DY 27: Nonlinear Dynamics, Synchronization and Chaos - Part II

Time: Thursday 9:30–12:00 Location: ZEU 160

DY 27.1 Thu 9:30 ZEU 160

Scaling of Chaos in Strongly Nonlinear Lattices — •Mario Mulansky — Max-Planck-Institut für die Physik komplexer Systeme, Dresden

Although it is now understood that chaos in complex classical systems is the foundation of thermodynamic behavior, the detailed relations between the microscopic properties of the chaotic dynamics and the macroscopic thermodynamic observations still remain mostly in the dark. In this work, we numerically analyze the probability of chaos in strongly nonlinear Hamiltonian systems and find different scaling properties depending on the nonlinear structure of the model. We argue that these different scaling laws of chaos have definite consequences for the macroscopic diffusive behavior, as chaos is the microscopic mechanism of diffusion. This is compared with previous results on chaotic diffusion [New J. Phys. 15, 053015 (2013)], and a relation between microscopic chaos and macroscopic diffusion is established.

DY 27.2 Thu 9:45 ZEU 160

Instability of Velocity-Verlet Integrator as Stochastic Process — •Lothar Brendel — Universität Duisburg-Essen

The Velocity-Verlet integrator is ubiquitous in simulations of classical many-body systems. Though being time symmetric, it is known to be stable “only” on exponentially long times. We model its loss of stability as a stochastic process and compare the resulting characteristics to actual simulations at the verge of stability.

DY 27.3 Thu 10:00 ZEU 160

“Beating” beats “Mixing” in Heterodyne Detection Schemes — •Gerard J. Verbiest[1] and Marcel J. Rost[2] — [1]JARA-FIT and II. Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany — [2]Kamerlingh Onnes Laboratory, Leiden University, P.O. Box 9504, 2300 RA Leiden, The Netherlands

Heterodyne detection schemes are widely used, as one can measure extremely high-frequencies signals that are otherwise difficult, or even impossible, to measure experimentally. A heterodyne detection scheme can down-convert a high-frequency signal to a lower, easily measurable frequency by mixing it with a reference signal. In general, *beating* and *mixing* are contrary effects: *beating* occurs with a linear interaction, whereas heterodyne *mixing* occurs, if the interaction is nonlinear. Therefore, *beating* is ought to be unimportant in heterodyne schemes, as it does not generate a *mixing* signal. In contrast to this, we show via a derivation of a general analytical model [1] that both *beating* and *mixing* are necessary to explain the generation of the heterodyne signal. *Beating* even dominates the heterodyne signal generated by *mixing*, if the nonlinearity of the system is of higher order than quadratic. Standard textbook equations fail in this case, as they are usually based on second order approximations. We confirm our results with both an experiment [2] and a full numerical calculation [3] on the example of Heterodyne Force Microscopy.

[1] G.J. Verbiest, and M.J. Rost, Nature Physics submitted
[2] G.J. Verbiest et al., Nanotechnology 24, 365701 (2013)
[3] G.J. Verbiest et al., Ultramicroscopy 135, 113 (2013)

DY 27.4 Thu 10:15 ZEU 160

Efficiency of Monte Carlo Methods in Chaotic Systems — •Jorge C. Leitão[1], João P. V. Lopes[2], and Eduardo G. Altmann[1] — [1]Max Planck Institute for The Physics of Complex Systems, Dresden, Germany — [2]Faculdade de Engenharia da Universidade do Porto, Porto, Portugal

Monte Carlo techniques have the potential of dramatically improving the efficiency of simulations of chaotic systems. However, in it is often unclear to which extent an improvement over uniform sampling simulations is actually achieved because the Monte Carlo method struggles to efficiently sample the relevant trajectories of the phase space (e.g., the simulation suffers from critical slowing down). In this talk we discuss the efficiency of different Monte Carlo methods applied to the problem of computing: 1. the distribution of finite-time Lyapunov exponents; and 2. the escape rate in scattering systems.

DY 27.5 Thu 10:30 ZEU 160

Magnetic Spatial Forcing of a Ferrofluid Layer — •Florian Maier, Ingo Rehberg, and Reinhard Richter — Experimentalphysik 5, Universität Bayreuth, D-95444 Bayreuth

In isotropic two-dimensional pattern-forming systems with broken up-down symmetry, hexagons are the first pattern to arise due to a transcritical bifurcation, as summarized in [1]. One famous example is the Rosensweig instability at an interface between ferrofluid and air subjected to a normal magnetic field [2]. However, stripes become the preferred pattern for a spatially periodic resonant forcing [1]. Experiments have been performed using a thin layer of ferrofluid forced by means of a one-dimensional array of current carrying wires [3] with $k_\mathrm{m} = k_\mathrm{c}$. Here k_m (k_c) denotes the modulation (capillary) wave number, respectively. We report new results for a larger aspect ratio, taking also into account a varying layer thickness.

