SOE 26: Networks: From Topology to Dynamics (joint session DY / SOE / BP)

Time: Thursday 15:30–17:00 Location: H47

SOE 26.1 Thu 15:30 H47

Complex Quantum Networks: From Universal Breakdown to Optimal Transport — •Oliver Mülken — Physikalisches Institut, Universität Freiburg, Freiburg, Deutschland

We study the transport efficiency of excitations on complex quantum networks with and without loops. For this we consider sequentially growing networks with different topologies of the sequential subgraphs. This can lead to a universal complete breakdown of transport for tree-like [1] or complete-graph-like [2] sequential subgraphs, while it leads to optimal transport for linear [1] or ring-like [2] sequential subgraphs. The transition to optimal transport for networks with loops can be triggered by systematically reducing the number of loops of complete-graph-like sequential subgraphs in a small-world procedure. These effects are explained on the basis of the spectral properties of the network's Hamiltonian. Our theoretical considerations are supported by numerical Monte-Carlo simulations for complex quantum networks with a scale-free size distribution of sequential subgraphs and a small-world-type transition to optimal transport in the case of loops.

[1] Phys. Rev. Lett. 115, 120602 (2015)
[2] arXiv:1511.00910

SOE 26.2 Thu 15:45 H47

Resilience of complex networks — •Baruch Barzel — Bar-Ilan University, Ramat-Gan, Israel

Resilience, a system's ability to adjust its activity to retain its basic functionality under errors, failures and environmental changes, is a defining property of many complex systems. Despite widespread consequences on human health, economy and the environment, events leading to loss of resilience, from economic collapse to mass extinctions in ecological networks, are rarely predictable and often irreversible. These limitations are rooted in a theoretical gap: the current analytical framework of resilience is designed to treat low dimensional models of a few interacting components, and hence it is unsuitable for characterizing multidimensional systems consisting of a large number of components that interact through a complex network.In this talk we will bridge this theoretical gap by introducing a set of analytical tools to identify the natural control and state parameters of a multi-dimensional complex system. This analytical framework allows us to systematically separate the role of the system's dynamics and topology, collapsing the behavior of different networks onto a single universal resilience pattern. Our results unveil the network characteristics that can enhance or diminish resilience, offering avenues to prevent the collapse of environmental, infrastructural or socio-economic systems.

SOE 26.3 Thu 16:00 H47

The totally asymmetric inclusion process (TASIP): how network topology determines condensation and transport properties — •Johannes Knebel, Markus F. Weber, Philipp Geiger, and Erwin Frey — Ludwigs-Maximilians-Universität, München, Deutschland

Transport phenomena are often modeled by the hopping of particles on regular lattices or networks. Such models describe, for example, the exclusive movement of molecular motors along microtubules: no two motors may occupy the same site. In our work, we study *inclusion processes* that are the bosonic analogues of the fermionic exclusion processes. In inclusion processes, many particles may occupy a single site and hopping rates depend linearly on the occupation of departure and arrival sites. Particles thus attract other particles to their own site. Condensation occurs when particles collectively cluster in one or in multiple sites, whereas the other sites become depleted.

We showed that inclusion processes on a network describe both the selection of strategies in evolutionary zero-sum games and the condensation of non-interacting bosons into multiple quantum states in driven-dissipative systems. The condensation is captured by the anti-symmetric Lotka-Volterra equation (ALVE), which constitutes a non-linearly coupled dynamical system. We derived an algebraic method to analyze the ALVE and to determine the condensates. Our approach allows for the design of networks that result in condensates with oscillating occupations, and yields insight into the interplay between network topology and transport properties.

SOE 26.4 Thu 16:15 H47

Growing Boolean networks together with their attractors — Andrey Sakryukin and •Konstantin Klemm — School of Science and Technology, Nazarbayev University, Astana, Kazakhstan

We present a computational method for finding attractors of Boolean dynamics under asynchronous update. Starting from a single node or small network, it builds up the queried network by iterative node addition. The core idea is the mechanism for restricting Boolean dynamics to a subnetwork. Here a natural restriction rule is defined so that node addition never leads to shrinking of an attractor's state set. This facilitates tracking growth, merging and annihilation of attractors as the network itself is being built up.

Applications to Boolean models of biological regulation as well as metastable states of discrete energy landscapes, e.g. NK model, are discussed. At `http://goo.gl/eRzFoo` the implementation of the method and further material are available for download.

SOE 26.5 Thu 16:30 H47

Synchronization of heterogeneous chemical relaxation oscillators — •Jan Frederik Totz[1], Julian Rode[1], Kenneth Showalter[2], and Harald Engel[1] — [1]Technische Universität Berlin, Berlin, Germany — [2]West Virginia University, Morgantown, USA

Recently discovered synchronization patterns, such as chimera states and intertwined cluster synchronization in networks of identical non-linear oscillators lead to the emergence of new theoretical concepts, most notably an extended master stability function for networks with permutation symmetries [1].

Optically coupled catalytic beads provide a versatile experimental tool to study the emergence of collective synchronization patterns with real oscillators under well-controlled laboratory conditions [2].

One important aspect is the impact of a broad oscillator frequency distribution. Instead of in-phase or cluster synchronization, experiments reveal phase wave synchronization through neighboring permutation symmetry clusters [3].

[1] Kuramoto, Battogtokh. Complex Syst. 4, 380 (2002); Pecora et al. Nat. Commun. 5, 4079 (2014) [2] Tinsley. Nat. Phys. 8, 662 (2012); Taylor et al. PCCP (2015) [3] Totz et al. PRE 92, 022819 (2015)

SOE 26.6 Thu 16:45 H47

Biologically implementable attractors in Boolean network models of gene regulation — •David F. Klosik and Stefan Bornholdt — Institut für Theoretische Physik, Universität Bremen

Boolean networks have successfully been used as a modeling approach for gene regulatory networks. It is a well-known fact that in general the attractor landscape can change dramatically when moving from the original parallel deterministic update scheme applied in the first studies to asynchronous or otherwise noisy schemes believed to more plausibly represent the actual processes in the cell. However, the main dynamical features of many biological regulatory networks (e.g., the cell cycle network in yeast) can be captured in a parallel Boolean model, as well, in addition to its own stochastic biochemical implementation within the cell. This leads to the question of when Boolean networks are in fact biologically implementable, keeping certain transients or attractors. We here approach this question with an autonomous Boolean network model with underlying continuous dynamics, that has been proven useful in simulating biochemical stochasticity in regulatory networks[1].

[1] S. Braunewell and S. Bornholdt, Superstability of the yeast cell-cycle dynamics: Ensuring causality in the presence of biochemical stochasticity, J. Theor. Biol. 245 (2007) 638-643.