DY 28: Nonlinear Dynamics, Synchronization and Chaos - Part I

Time: Wednesday 9:30–12:00 Location: BH-N 128

DY 28.1 Wed 9:30 BH-N 128

Synchronization by Decoupling — •Malte Schröder[1], Manu Mannattil[2], Debabrata Dutta[3], Sagar Chakraborty[2,4], and Marc Timme[1] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany — [2]Department of Physics, Indian Institute of Technology Kanpur, U.P. 208016, India — [3]CGG Services UK, Crompton Way, Crawley, West Sussex RH10 9QN, UK — [4]Mechanics and Applied Mathematics Group, Indian Institute of Technology Kanpur, U.P. 208016, India

Synchronization has a broad range of applications, from biological and ecological settings such as predator-prey dynamics and the migration of large populations, to technical systems such as lasers. In coupled chaotic systems, synchronization typically emerges only for a specific range of coupling parameters and is impossible otherwise. Here, we demonstrate that *restricting* the coupling to specific regions of phase space *widens* the range of coupling parameters where synchronization is achieved. This 'trick' works for simple master-slave systems of two coupled units as well as for larger networks of more complex interaction topologies.

DY 28.2 Wed 9:45 BH-N 128

Chaos synchronization by nonlinear coupling — •Johannes Petereit and Arkady Pikovsky — Universität Potsdam, Potsdam, Germany

Synchronization of chaos is a well known phenomenon that occurs in ensembles of coupled chaotic systems. It presents itself in different forms depending on the dynamics and the coupling scheme of the interacting systems. Previous researches have focussed on pairwise coupling implemented by a linear coupling operator. We used *nonlinear* coupling methods to link at least three systems.

In detail we coupled three logistic maps using two different nonlinear coupling schemes in order to check general properties of nonlinear coupling. We analyze different synchronization patterns in dependence on coupling strength by calculating appropriate synchronization measures and Lyapunov exponents. Possible extensions are also briefly discussed.

DY 28.3 Wed 10:00 BH-N 128

Permutation symmetries and phase wave synchronization on networks of heterogeneous chemical oscillators — •Jan Frederik Totz[1], Harald Engel[1], and Kenneth Showalter[2] — [1]Technische Universität Berlin, Berlin, Deutschland — [2]West Virginia University, Morgantown, USA

Synchronization phenomena are observed in a wide variety of systems ranging from synchronizing fireflies through firing neurons to electrical power grids [1,2]. Recently it has been demonstrated that permutation symmetries of the underlying oscillator networks are of fundamental importance for zero-lag synchronization patterns [3]. In this contribution, we address the question: What role do network symmetries play, when the frequency detuning of the individual oscillators is too large to allow for zero-lag synchronization? Experiments and simulations on networks of discrete chemical relaxation oscillators [4] reveal transitions from incoherence through partial synchronization to phase waves following symmetry clusters as a function of coupling strength.

[1] P. C. Bressloff, Waves in Neural Media: From Single Neurons to Neural Fields (Springer, 2014)

[2] A. Pikovsky, M. Rosenblum, and J. Kurths, Synchronization: A Universal Concept in Nonlinear Sciences (Cambridge University Press, 2003)

[3] L. M. Pecora, F. Sorrentino, A. M. Hagerstrom, T. E. Murphy, and R. Roy, Nat. Commun. 5, 4079 (2014)

[4] M. R. Tinsley, S. Nkomo, and K. Showalter, Nat. Phys. 8, 662 (2012)

DY 28.4 Wed 10:15 BH-N 128

On the Arrest of Synchronized Oscillations — •Darka Labavić and Hildegard Meyer-Ortmanns — School of Engineering and Science, Jacobs University Bremen, Bremen, Germany

We study the mutual conversion of regimes of collective fixed-point behavior and collective synchronized oscillations in a system of coupled dynamical units, which individually can be in an excitable or oscillatory state. The conversion is triggered by the change of a single bifurcation parameter [1]. Of particular interest is the arrest of oscillations. We identify the criterion that determines the seeds of arrest and the propagation of arrest fronts in terms of the vicinity to the future attractor. Due to a high degree of multistability we observe versatile patterns of phase locked motion in the oscillatory regime. Quenching the system into the regime, where oscillatory states are metastable, we observe qualitatively distinct approaches of the fixed-point attractor, depending on the initial seeds. If the seeds of arrest are isolated single sites of the lattice, the arrest propagates via bubble formation, visually similar to nucleation processes; if the seed is extended along a line of lowest amplitudes, the freezing follows the spatial patterns of phase-locked motion with long interfaces between arrested and oscillating units. For spiral patterns of oscillator phases these interfaces are arranged along the arms of the spirals.

