# 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

Dirk Helbing
Professorship of Computational
Social Science
ETH Zürich
Clausiusstrasse 50
CH-8092 Zürich
dhelbing@ethz.ch

## Overview of Invited Talks and Sessions

(Lecture rooms H36, H16, H1, and H43; Poster B1)

### Plenary Talk related to SOE

See PV for the full plenary program.

| | | | | |
|---|---|---|---|---|
| PV VI | Tue | 8:30– 9:15 | H1 | **Linking Individual to Collective Behavior in Complex Adaptive Networks** — •Jorge M. Pacheco |

### Invited Tutorial Talks

| | | | | |
|---|---|---|---|---|
| SOE 1.1 | Sun | 16:00–16:50 | H16 | **Predicting evolution: statistical mechanics and biophysics far from equilibrium** — •Michael Lässig |
| SOE 1.2 | Sun | 16:50–17:40 | H16 | **Voter models of social opinion formation.** — •Katarzyna Sznajd-Weron |
| SOE 1.3 | Sun | 17:40–18:30 | H16 | **Maximum-entropy methods for network reconstruction, systemic risk estimation, and early-warning signals** — •Diego Garlaschelli |

### Invited and Topical Talks

| | | | | |
|---|---|---|---|---|
| SOE 6.1 | Mon | 16:00–16:45 | H36 | **Degustibus est disputandum - The Emerging Science of Preference Formation** — •Ernst Fehr |
| SOE 12.1 | Wed | 9:30–10:15 | H36 | **Booms, bust and behavioral heterogeneity in stock prices** — •Cars Hommes |
| SOE 2.1 | Mon | 9:30–10:00 | H36 | **Structure and Dynamics of Multilayer Networks** — •Ginestra Bianconi |
| SOE 16.1 | Wed | 15:00–15:30 | H36 | **Blackouts from smart meters? Self-organized criticality and collective effects in power networks** — •Stefan Bornholdt |

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

| | | | | |
|---|---|---|---|---|
| SOE 6.2 | Mon | 17:00–17:45 | H36 | **Community Structure in Social and Financial Networks** — •Mason Porter |

### Invited talks of the joint symposium SYCS

See SYCS for the full program of the symposium.

| | | | | |
|---|---|---|---|---|
| SYCS 1.1 | Tue | 9:30–10:00 | H1 | **Theory far from infinity: chimera states without the thermodynamic limit** — •Daniel Abrams |
| SYCS 1.2 | Tue | 10:00–10:30 | H1 | **Chimera patterns: Influence of topology, noise, and delay** — •Eckehard Schöll |
| SYCS 1.3 | Tue | 10:30–11:00 | H1 | **Chimera states in quantum mechanics** — •Victor Manuel Bastidas Valencia |

| | | | | |
|---|---|---|---|---|
| SYCS 1.4 | Tue | 11:15–11:45 | H1 | **Synchronization in Populations of Chemical Oscillators: Phase Clusters and Chimeras** — •Kenneth Showalter |
| SYCS 1.5 | Tue | 11:45–12:15 | H1 | **Epileptic seizures: chimeras in brain dynamics** — •Klaus Lehnertz |

## Invited talks of the joint symposium SYSM

See SYSM for the full program of the symposium.

| | | | | |
|---|---|---|---|---|
| SYSM 1.1 | Thu | 9:30–10:00 | H1 | **Science Forecasts: Measuring, Predicting, and Communicating Scientific Developments** — •Katy Börner |
| SYSM 1.2 | Thu | 10:00–10:30 | H1 | **Mapping science with variable-order Markov dynamics reveal overlapping fields and multidisciplinary journals** — •Martin Rosvall |
| SYSM 1.3 | Thu | 10:30–11:00 | H1 | **Network algorithms for reputation and quality in scholarly data** — •Matúš Medo, Manuel Mariani, Yi-Cheng Zhang |
| SYSM 1.4 | Thu | 11:15–11:45 | H1 | **Modeling scientific networks in social media** — •Cassidy Sugimoto |
| SYSM 1.5 | Thu | 11:45–12:15 | H1 | **Modeling scientific collaboration across multiple scales: from individuals to Europe** — •Alexander Petersen |

## Sessions

| | | | | |
|---|---|---|---|---|
| SOE 1.1–1.3 | Sun | 16:00–18:30 | H16 | **Tutorial: Evolutionary Dynamics and Applications to Biology, Social and Economic Systems (SOE / DY / BP / jDPG)** |
| SOE 2.1–2.1 | Mon | 9:30–10:00 | H36 | **Structural Models of Social and Economic Networks (Topical Talk Ginestra Bianconi)** |
| SOE 3.1–3.6 | Mon | 10:00–11:30 | H36 | **Networks: From Topology to Dynamics I (joint session SOE / DY / BP)** |
| SOE 4.1–4.3 | Mon | 11:30–12:15 | H36 | **Traffic, Urban and Regional Systems** |
| SOE 5.1–5.4 | Mon | 12:15–13:15 | H36 | **Evolutionary Game Theory (joint session SOE / BP / DY)** |
| SOE 6.1–6.2 | Mon | 16:00–17:45 | H36 | **Young Scientist Award for Socio- and Econophysics (YSA) - Award Ceremony** |
| SOE 7.1–7.12 | Mon | 18:00–20:00 | Poster B1 | **Poster** |
| SOE 8.1–8.1 | Tue | 8:30– 9:15 | H1 | **Plenary talk Jorge Pacheco** |
| SOE 9.1–9.5 | Tue | 9:30–12:15 | H1 | **Chimera States: Coherence-Incoherence Patterns in Complex Networks (SYCS, joint symposium DY / SOE / BP)** |
| SOE 10.1–10.4 | Tue | 14:00–15:00 | H36 | **Chimera State: Symmetry breaking in dynamical networks (session accompanying symposium SYCS)** |
| SOE 11.1–11.3 | Tue | 15:00–15:45 | H36 | **Networks: From Topology to Dynamics II (joint session SOE / DY / BP)** |
| SOE 12.1–12.1 | Wed | 9:30–10:15 | H36 | **Behavioral Models for Stock Prices (Invited Talk Cars Hommes)** |
| SOE 13.1–13.4 | Wed | 10:15–11:15 | H36 | **Economic Models I** |
| SOE 14.1–14.4 | Wed | 11:15–12:15 | H36 | **Financial Markets and Risk Management I** |
| SOE 15.1–15.4 | Wed | 12:15–13:15 | H36 | **Economic models II** |
| SOE 16.1–16.1 | Wed | 15:00–15:30 | H36 | **Collective Failures in Energy Networks (Topical Talk Stefan Bornholdt)** |
| SOE 17.1–17.3 | Wed | 15:30–16:15 | H36 | **Social Systems, Opinion and Group Dynamics: Dynamics of Team and Network Formation** |
| SOE 18.1–18.2 | Wed | 16:15–16:45 | H36 | **Social Systems, Opinion and Group Dynamics: Opinions and Innovations** |
| SOE 19.1–19.3 | Wed | 16:45–17:30 | H36 | **Financial Markets and Risk Management II** |
| SOE 20.1–20.3 | Wed | 17:30–18:15 | H36 | **Economic models III** |
| SOE 21 | Wed | 18:15–19:00 | H36 | **Member's Assembly** |
| SOE 22.1–22.5 | Thu | 9:30–12:15 | H1 | **Scientometric Maps and Models of Science and Scientific Collaboration Networks (Symposium SYSM, joint SOE / DY / BP / jDPG)** |
| SOE 23 | Thu | 12:30–13:00 | Bibliothek Foyer | **Places and Spaces - Exhibition of Maps of Science** |

| | | | | |
|---|---|---|---|---|
| SOE 24.1–24.6 | Thu | 15:00–16:30 | H36 | **Scientometric maps and dynamical models of scientific collaboration networks (accompanying symposium SYSM)** |
| SOE 25.1–25.4 | Thu | 16:45–17:45 | H43 | **Networks: From Topology to Dynamics (joint session BP / SOE / DY)** |
| SOE 26.1–26.6 | Thu | 15:30–17:00 | H47 | **Networks: From Topology to Dynamics (joint session DY / SOE / BP)** |

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

Wednesday 18:15–19:00 H36

## SOE 1: Tutorial: Evolutionary Dynamics and Applications to Biology, Social and Economic Systems (SOE / DY / BP / jDPG)

Current model approaches for collective phenomena in biological, social and economic systems widely employ methods from statistical physics. This sequence of tutorial talks demonstrates how physical concepts allow the formulation of appropriate microscopic models, the numerical and analytical treatment to obtain phase diagrams and macroscopic equations of motion. Host-virus coevolution, social opinion formation and systemic risk of the interbank network are research frontiers illustrating fruitful applications (Session compiled by J.C.Claussen)

Time: Sunday 16:00–18:30 Location: H16

**Tutorial** SOE 1.1 Sun 16:00 H16

**Predicting evolution: statistical mechanics and biophysics far from equilibrium** — •Michael Lässig — Institut für theoretische Physik, Zülpicher Strasse 77, D-50937 Köln

The human flu virus undergoes rapid evolution, which is driven by interactions with its host immune system. We describe the evolutionary dynamics by a fitness model based on two biophysical phenotypes of the virus: protein folding stability and susceptibility to human immune response. This model successfully predicts the evolution of influenza one year into the future, which has important consequences for public health: evolutionary predictions can inform the selection of influenza vaccine strains. Based on this example, we discuss the role of statistical mechanics and biophysics in making evolutionary biology a predictive science.

**Tutorial** SOE 1.2 Sun 16:50 H16

**Voter models of social opinion formation.** — •Katarzyna Sznajd-Weron — Department of Theoretical Physics, Wroclaw University of Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw

Among many different subjects, opinion dynamics is one of the most studied in the field of sociophysics. In my opinion there are at least two important reasons why physicists study this topic. The first motivation comes from social sciences and can be described as a temptation to build a bridge between the micro and macro levels in describing social systems. Traditionally, there are two main disciplines that study social behavior - sociology and social psychology. Although the subject of the study is the same for both disciplines, the usually taken approach is very different. Sociologists study social systems from the level of the social group, whereas social psychologists concentrate on the level of the individual. From the physicist's point of view this is similar to the relationship between thermodynamics and statistical physics. This analogy raises the challenge to describe and understand the collective behavior of social systems (sociology) from the level of interpersonal interactions (social psychology). The second motivation to deal with opinion dynamics is related to the development of non-equilibrium statistical physics, because models of opinion dynamics are often very interesting from the theoretical point of view. A good example of such an interesting model is a broad class of voter models, including linear voter model and nonlinear q-voter model introduced in along with its modifications.

**Tutorial** SOE 1.3 Sun 17:40 H16

**Maximum-entropy methods for network reconstruction, systemic risk estimation, and early-warning signals** — •Diego Garlaschelli — Lorentz Institute for Theoretical Physics, University of Leiden, The Netherlands

The global financial crisis shifted the interest from traditional measures of "risk" of individual banks to new measures of "systemic risk", defined as the risk of collapse of an entire interbank system. In principle, estimating systemic risk requires the knowledge of the whole network of exposures among banks. However, due to confidentiality issues, banks only disclose their total exposure towards the aggregate of all other banks, rather than their individual exposures towards each bank. Is it possible to statistically reconstruct the hidden structure of a network in such a way that privacy is protected, but at the same time higher-order properties are correctly predicted? In this talk, I will present a general maximum-entropy approach to the problem of network reconstruction and systemic risk estimation. I will illustrate the power of the method when applied to various economic, social, and biological systems. Then, as a counter-example, I will show how the Dutch interbank network started to depart from its reconstructed counterpart in the three years preceding the 2008 crisis. Over this period, many topological properties of the network showed a gradual transition to the crisis, suggesting their usefulness as early-warning signals of the upcoming crisis. By definition, these early warnings are undetectable if the network is reconstructed from partial bank-specific information.

## SOE 2: Structural Models of Social and Economic Networks (Topical Talk Ginestra Bianconi)

Time: Monday 9:30–10:00 Location: H36

**Topical Talk** SOE 2.1 Mon 9:30 H36

**Structure and Dynamics of Multilayer Networks** — •Ginestra Bianconi — School of Mathematical Sciences Queen Mary University of London, London, UK

Multilayer networks describe the vast majority of complex systems from social networks, and interdependent infrastructure to the brain. In this talk I will present an overview of the rich interplay between structure and function in multilayer networks.

