XXXIX. Dynamics Days Europe

International Conference on Dynamics

Rostock, Germany

September 2–6, 2019

Book of Abstracts

Organizers:

Jens Starke, Institute of Mathematics

Michael Dreher, Institute of Mathematics

Oliver Kühn, Institute of Physics

Thomas Fennel, Institute of Physics

Conference Series Dynamics Days Europe

Dynamics Days Europe is a series of annual international conferences founded in the 1980s that provides a European forum for developments in the theory and applications of nonlinear dynamics. For over thirty years it has been bringing together researchers from a wide range of mathematical backgrounds for interdisciplinary research in nonlinear science. See http://www.dynamicsdays.org and https://www.dynamicsdays.info for detailed information about past and future events.

This year, the 39th Dynamics Days Europe takes place at the University of Rostock, which is one of the oldest Universities in northern Europe and celebrates its 600th anniversary in 2019. The conference is jointly organized by the Institute of Mathematics and Institute of Physics, which belong to the Faculty of Mathematics and Natural Sciences.

We are most grateful to everybody who helped to organize this conference. In particular, we thank the administrative and technical staff of the Institute of Mathematics and the Institute of Physics, Daniela Brandenburg, Susann Dittmer, Gabriella Keuer, Theresa Kozianka, Ralf Ludwig, Karin Martin, Sabrina Neumann, Annekatrin Pingel, Karin Ritzkowski, Heike Schubert, Solvejg Schweder, Andreas Straßburg, without whom it would have been impossible to organize this event. Furthermore we would like to thank numerous students and scientific staff, including Ashour Ahmed, Tomass Andersons, Martina Beese, Olga Bokareva, Anna Dittus, Prasanth B. Ganta, Andy Kaiser, Vlad Kochetov, Björn Kruse, Tobias Moehle, Christian Peltz, Alejandro Ramos, Joachim Seibt, Lennart Seiffert, Konstantinos Spiliotis, Paul Thomas, Tim Völzer. And finally, we would like to express our gratitude to the University of Rostock and the Collaborative Research Centre SFB 1270 for support the conference.

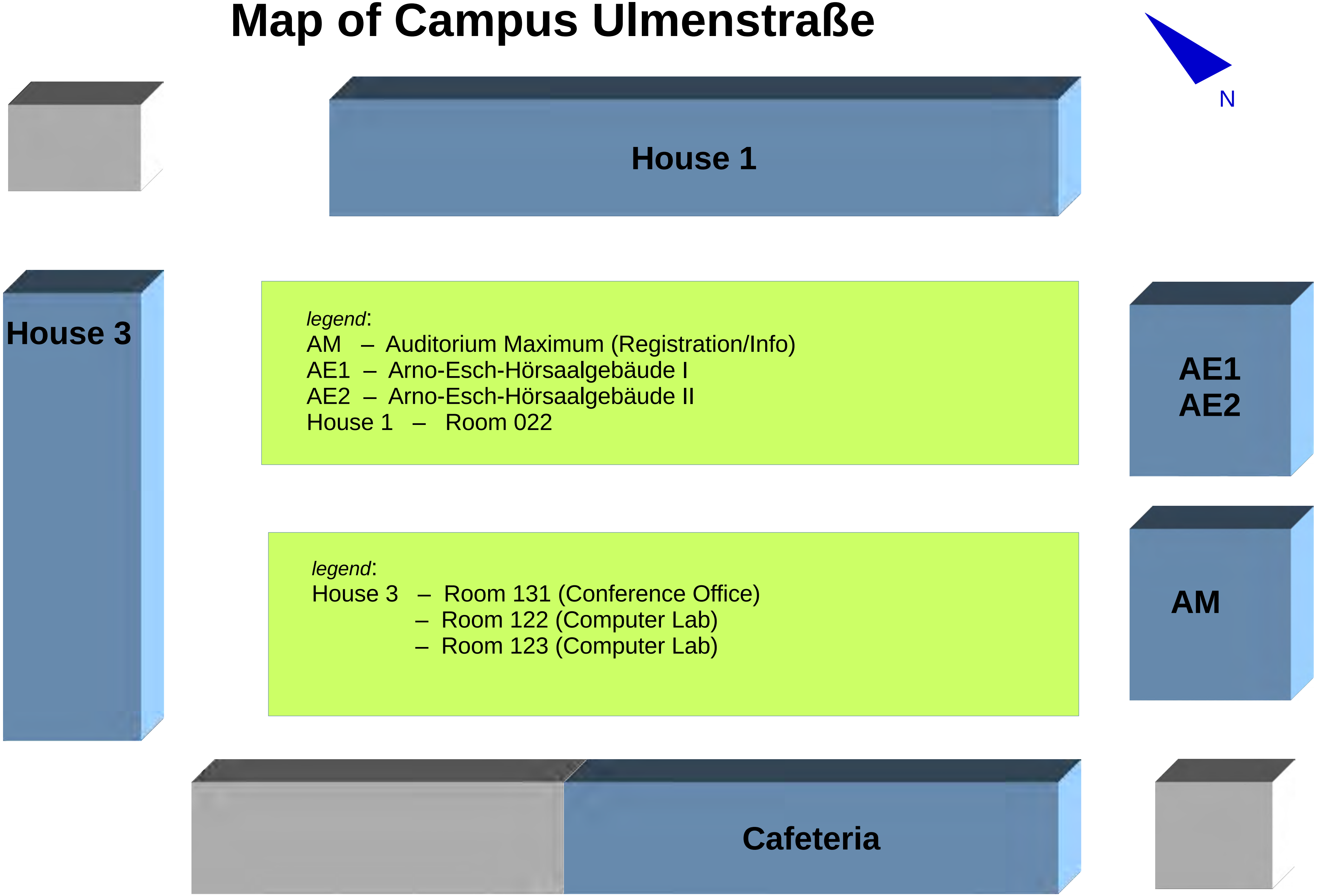
We warmly welcome all participants to enjoy exciting science, the beautiful city of Rostock, and the surrounding of the Baltic Sea.

Wishing you all a good week here in Rostock,

Jens Starke
Michael Dreher
Oliver Kühn
Thomas Fennel

Contents

Map of Campus Ulmenstraße



Remarks on the organisation

The conference venue

The scientific program will be held at the *Ulmencampus* of the University of Rostock. This is in convenient walking distance from the city centre (about 2 kilometres). To get there by public transport, you can take the tram line 3 (in direction *Neuer Friedhof* or *Platz der Jugend*) or the tram line 6 (in direction *Neuer Friedhof*) until the tram stop *Parkstraße* and then follow the signs. You can also take the suburban train S-Bahn to the stop *Parkstraße*.

All plenary lectures take place in the *Auditorium Maximum*, and all the other talks will be presented in the Auditorium Maximum, in the lecture theatres *Arno Esch 1* and *Arno Esch 2*, and in the room 022 of House 1. Each room has sockets for HDMI and VGA (the halls Auditorium Maximum, Arno Esch 1 and 2 even two of them). The local organizers will provide laptops, laser pointers, and experts of how to use the electronic devices. You are also welcome to use your own computer.

Registration, info point, and conference office

Registration will be in the Auditorium Maximum on Monday morning. There will be also an information point during the following days. Should you have any further questions, please contact the conference office in House 3 (room 131).

Access to the internet and computers

The University of Rostock participates in the *eduroam* system, and the eduroam credentials from your home institution should give you WLAN access in every building of the university. We provide computer pools in House 3 (rooms 122 and 123). Those participants who have requested a login for these computer pools when they registered at the conference website can pick up their respective username and password at the pools.

