DY 15: Nonlinear Dynamics, Synchronization and Chaos - Part I

Time: Wednesday 9:30–11:45 Location: HÜL 186

DY 15.1 Wed 9:30 HÜL 186

Coherent-structure theory for non-local generalised Kuramoto-Sivashinsky eqautions — Te-Sheng Lin[1], •Dmitri Tseluiko[1], Marc Pradas[2], Serafim Kalliadasis[2], and Demetrios Papageorgiou[2,3] — [1]Department of Mathematical Sciences, Loughborough University, UK — [2]Department of Chemical Engineering, Imperial College London, UK — [3]Department of Mathematics, Imperial College London, UK

We analyse coherent structures in non-local active-dissipative equations, using as a prototype a generalised Kuramoto-Sivashinsky (gKS) equation with a non-local term that is assumed to be a pseudo-differential operator with a spatially independent symbol. Such equations arise in various physical contexts, e.g. in the modelling of a liquid film flow in the presence of various external effects. As for the gKS equation, we show that dispersion regularises the chaotic behaviour and the solutions evolve into arrays of interacting pulses that can form bound states. Since the Shilnikov-type approach is not applicable for analysing bound states in non-local equations, we develop a weak-interaction theory. The non-locality changes the decay of the tails of the pulses from exponential to algebraic. This has strong influence on pulse interaction and bound-state formation, e.g., unlike for local equations, for a correct description of the interaction of pulses it is not sufficient to take into account only neighbouring pulses, in addition interactions become stronger and bound-state formation is speeded up, moreover the number of possible bound states is always finite. Theoretical predictions are corroborated by numerical experiments.

DY 15.2 Wed 9:45 HÜL 186

Multiplicity of Singular Synchronous States in the Kuramoto Model of Coupled Oscillators — •Maxim Komarov and Arkady Pikovsky — Department of Physics and Astronomy, Universität Potsdam, Karl-Liebknecht-Str 24/25, Bld. 28 D-14476 Potsdam, Germany

We study the Kuramoto model of globally coupled oscillators with a bi-harmonic coupling function. We develop an analytic self-consistency approach to find stationary synchronous states in the thermodynamic limit, and demonstrate that there is a huge multiplicity of such states, which differ microscopically in the distributions of locked phases. These synchronous regimes exist already prior to linear instability transition of the fully asynchronous state. In the presence of white Gaussian noise the multiplicity is lifted, but the dependence of the order parameters on coupling constants remains nontrivial.

DY 15.3 Wed 10:00 HÜL 186

Pattern formation in the synchronization dynamics of arrays of optomechanical oscillators — •Roland Lauter, Christian Brendel, Max Ludwig, Steven Habraken, and Florian Marquardt — Institut für Theoretische Physik II, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7 91058 Erlangen

We consider two-dimensional arrays of coupled optomechanical cells, each of which consists of a laser-driven optical cavity interacting with a mechanical (vibrational) mode. The mechanical modes can be driven in self-sustained oscillations. We study the collective classical nonlinear dynamics of the phases of these oscillations, which is described by the well-studied Kuramoto model and optomechanical extensions thereof. The model parameters can be tuned by the laser drives. We focus on pattern formation and find that, depending on the parameters, the phases may or may not synchronize in a stationary configuration of vortex-antivortex pairs. We identify a relevant length scale and find hysteresis associated to the synchronization transition. For some model parameters, this length scale becomes comparable to the lattice spacing, in which case the phase configurations develop structure on smaller and smaller scales and eventually settle into random patterns. Besides, we address the stability and time evolution of binary patterns in which all oscillators are initialized to phases of 0 or pi.

DY 15.4 Wed 10:15 HÜL 186

Simple mechanism for controlling pattern formation in coupled genetic circuits — •Darka Labavić, Prabesh Joshi, and Hildegard Meyer-Ortmanns — School of Engineering and Science, Jacobs University Bremen

We study a system of coupled genetic circuits - bistable frustrated units. Individual units show excitable or oscillatory behaviour depending on the choice of parameters [1]. The same regimes are present also for coupled units, with the same bifurcation parameter. Tuning this parameter we can generate pattern formation for a finite duration of time. Depending on the tuning speed, network topology, and coupling strength, we observe a rich dynamics with different time scales, self-organized pacemakers, spiral patterns, and planar waves. To demonstrate the complexity of the dynamics, we do a detail bifurcation analysis on two coupled units, and indicate how it extrapolates to a larger network.

