Physics of Socio-economic Systems Division
Fachverband Physik sozio-ökonomischer Systeme (SOE)

Jens Christian Claussen
Computational Systems Biology
Jacobs University Bremen
Research II
Campus Ring 1
28759 Bremen
j.claussen@jacobs-university.de

Marc Timme
Network Dynamics
Max-Planck Institute for Dynamics
and Self-Organization
Am Faßberg 17
37077 Göttingen
timme@nld.ds.mpg.de

Jan Nagler
ETH Zürich
Computational Physics, IfB
Wolfgang-Pauli-Str. 27
CH-8092 Zürich
jnagler@ethz.ch

Overview of Invited Talks and Sessions

(Lecture rooms GÖR 226 and HSZ 01; Poster P2-OG4)

Invited and Topical Talks

SOE 1.1	Mon	9:30–10:00	GÖR 226	**Quantifying the evolution of individual scientific impact** — •Roberta Sinatra
SOE 5.1	Mon	15:00–15:45	HSZ 01	**Complexity in Economics and Finance** — •Cees Diks
SOE 7.1	Tue	9:30–10:15	GÖR 226	**Diffusion of Innovations under Direct and Indirect Peers Pressure** — •Ernesto Estrada
SOE 10.1	Tue	14:00–14:45	GÖR 226	**Human behaviour and traffic flow** — •Michael Schreckenberg

Young Scientist Award for Socio- and Econophysics (YSA) - Prize Talk

SOE 5.2	Mon	16:00–16:45	HSZ 01	**Climate Change and Global Governance in an Uncertain World** — •Francisco C. Santos, Vítor V. Vasconcelos, Simon A. Levin, Jorge M. Pacheco

Invited talks of the joint symposium SYCM

See SYCM for the full program of the symposium.

SYCM 1.1	Wed	9:30–10:00	HSZ 02	**Mobility in shareability networks** — •Michael Szell
SYCM 1.2	Wed	10:00–10:30	HSZ 02	**Trail-following bacteria: from single particle dynamics to collective behaviour** — Anatolij Gelimson, Kun Zhao, Calvin K. Lee, W. Till Kranz, Gerard C. L. Wong, •Ramin Golestanian
SYCM 1.3	Wed	10:30–11:00	HSZ 02	**Mobility and Self-Organization in Multi-Layer Networks: A Meta-Foodweb example** — •Thilo Gross, Andreas Brechtel, Philipp Gramlich, Daniel Ritterskamp, Barbara Drossel
SYCM 1.4	Wed	11:15–11:45	HSZ 02	**Temporal Percolation in Critical Collective Mobility Systems** — •Andreas Sorge, Debsankha Manik, Jan Nagler, Marc Timme
SYCM 1.5	Wed	11:45–12:15	HSZ 02	**Modeling the evolution of cities** — •Marc Barthelemy

Sessions

SOE 1.1–1.1	Mon	9:30–10:00	GÖR 226	**Scientific Impact and Models for Growth of Science (Topical Talk Roberta Sinatra)**
SOE 2.1–2.4	Mon	10:00–11:15	GÖR 226	**Social Systems I**
SOE 3.1–3.4	Mon	11:15–12:15	GÖR 226	**Financial Models and Risk Management I**
SOE 4.1–4.1	Mon	14:00–14:45	HSZ 02	**Plenary Talk Stuart Kauffman**
SOE 5.1–5.2	Mon	15:00–17:00	HSZ 01	**YSA Award Session: Young Scientist Award for Socio- and Econophysics 2017**
SOE 6.1–6.18	Mon	17:00–20:00	P2-OG4	**Poster**

SOE 7.1–7.1	Tue	9:30–10:15	GÖR 226	**Innovation Dynamics on Networks (Invited Talk Ernesto Estrada)**
SOE 8.1–8.3	Tue	10:15–11:00	GÖR 226	**Economic Models I**
SOE 9.1–9.5	Tue	11:00–12:15	GÖR 226	**Evolutionary Game Theory (joint session SOE / BP / DY)**
SOE 10.1–10.1	Tue	14:00–14:45	GÖR 226	**Traffic and Organization of Cities**
SOE 11.1–11.3	Tue	14:45–15:30	GÖR 226	**Physics of Collective Mobility (joint session SOE / DY / BP / jDPG, accompanying the symposium)**
SOE 12	Tue	15:30–16:00	GÖR 226	**Annual Member's Assembly**
SOE 13.1–13.5	Wed	9:30–12:15	HSZ 02	**Symposium SYCM: Physics of Collective Mobility (SOE / DY / BP / jDPG)**
SOE 14.1–14.14	Wed	15:00–19:15	ZEU 160	**Focus: The Physics of Power-Grids – Fluctuations, Synchronization and Network Structures (joint session DY / SOE)**
SOE 15.1–15.12	Wed	15:00–18:15	GÖR 226	**Focus Session: Cities as complex systems**
SOE 16.1–16.12	Thu	9:30–13:00	GÖR 226	**Networks (joint session SOE / DY / BP)**
SOE 17.1–17.5	Thu	15:00–16:15	ZEU 147	**Networks: From Topology to Dynamics (joint session DY/ BP/SOE)**
SOE 18.1–18.5	Thu	15:00–16:15	GÖR 226	**Economic Models II**
SOE 19.1–19.3	Thu	16:15–17:00	GÖR 226	**Financial Markets and Risk Management II**
SOE 20.1–20.2	Thu	16:30–17:00	ZEU 147	**Chimera states: symmetry-breaking in dynamical networks (joint session DY/BP/SOE)**
SOE 21.1–21.6	Thu	17:00–18:30	GÖR 226	**Social Systems II**
SOE 22.1–22.9	Fri	9:30–12:30	ZEU 160	**Focus Session: Controlling Complex Networks in Nature and Engineering (joint DY / SOE / BP)**

Annual General Meeting of the Physics of Socio-economic Systems Division

Tue 15:30–16:00 GÖR 226

SOE 1: Scientific Impact and Models for Growth of Science (Topical Talk Roberta Sinatra)

Time: Monday 9:30–10:00 Location: GÖR 226

Topical Talk SOE 1.1 Mon 9:30 GÖR 226

Quantifying the evolution of individual scientific impact — •Roberta Sinatra — Central European University, Budapest, Hungary — Northeastern University, Boston, MA, USA

Despite the frequent use of numerous quantitative indicators to gauge the professional impact of a scientist, little is known about how scientific impact emerges and evolves in time. In this talk we quantify the changes in impact and productivity throughout a career in science and show that impact, as measured by influential publications, is distributed randomly within a scientist's sequence of publications. This random impact rule allows us to formulate a stochastic model that uncouples the effects of productivity, individual ability and luck, unveiling the existence of universal patterns governing the emergence of scientific success. The model assigns a unique individual parameter Q to each scientist, which is stable during a career and accurately predicts the evolution of a scientist's impact, from the h-index to cumulative citations. Finally, we show that the Q-parameter is more predictive of independent recognitions, like prizes, than cumulative citations, h-index or productivity.

SOE 2: Social Systems I

Time: Monday 10:00–11:15 Location: GÖR 226

SOE 2.1 Mon 10:00 GÖR 226

How smoking became uncool: clustered marginalization of minorities during social transitions — •Jonathan F. Donges[1,2], Carl-Friedrich Schleussner[1,3], Denis A. Engemann[4], and Anders Levermann[1] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Stockholm Resilience Centre, Stockholm, Sweden — [3]Climate Analytics, Berlin, Germany — [4]Cognitive Neuroimaging Unit, CEA DRF/I2BM, INSERM, Université Paris-Sud, Université Paris-Saclay, NeuroSpin center, Gif/Yvette, France

Large-scale transitions in societies are associated with both individual behavioural change and restructuring of the social network. These two factors have often been considered independently, yet recent advances in social network research challenge this view. Here we show that empirically observed societal marginalization and clustering of minorities emerge naturally during social transitions in a co-evolutionary adaptive network model. This is achieved by explicitly considering the interplay between individual interaction and a dynamic network structure in behavioural selection. We exemplify this mechanism by simulating how smoking behaviour and the network structure are reconfigured by changing social norms. Our results are consistent with empirical findings: The prevalence of smoking was reduced, remaining smokers were preferentially connected among each other and formed increasingly marginalized clusters. We show that self-amplifying feedbacks between individual behaviour and dynamic restructuring of the network are the main drivers of the transition.

SOE 2.2 Mon 10:15 GÖR 226

Opinion Dynamics by Learning from Social Feedback — •Sven Banisch and Eckehard Olbrich — Max Planck Institute for Mathematics in the Sciences, Inselstrasse 22, D-04103 Leipzig, Germany

We explore a new mechanism to explain polarization phenomena in opinion dynamics. The model is based on the idea that agents evaluate alternative views on the basis of the social feedback obtained on expressing them. A high support of the favored and therefore expressed opinion in the social environment is treated as a positive social feedback which reinforces the value associated to this opinion. In this paper we concentrate on the model with dyadic communication and encounter probabilities defined by an unweighted, time-homogeneous network. The model captures polarization dynamics more plausibly compared to bounded confidence opinion models and avoids extensive opinion flipping usually present in binary opinion dynamics. We perform systematic simulation experiments to understand the role of network connectivity for the emergence of polarization. We show that the likeliness that an agent adopts an extreme opinion is correlated with its position in the network, which may provide a possibility to assess the validity of the model by comparison with data from real world social network data.

SOE 2.3 Mon 10:30 GÖR 226

Influences of Norm Change and Bounded Rational Decision Making on Sustainability Transitions in a Two Sector Economic Growth Model — •Jakob Kolb[1,2] and Jobst Heitzig[1] — [1]Potsdam Institut für Klimafolgenforschung, Potsdam — [2]Humboldt Universität, Berlin

The Anthropocene is thought of as the age of the humans, where in the context of modeling, man-made processes and environmental dynamics can not be treated separately anymore. It is at the core of human agency, to keep the trajectory of this coupled system within the boundaries of a save and just operating space, to ensure prosperity for future generations. In all the common business-as-usual scenarios of future economic development and GHG emissions, this is not likely to happen. Therefore, we aim at investigating sustainability transitions towards independence from fossil resources. The German Energiewende has proven that besides economic realities, social dynamics such as opinion spreading can play a significant role in the choice of energy sources and thereby resource dependence of a society. Consequently, we study the co-dependence and co-evolution of social, economic and resource dynamic processes. Since we are interested in qualitative behavior of this complex system such as transient behavior and phase transitions rather than quantitative predictions, we use a conceptual model for our studies. This model combines a resource-dependent two-sector economic growth model with heterogeneous households with Fast and Frugal heuristics for household decision making, as well as an adaptive network approach to norm change amongst households.

SOE 2.4 Mon 10:45 GÖR 226

XXIst century governance as a complex system — •Sara Encarnação[1,2,6], Fernando P. Santos[2,6], Francisco C. Santos[2,6], Vered Blass[3], Juval Portugali[4], and Jorge M. Pacheco[5,6] — [1]Interdisciplinary Centre of Social Sciences, CICS.NOVA, FCSH/UNL, Lisboa, Portugal — [2]INESC-ID & IST, Universidade de Lisboa, Portugal — [3]Faculty of Management, Tel Aviv University, Israel — [4]ESLab, Tel Aviv University, Israel — [5]Centro de Biologia Molecular e Ambiental and Departamento de Matemática e Aplicações, Universidade do Minho, Braga, Portugal — [6]ATP-group, Lisboa, Portugal

The interaction between individuals within a society, organized in different sectors and with growing emphasis on civil institutions, is inherently complex and difficult to analyze. Here we employ tools from stochastic population dynamics and ecology to comprehend those interrelations, and to assess the impact of new policies on cross-sectorial dynamics and desirable societal changes. Our results evince the potential key-role that the civil sector has in enabling a paradigm shift in modern societies, especially if supported by the public sector. Interestingly, a later civil-private coordination may exempt that support. This dynamical perspective on inter-sectorial coordination can constitute a key asset for political actors concerned with the complex ecology of decisions that accrue to multi-level governance [Encarnação et al., R. Soc. Open Sci., in press].

15 min. break

SOE 3: Financial Models and Risk Management I

Time: Monday 11:15–12:15 Location: GÖR 226

SOE 3.1 Mon 11:15 GÖR 226

Complex network-based analysis of nonlinear dependencies in multidimensional financial time series — •Alexander Haluszczynski — Ludwig-Maximilians-Universität, Munich, Germany — risklab GmbH, Munich, Germany

Cross-correlation and mutual information based complex networks of the day-to-day returns of US S&P500 stocks between 1985 and 2015 have been constructed in order to investigate the mutual dependencies of the stocks and their nature. We show that both networks detect qualitative differences especially during (recent) turbulent market periods thus indicating strongly fluctuating interconnections between the stocks of different companies in changing economic environments.

A measure for the strength of nonlinear dependencies has been derived using surrogate data and led to interesting observations during periods of financial market crisis. In contrast to the prevailing view that dependencies reduce mainly to linear correlations during crisis it turned out that (at least in the crisis after 2008) nonlinear effects are significantly increasing.

Finally, we apply a Markowitz mean variance portfolio optimization and integrate the measure of nonlinear dependencies to scale the investment exposure. This leads to significant outperformance as compared to a fully invested portfolio.

SOE 3.2 Mon 11:30 GÖR 226

Can Bank-Specific Variables Predict Contagion Effects? — •Christoph Siebenbrunner[1], Michael Sigmund[2], and Stefan Kerbl[2] — [1]University of Oxford, Institute for New Economic Thinking — [2]Oesterreichische Nationalbank

Assessing the systemic risk a bank poses to the system has become a central part in regulating its capital requirements (e.g. the buffer for global or domestic systemically important banks). As with conventional risk types, systemic risks need to be quantified. Currently global regulators propose a range of bank-specific indicators that measure size and interconnectedness to proxy systemic risk. In this study we gauge the capacity of such indicators to explain contagion losses triggered by realizations of sizeable idiosyncratic shocks. We study contagion impact through different channels, separating these effects into first-round, nth-round, asset fire sale and mark-to-market losses. We evaluate the predictive power of models selected by best-subset selection and Lasso by applying 10-fold panel cross validation. We provide constructive proofs for the existence of clearing payment vectors and associated market equilibria for these contagion channels in a model of interlinked balance sheets. We provide algorithms that converge to the greatest market equilibrium in a finite number of steps. Our empirical results suggest that the Basel III indicator set performs well in comparison to alternative data sets of bank-specific indicators. We also find, however, that the proposed data sets without bank dummies do not perform well in capturing the relevance of the average network position for predicting contagion effects.

SOE 3.3 Mon 11:45 GÖR 226

Microscopic understanding of price cross-responses between stocks — •Shanshan Wang and Thomas Guhr — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany

Previous studies have discovered the existence of price cross-responses between stocks in correlated financial markets by empirical analysis. However, the cross-responses are not yet understood on a microscopic level. We therefore construct a price impact model between stocks in a correlated market. For the price change of a given stock induced by the short-run liquidity of this stock itself and by the information about other stocks, we introduce a self- and a cross-impact function of time lags. We then model the average cross-response functions for individual stocks by employing the impact functions of time lags, the impact functions of traded volumes and the trade-sign correlators. We find the self- and cross-impact functions are indispensable to compensate amplification effects which are due to the sign correlators integrated over time. We further quantify and interpret the price impacts of time lags in terms of temporary and permanent components.

SOE 3.4 Mon 12:00 GÖR 226

Improved Variance Reduced Monte-Carlo Simulation of in-the-Money Options — •Armin Müller — FernUniversität in Hagen, Lehrstuhl für angewandte Statistik und Methoden der empirischen Sozialforschung, Germany

Pricing derivatives with Monte-Carlo simulations involves standard errors that typically decrease at a rate proportional to N^(-0.5) where N is the sample size. Several approaches have been discussed to reduce the empirical variance for a given sample size. This talk presents a joint application of the put-call-parity approach and importance sampling to variance reduced option pricing. For this purpose, we examine non-path-dependent and path-dependent options. For European options, we observe dramatic variance reduction of several orders of magnitude, especially for in-the-money options. Also for arithmetic Asian options, we achieve a significant variance reduction.

SOE 4: Plenary Talk Stuart Kauffman

Time: Monday 14:00–14:45 Location: HSZ 02

Plenary Talk SOE 4.1 Mon 14:00 HSZ 02

The Emergence and Evolution of Life Beyond Physics — •Stuart Kauffman — Biochemistry and Biophysics, University of Pennsylvania; The Institute for Systems Biology, Seattle

The emergence and evolution of life is based on physics but is beyond physics. Evolution is an historical process arising from the non-ergodicity of the universe above the level of atoms. Most complex things will never exist. Human hearts exist. Prebiotic chemistry saw the evolution of many organic molecules in complex reaction networks, and the formation of low energy structures such as membranes. Theory and experiments suggest that from this, the spontaneous emergence of self reproducing molecular systems could arise and evolve. Such *collectively autocatalytic systems* cyclically link non-equilibrium processes whose constrained release of energy constitutes *work*, to construct the same constraints on those non-equilibrium processes. Cells do work to construct the boundary conditions that give the constrained releases of energy by which work they construct themselves.

Such systems are living, and can propagate their organization with heritable variations, so can be subject to natural selection. In this evolution, these proto-organisms emerge unprestatably, and afford novel niches enabling, not causing, further types of proto-organisms to emerge. With this, unprestatable new functions arise. The ever-changing phase space of evolution includes these functionalities. Since we cannot prestate these ever new functionalities, we can write no laws of motion for this evolution, which is therefore entailed by no laws at all, and thus not reducible to physics. Beyond entailing law, the evolving biosphere literally constructs itself and is the most complex system we know in the universe.