Posters

The poster session will be on Monday, from 4pm till 6pm, in the Foyer of the *Audimax*. Material for the attachement of posters (size A0) will be provided. The fields on the poster wall are numbered, and you find the number of your own poster in this booklet. To encourage discussions during coffee breaks and lunch breaks, the posters will be on display until Friday.

Lunch

Adjacent to the lecture halls, there is a university cafeteria which is open during lunch time. Enclosed in your conference materials you will find a map of smaller restaurants in the neighbourhood of the campus which offer lunch and dinner as well.

XXXIX. Dynamics Days Europe, University of Rostock, Germany, September 2 – September 6, 2019

	Sunday 01.09.2019	Monday 02.09.2019	Tuesday 03.09.2019	Wednesday 04.09.2019	Thursday 05.09.2019	Friday 06.09.2019
08:00 – 09:00		Registration				
09:00 – 09:45		Joachim Burgdörfer (Vienna), p. 29	E. K. U. Gross (Halle), p. 31	Jeroen Lamb (London), p. 33	Andreas Daffertshofer (Amsterdam), p. 35	Eduard Feireisl (Prague), p. 38
09:45 – 10:30		Arnd Scheel (Minneapolis), p. 29	Stuart Althorpe (Cambridge), p. 32	Just Herder (Delft), p. 34	Bettina Keller (Berlin), p. 36	Daniela Rupp (Zurich), p. 39
10:30 – 11:00		Posters & Coffee break				
11:00 – 11:20		Fischer, Kuwashima, Olmi, Gurusamy	Colet, Suzuki, Montoya, Mokhtari	Kettemann, Orlov, Novičenko, Katz	Just, Atay, Schöll, Isensee	Kashchenko , Iwase, Goldobin
11:20 – 11:40		Bader, Ebisawa, Ullner, Shimokawa	Beck, ~~Matcharashvili~~, Curbelo, Cisternas	Kaiser, Zviagin, Anishchenko, Kuznetsov	Richter, Blyuss, Ruzzene, Parlitz	Fülöp, Kawamoto, Eydam
11:40 – 12:00		Linke, Sampath, ~~Sajid~~, Crumeyrolle-Smieszek	Schäfer, Carl, Zhdanov, Gaiko	Taher, Boldyrev , Shepelev, Hasan	Slipantschuk, Bosschaert, Omel'chenko, Shimizu	Hinke Osinga (Auckland), p. 40
12:00 – 12:20		Cheesman, Isoshima, Ponomarenko, Itto	Totz, Krall, Trukhanova, Wolfrum	Böttcher, Zvyagin, Strelkova, Cardoso	Ryu, Schneider, Zakharova, Hegedűs	
12:30 – 14:00		Posters, Lunch break & discussion				
14:00 – 14:45	arrival	David Leitner (Reno), p. 30	Peter Szmolyan (Vienna), p. 32	Excursion (City of Rostock)	Sebastian Wieczorek (Cork), p. 37	departure
14:50 – 15:10		Timme, Kalkhouran, Fedorova, Néda	Constantinos Siettos (Naples), p. 33		Wolfram Just (London), p. 38	
15:10 – 15:30		Fette, Kakhki, Zeitlin, Gzal				
15:30 – 16:00		Maaß	Posters & Coffee break		Posters & Coffee break	
16:00 – 16:20		Posters	Rydin, Moskalenko, Hofmann, Yanagita		Barland, Zakharova, Provata, Cartwright	
16:20 – 16:40			Jacquod, Voit, Lohse, ~~Dana~~		Rombouts, Schöll, Berner, Contreras	
16:40 – 17:00			Plietzsch, Gong, Sommerfeld, Leonel		Kosiuk, Claussen, Omelchenko, Mermillod-Blondin	
17:00 – 17:20			Schiffer, Timperi, Schneider, Lozej		Avitabile, Stelzer, Rakshit, Filatrella	
17:20 – 17:40			Tyloo, Kaloudis, Gebhard, Yanchuk	Transfer to Hohe Düne	Desroches, Sieber, Jalan, Karaca	
17:40 – 18:00			Greiner, Russo, Salieva, Shamolin		Kaklamanos, ~~Saha~~, Ghosh, Mukhopadhyay	
18:00 – 22:00				Poul Hjorth (Copenhagen), p. 34 Dinner Talk & Conference Dinner		

legend:
Auditorium Maximum (AM)
AM, AE1, AE2, H1

XXXIX. Dynamics Days Europe, University of Rostock, Germany, Monday, September 2, 2019

Sept. 02, 2019	Auditorium Maximum (AM)	Arno-Esch-Hörsaalgebäude I (AE1)	Arno-Esch-Hörsaalgebäude II (AE2)	House 1, Room 022 (H1)
08:00 – 09:00	Registration			
09:00 – 09:45	Joachim Burgdörfer (Vienna) 29			
09:45 – 10:30	Arnd Scheel (Minneapolis) 29			
10:30 – 11:00	Posters & Coffee break			
11:00 – 11:20	Jost Leonhardt Fischer (M1-AM.1), p. 42	Fumiyoshi Kuwashima (M2-AE1.1), p. 44	Simona Olmi (C1-AE2.2), p. 86	Arumugam Gurusamy (C1-H1.1), p. 88
11:20 – 11:40	Rolf Bader (M1-AM.2), p. 42	Satoshi Ebisawa (M2-AE1.2), p. 45	Ekkehard Ullner (C1-AE2.2), p. 86	Michiko Shimokawa (C1-H1.2), p. 88
11:40 – 12:00	Simon Linke (M1-AM.3), p. 43	K. I. Amila Sampath (M2-AE1.3), p. 45	~~Zamra Sajid (C1-AE2.3)~~	Marlene Crumeyrolle-Smieszek (C1-H1.3), p. 89
12:00 – 12:20	Noah Cheesman (C1-AM.4), p. 85	Takashi Isoshima (M2-AE1.4), p. 45	Vladimir Ponomarenko (C1-AE2.4), p. 87	Yuichi Itto (C1-H1.4), p. 90
12:30 – 14:00	Posters, Lunch break & discussion			
14:00 – 14:45	David Leitner (Reno) 30			
14:50 – 15:10	Marc Timme (M3-AM.01), p. 47	Sara Ameli Kalkhouran (C2-AE1.1), p. 91	Antonina N. Fedorova (C2-AE2.1), p. 92	Zoltán Néda (C2-H1.1), p. 94
15:10 – 15:30	Michael Fette (M3-AM.02), p. 48	Mahla Mirzaee Kakhki (C2-AE1.2), p. 92	Michael G. Zeitlin (C2-AE2.2), p. 93	Majdi Gzal (C2-H1.2), p. 94
15:30 – 16:00	Philipp Maaß (M3-AM.03), p. 49	Posters & Coffee break		
16:00 – 16:20	Posters			
16:20 – 16:40				
16:40 – 17:00				
17:00 – 17:20				
17:20 – 17:40				
17:40 – 18:00				

XXXIX. Dynamics Days Europe, University of Rostock, Germany, September 2 – September 6, 2019

Monday

9:00-9:45	Joachim Burgdörfer: "Thermalization and quantum chaos"
9:45-10:30	Arnd Scheel: "Growing stripes"

