DY 10: Nonlinear Dynamics, Synchronisation and Chaos

Time: Tuesday 9:30–13:00 Location: MA 001

DY 10.1 Tue 9:30 MA 001

On nonlinear waves spreading in two-dimensional random lattices — •Tetyana V. Laptyeva, Joshua D. Bodyfelt, and Sergej Flach — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

We analyze the mechanisms and regimes of nonlinear waves spreading in random lattices, which are known to localize linear waves. More precisely, we extend our recent studies on the strong and weak chaos regimes of wave-packet subdiffusive spreading [1] to the case of two-dimensional lattices with tunable nonlinearity. The focus is put on the paradigmatic problem of compact excitation expansion in disordered (Klein-Gordon) lattice with a σ-parameterized nonlinearity $|u|^\sigma u$. Numerically obtained time-dependencies for the subdiffusion exponents support theoretical predictions of [2]. Moreover, going below critical nonlinearity power $\sigma_c = 1$ we observe the long-lasting strong chaos in subdiffusive wave-packet spreading. The possible ways of estimation, or, qualitative characterization of this process remain open for further exploration.

[1] T.V. Laptyeva, et al., Europhys. Lett. 91, 30001 (2010); J.D. Bodyfelt, et al., Phys. Rev. E 84, 016205 (2011); J.D. Bodyfelt, et al., Int. J. Bif. Chaos 21, 2107 (2011). [2] S. Flach, Chem. Phys. 375, 548 (2010).

DY 10.2 Tue 9:45 MA 001

Effects of rotation on the nonlinear friction of a damped dimer sliding on a periodic substrate — •Italo Neide — Faculty of Physics - University Duisburg-Essen, Duisburg, Germany

The aim of this work is to study the effects of rotation of the non linear friction of a damped dimer sliding on a 1D periodic substrate. Numerical simulations are performed with: a damping in the translational and rotational coordinate, throwing the dimer with a finite initial translational velocity (transient state); with the dimer subjected to an external force applied in the center of mass coordinate and with finite temperatures (steady state). The equations of motion in terms of center of mass and rotational coordinate show a roto-translational coupling, whose is activated for distinct regimes while the dimer is sliding, resulting in an energy transfer between the coordinates. The motivation of this work is to understand the rotational effects that emerges from the dynamics of the smallest object that can rotate, in order to achieve simple contributions to the understanding of the friction origin in nanometric scale.

DY 10.3 Tue 10:00 MA 001

Intraband dynamics in a one dimensional (1D) nonlinear Wannier-Stark ladder — •Petruta Anghel-Vasilescu and Sergej Flach — Max-Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

I will present new results on the dynamics of a wave packet in a 1D nonlinear Wannier-Stark ladder in the absence of interband Landau-Zener tunneling and discuss the observed different regimes of spreading of an initial single-site excitation. In the linear Wannier- Stark problem, the eigenvalue spectrum is equidistant and all normal modes are spatially localized. Nonlinearity induces frequency shifts and mode-to-mode interactions which can destroy the localization. For large values of the nonlinear coefficient we observe single-site trapping as a transient regime, followed by an explosive spreading and subdiffusion. For moderate nonlinearity strength the subdiffusion is found to be the only spreading regime. Finally for small nonlinearities we find linear Stark localization due to the presence of nonlinear Bloch oscillations. The sub-diffusive spreading was found to be very dependent on the strength of the applied electric field.

DY 10.4 Tue 10:15 MA 001

Frequency Analysis of Diffusion Processes in Coupled Standard Maps Using Graphics Cards — •Moritz Schönwetter[1,2], Sebastian Schröter[2], Peter Schlagheck[3], and Javier Madroñero[2] — [1]MPIPKS Dresden — [2]TU München — [3]Université de Liège, Belgium

An accurate description of phenomena arising in higher dimensional classical systems – e.g. dynamical tunneling [1] or stickiness [2] – requires the knowledge of the long term behaviour of a huge number of trajectories. This involves numerically challenging calculations which nowadays can be solved on reasonable time-scales with the use of modern Graphic Processing Units (*GPU*s).

