DY 18: Nonlinear Dynamics, Synchronization and Chaos

Time: Tuesday 10:00–12:15 Location: ZEU 147

DY 18.1 Tue 10:00 ZEU 147

Synchrony at Weak Coupling in the Complexified Kuramoto Model — •Moritz Thümler[1], Shesha G.M. Sriniva[2], Malte Schröder[1], and Marc Timme[1,3] — [1]Chair for Network Dynamics, Institute of Theoretical Physics & Center for Advancing Electronics Dresden (cfaed), TU Dresden — [2]Institute of Physics and Material Sciences, Universite du Luxembourg — [3]Lakeside Labs, Klagenfurt, Austria

We present the finite-size Kuramoto model analytically continued from real to complex variables and analyze its collective dynamics. For strong coupling, synchrony appears through locked states that constitute attractors, as for the real-variable system. However, synchrony persists in the form of *complex locked states* for coupling strengths K below the transition $K^{(\mathrm{pl})}$ to classical *phase locking*. Where complex locked states are stable, their imaginary parts indicate which units belong to the locked population in the original, real-variable system. We uncover a second transition at $K' < K^{(\mathrm{pl})}$ below which complex locked states become linearly unstable yet still exist for arbitrarily small coupling strengths. The results open up a path towards a new field of network dynamics with variables complexified by analytic continuation.

DY 18.2 Tue 10:15 ZEU 147

Predicting tipping points in driven nonlinear systems — •Gwendolyn Quasebarth[1], Moritz Thümler[1], and Marc Timme[1,2] — [1]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Technical University of Dresden, Dresden, Germany — [2]Lakeside Labs, Lakeside B04b, Klagenfurt, Austria

Tipping points mark parameter values beyond which a system qualitatively changes its collective dynamics, often in undesired ways. Standard response theory for nonequilibrium nonlinear systems predicts local deviations around a stable fixed point via a polynomial in the amplitude ϵ of the driving signal. However, such standard response theories (of arbitrary order in ϵ) necessarily fail to predict nonequilibrium tipping points. Here, we propose a novel nonlinear response theory that overcomes the constraints of polynomial response theory of any order. We illustrate our findings in a class of sinusoidally driven damped nonlinear oscillators.

DY 18.3 Tue 10:30 ZEU 147

Pseudo-laminar chaos from on-off intermittency — •David Müller-Bender[1], Rahil N. Valani[2], and Günter Radons[1,3] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]School of Mathematical Sciences, University of Adelaide, Adelaide, South Australia 5005, Australia — [3]ICM - Institute for Mechanical and Industrial Engineering, 09117 Chemnitz, Germany

In finite-dimensional, chaotic, Lorenz-like wave-particle dynamical systems one can find diffusive trajectories, which share their appearance with that of laminar chaotic diffusion [Phys. Rev. Lett. 128, 074101 (2022)] known from delay systems with lag-time modulation. Applying, however, to such systems a test for laminar chaos, as proposed in [Phys. Rev. E 101, 032213 (2020)], these signals fail such test, thus leading to the notion of pseudo-laminar chaos. The latter can be interpreted as integrated periodically driven on-off intermittency. We demonstrate that, on a signal level, true laminar and pseudo-laminar chaos are hardly distinguishable in systems with and without dynamical noise. However, very pronounced differences become apparent when correlations of signals and increments are considered. We compare and contrast these properties of pseudo-laminar chaos with true laminar chaos.

Details can be found in the preprint [arXiv:2211.01278 (2022)].

DY 18.4 Tue 10:45 ZEU 147

Power-flow-based circuit synthesis of neuronal dynamics — •Karlheinz Ochs[1], Sebastian Jenderny[1], and Philipp Hövel[2] — [1]Ruhr-Universität Bochum, Germany — [2]Christians-Albrechts-Universität zu Kiel, Germany

We present a modeling framework to study neuronal dynamics based on power-flow considerations. This is inspired by a circuit synthesis and analog electronics. Exemplified by the Hindmarsh-Rose model, we demonstrate that the proposed framework reproduces key characteristics of the dynamical model, including spiking and bursting behavior. This approach is a stepping stone towards the emulation of neuronal behavior on larger networks by means of analog circuits.