SOE 5: YSA Award Session: Young Scientist Award for Socio- and Econophysics 2017

Time: Monday 15:00–17:00 Location: HSZ 01

Invited Talk SOE 5.1 Mon 15:00 HSZ 01

Complexity in Economics and Finance — •Cees Diks — University of Amsterdam, CeNDEF

We discuss how expectations feedback and heterogeneity among agents can generate complex dynamics in economic and financial systems. The qualitative predictions of the resulting nonlinear models are very different from standard linear benchmarks, with important policy implications. For instance, the fundamental price can become unstable when interest rates are set too low, giving rise to multiple nonfundamental equilibria and/or global instability. This is illustrated in a central application, where we introduce heterogeneous expectations in a standard housing market model linking housing rental levels to fundamental buying prices. Using quarterly data we estimate the model parameters for eight different OECD countries. We find that the data support heterogeneity in expectations, with temporary endogenous switching between fundamental mean-reverting and trend-following beliefs based on their relative performance. Finally, a stochastic CUSP model is estimated for the same housing data to study the effect of time-varying mortgage rates in a stochastic setting.

Presentation of the Award to the Awardee

Prize Talk SOE 5.2 Mon 16:00 HSZ 01

Climate Change and Global Governance in an Uncertain World — •Francisco C. Santos[1,2], Vítor V. Vasconcelos[1,2], Simon A. Levin[3], and Jorge M. Pacheco[4,2] — [1]INESC-ID & Instituto Superior Técnico, Universidade de Lisboa, Portugal — [2]Applications of Theoretical Physics Group, Portugal — [3]Dept. of Ecology and Evolutionary Biology, Princeton University, USA — [4]CBMA & DMA, Universidade do Minho, Portugal

When attempting to avoid global warming, individuals often face a social dilemma in which, besides securing future benefits, it is also necessary to reduce the chances of future losses. We propose a simple population dynamics approach to this type of dilemmas, in which the risk of failure plays a central role in individual decisions. This model can be shown to capture some of the essential features discovered in recent key experiments, while allowing one to extend the experimental conditions to regions also of practical interest. Our results suggest that global coordination for a common good should be attempted through a polycentric structure of multiple small-scale agreements, in which perception of risk is high and uncertainty in collective goals is minimized. Whenever the perception of risk is low, our results indicate that sanctioning institutions may significantly enhance the chances of coordinating to tame the planet's climate, as long as they are implemented in a decentralized manner. Finally, we also discuss the impact on public goods dilemmas of heterogeneous political networks, growing agreements, and wealth inequality, including a distribution of wealth representative of existing inequalities among nations.

After the Award Session, there will be an informal get-together with beer and pretzels at the poster session

SOE 6: Poster

Posters can and should be on display during the whole day.

Time: Monday 17:00–20:00 Location: P2-OG4

SOE 6.1 Mon 17:00 P2-OG4

Where Has All the Surplus Gone? — •Stephen I. Ternyik and Stephen I. Ternyik — POB.201 D-82043Munich

The surplus value of tech-know-logical innovation has disappeared into the few pockets of rentier groups.The monetary flow of the conjunctural motion and energy-driven economic circuit was directed to the holders of natural resources and real estate, i.e. the return from economic rent-seeking became quantitatively greater than productive growth (r>g). Thus, the real socio-economic divide is between the return from rent and the combined return from labor & capital; the passive return from rent outperformed the active return from labor and capital. Unearned income has absorbed earned income (predator-prey-mechanism), causing the energetic momentum of global economic crisis. This is not only a Sisyphean problem of human economic history ; the point of economic singularity can in the nearer future only be achieved, if we will be able to calm down great economic fluctuations that cause unbearable pains for the majority of the human population. Recapturing the invested energy input via taxing economic rent is the simplest method to restore the economic balance of societal production.

SOE 6.2 Mon 17:00 P2-OG4

Phase Transitions in Autonomous Intersection Traffic? — •Dimitra Maoutsa, Debsankha Manik, Malte Schröder, and Marc Timme — Network Dynamics, Max Planck Institute for Dynamics and Self-Organisation

With the advent of self-driving (autonomous) vehicles, street traffic coordinated by traffic lights might soon not only be outdated, but also remarkably inefficient. Improved reactivity and precision of autonomous vehicles (compared to human drivers) opens up the possibility to more effectively coordinate conflicting traffic flows at intersections. Here we study the collective dynamics of intersection traffic managed by vehicle to infrastructure (V2I) communication [1] in combination with slot-based scheduling strategies that induce the formation of vehicle platoons [2]. We reveal under which conditions and how such a system undergoes a transition from free to congested flow and quantify the economic efficiency in dependence of control parameters. A shift from bounded to diverging traffic delays indicate the onset of efficiency losses. Such theoretical insights may help proposing optimized operating points for given traffic conditions and may therefore aid designing the prospective transit from conventionally to autonomously controlled traffic management.

References:

[1] Dresner & Stone, A multiagent approach to autonomous intersection management. J. Artif. Intell. Res. 31:591 (2008).

[2] Remi et al., Revisiting street intersections using slot-based systems, PLoS ONE, 11:e0149607 (2016).

SOE 6.3 Mon 17:00 P2-OG4

How long does it take to board an airplane? — •Reinhard Mahnke[1], Jevgenijs Kaupuzs[2], Eitan Bachmat[3], and Vidar Frette[4] — [1]Rostock University, Institute of Physics, D-18051 Rostock, Germany — [2]Riga Technical University, LV–1048 Riga, Latvia — [3]Ben–Gurion University, Beer-Sheva 84105, Israel — [4]Stord/Haugesund College, N–5528 Haugesund, Norway

A simple airplane-boarding model, introduced earlier by Frette and Hemmer, is considered. In this model, N passengers have reserved seats, but enter the airplane in arbitrary order.

We are looking for an analytical expression, which describes the mean boarding time depending on the total number of passengers N. For this purpose, we first determine precise values of the exponents and expansion coefficients in the asymptotic expression at $N \to \infty$. It is reached by mathematical calculations and fitting the Monte Carlo simulation data for very large N, up to $N \sim 6 \cdot 10^8$.

Finally, we compare the obtained analytical approximation to the simulation data for a realistic number of passengers $N \lesssim 500$ and find a good agreement.

SOE 6.4 Mon 17:00 P2-OG4

Emergent features of triadic relations in political networks — •Andres M. Belaza[1,2], Kevin Hoefman[2], Jan Ryckebusch[1], and Koen Schoors[2] — [1]Department of Physics and Astronomy, Ghent University — [2]Department of General Economics, Ghent University

We propose a model with five energy levels that encodes the dynamics of triadic relationships in a political network. The model builds

on insights gleaned from structural balance theory to which we add elements from Boltzmann-Gibbs statistical physics. We go beyond the restrictions of signed networks and introduce the concept of social temperature to encode exogenous effects. We start from the idea that two agents that maintain ties in a political network can be either enemies, or friends, or neutrals to each other. The generic Hamiltonian associated with the five energy levels contains three parameters. One is connected with a three-body interaction inspired on social balance theory. The other two parameters take into account the costs of symmetry breaking and of changing a link. We stress the role of the degeneracy of the different energy levels and how it affects the degree of frustration in the political network. The validity of our model is tested on an extended data set for the time series of triadic relationships for the standings between alliances in a massive multiplayer online role-playing game. We also analyze real-world data for the different factions that play a role in the current war in Syria. We find emerging properties in the triadic relationships between the nodes in a political network, for example reflecting itself in a persistent hierarchy between the different energy levels.

SOE 6.5 Mon 17:00 P2-OG4

Centrality Measures on a Temporal Fashion Network — •Jonas Braun[1], Frederik Wolf[2], Philipp Gert Josef Lorenz[2], Philipp Hövel[2], Colin Bauer[3], Julien Siebert[3], and Vitaly Belik[4] — [1]Department of Physics, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin — [2]Technische Universität Berlin — [3]Zalando SE — [4]Freie Universität Berlin

The dissemination of information in social networks is a process, in which some nodes in the network have a much more significant influence on the extent and speed of the spreading than others. Finding these highly influential spreaders has a great significance in understanding and controlling real world networks, suppressing or amplifying the spreading of information.

We analyse the real-world digital platform lookbook.nu, a social network for fashion bloggers. Using simulations on the observed topology as well as measuring real spreading of information, we evaluate centrality measures as an indicator for the power of spreaders on this particular social network.

Due to the dynamic nature of fashion trends, we find that topological changes of the network may occur on the same timescale as the spreading processes. Thus, we investigate whether established centrality measures apply in the context of such a temporal network.

SOE 6.6 Mon 17:00 P2-OG4

Large deviation properties of the Nagel-Schreckenberg model — •Wiebke Staffeldt and Alexander K. Hartmann — Institute of Physics, University of Oldenburg

The probability density function (pdf) $P(q)$ of traffic flow q in the Nagel-Schreckenberg model for one lane traffic [1] for different densities of cars ρ is studied. We apply recently introduced large deviation techniques [2, 3], that work with an artificial temperature to direct the system in different regions. After suitably rescaling the data we obtain the true distribution even in the tails with probabilities as low as 10^{-150} in order to investigate their differences in the low- and high density regime. Numerical simulations for several vehicle densities ρ are performed for two scenarios: the situation of equilibrium on a lane with periodic boundary conditions and a nonequilibirium situation such as all vehicles start at a traffic light. We analyse the shape of the distribution as a function of the density ρ. Furthermore, the influence of finite-size effects is analysed by comparing the results for different system sizes. In particular, we evaluate the rate function $\Phi(q) = -\frac{1}{L}\ln(P(q))$.

[1] K. Nagel and M. Schreckenberg, J. Phys. I 2, 2221 (1992)
[2] A. K. Hartmann, Phys. Rev. E **89**, 051203 (2014)
[3] A. K. Hartmann, Eur. Phys. J. B **84**, 627-634 (2011)

SOE 6.7 Mon 17:00 P2-OG4

Multiple games in the multiverse — •Vandana Revathi Venkateswaran and Chaitanya S. Gokhale — Research Group for Theoretical Models in Eco-Evolutionary dynamics, Department of Evolutionary Theory, Max Planck Institute for Evolutionary Biology, Plön

Evolutionary game theory has proved useful in analyzing interactions between agents in an evolutionary context. For a particular application, usually a single game is analyzed, which can have n strategies. A combination of two, two player two strategy (2x2) games was intensively studied to introduce the idea of Multi Game Dynamics (MGD) and later we studied various combinations of single multi-strategy games.

The results show that it is not always possible to decompose MGD into its constituent games if any constituent game has $n > 2$ and thus impossible to always predict dynamics of a combination of games even if the underlying games are well understood. Even if a game has a fixed-point as an ESS, when it is combined with other games, the combined MGD need not converge to that ESS.

Different initial conditions can lead to different dynamical outcomes. We provide a quantitative extension by analyzing the proportion of initial states deviating from the expected solution. Furthermore the idea of a combination of multiplayer evolutionary games is proposed where the conditions of $n > 2$ is no longer necessary.

SOE 6.8 Mon 17:00 P2-OG4

Lane Change Prediction in an Urban Area — •Karoline Griesbach[1] and Karl Heinz Hoffmann[2] — [1]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany, Telephone: +49 371 531 35456 — [2]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany, Telephone: +49 371 531 35456

The prediction of the lane change and its integration in advanced driving assistance systems can reduce traffic accidents. In the article a neural network for lane change prediction will be discussed. The neural network was implemented with three learning rules: delta rule, backpropagation and backpropagation with momentum. The prediction of right and left lane changes were considered. The input data was provided by a Naturalistic Driving study and divided into a training set and a validation set. The best prediction was achieved for the left lane change with a neural network with backpropagation (tpr = 72.09%, fpr = 0.00%). The prediction of the right lane change was not successful.

SOE 6.9 Mon 17:00 P2-OG4

Emergence of Social Badges — •Gorm Gruner Jensen and Stefan Bornholdt — Universität Bremen, Bremen, Deutschland

Social badges, easily detectable physical traits that strongly correlate with social status, are found in a wide variety of biological species. It is usually assumed that such badges signal an intrinsic strength, warning potential competitors to stay away and attracting potential mates. Under this assumption it is generally understood, that the correlation between badge and intrinsic strength must be strong in order for the receiver to benefit from reacting to it, and the badge must come at a cost in order to avoid false replicas.

We will present a different view, by introducing a minimalistic model in which the badge precedes any intrinsic property. The correlation between badge and social status emerges as a self-organized property due to the collective behavior of individual agents whose strength is affected by their self esteem, and whose self esteem is faithfully inferred from previous experience.

SOE 6.10 Mon 17:00 P2-OG4

Motif formation in the Japanese Business Firm Network — •Julian Maluck[1,2], Reik V. Donner[1], Hideki Takayasu[2], and Misako Takayasu[2] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Tokyo Institute of Technology, Japan

We investigate how characteristic patterns in the establishment of business relationships and merging agreements between firms explain the functional roles and organization of 3-party interactions in the Japanese Business Firm Network. By considering industry dependent linking patterns of newly established firms in an evolving network model, the conceptual understanding of the emergence of motifs at the meso-scale of the network can be improved. At the global scale, however, an observed overshoot of appearances of densely connected motifs in the model requires additional explanation in terms of merging preferences between firms. We provide evidence towards the tendency of Japanese business firms to merge with other firms that show similar patterns in their input/output allocations.

SOE 6.11 Mon 17:00 P2-OG4

Impacts of Regional Trade Agreements on the flow of goods and money in the world economy — Julian Maluck and •Reik V. Donner — Potsdam Institute for Climate Impact Research, Germany

Free trade agreements have received rising attention within the last decades, with trade deals having been negotiated at an increasing pace. Multi-regional input-output (MRIO) tables allow for a concise analysis

of trade relations between industries both at a national and international level. By evaluating an industry's dependency on its consuming and supplying industries from MRIO data, we construct two flow networks of goods and money, respectively. We present how flow networks can be utilized to quantify impacts of various Regional Trade Agreements by methods from complex network theory. Next to a comprehensive overview of these impacts, our results provide the basis for further detailed studies on the implications of specific design patterns within trade agreements.

SOE 6.12 Mon 17:00 P2-OG4

Opinion formation on networks: the topology may predict more than we think. — •Michael Schnabel and Daniel Diermeier — University of Chicago, Chicago, USA

We consider opinion formation on a given network, using interacting spin systems on arbitrary network topologies as a modeling framework, and propose to project the high dimensional state space of possible opinion configurations onto two dimensions that quantify the average opinion as well as the average local consensus in the network. For an Ising model these macroscopic order parameters would correspond to the magnetization M and the energy E. Our approach, however, is not restricted to the Ising model. This two dimensional representation allows to obtain model independent insight into predominant opinion configurations that are imposed by the network topology alone. We devise a numerical method, based on the Wang-Landau algorithm, to determine the density of states for arbitrary network topologies which essentially sets the stage on which the flow of opinions can unfold once a particular dynamical model has been specified. Our framework may be used to draw general conclusions about the typical distribution of opinions in small to medium sized networks (up to O(10^3) nodes), e.g. such as identifying network topologies that would facilitate (or prevent) the occurrence of consensus or fragmentation of opinions in the network, and may be applicable for a broad range of dynamical models.

SOE 6.13 Mon 17:00 P2-OG4

Heider balance in bilayer networks — •Piotr J Górski[1], Krzysztof Kułakowski[2], Przemysław Gawroński[2], and Janusz A Hołyst[1] — [1]Faculty of Physics, Warsaw University of Technology, ul. Koszykowa 75, 00-662 Warsaw, Poland — [2]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, al. Mickiewicza 30, 30-059 Kraków, Poland

In a social network links may describe friendly or hostile interpersonal relations. According to Heider balance theory these relations change in order to obtain a system of balanced link triads. A triad is balanced when four axioms are fulfilled; one of which is "a friend of my enemy is my enemy". Here, we analyze the formation of the Heider balance in a bilayer network governed by link dynamics. Each link evolves being influenced by its neighbor links from the same layer and its replica from the other layer. The relative strength of coupling between layers is modeled using a pair of coupling coefficients (β_1, β_2). We investigate systems with asymmetric layer coupling, i.e. $\beta_1 \neq \beta_2$. We discover tendencies driving system dynamics. We observe many phenomena, such as transitions between the ordered and unordered states (in terms of above mentioned tendencies), nonlinear oscillations of relations, and "master-slave effect" of layer dependence. The obtained results comprise rich diagrams of model parameters that allow us to identify the areas of coupling coefficients leading to high probability of attaining Heider balance.

SOE 6.14 Mon 17:00 P2-OG4

A behavioral spruce budworm predation model — Bhagyashree Hote[1], Manas Joshi[1], Reeve Ahmed[1], Maleeha Aziz[1], and •Jens Christian Claussen[1,2] — [1]Computational Life Science Program, Jacobs University Bremen — [2]Computational Systems Biology, Jacobs University Bremen

The spruce budworm model has become a classical model of predation of spruce budworms by birds [1]. In this model, the sublinear onset of predation is motivated by a metaphor that birds predate the spruce budworms only if this food source reaches awareness among the predators. Here, we explicitely introduce the fraction of birds that are aware of the additional food source as an additional dynamical variable and formulate a plausible dynamics for its increase and decay. For suitable parameters, the model shows an attracting spiral node, which results in damped oscillations of the prey density towards the fixed points.

