DY 15: Nonlinear Dynamics, Synchronization, Chaos I

Time: Monday 15:30–17:30 Location: BH-N 128

DY 15.1 Mon 15:30 BH-N 128

Ubiquity of macroscopic chaos in balanced networks of spiking neurons — •Alessandro Torcini[1], Ekkehard Ullner[2], and Antonio Politi[2] — [1]Laboratoire de Physique Théorique et Modélisation Université de Cergy-Pontoise - 2 avenue Adolphe Chauvin, Pontoise 95302 Cergy-Pontoise cedex, Île-de-France, France — [2]Institute for Complex Systems and Mathematical Biology and Department of Physics (SUPA), Old Aberdeen, Aberdeen AB24 3UE, UK

We revisit the behavior of a prototypical model of balanced activity in networks of spiking neurons. A detailed study of an appropriate thermodynamic limit for fixed density of connections shows that, when inhibition prevails, the asymptotic regime is characterized by a self-sustained irregular, macroscopic (collective) dynamics rather than being asynchronous. This holds true even for very small coupling strengths. A relationship with the collective chaos observed in standard (unbalanced) heterogeneous networks is also put forward and the role played by clustered states discussed.

DY 15.2 Mon 15:45 BH-N 128

Partial synchronisation in yeast cell populations — André Weber[1], Werner Zuschratter[1], and •Marcus J. B. Hauser[2] — [1]Leibniz-Institut für Neurobiologie Magdeburg, Germany — [2]Institut für Biometrie und Medizinische Informatik, Otto-von-Guericke-Universität Magdeburg, Germany

The mechanism of the transition between synchronised and desynchronised behaviour of intact yeast cells of the strain *Saccharomyces carlsbergenis* was investigated. In cell colonies of intermediate cell density, all cells remain oscillatory, in addition, a partially synchronised and a desynchronised state are accessible for experimental studies. In the partially synchronised state, the mean oscillatory period is shorter than that of the cells in a desynchronised state. Thus, synhronisation occurs due to entrainment to cells that oscillate more rapidly. This is typical for synchronisations due to phase advancement. However, the cells do not synchronise completely, as the distribution of the oscillatory frequencies only narrows but does not collapse to a single frequency. The desynchronisation is characterised by a broadening of the distribution of oscillation frequencies of the cells. Chimera states, i.e., the coexistence of a synchronised and a desynchronised parts of the population, could not be observed.

DY 15.3 Mon 16:00 BH-N 128

Synchronization in systems with linear, yet nonreciprocal interactions — •Christoph Räth, Michael Haslauer, and Ingo Laut — DLR, Institut für Materialphysik im Weltraum, Müncher Str. 20, 82234 Wessling

Synchronization of oscillatory subsystems is a widespread phenomenon in science. It is argued that the presence of nonlinearities is a necessary prerequisite for synchronization. Here, we study synchronization in complex plasmas consisting of microparticles in addition to the plasma. The particles can form 2D crystalline structures. They can melt via mode-coupling instability (MCI), which is a consequence of the effective nonreciprocal interactions. Synchronized particle motion during MCI-melting of 2D plasma crystal was reported in [1]. To disentangle the effects of nonlinearity and nonreciprocity on the emergence of synchronization, we solved numerically the nonlinear and the linearized system. Analyzing the synchronization with a new order parameter [2] reveals that a linearized version of the interaction model exhibits the same synchronization patterns as the full, nonlinear one. Further, theoretical considerations show that nonreciprocal interactions among particles generally provide a mechanism for the selection of dominant wave modes causing the system to show synchronized motion. Thus, we demonstrate numerically and analytically that also linear systems can synchronize and that the nonreciprocity of the interaction is the more decisive property for a n-body system to synchronize [3].

[1] L. Couëdel et al., Phys. Rev. E, 89, 053108 (2014) [2] I. Laut et al., EPL, 110, 65001 (2015) [3] C. Räth et al. (in preparation)

DY 15.4 Mon 16:15 BH-N 128

Synchronization of Viscoelastically Coupled Excitable Oscillators with Excitation-Contraction Coupling — •Florian Spreckelsen[1,2], Ulrich Parlitz[1,2,4], and Stefan Luther[1,2,3,4,5] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität Göttingen, Germany — [3]University Medical Center Göttingen (UMG), Institute of Pharmacology and Toxicology, Göttingen, Germany — [4]DZHK (German Center for Cardiovascular Research), Partner Site Göttingen, Germany — [5]Department of Physics and Department of Bioengineering, Northeastern University, Boston, USA

Viscoelastically coupled excitable oscillators are used to model individually beating spatially separated cardiomyocytes surrounded by an extra-cellular matrix (ECM) of collagen. This corresponds to the early states in the development of engineered heart muscle (EHM). Synchronization of the beating of the cardiomyocytes is necessary for functioning of EHM. We investigate how mechanical coupling via the ECM can synchronize two excitable oscillators with excitation contraction coupling and electromechanical feedback and how this synchronization depends on the rheological properties of the ECM.