	Session C1-AM	**Session C1-AE1**	**Session C1-AE2**	**Session C1-H1**
	Minisymposium M1-AM "Nonlinearities and self-organization in musical acoustics"	Minisymposium M2-AE1 "Chaotic and nonlinear dynamics for ICT"		
11:00-11:20	Jost Leonhardt Fischer "Shock wave characteristics in the initial transient of wind instruments"	Fumiyoshi Kuwashima "Stable THz wave generation using laser chaos"	Simona Olmi "Cross frequency coupling in next generation inhibitory neural mass models"	Arumugan Gurusamy "Discontinuous Galerkin methods for Keller-Segel chemotaxis system with general chemotactic sensitivity and cross-diffusion"
11:20-11:40	Rolf Bader "Viscoelastic memory effect as cause of musical instrument spectral flux and musical liveliness"	Satoshi Ebisawa "Chaotic oscillation of laser diode with optical injection and pseudorandom drive current"	Ekkehard Ullner "The brain activity at rest as self-sustained collective irregular dynamics in spiking networks"	Michiko Shimokawa "Breakup of falling droplets by instability of vortex ring"
11:40-12:00	Simon Linke "Describing minimum bow force using Impulse Pattern Formulation (IPF) – an empirical validation"	K.I. Amila Sampath "Electrically wavelength-tunable light source by means of stimulated Brillouin scattering in single-mode fibers"	~~Zamra Sajid "Modelling myeloproliferative neoplasms: Dynamics of myeloid cell line for Ph-negative MPNstion"~~ Cancelled	Marlene Crumeyrolle-Smieszek "Numerical simulation of convection of a phase change material in a rectangular cavity"
12:00-12:20	Noah Cheesman "The Painleve Paradox in 3D"	Takashi Isoshima "Control of wavefront propagation properties for natural computing in two-dimensional optical bistable devices"	Vladimir Ponomarenko "Dynamics of synchronization measures between autonomous regulation processes of heart rate and blood pressure"	Yuichi Itto "Entropy production rate of diffusivity fluctuations of RNA-protein particles"

14:00-14:45	David Leitner: "Mapping energy transport networks in proteins"

	Session C2-AM	**Session C2-AE1**	**Session C2-AE2**	**Session C2-H1**
	Minisymposium M3-AM "Structure and dynamics of future power grids"			
14:50-15:10	Marc Timme "Detecting state space dimensionality (and network size) from time series of few variables"	Sara Ameli Kalkhouran "Event-based model for digital oscillators"	Antonina Fedorova "Non-Gaussian states: a first sign of complex events"	Zoltan Neda "Flickering candle flames and their emergent synchronization. An experimental and dynamical systems approach"
15:10-15:30	Michael Fette "Bifurcational analysis of power system characteristics – Comparison to measurements in practical applications"	Mahla Mirzaee Kakhki "Topological steps toward walking colloidal bipeds"	Michael G. Zeitlin "Sheaves, schemes, and all that: new looking glass for quantum phenomena"	Majdi Gzal "Mathematical model for the nonlinear dynamics of valve spring"
15:30-16:00	Philipp Maaß Short-term power grid stability under stochastic feed-in of renewable energy sources			

XXXIX. Dynamics Days Europe, University of Rostock, Germany, Tuesday, September 3, 2019

Sept. 03, 2019	Auditorium Maximum (AM)	Arno-Esch-Hörsaalgebäude I (AE1)	Arno-Esch-Hörsaalgebäude II (AE2)	House 1, Room 022 (H1)
08:00 – 09:00				
09:00 – 09:45	E. K. U. Gross (Halle) 31			
09:45 – 10:30	Stuart Althorpe (Cambridge) 32			
10:30 – 11:00	Posters & Coffee break			
11:00 – 11:20	Pere Colet (M3-AM.03), p. 50	Norikazu Suzuki (C3-AE1.1), p. 95	Francisco Gonzalez Montoya (M4-AE2.1), p. 58	Fahimeh Mokhtari (C3-H1.1), p. 97
11:20 – 11:40	Christian Beck (M3-AM.04), p. 50	~~Teimuraz Matcharashvili (C3-AE1.2)~~	Jezabel Curbelo (M4-AE2.2), p. 59	Jaime Cisternas (C3-H1.2), p. 98
11:40 – 12:00	Benjamin Schäfer (M3-AM.05), p. 51	Peter Carl (C3-AE1.3), p. 96	Dmitry Zhdanov (M4-AE2.3), p. 59	Valery Gaiko (C3-H1.3), p. 98
12:00 – 12:20	Philippe Jacquod (M3-AM.08), p. 51	Verena Krall (C3-AE1.4), p. 97	Mariya Trukhanova (M4-AE2.4), p. 60	Matthias Wolfrum (C3-H1.4), p. 99
12:30 – 14:00	Posters, Lunch break & discussion			
14:00 – 14:45	Peter Szmolyan (Vienna) 32			
14:45 – 15:30	Constantinos Siettos (Naples) 33			
15:30 – 16:00	Posters & Coffee break			
16:00 – 16:20	Leonardo Rydin (M3-AM.07), p. 52	Olga Moskalenko (C4-AE1.1), p. 99	Timo Hofmann (M5-AE2.1), p. 61	Tatsuo Yanagita (C4-H1.1), p. 102
16:20 – 16:40	Carl Hendrik Totz (M3-AM.06), p. 52	Maximilian Voit (C4-AE1.2), p. 100	Alexander Lohse (M5-AE2.2), p. 62	~~Itzhack Dana (C4-H1.2)~~
16:40 – 17:00	Anton Plietzsch (M3-AM.09), p. 53	Chen Gong (C4-AE1.3), p. 100	Mara Sommerfeld (M5-AE2.3), p. 62	Edson Leonel (C4-H1.3), p. 103
17:00 – 17:20	Johannes Schiffer (M3-AM.10), p. 53	Kalle Timperi (C4-AE1.4), p. 101	Isabelle Schneider (M5-AE2.4), p. 62	Crt Lozej (C4-H1.4), p. 103
17:20 – 17:40	Melvyn Tyloo (M3-AM.11), p. 54	Konstantinos Kaloudis (C4-AE1.5), p. 101	Björn Gebhard (M5-AE2.5), p. 63	Serhiy Yanchuk (C4-H1.5), p. 104
17:40 – 18:00	Martin Greiner (M3-AM.12), p. 55	Lucia Russo (C4-AE1.6), p. 102	Olga Salieva (C4-AE2.6), p. 102	Maxim V. Shamolin (C4-H1.6), p. 104

XXXIX. Dynamics Days Europe, University of Rostock, Germany, September 2 – September 6, 2019

Tuesday

9:00-9:45 E.K.U. Gross: "Potential energy surfaces and Berry phases from the exact factorization: A rigorous approach to non-adiabatic dynamics"

9:45-10:30 Stuart Althorpe: "Real-time dynamics from imaginary-time path-integrals: theory and practice"

	Session C3-AM	Session C3-AE1	Session C3-AE2	Session C3-H1
	Minisymposium M3-AM "Structure and dynamics of future power grids"		Minisymposium M4-AE2 "Phase space geometry of Hamiltonian systems and applications"	
11:00-11:20	Pere Colet "Power grid frequency fluctuations and smart devices with dynamic demand control"	Norikazu Suzuki "Non-Markovianity and subdiffusion of volcanic seismicity"	Francisco Gonzalez Montoya "Revealing roaming on the double Morse potential energy surface with Lagrangian descriptors "	Fahimeh Mokhtari "On the sl2 -representation near the triple-zero bifurcation"
11:20-11:40	Christian Beck "Superstatistical methods for power grids"	~~Teimuraz Matcharashvili "Dynamic changes in the characteristics of the foundation structure and in the local seismic activity occurred during the construction of the hydroelectric power plant"~~ Cancelled	Jezabel Curbelo "Lagrangian study of phase space geometrical structures in 3D vector fields"	Jaime Cisternas "Dipolar chains and their hidden branches of equilibria"
11:40-12:00	Benjamin Schäfer "Power grid frequency: data-driven and statistical analysis"	Peter Carl "Signatures of low-dimensional intraseasonal motion in the data of a German climate station"	Dmitry Zhdanov "Phase space representation of quantum dynamics using squeezed coherent states"	Valery Gaiko "Global bifurcations of limit cycles and strange attractors in multi-parameter dynamical systems"
12:00-12:20	Philippe Jacquod "Optimal placement of inertia and primary control in high voltage power grids"	Verena Krall "Topological universality of ride-sharing efficiency and the impact of asymmetric request distributions"	Mariya Trukhanova "The gauge field theory in condensed matter physics"	Matthias Wolfrum "Phase-sensitive excitability of a limit cycle"