[1] Murray, Mathematical Biology (Springer, 2002).

SOE 6.15 Mon 17:00 P2-OG4

Size distribution of scientific paradigms in the Bornholdt-Jensen-Sneppen model on complex networks — Kim Philipp Jablonski[1] and •Jens Christian Claussen[1,2] — [1]Computational Life Science Program, Jacobs University Bremen — [2]Computational Systems Biology, Jacobs University Bremen

The Bornholdt-Jensen-Sneppen model [1] describes the emergence and decay of scientific paradigms by a stochastic dynamics of imitation of neighboring strategies, based on their overall abundance, in competition with a second mutational process introducing a new paradigm. This model has been shown to exhibit a powerlaw 2.5 statistics of the overall number of sites that have been touched by a paradigm. Here, we investigate the corresponding generalizations of this dynamics on complex networks. Our simulations indicate that, apart from minor deviations, the shape of the statistics remains preserved on different network topologies.

[1] S. Bornholdt, M.H. Jensen, K. Sneppen, Phys. Rev. Lett 106, 058701 (2011)

SOE 6.16 Mon 17:00 P2-OG4

Global Urban Energy Efficiency: Insights from scaling laws — •Ramana Gudipudi[1], Mathias K. B. Lüdeke[1], and Jürgen P. Kropp[1,2] — [1]Potsdam Institute for Climate Impact Research, Potsdam, 14412, Germany — [2]Department of Geo- and Environmental Sciences, University of Potsdam, Potsdam, 14476, Germany

The scaling properties of total urban energy use with city size were investigated based on a sample of 223 cities worldwide in developing and developed countries for the first time. We found sub-linear scaling of energy with population (slope = 0.88) but the quality of the fit appears to be relatively low ($R^2 = 0.83$) for the logarithmic variables. This can be significantly improved (R^2=0.9) by dividing the cities sample into two subsets separated by their degree of industrialization. Furthermore, it appears that – independent from the chosen industrialization threshold – the more service oriented cities scale almost linearly with size because of their infrastructure lock-in behavior while the industrialized cities with nascent infrastructure show a significantly lower exponent. According to this analysis, the energy consumption of larger industrialized cities is typically more energy efficient per cap than that of smaller cities which is good news given the strong global urbanization trend. The results also underscore the energy consumption traits of richer service oriented cities where size does not influence the energy consumption.

SOE 6.17 Mon 17:00 P2-OG4

Local or global, the request for a sustainable urban food system — •Steffen Kriewald, Prajal Pradhan, and Jürgen P. Kropp — Potsdam Institute for Climate Impact Research, Potsdam, Germany

The share of urban population has increased from 30% to 55% in the last sixty years and will further increase up to 65% by 2050. Hence, it is crucial to provide enough food for the growing urban population to ensure local, regional and global food security. For over 4000 urban agglomerations we investigated the possibility of regional food production to reduce dependency on global trade. Additionally we examined the main influencing factors which lead to a sustainable food supply, such as population growth, urban sprawl, diets - both in terms of quantity and composition as well as climate change. Introducing a spatially explicit urban footprint from food production we were able to identify regions where future expansion of agricultural areas is limited and intensification will no longer be an option due to the impacts of climate change.

SOE 6.18 Mon 17:00 P2-OG4

Optimization of urban food networks and its climate benefits — •Prajal Pradhan[1], Steffen Kriewald[1], Luis Costa[1], and Jürgen Kropp[1,2] — [1]Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany — [2]University of Potsdam, Potsdam, Germany

By 2050, urban population share grow to 65%. Therefore, feeding the growing urban population is crucial to ensure local, regional and global food security. However, food is mostly grown in nonurban regions. This reflects interdependency of hinterlands and urban areas in food production and consumption, which can be considered as urban foodshed.

We analyze urban foodshed for 7000 urban administrative units (UAUs) across the globe and estimate greenhouse gas emissions re-

lated to food transport applying two different methods: i) globalized agricultural trade where food is brought from an arbitrary site, ii) an optimization scenario where food demands are met by UAUs' peripheral regions. We also account for reduction of food waste and closing of crop yield gaps to understand their impacts on both globalization and optimization scenarios.

Our results show that mean distance, total distance, net food transport, net food transport distance and associated greenhouse gas emissions are lower for most UAUs in the optimization scenario compared to the globalization scenario. Our analyses on food waste reduction and yield gaps closing also result in lower estimates. Hence, our study provides new insights on required measures to decrease urban foodshed and to reduce emissions related to food transport.

SOE 7: Innovation Dynamics on Networks (Invited Talk Ernesto Estrada)

Time: Tuesday 9:30–10:15 Location: GÖR 226

Invited Talk SOE 7.1 Tue 9:30 GÖR 226

Diffusion of Innovations under Direct and Indirect Peers Pressure — •Ernesto Estrada — Dept. of Mathematics and Statistics, U Strathclyde, Scotland

How do innovations diffuse on a graph of agents? - I will start by a short introduction to the problem of diffusion on graphs, defining the graph Laplacian and some applications in areas ranging from autonomous robots to diffusion of innovations. Then, I will motivate the necessity of incorporating long-range interactions to account for certain physical diffusive processes. I will then introduce the k-path Laplacians as operators in l^2 Hilbert space and prove a few of their properties (boundedness, self-adjointnes). At this point I will introduce a generalisation of the diffusion equation on graphs by using Mellin- and Laplace-transformed k-path Laplacians. I will prove the existence of super-diffusive regimes for certain values of the parameter in the Mellin-transformed k-path Laplacian in one-dimension. Finally, I will introduce a multi-hopper model, that generalises the random walk model on graphs, by allowing non-nearest neighbours jumps. I will show the differences between this model and the random walk with Levy flights, which is valid only in the continuous space. I will prove that for certain asymptotic value of the parameters in the transforms of the k-path Laplacians, the multi-hopper reaches the minimum hitting and commute times in graphs of any topology. I will illustrate the results with the diffusion of innovations, such as a new teaching method among high schools and the adoption of a Biotech product among Brazilian farmers.

SOE 8: Economic Models I

Time: Tuesday 10:15–11:00 Location: GÖR 226

SOE 8.1 Tue 10:15 GÖR 226

A time-homogeneous system of money and antimoney in an agent-based multi good economy — •Julian Stein, Simon Lanzmich, and Dieter Braun — Systems Biophysics LMU

Financial crises appear through human history. One source of financial instability might be the creation of money, as the credit mechanism leads to non-local transfer of purchasing power [1]. Motivated by an analogy to particle physics, locality and time-homogeneity can be imposed on monetary systems. As a result, full reserve banking is implemented by a two-currency system of non-bank (money) and bank assets (antimoney) [2]. Payments are made by passing on money or receiving antimoney. A free floating exchange rate between non-bank assets and bank assets is established. Interestingly, credit creation is replaced in this monetary memory by a liquidity transfer that simultaneously transfers money and antimoney at a negotiated exchange rate. We want to study whether the problem of credit crunches is mitigated once a full time symmetry of the monetary system is maintained.

To compare the prevailing monetary system to the money-antimoney system, simulations in an agent-based random economy are performed. In the economy, households and firms apply different stochastic trading strategies to exchange goods (and liquidity) via a limit order book mechanism. The system's dynamics are studied with respect to price evolution and the agents' phase space distributions of the utility and monetary wealth, similar to recent studies [3,4].

[1] New J Phys 16, 033024 (2014), [2] Physica A 290, 491 (2001), [3] Rev ModPhys 81, 1703 (2009), [4] QFin 11.7, 991-1041 (2011)

SOE 8.2 Tue 10:30 GÖR 226

When does inequality freeze an economy? — Joao Pedro Jerico[1], Francois Landes[2], Isaac Perez Castillo[3], Matteo Marsili[2], and •Valerio Volpati[4] — [1]Departamento de Fisica General, Instituto de Fisica, Universidade de Sao Paulo, Brazil — [2]The Abdus Salam International Centre For Theoretical Physics (ICTP), Trieste, Italy — [3]Department of Complex Systems, Institute of Physics, UNAM, Mexico — [4]Institut de Physique Theorique, CEA, Gif-sur-Yvette, France

Inequality and its consequences are the subject of intense recent debate. Using a simplified model of the economy, we address the relation between inequality and liquidity, the latter understood as the frequency of economic exchanges. Assuming a Pareto distribution of wealth for the agents, that is consistent with empirical findings, we find an inverse relation between wealth inequality and overall liquidity. We show that an increase in the inequality of wealth results in an even sharper concentration of the liquid financial resources. This leads to a congestion of the flow of goods and the arrest of the economy when the Pareto exponent reaches one.

SOE 8.3 Tue 10:45 GÖR 226

Estimating a Hierarchy of Safetly Levels within Planetary Boundaries in a 3-dimensional Co-evolutionary Earh System Model — •Tim Kittel[1,2], Rebekka Koch[2], Jobst Heitzig[1], Guillaume Deffuant[3], Jean-Denis Mathias[3], and Jürgen Kurths[1,2,4] — [1]PIK Potsdam, Germany — [2]HU Berlin, Germany — [3]IRSTEA, Aubière, France — [4]University of Aberdeen, United Kingdom

In recent years, the Planetary Boundaries by Rockström et al. (2009), their superseding refinements by Steffen et al. (2015) and Social Foundations by Raworth (2012) have been under intensive investigation, particularly their interaction with each other. The framework on Topology of Sustainable Management (TSM) developed by Heitzig et al. (2016) demonstrated how a hierarchy of safety levels arises when taking the dynamics of the system and possible management options into account.

In this talk, we will present a 3-dimensional low-complexity co model of climate change, welfare growth and energy transformation which cannot be analyzed manually anymore needing the Saint-Pierre algorithm from viability input for the estimation of the safety levels.

The estimated current state face the so-called pressing lake dilemma, i.e. a decision between 2 qualitatively different pathways has to be made. One choice would be to avoid the transgression of the boundary but leading to a fossil-based economy where the growth has to be restricted all the time. The other choice would be to risk a temporary transgression of the boundaries but finally leading to a green economy.

SOE 9: Evolutionary Game Theory (joint session SOE / BP / DY)

Time: Tuesday 11:00–12:15 Location: GÖR 226

SOE 9.1 Tue 11:00 GÖR 226

Assortative matching with inequality in voluntary contribution games — •Stefano Duca, Dirk Helbing, and Heinrich H. Nax — D-GESS, ETH Zurich, Switzerland

Voluntary contribution games are a classic social dilemma in which the individually dominant strategies result in a poor performance of the population. The negative zero-contribution predictions from social dilemma situations give way to more positive (near-)efficient ones when assortativity, instead of random mixing, governs the matching process in the population. Under assortative matching, agents contribute more than what would otherwise be strategically rational in order to be matched with others doing likewise. An open question has been the robustness of such predictions in terms of provisioning of the public good when heterogeneity in budgets amongst individuals is allowed. Here, we show analytically that the consequences of permitting heterogeneity depend crucially on the exact nature of the underlying public-good provision efficacy, but generally are rather devastating. Using computational methods, we quantify the loss resulting from heterogeneity vis-a-vis the homogeneous case as a function of (i) the public-good provision efficacy and (ii) the population inequality.

SOE 9.2 Tue 11:15 GÖR 226

Anomalous Long-Term Behavior in Evolutionary Dynamics from Ergodicity Breaking — •Jan Nagler[1] and Frank Stollmeier[2] — [1]ETH Zurich — [2]MPI DS, Network Dynamics, Göttingen

Fluctuating environments determine life, ranging from the early stages of molecular evolution to the emergence and maintenance of cooperation in our society. Predicting the long-term evolution of species and strategies in uncertain environments is a long-standing challenge in evolutionary dynamics. For evolutionary games where the payoff a player receives is dependent on the fluctuating environmental state, we predict the dynamics in the long-term, i. e. the game's stationary states. For deterministically and stochastically varying payoff structures we find anomalous, sometimes counterintuitive, long-term behaviors which are markedly different from traditional games defined by constant payoffs. Intricately, the anomalous stationary states are sensitive to the covariance of the payoffs. In contrast to evolutionarily stable states of games with constant payoffs, where coexisting species necessarily receive equal payoffs, anomalous stable states can be unfair, meaning that, on average, two coexisting species may receive different payoffs. Moreover, environmental noise can induce transitions between different games. We introduce a classification for evolutionary games with payoff stochasticity, which contains the traditional games for vanishing payoff variance. Our framework, developed here analytically, robustly predicts the long-term evolution of species and strategies in fluctuating environments.

SOE 9.3 Tue 11:30 GÖR 226

Extinction properties in the coexistence two-species population induced by demographic fluctuation — •Hye Jin Park and Arne Traulsen — Department of Evolutionary Theory, Max Planck Institute for Evolutionary Biology, Plön, Germany

Two-species system can be described by the reaction rules which occur according to given rates. Due to this stochasticity a population size fluctuates, and the system is out of the deterministic system. Even thought the system has a stable fixed point in the deterministic case, it can be in an another state for the stochastic model. Since the population is never recovered once it goes to extinct, all populations go to extinct eventually unless the population size goes to infinity. Here, we investigate extinction properties of two-species system and examine which one is preferred to extinct first when two species can coexist for a long time. In this paper, we find the most probable trajectory to extinction in the species-abundances space using WKB (Wentzel-Kramers-Brillouin) method and show that the one of the species is preferred to extinct first as carrying capacity increases. In addition, we find that the mean time to extinction increases as a power law for small carrying capacity while exponentially increases for larger carrying capacity than certain value.

SOE 9.4 Tue 11:45 GÖR 226

Family-friendly zero-sum games — •Philipp M. Geiger, Johannes Knebel, Markus F. Weber, and Erwin Frey — Ludwigs-Maximilians-Universität, München, Deutschland

Here we study how network topology determines the long-time coexistence in the antisymmetric Lotka-Volterra equation (ALVE). The ALVE is the replicator equation of zero-sum games, in which interactions are defined by an antisymmetric matrix such that the gain of one strategy equals the loss of a dominated one. The interactions are represented by a weighted network: nodes correspond to strategies, the topology of directed links indicate their dominance relations, and the weights of links define their interaction strengths. Although one generically observes extinction of some nodes, there are network topologies in which all nodes coexist irrespective of the chosen weights. For example, in the rock-paper-scissors game, the network topology is a directed cycle of three nodes. This topology ensures coexistence of all nodes irrespective of the chosen weights.

In our work, we systematically construct nontrivial coexistence networks of the ALVE by mapping its long-time dynamics to an algebraic problem that we analyze by using concepts from graph theory. In particular, we characterize the kernel of an antisymmetric matrix in terms of Pfaffians and their relation to near-perfect matchings. We understand these coexistence networks as "family-friendly zero-sum games" in which all strategies coexist due to network topology.

SOE 9.5 Tue 12:00 GÖR 226

The role of spatio-temporal resource variability for information sharing and competition. — •Pawel Romanczuk[1,2,6], Matthieu Barbier[3], James Watson[4,5], and Simon A. Levin[6] — [1]Institut of Theoretical Biology, Dept. of Biology, Humboldt Universität zu Berlin, Germany — [2]Bernstein Center for Computational Neuroscience Berlin, Germany — [3]Centre for Biodiversity Theory and Modelling, CNRS, France — [4]The Global Economic Dynamics and the Biosphere programme, Swedish Royal Academy of Sciences, Stockholm Sweden — [5]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Oregon, USA — [6]Dept. of Ecology and Evolutionary Biology, Princeton University, Princeton, USA

Understanding and predicting how spatial and temporal variability of a resource affects the social behavior of interacting agents ("harvesters") is a fundamental problem in many social-ecological systems. Here we propose a simple, yet generic, lattice-based evolutionary model, to investigate the dependence of evolutionary stable social strategies on the spatial distribution and the effective life-time of the resource landscape. In particular, we identify distinct parameter region which favor different behavioral strategies: territoriality, individualism and information sharing. Finally, we discuss briefly the results of an agent-based model in continuous time and space together with a simplified analytical description, which fully align with our lattice-model results.

SOE 10: Traffic and Organization of Cities

Time: Tuesday 14:00–14:45 Location: GÖR 226

SOE 10.1 Tue 14:00 GÖR 226

Human behaviour and traffic flow — •Michael Schreckenberg — Fakultät für Physik, Universität Duisburg-Essen

SOE 11: Physics of Collective Mobility (joint session SOE / DY / BP / jDPG, accompanying the symposium)

Time: Tuesday 14:45–15:30 Location: GÖR 226

SOE 11.1 Tue 14:45 GÖR 226

Ricatti-Langevin Dynamics for Modeling of Air Traffic Performance Disruption and Recovery — •Norbert Fürstenau and Monika Mittendorf — Deutsches Zentrum für Luft- und Raumfahrt, Institut für Flugführung, 38108 Braunschweig, Deutschland

We describe research towards a predictive assistance tool for airport tower controllers to support optimal arrival and departure scheduling under extreme weather conditions (Xevents). As a formal basis we derive a generic nonlinear dynamics model of performance disruption and recovery. It will be used as basis for a predictive algorithm (e.g. extended Kalman filter) as core of the assistance system. We first show that a simple logistic function approach is sufficient for fitting empirical arrival rate data under (disruptive) winter storm disturbance at an international German airport to obtain characteristic traffic performance parameters. A comparable approach was recently published [1] as empirical support for a phase transition hypothesis of the (anticorrelated) normal wind to storm transition. The basic model is formally equivalent to the simplified 2nd-order (two-state) laser equation and allows for simulation of the disruption/recovery dynamics that exhibits the expected controllability of the traffic disruption. The model is derived from a Ricatti-Langevin equation with time dependent control parameters (disruption / recovery time constants) and external deterministic and stochastic disturbance due to wind/gust speed variation.

