

DY 67: Networks: From Topology to Dynamics (joint session DY/ BP/SOE)

Time: Friday 9:30–12:45

Location: BH-N 128

DY 67.1 Fri 9:30 BH-N 128

Networks: From Dynamics to Topology — ●JOSE CASADIEGO^{1,3} and MARC TIMME^{1,2,3} — ¹Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen, Germany — ²Institute for Nonlinear Dynamics, Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany — ³IMPRS 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.

DY 67.2 Fri 9:45 BH-N 128

Revealing the Topology of Circulatory Networks in Nature — ●MIRKO LUKOVIC¹ and ERIK MARTENS^{2,3} — ¹Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — ²Department of Biomedical Sciences, University of Copenhagen, Denmark — ³Department 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.

DY 67.3 Fri 10:00 BH-N 128

Symbolic Regression and Network Analysis for the prediction of El Nino — ●MARKUS ABEL¹, MARKUS QUADE¹, RUGGERO VASILE¹, AVI GOZ², SHLOMO HAVLIN³, and ARMIN BUNDE⁴ — ¹Ambrosys GmbH, Albert-Einstein Str. 1-5 Potsdam, Germany — ²Department of Solar Energy & Environmental Physics, Ben-Gurion University, Jerusalem, Israel — ³Department of Physics Bar-Ilan University Ramat-Gan 52900 Israel — ⁴Institute For Theoretical Physics, University of Giessen, Germany

In the context of the modeling of dynamical systems, statistical analysis and data-based modeling is a highly promising method. We use symbolic regression, in particular genetic programming and non-parametric 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.

DY 67.4 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.

DY 67.5 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.

DY 67.6 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

DY 67.7 Fri 11:15 BH-N 128

Nonlinear elasticity of athermal networks: a critical phenomenon — ●ABHINAV SHARMA¹, ALBERT LICUP¹, MICHAEL SHEINMAN¹, KARIN JANSEN², GJISE KOENDERINK², and FREDERICK MACKINTOSH¹ — ¹VU, Amsterdam, Netherlands — ²AMOLF, 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.

DY 67.8 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/ferronetwerk.html>

DY 67.9 Fri 11:45 BH-N 128

Exclusion processes on networks — ●IZAAK NERI^{1,2}, NORBERT KERN³, and ANDREA PARMEGGIANI³ — ¹Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38 01187 Dresden Germany — ²Max Planck Institute of Molecular Cell Biology and Genetics, Pfotenhauerstr. 108 01307 Dresden — ³Laboratoire Charles Coulomb UMR 5221 & CNRS, Université 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.

DY 67.10 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 LEHNERT¹, and ECKEHARD SCHÖLL¹ — ¹Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — ²Institut 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)

DY 67.11 Fri 12:15 BH-N 128

Efficient sampling of networks with high clustering — ●RICO FISCHER¹, JORGE LEITAO¹, TIAGO PEIXOTO², and EDUARDO ALTMANN¹ — ¹Max-Planck-Institut für Physik komplexer Systeme — ²University 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 \gg 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.

DY 67.12 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.