# SOE 25: Networks: From Topology to Dynamics III (joint session DY / SOE / BP)

Time: Friday 9:30–12:45 Location: BH-N 128

SOE 25.1 Fri 9:30 BH-N 128

**Networks: From Dynamics to Topology** — •Jose Casadiego[1,3] and Marc Timme[1,2,3] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany — [3]IMPRS Physics of Biological and Complex Systems, Göttingen Graduate School for Neurosciences, Biophysics and Molecular Biosciences, 37077 Göttingen, Germany

How single units interact in a complex network fundamentally underlies its collective dynamics. Yet, identifying the physical structure of interactions from recorded time series still poses a great challenge. Up-to-date methods either require (i) a detailed pre-knowledge of the units' dynamical features, (ii) to externally drive the network or (iii) the network dynamics to be at stable states, such as fixed points or limit cycles. Here we develop a theory to reveal physical interactions of networks that relies on recorded time series only. By decomposing the dynamics of single units in terms of network interactions of different orders (pairs, triplets, quadruplets,...), we pose network reconstruction as an error minimization problem. We propose a greedy algorithm to solve such minimization problems. Our approach is principally model independent, ensuring its generality and applicability in different fields and making it particularly suitable when structural connections are desired, dynamical features are unknown and perturbing the network is unfeasible. Thus, our approach may serve as a key stepping stone for the expanding field of model-independent network reconstruction.

SOE 25.2 Fri 9:45 BH-N 128

**Revealing the Topology of Circulatory Networks in Nature** — •Mirko Lukovic[1] and Erik Martens[2,3] — [1]Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany — [2]Department of Biomedical Sciences, University of Copenhagen, Denmark — [3]Department of Mathematical Sciences, University of Copenhagen, Denmark

Complex networks such as those used for communication, resource delivery and transportation are ubiquitous in nature and society. From the internet and urban traffic, to the intimate networks of the circulatory systems in our bodies, understanding how their topology and structure relate to their function and efficiency is an essential first step in their management. Given the wide variety of existing transport networks with structures that range from being tree-like to cases where there is an intricate arrangement of nested loops, our goal is to use circulation times of the flow in order to infer global properties of the underlying network structure. To this end we investigate circulatory transport networks by modeling the flow as a stochastic process whose first passage time properties we determine for a variety of different network topologies. We also set up a framework in which different branching rules of the flow can be tested and its effects on the first passage times analyzed. Our results will help develop an effective and non-invasive method for probing circulatory networks such as the human vascular system.

SOE 25.3 Fri 10:00 BH-N 128

**Symbolic Regression and Network Analysis for the prediction of El Nino** — •Markus Abel[1], Markus Quade[1], Ruggero Vasile[1], Avi Goz[2], Shlomo Havlin[3], and Armin Bunde[4] — [1]Ambrosys GmbH, Albert-Einstein Str. 1-5 Potsdam, Germany — [2]Department of Solar Energy & Environmental Physics, Ben-Gurion University, Jerusalem, Israel — [3]Department of Physics Bar-Ilan University Ramat-Gan 52900 Israel — [4]Institute For Theoretical Physics, University of Giessen, Germany

In the context of the modeling of dynamical systems, statistical analysis and data-based modeling is a hihgly promising method. We use symbolic regression, in particular genetic programming and nonparamtric regression to find effective models for the prediction of el Nino events. The data used consist of a novel method to form a network from the correlations of grid points in the El Nino basin. We compare our results with existing methods. Depending on the method used a predictive power of up to 100% is achieved, i.e. all events are correctly predicted.