[1] Fürstenau & Mittendorf (2016): Bernoulli-Langevin wind speed model for simulation of storm events. Z. Naturforsch. A, DOI: 10.1515/zna-2016-0238

SOE 11.2 Tue 15:00 GÖR 226

New York Taxi Rides as Point Processes — •Philip Marszal[1,2], Debsankha Manik[1], Andreas Sorge[1], and Marc Timme[1,2,3] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Gottingen, Germany — [2]Faculty of Physics, Georg August University Gottingen, 37073 Göttingen, Germany — [3]Department of Physics, University of Darmstadt, 64289 Darmstadt, Germany

Optimized ride sharing promises the flexibility of taxis with an efficiency close to that of public transportation. To provide a test environment for ride sharing algorithms, we here propose stochastic models characterizing the spatio-temporal request dynamics of taxis in New York City. On short time scales (48 minutes) and accumulating across spatial variation, we found the number of taxi pick-up events to be Poisson distributed, suggesting that the pick-up events can be modeled by a Poisson process. On long time scales (24 hours), the ride pick-up events can be modeled by an inhomogeneous Poisson process in space and time. Interestingly, the ride requests follow definitive patterns in time, yet vary strongly in space. Furthermore, a Gaussian mixture model of pick-up locations provides a possibility of inferring likely drop-off locations from initial conditions of a ride.

SOE 11.3 Tue 15:15 GÖR 226

The Simulation Unification: Towards a Python Toolbox to Model and Analyze Collective Mobility Systems — •Andreas Sorge[1,2,3], Marc Timme[1,2,3], and Debsankha Manik[1,2] — [1]MPI for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität, Göttingen, Germany — [3]Organization for Research on Complex Adaptive Systems (or-cas), Göttingen, Germany

Understanding the nonlinear dynamics, scaling behavior and critical transitions of collective mobility systems is crucial to optimize system performance and individual utility. As discrete events such as pick-ups and drop-offs govern their time evolution, it is intricate to apply standard analytical and computational methods from statistical physics and nonlinear dynamics. We develop a unifying theoretical and computational framework to efficiently model and simulate such systems. Based on a formal language, we develop a Python package that allows the simulationist to assemble modules in a toolbox-like fashion. The package ships with a number of topologies (e.g. $\mathbb{R}^2$, any kind of network) and different dispatching rules to bundle individual requests and assign them to vehicles. The user is free to combine them and to specify their own, as well as to feed in the spatio-temporal mobility demand pattern. An analysis module provides ample statistics to aggregate the dynamics and assess the performance of the simulated instance. We envision our package to facilitate both studying collective mobility and developing the necessary tools to do so in a reproducible manner.

SOE 12: Annual Member's Assembly

Agenda: 1. Report & Announcements, 2. Feedback & Suggestions for SOE 2018, 3. Elections, 4. Misc.

Time: Tuesday 15:30–16:00 Location: GÖR 226

The assembly is open to all participants (but only registered SOE members are entitled to vote). There will be an informal dinner at Monday afternoon (time and location tba during the sessions on Monday)

SOE 13: Symposium SYCM: Physics of Collective Mobility (SOE / DY / BP / jDPG)

Time: Wednesday 9:30–12:15 Location: HSZ 02

Invited Talk SOE 13.1 Wed 9:30 HSZ 02

Mobility in shareability networks — •Michael Szell — Centre for Social Sciences, Hungarian Academy of Sciences, Országház utca 30, 1014 Budapest, Hungary — Center for Network Science, Central European University, Nador utca 11, 1051 Budapest, Hungary — Center for Complex Network Research, Northeastern University, 177 Huntington Avenue, 02115 Boston, USA — moovel lab, Haupstätter Straße 149, 70178 Stuttgart, Germany — Senseable City Lab, MIT, 77 Massachusetts Ave, 02139 Cambridge, USA

We introduce the notion of shareability network, which allows us to model the collective benefits of sharing trips as a function of passenger inconvenience, and to efficiently compute optimal sharing strategies on massive datasets. We apply this framework to a dataset of millions of taxi trips taken in New York City, showing that cumulative trip length can be cut by 40%. This benefit comes with reductions in emissions and split fares, hinting toward a wide passenger acceptance. Shareability as a function of trip density saturates fast, suggesting effectiveness of the taxi sharing system also in cities with much sparser taxi fleets. We compute the shareability curves in several further world cities, and find that a natural rescaling collapses them onto a single, universal curve. We explain this scaling law with a simple model that predicts the potential for ride sharing in any city, using a few basic urban quantities and no adjustable parameters. Finally, we demonstrate how interactive data visualizations of re-ordered city spaces can effectively inform relevant stakeholders and the public about large-scale reductions of parking spaces in future scenarios of wide-spread car-sharing.

Invited Talk SOE 13.2 Wed 10:00 HSZ 02

Trail-following bacteria: from single particle dynamics to collective behaviour — Anatolij Gelimson[1], Kun Zhao[2,3], Calvin K. Lee[3], W. Till Kranz[1], Gerard C. L. Wong[3], and •Ramin Golestanian[1] — [1]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3NP, United Kingdom — [2]Key Laboratory of Systems Bioengineering, Ministry of Education, School of Chemical Engineering and Technology, Tianjin University, Tianjin, 300072, People's Republic of China — [3]Bioengineering Department, Chemistry & Biochemistry Department, California Nano Systems Institute, UCLA, 90095-1600, Los Angeles, CA, USA

Can we learn from bacteria how to coordinate our mobility, and navigate our way towards mutually beneficial collective states? Trail-following bacteria leave behind precious exopolysaccharides as marker of where they been, and use it to accelerate the formation of colonies. We study this phenomenon, by building a stochastic microscopic model for the pili-driven motility of bacteria that interact with trails which could be laid by themselves and others. We discuss its phenomenology both at the level of single bacterium dynamics and collective self-organization into colonies. We validate the model using Pseudomonas aeruginosa trajectories, and show that fitting the parameters at the single bacterium level leads to a good quantitative agreement between the predictions of the model for the collective behaviour of the colony and the corresponding experimental observations.

Invited Talk SOE 13.3 Wed 10:30 HSZ 02

Mobility and Self-Organization in Multi-Layer Networks: A Meta-Foodweb example — •Thilo Gross[1], Andreas Brechtel[2], Philipp Gramlich[2], Daniel Ritterskamp[1], and Barbara Drossel[2] — [1]Department of Engineering Mathematics, University of Bristol, Bristol, UK — [2]Institut für Festkörperphysik, TU Darmstadt, Darmstadt, Germany

The emergence of structures and patterns from diffusive motion has long fascinated scientists. This phenomenon is best known from systems in continuous space. In this talk I will propose a general approach for the study of such phenomena in certain multi-layer networks.

I focus on the example of ecological meta-foodwebs, which describe the dispersal of animals across a fragmented landscape. Each individual undergoes diffusive motion on a network where the nodes are habitats and the links are routes of potential migration. Furthermore, the individuals are subject to predator-prey interactions with other individuals, described by a complex food web. The meta-foodweb thus constitutes a large multiplex network-on-network system.

To study the onset of self-organized pattern formation I consider the dynamical stability of steady states. By exploiting the structure of the system it is possible to separate the effects of the food-web and the geographical network and write a master stability function for the system. The result is a reduced system that bears a remarkable resemblance to pattern forming systems in continuous space, but has much richer behaviour.

15 min. break

Invited Talk SOE 13.4 Wed 11:15 HSZ 02

Temporal Percolation in Critical Collective Mobility Systems — •Andreas Sorge[1,2,4], Debsankha Manik[1,2], Jan Nagler[3,4], and Marc Timme[1,2,4] — [1]MPI for Dynamics and Self-Organization, Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Georg-August-Universität, Göttingen, Germany — [3]Computational & Theoretical Physics, IfB, ETH Zürich, Switzerland — [4]Organization for Research on Complex Adaptive Systems (or-cas), Göttingen, Germany

A collective mobility system is a stochastic dynamical system that operates under opposing objectives. Its function is to both satisfy individual mobility demand in a timely fashion and make efficient use of the available transport vehicles. To understand and design such a system, one must study, devise and assess dispatching rules that bundle individual requests and assign them to vehicles. If overall mobility demand exceeds capacity, the system congests and ceases to function. Determining the capacity is henceforth crucial to assess any given dispatching rule and inform system design for optimized system performance and individual utility. Intriguingly, the brink to congestion constitutes a critical transition reminiscent of percolation in time. We develop a dynamic notion of criticality of such stochastic processes, mapping return times to spatial clusters of percolation theory. We present a method to algorithmically determine the critical point and exponents and its application to collective mobility systems in this temporal percolation paradigm.

Invited Talk SOE 13.5 Wed 11:45 HSZ 02

Modeling the evolution of cities — •Marc Barthelemy — IPhT/CEA, Saclay, France — CAMS/EHESS, Paris, France

The recent availability of data about cities and urban systems opens the exciting possibility of a 'new Science of Cities'. Urban morphogenesis, activity and residence location choice, mobility, urban sprawl and the evolution of urban networks are just a few of the important processes that can be discussed now from a quantitative point of view. In this talk, I will discuss how a data-informed approached can elaborate on urban economics models in order to get predictions in agreement with empirical observations. I will illustrate this approach on the growth of cities and the emergence of a polycentric structure of activity centers. I will conclude by highlighting some important challenges and possible research directions.

SOE 14: Focus: The Physics of Power-Grids – Fluctuations, Synchronization and Network Structures (joint session DY / SOE)

The resilient and sustainable energy supply via power grids is one of the main future challenges for science and technology. Since the dynamics of power grids can be described by models that resemble the structure of Kuramoto's famous model for synchronization, power grid modeling is a topic where nonlinear dynamics, statistical physics and network science meet an important topic from engineering. Especially the integration of renewable energy sources accompanied by grid decentralization and fluctuating power feed-in from wind and solar power generation raises novel challenges for power system stability and design which can be addressed from the viewpoint of physics. In this focus session we will cover different aspects of the question how fluctuations and network structure influence the stability of the power grid.

Organized by Oliver Kamps, Joachim Peinke, Philipp Maass

Time: Wednesday 15:00–19:15 Location: ZEU 160

Invited Talk SOE 14.1 Wed 15:00 ZEU 160

Asymmetry-Induced Synchronization Stability in Power-Grid Networks — •Adilson Motter — Northwestern University, Evanston, IL, USA

Synchronization is a paradigm for behavioral uniformity that can emerge from interactions and a necessary condition for the operation of coupled generators in power-grid networks. When the interacting entities are identical and their coupling patterns are also identical, the complete synchronization of the entire network is the state inheriting the system symmetry. As in other systems subject to symmetry breaking, such symmetric states are not always stable. Here, I will discuss the discovery of the converse of symmetry breaking—the scenario in which complete synchronization is not stable for identically coupled identical oscillators but becomes stable when, and only when, the oscillator parameters are judiciously tuned to nonidentical values. This corresponds to breaking the symmetry of the system to preserve the symmetry of the state. I will discuss how this implies that heterogeneity of dynamical units can facilitate and even be required for the stability of synchronous states in power grids and other oscillator networks. (Joint work with Takashi Nishikawa and Ferenc Molnar.)

SOE 14.2 Wed 15:30 ZEU 160

The benefit of cooperation in a simplified highly renewable European electricity infrastructure — Leon Schwenk-Nebbe[1], Jonas Hörsch[2], Mirko Schäfer[1], and •Martin Greiner[1] — [1]Department of Engineering, Aarhus University, Denmark — [2]Frankfurt Institute for Advanced Studies, Germany

We consider a simplified model of a future European electricity network with a high share of renewable generation. In a cost optimal design of such a system, most of the renewable generation capacity is placed at locations with favorable weather conditions, that is for instance onshore wind in countries bordering the North Sea and solar PV in South European countries. Countries with less favorable renewable generation conditions benefit from this capacity by importing the respective electricity as power flows through the transmission grid. Using flow tracing techniques, which are related to directed diffusion processes on networks, we disentangle the emerging pattern of imports and exports and assign shares of the distributed generation capacity in the European system to the countries which actually make use of them. This procedures yields nodal levelized costs, which incorporate both internal and external generation as well as transmission costs associated with the electricity consumption in a country. Compared to a scenario without transmission, these nodal levelized costs are reduced by about 15% and represent the benefit of cooperation.

SOE 14.3 Wed 15:45 ZEU 160

Scaling of transmission capacities in aggregated renewable electricity networks — Simon Bugge Siggaard[1], Chris Risager Poulsen[1], Jonas Hörsch[2], Mirko Schäfer[1], and •Martin Greiner[1] — [1]Department of Engineering, Aarhus University, Denmark — [2]Frankfurt Institute for Advanced Studies, Germany

Models of the electricity system often feature only a reduced spatial resolution, either due to lack of data or in order to reduce the complexity of the problem with respect to numerical calculations. For the determination of power flows in the respective electricity grid model, this reduced spatial resolution is connected to an aggregation procedure, which concerns both the network topology as well as the pattern of power imports and exports at the network nodes. The resulting flow patterns and transmission capacities of the system thus depend on the spatial resolution of the aggregated network. In this contribution, we investigate the scaling properties of aggregated power flows and transmission capacities on synthetic complex networks and a model of the European power grid, both including a high share of fluctuating renewable generation. The numerical findings are supported by analytical results for the scaling of power flows on aggregated two-dimensional lattices.

SOE 14.4 Wed 16:00 ZEU 160

Probabilistic methods for deterministic systems (on networks) — •Frank Hellmann — Potsdam-Institut für Klimafolgenforschung (PIK), Potsdam, Detuschland

I discuss how we use probabilistic, sampling based methods to understand and uncover dynamic properties of complex systems on networks. The motivating example are Kuramoto oscillators with inertia, which we interpret as a simple example of power grids.

Concretely I show how the underlying network topology leaves a quantifiable imprint on the dynamical properties of the overall system, in particular its ability to return to or stay close to synchronization, and how we can identify novel asymptotic states that are only accessible by perturbations at specific nodes.

SOE 14.5 Wed 16:15 ZEU 160

From conventional to renewable power: the role of grid heterogeneities — •Pedro Lind, Philipp Maass, Christoph Schiel, and Matthias Wolff — Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, 49076 Osnabrück, Germany

The influence of heterogeneities characterizing transmission lines and generators on the functioning of power grids is investigated, focusing on the situation where conventional power plants are replaced by renewable power sources.Two problems are addressed.

First, we study the probability of single line failure [1], showing that it is necessary to consider the maximum power at the generator where renewable power is injected into the grid, the mean injected power and operating time scales of human intervention. We derive a formula for the failure probability that incorporates all these three aspects as well as simple parameters characterizing the wind statistics at the envisaged injection node. Our derivation is based on empirical sets taken at the North Sea.

Secondly, we report on simulations of the time-dependent power flow in grids [2], where power input from a fraction of the generator nodes is fluctuating and follows stochastic dynamics mimicking statistical features of wind and solar power injection. Different measures of the grid stability are discussed, as, for example, frequency stability and phase synchronization.

[1] S. Backhaus and M. Chertkov, Phys. Today 66, 42-48 (2013).
[2] T. Nishikawa and A. E. Motter, New J. Phys. 17, 015012 (2015).

SOE 14.6 Wed 16:30 ZEU 160

Complex statistics of regenerative power feed-in — •Matthias Wächter, Mehrnaz Anvari, Patrick Milan, and Joachim Peinke — Instute of Physics and ForWind, Carl von Ossietzky University, 26111 Oldenburg, Germany

Future power grids are expected to experience a high share of renewable power generation. These renewable sources present pronounced

statistical features stemming from the turbulent and intermittent nature of the wind and solar resources. Such features include strongly intermittent power fluctuations as well as long-range and higher-order correlations in time and space. Moreover, photovoltaic power feed-in is characterized by jump-like behavior due to cloud borders. We will give an overview on the current knowledge of these complex statistics specific for renewable power, which will pose significant challenges for future power grids.

15 min. break

Invited Talk SOE 14.7 Wed 17:00 ZEU 160

Nonlinear Rerouting and Response in Electric Power Networks — •Marc Timme[1,2], Dirk Witthaut[3], and Xiaozhu Zhang[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization and Technical University of Darmstadt — [2]http://networkdynamics.info — [3]FZ Julich

Networks dominate our daily life – and most of them are dynamic. For instance, almost all of the infrastructure we use today, from simple lights to hospital treatment, from communication to transport systems, crucially depend on electric energy reliably supplied via power grids. The ongoing integration of renewable energy sources, being smaller, more heterogeneous, decentralized and more fluctuating, implies more strongly networked systems with more distributed operation states. In our research group we aim to understand fundamental principles underlying the collective nonlinear dynamics of networked systems in general. This talk highlights recent developments and provide two examples of collective phenomena in decentrally organized power grids. First, we offer a theory of non-local rerouting of electricity upon line failure, providing an accurate prediction of flow redistribution that goes beyond local predictors. Second, we analyze patterns of dynamic responses to distributed fluctations across time scales and demonstrate under which conditions the notion of a "variation in the grid frequency" breaks down.

See also: Phys. Rev. Lett. 109:064101 (2012); Phys. Rev. Lett. 116:138701 (2016); Zhang et al., DPG talk (2017); New J. Phys. 14:083036 (2012); Nature Comm. 7:11061 (2016).

