DY 14: Focus Session: Chimera states: symmetry-breaking in dynamical networks (joint session DY/ BP)

Chimera states in dynamical networks consist of coexisting domains of spatially coherent (synchronized) and incoherent (desynchronized) behavior. They are a manifestation of spontaneous symmetry-breaking in systems of identical, nonlocally coupled oscillators, and have recently been found in different forms (phase chimeras, amplitude chimeras, multi-headed, 1D, 2D, or 3D). Such phenomena may occur in a variety of physical, chemical, biological, technological, or socio-economic systems, for instance in coupled optical systems, neural networks, mechanical, chemical or electrochemical oscillators, power grids, or communication networks. (Organizer: Eckehard Schöll)

Time: Tuesday 9:30–12:30 Location: BH-N 243

Invited Talk DY 14.1 Tue 9:30 BH-N 243

Basins of Attraction for Chimera States — •Erik Andreas Martens[1,2], Mark Panaggio[3,4], and Daniel Abrams[4,5] — [1]Dept. of Biomedical Sciences, University of Copenhagen, Blegdamsvej 3, 2200 Copenhagen, Denmark — [2]Dept. of Mathematical Sciences, University of Copenhagen, Universitetsparken 5, 2200 Copenhagen, Denmark — [3]Dept. of Mathematics, Rose-Hulman Institute of Technology, Terre Haute, Indiana 47803 — [4]Dept. of Engineering Sciences and Applied Mathematics, Northwestern University, Evanston, Illinois 60208 — [5]Northwestern Institute on Complex Systems, Northwestern University, Evanston, Illinois 60208, USA

The coexistence of synchronized and desynchronized regions in populations of identical oscillators, known as chimera states, has received much attention following their recent experimental discovery. Chimeras occur only for special initial conditions; yet, despite numerous theoretical efforts their basins of attraction remain unexplored. We provide the first analysis of their basins of attraction by studying the simplest chimera system with two populations, allowing for three configuration patterns: one fully synchronized and two partly synchronized patterns. The basins form a complex twisting motion around an invariant ray; our perturbative analysis allows the prediction of the asymptotic states and the associated destination maps. Understanding the precise nature of the basins is needed to develop control methods to switch between chimeric configuration patterns, which may may be exploited for technological applications and serve function in neural biology.

Invited Talk DY 14.2 Tue 10:00 BH-N 243

Hysteretic transitions and chaotic chimera states in networks of Kuramoto oscillators with inertia — •Simona Olmi — CNR - Istituto dei Sistemi Complessi, Sesto Fiorentino, Italy — INFN sez. Firenze, Sesto Fiorentino, Italy

We report finite size numerical investigations and mean field analysis of a Kuramoto model with inertia for fully coupled and diluted systems. In particular, we examine for a Gaussian distribution of the frequencies the transition from incoherence to coherence for increasingly large system size and inertia. For sufficiently large inertia the transition is hysteretic and within the hysteretic region clusters of locked oscillators of various sizes and different levels of synchronization coexist. A modification of the mean field theory developed by Tanaka, Lichtenberg, and Oishi [Physica D, 100 (1997) 279] allows to derive the synchronization profile associated to each of these clusters. By increasing the inertia the transition becomes more complex, and the synchronization occurs via the emergence of clusters of whirling oscillators. The presence of these groups of coherently drifting oscillators induces oscillations in the order parameter. We have shown that the transition remains hysteretic even for randomly diluted networks up to a level of connectivity corresponding to few links per oscillator. Finally an extension to a system of two symmetrically coupled networks of Kuramoto oscillators with inertia is reported. In this system the existence and the dynamical properties of novel chaotic chimera states are investigated, concentrating both on the microscopic dynamics and the macroscopic behavior.

Invited Talk DY 14.3 Tue 10:30 BH-N 243

Transient amplitude chimeras: the impact of time delay and noise — •Anna Zakharova[1], Julien Siebert[1], Sarah Loos[1], Aleksandar Gjurchinovski[2], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Germany — [2]Institute of Physics, Faculty of Natural Sciences and Mathematics, Sts. Cyril and Methodius University, Skopje, Macedonia

For a network of Stuart-Landau oscillators with symmetry-breaking coupling we find chimera behavior with respect to amplitude dynamics rather than the phase (amplitude chimeras). We investigate the role of time delay and noise for these coherence-incoherence patterns. In more detail, we address the question of how time delay and noise influence the lifetime of transient amplitude chimeras.