SOE 25.4 Fri 10:15 BH-N 128

**Model selection and hypothesis testing for large-scale network models with overlapping groups** — •Tiago P. Peixoto — Institut für Theoretische Physik, Universität Bremen

The effort to understand network systems in increasing detail has resulted in a diversity of methods designed to extract their large-scale structure. Unfortunately, many of these methods yield diverging descriptions of the same network, making both the comparison and understanding of their results a difficult challenge. A possible solution to this outstanding issue is to shift the focus away from arbitrary methods, and move towards principled approaches based on statistical inference of generative models. In this talk we consider the comparison between a variety of generative models including features such as degree correction, where nodes with arbitrary degrees can belong to the same group, and community overlap, where nodes are allowed to belong to more than one group. Because such model variants possess an increased number of parameters, they become prone to overfitting. We present a method of model selection based on the minimum description length criterion and posterior odds ratios that is capable of fully accounting for the increased degrees of freedom of the larger models, and selects the best one according to the statistical evidence available in the data. In applying this method to many empirical datasets from different fields, we observe that community overlap is very often not supported by statistical evidence, and is selected as a better model only for a minority of them. On the other hand, we find that degree-correction tends to be almost universally favored by the available data.

SOE 25.5 Fri 10:30 BH-N 128

**Breakdown of quantum transport in scale-free networks** — •Nikolaj Kulvelis and Oliver Mülken — Uni-Freiburg, Deutschland

We apply the model of continuous time quantum walks (CTQW) to a subset of scale-free networks (SFN) containing solely trees. A quantity characterising the global transport for large time scales is introduced and, by means of estimating the dominant spectral degeneracy, calculated for given system size and branching strength. Taking the limit of infinite system size a phase transition resembling breakdown of transport is observed beyond a critical branching strength. All our analytic calculations are supported by Monte Carlo simulations and discussed.

SOE 25.6 Fri 10:45 BH-N 128

**Two-dimensional unimodular Lattice Triangulations as small-world and scale-free networks** — •Benedikt Krüger, Ella Schmidt, and Klaus Mecke — Institut für Theoretische Physik, Staudtstr. 7, 91058 Erlangen

Triangulations are an important tool in physics for describing curved geometries. Unimodular triangulations on 2d lattices can also be considered as connected, simple, and maximal planar graphs, which allows the appliance of methods from graph theory on triangulations. We calculate the scaling behaviour of the degree distribution, clustering coefficient and the average shortest path length for random triangulations. Introducing a simple measure for the order of a triangulation and interpreting it as the energy of the triangulation we measure canonical averages of these observables using Monte-Carlo-Simulations. We find a crossover behaviour of all considered observables at small negative temperatures and hints for small-world and scale-free behaviour in certain temperature ranges.

### 15 min. break

SOE 25.7 Fri 11:15 BH-N 128

**Nonlinear elasticity of athermal networks: a critical phenoemenon** — •Abhinav Sharma[1], Albert Licup[1], Michael Sheinman[1], Karin Jansen[2], Gijse Koenderink[2], and Frederick Mackintosh[1] — [1]VU, Amsterdam, Netherlands — [2]AMOLF, Amsterdam, Netherlands

Biopolymer networks exhibit highly interesting mechanical behavior. An instructive model system is that of a network composed of rope-like filaments–zero resistance to compression but finite resistance to stretching. For networks with connectivity below Maxwell point,there is no elastic modulus for small deformations. However,when networks are subjected to an external strain, stiffness emerges spontaneously beyond a critical strain. We demonstrate that the spontaneous emergence of elasticity is analogous to a continuous phase transition. The critical point is not fixed but depends on the geometry of the underlying network.The elastic behavior near the critical point can be described analogous to that of Magnetization in ferromagnetic material near the curie temperature.Surprisingly, the critical exponents are independent of the dimensionality and depend only on the average connectivity in the network.By including bending interactions in the rope network, we can capture the mechanical behavior of biologically relevant networks. Bending rigidity acts as a coupling constant analogous to the external magnetic field in a ferromagnetic system. We show that nonlinear mechanics of collagen are successfully captured by our framework of regarding nonlinear mechanics as a critical phenomenon.

SOE 25.8 Fri 11:30 BH-N 128

**Coarsening dynamics of transient networks in an experiment with dipolar hard spheres** — •Armin Koegel and Reinhard Richter — Experimentalphysik 5, Universität Bayreuth, D-95440 Bayreuth, Germany

Permanent magnetic dipoles may self-assemble to linear chains and rings, even without an externally applied magnetic field. This has been investigated for nano-sized particles in ferrofluids; see e.g. [1,2] However, in this system the emerging structures and their dynamics are difficult to observe. Similar aggregates have also been observed in a mixture of glass beads and magnetized steel spheres, which are shaken in a vessel [3]. In the present contribution we focus on the formation of transient networks in this system, when quenching the amplitude of the vibrations [4]. We analyze the evolving networks by the number of spheres in a network cluster, its gyration radius, and its average shortest path length.