SOE 14.8 Wed 17:30 ZEU 160

Impact of Wind Feed-in on Power System Stability and Quality — •Katrin Schmietendorf[1], Joachim Peinke[1], and Oliver Kamps[2] — [1]Universität Oldenburg, ForWind — [2]Universität Münster, Center for Nonlinear Science

Feed-in fluctuations are one of the major challenges for future electrical power grids. Short-term fluctuations on the second and sub-second scale are not counteracted by standard load balancing mechanisms. Moreover, on these time scales feed-in fluctuations are strongly non-Gaussian with intermittent increment statistics. We focus on short-term wind power fluctuations with realistic properties: temporal correlation, power spectrum, and intermittent increments. We discuss the implications on power system stability in terms of noise-induced desynchronization. Furthermore, we show that the turbulent nature of wind significantly reduces power quality as it is directly transferred into the fluctuations of frequency and voltage.

SOE 14.9 Wed 17:45 ZEU 160

Collective Network Dynamics of Electric Power Grids — Xiaozhu Zhang[1,2], Dirk Witthaut[3], and •Marc Timme[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization and Technical University of Darmstadt — [2]http://networkdynamics.info — [3]FZ Julich

Networks dominate our daily life – and most of them are dynamic. For instance, almost all of the infrastructure we use today, from simple lights to hospital treatment, from communication to transport systems, crucially depend on electric energy reliably supplied via power grids. The ongoing integration of renewable energy sources, being smaller, more heterogeneous, decentralized and more fluctuating, implies more strongly networked systems with more distributed operation states. In our research group we aim to understand fundamental principles underlying the collective nonlinear dynamics of networked systems in general. This talk highlights recent developments and provide two examples of collective phenomena in decentrally organized power grids. First, we offer a theory of non-local rerouting of electricity upon line failure, providing an accurate prediction of flow redistribution that goes beyond local predictors. Second, we analyze patterns of dynamic responses to distributed fluctations across time scales and demonstrate under which conditions the notion of a "variation in the grid frequency" breaks down.

This is work with various other colleagues. see also: Phys. Rev. Lett. 109:064101 (2012); Phys. Rev. Lett. 116:138701 (2016); New J. Phys. 14:083036 (2012); Nature Comm. 7:11061 (2016).

SOE 14.10 Wed 18:00 ZEU 160

Topology related Instabilities driven by Intermittent Fluctuations in Distribution Grids — •Sabine Auer[1,2], Frank Hellmann[1], and Jürgen Kurths[1,2,3,4] — [1]Potsdam Institute for Climate Impact Research, 14412 Potsdam, Germany — [2]Department of Physics, Humboldt University Berlin, 12489 Berlin, Germany — [3]Institute of Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen AB24 3FX, UK — [4]Department of Control Theory, Nizhny Novgorod State University, 606950 Nizhny Novgorod, Russia

The impact of increased shares in variable renewable energy sources on the power system is subject to a controversial public debate. The question to what extent grid stability is influenced, especially the effect on distribution grids, is not well-understood but has come into focus, recently.

Thus, we investigated the influence of intermittent fluctuations from renewables on frequency stability with respect to network topology. Here, single node fluctuations are exerted onto each node of a typical distribution grid and the reaction in network frequency is quantified studying the frequency tail distributions.

We chose two prominent model cases which stand for today's Mid-Voltage distribution and potential future micro grids. Results and potential balancing measures as decentral smart grid control with the help from electric vehicles will be discussed.

SOE 14.11 Wed 18:15 ZEU 160

Power Grid Resilience: Short-term Fluctuations and Intermittency — •Hauke Haehne, Matthias Waechter, and Joachim Peinke — Carl von Ossietzky University Oldenburg, Institute of Physics and ForWind, 26111 Oldenburg, Germany

Future power grids will be fed by a high share of renewable generation with strongly intermittent fluctuation patterns of produced power. This poses new challenges for resilient grid operation. From a physical perspective, the frequency of the alternating current in a power grid provides information on the instantaneous ratio of demand to production. We use high-resolution frequency measurements of the continental European power grid to analyze resilience regimes of the electric transport and actor system. We characterize fluctuations on different time scales and compare our findings to prior results from renewable power systems analysis. We combine stochastic methods and network dynamics, data analysis and simulations.

SOE 14.12 Wed 18:30 ZEU 160

Frequency Fluctuations in Power Grids: From Observed Data to Lévy-stable Laws — •Benjamin Schäfer[1], Kazuyuki Aihara[2], Dirk Witthaut[3,4], and Marc Timme[1,5] — [1]Network Dynamics, Max Planck Institute for Dynamics and Selforganization (MPIDS), Göttingen — [2]Institute of Industrial Science, The University of Tokyo, Komaba, Meguro-ku, Tokyo, Japan — [3]Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), Jülich — [4]Institute for Theoretical Physics, University of Cologne, Köln — [5]Department of Physics, Technical University of Darmstadt, Darmstadt

The ongoing energy transition (*Energiewende*) to replace fossil by renewable energy sources raises new challenges for power grid design and control, because renewables do not supply a constant power but introduce fluctuations to the grid. Here, we analyze fundamental dynamics of power grid frequency fluctuations. We analyze specific frequency data for the continental European grid, the British grid, the Japanese power grids as well as for the Eastern Interconnection in North America. We model the underlying stochastic process using (generalized) Fokker-Planck equations and validate our analytical predictions by Monte-Carlo simulations. We conclude that dominant contributions to the frequency fluctuations in a grid may be approximated by a single variable, the average frequency deviation, modeled as a random variable following a Lévy-stable distribution.

SOE 14.13 Wed 18:45 ZEU 160

Mathematical models for the transient stability of conventional power generating stations connected to low inertia

systems — •Marios Zarifakis[1], William T Coffey[2], Yuri P Kalmykov[3], and Sergei V Titov[4] — [1]Electricity Supply Board, Generation, Asset Management, Dublin 2, Ireland — [2]Department of Electronic and Electrical Engineering, Trinity College, Dublin 2, Ireland — [3]Laboratoire de Mathématiques et Physique (EA 4217), Université de Perpignan Via Domitia, F-66860, Perpignan, France — [4]Kotelnikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, Vvedenskii Square 1, Fryazino 141120, Russia

Recent experience shows that this increase of power generation sources influences the behaviour of grid connected generating units. One observation is the change in the generated power after a transient disturbance especially its oscillatory behaviour accompanied by similar oscillatory behaviour of the grid frequency. An understanding of such behaviour of generators under various disturbances requires a new modelling technique. Therefore, a mathematical model of a generating station based on a system of coupled nonlinear differential equations and suitable for analysis of its stability is presented. The mathematical model will allow one to highlight limitations to the operational range of synchronous generators and could also be used to identify limits to the amount of total inertia necessary to maximise the usage of grid connected non-synchronous generators such as wind turbines and solar photo-voltaic installations.

SOE 14.14 Wed 19:00 ZEU 160

Langevin analysis of large scale power outages - A case study — •Frank Ehebrecht[1] and Oliver Kamps[2] — [1]Institut für Theoretische Physik, WWU Münster, Germany — [2]Center for Nonlinear Science, WWU Münster, Germany

The anticipation of critical transitions in complex systems is a field of active research in such diverse disciplines as ecology, climate research or engineering [1]. In [2] large scale power outages are considered as critical transitions in the operation of power grids. It was shown for the large scale power outage on August 10 in 1996 in the USA that the event could be anticipated from critical fluctuations of the system frequency.

In this talk we present results from the analysis of two different data sets of the system frequency from the same event that have been measured at two different positions in the grid. We show that critical fluctuations seem not to be a reliable indicator for a critical transition in the power grid. In contrast to that, analyzing the data from the viewpoint of Langevin equations by estimating the drift and diffusion coefficients shows to be more reliable to anticipate the outage.

[1] M. Scheffer et. al., Nature, 461, 2009

[2] E. Cotilla-Sanchez et. al., IEEE Transactions on Smart Grid, 3, 2012

SOE 15: Focus Session: Cities as complex systems

Cities form complex systems exhibiting nontrivial statistics and dynamics. Not only the scaling of city sizes, but connectivity, infrastructure usage and spatial densities can be analyzed for scaling laws. Urban growth is steered by decisions of individuals and companies where to settle and sell. Efficiency of transport and trade networks are essential for sustainable development of cities. The Focus Session provides an overview of current research and future trends in this area. (Focus Session organized by Diego Rybski)

Time: Wednesday 15:00–18:15 Location: GÖR 226

SOE 15.1 Wed 15:00 GÖR 226

Urban Economic Development: Agriculture, Industry, and Services — •Diego Rybski, Prajal Pradhan, and Jürgen P. Kropp — Potsdam Institute for Climate Impact Research – PIK, Member of Leibniz Association, P.O. Box 601203, 14412 Potsdam, Germany

With the purpose of analyzing the sectoral composition of cities' gross domestic product (GDP) we consider US Metropolitan Statistical Areas (MSA) and the partitioning into agrarian, industrial, and service GDP. In order to characterize the transfer of GDP shares between the sectors in the course of economic development we explore a simple system of differential equations which has previously been proposed for countries. Fitting the model to more than 90 MSA we find that according to the obtained parameters the majority belongs to 5 of 8 groups. The purely consecutive transfer is not representative for the set of MSA.

SOE 15.2 Wed 15:15 GÖR 226

The city in 2 and 3 dimensions: monocentric analysis and scaling of land use and population density — •Rémi Lemoy and Geoffrey Caruso — University of Luxembourg, Maison des Sciences Humaines, 11 Porte des Sciences, L-4366 Esch-Belval, Luxembourg

In this work we study the profile of land use and population density in European cities with respect to the distance to the city centre. We use the GMES Urban Atlas database, providing a precise description of land use at 5m resolution in the 300 major European urban areas (more than 100.000 inhabitants). We combine this dataset with population density from the Geostat population grid, which covers the whole of European Union with a 1km^2 resolution. Population is allocated proportionally to surface and weighted by soil sealing and density classes of the GMES data.

We analyse the evolution with distance to the city centre of population density and of the share of artificial land. We analyse the scaling of these curves with respect to city population. We find that land use curves tend to scale (in 2 dimensions) like the square root of city population. Population curves tend to scale (in 3 dimensions) like the city population to a power close to 1/3.

These results allow us to propose a simple intra-urban description of a representative European city, whose size can be defined based on the scaling relationships we obtain. This is useful for the calibration and validation of monocentric urban economic models. Further, our analysis provides a coherent definition of cities of different sizes and hence a new way to interrogate inter-urban scaling laws or Zipf's law.

SOE 15.3 Wed 15:30 GÖR 226

Zipf's Law for Australia: An outlier? — Somwrita Sarkar[1] and •Peter Alexander Robinson[2] — [1]Faculty of Architecture, Design and Planning, The University of Sydney, Australia — [2]School of Physics, The University of Sydney, Australia

Various studies of city size distributions across the planet have shown what is now known as Zipf's law, which says that the distribution of city sizes fits a power law: the number of cities with populations greater than N is roughly proportional to 1/N. We explore this relationship and its historical evolution for city size distributions in Australia (from 1922 to 2015), and find that Zipf's Law does not hold for Australia. Rather, a different organization emerges with (a) the Zipf exponent close to 0.7, suggesting a 'flatter' distribution with the biggest cities having larger sizes, and (b) a 'missing middle' with no middle-sized cities (of approximately 500,000 to 1 million). Curiously, when the five largest cities (Sydney, Melbourne, Brisbane, Perth and Adelaide) are removed and the analysis re-performed for the smaller cities, the exponent is close to unity, maintaining itself as stable from 1922 to 2015. These empirical findings will be presented and some preliminary thoughts on this outlier behavior will be discussed. Two hypotheses will be considered: (a) the possibility that smaller (regional) and larger cities in Australia are following different growth processes, and (b) the possibility that each state in the country could be behaving as a 'country'. Relationships of these hypotheses with Australia's colonial history and relatively young urban settlement will be discussed. Implications for urban and regional development will also be discussed.

SOE 15.4 Wed 15:45 GÖR 226

Discovering the laws of urbanisation — •Filippo Simini and

Charlotte James — Department of Engineering Mathematics, University of Bristol, UK

In 2012 the world's population exceeded 7 billion, and since 2008 the number of individuals living in urban areas has surpassed that of rural areas. This is the result of an overall increase of life expectancy in many countries that has caused an unprecedented growth of the world's total population during recent decades, combined with a net migration flow from rural villages to urban agglomerations. While it is clear that the rate of natural increase and migration flows are the driving forces shaping the spatial distribution of population, a general consensus on the mechanisms that characterise the urbanisation process is still lacking. Here we present two fundamental laws of urbanisation that are quantitatively supported by empirical evidence: 1) the number of cities in a country is proportional to the country's total population, irrespective of the country's area, and 2) the average distance between cities scales as the inverse of the square root of the country's population density. We study the spatio-temporal evolution of population considering two classes of models, Gravity and Intervening Opportunities, to estimate migration flows and show that they produce different spatial patterns of cities. Moreover, both models suggest that the formation and growth of cities is possible only if the migration rate is sufficiently higher than the rate of natural increase.

SOE 15.5 Wed 16:00 GÖR 226

Urban systems rank diversity — •Roberto Murcio, Clementine Cottineau, Michael Batty, Elsa Arcaute, and Robin Morphet — University College London, London, UK

Digest the complex temporal dynamics of hierarchical communities is hard to attain in a way that capture the changes in rank and size of its members. Particularly, in urban systems, scaling laws and rank clocks approaches have proved to capture much of this dynamic at macro and micro scales respectively, summarizing the variation of urban attributes with city size. Here we argue that examining the behaviour of the rank itself, measuring the number of cities occupying that rank over time, could give some insights about the self-organization process these urban hierarchical structures experience as the system evolves in time. We applied this distribution, namely rank diversity, to three different urban systems: UK and USA (1900 to 2010) and former Soviet Union cities (1840 to 2010). Our findings point out the profound differences between the UK and the USA/Soviet Union urban structures, reinforcing the notion that there is no rank-size universality to be found in cities. Exploring the moments of the distribution and applying classical Zipf's law corpus analysis, we clustered cities in three categories: "seed", containing cities that practically do not change their rank in time; "epoch-dependant", comprising those [cities] which fluctuation in rank is considerably and finally, if a city exhibit a limited change in rank, we labelled as a "content bearing" city. The size of the seed set is similar in all urban systems while the tail is more similar between USA and the Soviet Union than with the UK.

SOE 15.6 Wed 16:15 GÖR 226

Statistical issues in scaling laws' estimation — •Jose M. Miotto[1], Jorge C. Leitão[2], Martin Gerlach[3], and Eduardo G. Altmann[4] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]iCourts, University of Copenhagen, Copenhagen, Denmark — [3]Department of Chemical and Biological Engineering, Northwestern University, Chicago, USA — [4]School of Mathematics and Statistics, University of Sydney, Sydney, Australia

One of the most celebrated findings in complex systems in the last decade is that different indexes y (e.g. patents) scale nonlinearly with the population x of the cities in which they appear, i.e. $y \sim x^{\beta}$, $\beta \neq 1$. More recently, the generality of this finding has been questioned in studies that used new databases and different definitions of city boundaries. We investigated the existence of nonlinear scaling, using a probabilistic framework in which fluctuations are accounted for explicitly. In particular, we show that this allows not only to (i) estimate β and confidence intervals, but also to (ii) quantify the evidence in favour of $\beta \neq 1$ and (iii) test the hypothesis that the observations are compatible with the nonlinear scaling. We employ this framework to compare five different models to 15 different datasets and we find that the answers to points (i)*(iii) crucially depend on the fluctuations contained in the data, on how they are modelled, and on the fact that the city sizes are heavy-tailed distributed.

15 min. break

SOE 15.7 Wed 16:45 GÖR 226

Formulae of urban attractiveness — •Stanislav Sobolevsky[1], Iva Bojic[2], Alexander Belyi[2], and Carlo Ratti[2] — [1]New York University — [2]Massachusetts Institute Of Technology

Scientific studies investigating the laws and regularities of human behavior are nowadays increasingly relying on the wealth of widely available digital information produced by human social activity. In this paper, we leverage big data created by three different aspects of human activity (i.e., geotagged photographs and tweets as well as bank card transactions whenever available) in Europe and the US for quantifying city attractiveness for the foreign visitors. An important finding is the strong superlinear scaling of city attractiveness with its population size. The observed scaling exponent stays around 1.5 - nearly the same for different ways of defining cities, different data sources and different geographies, emphasizing the robustness of our finding. In contrary to cities, exponents for country attractiveness are less than one, indicating sublinearity. Finally, scaling exponent for the foreign attractiveness of the US states, which are smaller, but still composite areas similar to countries, fells somewhere in between values of exponents for city and country attractiveness, but still tend to be slightly sublinear similar to the case of countries. After getting those results, we propose and evaluate a possible explanatory mechanism for the observed effects based on a simple discrete choice model.