15 min. break

DY 14.4 Tue 11:15 BH-N 243

Clusters, chimeras and localized turbulence under nonlinear global coupling — •Lennart Schmidt, Sindre W. Haugland, and Katharina Krischer — Physik-Department, Nonequilibrium Chemical Physics, Technische Universität München, Garching, Germany

The coexistence of coherently and incoherently oscillating parts in a system of identical oscillators with symmetrical coupling, i.e. a chimera state, is even observable with uniform global coupling. We investigate the prerequisites for chimera states in globally coupled systems. It turns out that a clustering mechanism constitutes the first symmetry-breaking step as it splits the system into two groups. We demonstrate this by means of two different cluster solutions giving rise to two different chimera states. Consequently, essential features of the cluster solutions can be rediscovered in the corresponding chimera states. Furthermore, we compare the chimera states to localized turbulence and discuss their qualitative differences.

Given a chimera state with synchronized and desynchronized regions of the same size, interchanging both phases again yields a solution to the underlying equations. We observe this process of alternation emerging spontaneously. Studying different initial conditions, we could identify the growth of the turbulent domain as being responsible for the repeatedly occurring interchanges.

DY 14.5 Tue 11:30 BH-N 243

Amplitude-phase coupling drives chimera states in small globally coupled laser networks — Fabian Böhm[1] and •Kathy Lüdge[2] — [1]Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institut f. Theo. Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany Berlin, Germany

Chimera states are an intriguing and widely discussed phenomenon, in which an ensemble of coupled systems self-organizes into spatially seperated regions of coherence and incoherence. While we still lack a complete understanding of this general phenomen, three common existence criteria have been formulated in the past which demand large system sizes with non-local coupling and specially prepared initial conditions. For a network of globally coupled semiconductor lasers with time-delayed optical feedback, we show the existence of chimera states that defy these existence criteria. The typical regions of coherence and incoherence were found to exist for the amplitude and phase of the electrical field as well as the inversion of the electrons. Their stability does not depend on the system size which allows for the formation of chimera states in a system of only four coupled lasers. The formation of the chimera states can be linked to regions of multistability.Their occurence is driven by the amplitude-phase coupling of the semiconductor lasers.

DY 14.6 Tue 11:45 BH-N 243

Chimera states in Van der Pol oscillators: Impact of local dynamics and time delay — •Iryna Omelchenko[1], Anna Zakharova[1], Julien Siebert[1], Philipp Hövel[1,2], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität

Berlin — [2]Bernstein Center for Computational Neuroscience, Berlin

We discuss the phenomena of chimera states that exhibit spatial coexistence of regular synchronized and irregular incoherent regions in a network of nonlocally coupled Van der Pol oscillators. Tuning the bifurcation parameter of the individual units allows us to interpolate between regular sinusoidal and relaxation oscillations. We discuss the impact of these local dynamics on the occurrence of chimera states in the system, regimes of their stability in the parameter space, and analyze the influence of time delay introduced in the coupling.

DY 14.7 Tue 12:00 BH-N 243

Robustness of chimera states for coupled FitzHugh-Nagumo oscillators — •Philipp Hövel[1,2], Iryna Omelchenko[1], Eckehard Schöll[1], Johanne Hizanidis[3], and Astero Provata[3] — [1]Technische Universität Berlin — [2]Bernstein Center for Computational Neuroscience Berlin — [3]National Center for Scientific Research "Demokritos", Athens

Chimera states are complex spatio-temporal patterns that consist of coexisting domains of spatially coherent and incoherent dynamics. This counterintuitive phenomenon was first observed in systems of identical oscillators with symmetric coupling topology. Can one overcome these limitations? To address this question, we discuss the robustness of chimera states in networks of FitzHugh-Nagumo oscillators. Considering networks of inhomogeneous elements with regular coupling topology, and networks of identical elements with irregular coupling topologies, we demonstrate that chimera states are robust with respect to these perturbations, and analyze their properties as the inhomogeneities increase. We find that modifications of coupling topologies cause qualitative changes of chimera states: additional random links induce a shift of the stability regions in the system parameter plane, gaps in the connectivity matrix result in a change of the multiplicity of incoherent regions of the chimera state, and hierarchical geometry in the connectivity matrix induces nested coherent and incoherent regions.

DY 14.8 Tue 12:15 BH-N 243

Chimera states and the interplay between initial conditions and non-local coupling — •Peter Kalle[1,2], Anna Zakharova[1], Vladimir García-Morales[2], Katharina Krischer[2], and Eckehard Schöll[1] — [1]TU Berlin, Institut für Theoretische Physik — [2]TU München, E19 - Chemische Physik fern vom Gleichgewicht

This talk addresses the impact of initial conditions and non-local coupling on the emergence of chimera states in networks of Stuart-Landau oscillators. An intuitive approach is presented by which it is possible to successfully predict and explain the occurrence of chimera states. Following this, some of the main properties of chimera states are discussed in the light of this approach.