DY 15.5 Mon 16:30 BH-N 128

Synchronization of excitation waves in excitable media using low-pass filtered signals. — •Baltasar Rüchardt[1], Jochen Bröcker[4], and Ulrich Parlitz[1,2,3] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Georg-August-Universität Göttingen, Institute for Nonlinear Dynamics, Göttingen, Germany — [3]German Center for Cardiovascular Research (partnersite Göttingen), Göttingen, Germany — [4]University of Reading, Reading, UK

Excitable media are spatially extended systems with diffusion-like local transport in at least one variable. They respond strongly in this variable if it is pertubated above a threshold. They are suitable for modelling the electric activity in the heart muscle.

In this contribution we demonstrate that it is possible to synchronize two systems of excitable media by means of a uni-directional coupling with spatially low-pass filtered signals. The resulting ability of reconstructing the full spatio-temporal dynamics from a sequence of blurred images is crucial for recovering dynamical information in cardiac experiments using multichannel ECG measurements and synchronization based data assimilation methods.

DY 15.6 Mon 16:45 BH-N 128

Synchronization of high dimensional systems using an ensemble approximation of the inverse linearized delay coordinates map — Flavia R. Pinheiro[1], Peter Jan van Leeuwen[1], and •Ulrich Parlitz[2] — [1]Dept. of Meteorology, University of Reading, UK and the National Centre for Earth Observation (NCEO) — [2]Max Planck Institute for Dynamics and Self-Organization, Göttingen

Synchronization of uni-directly coupled systems can be significantly improved by using delay reconstruction of states in the coupling term [1], [2]. This approach, however, requires the computation and (pseudo) inversion of the Jacobian matrix of the delay coordinates map which is for high dimensional systems computationally extremely expensive. As an alternative, we present a method for approximating the required Jacobian matrix using an ensemble approach [3]. The feasibility and efficacy of this coupling scheme is demonstrated for D-dimensional Lorenz-96 systems with D ranging from 20 to 1000. With its capability to achieve synchronization of high dimensional systems this approach may serve as a building block of novel data assimilation schemes (nonlinear particle filters) [3].

[1] D. Rey et al.. Phys. Lett. A. 378, 869-873 (2014) DOI: 10.1016/j.physleta.2014.01.027
[2] D. Rey et al., Phys. Rev. E. 90: 062916 (2014) DOI: 10.1103/PhysRevE.90.062916
[3] F. R. Pinheiro, P. J. van Leeuwen, and U. Parlitz, to appear in Q. J. R. Meteorol. Soc., DOI: 10.1002/qj.3204

DY 15.7 Mon 17:00 BH-N 128

A bifurcation approach to the synchronization of coupled van der Pol oscillators — •Jorge Galan — Applied Mathematics. University of Sevilla

The van der Pol Oscillator is the canonical example of a planar limit cycle and has been extensively studied in the dynamical system community. Its coupled version has become the basic model of nonlinear dynamical system undergoing mutual synchronization.

We investigate the parameter dependence of the solutions of

$$\ddot{x} - (\lambda_1 - x^2)\dot{x} + x + \beta x^3 + \mu(\dot{x} - \dot{y}) = 0\,,$$
$$\ddot{y} - (\lambda_2 - y^2)\dot{y} + (1+\delta)y + \beta y^3 + \mu(\dot{y} - \dot{x}) = 0.$$

The basic tool for our study has been continuation of the unique equilibrium point of the system; the origin. The appearance of Hopf bifurcations accounts for the regions where oscillations are present. The families of periodic orbits have been followed as the parameters are varied with special attention to the bifurcations and resonances and their relation to synchronization. In particular, we have tried to clarify the presence of a special synchronization regime on an infinitely long band in parameter space between oscillator death and the quasiperiodic area. We present partial bifurcation diagrams both for the van der Pol ($\beta = 0$) and Duffing-van der Pol ($\beta \neq 0$) scenarios.

The structure of the synchronization regions in the parameter space is organized around curves of limit point bifurcations of periodic orbit where isolas are formed and a special curve where a tangency condition with a appropriate Poincare section is present.

DY 15.8 Mon 17:15 BH-N 128

Generalized synchronization of a population of semiconductor lasers in some-to-all coupling configuration — •Axel Dolcemascolo[1], Francesco Marino[2], Romain Veltz[3], and Stéphane Barland[1] — [1]Université de Nice, CNRS, Institut Non Linéaire de Nice, Sophia Antipolis, France — [2]Dipartimento di Fisica, Università di Firenze, INFN, Sezione di Firenze, Italy — [3]Inria Sophia Antipolis, MathNeuro Team, Sophia Antipolis, France

Synchronization between different oscillators occurs in many natural and technological systems, from cardiac pacemaker cells to electronic components or coupled lasers. Here we explore a system of around 500 lasers arranged in an array, which are coupled together with an opto-electronic coupling, where the intensity of the emitted light (after continuous component removal and a saturable nonlinear function) controls the current used to drive collectively all the lasers. The coupling is of some-to-all type, where an arbitrary set of the devices is coupled with the whole population.

The particular case of just one coupled laser has already been studied in *Chaotic spiking ...* by Kais Al-Naimee et al., New J. Phys. 11 (2009), where it has been shown that one single laser can produce a sequence of slow chaotic spiking as a result of an incomplete homoclinic scenario to a saddle-focus. Here we study experimentally the different types of dynamics that emerge when changing the set of feedback lasers while also keeping constant the feedback strength, and the emergence of chaos and synchronization when changing control parameters such as the coupling strength and the operating point of the whole array.