[1] D. Labavić and H. Meyer-Ortmanns, Chaos **24**, 043118 (2014)

[2] D. Labavić and H. Meyer-Ortmanns, *On the Arrest of Synchronized Oscillations*, submitted

DY 28.5 Wed 10:30 BH-N 128

Synchronizing noisy and chaotic oscillators with non-uniform couplings — •Bernard Sonnenschein[1], Thomas K. DM. Peron[2], Francisco A. Rodrigues[3], Jürgen Kurths[1,4], and Lutz Schimansky-Geier[1] — [1]Department of Physics, Humboldt-Universität zu Berlin, Germany — [2]Instituto de Fisica de Sao Carlos, Universidade de Sao Paulo, Brazil — [3]Departamento de Matematica Aplicada e Estatistica, Instituto de Ciencias Matematicas e de Computacao, Universidade de Sao Paulo, Brazil — [4]Potsdam Institute for Climate Impact Research, Potsdam, Germany

It is well-known that coupled oscillatory units tend to synchronize. However, many open questions remain, if the couplings are heterogeneous, e.g. in their strengths or in their effects (attractive vs. repulsive). We investigate all-to-all coupled networks that are composed of two intertwined populations. All the oscillators are characterized by two individual coupling strengths and these are the same within the populations, but different between them. One of the coupling constants tells how strongly the single element feels the mean field, while the other one quantifies the strength of the contribution to the mean field. Furthermore, coupling constants are allowed to be negative. For the node dynamics we consider two very different models, chaotic Rössler systems and noisy Kuramoto phase oscillators. Intriguingly, in both models similar states of discordant synchronization can be found. We report so-called blurred pi states, chimera-like points and reentrant synchronization. For the noisy Kuramoto model we derive analytical results providing a deeper understanding of the numerical observations.

DY 28.6 Wed 10:45 BH-N 128

Kuramoto Dynamics in Hamiltonian Systems — Dirk Witthaut[1,2] and •Marc Timme[2,3] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Goettingen — [2]Effciency, Emergence and Economics of Future Supply Networks, FZ Julich — [3]Institute for Nonlinear Dynamics, University of Goettingen

The Kuramoto model constitutes a paradigmatic model for the dissipative collective dynamics of coupled oscillators, characterizing in particular the emergence of synchrony (phase locking). Here we present a classical Hamiltonian (and thus conservative) system with 2N state variables that in its action-angle representation exactly yields Kuramoto dynamics on N-dimensional invariant manifolds, http://dx.doi.org/10.1103/PhysRevE.90.032917 (2014). We show that locking of the phase of one oscillator on a Kuramoto manifold to the average phase emerges where the transverse Hamiltonian action dynamics of that specific oscillator becomes unstable. Moreover, the inverse participation ratio of the Hamiltonian dynamics perturbed off the manifold indicates the global synchronization transition point for finite N more precisely than the standard Kuramoto order parameter. The uncovered Kuramoto dynamics in Hamiltonian systems thus distinctly links dissipative to conservative dynamics, with options of experimental realization (Witthaut et al., in prep.).

15 min. break

DY 28.7 Wed 11:15 BH-N 128

Nonlinear effects in semiconductor quantum dot microlasers — •Elisabeth Schlottmann[1], Steffen Holzinger[1], Sören Kreinberg[1], Leon Messner[1], Christian Schneider[2], Sven Höfling[2,3], Martin Kamp[2], Janik Wolters[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Technische Physik, Universität Würzburg, W, Germany — [3]Present address: SUPA, School of Physics and Astronomy, University of St Andrews, United Kingdom

Semiconductor microlasers with a few tens of quantum dots in the active layer exhibit ultra-low laser thresholds in the semiclassical limit, while showing genuine quantum effects below threshold. Today, it is well known that classical lasers under optical feedback or external injection posess highly non-linear behavior. However, the transition from classical to quantum chaos is hardly understood.

In our experiments we investigate non-linear effects in InGaAs/GaAs quantum dot micropillar lasers, aiming to expand the semiclassical Lang-Kobayashi physics to the quantum regime. To this end, we measured the influence of time-delayed feedback from a 2 m long external cavity on the first and second order autocorrelation of the emitted radiation. With external injection of low intensity laser light, we pave the way for external quantum control of microlasers.

DY 28.8 Wed 11:30 BH-N 128

Synchronization in coupled organ pipes — •Jakub Sawicki[1], Markus Abel[2], and Eckehard Schöll[1] — [1]Technische Universität Berlin, Berlin, Germany — [2]University of Potsdam, Potsdam, Germany

We investigate synchronization in coupled organ pipes. Synchronization and reflection in the organ lead in special cases to undesired weakening of the sound. Experiments show that sound interaction is highly complex and nonlinear. As a model we consider two delay-coupled Van-der-Pol oscillators with distance-dependent coupling. Analytically, we investigate phenomena as synchronization frequency and bifurcation scenarios which occur at the boundaries of the Arnold tongues. We successfully compare our results to experimental data.

DY 28.9 Wed 11:45 BH-N 128

Coupled organ pipes - Numerical investigations and new synchronization experiments — •Jost Leonhardt Fischer[1], Rolf Bader[1], and Markus Abel[2,3] — [1]Systematische Musikwissenschaft, Universität Hamburg, Deutschland — [2]Institut für Physik und Astronomie, Universität Potsdam, Deutschland — [3]Ambrosys GmbH, Potsdam, Deutschland

Motivated by recent synchronization experiments with slightly detuned organ pipes we show that mutual interaction between two organ pipes which lead to synchronization can be properly depicted by methods of numerical simulation. Therefore we integrated the fully compressible Navier-Stokes equations with suitable initial and boundary conditions using an LES-Model. This gives a deep insight into the fluiddynamical and aeroacoustical first principles of sound generation and sound radiation of organ pipes. Furthermore we show first results of new synchronization experiments with equally tuned pairs of organ pipes. We observed abrupt switching between anti- and in-phase synchronization, depending on the distance of the pipes, respectively the time delay of the coupling.