15 min. break

DY 18.5 Tue 11:15 ZEU 147

On the Correlation of Functionality and Lyapunov Stability in Oscillator-based Ising machines — •Bakr Al Beattie[1], Maximiliane Noll[2], Hermann Kohlstedt[2], and Karlheinz Ochs[1] — [1]Ruhr-Universität Bochum, Lehrstuhl für digitale Kommunikationssysteme, Bochum, Deutschland — [2]Christian-Albrechts-Universität zu Kiel, Lehrstuhl für Nanoelektronik, Kiel, Deutschland

Oscillator-based Ising machines are a promising analog approach for dealing with combinatorial optimization problems that are classified as NP (nondeterministic polynomial). The idea is to mimic the Ising model by coupling electrical oscillators that behave like the spins of the Ising model. Here, the coupling should somehow map the Ising Hamiltonian onto the energy of electrical system. With this contribution, we demonstrate numerical evidence demonstrating the correlation between the Ising machine*s functionality and stability. We make use of the well-known Kuramoto model to describe a coupled oscillator network and show stability to be the key property that makes an Ising machine solve optimization problems. Furthermore, we give an answer to the question: when has an Ising machine finished solving a mapped problem?

DY 18.6 Tue 11:30 ZEU 147

Manifolds of equilibrium states in ensembles of globally coupled oscillators — •Michael Zaks — Humboldt Universität zu Berlin, Berlin, Germany

Global fields generated by ensembles of coupled oscillators are responsible for many unusual kinds of collective behavior. Among their most striking effects are existence of numerous constants of motion and a drastic reduction in the number of degrees of freedom. Here, we offer a simpler approach, restricted to the widespread situations in which the number of parameters defining the action of the global fields is smaller than the overall number of elements in the ensemble. In the phase space of such ensembles, high-dimensional manifolds composed of the equilibrium states can generically arise. Existence of these manifolds is not related to symmetries. In the simplest cases, such continua of steady states are attracting or repelling as a whole; in general, however, their stability with respect to transversal perturbations varies in the course of the motion along the manifold. Remarkably, the suggested mechanism does not require that all oscillators are identical: the sufficiently strong global field is able to counteract diversity among the ensemble units and halt the temporal evolution.

DY 18.7 Tue 11:45 ZEU 147

X-ray imaging of the sonoluminescent cavitation bubble collapse with single XFEL pulses — •Hannes Paul Hoeppe[1], Atiyeh Aghelmaleki[2], Juan Manuel Rosselló[3], Malte Vassholz[1], Markus Osterhoff[1], Daniel Schwarz[4], Johannes Hagemann[4], Robert Mettin[2], Anders Madsen[5], and Tim Salditt[1] — [1]Institute for X-ray Physics, Georg-August-University, Göttingen, Germany — [2]Third Institute of Physics, Georg-August-University, Göttingen, Germany — [3]Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia — [4]Center for X-ray and Nano Science, Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [5]European X-Ray Free-Electron Laser Facility, Schenefeld, Germany

We study the dynamics and in particular the collapse of a single cavitation bubble in water. A cavitation bubble is trapped and driven by an ultrasonic field leading to nonlinear radial oscillations. During its periodic collapses, extreme pressure and temperature is reached which can lead to the formation of a plasma core and the emission of light. The fast evolving pressure, density and temperature distribution and the shape of the bubble during its collapse has so far only been accessible by simulations. Full-field X-ray phase contrast imaging provides quantitative information of the density distribution of the sample. Implemented at X-ray free-electron lasers, this enables the investigation of fast processes and extreme states of matter with a unique contrast.

We present the evolution of the bubble's density profile during the sonoluminescent collapse and the current state of analysis.

DY 18.8 Tue 12:00 ZEU 147

Quantum synchronization in a network of dissipatively coupled linear oscillators — •Juan Moreno[1], Christopher W Wächtler[2], and Alexander Eisfeld[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Department of Physics,University of California Berkeley, CA, 94720-7300

Synchronization in classical systems has a long history and by now is a very well understood phenomenon. However, the question whether the classical notions of synchronization can be extended to the quantum regime has only recently been addressed in investigations of classically inspired models like quantum Van der Pol oscillators as well as models without classical analog. Inspired by the theoretical prediction that two-level atoms are able to synchronize even without interacting directly [1], we investigate a network of dissipatively coupled quantum harmonic oscillators. Within a mean-field approximation we find that the network is able to synchronize. For the fully quantum system described in terms of a Lindblad master equation we analyze various measures that have been proposed in the literature. Additionally, we investigate the Liouvillian spectrum in order to draw connections between the spectrum and the synchronization measures.

[1] PRA 101, 042121 (2020)