In the present contribution we consider the complex dynamics of two coupled standard maps. Using the methods of (time-) frequency analysis [3] and classical perturbation theory we investigate the associated Arnold web of resonances in appropriate coordinates. Special attention is dedicated to possible diffusion channels which are observed in the long-time evolution of this web.

[1] O. Brodier, P. Schlagheck, D. Ullmo; Ann. Phys. **300** (2002), 88.

[2] E. Altmann, H. Kantz; Europhys. Lett. **78** (2007), 10008.

[3] J. Laskar; Physika D **67** (1993), 257.

DY 10.5 Tue 10:30 MA 001

Parameter-space for a dissipative Fermi-Ulam model — •Diego Fregolente Mendes de Oliveira — Institute for Multiscale Simulations - Friedrich-Alexander Universität - D-91052 - Erlangen - Germany

The parameter-space for a dissipative bouncing ball model under the effect of inelastic collisions is studied. The system is described by using a two-dimensional nonlinear area-contracting map. The introduction of dissipation destroys the mixed structure of phase space of the non-dissipative case leading to the existence of a chaotic attractor and attracting fixed points which may coexist for certain ranges of control parameters. We have computed the average velocity for the parameter space and we have made a connection with the parameter space based on the maximum Lyapunov exponent. For both cases we have found an infinite family of self-similar structures of shrimp-shape which correspond to the periodic attractors embedded in a large region which corresponds to the chaotic motion. The procedure is of broad interest and can be extended to many other different two dimensional area contracting models.

DY 10.6 Tue 10:45 MA 001

Coexistence of exponentially many chaotic spin-glass attractors — Yitzhak Peleg[1], Meital Zigzag[1], Wolfgang Kinzel[2], and •Ido Kanter[1] — [1]Department of Physics, Bar-Ilan University, IL-52900 Ramat-Gan, Israel — [2]Institute for Theoretical Physics, University of Wuerzburg, Am Hubland, DE-97074 Wuerzburg, Germany

chaotic network of size N with delayed interactions which resembles a pseudo-inverse associative memory neural network is investigated. For a load $\alpha = P/N < 1$, where P stands for the number of stored patterns, the chaotic network functions as an associative memory of 2P attractors with macroscopic basin of attractions which decrease with α. At finite α, a chaotic spin-glass phase exists, where the number of distinct chaotic attractors scales exponentially with N. Each attractor is characterized by a coexistence of chaotic behavior and freezing of each one of the N chaotic units or freezing with respect to the P patterns. Results are supported by large scale simulations of networks composed of Bernoulli map units and Mackey-Glass time delay differential equations.

DY 10.7 Tue 11:00 MA 001

Spin-orbital phase synchronization in the magnetic field-driven electron dynamics — •Levan Chotorlishvili and Jamal Berakdar — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

We study the dynamics of an electron confined in a one-dimensional double quantum dot in the presence of driving external magnetic fields. The orbital motion of the electron is coupled to the spin dynamics by spin orbit interaction of the Dresselhaus type. We derive an effective time-dependent Hamiltonian model for the orbital motion of the electron and obtain a synchronization condition between the orbital and the spin dynamics. From this model we deduce an analytical expression for the Arnold tongue and propose an experimental scheme for realizing the synchronization of the orbital and spin dynamics.