SOE 15.8 Wed 17:00 GÖR 226

Scaling of professional connections and urban performance — •Stanislav Sobolevsky[1], Iva Bojic[2], Lyndsey Rolheiser[2], Anthony Vanky[2], Homgmou Zhang[2], and Vijayragunath Aruswamy[3] — [1]New York University — [2]Massachusetts Institute Of Technology — [3]LinkedIn Corporation

Recent studies have shown that many aggregate socio-economic characteristics of the city do not grow proportionally with population, but scale superlinearly with city size. This means larger cities see a bigger increase of various features of socio-economic activity per capita. In this research we consider an additional important quantity - connectivity of the professional population (as measured by the amount of LinkedIn connections). We analyze this connectivity in relation to city population and its economic performance. Consistent with previous findings, our results show that professional connectivity across the US cities scales superlinearly with the city size. Furthermore, this superlinear relationship is quite significant with a scaling exponent of roughly 1.3. We find this exponent being mitigated by industry: the lowest for manufacturing, transportation, construction and the highest for media, arts and design. Similar patters are also observed in European countries - Spain, Germany and France. Finally, with respect to an overall scaling trend, individual cities can be characterized by the relative coefficient of connectivity versus the trend expectation. We highlight the strong relationship between this relative connectivity and city-level income and unemployment; a finding that can potentially lead to using connectivity as an indicator of economic health.

SOE 15.9 Wed 17:15 GÖR 226

Predicting the response of urban real estate markets to socio-spatial dynamics — •Aike Alexander Steentoft and Markus Schläpfer — ETH Future Cities Laboratory, Singapore

Cities connect people and create opportunities for exchanges which promotes social and economic enrichment. In this work, we present a complementary perspective on how social life in a city interacts with its economic environment. More specifically, we analyze the gentrification phenomenon where urban migration boosts the real estate market. To that end, we use Twitter and Foursquare data to track the interconnected network of people and places in New York City from 2012 to 2016. Following the approach of Hristova, the socio-spatial dynamics are quantified using "four metrics of the social diversity of places which relate to their social brokerage role, their entropy, the homogeneity of their visitors and the amount of serendipitous encounters they are able to induce" [Hristova et al. 2016]. At the same time, we use Zillow data for New York City neighborhoods to track the dynamics of the residential real estate market where we define adjusted price and value indices to overcome biases caused by exogenous influences. We correlate these indices with the social diversity measures, contributing to the understanding of an adaptive economic environment, and ultimately providing early warning signals of escalating real estate prices.

SOE 15.10 Wed 17:30 GÖR 226

Spatial scaling behaviour of an optimized highly renewable European electricity system — •Jonas Hörsch, Tom Brown,

and Stefan Schramm — Frankfurt Institute for Advanced Studies (FIAS), Goethe-Universität, 60438 Frankfurt am Main, Germany

Techno-Economic investment planning of electrical energy systems is mostly based on optimizing large-scale spatial Linear Programming (LP) problems that find the spatial distribution of generation and transmission capacities for minimal capital and operating costs. The tractable spatial resolution of this type of problem is strongly limited by computational complexity, so that many studies of renewable energy integration have reduced the network to representative nodes with as few as one node per country. In this study a clustering algorithm is used to reduce the number of nodes and lines of a high resolution network-solution while preserving the most important transmission corridors. Preliminary results are presented that quantify the effects of the spatial scale on the operation of the electrical network and the threshold to a necessary scale invariance of the energy flows.

SOE 15.11 Wed 17:45 GÖR 226

Spatial correlations, clustering and percolation-like transitions in homicide crimes — •Haroldo Ribeiro — Universidade Estadual de Maringa, Maringa, Brazil

The spatial dynamics of criminal activities has been recently studied through statistical physics methods; however, models and results have been focused on local scales (city level) and much less is known about these patterns at larger scales such as at a country level. Here we report on a characterization of the spatial dynamics of the homicide crimes along the Brazilian territory using data from all cities (˜5000) in a period of more than thirty years. Our results show that the spatial correlation function in the per capita homicides decays exponentially with the distance between cities and that the characteristic correlation length displays an acute increasing trend in the latest years. We also investigate the formation of spatial clusters of cities via a percolation-like analysis, where clustering of cities and a phase transition-like behavior describing the size of the largest cluster as a function of a homicide threshold are observed. This transition-like behavior presents evolutive features characterized by an increasing in the homicide threshold (where the transitions occur) and by a decreasing in the transition magnitudes (length of the jumps in the cluster size). We believe that our work sheds new lights on the spatial patterns of criminal activities at large scales, which may contribute for better political decisions and resources allocation as well as opens new possibilities for modeling criminal activities by setting up fundamental empirical patterns at large scales.

SOE 15.12 Wed 18:00 GÖR 226

Tracking urban evolution - a way to investigate allometric scaling over time? — Hendrik Herold, •Robert Hecht, and Martin Behnisch — Leibniz Institute of Ecological Urban and Regional Development Dresden, Germany

Studying cities as complex systems requires reliable data on their spatial structure and development. Available remote sensing-based datasets allow for following the urban growth since the 70ies on a global scale. However, most of the urban development in European and most of North American cites has taken place before this era. In this work, we present an approach for delineating the physical structure, in particular the city borders, from digitized historical topographic maps. This includes a generic image analysis part as well as an uncertainty modeling component. Germany is the testbed for this study. The approach enables to track the urban evolution back to the era of the beginning of the trigonometric survey and hence back to the beginning industrialization. This data allows to measure the degree of urbanization and in particular urban sprawling on a long-term perspective. This could also form the basis for investigating the allometric scaling of cities over time.

SOE 16: Networks (joint session SOE / DY / BP)

Time: Thursday 9:30–13:00 Location: GÖR 226

SOE 16.1 Thu 9:30 GÖR 226

Structure and dynamics of multiplex networks: beyond degree correlations — •Kaj-Kolja Kleineberg — Computational Social Science, ETH Zurich, Clausiusstrasse 50, CH-8092 Zurich, Switzerland

The organization of constituent network layers to multiplex networks has recently attracted a lot of attention. Here, we show empirical evidence for the existence of relations between the layers of real multiplex networks that go beyond degree correlations. These relations consist of correlations in hidden metric spaces that underlie the observed topology. We discuss the impact and applications of these relations for trans-layer link prediction, community detection, navigation, game theory, and especially for the robustness of multiplex networks against random failures and targeted attacks. We show that these relations lead to fundamentally new behaviors, which emphasizes the importance to consider organizational principles of multiplex networks beyond degree correlations in future research.

SOE 16.2 Thu 10:00 GÖR 226

Large-deviation properties of the stochastic block model — •Stephan Adolf[1], Tiago P. Peixoto[2], and Alexander K. Hartmann[1] — [1]Institut of Physics, University of Oldenburg — [2]Department of Mathematical Sciences, University of Bath

In this contribution we study the distribution of the size of the largest components for the stochastic block model. The stochastic block model is a generative model for graphs, which can be used to model social relationships [1, 2]. Suppose $N \in \mathbb{N}$ vertices which can partioned into at least two groups (also called blocks). For generating a graph in the stochastic block model ensemble one inserts edges between pairs of vertices with different probabilities depending on whether the vertices are in the same group or not [1]. To obtain the distribution of the size of the largest component over the full support we use a large-deviation method [3] to determine even small probabilities (like for example 10^{-100}). We compare the results to those obtained for Erdős-Rhényi random graphs.

[1] A. Decelle and F. Krzakala and C. Moore and L. Zdeborová, Phys. Rev. E **84**, 066106 (2011)
[2] P.W. Holland and K.B. Laskey and S. Leinhardt, Social networks **5**, 109-137 (1983)
[3] A.K. Hartmann, Eur. Phys. J. B **84**, 627-634 (2011)

SOE 16.3 Thu 10:15 GÖR 226

Improving Causal Gaussian Bayesian Network Inference using Parallel Tempering — •Pascal Fieth[1], Gilles Monneret[2,3], Andrea Rau[3], Florence Jaffrézic[3], Alexander K. Hartmann[1], and Gregory Nuel[2] — [1]IfP, University of Oldenburg, Germany — [2]LPMA, CNRS 7599, UPMC, Paris, France — [3]GABI, INRA, Jouy-en-Josas, Paris, France

Gene regulatory networks describe causal relationships in biological processes like signal transduction or disease mechanisms. A considerable interest exists in supporting experimental network inference by developing computational methods to infer gene regulatory networks from available gene expression data.

To infer causality within those networks from mixed, observational and intervention, data, we make use of causal orderings and Gaussian Bayesian networks. An introduction to the necessary foundations is given. In the presented framework, for a given causal ordering, the likelihood of the model network can be maximized analytically. The space of causal orderings, growing as $n!$ for n genes, can be reliably explored via a simple Markov Chain Monte Carlo algorithm[1] for 10-20 genes only.

We show that parallel tempering helps in finding the orderings with highest maximum likelihood estimators as well as in exploring the set of alternative orderings with comparable maximum likelihood estimators for networks with > 50 genes.

[1] A. Rau, F. Jaffrézic, G. Nuel, BMC Sys. Biol., **7**(1):111 (2013)

SOE 16.4 Thu 10:30 GÖR 226

Phase transition in detecting causal relationships from obervationaland interventional data — •Alexander K. Hartmann[1] and Gregory Nuel[2] — [1]Institut for Physics, University of Oldenburg, Germany — [2]Laboratory of Probability and Stochastic Models (LPMA), Université Pierre et Marie Curie, Paris, France

Analysing data of, e.g., gene-expression experiments, and modelling it

via network-based approaches is one of the main data analysis tasks in modern science. If one is interested in modelling *correlations*, approaches like the inverse Ising model can be used, which is already algorithmically challenging. If one wants to analyse even *causal relationships*, i.e., beyond correlations, it becomes even harder.

One way out is to include interventions to the system, e.g., by knocking out genes when studying gene expression. This allows, in principle, to get a grip on the causal structure of a system. Here, we model the data using Gaussian Bayesian networks defined on directed acyclic graphs (DAGs). Our approach [1] allows for multiple interventions in each single experiment and calculating joint maximum likelihoods (MLs) for the complete network. Furthermore, we have to sample different causal orderings, which induce different DAGs. The sampling is efficient because we approximate the full ML by probabilities of orderings of triplets. This allows us to study the quality of the causality detection as a function of the fraction of interventional experiments. We observe an information phase transition between phases where the causal structure cannot be detected and where it can be detected.
[1] A. Rau, F. Jaffrézic, and G. Nuel, BMC Sys. Biol. **7**:111 (2013)

SOE 16.5 Thu 10:45 GÖR 226

Surveillance for outbreak detection in livestock-trade networks — •Philipp Hövel[1], Frederik Schirdewahn[1], Andreas Koher[1], Vitaly Belik[2], Hartmut H. K. Lentz[3], and Vittoria Colizza[4] — [1]TU Berlin — [2]FU Berlin — [3]Friedrich-Loeffler-Institut — [4]INSERM Paris

We analyze a temporal network of livestock trade and present results of numerical simulations of epidemiological dynamics. The considered network is the backbone of the pig trade in Germany [1], which forms a major route of disease spreading between agricultural premises. The network is comprised of farms connected by a link, if animals are traded between them. We propose a concept for epidemic surveillance generally performed on a subset of the system due to limited resources. The goal is to identify agricultural holdings that are more likely to be infected during the early phase of an epidemic outbreak. These farms, which we call *sentinels* [2], are excellent candidates to monitor the whole network. To identify potential sentinel nodes, we determine most probable transmission routes by calculating functional clusters. These clusters are formed by nodes that have similar invasion paths. Then, we select sentinels by choosing nodes out of every cluster. We show that any epidemic outbreak can be reliably detected at an early stage by monitoring a small number of those sentinels.

[1] H. H. K. Lentz, A. Koher, P. Hövel, J. Gethmann, C. Sauter-Louis, T. Selhorst, and F. Conraths, PLoS ONE, **11**, e0155196 (2016). [2] P. Bajardi, A. Barrat, L. Savini, V. Colizza, J. Roy. Soc. Interface **9**, 2814 (2012).

SOE 16.6 Thu 11:00 GÖR 226

Outbreaks of interacting dynamics — •Fakhteh Ghanbarnejad — Institut für Theoretische Physik, Technische Universität Berlin

Susceptible-Infective-Susceptible (SIS) and Susceptible-Infective-Recovered (SIR) are two successful idealized and simplified models for understanding the dynamics of infectious diseases. Nevertheless deadly records of some cases like tuberculosis during the 1918-1919 Spanish Flu and unexpected HIV cases in presence of hepatitis B and C, TB and Malaria, and vice versa, showed us that interaction between two spreading dynamics can dramatically change the epidemic dynamics. Here we investigate some microscopic mechanisms which might lead to the unexpected macroscopic outbreaks; In this work, we study spreading of two diseases: either cooperative or competitive interacting as a SIS or/and a SIR dynamics and address similarities and differences in comparison to other minimal cooperative models, i.e. SIR-SIR [1] and SIS-SIS [2]. We build up an idealized and simplified model and treat it in mean field approximations as well as stochastic agent based models. We find out in presence of cooperation an emerging region in the parameter space where the stable endemic and stable free-disease states co-exist. Interestingly this region appears differently in comparison to the SIR-SIR and SIS-SIS models. Also We track the dynamics on random generated networks; And argue how topological features can facilitate or neutralize the cooperation/competition effects.

[1] EPL 104 (2013) 50001; Nature Physics 11, 936-940 (2015); Rev. E 93, 042316. [2] arXiv:1603.09082v1.

15 min. break

SOE 16.7 Thu 11:30 GÖR 226

Collective navigation of complex networks: Participatory greedy routing — •Kaj-Kolja Kleineberg and Dirk Helbing — Computational Social Science, ETH Zurich, Clausiusstrasse 50, CH-8092 Zurich, Switzerland

Many networks are used to transfer information or goods, in other words, they are navigated. The larger the network, the more difficult it is to navigate efficiently. Indeed, information routing in the Internet faces serious scalability problems due to its rapid growth, recently accelerated by the rise of the Internet of Things. Large networks like the Internet can be navigated efficiently if nodes, or agents, actively forward information based on hidden maps underlying these systems. However, in reality most agents will deny to forward messages, which has a cost, and navigation is impossible. Can we design appropriate incentives that lead to participation and global navigability? Here, we present an evolutionary game where agents share the value generated by successful delivery of information or goods. We show that global navigability can emerge, but its complete breakdown is possible as well. Furthermore, we show that the system tends to self-organize into local clusters of agents who participate in the navigation. This organizational principle can be exploited to favor the emergence of global navigability in the system.

SOE 16.8 Thu 11:45 GÖR 226

Epidemic threshold in temporally-switching networks — Leo Speidel[1], •Konstantin Klemm[2,3], Victor M. Eguiluz[2], and Naoki Masuda[4] — [1]University of Oxford, UK — [2]IFISC, Palma, Spain — [3]Nazarbayev University, Astana, Kazakhstan — [4]University of Bristol, UK

Data of physical contacts and face-to-face communications suggest temporally varying networks as the media on which infections take place among humans and animals. Epidemic processes on temporal networks are complicated by complexity of both network structure and temporal dimensions. We develop a theory to understand the susceptible-infected-susceptible epidemic model on arbitrary temporal networks, where each contact is used for a finite duration. We show that temporality of networks always lessens the epidemic threshold such that infections persist more easily in temporal networks than in their static counterparts [1]. The effect of temporality on the epidemic threshold, which depends on a data set, is approximately predicted by the magnitude of a commutator norm.

[1] Speidel, Klemm, Eguíluz & Masuda, New J Phys 18, 073013 (2016).

SOE 16.9 Thu 12:00 GÖR 226

Correlations in sectoral value added growth in the global economic network — •Julian Maluck and Reik V. Donner — Potsdam Institute for Climate Impact Research, Germany

Complex supply chains have resulted in increasing interconnectedness within the International Trade Network (ITN). In this context the question arises how industries adapt to changes in the demand and supply of their trading partners. We address this problem by empirically analyzing both positive and negative correlations of value added growth between industries and construct the World Economic Performance Network (WEPN). By comparing topological characteristics of the WEPN and the ITN we obtain insights into the interconnection between trade relations and correlations in economic performance. We observe that trade relations of higher orders are particularly important for assessing performance correlations on an international level. Our results contribute to a better understanding of the consequences from demand and supply changes within the ITN from a model-independent analysis.

SOE 16.10 Thu 12:15 GÖR 226

Timescale of reaching stable state with relation to different ranking strategies in the stable marriage problem. — •Piotr Nyczka — Jacobs University Bremen, Germany

Stable marriage problem is wery well known topic. However there is still plenty of room for further investigation. In my presentation I will discuss process of reaching the stable state in the system consisting of two different types of agents.

Agents from two sets (eg. men and women) undergo random encounters and then decide whether they want to be together or not. They want to form a new couple only in the case where, as a result of this change, both of them will end up with "better" partner than actual one.

Each agent have its personal ranking list with "attraciveness" scores for potential partners of opposite sex and it's possible to make network

out of these lists. In my presentation I will focus on relation between structure of this network, and timescale of process of reaching stable state. There is very strong and interesting relation between them, definitely worth of further investigation.

SOE 16.11 Thu 12:30 GÖR 226

Identifying the driving processes of coupled friendship and enmity dynamics in a two-layer network model — •Maximilian Sadilek[1] and Stefan Thurner[1,2,3] — [1]Section for Science of Complex Systems, Medical University of Vienna, Spitalgasse 23, A-1090, Austria — [2]Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501, USA — [3]International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria

With the advent of social media it has become possible to study human social relations in a quantitative way. However, in most cases only data on positive relations (like friendship) are available while social balance theory states that in a social network positive and negative relations strongly depend on each other.

In the massive multiplayer online game PARDUS players can mark each other not only as friends but also as enemies, leading to a two-layer multiplex network structure.