14:00-14:45 Peter Szmolyan: "Geometric singular perturbation theory beyond the standard form"

14:45-15:30 Constantinos Siettos: "To the infinity and beyond: Some ODEs and PDEs case studies"

	Session C4-AM	Session C4-AE1	Session C4-AE2	Session C4-H1
	Minisymposium M3-AM "Structure and dynamics of future power grids"		Minisymposium M5-AE2 "PDEs and dynamics with symmetries"	
16:00-16:20	Leonardo Rydin "Tackling stability for conventional and inverter-based power grids in the presence of resistive terms"	Olga Moskalenko "Jump intermittency near the boundary of generalized synchronization in systems with complex topology of attractor"	Timo Hofmann "Symplectic local Lyapunov exponents are symmetric"	Tatsuo Yanagita "Emergence of quasi-equilibrium in Hamiltonian systems"
16:20-16:40	Carl Hendrik Totz "Control of synchronization in two-layer power grids"	Maximilian Voit "Dimensional reduction in coupled heteroclinic cycles"	Alexander Lohse "Symmetry effects on non-asymptotic attraction"	~~Itzhack Dana "Accelerator modes and chaotic superdiffusion of periodically kicked interacting particles"~~ Cancelled
16:40-17:00	Anton Plietzsch "A generalized linear response theory for renewable fluctuations in lossy microgrids"	Chen Gong "Repulsively coupled Kuramoto-Sakaguchi phase oscillators ensemble subject to common noise"	Mara Sommerfeld "Hamiltonian relative equilibria in symplectic representations of compact connected groups"	Edson Leonel "An investigation of chaotic diffusion in a family of Hamiltonian mappings whose angles diverge in the limit of vanishingly action"
17:00-17:20	Johannes Schiffer "Almost global synchronization in droop-controlled microgrids - a multivariable cell structure approach"	Kalle Timperi "Transitions in random dynamical systems with bounded uncertainty"	Isabelle Schneider "Symmetry-breaking control of reaction-diffusion equations"	Crt Lozej "Structure, size and statistical properties of chaotic components in Hamiltonian systems with divided phase space"
17:20-17:40	Melvyn Tyloo "The key player problem in realistic large-scale power grids"	Konstantinos Kaloudis "A Bayesian nonparametric approach to the approximation of the global stable manifold"	Björn Gebhard "An equivariant degree and periodic solutions of the N-vortex problem"	Serhiy Yanchuk "Coexistence of Hamiltonian-like and dissipative dynamics in chains of coupled oscillators with skew-symmetric coupling"
17:40-18:00	Martin Greiner "Renewable energy networks"	Lucia Russo "Symmetry and bifurcations in ring networks with periodically switched connections"	Evgeny Galakhov and Olga Salieva "Uniqueness of the trivial solution for some quasilinear inequalities"	Maxim V. Shamolin "Integrable dynamical systems with dissipation"

XXXIX. Dynamics Days Europe, University of Rostock, Germany, Wednesday, September 4, 2019

Sept. 04, 2019	Auditorium Maximum (AM)	Arno-Esch-Hörsaalgebäude I (AE1)	Arno-Esch-Hörsaalgebäude II (AE2)	House 1, Room 022 (H1)
08:00 – 09:00				
09:00 – 09:45	Jeroen Lamb (London) 33			
09:45 – 10:30	Just Herder (Delft) 34			
10:30 – 11:00	Posters & Coffee break			
11:00 – 11:20	Stefan Kettemann (M3-AM.13), p. 56	Vladimir Orlov (M6-AE1.1), p. 64	Viktor Novičenko (C5-AE2.1), p. 105	Shmuel Katz (C5-H1.1), p. 107
11:20 – 11:40	Franz Kaiser (M3-AM.14), p. 56	Andrei Zviagin (M6-AE1.2), p. 65	Vadim Anishchenko (C5-AE2.2), p. 105	Maxim Kuznetsov (C5-H1.2), p. 108
11:40 – 12:00	Halgurd Taher (M3-AM.15), p. 57	Aleksandr Boldyrev (M6-AE1.3), p. 65	Igor Shepelev (C5-AE2.3), p. 106	Cris Ragheb Hasan (C5-H1.3), p. 108
12:00 – 12:20	Philipp Böttcher (M3-AM.16), p. 57	Victor Zvyagin (M6-AE1.4), p. 65	Galina Strelkova (C5-AE2.4), p. 106	Silvana Cardoso (C5-H1.4), p. 109
12:30 – 14:00	Posters, Lunch break & discussion			
14:00 – 17:20	Excursion (City of Rostock)			
17:20 – 18:00	Transfer to Hohe Düne			
18:00 – 22:00	Poul Hjorth (Copenhagen) Dinner Talk & Conference Dinner			

Wednesday

9:00-9:45	Jeroen Lamb: "Bifurcations in random dynamical systems"
9:45-10:30	Just Herder: "Towards dynamic synthesis in compliant mechanisms"

	Session C5-AM	Session C5-AE1	Session C5-AE2	Session C5-H1
	Minisymposium M3-AM "Structure and dynamics of future power grids"	Minisymposium M6-AE1 "Solvability and qualitative behaviour of solutions for viscoelastic fluids dynamics models"		
11:00-11:20	Stefan Kettemann "Propagation of disturbances in power grids"	Vladimir Orlov "On some fractional models of viscoelastic mediums"	Victor Novicenko "Adaptive delayed feedback control to stabilize in-phase synchronization in complex oscillator networks"	Shmuel Katz "Solitary waves in a non-integrable chain with double-well potentials"
11:20-11:40	Franz Kaiser "The impact of network topology on failure spreading in power grids"	Andrei Zviagin "Weak solvability of thermo-model for one viscoelastic fluid"	Vadim Anishchenko "Target waves and new chimera structures in a 2D lattice of nonlocally coupled Van der Pol oscillators"	Maxim Kuznetsov "Investigation of Turing structures formation under the influence of wave instability"
11:40-12:00	Halgurd Taher "Enhancing power grid synchronization and stability through time delayed feedback control"	Aleksandr Boldyrev "Uniform attractors for weak solutions to viscoelastic media with memory"	Igor Shepelev "Formation mechanisms of spiral and double-well chimeras in a 2D lattice of coupled bistable FitzHugh-Nagumo oscillators"	Cris Ragheb Hasan "Existence and stability of periodic travelling waves: who will prevail in a Rock-Paper-Scissors game?"
12:00-12:20	Philipp Böttcher "Time delay effects in the control of synchronous electricity grids"	Victor Zvyagin "On the weak solvability of initial-boundary value problems for a class of integro-differential equations with memory"	Galina Strelkova "Forced synchronization of a heterogeneous multilayer network of nonlocally coupled maps"	Silvana Cardoso "Convective nano-flow in self-assembled precipitate membranes"

