radons — Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany

We aim at an understanding of the dynamical properties of a periodically driven damped harmonic oscillator coupled to a system showing complex hysteresis, such as a random field Ising model at zero temperature. In a first step we investigate a simplified model, the harmonic oscillator coupled to independent spins in quenched random local fields. The model is characterized by continuous (position, velocity, phase) and discrete (spin) degrees of freedom, which classifies it as a hybrid system. By applying established methods of dynamical systems theory and time series analysis, such as Poincaré sections, the determination of Kaplan-Yorke and box-counting dimensions, and by Fourier analysis, we show, how in this system chaos emerges. Furthermore we investigate the dynamical behavior of the system for an increasing number of spins. In doing so we are specifically interested in the behavior as the thermodynamic limit is approached. In this limit the system behaves like a driven harmonic oscillator with an additional nonlinear smooth external force, which means, that the hybrid character of the system vanishes.

DY 72.7 Thu 15:30 Poster A

Application of Closed Orbit Theory to Magnetoexcitons in Cuprous Oxide — •Jonathan Luft genannt Philipps, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

Highly excited excitons in cuprous oxide can be described as hydrogen-like Rydberg systems. As there are many semiclassical approaches for the description of the hydrogen atom, we want to apply the closed orbit theory to describe the excitons in cuprous oxide. In contrast to hydrogen atoms, describing these excitons is more challenging due to the underlying band structure. Via calculating the classical trajectories of these highly excited excitons and applying closed orbit theory, we are able to determine the semiclassical photoabsorption spectra. The resulting absorption spectra will be compared with experimental results.

DY 72.8 Thu 15:30 Poster A

Dynamics of asymmetrically coupled systems: averaging over qualitatively different systems? — •Domenic Wagner[1] and Jens Christian Claussen[2,1] — [1]INB, Universität zu Lübeck, Germany — [2]Computational Systems Biology, Jacobs University Bremen, Germany

Studying the dynamics of large coupled nonlinear systems with random interactions is a common approach to model the dynamics of a wide range of biological systems. One of the key parameters of stability has been identified in [1] as the asymmetry parameter of the coupling matrix. In [1| the Ljapunov exponent (of trajectories driven by a common noise source) has been investigated including averaging over many different coupling matrices, which however can belong to systems with qualitatively different phase spaces and attraction sets.

We investigate specific of these cases including dynamics from evolutionary game theory and neural networks.

[1| L. Molgedey, J. Schuchhardt, H.G. Schuster, PRL 69, 3717 (1992)

DY 72.9 Thu 15:30 Poster A

Stochastic Differential Equations Driven by Deterministic Chaotic Maps: Analytic Solutions of the Perron-Frobenius Equation — •Griffin Williams and Christian Beck — School of Mathematical Sciences, Queen Mary University of London, Mile End Road, E1 4NS UK

We consider discrete-time dynamical systems systems with a linear relaxation dynamics that are driven by deterministic chaotic forces. By perturbative expansion in a small time scale parameter, we derive from the Perron-Frobenius equation the corrections to ordinary Fokker-Planck equations in leading order of the time scale separation parameter. We present analytic solutions to the equations for the example of driving forces generated by N-th order Chebychev maps. The leading order corrections are universal for $N \geq 4$ but different for $N = 2$ and $N = 3$. We also study diffusively coupled Chebychev maps as driving forces.

DY 72.10 Thu 15:30 Poster A

Driven soliton molecule vibrations: Real-time studies of nonlinear behavior — •Felix Kurtz[1], Daniel R. Solli[1,2], Georg Herink[3], and Claus Ropers[1] — [1]IV. Physical Institute - Solids and Nanostructures, University of Göttingen, Germany — [2]Department of Electrical Engineering, University of California, Los Angeles, USA — [3]Experimental Physics III, University of Bayreuth, Germany

Many nonlinear systems exhibit solitons, localized excitations balanced by dispersion and nonlinearity, which also can bind together in so-called soliton molecules. Here, we study the behavior of soliton molecules in a mode-locked laser oscillator. By employing the time-stretch dispersive Fourier transform (TS-DFT), we experimentally access the previously hidden internal dynamics of soliton molecules, tracking their pulse separation and relative phase in real-time. A diverse set of dynamical trajectories is observed, including periodic oscillations of the pulse separation and relative phase [1]. Moreover, we actively drive internal vibrations over a range of frequencies and amplitudes. We identify internal resonances of the soliton molecules and detect higher harmonic and subharmonic responses.