## SOE 3: Networks: From Topology to Dynamics I (joint session SOE / DY / BP)

Time: Monday 10:00–11:30 Location: H36

SOE 3.1 Mon 10:00 H36

**Revealing physical interaction networks from nonlinear dynamics** — Jose Casadiego[1], Dimitra Maoutsa[1], Hauke Hähne[1], Mor Nitzan[2], and •Marc Timme[1] — [1]Network Dynamics, MPI for Dynamics and Self-Organization, Göttingen, Germany — [2]Racah Institute of Physics, The Hebrew University of Jerusalem, Israel

Structural connectivity of networks reflects the direct physical interactions between pairs of dynamical units, as opposed to effective, functional or other statistical measures of connectivity. How to uncover physical interaction structure from measured time series of networked systems remains an open question. Here we present a dynamical systems' view on collective network dynamics, thereby proposing an approach to reveal physical interaction networks from the nonlinear dynamics they generate. Introducing the notion of *explicit dependency matrices*, we present two examples: one, where the time series consists of the full network states as a function of time, the other, where the time series exhibits only partial information about the full states. We apply the latter to neural circuit dynamics where the observables are spike timing data, i.e. only a discrete, state-dependent output of the neurons. These results may help revealing network structure for systems where direct access to dynamics is simpler than to connectivity.

For an introductory review of the state of the art, see
J. Phys. A: Math. Theor. 47 343001 (2014)

http://dx.doi.org/10.1088/1751-8113/47/34/343001

SOE 3.2 Mon 10:15 H36

**Theory and experiments on anomalous critical and supercritical connectivity transitions** — •Jan Nagler — ETH Zurich

The emergence of large-scale connectivity on an underlying network or lattice, the so-called percolation transition, has a profound impact on the system's macroscopic behaviours. There is thus great interest in controlling the location of the percolation transition to either enhance or delay its onset and, more generally, in understanding the consequences of such control interventions. Here we report on the sudden emergence of large-scale connectivity that results from repeated, small interventions designed to delay the percolation transition. These transitions exhibit drastic, unanticipated and sometimes exciting consequences in complex networked systems but also pose experimental challenges. In particular, I will report on both theoretical and experimental progress (D'Souza & Nagler, Nature Physics 11:531, 2015; Nagler et al., unpublished).

SOE 3.3 Mon 10:30 H36

**What does Big Data tell? Sampling the social network by communication channels** — •János Török[1,2], Yohsuke Murase[3], Hang-Hyun Jo[4,5], János Kertész[2,1,5], and Kimmo Kaski[5] — [1]Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest H-1111, Hungary — [2]Center for Network Science, Central European University, Budapest H-1051, Hungary — [3]RIKEN Advanced Institute for Computational Science, Kobe, Hyogo 650-0047, Japan — [4]BK21plus Physics Division and Department of Physics, Pohang University of Science and Technology, Pohang 37673, Republic of Korea — [5]Department of Computer Science, Aalto University School of Science, P.O. Box 15500, Espoo, Finland

Big Data has become the primary source of understanding the structure and dynamics of the society at large scale. However, usually one has information only about one of the channels, which should be considered as a sample of the whole. We show by simulations and analytical methods that this sampling may lead to bias. For example, while it is expected that the degree distribution of the whole social network has a maximum at a value larger than one, we get with reasonable assumptions about the sampling process a monotonously decreasing distribution as observed in empirical studies of single channel data. Also we find, that assortativity may occur or get strengthened due to the sampling process. We analyze the far-reaching consequences of our findings.

SOE 3.4 Mon 10:45 H36

**Effective Distances in Complex Networks** — Flavio Iannelli[1], •Andreas Koher[2], Philipp Hövel[2], and Igor M. Sokolov[1] — [1]Humboldt Universität zu Berlin, Germany — [2]Technische Universität Berlin, Germany

The analysis of global epidemics revealed that physical distances can hardly be used to forecast the outbreak dynamics. Instead, a network-based measure which has been introduced recently [1] allows to predict infection arrival times with a surprisingly high accuracy. The so-called effective distances are solely based on the (weighted) network topology.

We present an alternative approach, which is motivated by a fundamental property from the theory of random walks: The distribution of first passage times. This random walk based distance allows to forecast disease dynamics on various topologies. For the special case of highly heterogeneous networks it reduces to the previously introduced effective distance.

[1] Brockmann D, Helbing D "The hidden geometry of complex, network-driven contagion phenomena." Science. 2013;342(6164):1337–1342

SOE 3.5 Mon 11:00 H36

**A Geometrical Approach to Infection Dynamics on Temporal Networks** — •Felix Herrmann[1], Philipp Hövel[1], Vitaly Belik[1], Andreas Koher[1], Hartmut H. K. Lentz[2], and Dirk Brockmann[3,4] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Friedrich-Loeffler-Institut, Greifswald — [3]Institut für Theoretische Biologie, Humboldt-Universität zu Berlin — [4]Robert Koch-Institut, Berlin

We investigate the extension of a recently introduced geometrical approach for the description of spreading processes on static undirected networks [1] to directed temporal networks. Its key quantity is a probabilistically motivated "effective distance" between nodes, which is based on the weights of the links and allows reliable predictions of disease arrival times and the identification of the origin of spreading processes. The approach has already been successfully applied to study infection dynamics on a static undirected air traffic network [1].

By demonstrating how this approach can be generalized, we contribute to a framework for the investigation of spreading dynamics on temporal networks. Specifically, we consider an empirical livestock trade network in Germany, consisting of 97,980 nodes (agricultural holdings) and 6,359,697 temporal edges (trade events) [2], and use a SIR model to simulate the local dynamics of the nodes. Strong fluctuations in the activity of the nodes render the application of the geometrical approach particularly challenging.

[1] D. Brockmann and D. Helbing, Science 342, 1337 (2013).
[2] H. H. K. Lentz et al., Phys. Rev. Lett. 110, 118701 (2013).

SOE 3.6 Mon 11:15 H36

**Controlling recurrent epidemics on temporal networks** — •Vitaly Belik[1,2], Florian Fiebig[1], Hartmut H K Lentz[3], and Philipp Hövel[1,4] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Helmholtz Zentrum für Infektionsforschung, Braunschweig — [3]Institute of Epidemiology, Friedrich-Loeffler-Institute, Greifswald — [4]Bernstein Center for Computational Neuroscience Berlin, Humboldt Universität zu Berlin

We consider a rucurrent epidemic on a temporal network. The goal of the control is to reduce the prevalence or make the epidemic extinct, respectively. To this end we propose a protocol based on rewiring the edges away from infected nodes, after they are detected as those: instead of an infected node, we randomly choose a healthy one (or perceived as such). In contrast to coevolutionary adaptive networks, the intrinsic dynamics of the network is taken into account by our approach alongside with the adaptive rewiring. The proposed control scheme significantly expands the range of a disease-free parameter region. For example, on the network of German pig trade, diseases with detection times up to 10 days and infectious periods up to 3 months could be efficiently controlled by our method [1]. Thus changing the behaviour of trading partners could have significant impact on the epidemic outcome.

[1]V Belik, F Fiebig, HHK Lentz, P Hövel arXiv preprint arXiv:1509.04054

## SOE 4: Traffic, Urban and Regional Systems

Time: Monday 11:30–12:15 Location: H36

SOE 4.1 Mon 11:30 H36

**Fluctuation analysis of German electricity power production: Comparison of classical and renewable sources** — Hynek Lavicka[1] and •Jiri Kracik[2] — [1]Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Physics, Břehová 7, CZ-11519 Prague 1, Czech Republic — [2]Charles University in Prague, Faculty of Social Sciences, Institute of Economic Studies, Opletalova 26. CZ-11000 Prague 1, Czech Republic

We perform analysis of time series of electric power load production by type of power plant in Germany between 2010 and end of 2014. We report presence of 1/f noise with additional peaks for most of time series. Performing test statistics we obtain indication of presence of autocorrelations. Detailed analysis using MFDFA allowed to distribute electric power sources into three groups according to presence of type of autocorrelation. Solar, wind and gas power plants and other renewable enegy sources exhibit anti-persistent behaviour while nuclear power plants, combined heat and power and Run-of-the-river hydroelectricity show persistent behaviour and finally, coal power plants mostly present uncorrelated behaviour. All sources share wide multi-fractal spectra of correlations while distribution multi-fractal spectrum is rather narrow and the distribution function deviates from Gaussian distribution.

SOE 4.2 Mon 11:45 H36

**Risk modeling in Spanish indebted municipalities using Generalized Power Law distributions** — •Faustino Prieto and José María Sarabia — University of Cantabria, Department of Economics, Santander, Spain.

In this paper, we studied how the debt is distributed across municipalities in Spain. These local entities are financied by the central state, by the autonomous community to which they belong, and by their local revenues. Their expenditure are directed at providing essential local services to people in their local area as, for example, street cleaning, local police, etc. For different reasons, they decide to contract debt. In that context, the aim of this study was to find an adecuate probabilistic model for that debt. First, we found that the Power Law model was only adecuated in the upper tail of the distribution, which means that only the most indebted local entities followed a power law behaviour. Then, for all the Spanish indebted municipalities dataset, in the period 2008-2014, we fitted different probabilistic models by máximum likelihood, compared them by the Bayesian Information criterion, and found that a new Generalized Power Law (GPL) distribution provided the better fit. Finally, we tested the goodness-of-fit of that new GPL model by a Kolmogorov-Smirnov test method based on bootstrap resampling. We found that the new GPL distribution can be an adequate framework for modeling the debt of municipalities.

SOE 4.3 Mon 12:00 H36

**Urban scaling observed in Japanese telephone book data** — •Takaaki Ohnishi[1,2], Takayuki Mizuno[3,2], Chihiro Shimizu[2], and Tsutomu Watanabe[4,2] — [1]Graduate School of Information Science and Technology, The University of Tokyo, Tokyo, Japan — [2]The Canon Institute for Global Studies, Tokyo, Japan — [3]Information and Society Research Division, National Institute of Informatics, Tokyo, Japan — [4]Graduate School of Economics, The University of Tokyo, Tokyo, Japan

How different urban properties (such as number of hospitals, shops, patents, and crimes) depend on city size? It has been demonstrated that most urban properties $Y$ follow the allometric scaling law $Y \propto N^{\beta}$, where $N$ and $\beta$ are population size of a city and the scaling exponent. Urban infrastructure has been shown to scale sub-linearly ($\beta < 1$) reflecting large cities don't need large infrastructure, whereas output and income have been shown to scale super-linearly ($\beta > 1$) reflecting high per capita in large cities. We empirically analyze urban scaling observed in Japanese telephone book data. This data are renewed every 4 months, offering comprehensive latest address info on nearly all shops, firms, hospitals, schools, parks, etc on a nationwide scale. These urban properties are divided into 332 categories depending on the urban role. This allows us to study and discuss systematically the scaling exponent that are associated with various aspects of urban properties. We show that obtained scaling exponents help to characterize urban properties.

## SOE 5: Evolutionary Game Theory (joint session SOE / BP / DY)

Time: Monday 12:15–13:15 Location: H36

SOE 5.1 Mon 12:15 H36

**Evolutionary ecological-economic modelling: Ecological instability and economic growth** — •Sylvie Geisendorf[1], Frank Beckenbach[2], and Christian Klippert[1] — [1]ESCP Europe Campus Berlin, Heubnerweg 8-10, 14059 Berlin, Germany — [2]University of Kassel

The paper proposes an evolutionary ecological-economic model taking into account the complexity of the ecological as well as the economic system. We argue that Economics should consider ecological complexity and the co-dynamics of the economic and ecological system to better understand drivers and restrictions of economic evolution. At the same time, the development of a regenerative resource is affected by the internal growth dynamics of the economy. Given that no economic activity is conceivable without using natural resources and relying on natural systemic services, there is a surprising simplification of the natural system in economic models. The model we propose has three particularities distinguishing it from traditional resource economic models. (1) it implements a multi-dimensional link between the economic and ecological system, considering side effects of the production process like waste or emissions. (2) it uses a difference equation approach for the biological resource instead of the typical differential one, to allow for the whole range of stability regimes and (3) it links this resource system to an evolving, agent-based economy instead of the standard optimization calculus.

SOE 5.2 Mon 12:30 H36

**Changing the rules of the game as an emergent feature of the dynamics** — •Darka Labavić and Hildegard Meyer-Ortmanns — Jacobs University Bremen, Bremen, Germany

We consider $(N, r)$ games of competition with $N$ species and $r < N$ prey and predators. Basic reactions include predation, reproduction, decay, and diffusion, without a hard constraint on the occupation number per site. For special combinations of $N$ and $r$ we observe the option to see games within games for an appropriate choice of parameters. As one of the simplest examples we analyze a $(6, 3)$ game. Once the players segregate from a random initial distribution, domains on a coarse scale emerge, which play a $(2, 1)$-game at their boundaries, while agents inside the domains play rock-paper-scissors (that is, $(3, 1)$), leading to the formation of spirals with species chasing each other. The $(2, 1)$-game has a winner in the end, so that the coexistence of domains is transient, while agents inside the remaining domain coexist, until demographic fluctuations lead to the survival of only a single species. This means that we observe a dynamical generation of multiple scales in space and time with an emerging change of rules on the coarse scale starting from a simple set of rules on the unit scale of the grid. In view of predicting these features, we derive the deterministic limit within a van Kampen expansion. A linear stability analysis reproduces the number of forming domains and their composition in terms of species. A comparison of analytical predictions with Gillespie simulations also reveals the impact that the various sources of stochastic fluctuations have on the dynamics, even on its qualitative features.