18:00-22:00	Poul Hjorth: "Big grants and big data"

XXXIX. Dynamics Days Europe, University of Rostock, Germany, Thursday, September 5, 2019

Sept. 05, 2019	Auditorium Maximum (AM)	Arno-Esch-Hörsaalgebäude I (AE1)	Arno-Esch-Hörsaalgebäude II (AE2)	House 1, Room 022 (H1)
08:00 – 09:00				
09:00 – 09:45	Andreas Daffertshofer (Amsterdam) 35			
09:45 – 10:30	Bettina Keller (Berlin) 36			
10:30 – 11:00	Posters & Coffee break			
11:00 – 11:20	Wolfram Just (M7-AM.1), p. 66	Fatihcan Atay (M8-AE1.1), p. 68	Eckehard Schöll (M9-AE2.1), p. 71	Jonas Isensee (C6-H1.2), p. 110
11:20 – 11:40	Martin Richter (M7-AM.2), p. 66	Konstantin Blyuss (M8-AE1.2), p. 69	Giulia Ruzzene (M9-AE2.2), p. 71	Ulrich Parlitz (C6-H1.1), p. 110
11:40 – 12:00	Julia Slipantschuk (M7-AM.3), p. 67	Maikel Bosschaert (M8-AE1.3), p. 69	Oleh Omel'chenko (M9-AE2.3), p. 72	Taro Shimizu (C6-H1.3), p. 111
12:00 – 12:20	Jung-Wan Ryu (C6-AM.4), p. 109	Isabelle Schneider (M8-AE1.4), p. 69	Anna Zakharova (M9-AE2.4), p. 72	Ferenc Hegedűs (C6-H1.4), p. 112
12:30 – 14:00	Posters, Lunch break & discussion			
14:00 – 14:45	Sebastian Wieczorek (Cork) 37			
14:45 – 15:30	Wolfram Just (London) 38			
15:30 – 16:00	Posters & Coffee break			
16:00 – 16:20	Stéphane Barland (M10-AM.1), p. 75	Anna Zakharova (M11-AE1.1), p. 80	Astero Provata (M9-AE2.5), p. 73	Julyan Cartwright (C7-H1.1), p. 116
16:20 – 16:40	Jan Rombouts (M10-AM.2), p. 76	Eckehard Schöll (M11-AE1.2), p. 81	Rico Berner (M9-AE2.6), p. 73	Maximiliano Contreras (C7-H1.2), p. 116
16:40 – 17:00	Ilona Kosiuk (M10-AM.3), p. 77	Jens Christian Claussen (M11-AE1.3), p. 82	Iryna Omelchenko (M9-AE2.7), p. 74	Alexandre Mermillod-Blondin (C7-H1.3), p. 117
17:00 – 17:20	Daniele Avitabile (M10-AM.4), p. 77	Florian Stelzer (M11-AE1.4), p. 82	Sarbendu Rakshit (C7-AE2.4), p. 113	Giovanni Filatrella (C7-H1.4), p. 118
17:20 – 17:40	Mathieu Desroches (M10-AM.5), p. 78	Jan Sieber (M11-AE1.5), p. 83	Sarika Jalan (C7-AE2.5), p. 114	Ertuğrul Karaca (C7-H1.5), p. 119
17:40 – 18:00	Panagiotis Kaklamanos (M10-AM.6), p. 78	~~Arindam Saha (C7-AE1.6)~~	Saptarshi Ghosh (C7-AE2.6), p. 115	Aritra K. Mukhopadhyay (C7-H1.6), p. 120

XXXIX. Dynamics Days Europe, University of Rostock, Germany, September 2 – September 6, 2019

Thursday

9:00-9:45	Andreas Daffertshofer: "Phase reduction of network dynamics of coupled oscillators"
9:45-10:30	Bettina Keller: "Markov models for complex molecular dynamics"

	Session C6-AM	Session C6-AE1	Session C6-AE2	Session C6-H1
	Minisymposium M7-AM "Spectral methods in applied mathematics"	Minisymposium M8-AE1 "Dynamics of delay differential equations and applications"	Minisymposium M9-AE2 "Synchronization patterns in networks"	
11:00-11:20	Wolfram Just "Transfer operator technique for analytic maps, or: Chaos in the Hilbert space"	Fatihcan Atay "Consensus-type problems on networks with time delays"	Eckehard Schöll "Partial synchronization in complex networks"	Jonas Isensee "Predicting spatio-temporal time series using dimension reduced local states"
11:20-11:40	Martin Richter "Convergence properties of transfer operators for billiards with a mixed phase-space"	Konstantin Blyuss "Mathematical modelling of awareness-based disease control"	Giulia Ruzzene "Minimal action to control chimera states"	Ulrich Parlitz "Predicting high dimensional chaos using machine learning"
11:40-12:00	Julia Slipantschuk "Transfer operator approach to ray tracing in circular domains"	Maikel Bosschaert "Initialization of homoclinic solutions near Bogdanov-Takens points in delay differential equations"	Oleh Omel'chenko "Quasiperiodic Chimera states"	Taro Shimizu "Measuring Lyapunov spectrum of large chaotic systems with global coupling by time series analysis"
12:00-12:20	Jung-Wan Ryu "New type of oscillation death in coupled counter-rotating identical nonlinear oscillators"	Isabelle Schneider "Mechanisms of delayed feedback control"	Anna Zakharova "Control of synchronization patterns in multilayer networks"	Ferenc Hegedüs "Control of multistability in harmonically driven nonlinear oscillators via a temporary addition of a second harmonic component to the driving"

14:00-14:45	Sebastian Wieczorek: "Rate-induced tipping points: Beyond classical bifurcations"
14:45-15:30	Wolfram Just: "Control of pedestrian flows: Social dynamics beyond modelling"

	Session C7-AM	Session C7-AE1	Session C7-AE2	Session C7-H1
	Minisymposium M10-AM "Recent advances in slow-fast dynamics"	Minisymposium M11-AE1 "Recent advances in time-delayed systems"	Minisymposium M9-AE2 "Synchronization patterns in networks"	
16:00-16:20	Stephane Barland "Experimental observation of low dimensional dynamics in a fully connected network of spiking lasers"	Anna Zakharova "Designing solitary states by time delays"	Astero Provata "Mechanisms underlying the formation of Chimera states in brain dynamics"	Julyan Cartwright "The bee Trigona builds its comb like a crystal"
16:20-16:40	Jan Rombouts "Dynamically changing bistable switches in the cell cycle"	Eckehard Schöll "Delay-induced chimeras in neural networks with fractal topology"	Rico Berner "Self-organization on complex oscillator networks with adaptive coupling"	Maximiliano Contreras "Complete synchronization emergence under advection"
16:40-17:00	Ilona Kosiuk "Geometric singular perturbation theory meets cell biology: new challenges and recent advances"	Jens Christian Claussen "Sleep bout statistics from sleep depth diffusion models: including a REM step and its influence on the distributions"	Iryna Omelchenko "Chimera control in small networks"	Alexandre Mermillod-Blondin "Diagnostics of fs-laser induced plasma formation in bulk fused silica with the help of low-order harmonic emission"
17:00-17:20	Daniele Avitabile "Canards and slow passage through bifurcations in infinite-dimensional dynamical systems"	Florian Stelzer "Performance boost of time-delay reservoir computing by non-resonant clock cycle"	Sarbendu Rakshit "Intralayer synchronization in evolving multiplex hypernetworks"	Giovanni Filatrella "Josephson junctions for signal detection "
17:20-17:40	Mathieu Desroches "Canards in excitatory networks and their mean-field limits"	Jan Sieber "Temporal dissipative solitons and their spectrum"	Sarika Jalan "Impact of multiplexing on spatiotemporal dynamical patterns in networks: Role of inhibition"	Ertugrul Karaca "AB initio study of superconductivity and electron-phonon interaction in the tetragonal BiLi"
17:40-18:00	Panagiotis Kaklamanos "Geometry of an extended prototypical three-timescale system: bifurcations of mixed-mode oscillations"	Arindam Saha "Extreme events in delay-coupled relaxation oscillators" — Cancelled	Saptarshi Ghosh "Taming chimera state using heterogeneous delays"	Aritra Mukhopadhyay "Dimensional coupling induced current reversal in two-dimensional driven lattices"