We discuss the dynamics of friendship and enmity relations between thousands of players in PARDUS. We identify and quantify the driving processes of the associated two-layer social network formation. Well known sociological hypotheses like "The enemy of my enemy is my friend" turn out to be important building blocks of understanding the dynamics of the coupled formation of friendly and hostile interactions within a society.

SOE 16.12 Thu 12:45 GÖR 226

Master Stability Functions reveal Turing Instabilities in Multi-layer Foodwebs — Andreas Brechtel[2], Philipp Gramlich[2], Daniel Ritterskamp[1], Barbara Drossel[2], and •Thilo Gross[1] — [1]University of Bristol, UK — [2]Technische Universität Darmstadt

Many systems in science and technology can be described as multilayer networks, which are known to exhibit phenomena such as catastrophic failure cascades and pattern-forming instabilities.

A particular class of multilayer networks describes systems where different interacting copies of a local network exist in different spatial locations, including for instance regulatory and metabolic networks of identical cells and interacting habitats of ecological populations.

Here, we show that such systems can be analyzed by a master stability function (MSF) approach, which reveals conditions for diffusion-driven instabilities (DDIs).

We demonstrate the methodology on the example of state-of-the-art meta-foodweb models, where it reveals diffusion-driven instabilities that lead to localized dynamics and spatial patterns.

This type of approach can be applied to a variety of systems from nature, science and engineering to aid the understanding and design of complex self-organizing systems.

SOE 17: Networks: From Topology to Dynamics (joint session DY/ BP/SOE)

Time: Thursday 15:00–16:15 Location: ZEU 147

SOE 17.1 Thu 15:00 ZEU 147

Response Patterns for Fluctuations in Complex Flow Networks — •Xiaozhu Zhang[1], Sarah Hallerberg[1,2], Moritz Moritz Matthiae[3], Dirk Witthaut[3,4], and Marc Timme[1,5] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen — [2]Faculty for Engineering and Computer Science, Hamburg University of Applied Science, 20099 Hamburg — [3]Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), Forschungszentrum Jülich, 52428 Jülich — [4]Institute for Theoretical Physics, University of Cologne, 50937 Köln — [5]Department of Physics, Technical University of Darmstadt, 64289 Darmstadt

Dynamic collective phenomena prevail in networked systems across physics, biology and engineering. How external signals generate distributed responses patterns in such systems fundamentally underlies their function, yet is far from fully understood. Here we analyze the collective response patterns of oscillatory networks to fluctuating input signals. For an arbitrary network topology, we analytically find distinct response patterns to fall into three distinct frequency regimes: homogeneous responses across the network at low frequencies, topology-dependent resonances at intermediate frequencies and are frequency-dependent, localized responses at high frequencies. These results render regime-specific implications for real-world network design and control, in particular for transport and supply networks, e.g. electric power grids.

SOE 17.2 Thu 15:15 ZEU 147

Control of chimeras in small networks — Iryna Omelchenko[1], Oleh Omel'chenko[2], Anna Zakharova[1], Matthias Wolfrum[2], and •Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Weierstrass Institute, Mohrenstraße 39, 10117 Berlin, Germany

We propose a control scheme which can stabilize and fix the position of chimera states in small networks [1]. Chimeras consist of coexisting domains of spatially coherent and incoherent dynamics in systems of nonlocally coupled identical oscillators. Chimera states are generally difficult to observe in small networks due to their short lifetime and erratic drifting of the spatial position of the incoherent domain. The control scheme, like a tweezer, might be useful in experiments, where usually only small networks can be realized.

[1] I. Omelchenko, O. E. Omel'chenko, A. Zakharova, M. Wolfrum, and E. Schöll, Phys. Rev. Lett. **116**, 114101 (2016).

SOE 17.3 Thu 15:30 ZEU 147

Scaling Laws in Spatial Network Formation — •Nora Molkenthin[1,2] and Marc Timme[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, German — [2]Institute for Nonlinear Dynamics, Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany

Geometric constraints strongly impact the formation of networked systems. Examples range from amino acid chains folding to proteins structures to rearranging particle aggregates. The dynamical self-organization of the interaction network in such systems is far from fully understood. Here, we analyze a class of spatial network formation processes by introducing a mapping from geometric to graph-theoretic constraints. Combining stochastic and mean field analyses yields an algebraic scaling law for the extent (graph diameter) of the resulting networks with system size, in contrast to logarithmic scaling known for networks without constraints. Intriguingly, the exponent falls between that of self-avoiding random walks and that of space filling arrangements, consistent with experimentally observed scaling (of the spatial radius of gyration) for protein tertiary structures.

SOE 17.4 Thu 15:45 ZEU 147

Boolean network analysis reveals interaction networks among low-abundance species in the human gut microbiome — •Jens Christian Claussen[1], Jurgita Skiecevičiene[2], Jun Wang[3], Philipp Rausch[6,5], Tom H. Karlsen[4], Wolfgang Lieb[5], John F. Baines[5,6], Andre Franke[5], and Marc-Thorsten Hütt[3] — [1]Computational Systems Biology, Jacobs University Bremen — [2]U Kaunas — [3]KU Leuven — [4]U Oslo — [5]UKSH, U Kiel — [6]MPI Plön

Microbiome compositions in clinical context gained recent interest. Most analyses infer interactions among highly abundant species. The large number of low-abundance species has received less attention. Here we present a novel analysis method based on Boolean operations applied to microbial co-occurrence patterns. We calibrate our approach with simulated data based on a dynamical Boolean network model from which we interpret the statistics of attractor states as a theoretical proxy for microbiome composition. We show that for given fractions of synergistic and competitive interactions in the model our Boolean abundance analysis can reliably detect these interactions. In our human gut microbiome dataset, we find a large number of highly significant synergistic interactions among these low-abundance species, forming a connected network, and a few isolated competitive interactions.

SOE 17.5 Thu 16:00 ZEU 147

Complex Contagion and Coordinated Response in Animal Groups — •Winnie Poel[1,6], Bryan Daniels[3], Colin Twomey[2], Iain Couzin[4,5], and Pawel Romanczuk[1,6] — [1]Inst. of Theor. Biol., Dept. of Biol., Humboldt Universität zu Berlin — [2]Dept. of Ecology and Evolutionary Biol., Princeton University, Princeton, US — [3]ASU-SFI Center for Biosocial Complex Systems, Arizona State University, US — [4]Dept. of Collective Behaviour, MPI for Ornithology, Konstanz, Germany — [5]Dept. of Biology, University of Konstanz, Germany — [6]Bernstein Center for Computational Neuroscience Berlin, Germany

Our work focuses on the underlying communication network in animal swarms that enables coordinated movement and collective information processing in large groups while taking into account the limited attention and cognitive ability of each individual. Here, we study the influence of network structure on processes of behavioral complex contagion in fish groups. Specifically, we investigate the spreading of startling behavior in golden shiners on empirically inferred networks built on their individual visual perception of neighbors [1]. Using a simple adapted SIR model [2] we aim to uncover how the spatial configuration of a swarm (and thus its visual interaction network) aid to amplify or dampen out the information send out by a certain individual.

[1] Rosenthal, S., et al., PNAS 112.15 (2015): 4690-4695
[2] Dodds, P., et al., J. Theor. Biol. 232.4 (2005): 587-604

SOE 18: Economic Models II

Time: Thursday 15:00–16:15 Location: GÖR 226

SOE 18.1 Thu 15:00 GÖR 226

Sector-Coupling of a Highly Renewable German Energy System — •Clara Steinebach, Tom Brown, and Stefan Schramm — Frankfurt Institute for Advanced Studies, Frankfurt, Germany

Energy consumption is made up of four major sectors – electricity, heat, transport and industry, each of which contribute about one-fourth of the final energy consumption in Europe. In order to reduce the CO2 emissions, synergies from coupling these sectors have to be investigated and used. The coupling of electricity to other sectors, such as transport and heating, offers new cost-effective options for evening out seasonal- and synoptic-scale fluctuations of renewables like wind and solar, particularly given the low cost of long-term thermal energy storage. This work focuses on the German energy system. The cost-optimal low-carbon system is calculated, incorporating electricity demand, electrified transport and partially-electrified heating demand. By coupling these energy sectors and using battery storage from battery electric vehicles (BEV) and the thermal storage possibilities from the heating sector, stationary electricity storage needs can be reduced or even be eliminated.

SOE 18.2 Thu 15:15 GÖR 226

A pure optimization paradigm is not sufficient to account for sustainable policies — •Wolfram Barfuss[1,2], Jonathan F. Donges[1,3], Steven Lade[3], and Jürgen Kurths[1,2,4] — [1]Potsdam Institute for Climate Impact Research, GER — [2]Humbold University, Berlin, GER — [3]Stockholm Resilience Centre, Stockholm University, SWE — [4]University of Aberdeen, UK

Optimization is a widely used paradigm to deduce the course of action in many sustainability contexts, from integrated assessment models to natural resource management. Simultaneously, a wide range of criticisms and refinements of the optimization approach exist. These include aspects involving the discounting of future rewards and the treatment of multiple kinds of uncertainty. Here we demonstrate by a counterexample that a pure optimization of accumulated discounted rewards is not sufficient to reach a sustainable policy. This is done by introducing a conceptual model example based on a Markov decision process, formalizing a social-ecological tipping interaction. We translate the notion of sustainability into a definition of sustainable policy, which is capable of 'meeting the needs of the present without compromising the ability to meet those of the future' by introducing a minimum acceptable reward value. We further introduce a general return function, unifying a discounted with an average reward setting. The simplicity of our model allows a full analytical treatment, including a discussion of the discount factor as a free parameter. Overall, this suggests that care should be taken under what conditions an optimization approach is used to not result in undesired outcomes.

SOE 18.3 Thu 15:30 GÖR 226

Explosive Transitions and Hysteresis in Economically Driven Percolation — •Malte Schröder[1], Marc Timme[1,2], and Dirk Witthaut[3,4] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen — [2]Department of Physics, Technical University of Darmstadt, 64289 Darmstadt — [3]Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), 52428 Jülich — [4]Institute for Theoretical Physics, University of Cologne, 50937 Köln

The evolution of connectivity fundamentally underlies the function of many networked systems, with particular impact in social and economic networks. Standard percolation models describe how globally connected structures emerge when new local connections are formed based on random processes. In most social and economic systems, however, connections are established deliberately by the individuals in the network and are thus inherently not random. Here, we study network percolation for links established on the basis of economic decisions. We show that the underlying, global optimization problems can be mapped *exactly* to a local percolation problem that allows an efficient solutions. This new class of non-random percolation processes exhibits parametric changes from continuous to discontinuous features akin to explosive percolation transitions as well as hysteresis precisely because link addition is not random but directly driven by optimization.

SOE 18.4 Thu 15:45 GÖR 226

Non-Ergodicity and Symmetry Breaking in Time — •Mark Kirstein — TU Dresden, Germany

Complexity science harnesses tools from complexity science among others dynamical systems theory, network theory or cellular automata (CA). CA are one such tool, they are comprised of identical components, each interact following simple rules. 4 universality classes of pattern formation are identified in CA. The first three classes can all be handled by dynamical systems theory, whereas in class 4 ever evolving unpredictable patterns emerge. Questions relating to the long-term evolution of most of the interesting variables in economics are undecidable (e.g. What is the value of an asset prices in x days in the future?). Long-term prediction is out of reach for class 4. That is because class 4 entails computational irreducible evolutions. To answer such questions, time has to elapse. The history of economics and finance reveals no systematically successful prediction systems of such class 4 processes, although many economic processes fall into class 4.

I present a framework which uses a property of mathematical systems called broken ergodicity to explain broken symmetries in time. Broken time symmetry is one of the most fundamental broken symmetries that can occur. Broken symmetries in time question the nature of causality. I will elaborate how this leads to a quantum-like observer effect of economics and provide interesting relationships how this connects to black swans, the Lucas' critique, Goodhart's law and reflexivity.

SOE 18.5 Thu 16:00 GÖR 226

Solving Europe's most critical problems — •Hans G Danielmeyer and Thomas Martinetz — INB Uni Luebeck

Under SOE's umbrella we discovered and described the industrial society's natural long-term dynamics. The complexity of its main subsystems is prohibitive, but all constructive interactions of human nature and systems engineering reduce to six physical relations with three inherited time constants of the human species. Six unique analytic solutions reproduce the main G7 level data without fitting parameter. This includes per capita saturation and aging.

Unfortunately, zero interest and financial instability prevent reaching the natural final states. We suggest now long-term correction paths for Europe's 10 G7 level nations. In 2100 they may be dominated by healthy seniors unless retirement age increases by 1 year every 6 years. The money meant for subsidizing growth arrived in the top decile's 55 and 90% total income and wealth. This must be corrected because it forms a transnational class and a weakened middle class with the corresponding public debt. When the middle is lost as national stronghold extreme wing parties challenge democratic governments successfully as observed.

SOE 19: Financial Markets and Risk Management II

Time: Thursday 16:15–17:00 Location: GÖR 226

SOE 19.1 Thu 16:15 GÖR 226

Fractal methods for fractional cointegration — •Ladislav Kristoufek — Charles University, Prague, Czech Republic — Institute of Information Theory and Automation, Czech Academy of Sciences, Prague, Czech Republic

Detrended fluctuation analysis (DFA) and detrending moving average (DMA) methods are standardly used for fractional differencing parameter d estimation. Recently, the DFA and DMA based estimators of standard regression parameters have been proposed. The estimators possess some desirable properties with regards to long-range dependence, trends, seasonalities and heavy tails. We study properties of both estimators beyond the general fractional cointegration framework, i.e. we examine a simple model $y_t = \alpha + \beta x_t + u_t$, where $x_t \sim I(d)$ and $u_t \sim I(d-b)$ which implies $y_t \sim I(\max[d, d-b])$. The fractional cointegration requires $b > 0$ while the standard cointegration $CI(1,1)$ assumes $x_t, y_t \sim I(1)$ and $u_t \sim I(0)$. We are interested in various combinations of d and b parameters ($0 \leq d, b \leq 1$, i.e. we cover not only the fractional cointegration framework). We provide a broad Monte Carlo simulation study focusing on different time series lengths, combination of d and b parameters, and on possible spurious relationships. Specifically, we compare the estimators based on DFA and DMA with the standard OLS procedure under true and spurious relationships ($\beta = 0$ and $\beta \neq 0$). Based on the bias, standard error and mean squared error of the estimators, the new procedures outperform OLS for various settings (e.g. with $d = 1$ and $b < 0.5$).

SOE 19.2 Thu 16:30 GÖR 226

Efficency of information processing systems — •Roland Rothenstein — Hannover, Germany

We present three new findings related to the efficient market hypothesis.

First we expand the focus for the definition of efficiency and its applications from markets to all information processing systems. Second we derive a formula to quantify the efficiency of such systems between 0% and 100% in dependence from given information. With the derived definition we thirdly show that the inefficiency of a system can have two different sources. One source is the possibility to use information to predict a concrete event with higher than chance level. The other is that the pricing/ quotes in the system does not reflect the probability distribution of the possible events.

Finally we demonstrate the calculation of efficiency on a simple toy model (tossing coin) to show how one can exactly quantify the efficiency of a system, if all probabilities are known.

SOE 19.3 Thu 16:45 GÖR 226

The efficient market hypothesis and the speed of light — •Robert Marx — TU-Dresden, Faculty of Business and Economics, Dresden, Germany

A structural change has been taking place in financial markets for about a decade, which led to its increasing technologization. Nowadays transactions are executed electronically on the exchanges and machines place orders based on algorithms. This allows a transaction rate of ever higher frequency. A part of this trade is called high-frequency trading. So far it is not clear how this kind of trade is to be judged. Much of the evidence suggests that it increases liquidity, translates new information faster into a price reaction, and thus generates more accurate prices. On the other hand, slower participants are suspended. In order to be able to assess the high-frequency trade, physical space must be included. For high-frequency traders, it plays a role where they are located in physical space relative to a stock exchange and the source of information. Their decision is influenced by the latency, which is determined by the speed of light in the used transmission medium and the bridged distance. Traditional financial models do not take into account any physical space or the principle of locality. In the context of the efficient market hypothesis (EMH), no judgment can be made regarding high-frequency trading as long as space is not included. Is it efficient? Is it fair? In the following, a model is presented, in which the EMH is examined more closely in a space-time metric.

SOE 20: Chimera states: symmetry-breaking in dynamical networks (joint session DY/BP/SOE)

Time: Thursday 16:30–17:00 Location: ZEU 147

SOE 20.1 Thu 16:30 ZEU 147

The emergence of chimera states in arrays of cilia — •Thomas Niedermayer and Markus Bär — Physikalisch-Technische Bundesanstalt (PTB), Berlin

Systems of non-locally coupled, identical phase oscillators exhibit the coexistence of coherent and incoherent regions. These intriguing dynamical states, termed chimeras, have been studied theoretically in recent years and their emergence is hypothesized for instance in unihemispheric sleep and ventricular fibrillation. However, observations directly linked to theory were only made in engineered systems.

We have reconsidered our previously published phase oscillator model for hydrodynamic interactions of flagella and cilia, thread-like projections of eukaryotic cells. This simple, yet realistic, minimal model gives rise to the well-established phenomenon of metachronal waves. Here, we show that it additionally comprises all necessary and sufficient conditions for the emergence of chimera states. In particular, the flexibility of cilia might function as a lever between synchronous and asynchronous dynamics, that is a switch between two qualitatively different motility states. Our theoretical predictions provide a testable hypothesis in experimental and computational studies of large cilia arrays.