SOE 5.3 Mon 12:45 H36

**A synthetic codon replicator with tRNA** — •Simon Alexander Lanzmich and Dieter Braun — Systems Biophysics, Physics Department, Nanosystems Initiative Munich and Center for NanoScience, LMU Munich, Germany

Every evolving system requires the storage and replication of genetic information. Modern biology solves this using an RNA-dominated machinery (ribosome and a pool of tRNAs) to encode proteins. The proteins in turn replicate genetic information. In contrast, early life most probably replicated genes using a pool of short RNA sequences.

To approach above chicken and egg problem, we explore an autonomous, waste-free, and purely thermally driven replication mechanism. Instead of chemical base-by-base replication, it operates on successions of multi-base codons. The molecules used have a hairpin loop at each end and are derived from transfer RNA. They encode and replicate a binary code at the anticodon sites of tRNA.

Replication of a template succession of tRNAs is facilitated by temperature oscillations and proceeds in three logical steps. (1) Strands with matching anticodons bind to the template. (2) Fluctuations in the bound strands' hairpins allow for the hybridization to neighboring strands. (3) Subsequent heating splits the replicate from the template, freeing both for the next cycle. This physical ligation chain reaction proceeds cross-catalytically. Instead of chemical backbone ligation, matching strands are linked by physical base pairing.

SOE 5.4 Mon 13:00 H36

**Stepwise cooperation of molecular replicators** — •Georg Urtel and Dieter Braun — Systems Biophysics, Ludwig-Maximilians-Universität München, Amalienstr. 54, D- 80799 München, Germany

Life emerged from the ability of informational polymers to pass on sequences to other polymers before they degrade. Before competition between living species, the first selection pressure was to replicate faster than degradation. What were the strategies the molecules could take?

Based on biological evidence, DNA or RNA replicators require a defined binding site to start replication. We study experimentally and theoretically three geometries of the binding site: linear single binding,

hairpin binding and two opposing binding locations. The geometries have fundamentally different, increasing replication speeds.

Interestingly, two hairpin replicators cooperate readily and form the fastest replicating geometry. After incomplete replication, they bind by hybridization and cooperate by forming a crossbreed species. This cooperation of two replicators retains most of the sequence information of both hairpins. Under conditions where hairpins are doomed to degrade, their crossbreed is replicating fast enough to survive. As a result, two initially separated hairpins survive by diffusional mixing and the colocalized crossbreeding.

Our experiments show a stepwise evolution of replicator geometries. Already at a molecular level, cooperation was an advantageous strategy under Darwinian evolution.

## SOE 6: Young Scientist Award for Socio- and Econophysics (YSA) - Award Ceremony

Time: Monday 16:00–17:45 Location: H36

**Invited Talk** SOE 6.1 Mon 16:00 H36

**Degustibus est disputandum - The Emerging Science of Preference Formation** — •Ernst Fehr — University of Zurich, Department of Economics

In modern economics individuals' preferences are taken as given. They are the unmoved movers of action. Preferences are, however, formed by social, economic and biological forces. This lecture will document recent insights into preference formation and how this helps explain hitherto unexplained (or insuffienciently explained), yet important, phenomena such as the impact of poverty on time and risk preferences which may contribute to behaviors that reinforce poverty, the role of culture and social norms in health-related behaviors, the psychological sources of war and conflicts, or the impact of nuclear catastrophes on risk taking and time discounting.

**Presentation of the YSA to the awardee**

**Prize Talk** SOE 6.2 Mon 17:00 H36

**Community Structure in Social and Financial Networks** — •Mason Porter — University of Oxford, UK

Networks consist of entities (represented by nodes) connected to each other via ties (represented by edges). To gain insights into networks, it is often useful to coarse-grain them to explore mesoscale structures. The best-studied type of mesoscale network structure is a "community", which consists of a dense set of nodes that is (hopefully) connected sparsely to other dense sets of nodes. In this talk, I'll discuss a couple of methods for detecting communities in networks — one based on maximizing a quality function called "modularity" and another based on local perspective — and I'll discuss applications to social and financial networks. I'll also provide some cautionary notes about studying community structure in networks and briefly discuss some other mesoscale structures (e.g. core–periphery structure) and why they are important for social and financial applications.

**After the YSA award session, there will be an informal get-together with beer + pretzels, combined with the poster session**

## SOE 7: Poster

Time: Monday 18:00–20:00 Location: Poster B1

SOE 7.1 Mon 18:00 Poster B1

**A Geonomic Reflection (Globalistics/Geonomics/Energetics)** — •Stephen I. Ternyik — POB. 201 82043 Munich

A human social economy is, in historical and empirical terms, an evolving energy transduction system, i.e. there exists physically a cybernetic circuit of natural input—economic conversion—social output—financial transaction. Since 1989, we can observe a rapidly growing world exchange of natural resources and economic values in the global monetary economy. According to the geonomic calculation model, the following formula is used in the scientific discourse (Production/minus/Rent=Wages/plus/Interest; P-R=W+I); the (neo)classical model reads P=R+W+I. The geo-economic point of view is marked by the physical fact (Land Value) that the access to natural resources (e.g.energy)decides about the production/distribution of wealth, income and assets, i.e. the land monopoly on natural resources is reinforced by the monetary monopoly of private commercial banking (the inter-changeability of unlimited fiat money with limited natural resources of the earth; taxation remains focused on W and I, not on R). These artificial imbalances in economic book-keeping/accounting of human-nature-interaction have lead to globally unsustainable economic practices of production and exchange, i.e. the total costs of these accounting models are outnumbering the real global benefits, in terms of socio-economic and eco-logical consequences. An economic course correction can be achieved via the application of geonomic thought.

SOE 7.2 Mon 18:00 Poster B1

**Influence of triadic motifs on the dynamics of epidemic networks** — •Ilja Rausch, Marco Winkler, and Haye Hinrichsen — Institute for Theoretical Physics, University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Networks have become an important tool for the analysis of a variety of dynamic systems such as financial markets, coupled oscillators or epidemics. Looking at structure properties such as clustering or overrepresentation of certain motifs can lead to new insights on how networks evolve in time. In our research we want to investigate how the occurrence of specific types of triadic motifs can influence the dynamics of disease spreading on Steiner Triple Systems. In order to model the infection spreading, we consider the *SIR model* where susceptibles (S) interact with the infected (I) at rate $\beta$ and are removed (R) due to recovery or death at rate $\gamma$. We use numerical simulations and recently developed techniques such as Node Specific Pattern Mining (NoSPaM) and Z-core analysis to investigate the effect of overrepresented triadic motifs on the clustering coefficient and network output for different values of $\beta$ and $\gamma$.

SOE 7.3 Mon 18:00 Poster B1

**A co-evolutionary conceptual model of global pre-industrial societies** — •Jan Nitzbon[1,2] and Jobst Heitzig[1] — [1]Potsdam Institut für Klimafolgenforschung — [2]Georg-August-Universität Göttingen

The evolution of the earth system cannot be described without the "human factor" anymore. Co-evolutionary modeling approaches thus aim at incorporating socio-economic dynamics of the society into the description of natural systems in order to obtain a more holistic picture of the world-earth system.

We present a conceptual, low-dimensional, deterministic model which describes the co-evolution of globally aggregated key observables of the earth system. These include natural variables such as atmospheric, oceanic and land carbon stocks, as well as socio-economic quantities such as population, economic output or wellbeing. The goal of the model study is to identify the dominant feedbacks in the coupled dynamics of the "ecosphere" and the "anthroposhere" and to get deeper insights into the underlying topology of these spaces.

In particular we investigated a simplified model scenario which describes pre-industrial societies. Most of the model parameters can roughly be estimated on the basis of available global data. Those associated with a high uncertainty have been varied during bifurcation analyses. The results reveal a partition of the parameter space into several regimes which are characterized by qualitatively different transient and asymptotic behaviors of the system, ranging from ending up surely on an unpopulated hot desert planet to uninterrupted oscillations.

SOE 7.4 Mon 18:00 Poster B1

**Price response in correlated financial markets: empirical results** — •Shanshan Wang, Rudi Schäfer, and Thomas Guhr — Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany

Previous studies of the stock price response to individual trades focused on single stocks. We empirically investigate the price response of one stock to the trades of other stocks. How large is the impact of one stock on others and vice versa? – This impact of trades on the price change across stocks appears to be transient instead of permanent. Performing different averages, we distinguish active and passive responses. The two average responses show different characteristic dependences on the time lag. The passive response exhibits a shorter response period with sizeable volatilities, and the active response a longer period. We also study the response for a given stock with respect to different sectors and to the whole market. Furthermore, we compare the self-response with the various cross-responses. The correlation of the trade signs is a short-memory process for a pair of stocks, but it turns into a long-memory process when averaged over different pairs of stocks.

SOE 7.5 Mon 18:00 Poster B1

**Effects of Microscopic Limit Order Book Structure on Price Formation** — •Martin Vogt and Stephan Eule — Max-Planck-Institut für Dynamik und Selbstorganisation, Am Faßberg, 37077 Göttingen

Most modern financial markets employ an electronic limit order book to temporarily store supply and demand in form of unexecuted buy and sell limit orders. In a high frequency setting, the central economic question of price formation is governed by the static and dynamic properties of the order book in a continuous double auction market system. Prior analyses of high frequency, high resolution order book data have mainly focused on three different issues:

(i) Static statistics of price determining quantities such as spread size and price jump distributions,

(ii) how the flow of incoming limit and market orders and their cancellations influence those statistics,

(iii) and the effect of the order book's state itself on the dynamics of the order flow.

While these issues govern price formation on short scales, past analyses have shown that dynamic properties of order books such as price relaxation and order book resilience are important factors when trading frequently. Consequently, these dynamic properties are important determinants of optimal execution strategies. We investigate the dynamic properties in a zero intelligence setting and compare them to the assumptions of previous optimal execution models as well as real market data from the Deutsche Börse.

SOE 7.6 Mon 18:00 Poster B1

**Structural Organization in King Penguin Colonies** — •Richard Gerum[1], Ben Fabry[1], Claus Metzner[1], Céline Le Bohec[2,3], Francesco Bonadonna[4], Anna Nesterova[2], and Daniel Zitterbart[1,5] — [1]University of Erlangen-Nürnberg, Germany — [2]CNRS/UdS, Strasbourg, France — [3]CSM LIA-647 BioSensib, Monaco — [4]CEFE-CNRS, Montpellier, France — [5]AWI, Bremerhaven, Germany

King penguins (*Aptenodytes patagonicus*) that show territorial behaviour during breeding, incubate their single egg on their feet. Thus they can adjust their positions to avoid the proximity of other penguins, while retaining a compact colony structure. A preliminary analysis of aerial imagery reveals that the resulting structure shows a spatial periodicity in density, thus resembling locally the structure of hexagonally arranged crystals. Every penguin keeps its neighbours at least 1.1m away, except couples which have an average distance of 0.45m. Distances and angles to neighbours differ for couples in comparison to solitary penguins, but these differences vanish when couples are treated as a single unit, thus implying that couples don't disturb the colony structure. Couples tend to cluster, as more couples are found next to other couples than solitary penguins, which could be caused by synchronisation in breeding behaviour of nearby penguins. These results can help to answer questions regarding formation and structure of breeding colonies.

SOE 7.7 Mon 18:00 Poster B1

**Measurability and Characteristics of Structural Metrics and Business Scores for HR development** — •Jan Moritz Joseph[1] and Matthias Hudečeck[2] — [1]joseph@iti.uni-luebeck.de — [2]m.hudecek@systemische-potentiale.de

Here we analyze structural metrics that are measured for business evaluation and leadership decisions in the field of HR development. We focus on results of feedbacks and data based on questionnaires to evaluate the measurability of the metrics in order to demonstrate their significance and determine their relevance. Both characteristics are major issues for organization of companies since policy makers orient key business parameters and human resources development toward the results of measures and the value of metrics. This is an especially relevant topic as multiple business parameters are unified into scores to accelerate changes in orientation. We argue that profound statistical understanding is crucial to interpret data from questionnaires correctly.

SOE 7.8 Mon 18:00 Poster B1

**Correlations of Value Added Growth in the World Trade Network** — Julian Maluck[1,2] and •Reik V. Donner[1] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Tokyo Institute of Technology, Tokyo, Japan

International trade has grown considerably during the process of globalization. Complex supply chains for the production of goods have resulted in an increasingly connected International Trade Network [1]. Here, we investigate empirically to what extent the topological properties of the ITN provide information about the correlations in the production of two industry sectors. We observe that although direct trade relations between industries serve as important indicators for correlations in the industries' value added, opportunities of substitution for required production inputs as well as second-order trade relations cannot be neglected. Our results contribute to a better understanding of the relation between trade and economic productivity. They serve as a basis for more accurate modeling techniques and better interpretation of the impacts of a node's failure due to economic crises.