[1] P.G. De Gennes and A. Pincus, *Phys. Kondens. Mater.* **1**, 189 (1970).

[2] T. A. Prokopieva, V. A. Danilov, S. S. Kantorovich, Ch. Holm, *Phys. Rev. E* **80**, 031404 (2009).

[3] D. L. Blair, A. Kudrolli, *Phys. Rev. E* **67**, 021302 (2003).

[4] http://www.ep5.uni-bayreuth.de/de/research/Magnetic-Soft-Matter/video/ferronetwork.html

SOE 25.9 Fri 11:45 BH-N 128

**Exclusion processes on networks** — •Izaak Neri[1,2], Norbert Kern[3], and Andrea Parmeggiani[3] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38 01187 Dresden Germany — [2]Max Planck Institute of Molecular Cell Biology and Genetics, Pfotenhauerstr. 108 01307 Dresden — [3]Laboratoire Charles Coulomb UMR 5221 & CNRS, Universite Montpellier 2, F-34095, Montpellier, France

We present a study of exclusion processes on complex networks, as a paradigmatic model for transport subject to excluded volume interactions. Building on the phenomenology of a single segment and borrowing ideas from random networks we investigate the effect of connectivity on transport. In particular, we argue that the presence of disorder in the network crucially modifies the large scale transport features: disorder induces strong density heterogeneities in the network such that certain regions of the network are almost fully congested while other regions allow for free flow of matter.

SOE 25.10 Fri 12:00 BH-N 128

**Synchronization-Desynchronization Transitions in Complex Networks: An Interplay of Distributed Time Delay and Inhibitory Nodes** — •Carolin Wille[1,2], Judith Lehnert[1], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

We investigate the combined effects of distributed delay and the balance between excitatory and inhibitory nodes on the stability of synchronous oscillations in a network of coupled Stuart–Landau oscillators. To this end a network model is proposed for which the stability can be investigated analytically. It is found that beyond a critical inhibition ratio synchronization tends to be unstable. However, increasing distributional widths can counteract this trend leading to multiple resynchronization transitions at relatively high inhibition ratios. All studies are performed on two distribution types, a uniform distribution and a Gamma distribution.[1]

[1] C. Wille, J. Lehnert, and E. Schöll, Phys. Rev. E 90, 032908 (2014)

SOE 25.11 Fri 12:15 BH-N 128

**Efficient sampling of networks with high clustering** — •Rico Fischer[1], Jorge Leitao[1], Tiago Peixoto[2], and Eduardo Altmann[1] — [1]Max-Planck-Institut für Physik komplexer Systeme — [2]University of Bremen

The problem in network generation is to obtain networks which satisfy specified properties but that are otherwise random. Traditional Markov Chain Monte Carlo methods (like Metropolis-Hastings) can be used in this problem but often fail in important cases, e.g., they do not correctly sample random networks with high clustering coefficients due to a rough >> landscape, which typically leads to abrupt phase transitions, metastable states and hysteresis. In this talk we show how an efficient sampling of high-clustering networks is obtained using multicanonical Monte-Carlo methods. We characterize the efficiency of this method, we use it to investigate the phase transition methods, and we explore different applications.

SOE 25.12 Fri 12:30 BH-N 128

**Shape and scaling of spatially embedded transport networks** — •Robin de Regt and Christian von Ferber — Coventry University, UK

Real world transport networks are usually embedded in two- or three-dimensional space. Here, we explore the shape and scaling properties of these spatially embedded complex networks. The work presented we focus on the interplay of spatial embedding and scaling statistics. In particular, complex transport networks of public transport appear to show that spatial and scaling properties within these networks are closely correlated. To support our claim we have analysed a number of public transport networks in a number of large scale conglomerations.