15 min break

DY 10.8 Tue 11:30 MA 001

Reliable Dynamics in Boolean and continuous networks — •Eva Gehrmann[1], Tiago P. Peixoto[2], and Barbara Drossel[1] —

[1]Institut für Festkörperphysik, TU Darmstadt — [2]Institut für Theoretische Physik, Universität Bremen

We compare continuous and Boolean dynamics of gene regulatory networks that have entirely reliable trajectories, i.e., the sequence of states in the Boolean model does not depend on the order in which nodes are updated. So far, little is known about general conditions under which a Boolean simplification captures correctly the dynamics in gene regulation networks. Previous research suggests that not the topology and size of a network determine the extent of agreement between Boolean and continuous models, but the features of the network. We investigate the dynamical behavior of networks that have entirely reliable trajectories in the Boolean model version, i.e., trajectories with Hamming distance 1 between subsequent states. We translate the Boolean model for gene activity into continuous dynamics for mRNA and protein concentrations using sigmoidal Hill functions and analyze the resulting time-series of hundreds of networks with different sizes and different lengths of the trajectories. For entirely reliable trajectories, we find perfect agreement between the Boolean and the continuous dynamics. In order to assess the importance of having reliable trajectories, we also use models where the average Hamming distance between subsequent states is larger than 1. A careful analysis reveals the reasons why the good agreement between the Boolean and the continuous dynamics is destroyed in many networks with larger Hamming distance.

DY 10.9 Tue 11:45 MA 001

Synchronization in mutually delay-coupled semiconductor lasers and its decay due to bubbling — •Konstantin Hicke[1], Jordi Tiana-Alsina[2], Xavier Porte[1], Miguel Soriano[1], M. Carme Torrent[2], Jordi Garcia-Ojalvo[2], and Ingo Fischer[1] — [1]Instituto de Fisica Interdisciplinar y Sistemas Complejos, IFISC (UIB-CSIC), Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain — [2]Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya, Campus de Terrassa, Edif. GAIA, Rambla de Sant Nebridi s/n, Terrassa E-08222 Barcelona, Spain

Coupled semiconductor lasers are ideal testbeds to study synchronization properties of delay-coupled systems. At the same time they are promising for applications. An aspect which is therefore important is how synchronization can get lost. Here we present experimental results for the dynamics of two mutually coupled semiconductor lasers in a relay-coupling-configuration. We achieve excellent zero-lag chaos synchronization of the lasers' output intensities. Moreover, we demonstrate how the overall synchronization quality decreases with increasing pump current. We identify this to be due to an increase of the occurence of intermittent desynchronization events which we attribute to noise-induced bubbling. We point out the difference to global transverse instabilities of the synchronization and the resulting on-off intermittency. This is completed by a detailed analysis of the desynchronization events.

DY 10.10 Tue 12:00 MA 001

Global synchronisation of excitable units induced by network dynamics — •Claudio J. Tessone[1] and Damián H. Zanette[2] — [1]Chair of Systems Design, ETH Zürich. Kreuzplatz 5, CH-8032 Zürich, Switzerland — [2]Departamento de Física Estadística e Interdisciplinar, Centro Atómico Bariloche. R8400 S. C. de Bariloche, Argentina

In many cases of interest, the structure describing the interaction network underlying a given system evolves over time. However, its full –often complex– structure, becomes apparent only when seen over long time-scales, in many cases much larger than those associated with the internal dynamics of the elements represented by the nodes. Take a social network as a prototypic example: individuals can interact only with a very limited subset of their acquaintances over a given period of time. Then, over a limited interval, the network looks rather sparse. Despite of this, several dynamical processes are able to survive and spread though real-world networks, such as diseases and opinions. In this contribution, we study a sparsely connected network of excitable FitzHugh-Nagumo units (not subject to any kind of perturbation), in which the edges randomly rewire at a given rate. We show that a globally synchronised state can be induced solely by the network dynamics. If the rewiring rate is too slow or fast, no emergent dynamics appear, and the units rest in the fixed point of the dynamics. However, there exists an intermediate range of values of the rate of link recombination where all the units fire in a synchronised fashion. This shows that this phenomenon is not a trivial one induced by global coupling, but the outcome of an interplay between node and network dynamics.