[1] J. Maluck, R.V. Donner: A Network of Networks Perspective on Global Trade. PLoS ONE 10(7), e0133310 (2015)

SOE 7.9 Mon 18:00 Poster B1

**Oscillating hysteresis in the $q$-neighbor Ising model** — •Arkadiusz Jedrzejewski, Anna Chmiel, and Katarzyna Sznajd-Weron — Department of Theoretical Physics, Wroclaw University of Technology, Wroclaw, Poland

We modify the kinetic Ising model with Metropolis dynamics, allowing each spin to interact only with q spins randomly chosen from the whole system, which corresponds to the topology of a complete graph. We show that the model with $q \geqslant 3$ exhibits a phase transition between ferromagnetic and paramagnetic phases at temperature $T^*$, which linearly increases with $q$. Moreover, we show that for $q = 3$ the phase transition is continuous and that it is discontinuous for larger values of $q$. For $q > 3$, the hysteresis exhibits oscillatory behavior - expanding for even values of $q$ and shrinking for odd values of $q$. Due to the mean-field-like nature of the model, we are able to derive the analytical form of transition probabilities and, therefore, calculate not only the probability density function of the order parameter but also precisely determine the hysteresis and the effective potential showing stable, unstable, and metastable steady states. Our results show that a seemingly small modification of the kinetic Ising model leads not only to the switch from a continuous to a discontinuous phase transition, but also to an unexpected oscillating behavior of the hysteresis and a puzzling phenomenon for $q = 5$, which might be taken as evidence for the so-called mixed-order phase transition.

SOE 7.10 Mon 18:00 Poster B1

**Agent based modelling of the diffusion of innovations** — •Florian Senger — Fraunhofer ISI, Breslauer Str. 38, 76139 Karlsruhe

The work presented here is part of a PhD thesis, where methods from physics of social systems were combined with methods from evolutionary economics to develop an agent-based model to mimic the dynamics of regime changes in socio-technical systems. Therefore the demand side was modelled as consumer agents according to a distribution of endowments and needs, connected to each other in a social network, influencing each other in a voter-model-like manner and the supply side as explicit company agents consisting of genes in an evolutionary sense, producing a technology in a quality depending on their particular fitness, taking influence on particular areas of the consumer network via marketing and changing the alleles of their genes by a process of imitating and stochastically innovating, getting feedback on their fitness by the degree of success with the consumers. In this presentation results will be shown for different time scales and different geographical distributions of consumer agents and it will be shown how the model

is applied to the case of forms of regional mobility based on empirical data.

SOE 7.11 Mon 18:00 Poster B1

**Evolutionary stability of mixed strategies on graphs** — Yan Li[1], •Jens Christian Claussen[2], and Xinsheng Liu[1] — [1]Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China — [2]Computational Systems Biology, Jacobs University Bremen, Germany

Up to the present, the study of evolutionary dynamics mostly focused on pure strategy games in finite discrete strategy space, either in well-mixed or structured populations. In this paper, we study mixed strategy games in continuous strategy space on graphs of degree k. Each player is arranged on a vertex of the graph. The edges denote the interaction between two individuals. In the limit of weak selection, we first derive the payoff functions of two mixed strategies under three different updating rules, named birth-death, death-birth and imitation. Then we obtain the conditions for a strategy being continuously stable strategy (CSS), we also confirm that the equilibrium distribution corresponding to the CSS is neighborhood attracting and strongly uninvadable. Finally we apply our theory to the Prisoner's Dilemma and the snowdrift game to obtain possible CSS. Simulations are performed for the two special games and the results are well consistent with the conclusions.

SOE 7.12 Mon 18:00 Poster B1

**Optimal cervical cancer preventing strategies. Model for Moldova** — •Andrzej Jarynowski[1,2] and Ghennadii Gubceac[1] — [1]Moldova State University, Kishinev, Moldova — [2]Jagiellonian University, Cracow, Poland

We built the model, that aggregated the most important paths of infection (HPV virus), cancer development and prevention scenarios (more than 100 equations and 200 parameters). We observe both behavioral change (sexuality increase) and demographical change (population ageing). We have run computer simulation to prepare cost/benefit analysis for different vaccination strategies, various screening programs and preventive programs (using condoms) for Moldova, based on its own demography and sexual behavior. In our setup, obligatory vaccination seems to not be so crucial (for none of realistic scenarios increase of cancer cases is possible) for public health, as in most countries in European Union. However, national screening practice must be verified in terms of efficiency. We propose more optimal screening guidelines (with prevention cost 5-12k EUR per QALY), which could provide saving perspective in 10-15 year in range 150-300k EUR yearly. Targeted vaccination could be also consider, because population effect are similar to high frequencies screening schema with 1-1.5M EUR savings yearly.

## SOE 8: Plenary talk Jorge Pacheco

Time: Tuesday 8:30–9:15 Location: H1

**Plenary Talk** SOE 8.1 Tue 8:30 H1

**Linking Individual to Collective Behavior in Complex Adaptive Networks** — •Jorge M. Pacheco — Departamento de Matemática e Aplicações, Universidade do Minho, 4710 - 057 Braga, Portugal

A central problem in Physics is to understand how collective behavior results from a given two- or N- body fundamental interaction. Similarly, in a society, a central problem is to understand the link between individual social behavior and emergent collective phenomena (vaccination, epidemics, crowd behavior, diffusion of innovations, etc). Here I address this problem by letting individuals engage in pair-wise interactions by means of a well-defined social dilemma (a prisoners dilemma of cooperation). These individuals are embedded in a social network that is both complex and adaptive. Adaptation here allows individuals to manifest preferences and resolve conflicts of interest, reshaping the network accordingly. Exact Monte-Carlo simulations reveal the inadequacy of any of the tools developed to date (mostly in the realm of Physics) to predict the co-evolutionary dynamics of the population at large. I will present and discuss in detail an adaptive-network-sensitive observable that is capable of predicting the collective, population-wide dynamics, given prior knowledge of the fundamental rules that govern the social interaction between 2 individuals in a social network.

## SOE 9: Chimera States: Coherence-Incoherence Patterns in Complex Networks (SYCS, joint symposium DY / SOE / BP)

Time: Tuesday 9:30–12:15 Location: H1

**Invited Talk** SOE 9.1 Tue 9:30 H1

**Theory far from infinity: chimera states without the thermodynamic limit** — •Daniel Abrams — Northwestern University, Evanston, IL, USA

Chimera states are surprising symmetry-broken patterns in networks of coupled oscillators which often coexist with fully symmetric states. Much of the theory for chimera states focuses on networks with an infinite number of oscillators. In this talk, I will discuss some new results for the finite-N case, showing that stable chimera states are possible with as few as 4 oscillators. This suggests that they may be easily constructed in experimental or engineered systems, and may even occur naturally.

**Invited Talk** SOE 9.2 Tue 10:00 H1

**Chimera patterns: Influence of topology, noise, and delay** — •Eckehard Schöll — Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Chimera patterns, which consist of coexisting spatial domains of coherent and incoherent dynamics, are studied in networks of oscillators involving amplitude as well as phase dynamics, complex hierarchical (fractal) topologies, noise, and delay. We show that a plethora of novel chimera patterns arise if one goes beyond the Kuramoto phase oscillator model. For the FitzHugh-Nagumo system, the Van der Pol oscillator, and the Stuart-Landau oscillator with symmetry-breaking coupling we find various multi-chimera patterns [1], including amplitude chimeras and chimera death [2]. To test the robustness of chimera patterns, we study small-world and hierarchical topologies. We also address the robustness of amplitude chimera states in the presence of noise [3], and the emergence of coherence-resonance chimeras [4]. If delay is added, the lifetime of transient chimeras can be drastically increased, and novel phenomena like stochastic resonance of delayed-feedback chimeras can arise.

[1] I. Omelchenko et al., Phys. Rev. Lett. 110, 224101 (2013). I. Omelchenko et al., Phys. Rev. E 91, 022917 (2015). I. Omelchenko et al., Chaos 25, 083104 (2015). [2] A. Zakharova, M. Kapeller, and E. Schöll, Phys. Rev. Lett. 112, 154101 (2014). [3] S. Loos, J. C. Claussen, E. Schöll, and A. Zakharova, Phys. Rev. E (2016), arXiv:1508.04010v2. [4] N. Semenova, A. Zakharova, V. Anishchenko, and E. Schöll (2016), arXiv:1512.07036.

**Invited Talk** SOE 9.3 Tue 10:30 H1

**Chimera states in quantum mechanics** — •Victor Manuel Bastidas Valencia — Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, 117543 Singapore, Singapore

Chimera states are a hallmark of self-organization in non-linear dynamical systems [1]. These intriguing states are characterized by the spatial coexistence of synchronized and desynchronized motion in a complex network [2,3]. In this talk, I will discuss the emergence of Chimera states in a network of N coupled quantum van der Pol oscillators with a ring topology. Among the diverse quantum signatures of Chimera

states, I will describe the formation of Chimera-like quantum correlations in the network. In addition, I will show how Chimera states can be characterized by using concepts of quantum information theory such as the quantum mutual information. By using this approach, one can show that Chimera states exhibit lower mutual information than a synchronized state, but higher mutual information than a desynchronized one, which extends in a natural way the definition of chimera states to quantum mechanics [4].

[1] M. J. Panaggio and D. M. Abrams, Nonlinearity **28**, R67 (2015).
[2] Y. Kuramoto and D. Battogtokh, Nonlin. Phenom. in Complex Syst. **5**, 380 (2002)
[3] D. M. Abrams and S. H. Strogatz, Phys. Rev. Lett. **93**, 174102 (2004).
[4] V. M. Bastidas, I. Omelchenko, A. Zakharova, E. Schöll, and T. Brandes, Phys. Rev. E **92**, 062924 (2015).

**15 min. break**

**Invited Talk** SOE 9.4 Tue 11:15 H1
**Synchronization in Populations of Chemical Oscillators: Phase Clusters and Chimeras** — •Kenneth Showalter — West Virginia University, Morgantown, USA

We have studied heterogeneous populations of chemical oscillators to characterize different types of synchronization behavior. The formation of phase clusters in stirred suspensions of Belousov-Zhabotinsky oscillators is described, where the (global) coupling occurs through the medium. We then describe the formation of phase clusters and chimera states in populations of photosensitive oscillators. The nonlocal coupling occurs via illumination intensity that is dependent on the state of each oscillator. The behavior of oscillators in ring configurations as a function of the number of oscillators is described, including traveling cluster states.

References: A. F. Taylor et al., Angewandte Chemie Int. Ed. 50, 10161 (2011); M. R. Tinsley et al., Nature Physics 8, 662 (2012); S. Nkomo et al., Phys. Rev. Lett. 110, 244102 (2013); J. F. Totz et al., Phys. Rev. E 92, 022819 (2015).

**Invited Talk** SOE 9.5 Tue 11:45 H1
**Epileptic seizures: chimeras in brain dynamics** — •Klaus Lehnertz — Universität Bonn

Epilepsy is a complex malfunction of the brain that affects approximately 50 million people worldwide. Epileptic seizures are the cardinal symptom of this multi-facetted disease and are usually characterized by an overly synchronized firing of neurons. Seizures can not be controlled by any available therapy in about 25% of individuals, and knowledge about mechanisms underlying generation, spread, and termination of the extreme event seizure in humans is still fragmentary.

There is now increasing evidence for the existence of large-scale epileptic networks in which all constituents can contribute to the generation, maintenance, spread, and termination of even focal seizures as well as to the many pathophysiologic phenomena seen during the seizure-free interval. Using concepts and analysis tools from nonlinear dynamics, statistical physics, synchronization and network theory, significant progress has been made over the last decade in characterizing the connection structure of large-scale epileptic networks and in understanding their long-term dynamics. Model simulations of complex oscillator networks with connection structures seen in human epilepsies indicate that seizure-like activities can be regarded as self-initiated and self-terminated chimera states. Altogether, findings open promising directions for the development of new therapeutic possibilities.

## SOE 10: Chimera State: Symmetry breaking in dynamical networks (session accompanying symposium SYCS)

Time: Tuesday 14:00–15:00 Location: H36

SOE 10.1 Tue 14:00 H36
**Controlling Chimera States - The influence of excitable units** — •Philipp Hövel[1,2], Thomas Isele[1], Johanne Hizanidis[3,4], and Astero Provata[3] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Germany — [2]Bernstein Center for Computational Neuroscience Berlin, Humboldt Universität zu Berlin, Germany — [3]National Center for Scientific Research "Demokritos", Athen, Greece — [4]Crete Center for Quantum Complexity and Nanotechnology, University of Crete, Heraklion, Greece

We explore the influence of a block of excitable units on the existence and behavior of chimera states in a nonlocally coupled ring-network of FitzHugh-Nagumo elements. The FitzHugh-Nagumo system, a paradigmatic model in many fields from neuroscience to chemical pattern formation and nonlinear electronics, exhibits oscillatory or excitable behavior depending on the values of its parameters. Until now, chimera states have been studied in networks of coupled oscillatory FitzHugh-Nagumo elements. In the present work, we find that introducing a block of excitable units into the network may lead to several interesting effects. It allows for controlling the position of a chimera state as well as for generating a chimera state directly from the synchronous state.