XXXIX. Dynamics Days Europe, University of Rostock, Germany, Friday, September 6, 2019

Sept. 06, 2019	Auditorium Maximum (AM)	Arno-Esch-Hörsaalgebäude I (AE1)	Arno-Esch-Hörsaalgebäude II (AE2)
08:00 – 09:00			
09:00 – 09:45	Eduard Feireisl (Prague) 38		
09:45 – 10:30	Daniela Rupp (Zurich) 39		
10:30 – 11:00	Posters & Coffee break		
11:00 – 11:20	Ilia Kashchenko (C8-AM.1), p. 121	Tatsuya Iwase (C8-AE1.1), p. 122	Denis Goldobin (C8-AE2.1), p. 123
11:20 – 11:40	Agnes Fülöp (C8-AM.2), p. 121	Atsushi Kawamoto (C8-AE1.2), p. 122	Sebastian Eydam (C8-AE2.2), p. 123
11:40 – 12:20	Hinke Osinga (Auckland) 40		
12:30 – 14:00	Posters, Lunch break & discussion		
14:00 – 18:00	departure		

Friday

9:00-9:45	Eduard Feireisl: "On solving ill-posed problems"
9:45-10:30	Daniela Rupp: "Imaging ultrafast dynamics in helium nanodroplets"

	Session C8-AM	Session C8-AE1	Session C8-AE2
11:00-11:20	Ilia Kashchenko "The dynamics of equation with large state-dependent delay"	Tatsuya Iwase "Decentralized topology optimization implemented as a self-organization of multi-agent systems"	Denis Goldobin "Macroscopic reductions for oscillator populations beyond Ott-Antonsen ansatz"
11:20-11:40	Agnes Fülöp "Chaoticity of the non-Abelian gauge field theory on lattice considering the complexity"	Atsushi Kawamoto "Collective motion pattern analysis on self-propelled particles using Rayleigh-Morse models"	Sebastian Eydam "Mode-locked solutions in systems of globally-coupled phase oscillators"

11:40-12:20	Hinke Osinga: "Robust chaos: a tale of blenders, their computation, and their destruction"

1 Invited Presentations

Monday, September 02, 2019

09:00 – 09:45 Joachim Burgdörfer, p. 29
Vienna University of Technology (Austria)
Thermalization and Quantum Chaos

09:45 – 10:30 Arnd Scheel, p. 29
University of Minnesota (USA)
Growing stripes

14:00 – 14:45 David Leitner, p. 30
University of Nevada (USA)
Mapping energy transport networks in proteins

Tuesday, September 03, 2019

09:00 – 09:45 E. K. U. Gross, p. 31
Max-Planck-Institute of Microstructure Physics, Halle (Germany)
and *Fritz Haber Center, Institute of Chemistry,*
The Hebrew University Jerusalem (Israel)
Potential energy surfaces and Berry phases from the exact factorization: A rigorous approach to non-adiabatic dynamics

09:45 – 10:30 Stuart Althorpe, p. 32
University of Cambridge (UK)
Real-time dynamics from imaginary-time path-integrals: theory and practice

14:00 – 14:45 Peter Szmolyan, p. 32
Vienna University of Technology (Austria)
Geometric singular perturbation theory beyond the standard form

14:45 – 15:30 Constantinos Siettos, p. 33
University of Naples Federico II, Department of Applied Mathematics and Applications (Italy)
To the infinity and beyond: Some ODEs and PDEs case studies

Wednesday, September 04, 2019

09:00 – 09:45 Jeroen Lamb, p. 33
Imperial, London (UK)
Bifurcations in random dynamical systems

09:45 – 10:30 Just Herder, p. 34
Delft University of Technology (The Netherlands)
Towards dynamic synthesis in compliant mechanisms

starts 18:00 Poul Hjorth, p. 34
Technical University of Denmark (Denmark)
Big grants and big data

Thursday, September 05, 2019

09:00 – 09:45 Andreas Daffertshofer, p. 35
Vrije Universiteit Amsterdam (The Netherlands)
Phase reduction of network dynamics of coupled oscillators

09:45 – 10:30 Bettina Keller, p. 36
Freie Universität Berlin (Germany)
Markov models for biomolecular systems

14:00 – 14:45 Sebastian Wieczorek, p. 37
University College Cork (Ireland)
Rate-induced tipping points: Beyond classical bifurcations

14:45 – 15:30 Wolfram Just, p. 38
Queen Mary University of London (UK)
Control of pedestrian flows: Social dynamics beyond modelling

Friday, September 06, 2019

09:00 – 09:45 Eduard Feireisl, p. 38
Czech Academy of Sciences, Prag (Prag, Czech Republic)
On solving ill-posed problems

09:45 – 10:30 Daniela Rupp, p. 39
ETH Zürich (Switzerland)
Imaging ultrafast Dynamics in Helium Nanodroplets

11:40 – 12:20 Hinke Osinga, p. 40
The University of Auckland, Department of Mathematics (New Zealand)
Robust chaos: a tale of blenders, their computation, and their destruction

Monday, September 02, 2019, 09:00 – 09:45 AM

Thermalization and quantum chaos

Joachim Burgdörfer
Vienna University of Technology, Institute for Theoretical Physics, Austria

Ergodic and chaotic motion in phase space were identified by Boltzmann more than a century ago as the key prerequisite to attain thermal equilibrium in classical many-body systems. The transcription of this notion to the realm of quantum mechanics has still remained a matter of lively debate. Does an isolated quantum many-body system initially prepared in a non-stationary state thermalize and, if so, what are the signatures and time scales of the approach to equilibrium? Moreover, can the notion of classical-quantum correspondence be extended to statistical mechanics of non-equilibrium systems? Is the breakdown of quantum integrability and the appearance of quantum chaos as signified by universality classes of level statistics necessary to attain thermalization?

In this talk, I will discuss the interplay between quantum chaos and thermalization for a prototypical closed Fermi-Hubbard many-body system out of equilibrium. Such systems have become accessible in experiments investigating "quenches" of ultracold gases. We probe the state of thermalization by recording the reduced one-particle density matrix (1RDM) of the impurity (or test particle) embedded in the Fermi-Hubbard system. Employing an exact diagonalization and calculating the time-evolution of the N-particle state, we address the question as to whether the 1RDM approaches the canonical distribution function considered to be the hallmark of thermalization and explore its connection to quantum chaos.

Work in collaboration with Mahdi Kourepaz, Fabian Lackner, Stefan Donsa and Iva Brezinova.

