SYCS 1: Chimera States: Coherence-Incoherence Patterns in Complex Networks

Time: Tuesday 9:30–12:15 Location: H1

Invited Talk SYCS 1.1 Tue 9:30 H1

Theory far from infinity: chimera states without the thermodynamic limit — •Daniel Abrams — Northwestern University, Evanston, IL, USA

Chimera states are surprising symmetry-broken patterns in networks of coupled oscillators which often coexist with fully symmetric states. Much of the theory for chimera states focuses on networks with an infinite number of oscillators. In this talk, I will discuss some new results for the finite-N case, showing that stable chimera states are possible with as few as 4 oscillators. This suggests that they may be easily constructed in experimental or engineered systems, and may even occur naturally.

Invited Talk SYCS 1.2 Tue 10:00 H1

Chimera patterns: Influence of topology, noise, and delay — •Eckehard Schöll — Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Chimera patterns, which consist of coexisting spatial domains of coherent and incoherent dynamics, are studied in networks of oscillators involving amplitude as well as phase dynamics, complex hierarchical (fractal) topologies, noise, and delay. We show that a plethora of novel chimera patterns arise if one goes beyond the Kuramoto phase oscillator model. For the FitzHugh-Nagumo system, the Van der Pol oscillator, and the Stuart-Landau oscillator with symmetry-breaking coupling we find various multi-chimera patterns [1], including amplitude chimeras and chimera death [2]. To test the robustness of chimera patterns, we study small-world and hierarchical topologies. We also address the robustness of amplitude chimera states in the presence of noise [3], and the emergence of coherence-resonance chimeras [4]. If delay is added, the lifetime of transient chimeras can be drastically increased, and novel phenomena like stochastic resonance of delayed-feedback chimeras can arise.

[1] I. Omelchenko et al., Phys. Rev. Lett. 110, 224101 (2013). I. Omelchenko et al., Phys. Rev. E 91, 022917 (2015). I. Omelchenko et al., Chaos 25, 083104 (2015). [2] A. Zakharova, M. Kapeller, and E. Schöll, Phys. Rev. Lett. 112, 154101 (2014). [3] S. Loos, J. C. Claussen, E. Schöll, and A. Zakharova, Phys. Rev. E (2016), arXiv:1508.04010v2. [4] N. Semenova, A. Zakharova, V. Anishchenko, and E. Schöll (2016), arXiv:1512.07036.

Invited Talk SYCS 1.3 Tue 10:30 H1

Chimera states in quantum mechanics — •Victor Manuel Bastidas Valencia — Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, 117543 Singapore, Singapore

Chimera states are a hallmark of self-organization in non-linear dynamical systems [1]. These intriguing states are characterized by the spatial coexistence of synchronized and desynchronized motion in a complex network [2,3]. In this talk, I will discuss the emergence of Chimera states in a network of N coupled quantum van der Pol oscillators with a ring topology. Among the diverse quantum signatures of Chimera states, I will describe the formation of Chimera-like quantum correlations in the network. In addition, I will show how Chimera states can be characterized by using concepts of quantum information theory such as the quantum mutual information. By using this approach, one can show that Chimera states exhibit lower mutual information than a synchronized state, but higher mutual information than a desynchronized one, which extends in a natural way the definition of chimera states to quantum mechanics [4].

[1] M. J. Panaggio and D. M. Abrams, Nonlinearity **28**, R67 (2015).
[2] Y. Kuramoto and D. Battogtokh, Nonlin. Phenom. in Complex Syst. **5**, 380 (2002)
[3] D. M. Abrams and S. H. Strogatz, Phys. Rev. Lett. **93**, 174102 (2004).
[4] V. M. Bastidas, I. Omelchenko, A. Zakharova, E. Schöll, and T. Brandes, Phys. Rev. E **92**, 062924 (2015).

15 min. break

Invited Talk SYCS 1.4 Tue 11:15 H1

Synchronization in Populations of Chemical Oscillators: Phase Clusters and Chimeras — •Kenneth Showalter — West Virginia University, Morgantown, USA

We have studied heterogeneous populations of chemical oscillators to characterize different types of synchronization behavior. The formation of phase clusters in stirred suspensions of Belousov-Zhabotinsky oscillators is described, where the (global) coupling occurs through the medium. We then describe the formation of phase clusters and chimera states in populations of photosensitive oscillators. The nonlocal coupling occurs via illumination intensity that is dependent on the state of each oscillator. The behavior of oscillators in ring configurations as a function of the number of oscillators is described, including traveling cluster states.

References: A. F. Taylor et al., Angewandte Chemie Int. Ed. 50, 10161 (2011); M. R. Tinsley et al., Nature Physics 8, 662 (2012); S. Nkomo et al., Phys. Rev. Lett. 110, 244102 (2013); J. F. Totz et al., Phys. Rev. E 92, 022819 (2015).

Invited Talk SYCS 1.5 Tue 11:45 H1

Epileptic seizures: chimeras in brain dynamics — •Klaus Lehnertz — Universität Bonn

Epilepsy is a complex malfunction of the brain that affects approximately 50 million people worldwide. Epileptic seizures are the cardinal symptom of this multi-facetted disease and are usually characterized by an overly synchronized firing of neurons. Seizures can not be controlled by any available therapy in about 25% of individuals, and knowledge about mechanisms underlying generation, spread, and termination of the extreme event seizure in humans is still fragmentary.

There is now increasing evidence for the existence of large-scale epileptic networks in which all constituents can contribute to the generation, maintenance, spread, and termination of even focal seizures as well as to the many pathophysiologic phenomena seen during the seizure-free interval. Using concepts and analysis tools from nonlinear dynamics, statistical physics, synchronization and network theory, significant progress has been made over the last decade in characterizing the connection structure of large-scale epileptic networks and in understanding their long-term dynamics. Model simulations of complex oscillator networks with connection structures seen in human epilepsies indicate that seizure-like activities can be regarded as self-initiated and self-terminated chimera states. Altogether, findings open promising directions for the development of new therapeutic possibilities.