SOE 10.2 Tue 14:15 H36
**Stability analysis of long-living transient amplitude chimeras** — •Liudmila Tumash, Anna Zakharova, Judith Lehnert, and Eckehard Schöll — Institut für Theoretische Physik,TU-Berlin, Hardenbergstr 36, 10623 Berlin, Germany,

Chimera states are characterized by a spontaneous break-up of a network of identical elements into coexisting domains of coherent (synchronized) and incoherent (desynchronized) dynamics. We study networks with coupled phase and amplitude dynamics. In contrast to classical phase chimeras, pure amplitude chimeras exhibit domains of coherent and incoherent dynamics with respect to the amplitude, but the phases are always regular and correlated. These states are long-living transients. In this work we investigate networks of Stuart-Landau oscillators with symmetry-breaking non-local coupling, in which amplitude chimeras can occur [1]. We verify the hypothesis that amplitude chimeras represent saddle-states in a high-dimensional phase space by calculating the Floquet exponents and the corresponding Floquet eigenvectors. In this way we can explain the dependence of the transient times upon coupling strength, coupling range and network size.

[1] A. Zakharova, M. Kapeller, E. Schöll, Phys. Rev. Lett. **112**, 154101 (2014).

SOE 10.3 Tue 14:30 H36
**Chimera patterns under the impact of noise** — •Sarah A. M. Loos[1], Jens Christian Claussen[2], Eckehard Schöll[1], and Anna Zakharova[1] — [1]Institut für Theoretische Physik, TU Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany — [2]Computational Systems Biology Lab, Campus Ring 1, Jacobs University Bremen, D- 28759 Bremen, Germany

We investigate two types of chimera states, i.e., patterns consisting of coexisting spatially separated domains with coherent and incoherent dynamics, under the influence of noise [1]. Both chimera states arise in ring networks of Stuart-Landau oscillators with symmetry-breaking coupling [2]. Amplitude chimeras are characterized by temporally periodic dynamics throughout the whole network, but spatially incoherent behavior with respect to the amplitudes in a part of the system. They are long-living transients. Chimera death states generalize chimeras to stationary inhomogeneous patterns (oscillation death), which combine spatially coherent and incoherent domains. We analyze the impact of random perturbations on their occurrence and on their lifetimes, addressing the question of robustness of chimera states in the presence of additive white noise.

[1] S. A. M. Loos et al., arXiv:1508.04010v2, (2015).
[2] A. Zakharova et al., Phys. Rev. Lett. 112, 154101 (2014).

SOE 10.4 Tue 14:45 H36
**A classification scheme of chimera states** — •Felix P. Kemeth[1,2], Sindre W. Haugland[1,2], Lennart Schmidt[1], Ioannis G. Kevrekidis[2,3], and Katharina Krischer[1] — [1]Physik-Department, Nonequilibrium Chemical Physics, Technische Universität München, James-Franck-Str. 1, D-85748 Garching, Germany — [2]TUM Institute for Advanced Study, Lichtenbergstraße 2a, D-85748

Garching, Germany — [3]The Department of Chemical and Biological Engineering, Princeton University, Princeton, NJ 08544, USA

The vast and continuously growing number of chimera or chimera-like states discovered in recent years demands a classification of the various manifestations of these dynamical hybrid states. We propose systematic and reductive approaches to characterize chimera states in systems with and without spatial extent, respectively. For locally and non-locally coupled systems, that is for systems involving a spatial extension, we apply a discrete version of the Laplace operator on spatio-temporal data sets exhibiting coexistence of coherent and incoherent regions. Regarding its statistical properties we introduce a detailed classification of chimera states into groups sharing the same qualitative behavior. For globally coupled systems without a spatial dimension, the statistics of pairwise Euclidean distances between all oscillators allow a similar analysis. This classification helps clarify the different facets of chimera states and broadens our understanding of this peculiar phenomenon.

## SOE 11: Networks: From Topology to Dynamics II (joint session SOE / DY / BP)

Time: Tuesday 15:00–15:45 Location: H36

SOE 11.1 Tue 15:00 H36

**Collective Failure due to Multistability in Oscillator Networks and Power Grid** — •Debsankha Manik[1], Dirk Witthaut[2], and Marc Timme[1] — [1]Network Dynamics Group, Max Planck Institute for Dynamics anf self-Organization, 37077 Göttingen — [2]Forschungszentrum Jülich, Institute of Energy and Climate Research Systems Analysis and Technology Evaluation (IEK-STE), 52425 Jülich

Networks of phase oscillators model the collective dynamics of various interacting physical and biological systems, ranging from electric power grid operation to neuronal rhythms. Here we show that the number of stable steady states in phase oscillator systems scales with the length of the topological cycles in the network such that for non-global coupling, multistable steady states may emerge. The clustering of similar natural frequencies favour fewer stable states, whereas homogeneous frequency distributions favour more. Intriguingly, multistability prevails even under conditions for which stable states have been claimed to be unique. This multistability may have significant impact on the collective dynamics of such networks: for example, in power grids where the transmission lines have structural limitations on the maximum load they can safely carry, perturbations may induce switching to different steady states, strongly alter the flow patterns, and in turn yield a collective failure of the grid.

Supported by the BMBF under grant no. 03SF0472E.

SOE 11.2 Tue 15:15 H36

**Geometric organization of real multiplex networks** — •Kaj Kolja Kleineberg[1], Marian Boguna[1], M. Angeles Serrano[1], and Fragkiskos Papadopoulos[2] — [1]Departament de Fisica Fonamental, Universitat de Barcelona, Marti i Franques 1, 08028 Barcelona, Spain — [2]Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology

Real complex networks are organized to perform certain functions, among which targeted transport is important in a broad range of real systems, such as the Internet, social networks, or transportation networks. In reality, networks are not isolated entities but instead form interacting parts of larger and more complex systems. These systems are not a random combination of single networks, but instead are organized in a certain way. We investigate the geometric organization of multilayer networks and its implications. We find significant metric correlations between different layers. These correlations are key to answer many important questions concerning real multilayer systems. Metric correlations allow for inter-layer link prediction and the definition and detection of multidimensional communities. Metric correlations improve mutual greedy routing, that is targeted navigation in the whole multilayer system. Interestingly, only in the presence of metric correlations does the whole system outperform its single layers. We find that optimal correlations make multilayer systems perfectly navigable. Finally, we show how correlations present in the real Internet multiplex help navigating the digital world. Our findings have important implications for the design of real multilayer systems.

SOE 11.3 Tue 15:30 H36

**Interplay of shape and degree distribution in complex networks** — •Robin de Regt and Christian von Ferber — Applied Mathematics Research Centre, Coventry University, UK

Complex networks are often described without geometry. Here, we explore possibilities of how an embedding of such networks in real space (e.g. 2D or 3D) may reveal interesting correlations between standard measures such as degree distributions and the shapes these structures may attain when embedded in a given space.

## SOE 12: Behavioral Models for Stock Prices (Invited Talk Cars Hommes)

Time: Wednesday 9:30–10:15 Location: H36

**Invited Talk** SOE 12.1 Wed 9:30 H36

**Booms, bust and behavioral heterogeneity in stock prices** — •Cars Hommes — University of Amsterdam, CeNDEF

We discuss behavioral models with heterogeneous expectations to describe booms and busts in speculative asset markets. Investors are boundedly rational and switch between different investment strategies, such as fundamentalists or chartists. We discuss theoretical work, with empirical applications to the stock market and to housing markets. We also discuss the emergence of bubbles and crashes in laboratory experiments with human subjects. Finally, we discuss how policy may mitigate speculative asset bubbles.

## SOE 13: Economic Models I

Time: Wednesday 10:15–11:15 Location: H36

SOE 13.1 Wed 10:15 H36

**A Meta-Theory of Economic Models - General Constrained Dynamic Models (GCDM) in Analogy to Classical Mechanics** — •Florentin Glötzl — Wirtschaftsuniversität Wien, Institute for Ecological Economics, Welthandelsplatz 2/D5, AT 1020 Wien

Drawing from classical mechanics, we propose General Constrained Dynamic Models (GCDM) as the basis for a novel and encompassing understanding of economic models from a mathematical and theoretical perspective. Economic models differ in their essence in the choice of which variables are exogenous an which are endogenous i.e. assumptions about the power of agents to influence variables.

In analogy to classical mechanics we explicate the power of in GDCM in a formal framework in which the dynamics of the system are determined by the economic force f applied by an agent (or aggregated sector) to change a variable and his power p (the analogy to 1/inertial mass in physics) to enforce his interest.

In the GCDM framework the difference between various economic theories and models is explicitly shown to be the result of different assumptions about the power relationships in the economy. The as-

sumption that an agent has complete power to determine the change of a certain variable corresponds to the variable being exogenous. If no agent has full power to influence the variable it is endogenous.

While in standard economic models power is always dichotomously one-sided, GCDM allows allows for mixed power relationships. It can thus can also illustrate the result space between the various common economic models and thus better depict reality.

SOE 13.2 Wed 10:30 H36

**The Convergence to General Equilibrium in an Agent-Based Model in Continuous Time** — •Oliver Richters — International Economics, Carl von Ossietzky University Oldenburg

General Constrained Dynamic Models (GCDM) have been proposed as a meta theory of economic models. This contribution studies the capacities of this approach to reproduce General Equilibrium Models that are at the core of today's macroeconomic research. They attempt to provide a set of prices leading to an equilibrium of supply and demand on interacting markets.

The models are formulated such that a unique, stable equilibrium exists and deviations can be treated in linear order. They generally rely on some form of representative agent 'mean field' hypothesis, because given heterogeneity in preferences and endowment among agents, multiple equilibria may exist. Within these models, spontaneous emergence of extreme events or endogenous instabilities are impossible.

Most models assume that the price determination process happens instantly and trade 'at wrong prices' is absent. The contribution shows that this assumption can be dropped, leading to a path dependend convergence path.

SOE 13.3 Wed 10:45 H36

**A prisoners dilemma model with continous time and continous decision space** — •Erhard Gloetzl — Karl-Kautsky-Weg 26, 4040 Linz Österreich

Recently in close analogy to constrained dynamics in classical mechanics *General Constrained Dynamic Models* (GCD-models) were introduced as general framework for economic models. A lot of economic models can be understood as special cases of GCD-models. We show that even game theoretical models can be understood as discretisation of GCD-models. Especially we discuss a *continuous prisoners dilemma* with continuous time and continuous decision space which yields the standard prisoner dilemma by discretisation of time and discretisation of decision space (cooperation, defection). An essential feature of GCD-models are so called *power factors* which correlate more or less to the inverse of the inertial mass. We discuss the introduction of power factors to the prisoners dilemma and the application of this model to political economy. Further extensions to other game theoretical models are discussed.

SOE 13.4 Wed 11:00 H36

**Agent-Based Post-Keynesian Stock-Flow Consistent Models in Continuous Time** — •Oliver Richters — International Economics, Carl von Ossietzky University Oldenburg

General Constrained Dynamic Models (GCDM) have been proposed as a meta theory of economic models. This contribution studies the capacities of this approach to reproduce Stock-Flow Consistent (SFC) models widely used in Post-Keynesian Economics. SFC models are usually formulated in discrete time and their proponents underline the necessity to model monetary stocks and flows and their accounting identities consistently. The latter constrain the dynamics of the model economy.

The SFC approach is transformed into continuous time dynamics and respecting accounting identities leads to dynamics under constraints similar to Newtonian mechanics. Some adaptions of existing SFC models are presented.

The formalism allows to study these models mit methods of Lagrangian mechanics that are also widely used in other fields of economics, but not yet in the Post-Keynesian school of thought.

## SOE 14: Financial Markets and Risk Management I

Time: Wednesday 11:15–12:15 Location: H36

SOE 14.1 Wed 11:15 H36

**Leads versus lags in the relationship between company performance and stock price in the automotive sector: An event coincidence analysis** — Philipp Koltermann[1] and •Reik V. Donner[2] — [1]Dresden University of Technology, Dresden, Germany — [2]Potsdam Institute for Climate Impact Research, Potsdam, Germany

Enterprises traded at stock exchanges are obliged to regularly publish information on their economic performance, which is of great value for potential investors and shareholders in order to decide whether to buy, hold or sell stocks. Here, we aim to identify the associated time scales at which such decisions are made: Is there robust evidence for instantaneous and/or delayed responses of the stock price to particularly good/bad performance indicators, indicating that reported numbers act as external shocks to the market? Or vice versa: To what extent are economic figures already included in the stock price evolution prior to the reporting date, pointing to the relevance of investors' expectations based on the sectoral development? In order to test for the statistical significance of corresponding relationships, we apply the recently developed method of event coincidence analysis to an ensemble of nine German companies from the automotive sector (car manufacturers as well as suppliers) spanning the time interval from 2000 to 2015. After correcting for the sectoral evolution and the impact of the world economic crisis in 2008/09, our analysis reveals clear evidence for instantaneous and/or delayed responses, but no robust indication for anticipatory effects.