DY 10.11 Tue 12:15 MA 001

Onset of Synchronization in Complex Networks of Noisy Oscillators — •Bernard Sonnenschein[1,2] and Lutz Schimansky-Geier[1,2] — [1]Institute of Physics, Humboldt University at Berlin, Newtonstr. 15, 12489 Berlin, Germany — [2]Bernstein Center for Computational Neuroscience, Philippstr. 13, 10115 Berlin, Germany

We investigate noisy Kuramoto oscillators on networks that are undirected and complex. Our problem allows to study the effects and the interplay of networks with a given degree distribution, diversity of oscillators and noise acting on the natural frequencies.

We derive the critical coupling strength for the onset of synchronization by approximating the complex network by a weighted fully connected network.

We find that the critical coupling strength is a product of two factors. The first one depends solely on the network topology, while the second factor is a function of the noise intensity and the diversity of the oscillators. Our result is applied to a dense small-world network model in order to provide numerical verification.

We obtain a satisfying agreement between simulations and theory for the critical coupling strength, regardless of whether we consider the dependencies on the topology or the dependencies on the diversity.

Only for a smaller number of edges in the network, the critical coupling strength is slightly overestimated by our approximation technique, but the functional dependencies can still be reproduced qualitatively.

DY 10.12 Tue 12:30 MA 001

Synchronized Cluster Formation in Coupled Laser Networks — Micha Nixon[1], Motti Fridman[1], Eitan Ronen[1], Asher Friesem[1], Nir Davidson[1], and •Ido Kanter[2] — [1]Weizmann Institute of Science, Dept. of Complex Systems, Rehovot, Israel — [2]Bar-Ilan University, Dept. of Physics, Ramat-Gan, Israel

We experimentally investigated networks of up to seven lasers with homogeneous bidirectional time-delayed coupling and established the following fundamental rules governing their synchronization state [1]. A network exhibits only two synchronized states: zero-lag synchronization, where all the lasers are synchronized to each other, occurs for networks with at least one odd numbered loop. Or sub- lattice synchronization, where the network splits into two synchronized clusters of alternating lasers that are not synchronized with each other, occurs for networks comprised only of even numbered loops. This implies that the synchronization state of the network is governed by a non-local phenomenon; hence, it cannot be deduced by decomposing the network into sub-structures that maintain their individual synchronization states.

Very recently we extended the experimental investigation of synchronized cluster formation to unidirectional coupled laser networks with a much larger number of lasers that also include heterogeneous coupling delay time [2].

[1] M. Nixon, et. al., Phys. Rev. Lett., 106, 22 (2011).
[2] M. Nixon et al., submitted (2011).

DY 10.13 Tue 12:45 MA 001

Measures for correlations and complexity based on exponential families — •Otfried Gühne[1], Sönke Niekamp[1], and Tobias Galla[2] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen — [2]Complex Systems and Statistical Physics Group, School of Physics and Astronomy, University of Manchester, Manchester M13 9PL, United Kingdom

Correlations between different parts of a physical system are ubiquitous in nature. Their characterization is crucial for the study of complex systems, but also interesting from the viewpoint of quantum information theory. To quantify such correlations, measures based on the notion of exponential families have been studied [T. Kahle *et al.,* Phys. Rev. E **79**, 026201 (2009)]. The basic element of this approach is to use the distance of a probability distribution to the thermal states of k-particle Hamiltonians as a measure of the correlations in the distribution.

For the case of classical probability distributions, we show that such measures are lacking some desirable properties of correlation measures. However, we propose a modified definition which can be used to overcome this problem [T. Galla *et al.,* arXiv:1107.1180]. In the quantum case, the probability distribution is replaced by a density matrix, but still the same type of correlation measures can be defined. We present an algorithm to compute such measures efficiently for quantum states. We also demonstrate that this approach can be used to show that certain relevant quantum states (such as the cluster states) cannot be approximated by ground states of two-body Hamiltonians.