SOE 20.2 Thu 16:45 ZEU 147

Origins of alternating chimeras — •Sindre W. Haugland, Felix P. Kemeth, and Katharina Krischer — Physik-Department, Nonequilibrium Chemical Physics, Technische Universität München, James-Franck-Str. 1, D-85748 Garching, Germany

Oscillatory media can exhibit the coexistence of synchronized and desynchronized regions, so-called chimera states, for uniform parameters and symmetrical coupling. In a phase-balanced chimera state, where the totals of synchronized and desynchronized regions, respectively, are of the same size, the symmetry of the system allows for an alternative solution to the underlying equations, in which the dynamics of the phases are interchanged. Recently, we observed this kind of interchange as a self-emergent, self-sustained phenomenon in simulations of an oscillatory medium governed by a complex Ginzburg-Landau equation with nonlinear global coupling, and classified it as an alternating chimera (Sci. Rep. 5, 9883 (2015)). Here, we present more systematic research on its origin and dynamics, revealing new, related states, notably a form of self-sustained alternating regular subclustering, and providing additional insights into its mechanism of emergence. Working with minimal models, we are able to reproduce important features of the oscillatory medium close to the alternating chimera, and to identify several specific bifurcations in which these features are created and destroyed. Our results broaden the knowledge about self-emergent and self-sustained chimera states, particularly regarding alternating chimeras, and may help improve our understanding of chimera-like phenomena observed in biology.

SOE 21: Social Systems II

Time: Thursday 17:00–18:30 Location: GÖR 226

SOE 21.1 Thu 17:00 GÖR 226

Explosive dynamics of social networks — •Nora Molkenthin[1,2] and Marc Timme[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]Institute for Nonlinear Dynamics, Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany

Explosive transitions in and on complex networks have recently attracted attention for percolation and synchronization processes. Here we introduce a novel one-parameter family of random network ensembles that exhibit an explosive transition of the degree distribution. The model can be applied to the dynamics of social network interactions, where the parameter measures the degree of decision power in pairwise interactions between individuals. The revealed mechanism underlying the transition may help to understand the key structural difference between large online communities and personal face-to-face friendships.

SOE 21.2 Thu 17:15 GÖR 226

Dynamic Content-Communities on Social Networks — •Philipp Lorenz[1], Frederik Wolf[1], Jonas Braun[2], Philipp Hövel[1], Colin Bauer[3], Julien Siebert[3], and Vitaly Belik[4] — [1]TU Berlin, Hardenbergstraße 36, 10623 Berlin — [2]HU Berlin — [3]Zalando SE — [4]FU Berlin

One of the best studied property of real world networks is their community structure, which represents their composition of dense subnetworks. They can be overlapping [1], hierarchical [2] and temporal [3]. In human social networks all of these properties come into play [4] and can be found on different levels.

On Internet platforms content is posted and within that, trends can be captured as communities of linked topics. They behave highly dynamical, they are born, merge, split or grow and shrink, so capturing them required new methods for temporal community analysis.

Such clusters of topics can move and spread rapidly on social networks. Since these movements depend strongly on the underlying topology, we created multilayer networks, which link contents to users and uncover their relations and interplay.

[1] Palla, G. et al., Nature 435, 7043 (2005) [2] Peixoto, T. P., Phys. Rev.X 4, 011047 (2014) [3] Palla, G. et al., Nature 446, 664 (2007) [4] Sekara, V. et al., PNAS 113, 36, (2016)

SOE 21.3 Thu 17:30 GÖR 226

Lévy deviations from proportional effect in online attention — •Jose M. Miotto[1] and Eduardo G. Altmann[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]School of Mathematics and Statistics, University of Sydney, Sydney, Australia

The competition for the attention of users is a central element of the Internet. Crucial issues are the origin and predictability of big hits, the few items that capture a big portion of the total attention. We address these issues analysing 10 million time series of videos' views from YouTube. We find that the average gain of views is linearly proportional to the number of views a video already has, in agreement with usual rich-get-richer mechanisms and Gibrat's law, but this fails to explain the prevalence of big hits. The reason is that the fluctuations around the average views are themselves heavy tailed. Based on these empirical observations, we propose a stochastic differential equation with Lévy noise as a model of the dynamics of videos. We show how this model is substantially better in estimating the probability of an ordinary item becoming a big hit, which is considerably underestimated in the traditional proportional-growth models.

SOE 21.4 Thu 17:45 GÖR 226

Elo vs. Fifa ranking: how to best estimate the strength of soccer teams? — Patrick Bücker, Oliver Rubner, and •Andreas Heuer — Institut für Physikalische Chemie, WWU Münster, 48149 Münster

In chess it is common to attribute an Elo value to each player as a measure of his/her quality. From the difference of the Elo values of two players the probabilities of the possible outcomes of a chess match can be predicted.

Recently, the Elo approach has been generalized to soccer for club teams as well as for national teams [1]. On the national level the Elo ranking system opposes the better known Fifa ranking system.

Based on the known probabilistic properties of soccer matches [2] we have analysed the strengths and weaknesses of the Elo approach. It turns out that in particular for the relevant case of time-dependent variations of the team strengths the Elo approach performs very well and allows a reliable prediction of the outcome of soccer matches. Furthermore, possible improvements are suggested and a comparison with the Fifa ranking is discussed.

[1] http://www.eloratings.net
[2] A. Heuer, O. Rubner, PLoS ONE 9, e104647 (2014)

SOE 21.5 Thu 18:00 GÖR 226

Order statistics of horce racing and the randomly broken stick — •Julius Bonart — Financial Computing & Analytics, Department of Computer Science, University College London, WC1E 6BT

We find a remarkable agreement between the statistics of a randomly divided interval and the observed statistical patterns and distributions found in horse racing betting markets. We compare the distribution of implied winning odds, the average true winning probabilities, the implied odds conditional on a win, and the average implied odds of the winning horse with the corresponding quantities from the "randomly broken stick problem". We observe that the market is at least to some degree informationally efficient. From the mapping between exponential random variables and the statistics of the random division we conclude that horses' true winning abilities are exponentially distributed.

SOE 21.6 Thu 18:15 GÖR 226

Innovation- and information production rate for sentences of particular length — •Bo Liu[1], Stefan Thurner[1,2,3,4], Rudolf Hanel[1], and Bernat Corominas-Murtra[1] — [1]Section for Science of Complex Systems, Medical University of Vienna, Spitalgasse 23, A-1090, Austria — [2]Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501, USA — [3]International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria — [4]Complexity Science Hub Vienna, Josefstädter Straße 39, A-1080, Austria

Innovations are part of our lives and are the engines that boost our society. The understanding of the underlying dynamics is therefore essential. Language has been considered as a relatively simple toy model to study innovation dynamics. Information in language is encoded in units of different sizes: letters, words, sentences and paragraph. While at the level of letters, many results on information production rate exist, on the level of sentences much less is known. A simple measure of "innovation rate" in language is the so-called Heaps' exponent. We investigate subtexts which are composed of sentences with a particular length (number of words). A non-monotonic behavior of the Heaps' exponent vs. sentence lengths is found, with a maximum value at around sentence length 7. Similar behavior appears in the Zipf exponent and the cross entropy, which measures the information production rate. We analyze texts of the Corpus of Historical American English (CoHA) from 1800 to 2000 and find that the discovered pattern is slightly becoming stronger across history.

SOE 22: Focus Session: Controlling Complex Networks in Nature and Engineering (joint DY / SOE / BP)

The control of complex dynamical networks is of great current interest, especially in the light of various applications in nature and engineering, e.g., brain, genetic networks, communication, transport and supply networks, power grids. Important issues are the control of networks with complex topologies and heterogeneous components, in particular by making small local perturbations to steer the system to a desired target state or stabilize a desired state.

Organized by Eckehard Schöll and Anna Zakharova

Time: Friday 9:30–12:30 Location: ZEU 160

Invited Talk SOE 22.1 Fri 9:30 ZEU 160

Influence of network topology on spreading of epileptic seizure — •Simona Olmi[1], Spase Petkoski[2], Fabrice Bartolomei[2,3], Maxime Guye[4], and Viktor Jirsa[2] — [1]Weierstrass Institute, Berlin, Germany — [2]Aix-Marseille Univ, Inserm, Institut de Neurosciences des Systémes, Marseille, France — [3]Assistance Publique, Hôpitaux de Marseille, Hôpital de la Timone, Service de Neurophysiologie Clinique, Marseille, France — [4]Faculté de Médecine de la Timone, Centre de Résonance Magnétique et Biologique et Médicale, Medical School of Marseille, Aix-Marseille Université, Marseille, France

In partial epilepsy, seizures originate in a local network, the so-called epileptogenic zone, before recruiting other close or distant brain regions. Correctly delineating the epileptogenic and the propagation zone is essential for successful resective surgery. In particular the stereotaxic EEG (SEEG) is used to edge the zone to resect. However the propagation pathways of epileptic seizures are still largely unknown. Using a specific dynamical model for epilepsy [1], we then predict the recruitment network given the seizure origins and we try to understand the role played by the topology in constraining the recruitment process. The identification of the minimal number of connections that allows the seizure to propagate, via the application of linear stability analysis, and the choice of the optimal set of links to be cut in order to stop seizure propagation might reveal an approach to improve the success rate of epilepsy surgery. [1] Jirsa VK, Stacey WC, Quilichini PP, Ivanov AI, Bernard C (2014) 137:2210-2230.

Invited Talk SOE 22.2 Fri 10:00 ZEU 160

Chimera patterns induced by complex connectivity in Leaky Integrate-and-Fire Networks — •Astero Provata[1], Nefeli Tsigkri-DeSmedt[1], Johanne Hizanidis[1], Philipp Hoevel[2], and Eckehard Schoell[2] — [1]Intitute of Nanoscience and Nanotechnology, National Center for Scientific Research "Demokritos", 15310 Athens, Greece — [2]Institut fur Theoretische Physik, Technische Universitaet Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany a

We study synchronization patterns in ring networks of Leaky Integrate-and-Fire(LIF) oscillators under different connectivity schemes. Earlier studies have demonstrated the formation of chimera and multichimera states in LIF networks with nonlocal connectivity and specific ranges of parameters. Because in natural networks the connectivity takes complex schemes we investigate here the modifications in the form of the chimera states under: a) reflecting connectivity and b) diagonal connectivity. In case a) we show numerically that reflecting connectivity induces a novel chimera pattern in which near-threshold elements coexist with oscillating ones. The oscillating elements form arch-shaped mean phase velocity profiles while the potentials of the near-threshold elements never drop to the resting state. In case b) the diagonal connectivity induces multichimera states whose mean phase velocity profile changes its multiplicity as the coupling constant varies, while regimes of classic multichimera states are separated by synchronous regimes.The new synchronization patterns demonstrate the influence of complex connectivity in network synchronization.

SOE 22.3 Fri 10:30 ZEU 160

Coherence-Resonance Chimeras in a Neural Network — •Anna Zakharova[1], Nadezhda Semenova[2], Vadim Anishchenko[2], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Department of Physics, Saratov State University, Astrakhanskaya street 83, 410012 Saratov, Russia

We show that chimera patterns can be induced by noise in nonlocally coupled neural networks in the excitable regime. In contrast to classical chimeras, occurring in noise-free oscillatory networks, they have features of two phenomena: coherence resonance and chimera states. Therefore, we call them coherence-resonance chimeras [1]. These patterns demonstrate the constructive role of noise and appear for intermediate values of noise intensity, which is a characteristic feature of coherence resonance. In the coherence-resonance chimera state a neural network of identical elements splits into two coexisting domains with different behavior: spatially coherent and spatially incoherent, a typical property of chimera states. Moreover, these noise-induced chimera states are characterized by alternating behavior: coherent and incoherent domains switch periodically their location. We show that this alternating switching can be explained by analyzing the coupling functions.

[1] N. Semenova, A. Zakharova, V. Anishchenko, E. Schöll, Coherence-resonance chimeras in a network of excitable elements, Phys. Rev. Lett. 117, 014102 (2016)

SOE 22.4 Fri 10:45 ZEU 160

Self-controlled latching dynamics in simple models with attractor-ruins — •Diemut Regel and Marc Timme — Network Dynamics, MPI for Dynamics and Self-Organization, 37077 Goettingen, Germany

Standard models of natural computation commonly exhibit attractors as their core concept, with convergence dynamics towards them viewed as the completion of a computational task, e.g. the recognition of an object or the processing of a piece of information [1]. Higher cognitive activities such as free association have been proposed to be representable by latching dynamics [2], a repeated switching between representative system states by dynamical parameter drifting that is intrinsically controlled by the system itself. Yet, how such latching might be achieved and which mechanism may cause latching in dynamical systems is not well understood. Here we propose simple models of latching dynamics and reveal fundamental mechanisms of their self-control options.

[1] J.J. Hopfield, Proc. Natl. Acad. Sci. (1982).
[2] A Treves, Cogn. Neuropsychol. (2005).

SOE 22.5 Fri 11:00 ZEU 160

Interaction Control to Synchronize Non-synchronizable Networks — •Malte Schröder[1], Aditya Tandon[2], Sagar Chakraborty[2], Dirk Witthaut[3], Jan Nagler[4], and Marc Timme[1] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]Department of Physics, Indian Institute of Technology Kanpur, Kanpur, Uttar Pradesh 208016, India — [3]Forschungszentrum Jülich, Institute for Energy and Climate Research (IEK-STE), 52428 Jülich, Germany — [4]Computational Physics, IfB, ETH Zurich, 8093 Zurich, Switzerland

Synchronization constitutes one of the most fundamental collective dynamics across networked systems. Whether a system may synchronize depends on the internal unit dynamics as well as the topology and strength of their interactions. For chaotic units with certain interaction topologies synchronization might be impossible across all interaction strengths, meaning that these networks are non-synchronizable.

Here we propose the concept of interaction control, generalizing transient uncoupling, to induce desired collective dynamics in complex networks. Intriguingly, localizing interactions in phase space by a fixed control scheme enables stable synchronization across *all* connected networks regardless of topological constraints. Interaction control may thus ease the design of desired collective dynamics, even without knowledge of the networks exact interaction topology.

15 min break

SOE 22.6 Fri 11:30 ZEU 160

Complex communication in automotive networks — •Christian Pigorsch — BMW AG, Hufelandstraße 1, 80788 München

Different types of automotive networks have been used for the communication in BMW vehicles. For communication across such heterogeneous networks, it is important to ensure stability and robustness, especially for safety related use cases. This is accomplished by evaluating the in-car implementation by means of statistical parameters and comparing the results with the specification. This timing analysis approach, and the questions it introduces, will be illustrated in this talk using several examples. The overall goal of the communication design is optimal utilization of communication resources.

SOE 22.7 Fri 11:45 ZEU 160

On the Impact of Network Topology on Distributed Constraint-Satisfaction Problems — •Henning Blunck[1], Dieter Armbruster[2], Julia Bendul[1], and Marc-Thorsten Hütt[1] — [1]Jacobs University Bremen, Bremen, Germany — [2]Arizona State University, Tempe, AZ, USA

The scheduling of operations to machines is a core logistic challenge with a multitude of applications in our complex industrialized world. As part of the so called "fourth industrial revolution", distributed, agent-based approaches to this problem are receiving renewed attention, with important questions about the design about such systems still unanswered.

In the light of the above, we investigate the more general question how network structure influences the solution performance of distributed constraint-satisfaction problems, here the problem of finding a k-coloring. In particular, we study the impact of "leader"-nodes, nodes introduced specifically to collect and distribute information from large parts of the network.

The results we find shed light on the role of hubs in coordination processes on networks with direct implications not only on long held beliefs in the domain of agent-based production control, but Multi-Agent system design and organization theory.

SOE 22.8 Fri 12:00 ZEU 160

Towards an integrated model for stochastic effects in power system dynamics and control — •Philipp C. Böttcher and David Kleinhans — NEXT ENERGY | EWE Research Centre for Energy Technology, Carl-von-Ossietzky-Straße 15, 26129 Oldenburg

While today's energy system heavily relies on fossil fuels, the energy systems of tomorrow most likely will be realised with a large share of renewable energies. This will have several advantages, but also introduces highly volatile energy sources without inertia into a system designed for conventional energy sources with large rotating generator masses. To cope with the strongly fluctuating energy resources various aspects of the current energy system have to change, such as e.g. modifications to the grid, demand side management, or investment into new technology.

The scope of this work is to investigate the stochastic effects in power system dynamics and control. For this purpose we aim to develop an integrated stochastic model, which reflects the grid codes for power frequency control by the *European Network of Transmission Operators* (ENTSO-E). The power frequency measurements reveal clear signatures of the grid codes. We present these results and outline the intended stochastic modelling approach.

SOE 22.9 Fri 12:15 ZEU 160

Principal Components of the European Power System — •Fabian Hofmann, Jonas Hoersch, and Stefan Schramm — Frankfurt Institute for Advanced Studies, Frankfurt, Germany

The European power system represents a huge network of different nodes, each with a complex time-dependent behaviour. In order to efficiently integrate renewable energy sources, such as wind and solar, it is a major task to understand and handle their additional effects. In particular, the more renewables in the system, the more the power generation will be subject to the weather. We therefore build up a european power system, which is dominated by non-conventional power generators, and extract general time-dependant patterns from it by applying a Principal Component Analysis to the timeseries of the nodes. This reduces the multivariate dimension of the system to a small number of general patterns, which are though uncorrelated but may not necessarily be statistically independent. Furthermore, these dominating patterns determine main flows in the network and can be used to align investments and network design.