SOE 14.2 Wed 11:30 H36

**Stability and hierarchy of quasi-stationary states: financial markets as an example** — •Yuriy Stepanov[1], Rudi Schäfer[1], Thomas Guhr[1], Joachim Peinke[2], and Philip Rinn[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg — [2]Institute of Physics and ForWind, Carl-von-Ossietzky University Oldenburg, Oldenburg, Germany

We combine geometric data analysis and stochastic modeling to describe the collective dynamics of complex systems. As an example we apply this approach to financial data and focus on the non-stationarity of the market correlation structure. We identify the dominating variable and extract its explicit stochastic model. This allows us to establish a connection between its time evolution and known historical events on the market. We discuss the dynamics, the stability and the hierarchy of the recently proposed quasistationary market states.

[1] YS, Rinn P, Guhr T, Peinke J and and Schäfer R, J. Stat. Mech. 2015 (2015) P08011

SOE 14.3 Wed 11:45 H36

**Gold, currencies and market efficiency** — •Ladislav Kristoufek[1,2] and Miloslav Vosvrda[1,2] — [1]Institute of Information Theory and Automation, Czech Academy of Sciences, Czech Republic — [2]Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Czech Republic

Gold and currency markets form a unique pair with specific interactions and dynamics. We focus on the efficiency ranking of gold markets with respect to the currency of purchase. By utilizing the Efficiency Index (EI) based on fractal dimension, approximate entropy and long-term memory on a wide portfolio of 142 gold price series for different currencies, we construct the efficiency ranking based on the extended EI methodology we provide. Rather unexpected results are uncovered as the gold prices in major currencies lay among the least efficient ones whereas very minor currencies are among the most efficient ones. We argue that such counterintuitive results can be partly attributed to a unique period of examination (2011-2014) characteristic by quantitative easing and rather unorthodox monetary policies together with the investigated illegal collusion of major foreign exchange market participants, as well as some other factors discussed in some detail.

SOE 14.4 Wed 12:00 H36

**Statistical Properties of DAX Limit Order Books on Xetra** — •Winfried Reimann and Stephan Eule — Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany

Most modern financial markets nowadays employ limit order books to temporarily store buy and sell orders and execute them. In these order books the central economic question of price formation can be investigated from a microscopic point of view using high frequency data. Prior analyses of such data have mainly focused on three different issues:

(i) Statistics of price determining quantities such as price jump distributions and market impact;

(ii) the influence of order placement and cancellations on those statistics;

(iii) the effect of the order book's state itself on the dynamics of the order flow.

We apply such analyses for the first time to order books from Deutsche Börse's continuous trading market Xetra. Thereby we focus on the influence of the book's state on the order flow. The idea behind that is that financial markets as complex systems have their own internal dynamics with multiple feedback mechanisms, in which external information only partly influences the price formation. We aim at discovering such feedback mechanisms.

## SOE 15: Economic models II

Time: Wednesday 12:15–13:15 Location: H36

SOE 15.1 Wed 12:15 H36

**Two faces of word-of-mouth: Understanding the impact of social interactions on demand curves for innovative products** — Katarzyna Maciejowska[1], Arkadiusz Jedrzejewski[1], Anna Kowalska-Pyzalska[1], Katarzyna Sznajd-Weron[2], and •Rafal Weron[1] — [1]Department of Operations Research, Wroclaw University of Technology, Poland — [2]Department of Theoretical Physics, Wroclaw University of Technology, Poland

Word-of-mouth (WOM) is a puzzling phenomenon. It strongly influences the innovation diffusion process and is responsible for the 'S' shape of the adoption curve. However, it is not clear how WOM affects demand curves for innovative products and strategic decisions of producers. We build an agent-based model of innovation diffusion, which links the opinions of individuals with their market behavior via the concept of reservation prices. Using Monte Carlo simulations (for artificial and real social networks from Facebook and Google+) and mean-field semi-analytical treatment (for artificial networks) we demonstrate that WOM may have ambiguous consequences and should be taken into account when designing marketing strategies. Conditional on the targeted penetration level and the market price, the company should aim either at weakening or strengthening the WOM effect. By doing so, it can increase the demand and increase potential revenues.
(Submitted to: Int. J. Research in Marketing)

SOE 15.2 Wed 12:30 H36

**Ising model of financial markets with many assets** — •Alexander Eckrot and Jan Jurczyk — Universität Regensburg, Regensburg, Germany

In the past many models have emerged with the purpose of studying the regularities of financial markets. Most of these models focused on markets with only one asset. Since these models can not catch the complex correlations between the prices of different assets, we want to take a further step and propose an Ising model of a multi-asset market. This model able to reproduce the most important stylized facts for every asset and shows complex cross-correlations between the assets.

SOE 15.3 Wed 12:45 H36

**Evaluating Multilevel Predictions from Trading Data** — •Sven Banisch[1], Robin Lamarche-Perrin[2], and Eckehard Olbrich[1] — [1]Max Planck Institute for Mathematics in the Sciences, Inselstrasse 22, D-04103 Leipzig, Germany. — [2]Laboratoire d'Informatique de Paris 6, UPMC - Sorbonne Universités, Paris, France.

If one wants to predict the behaviour of a complex, multi-level system such as the economy one can use observables on different levels of aggregation. Naively, one might think that going to a higher aggregation level always deteriorates performance because it means losing information and therefore using a microscopic description is the best. However, this is usually not the case since no complete microscopic model is available in most applications. Instead, the predictor has to be inferred from data which may become practically infeasible due to high-dimensional microscopic state spaces and exponentially increasing data requirements. We study the trade-off between the higher information content of less aggregated descriptions and the better inferrability of higher-level aggregates on real world data on international trade. We compare different predictors for GDP growth considering aggregations over meaningful groups of products representing mesoscopic levels of the export structure and highly aggregated measures of economic complexity (Hidalgo/Hausmann 2009) and fitness (Tacchella et al. 2012) previously shown to have predictive power regarding the growth potential of countries. We present evidence that mesoscopic observables may outperform these highly-aggregated measures while still allowing proper inference of the predictor from the limited amount of data.

SOE 15.4 Wed 13:00 H36

**Employment trajectories in the Stockholm County: networks and sequences** — •Hernan Mondani — Department of Sociology, Stockholm University, 10691 Stockholm, Sweden

An individual's career path in the labour market is likely to be influenced by other people within the organization she is employed at, as well as by the characteristics of the organization itself. In this study, we use Swedish longitudinal register data on employment in the Stockholm County to study the statistical properties of employment trajectories for a whole region. Employment trajectories are modelled as network paths through organizations. We look at statistics of permanence and switching between organizations, and how they correlate to the dimensions of public or private ownership and organizational size. Sequence analysis is used to cluster typical trajectories and their hierarchical structure along the mentioned dimensions.

Keywords: labour market dynamics, employment trajectories, sequence analysis.

## SOE 16: Collective Failures in Energy Networks (Topical Talk Stefan Bornholdt)

Time: Wednesday 15:00–15:30 Location: H36

**Topical Talk** SOE 16.1 Wed 15:00 H36

**Blackouts from smart meters? Self-organized criticality and collective effects in power networks** — •Stefan Bornholdt — Institut für Theoretische Physik, Universität Bremen

The average economic agent is often used to model the dynamics of simple markets, based on the assumption that the dynamics of a system of many agents can be averaged over in time and space. A popular idea that is based on this seemingly intuitive notion is to dampen electric power fluctuations from fluctuating sources (as, e.g., wind or solar) via a market mechanism, namely by variable power prices that adapt demand to supply. The standard model of an average economic agent predicts that fluctuations are reduced by such an adaptive pricing mechanism. However, the underlying assumption that the actions of all agents average out on the time axis is not always true in a market of many agents [1,2]. I review mechanisms for possible collective effects in markets of many consumers and discuss these in the context of the former concept of self-organized criticality, originally proposed for large fluctuations in nature.

[1] S. Krause, S. Börries, & S. Bornholdt, Phys. Rev. E 92, 012815 (2015). [2] A. Pentland, Economics: Simple market models fail the test, Nature 525 (2015) 190.

## SOE 17: Social Systems, Opinion and Group Dynamics: Dynamics of Team and Network Formation

Time: Wednesday 15:30–16:15 Location: H36

SOE 17.1 Wed 15:30 H36

**Is bigger always better? How local online social networks can outperform global ones** — •Kaj Kolja Kleineberg and Marian Boguna — Departament de Fisica Fonamental, Universitat de Barcelona, Marti i Franques 1, 08028 Barcelona, Spain

The overwhelming success of online social networks, the key actors in the cosmos of the Web 2.0, has reshaped human interactions on a worldwide scale. To help understand the fundamental mechanisms which determine the fate of online social networks at the system level, we describe the digital world as a complex ecosystem of interacting networks. Here, we discuss the impact of heterogeneity in network fitnesses induced by competition between an international network, such as Facebook, and local services. To this end, we construct a 1:1000 scale model of the digital world, consisting of the 80 countries with the most Internet users. We show how inter-country social ties induce increased fitness of the international network. Under certain conditions, this leads to the extinction of local networks; whereas under different conditions, local networks can persist and even dominate the international network completely. These findings provide new insights into the possibilities for preserving digital diversity.

SOE 17.2 Wed 15:45 H36

**Why some teams perform and other do not: Quantifying and analyzing human-human interactions in early stage product design teams** — •Achim Gerstenberg and Martin Steinert — Department of Engineering Design and Materials, NTNU

The concept creation and evaluation phase of early stage engineering product design is often conducted in co-located design teams. We wonder what makes some teams perform outstandingly and create innovative products while others deliver conservative solutions. We believe that one decisive component is how team members interact subconsciously with one another. We suggest an experimental setup for quantifying and analyzing human-human interactions that lead to in-group relatedness. We propose to measure spatial proximity and touch between group members, body orientation and posture, gestures and eye contact as indicators for in-group relatedness. This concept of relatedness is linked to intrinsic motivation, learning ability and favoring group over individual gains. We aim to use multivariate and time series analysis for identifying statistically significant correlations between indicators of in-group relatedness and performance. The aim of this presentation is to initiate a discussion about the experimental design and the data analysis.

SOE 17.3 Wed 16:00 H36

**Why a hypothetical 4-point rule would be good for soccer** — •Andreas Heuer[1], Dennis Riedl[1,2], and Bernd Strauss[2] — [1]Institute f. Phys. Chemistry, WWU Münster — [2]Institute of Sport and Exercise Sciences, WWU Münster

It is shown how the rules of a soccer match influence the actual outcome via the impact of psychological effects [1]. More specifically, we present a statistical framework which allows one to define the theoretical distribution of final goal differences. Comparison with the actual distribution, determined for different international leagues, reveals significant deviations. They are mainly reflected by an increase of the actual number of draws. This effect is stronger in the case of the 2-point rule (mainly before 1995) as compared to the 3-point rule. Extrapolation suggests that in case of a hypothetical 4-point rule this effect should disappear. Since the increased number of draws reflects a more passive behavior during the final stage of a match [2,3], the introduction of the 4-point rule would thus very likely improve the quality of soccer matches. We show that this result is in quantitative agreement with the prediction of the prospect theory [4], describing the human behavior in different socio-economic situations.

[1] D Riedl, B. Strauss, A. Heuer, J. Sport Exerc. Psychol. 37, 316-326 (2015).

[2] A. Heuer, O. Rubner, PloS ONE 7/11, e47678 (2012).

[3] A. Heuer, Der perfekte Tipp - Statistik des Fußballspiels, Wiley-VCH, Weinheim (2012).

[4] D. Kahnemann, Thinking: fast and slow, Allen Lane (2011).

## SOE 18: Social Systems, Opinion and Group Dynamics: Opinions and Innovations

Time: Wednesday 16:15–16:45 Location: H36

SOE 18.1 Wed 16:15 H36

**Phase transitions in the hybrid q-r-w-voter model on complete graph** — •Piotr Nyczka[1] and Katarzyna Sznajd-Weron[2] — [1]Jacobs University, Bremen, Germany — [2]Wrocław University of Technology, Wrocław, Poland

The subject of this paper is the analysis of fundamental properties of the opinion dynamics model which goes far beyond the q-voter model. We have delivered analysis of the hybrid q-r-w-voter model which is an extended q-voter model with addition of two types of nonconformity (applied with different probabilities, which are parameters of the model) and with specific thresholds of minimal majority in the group, needed for effective interaction. Purpose of this extension was the attempt to generalize some binary models of opinion dynamics: voter model, Sznajd model q-voter model and modified majority model and to go beyond that.

There was an order-disorder phase transition present, but it could be continuous or discontinuous. We have discovered how parameters of the model influence the type of transition, and what is the difference between two types of nonconformity (anticonformity and independence) in terms of phase diagrams. It is worth to mention that this difference could manifest itself or remain hidden, depending on the parameters of the model.