[1] P. Kaluza and H. Meyer-Ortmanns, Chaos **20**, 043111(2010)

15 min break

DY 15.5 Wed 10:45 HÜL 186

Stuart-Landau oscillators with a conservation law: chimera states and clustering — •Lennart Schmidt[1,2], Katharina Krischer[1], and Vladimir García-Morales[1] — [1]Physik-Department, Nonequilibrium Chemical Physics, Technische Universität München, Garching, Germany — [2]Institute for Advanced Study - Technische Universität München, Garching, Germany

We describe a population of Stuart-Landau oscillators with a nonlinear global coupling. This coupling leads to conserved harmonic oscillations of the mean field. In simulations we observe various kinds of dynamics, including two types of chimera states. Furthermore, tuning the amplitude of the mean-field oscillations gives rise to a transition from the synchronized state to clusters via a Hopf bifurcation. At the Hopf bifurcation two groups emerge out of the whole population, oscillating in anti-phase as to fulfill the conservation law. Since in general the frequency of the new limit cycle is incommensurate to the frequency of the mean-field oscillations, one observes quasiperiodic dynamics.

DY 15.6 Wed 11:00 HÜL 186

Robustness of chimera states in neural system — •Iryna Omelchenko[1,2] and Philipp Hövel[1,2] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Bernstein Center for Computational Neuroscience, Humboldt-Universität zu Berlin

Chimera states are peculiar patterns characterized by coexistence of spatial regions with regular synchronized and irregular incoherent motion in systems of nonlocally coupled elements. We investigate the cooperative dynamics of nonlocally coupled neural populations modeled by FitzHugh-Nagumo systems, where each individual system displays oscillatory local dynamics. In this system, next to the classical chimera state, which exhibits one coherent phase-locked and one incoherent region, we find a new class of dynamics that possesses multiple domains of incoherence [1].

To address the question of robustness of chimera states, inhomogeneity of the local units is introduced in the system via a distribution of threshold parameters of individual FitzHugh-Nagumo oscillators. In dependence on the inhomogeneous system's parameter distribution, we analyze existence of chimera and multi-chimera states in the system.

[1] I. Omelchenko, O.E. Omel'chenko, P. Hövel, and E. Schöll. Phys. Rev. Letters 110, 224101 (2013).

DY 15.7 Wed 11:15 HÜL 186

Clustered Chimera States in Systems of Type-I Excitability — •Andrea Vüllings[1], Johanne Hizanidis[2], Iryna Omelchenko[1,3], and Philipp Hövel[1,3] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]National Center of Scientific Research "Demokritos", Agia Paraskevi, 15310 Athens, Greece — [3]Bernstein Center for Computational Neuroscience, HU Berlin, Philippstr. 13, 10115 Berlin, Germany

Chimera is a fascinating phenomenon of coexisting synchronized and desynchronized behaviour discovered in networks of nonlocally coupled identical phase oscillators more than ten years ago. Since then, chimeras were found in numerous theoretical and experimental studies and more recently in models of neuron dynamics as well [1,2]. In this work, we consider a generic model for a saddle-node bifurcation on a limit cycle representative for neuron excitability type I. We obtain chimera states with multiple coherent regions (clustered chimeras) depending on the distance from the excitability threshold as well as the range of nonlocal coupling. A detailed stability diagram for these chimera states as well as other interesting coexisting patterns like travelling waves will be presented. Finally, in order to gain more insight into the observed dynamics we will employ a modified Kuramoto phase oscillator model as a good approximation to our system above the bifurcation point.

[1] I. Omelchenko *et al.*, *Phys. Rev. Lett.* **110**, 224101 (2013).
[2] J. Hizanidis *et al.*, *Int. J. Bif. Chaos* (2013).

DY 15.8 Wed 11:30 HÜL 186

Robustness of Chimera States in Nonlocally Coupled Networks of Nonidentical Logistic Maps — •Anne-Kathleen Malchow[1], Philipp Hövel[1,2], and Iryna Omelchenko[1,2] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Bernstein Center for Computational Neuroscience, Humboldt-Universität zu Berlin, Philippstraße 13, 10115 Berlin, Germany

We investigate the spatio-temporal dynamics of a ring-network of nonlocally coupled discrete maps, where each element is coupled to a certain number of nearest neighbors. The local dynamics are described by logistic maps with nonlinearity parameters drawn from some fixed distribution within the chaotic regime.

Besides synchronous and spatially chaotic states, we focus particularly on the existence of spatially coherent solutions as well as on the presence of multistable chimera-like states at the transition from coherence to incoherence. Chimera-like states are characterized by a hybrid spatial structure, as they are partially coherent and partially incoherent.

Varying the range and strength of the coupling and especially the variance of the distribution of the nonlinearity parameter values, which denotes the extent of inhomogeneity in the system, we analyze the stability of the different states and compare their stability regions with the case of identical elements.