Monday, September 02, 2019, 09:45 – 10:30 AM

Growing stripes

Arnd Scheel
University of Minnesota, USA

Interfaces or boundaries affect the formation of crystalline phases in sometimes dramatic ways. Examples range from the alignment of convection roles in Benard convection perpendicular to the boundary, to the robust patterning through presomites in limb formation. In this talk, we ask how apical growth of a domain controls the formation of striped patterns in model equations such as the Allen-Cahn, the Cahn-Hilliard, and the Swift-Hohenberg equation. We show that much of the information about such apical growth processes can be summarized in what a variety that we call the moduli space, which relates the rate of growth to crystallographic parameters. The talk will discuss the connection between singularities of the moduli space, phase transitions in the growth process, and mathematical tools used in the analysis.

AM **Monday, September 02, 2019, 14:00 – 14:45**

Mapping energy transport networks in proteins

David Leitner
University of Nevada, USA

Elucidation of energy transport in proteins is central toward understanding how they function, which has motivated the development of a variety of computational and experimental techniques to map energy transport pathways. Once a network of pathways has been identified we aim to model vibrational energy transport on the network by master equation simulations. After summarizing some of the methods we have developed and applied to locate networks of energy transport in proteins, I will discuss comparisons of the results of all-atom nonequilibrium and master equation simulations of energy transport in a small protein, HP36. From that and other recent work, we have identified an interesting scaling rule relating conformational fluctuations of the protein, which can be determined by equilibrium simulations, and the rate of energy transfer across non-bonded contacts. While discussing our computational work on vibrational energy transport in proteins I will also make contact with a number of recent experimental studies.

Tuesday, September 03, 2019, 09:00 – 09:45 AM

Potential energy surfaces and Berry phases from the exact factorization: A rigorous approach to non-adiabatic dynamics

E. K. U. Gross

Max-Planck-Institute of Microstructure Physics, Halle, Germany

and

Fritz Haber Center, Institute of Chemistry, The Hebrew University Jerusalem, Israel

The starting point of essentially all modern electronic-structure techniques is the Born-Oppenheimer (BO) approximation. It not only makes calculations feasible, the motion of nuclear wave packets on the lowest BO potential energy surface often provides us with an intuitive and accurate picture of chemical reactions and, for small-amplitude motion, it yields an excellent way to determine vibrational spectra. To go beyond the adiabatic limit is notoriously difficult. Here we present a novel approach to non-adiabatic effects that is based on the exact factorization [1] of the full electron-nuclear wave function into a purely nuclear part and a many-electron wave function which parametrically depends on the nuclear configuration and which has the meaning of a conditional probability amplitude. The equations of motion for these wavefunctions lead to a unique definition of *exact* potential energy surfaces as well as *exact* geometric phases, both in the time-dependent and in the static case. We discuss a case where the exact Berry phase vanishes although there is a non-trivial Berry phase for the same system in Born-Oppenheimer approximation [2], implying that in this particular case the Born-Oppenheimer Berry phase is an artifact. In the time-domain, whenever there is a splitting of the nuclear wavepacket in the vicinity of an avoided crossing of BO surfaces, the exact time-dependent surface shows a nearly discontinuous step [3]. This makes the classical force on the nuclei jump from one to another adiabatic surface. Based on this observation, we deduce a novel mixed-quantum-classical algorithm whose unique feature is that the trajectories are coupled. Without recourse to Tully surface hopping and without any added decoherence correction, the new algorithm provides a rather accurate, (much improved over surface hopping) description of decoherence [4]. This is demonstrated for the photo-induced ring opening of oxirane [5]. We present a multi-component density functional theory [6,7] that provides an avenue to make the fully coupled electron-nuclear system tractable for very large systems. Finally, we explore the possibility of describing non-adiabatic effects in, e.g., proton transfer by R-dependent nuclear masses [8].

[1] A. Abedi, N.T. Maitra, E.K.U. Gross, Phys. Rev. Lett. **105**, 123002 (2010).

[2] S.K. Min, A. Abedi, K.S. Kim, E.K.U. Gross, Phys. Rev. Lett. **113**, 263004 (2014).

[3] A. Abedi, F. Agostini, Y. Suzuki, E.K.U. Gross, Phys. Rev. Lett. **110**, 263001 (2013).

[4] S.K. Min, F. Agostini, E.K.U. Gross, Phys. Rev. Lett. **115**, 073001 (2015).

[5] S.K. Min, F. Agostini, I. Tavernelli, E.K.U. Gross, J. Phys. Chem. Lett. **8**, 3048 (2017).

[6] R. Requist, E.K.U. Gross, Phys. Rev. Lett. **117**, 193001 (2016).

[7] Chen Li, R. Requist, E.K.U. Gross, Journal of Chemical Physics **148**, 084110 (2018).

[8] A. Scherrer, F. Agostini, D. Sebastiani, E.K.U. Gross, R. Vuilleumier, Phys. Rev. X **7**, 031035, (2017).

AM **Tuesday, September 03, 2019, 09:45 – 10:30**

Real-time dynamics from imaginary-time path-integrals: theory and practice

Stuart Althorpe
University of Cambridge, UK

Imaginary-time path-integrals or 'ring-polymers' are a long-established practical technique for simulating quantum Boltzmann statistics. More recently, they have also been used to simulate real-time dynamics, using the centroid molecular dynamics (CMD) and (thermostatted) ring-polymer molecular dynamics ((T)RPMD) methods. Here, we show that the theoretical basis of CMD and RPMD is a classical dynamics which arises when the exact quantum dynamics is represented using path-integrals and is coarse-grained to make it a smooth and differentiable function of imaginary-time. This 'Matsubara' dynamics cannot be used as a practical method (because of a severe sign problem), but can be used to critique and refine heuristic methods such as CMD and RPMD, which turn out to be approximations to Matsubara dynamics that avoid the phase. In particular, we will show how to extend quantum simulations of the infrared spectrum of liquid water and ice to lower temperatures (150 K) than hitherto possible.

AM **Tuesday, September 03, 2019, 14:00 – 14:45**

Geometric singular perturbation theory beyond the standard form

Peter Szmolyan
Vienna University of Technology, Austria

Due to the efforts of many people geometric singular perturbation theory (GSPT) has developed into a very successful branch of applied dynamical systems. GSPT has proven to be very useful in the analysis of an impressive collection of diverse problems from natural sciences, engineering and life sciences. Fenichel theory for normally hyperbolic critical manifolds combined with the blow-up method at non-hyperbolic points is often able to provide remarkably detailed insight into complicated dynamical phenomena, often even in a constructive way. Much of this work has been carried out in the framework of slow-fast systems in standard form, i.e. for systems with an a priori splitting into slow and fast variables.

More recently GSPT turned out to be useful for systems for which the slow-fast structures and the resulting applicability of GSPT are somewhat hidden. Problems of this type include singularly perturbed systems in non-standard form, problems depending singularly on more than one parameter and smooth systems limiting on non-smooth systems as a parameter tends to zero. Often several distinct scalings must be used to cover the dynamics of interest and matching of these different scaling regimes is carried out by the blow-up method.

In this talk I will survey these developments and illustrate their relevance in the context of selected models from cell biology.

Tuesday, September 03, 2019, 14:45 – 15:30 AM

To the infinity and beyond: Some ODEs and PDEs case studies

Constantinos Siettos
University of Naples Federico II, Department of Applied Mathematics and Applications, Italy

The study of mathematical models whose dynamics go to infinity -blow up- in finite time is a topic of widespread interest in many areas of mathematics and physics. We address a numerical framework [1] that, upon suitable transformations allows the system to "go beyond infinity" to the other side, with the solution becoming again not-singular and the numerical computations continuing normally. In Ordinary Differential Equations (ODE) the "crossing" of infinity can happen instantaneously; In Partial Differential Equations (PDEs) the crossing of infinity persists for a finite time, and it is also mobile in space necessitating the introduction of computational *buffer zones* in which an appropriate singular transformation is continuously (locally) detected and performed. The proposed approach could set the stage for a systematic numerical analysis of blowing up dynamics bypassing infinity in a broader range of evolution biologically and physically inspired examples.