We answered these questions in the case of complete graph. Further investigation should be conducted on other types of networks to answer the question of the generality of results.

SOE 18.2 Wed 16:30 H36

**Fostering Peace - The normative Peace Project** — •Hermann Rampacher — Rampacher & Partner GbR VDE

In normative socio-dynamics for every society sets of mutually correlated actions {a(i)} can be constructed. If an a(i) is done a potential damage d is arising, measured by the average collective cost of restoring the situation ex ante. If all a(i) are refrained from doing, the potential damage is minimal and peace between men, states, and between men and nature are maintained. In other word: If all norms n(i), which forbid the a(i), are obeyed, the over-all peace is maintained. If the collective co-operation is declining, the n(i) are violated more frequently: peace is put in risk. To restore peace on a lower level, agents have to intervene by fostering compliance with n(i) of higher d[n[a(i)]] at the expense of compliance with n(j) of lower d[[a(j)]]. Every intervention entails risks. Their value depends on the competence of the responsible agents and the ressources they have. once the violations of norms with lower damage potantial reaches a critical level, the interventions are bocoming out of all propotions to restore peace. Hence more violations of norms by further agents are likely to result as side-effects of the primary interventions. Hence these violations my spread - due to correlations between the a(j) - in the manner of an epidemic or pandemic: justice an peace are declining rapidyl.

## SOE 19: Financial Markets and Risk Management II

Time: Wednesday 16:45–17:30 Location: H36

SOE 19.1 Wed 16:45 H36

**Optimal energy-mix and portfoliomanagement on the basis of German electricity data** — •Magda Schiegl — University of Applied Sciences Landshut

The 2013 German electricity data, namely the load and the production of fluctuating renewable sources of energy (RE), are analysed. The data of the renewable sources consist of on- and off-shore wind and photo-voltaic energy production. We analyse the statistical properties, including the tail behaviour of the distribution functions. It is well known that a remarkable amount of back-up energy is needed to bridge the RE-induced low-power periods * see for instance (1). The magnitude of the back-up capacity is dependent on the RE-energy-mix. We derive a statistical model that allows the analytical calculation of the optimal energy-mix for a minimum back-up energy. Our model is closely related to the Markowitz-model used in portfoliomanagement. We explain why this model delivers very good approximations for the RE-energy-mix problem. Within this framework we analyse the impact of energy storage on the optimal energy-mix and the back-up energy. We further discuss the dependence on different storage properties as for instance magnitude and efficiency.

(1) F. Wagner, Electricity by intermittent sources: An analysis based on the German situation 2012, Eur. Phys. J. Plus (2014), 129: 20

SOE 19.2 Wed 17:00 H36

**Comparing systemic risk measures to portfolio optimization models** — •Jan Jurczyk and Alexander Eckrot — Universtätsstraße 31, 93053 Regensburg

In this talk we compare systemic risk measures based on the covariance matrix and its eigenvectors to to the ground-state energies of three portfolio distribution models. Namely the mean variance model with constraints, the value at risk model with constraints and the index tracking model. We present the algorithms used in order to generate the optimal portfolios for each model and show a connection between changes in ground-state energies and the systemic risk measure.

SOE 19.3 Wed 17:15 H36

**Detrended fluctuation analysis as a regression framework: Estimating dependence at different scales** — •Ladislav Kristoufek — Institute of Information Theory and Automation, Czech Academy of Sciences, Czech Republic — Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Czech Republic

We propose a framework combining detrended fluctuation analysis with standard regression methodology. The method is built on detrended variances and covariances and it is designed to estimate regression parameters at different scales and under potential non-stationarity and power-law correlations. The former feature allows for distinguishing between effects for a pair of variables from different temporal perspectives. The latter ones make the method a significant improvement over the standard least squares estimation. Theoretical claims are supported by Monte Carlo simulations. The method is then applied on selected examples from physics, finance, environmental science and epidemiology. For most of the studied cases, the relationship between variables of interest varies strongly across scales.

## SOE 20: Economic models III

Time: Wednesday 17:30–18:15 Location: H36

SOE 20.1 Wed 17:30 H36

**National growth as part of the natural sciences and EU divergence** — •Hans G Danielmeyer and Thomas Martinetz — Institut für Neuro- und Bioinformatik, Uni Lübeck

We use our natural theory of macroeconomic growth for little projects that may reverse the disintegration of the EU.

The theory's analytic solutions reproduce the per capita leading G7 nation's data without fitting parameter for the educational and technical infrastructure, annual working and spare time, GDP and life expectancy. Economic equilibrium between demand and supply is provided by industrial engineering with technical progress. The inherited and educated human capacities synchronize technical progress for half a millennium with the mean G7 life expectancy. Since all long-term parameters are biologic constants of the human species the theory has forecasting power.

The OECD publishes the classical data for EU nations with traditional policy recommendations. Every inconsistency with the natural theory identifies a national problem. The idea is that a small group of young SOE members divides the provided OECD reports, inserts the OECD data into the G7 plots of the natural theory, and compares the OECD recommendations with the recommendations following from the nation's position in the plots.

The results will be reported in SOE 2017.

SOE 20.2 Wed 17:45 H36

**A Demographic-Economics Agent-Based Model:the Relationship between Economic Sustainability and Population Dynamics** — •Yuting Lou — The University of Tokyo, Japan

This study sets up a bottom-up approach to the issue of population economics. We build an original demographic-macroeconomics multi-agent model (DEMM), which simplifies the macroeconomic dynamics into three core modules: producing, trading with neighbors and distributing, but with the coupled dynamical population structures. Based on thousands of simulations by tuning the control parameters (tax rate and innovation), we construct the phase diagrams for the pure economic dynamics in DEMM, whose core mechanism follows the law of jungle, i.e. in an anti-diffusional positive feed-back style. Without population dynamics, the society may have sustainable good economics with high GDP and low poverty rate, along with other four phases featuring different relaxation time and poverty level. Several main factors such as production efficiency, demand saturation, education efficiency and compulsory education are discussed. With the population dynamics, the phase diagrams are distorted in most cases and the society are waning towards extinction without poverty or towards massive poverty without extinction. Except for that the birth/death rate fluctuates in an alternate way, which may lead to prosperity followed by depression in both aspects of population and economics, there will be no rescue from the extinction and poverty.

SOE 20.3 Wed 18:00 H36

**Phase transitions and relaxations in an agent-based macroeconomic model** — •Wenzhi Zheng[1] and Yu Chen[2] — [1]Teasic137@gmail.com — [2]Chen@k.u-tokyo.ac.jp

An economic system can give rise to very rich and complex phenomena which often puzzle theorists and policy makers. In economic history, although periods of prosperity, recession and depression can be identified in hindsight, it is difficult for us to confirm whether those economies have reached, or are approaching the equilibrium. In other words, the large fluctuations suffered by these economies might be only a transient regime. In this research, we construct a minimal agent-based macroeconomic model to study the equilibrium states and the relaxation towards the equilibrium. We find that there exists a phase transition between a sustainable economy, characterized by high production, long-term profitability of firms and wealthy households, and a bankrupt economy, characterized by low production, short-term profitability of firms and poor households. The phase transition is controlled by the combination of the profitability of firms and the welfare indicator. Furthermore, we find that the heterogeneity of firms strongly influences the relaxation towards the equilibrium. In the model economy consisting of heterogeneous firms, the relaxation near the critical point is featured with stronger fluctuations and longer relaxation time. Under the circumstances, policy makers and stakeholders may miss the forest for the trees: being unable to perceive the global trends while desperately trying to deal with the small scale fluctuations or to catch up with the local trends.

## SOE 21: Member's Assembly

Annual Members Assembly of the SOE division (agenda: report on activities, elections (if applicable), and suggestions (symposia, focus sessions, plenary speakers) for the next conference, March 19-24, 2017 in Dresden)

Time: Wednesday 18:15–19:00 Location: H36

**After the assembly there will be an informal dinner downtown (location tba during the assembly)**

## SOE 22: Scientometric Maps and Models of Science and Scientific Collaboration Networks (Symposium SYSM, joint SOE / DY / BP / jDPG)

Time: Thursday 9:30–12:15 Location: H1

**Invited Talk** SOE 22.1 Thu 9:30 H1

**Science Forecasts: Measuring, Predicting, and Communicating Scientific Developments** — •Katy Börner — Indiana University

In a knowledge-based economy, science and technology are omnipresent and their importance is undisputed. Equally evident is the need to allocate resources, both monetary and human, in an effective way to foster innovation. In the preceding decades, data mining, metrics, and indicators have been embraced to gain insights into the structure and evolution of science; but there have been no significant efforts into mathematical, statistical, and computational models that can predict future developments in science, technology, and innovation (STI). While it may not be possible to predict the nature, essence, or the precise extent of impact of the next scientific or technological innovation, it is often possible to predict the circumstances leading to it, i.e., where it is most likely to happen and under which conditions. See Scharnhorst, Börner, and Besselaar, eds. 2012. Models of Science Dynamics: Encounters Between Complexity Theory and Information Science. Springer Verlag for an overview of major model types.

This talk reviews and demonstrates the power of computational models for simulating and predicting possible STI developments and futures. In addition, it showcases novel means to broadcast moderated STI forecasts to make them accessible and understandable for a general audience.

**Invited Talk** SOE 22.2 Thu 10:00 H1

**Mapping science with variable-order Markov dynamics reveal overlapping fields and multidisciplinary journals** — •Martin Rosvall — Umeå University, Sweden

To better understand the parallel human endeavor of science, we need good maps that both simplify and highlight the flows of ideas and underlying research organization. However, current maps of science cannot effectively identify the multilevel and overlapping fields of science with multidisciplinary journals. For example, whereas maps based on citations between journals in first-order Markov models can only assign each journal to a single field, maps based on multi-step citation chains in higher-order Markov models become computationally infeasible already for moderate-sized systems. To overcome these problems, we introduce a method that uses model selection to find the appropriate variable-order Markov model. We also present interactive maps of science that highlights the assignments of multidisciplinary journals and how ideas flow through those journals.

**Invited Talk** SOE 22.3 Thu 10:30 H1

**Network algorithms for reputation and quality in scholarly data** — •Matúš Medo, Manuel Mariani, and Yi-Cheng Zhang — University of Fribourg, Fribourg, Switzerland

The ever-increasing quantity and complexity of scientific production have made it difficult for researchers to keep track of advances in their own fields. This, together with growing popularity of online scientific communities, calls for the development of effective information filtering tools. Network theory is an important driving aspect for such algorithms. We will first discuss the case of an online scientific community where users and papers form a bipartite network which can be effectively used to evaluate the reputation of users and fitness of papers. We show that when the input data is extended to a multilayer network including users, papers and authors, the resulting performance improves on multiple levels. In particular, top papers have higher citation count and top authors have higher h-index than top papers and top authors chosen by other algorithms. We will then move to stress the role of time in scholarly data. Most research metrics either ignore time (such as the h index) or consider it in an ad-hoc fashion (such as the m quotient). On the example of PageRank which has been used in the past to assess the quality of papers, we show that a demonstrably better ranking of papers can be obtained by considering time in a principled way.

**15 min. break**

**Invited Talk** SOE 22.4 Thu 11:15 H1

**Modeling scientific networks in social media** — •Cassidy Sugimoto — School of Informatics and Computing, Indiana University Bloomington, USA

This talk will examine the role of social media in constructing new or reinforcing old epistemic communities. In particular, we will analyze the interconnectivity of scientists on social media platforms according to their disciplinary affiliation and the degree to which these networks reinforce or contrast with models constructed through collaboration and citation relations. We will analyze the role of gender and other socio-demographic characteristics where possible.

**Invited Talk** SOE 22.5 Thu 11:45 H1

**Modeling scientific collaboration across multiple scales: from individuals to Europe** — •Alexander Petersen — IMT Lucca Institute for Advanced Studies, Lucca, Italy

Quantitative measures are becoming increasingly prevalent at all scales of scientific evaluation, largely due to the advent of large comprehensive publication databases that allow for detailed studies of ideas, people, and institutions, and the vast networks connecting them. As such, there is plenty of room to apply methods from complex systems to address policy-oriented issues relevant to the entire science system. In the first half, I will discuss micro-scale patterns of collaboration from a researcher's local 'ego' perspective, showing that scientific collaboration is characterized by a high turnover rate juxtaposed with frequent 'life partners'. I will show that these extremely strong collaborations have a significant positive impact on productivity and citations – the apostle effect – representing the measurable advantage of 'super' social ties. In the second half, I will discuss macro-scale collaboration patterns concerning the evolution the European Research Area (ERA), a cross-border labor, funding, and mobility scheme aimed at fostering innovation and growth within Europe. However, despite decades of integration policies, recent analyses have shown there to be little cross-border integration in the EU above global trends – i.e. Europe remains a collection of national innovation systems. I will show that high-skilled mobility – i.e. brain drain, largely from East to West following the 2004/2007 EU enlargement – can explain why the cross-border integration of R&D within the ERA is lagging.