[1] G. Herink, F. Kurtz, B. Jalali, D.R. Solli, C. Ropers, *Science* **356**, 50-54 (2017)

DY 72.11 Thu 15:30 Poster A

Magnetic Phenomena in Spiking Neural Networks — •Andreas Baumbach[1], Mihai Petrovici[1,2], Karlheinz Meier[1], and Johannes Schemmel[1] — [1]Heidelberg University, Kirchhoff Institut for Physics, Heidelberg, Germany — [2]University of Bern, Department of Physiology, Bern, Switzerland

Systems close to criticality are always of particular interest. The arguably simplest model known to exhibit critical phenomena is the Ising model for ferromagnetism. Recent work on spiking neural networks developed a description of these biologically inspired networks under poissonian noise input as a Boltzmann machine. As such a description is widely used in neuroscience to effectively describe biological models and data one would expect that all the phenomena known from statistical physics can also be observed in these systems.

This work investigates a simplified model, the Neuralsampling framework introduced by Buesing et al., which we modify to include exponentially decaying interactions (resembling biological interactions) in an Ising-like network. While the global properties, like the unordered phase in the infinite temperature limit and the ordered phase in the zero temperature limit, we show that the phase diagram of this model shows richer phenomena than the classical Ising model. For example it allows a system to pass through multiple phases, rather than only the unordered-ordered transition, while cooling down.

DY 72.12 Thu 15:30 Poster A

Chain and ladder models with two-body interactions and analytical ground states — Sourav Manna[1] and •Anne E. B. Nielsen[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, D-01187 Dresden, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, D-01187 Dresden, Germany

We consider a family of spin-1/2 models with few-body, SU(2) invariant Hamiltonians and analytically known ground states related to the Haldane-Shastry (HS) wavefunction. The spins are placed on the surface of a cylinder, and the standard HS model is obtained by placing the spins with equal spacing in a circle around the cylinder. Here, we show that another interesting family of models with two-body exchange interactions is obtained if we instead place the spins along one or two lines parallel to the cylinder axis, giving rise to chain and ladder models, respectively. In this case, the circumference of the cylinder can be changed independently from the other length scales in the system, and we use Monte Carlo simulations and analytical investigations to study how the circumference affects the properties of the models. If the circumference is large compared to the other length scales in the system, we find that the two legs of the ladder decouple into two chains with HS-like properties, and if the circumference is small compared to the other length scales the wavefunction reduces to a product of singlets

DY 72.13 Thu 15:30 Poster A

Constant pressure regime in hydraulic fracturing — •Anton Solovev[1,2] and Yuri Petrov[2,3] — [1]Center for Advancing Electronics Dresden cfaed, TU Dresden, Dresden, Germany — [2]St Petersburg State University, St Petersburg, Russia — [3]Institute of Problems of Mechanical Engineering of the RAS, St Petersburg, Russia

Hydraulic fracturing is a process of fracture development and propagating in a brittle medium as a result of pressurized fluid injection.

Our study is based on a one-dimensional local elastic model (the PKN model) in particle velocity formulation. We investigate how a non-stationary component of the influx function affects the hydrofracturing in an impermeable rock formation.

Further, we propose an influx function that results in almost constant maximum pressure inside the fracture. Typically in literature constant influx is considered instead. However, it produces unbounded growth of pressure and therefore is not always suitable for describing a pumping engine working in a steady regime.