[1] R. Peter, M. Hilt, F. Ziebert, J. Bammert, C. Erlenkämper, N. Lorscheid, C. Weitenberg, A. Winter, M. Hammele, and W. Zimmermann, Phys Rev. E, **71**, 046212 (2005).
[2] M. D. Cowley and R. E. Rosensweig, J. Fluid Mech., vol. **30**, no. 4, pp. 671-688 (1967).
[3] Th. Friedrich, A. Lange, I. Rehberg, R. Richter, Magnetohydrodynamics, Vol. **47**, No. 2, pp. 167-173 (2011).

15 min break

DY 27.6 Thu 11:00 ZEU 160

Periodically driven oscillatory demixing — •Martin Rohloff[1,2], Julian Vogel[1,2], and Jürgen Vollmer[1,2] — [1]Max Planck Institute for Dynamics and Self-Organisation (MPIDS), 37077 Göttingen, Germany — [2]Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany

Demixing of multiphase fluids with a constant supply of supersaturation can give rise to episodic precipitation of potentially catastrophic impact: geysers, lake outbreaks, volcano eruptions and tropical rain. In all these processes the frequency of this oscillatory demixing is a function of the intensity of the continuous supply. Often, however, convection leads to a periodic modulation of the supply.

Here we present a lab experiment in which repeated precipitation cycles can be observed: A binary liquid mixture that undergoes oscillatory demixing when subjected to a shallow temperature ramp [1]. We perform turbidity measurements to determine the period of the precipitation cycles. Depending on amplitude and frequency of the supply we observe synchronization as well as conditions where only the average supersaturation supply rate is important.

[1] Lapp, T., M. Rohloff, J. Vollmer, B. Hof, 2012 Exp. Fluids 52, 1187

DY 27.7 Thu 11:15 ZEU 160

Chaotic and statistical properties of two coupled Pomeau-Manneville maps — •Matteo Sala[1], Cesar Manchein[2], and Roberto Artuso[3] — [1]MPI PKS, Dynamical systems and Social Dynamics, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Departamento de Física, Universidade do Estado de Santa Catarina, 89219-710 Joinville, Brazil — [3]Center for Nonlinear and Complex Systems, Dipartimento di Scienza ed Alta Tecnologia, Via Valleggio 11, 22100 Como, Italia

By considering a 2-D map on the torus defined by two identical Pomeau-Manneville maps interacting through a linear coupling, we study the subtle interplay between *intermittency* (due to the marginal instability) and *synchronization* (due to the coupling). In particular, we focus on the weak coupling regime in the range of nonlinearity for which the 1-D Pomeau-Manneville map admits an absolutely continuous invariant measure. Our analysis is based on the phase-space *filling rate* of non-synchronized orbits and the associated statistics of both the *recurrence times* and the *finite-time Lyapunov exponents*. Two main results show up: *i*) the detection of a clear stretched-exponential trend in both the phase-space filling rate and the decay of rare values probability for the Lyapunov exponent and *ii*) the coexistence of regular and anomalous behavior in the cumulative probability of recurrence times. These points lead to the conclusion that even a linear, very weak interaction between nonlinear intermittent systems can bring into play extremely non-trivial dynamical features.

DY 27.8 Thu 11:30 ZEU 160

Characterisation of slow cardiovascular oscillations by syn-

chronisation techniques — •Kathrin Dabelow[1], Jan W. Kantelhardt[1], Alexander Müller[2], Petra Barthel[2], and Georg Schmidt[2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg — [2]Medizinische Klinik und Deutsches Herzzentrum der Technischen Universität München

Variations of human heart rate and blood pressure, i. e. cardiovascular oscillations, naturally occur in the high-frequency (HF) regime due to influences of the repiratory process. Also at lower frequencies (LF regime) variations can be found but the specific underlying mechanisms are still subject to discussion. We study the phase synchronisation properties of heart rate and blood pressure time series. Firstly, we decompose the frequency spectrum of cardiovascular signals into overlapping bands of logarithmically equal width. Within each band the synchronisation of the signal with a time-shifted copy, as well as the synchronisation between different signals is analysed in order to determine differences between the HF and LF range. In addition, the prognostic power of these methods is evaluated in patients that survived a myocardial infarction.

DY 27.9 Thu 11:45 ZEU 160

Unveiling generalized synchronization among coupled oscillators and geophysical signals: A recurrence perspective — •Reik V. Donner[1,2], Jan H. Feldhoff[2,3], and Jonathan F. Donges[2,4] — [1]Max Planck Institute for Biogeochemistry, Jena, Germany — [2]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [3]Department of Physics, Humboldt University, Berlin, Germany — [4]Stockholm Resilience Centre, Stockholm University, Sweden

The emergence of complex synchronization phenomena is a characteristic feature of many nonlinear systems. Among other types, generalized synchronization (GS) describes the mutual locking of the different dynamical degrees of freedom in the most general sense. As a consequence, GS is not necessarily reflected in a simple functional interdependence between the variables of two systems, which makes its detection from time series a challenging task. Here, we introduce a set of new indicators of GS based on the concept of recurrences in phase space. Numerical results for two coupled Rössler systems in different dynamical regimes reveal that indicators utilizing recurrence network transitivity as a proxy for the effective dimensionality of the system under study exhibit a particularly good performance in detecting the known transition to GS from short time series data. The corresponding potentials for the analysis of real-world data are exemplified using some time series reflecting climate and ecosystem variability.