**Right after the symposium, participants are invited to enjoy a guided tour of the Places and Spaces: Mapping Science exhibition (http://scimaps.org) on display in the foyer of the university library.**

## SOE 23: Places and Spaces - Exhibition of Maps of Science

Time: Thursday 12:30–13:00 Location: Bibliothek Foyer

**Following the symposium, Katy Börner and Andrea Scharnhorst will provide a guided tour through the maps of science exhibited in the foyer of the university library. The maps will be on display continuously during the week.**

## SOE 24: Scientometric maps and dynamical models of scientific collaboration networks (accompanying symposium SYSM)

Time: Thursday 15:00–16:30 Location: H36

SOE 24.1 Thu 15:00 H36

**Reclaiming the value of interdisciplinary research: a new index of scientific impact** — •Elisa Omodei, Manlio De Domenico, and Alex Arenas — Department of Mathematics and Computer Science, Rovira i Virgili University, Tarragona, Spain

Defining an appropriate measure to assess the impact of scientific research represents a fundamental task of today's science of science. Nowadays most funding and hiring decisions are in fact based on quantitative indices of production. Several measures have been proposed, from citation count and the h-index, to more advanced graph-based metrics such as the science author rank algorithm. An important issue that has been mostly ignored by the previously proposed indices is the opportune ranking of scholars who work at the crossroad of different research areas and disciplines. Their scientific production is in fact very often underestimated because its impact cannot be assessed by considering only the specific discipline of the department of affiliation. Here we propose a method based on the analysis of bipartite interconnected multilayer networks of citations and disciplines, to assess scholars, institutions and countries interdisciplinary importance. Using data about physics publications and US patents, we compare the ranking obtained using our method to those obtained using other indices of scientific impact, and show that the scholars whose work has had fundamental implications in different areas are indeed found to gain importance when ranked according to our method.

SOE 24.2 Thu 15:15 H36

**A textual measure of the interdisciplinarity of scientific papers** — •Laercio Dias, Martin Gerlach, and Eduardo G. Altmann — Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

We are interested in investigating the role and impact of interdisciplinary publications in the evolution of scientific ideas. A crucial point is how to quantify interdisciplinarity. The traditional approach is to use citation networks. The goal of our work is to construct a measure of interdisciplinarity entirely based on the text of articles, taking advantage of the increasing availability of full text of publications. We propose and compare different methods based on Jensen-Shannon-type of divergences, following the ideas recently proposed in Ref. [1].

[1] M. Gerlach, F. Font-Clos, and E. G. Altmann, "On the similarity of symbol-frequency distributions with heavy tails", aXiv:1510.00277 (2015)

SOE 24.3 Thu 15:30 H36

**Dynamical model of the scientific process: Knowledge generation embedded in the scientific map of science** — •Jan Moritz Joseph[1] and Jens Christian Claussen[2,3] — [1]Institut für Technische Informatik, Universität zu Lübeck, Germany — [2]Computational Systems Biology, Jacobs University Bremen, Germany — [3]INB, Universität zu Lübeck, Germany

We investigate a dynamical growth model [1] of the scientific process comprised by authors writing collaborative papers, where the location of authors and papers are defined in a scientific space [2] in which distances in these "maps of science" are defined by similarity between document texts. The goal of our model is to provide a minimal model of the dynamical evolution of the topological structure (beyond network adjacency and geographical author location) of scientific publications. The model fosters novelty and multidisciplinary of new papers, as well as a retirement mechanism which prevents large groups to dominate topics forever. We demonstrate that our model can generate a non-trivial topological structure comparable to [2,3]. We examine special and structural characteristics of the model in comparison to available data of the UCSD Map of Science [3]. While our model is in some sense minimalistic, it allows to study the influence of global steering parameters on the development of science.

[1] J.M. Joseph and J.C. Claussen, arXiv.org/abs/1407.8422

[2] K.W. Boyack, R. Klavans and K. Börner, Mapping the backbone of Science, Scientometrics 64, 351 (2005)

[3] K. Börner et al., Plos One 7, e39464 (2012)

SOE 24.4 Thu 15:45 H36

**Evolution of scientific collaboration and discovery on epistemological graphs** — •Fariba Karimi[1] and Ammar Nejati[2] — [1]GESIS institue for computational social science, Cologne, Germany — [2]Physics Department, Bonn University

Scientific research is not a task performed by isolated researchers; researchers communicate their ideas, inspire each other and eventually, make a major impact by their scientific discoveries. The new ideas can diffuse in the collaboration network by an adoption mechanism and create a macro-scale impact on the dynamic of science and its paradigm shifts. So far in modelling scientific collaboration, it has been assumed that research topics are objects that scientists pick from a 'pool of ideas', and research collaborations are not related to the inherent structure of the underlying scientific field. Although these assumptions simplify the modelling of scientific collaboration and discovery, they provide no insight on how research topics are connected intrinsically, and to what extend such a connectivity impacts the discoverability of new ideas or the collaboration pattern. In this work, we model the process of scientific discovery and collaboration by assuming that the scientific activity occurs on an underlying (static) epistemological network. Researchers move and discover this network, they establish collaborations with nearby researchers and they can adopt new researchers into the field. Our results show that through this discovery and collaboration 'game', large-scale scientific collaboration patterns emerge, novel scientific fields are established and ultimately, scientific paradigms change in the course of evolution.

SOE 24.5 Thu 16:00 H36

**Using arxiv data to estimate interdisciplinarity and its impact on academic success** — Leonhard Horstmeyer[1] and •Stefan Pfenninger[2] — [1]Max-Planck-Institute for Mathematics in the Sciences, Leipzig, Germany — [2]ETH Zurich

Interdisciplinarity in research is hard to capture formally and empirically, in particular in the context of preprint publishing. We introduce an entropy-based measure of author interdisciplinarity. We put forward a cleaning algorithm for preprint databases and a clustering algorithm for scientific communities based on mixture models. Equipped with these we study the arxiv.org database with respect to the community dynamics and the relation between interdisciplinarity and estimates of academic success such as the network centrality or the impact factor of the journals in which arxiv submissions were published.

SOE 24.6 Thu 16:15 H36

**Citation Networks and Economic Pluralism** — •Florentin Glötzl — Welthandelsplatz 2/D5, 1020 Wien

Pluralism has become a central issue not only in the public discourse but also in heterodox economics, as the focus on impact factors and rankings based on citations continues to increase. This marketization of science has been an institutional vehicle for the economic mainstream to promote its ideas. Citations thus have become a central currency in economics as a discipline. At the same time they allow to reveal patterns of interaction, segregation, clusters and cliques in the discourse. This endeavor is paticularly important in the context of a contested discipline such as economics, where heterodox scholars have been increasingly marginalized.

In this paper we investigate these patterns applying bibliometric tools as well as social network analysis and graph theory to citations on the journal level for 254 major journals in economics between 1956 and 2014.

We find that articles in heterodox journals cite more heterodox journals than articles in orthodox journals, but still have negative "citation

export rates", thereby reinforcing the institutional dominance of the mainstream. Orthodox journals completely disregard heterodox journals. Moreover, the citation networks reveal a clear "mainstream core - heterodox periphery" structure which has formed over the last decades. This is consistent with the paradigmatic map of the current discourse in the discipline of economics by Dobusch & Kapeller (2012). These findings imply serious questions for economic pluralism in the future.

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

Joint session with SOE and DY organized by BP.

Time: Thursday 16:45–17:45 Location: H43

SOE 25.1 Thu 16:45 H43

**Fluctuations and transients in the actin cytoskeleton of chemotactic amoeba** — •Jose Negrete JR[1,2], Alain Pumir[3], Hsing-Fang Hsu[2], Christian Westendorf[4], Marco Tarantola[2], Carsten Beta[2,5], and Eberhard Bodenschatz[2,6,7] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute for Dynamics and Selforganization, Göttingen, Germany — [3]Ecole Normale Supérieure de Lyon, France — [4]University of Graz, Austria — [5]University of Potsdam, Germany — [6]University of Göttingen, Germany — [7]Cornell University, Ithaca, USA

Biological systems with their complex biochemical networks are known to be intrinsically noisy. Here we investigate the oscillatory dynamics in the actin cytoskeleton of chemotactic amoeboid cells. We show that the large phenotypic variability in the polymerization dynamics can be accurately captured by a generic nonlinear oscillator model in the presence of noise. The relative role of the noise is fully determined by a single dimensionless parameter, experimentally measurable, and whose distribution completely characterizes the possible cellular behavior. Also, we perturbed experimentally the oscillatory cytoskeletal dynamics by a short chemoattractant pulse and measured the spatio-temporal response of filamentous actin reporter, LimE, and depolymerization regulators Coronin1 and Aip1. After pulsing, we observed self oscillating cells to relax back to their oscillatory state after a noisy transient. Particularly long transients were observed for cells initially displaying highly correlated oscillations.

SOE 25.2 Thu 17:00 H43

**Distribution of pair-wise covariances in neuronal networks** — •David Dahmen[1], Markus Diesmann[1,2,3], and Moritz Helias[1,3] — [1]Inst. of Neurosc. and Med. (INM-6) and Inst. for Advanced Simulation (IAS-6) and JARA BRAIN Inst. I, Jülich Research Centre, Germany — [2]Dept. of Psychiatry, Psychotherapy and Psychosomatics, Medical Faculty, RWTH Aachen University, Aachen, Germany — [3]Dept. of Physics, Faculty 1, RWTH Aachen University, Germany

Massively parallel recordings of spiking activity in cortical circuits show large variability of covariances across pairs of neurons [Ecker et al., Science (2010)]. In contrast to the low average, the wide distribution of covariances and its relation to the structural variability of connections between neurons is still elusive. Here, we derive the formal relation between the statistics of connections and the statistics of integral pairwise covariances in networks of Ornstein-Uhlenbeck processes that capture the fluctuations in leaky integrate-and-fire and binary networks [Grytskyy et al., Front. Comput. Neurosci. (2013)]. Spin-glass mean-field techniques [Sompolinsky and Zippelius, Phys. Rev. B (1982)] applied to a generating function representing the joint probability distribution of network activity [Chow and Buice, J. Math. Neurosci. (2015)] yield expressions that explain the divergence of mean covariances and their width when the coupling in the linear network approaches a critical value. Using these relations, distributions of correlations provide insights into the properties of the structure and the operational regime of the network. Partly supported by Helmholtz Association: VH-NG-1028 and SMHB; EU Grant 604102 (HBP).

SOE 25.3 Thu 17:15 H43

**Global stability reveals critical components in the structure of multi-scale neural networks** — •Jannis Schuecker[1,4], Maximilian Schmidt[1,4], Sacha J. van Albada[1], Markus Diesmann[1,2,3], and Moritz Helias[1,3] — [1]Inst of Neurosci and Medicine (INM-6) and Inst for Advanced Simulation (IAS-6) and JARA BRAIN Institute I, Jülich Research Centre — [2]Department of Psychiatry, Psychotherapy and Psychosomatics, Medical Faculty, RWTH Aachen University — [3]Department of Physics, Faculty 1, RWTH Aachen University — [4]These authors contributed equally

One of the major challenges of neuroscience is the integration of the available experimental data into a coherent model of the brain. In this endeavor, the exploration of the inevitable uncertainties in anatomical data should be guided by physiological observations. To this end we devise a method based on a mean-field reduction of spiking network dynamics for shaping the phase space of large-scale network models according to fundamental activity constraints, prohibiting quiescence and requiring global stability. In particular, we apply this framework to a multi-area spiking model of macaque visual cortex and obtain plausible layer- and area-specific activity [Schuecker et al. 2015, arXiv:1509.03162] by controlling the location of the separatrix dividing the phase space into realistic low-activity and unrealistic high-activity states. The study systematically identifies modifications to the population-level connectivity within and between areas critical for the stability of the network. Partly supported by Helmholtz association: VH-NG-1028 and SMHB; EU Grant 604102 (HBP).

SOE 25.4 Thu 17:30 H43

**From Interactions to Topology: A Population Dynamics Approach to Network Formation** — •Adrian Fessel and Hans-Günther Döbereiner — Institut für Biophysik, Universität Bremen, Deutschland

We present a mean-field model integrating interactions between populations of nodes to mimic the evolution of transportation networks. Changes in network topology are partitioned in basic events representing, e.g., fusion or growth of network fragments. Local dependencies are reflected by rate constants modifying the frequency of occurence of a given event.
The model presented shows promising results when compared to the percolating network of the slime-mold *Physarum polycephalum* [*Phys. Rev. Lett.* **109**, 078103 (2012)].

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

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

SOE 26.1 Thu 15:30 H47

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

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

world-type transition to optimal transport in the case of loops.

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

SOE 26.2 Thu 15:45 H47

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

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

SOE 26.3 Thu 16:00 H47

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

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

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

SOE 26.4 Thu 16:15 H47

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

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

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

SOE 26.5 Thu 16:30 H47

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

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

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

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

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

SOE 26.6 Thu 16:45 H47

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

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

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