SOE 6: Networks: From Topology to Dynamics (joint session DY/SOE)

Time: Monday 15:00–17:45 Location: H20

SOE 6.1 Mon 15:00 H20

Inhibition induced explosive synchronization in multiplex networks — •Sarika Jalan — IIT Indore

To date, explosive synchronization (ES) is shown to be originated from either degree-frequency correlation or inertia of phase oscillators. Of late, it has been shown that ES can be induced in a network by adaptively controlled phase oscillators. We show that ES can occur in any network by appropriately multiplexing it with another layer. We devise an approach which leads to the occurrence of ES with hysteresis loop in a network upon its multiplexing with a negatively coupled (or inhibitory) layer. We discuss the impact of various structural properties of positively coupled (or excitatory) and inhibitory layer along with the strength of multiplexing in gaining control over the induced ES transition. This investigation is a step forward in highlighting the importance of multiplex framework not only in bringing novel phenomena which are not possible in an isolated network but also in providing more structural control over the induced phenomena.

SOE 6.2 Mon 15:15 H20

Coarsening dynamics of transient ferrogranular networks under influence of a horizontal magnetic field - network alignment and magnetization in experiments and simulations — Justus Miller[1], Pedro Sanchez[2], Sofia Kantorovich[2,3], and •Reinhard Richter[1] — [1]Experimentalphysik 5, Universität Bayreuth, Bayreuth, Germany — [2]University of Vienna, Vienna, Austria — [3]Ural Federal University, Ekaterinburg, Russia

We investigate the phase separation of a shaken mixture of glass and magnetised steel spheres after a sudden quench of the shaker amplitude. Then transient networks of steel spheres emerge in the experiment, as well as in simulations. Analyzing the network evolution by network specific parameters like the mean number of neighbours or network efficiency we have uncovered three regimes (Kögel et al. Soft Matter **14** 2018), previously established by H. Tanaka (2000) for the viscoelastic phase separation of dynamically asymmetric mixtures.

Here we present new results for the network evolution under influence of a horizontally applied magnetic field. With increasing field strength the branched networks are more and more replaced by linear chains. We quantitatively characterize the average orientation of the network edges with respect to the direction of the applied field in experiment and simulations and explore the consequences for the magnetization curves.

SOE 6.3 Mon 15:30 H20

Asymptotically Exact Solution of the Fredrickson-Andersen Model — Koray Önder[1,2], •Till Kranz[1,2], and Matthias Sperl[2,1] — [1]Institut für Theoretische Physik, Uni Köln — [2]Institut für Materialphysik im Weltraum, DLR Köln

Kinetically constrained models describe many phenomena from opinion dynamics to amorphous solids [1]. The Fredrickson-Andersen model—a kinetically constrained lattice model—displays an ergodic to non-ergodic transition. Simulations indicate a slow two-step relaxation of dynamical correlation functions close to the transition point. We derive an asymptotically exact solution for the dynamical occupation correlation function of the Fredrickson-Andersen model on the Bethe lattice by identifying an exact expression for its memory kernel. The exact solution proves an empirical scaling relation [2] between critical exponents and allows to calculate the exponents explicitly. In addition, we propose an approximate dynamics that describes numerical data away from the critical point over many decades in time.

[1] F. Ritort and P. Sollich, Adv. Phys. **52**, 219 (2003)
[2] M. Sellitto, Phys. Rev. Lett. **115**, 225701 (2015)

SOE 6.4 Mon 15:45 H20

Assessing and improving the replication of chaotic attractors by means of reservoir computing — •Alexander Haluszczynski[1,3], Christoph Raeth[2], Ingo Laut[2], and Mierk Schwabe[2] — [1]Ludwig-Maximilians-Universität, München, Deutschland — [2]Deutsches Zentrum für Luft- und Raumfahrt, Weßling, Deutschland — [3]Allianz Global Investors, München, Deutschland