DY 72.14 Thu 15:30 Poster A

Optimal conditions for coupled geological carbon storage and enhanced oil recovery — •Pegah Shakeri[1,2] and Ghasem Zargar[2] — [1]Saarland University, Experimental Physics, Saarbrücken, Germany — [2]Petroleum University of Technology, Ahvaz, Iran

Utilization of anthropogenic carbon dioxide as an enhanced oil recovery agent has been introduced as a practical solution to compensate for the costs of carbon capture and geological storage by the revenues of the produced oil. A series of experimental laboratory work and simulation studies at the reservoir scale were conducted to examine the impact of several reservoir parameters (e.g. rock type, degree of heterogeneity, relative permeability hysteresis, etc.) and different flood schemes and design variables on the performance of coupled CO2 sequestration and enhanced oil recovery (EOR) process. The design of experiment method in conjunction with response surface methodology was employed for sensitivity analysis and optimization purpose. It was concluded that, in general, applying vertical injection and production wells for Water Alternative CO2 Gas injection (WAG) scheme under the miscible condition in less heterogeneous carbonate reservoirs with lower permeability contrast are the most satisfying combination for coupled CO2 sequestration and enhanced oil recovery. It was also observed that hysteresis plays a significant role in CO2 entrapment especially in alternating injection scenarios due to successive imbibition and drainage cycles occurring during the process. High saturation of trapped gas lowers oil relative permeability which leads to a better but slower oil sweep in the reservoir.

DY 72.15 Thu 15:30 Poster A

Local Riemannian geometry of model manifolds and its implications for practical parameter identifiability — •Daniel Lill[1], Jens Timmer[1,2], and Daniel Kaschek[1] — [1]Institute of Physics, Freiburg University — [2]BIOSS Centre for Biological Signaling Studies, Freiburg University

When dynamic models are fitted to time-resolved experimental data, parameter estimates can be poorly constrained albeit being identifiable in principle. This means that along certain paths in the parameter space, the negative log-likelihood does not exceed a given threshold but remains bounded. This so-called practical non-identifiability can only be detected by Monte Carlo sampling or systematic scanning by the profile likelihood method. In contrast, any method based on a Taylor expansion of the log-likelihood around the optimum, e.g., parameter uncertainty estimation by the Fisher Information Matrix, reveals no information about the boundedness at all.

We show that for some dynamic models the information about the bounds of the log-likelihood is already contained in the Christoffel symbols, which are computed from model sensitivities up to order two at the optimum. Assuming constant Christoffel symbols in the geodesic equation, approximate Riemannian Normal Coordinates are constructed. The new coordinates give rise to an approximative log-likelihood, featuring flat directions and bounds similar to that of the original log-likelihood.

DY 72.16 Thu 15:30 Poster A

Investigation of nanofiber mats by statistical examination of AFM images — •Tomasz Blachowicz[1], Tobias Böhm[2], and Andrea Ehrmann[2] — [1]Silesian University of Technology, Institute of Physics - Center for Science and Education, 44-100 Gliwice, Poland — [2]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, 33619 Bielefeld, Germany

Image processing of pictures from fibers and fibrous materials allows for investigating diverse geometrical properties, such as yarn hairiness, fiber bifurcations, or fiber lengths and diameters. Such irregular sample sets are naturally suitable to statistical examination of the images, using a random-walk algorithm, resulting in the calculation of the so-called Hurst exponent. While previous investigations have proven the appropriateness of this method for examinations of different fibers, yarns and textile fabrics [1-3], a recent study used AFM (atomic force microscopy) images, split into different gray scales, to analyze and quantify differences between various nanofiber mats created from polyacrylonitrile. Besides a strong influence of the nanofiber diameters, a significant impact of the AFM settings became visible, offering an additional optimization tool for AFM measurements.

[1] T. Blachowicz, A. Ehrmann, K. Domino, Physica A: Statistical Mechanics and its Applications 452, 167-177 (2016)

[2] A. Ehrmann, T. Blachowicz, K. Domino, S. Aumann, M. O. Weber, H. Zghidi, Text. Res. J. 85, 2147-2154 (2015)

[3] A. Ehrmann, T. Blachowicz, H. Zghidi, M. O. Weber, Journal of Physics: Conference Series 633, 012101 (2015)