The prediction of complex nonlinear dynamical systems with the help of machine learning techniques has become increasingly popular. In particular, the so-called "reservoir computing" method turned out to be a very promising approach especially for the reproduction of the long-term properties of the system [1]. Yet, a thorough statistical analysis of the forecast results is missing. So far the standard approach is to use purely random Erdös-Renyi networks for the reservoir in the model. It is obvious that there is a variety of conceivable network topologies that may have an influence on the results. Using the Lorenz System we statistically analyze the quality of predicition for different parametrizations - both the exact short term prediction as well as the reproduction of the long-term properties of the system as estimated by the correlation dimension and largest Lyapunov exponent. We find that both short and longterm predictions vary significantly. Thus special care must be taken in selecting the good predictions. We investigate the benefit of using different network topologies such as Small World or Scale Free networks and show which effect they have on the prediction quality. Our results suggest that the overall performance is best for small world networks. [1] J. Pathak et al., Chaos, 27, 121102 (2017)

SOE 6.5 Mon 16:00 H20

Principal Eigenvector Localization in Multilayer Networks — •Priodyuti Pradhan[1] and Sarika Jalan[1,2] — [1]Complex Systems Lab, Discipline of Physics, Indian Institute of Technology Indore, Khandwa Road, Simrol, Indore-453552, India — [2]Centre for Biosciences and Biomedical Engineering, Indian Institute of Technology Indore, Khandwa Road, Simrol, Indore-453552, India

Starting with a multilayer network (MN) corresponding to a delocalized PEV, we rewire the network edges using an optimization technique such that the PEV of the rewired MN becomes more localized. The localization of an eigenvector refers to a state where few components of the vector take very high values, and rest of the components take very small values. For a two layers MN, the optimization process can be implemented in two different edge rewiring protocols; (1) by rewiring edges in both-layers or (2) by rewiring edges in only one layer. We reveal that for both the rewiring protocols, though there is an emergence of various specific structural features, the different rewiring protocols lead to a noticeable difference in the spectral properties of the optimized MN. For the both-layers rewiring protocol, PEV is sensitive to a single edge rewiring in the optimized MN, and however, interestingly, we get rid of this sensitivity of PEV for the single-layer rewiring protocol. This sensitivity in the localization behavior of PEV is accompanied by the second largest eigenvalue lying very close to the largest one. Furthermore, analysis of MNs constructed using real-world social and biological data show a good agreement with the simulation results for model MN.

15 min. break

SOE 6.6 Mon 16:30 H20

Topology vs. Node Dynamics in Collective Adaptation to Risk — Matthew Grobis[1], Colin Twomey[2], Joseph Bak-Coleman[1], •Winnie Poel[3,4], Bryan Daniels[5], Pawel Romanczuk[3,4], and Iain Couzin[6,7] — [1]Princeton University, USA — [2]University of Pennsylvania, USA — [3]Humboldt Universität zu Berlin — [4]Bernstein Center for Computational Neuroscience Berlin, Germany — [5]Arizona State University, USA — [6]Max Planck Institute for Ornithology, Germany — [7]University of Konstanz, Germany

Our research focuses on the mechanism used by large animal groups to reliably collectively process information on external threats like predation. Specifically, we are interested in the role of an individual's internal state vs. the structure of the group in collective reaction to perceived risk. Using a generic contagion model [1], we study behavioral response cascades in fish schools based on empirically inferred visual interaction networks [2]. We aim to uncover if and how the spatial configuration of the group (i.e. structure of its visual interaction network) and the individual response parameters affect the collective responsiveness.

[1] Dodds PS, Watts DJ (2005) Journal of Theoretical Biology 232(4):587-604
[2] Rosenthal et Al. (2015) PNAS 112(15):4690-4695

SOE 6.7 Mon 16:45 H20

Structure and dynamics of non-normal networks — •Malbor Asllani — University of Limerick, Limerick, Ireland

Network theory has been a groundbreaking research field in science for the last 20 years, conceivably the only one that could glue together disparate and even contrasting disciplines such as physics, economy, biology or sociology. A network materializes the complex interactions between the composing entities of large systems, it thus defines the natural and structural backbone for describing complex systems, which dynamics is unavoidably bound to the network properties. Based on a detailed study involving a large set of empirical networks arising from a wide spectrum of research fields, we claim that strong non-normality is indeed a universal property in network science [1]. Dynamical processes evolving on non-normal networks exhibit a peculiar behavior, initial small disturbances can undergo a transient phase and be strongly amplified although the system is linearly stable [2]. We hence propose several models to generate complex non-normal networks to explain the origin of such property. Because of the non-normality of the networked support, the comprehension of the dynamical properties goes beyond the classical linear spectral methods, while we show that the pseudo-spectrum is able to capture such behavior. This response is very general and it challenges our understanding of natural processes grounded in real networks, as we illustrate in the Generalised Lotka-Volterra model.

[1] M. Asllani and T. Carletti, Sci. Adv. 4, eaau9403 (2018). [2] M. Asllani and T. Carletti, Phys. Rev. E 97, 042302 (2018).

SOE 6.8 Mon 17:00 H20

Chimera States in Networks of Type-I Morris-Lecar Neurons — •Philipp Hövel[1], Ali Calim[2], Mahmut Ozer[3], and Muhammet Uzuntarla[2] — [1]School of Mathematical Science, University College Cork, Ireland — [2]Department of Biomedical Engineering, Bulent Ecevit University, Turkey — [3]Department of Electrical and Electronics Engineering, Bulent Ecevit University, Turkey

Chimeras are complex spatio-temporal patterns that emerge as coexistence of both coherent and incoherent groups of coupled dynamical systems. Here, we investigate the emergence of chimera states in nonlocal networks of type-I Morris-Lecar neurons coupled via chemical synapses. This constitutes a more realistic neuronal modeling framework than previous studies of chimera states, since the Morris-Lecar model provides biophysically more relevant control parameters to describe the activity in actual neural systems. We explore systematically the transitions of dynamic behavior and find that different types of synchrony appear depending on the excitability level and nonlocal network features. Furthermore, we map the transitions between incoherent states, traveling waves, chimeras, synchronized states and global amplitude death in the parameter space of interest. This work contributes to a better understanding of biological conditions giving rise to the emergence of chimera states in neural medium.

Reference: A. Calim, M. Ozer, P. Hövel, M. Uzuntarla, Phys. Rev. E (2018) in print.

SOE 6.9 Mon 17:15 H20

Terminal Transient Phase of Chimera States — •Thomas Lilienkamp[1] and Ulrich Parlitz[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität Göttingen, Germany

In spatially homogeneous systems regions with regular and coherent motion may coexist with regions where irregular and incoherent dynamics occurs. In many cases, chimera states are actually chaotic transients which self-terminate abruptly e.g. towards the completely coherent state. Recent studies of chaotic transients in various systems show, that although the process of self-termination seems to be abrupt [1], a particular final transition phase in state space could be verified, called the "Terminal Transient Phase" [2, 3]. Using small but finite perturbations it was shown, that the state space structure is significantly different in this transition zone. We detected this behavior also in different spatially extended systems which exhibit chimera states. Furthermore, the spatial distribution of perturbations which have a significant impact on trajectories just before the collapse turns out to be correlated with the state of the system. Thus, before its self-termination the chimera state is mostly "vulnerable" only at specific regions of the spatial domain.

[1] T. Lilienkamp, J. Christoph, and U. Parlitz. Phys. Rev. Lett. 119, 054101 (2017)

[2] T. Lilienkamp and U. Parlitz. Phys. Rev. Lett. 120, 094101 (2018)

[3] T. Lilienkamp and U. Parlitz, Phys. Rev. E 98, 022215 (2018)

SOE 6.10 Mon 17:30 H20

Synchronization of time-varying networks with coupling delays — •Otti D'Huys[1], Javier Rodríguez-Laguna[2], Manuel Jiménez-Martín[2], and Elka Korutcheva[2] — [1]Department of Mathematics, Aston University, B4 7ET Birmingham, United Kingdom — [2]Departamento de Física Fundamental, UNED, Spain

We study the effect of a fluctuating topology in delay-coupled networks. Such network fluctuations are common, for instance, between interacting neurons, or networks modeling social interactions.

We concentrate on the synchronization properties of chaotic maps. The topology fluctuates between an ensemble of small-world networks. The dynamics is characterized by three timescales: the internal time scale of the node dynamics, the connection delay along the links, and the timescale of the network fluctuations. When the network fluctuations are faster than the coupling delay and the internal time scale, the synchronized state can be stabilized by the fluctuations. As the network time scale increases, the synchronized state becomes unstable when both time scales collide.

We complement these results with an analytical theory in the linearized limit. Two limit cases allow an interpretation in terms of an 'effective network': When the network fluctuations are much faster than the internal time scale and the coupling delay, the effective network topology is the average over the different topologies. When coupling delay and network fluctuation time scales collide, the effective topology is the geometric mean over the different topologies.