This is joint work with Panayotis Kevrekidis (University of Massachusetts Amherst, Department of Mathematics and Statistics, Amherst, USA) and Yannis Kevrekidis (Johns Hopkins University, Department of Chemical and Biological Engineering, Department of Applied Mathematics and Statistics, Medical School, Baltimore, USA).

[1] P. G. Kevrekidis, C. I. Siettos, Y. G. Kevrekidis, Nature Comm. **8**, 1562 (2017).

Wednesday, September 04, 2019, 09:00 – 09:45 AM

Bifurcations in random dynamical systems

Jeroen Lamb
Imperial, London, UK

While topical applications increasingly rely on models of dynamical systems driven by noise, the corresponding theory for random dynamical systems still remains in its infancy. This talk surveys some recent insights into how random dynamical systems may exhibit bifurcations, i.e. qualitative changes in dynamical behaviour under the variation of parameters.

AM **Wednesday, September 04, 2019, 09:45 – 10:30**

Towards dynamic synthesis in compliant mechanisms

Just Herder
Delft University of Technology, The Netherlands

Compliant mechanisms move due to elastic deformation of slender segments. They are used extensively in precision machines and instruments but tend to suffer from undesired dynamics. Rather than designing compliant mechanisms based on kinematics and subsequently reduce undesired symptoms we aim to avoid these by considering dynamics from the outset in the design process. After developing this approach for static and dynamic balancing in linkage type mechanisms, we currently develop a similar approach for compliant mechanisms. We will show several results and discuss opportunities for further development of our approach.

Conference Dinner **Wednesday, September 04, 2019, starts 18:00**

Big grants and big data

Poul Hjorth
Technical University of Denmark, Denmark

"To Archimedes came a youth eager for knowledge.
Teach me, O master, he said, that art divine
Which has rendered so noble a service to the lore of the heavens,
And behind Uranus another planet revealed.

Truly, the sage replied, this art is divine as thou sayest,
But divine it was ere it ever the Cosmos explored,
Ere noble service it rendered the lore of the heavens,
And behind Uranus another planet revealed.
What in the Cosmos thou seest is but the reflection of God,
The God that reigns in Olympus is Number Eternal."

— K. G. J. Jacobi

Thursday, September 05, 2019, 09:00 – 09:45 AM

Phase reduction of network dynamics of coupled oscillators

Andreas Daffertshofer
Vrije Universiteit Amsterdam, The Netherlands

Phase synchronization is seminal in the study of emergent collective behavior in oscillatory networks. However, defining the phase – let alone its dynamics – can be a challenge. In this talk, common and less common techniques will be sketched to reduce (weakly coupled) oscillatory systems to networks of phase oscillators.

Many phase reduction techniques seek for a Hopf normal form description. Unfortunately, there are many difficulties when deriving the proper network normal form. Alternative analytical techniques employ time scale separation and/or averaging over cyclic variables, which may provide much intuition about the dynamical spectrum but can lack accuracy. Benefits and pitfalls of both types of techniques will be outlined. The resulting dynamics will be compared with direct numerical assessments for two classic examples: networks of Brusselators and a more elaborate model of coupled Wilson-Cowan oscillators. In both cases, the analytically derived phase dynamics can strongly depend on the employed phase reduction technique. What makes this all but trivial is that different types of phase reduction may only be suitable for different parameter ranges of the network dynamics under study.

As said, for complex networks of coupled oscillators, the concept of phase synchronization is the paradigm to investigate emergent collective phenomena. This is because the notion of phase allows for a direct and unique identification of the state of high-dimensional oscillator systems in terms of a one-dimensional variable, thus substantially facilitating subsequent analytical analyses. A vast amount of literature about modeling phase synchronization phenomena has accumulated. Oscillatory behavior of complex networks abounds on all scales. Examples range from electronic circuits to power grids, from cardiac pacemakers to circadian rhythms, from flashing fireflies to social behavior. Throughout these examples, phase oscillator networks have proven successful in describing transitions between incoherence and global synchronization. Since many of these transitions have been observed in experiments, it comes as no surprise that phase oscillator networks are still frontrunners for predicting non-trivial collective behaviors from multi-stability to chimera states. The challenges in phase reduction techniques, however, render a discussion about the predictive capacity of such models mandatory, certainly when it comes to forecasting the dynamical outcome(s) of 'real' oscillator networks.

Pietras, B., & Daffertshofer, A. (2019). *Network dynamics of coupled oscillators and phase reduction techniques.* Physics Reports. https://doi.org/10.1016/j.physrep.2019.06.001

AM **Thursday, September 05, 2019, 09:45 – 10:30**

Markov models for biomolecular systems

Bettina Keller
Freie Universität Berlin, Germany

The dynamics of large biomolecular systems, such as proteins in solution, are nonlinear and take place in an extremely high-dimensional space. Often the dynamic process can be approximated by an overdamped Langevin equation of motion in some lower-dimensional space. The resulting stochastic process is still nonlinear, but can now be analyzed in terms of a Fokker-Planck equation and the associated propagator. This approach has the enormous advantage that the matrix representations of this propagator can be estimated from realizations of the stochastic process, e.g. from classical molecular-dynamics simulations of the biomolecular system. In the past two decades, the combination of classical molecular-dynamics simulations, and estimation and analysis of the Fokker-Planck propagator have developed into a set of extremely powerful methods which are summarized under the name Markov models. I will demonstrate how to interpret the dominant eigenspectrum of the Fokker-Planck propagator as molecular motions. I will introduce a variational principle which allows one to systematically minimize the approximation error of a Markov model by designing system-adapted ansatz functions. Finally, I will briefly discuss how to account for perturbations in the potential energy function using path-reweighting methods.

Thursday, September 05, 2019, 14:00 – 14:45 AM

Rate-induced tipping points: Beyond classical bifurcations

Sebastian Wieczorek
University College Cork, Ireland

Many nonlinear systems are subject to continuously changing external conditions. For a system near a stable state (an attractor) we might expect that as external conditions change with time, the stable state will change too. In many cases the system may adapt to changing external conditions and track (adiabatically follow) the moving stable state. However, tracking may not always be possible owing to nonlinearities and feedbacks in the system. So far, the main focus has been on dangerous levels of external conditions (classical bifurcations) where the stable state turns unstable or disappears causing the system to move to a different and often undesired state. We describe this phenomenon as bifurcation-induced tipping or simply B-tipping. However, critical levels are not the only critical factor for tipping. Some systems can be particularly sensitive to how fast the external conditions change and have critical rates: they suddenly and unexpectedly move to a different state if the external input changes too fast. It happens even though the moving stable state never loses stability! We describe this phenomenon as rate-induced tipping or simply R-tipping. Being a genuine non-autonomous instability, R-tipping cannot be captured by the classical bifurcation theory and thus requires an alternative mathematical framework.

In the first part of the talk, we demonstrate R-tipping in a simple ecosystem model where environmental changes are represented by time-varying parameters. We define R-tipping as a critical transition from the herbivore-dominating equilibrium to the plant-only equilibrium, triggered by a smooth parameter shift. We then show how to complement the classical bifurcation diagram with information on nonautonomous R-tipping that cannot be captured by the classical bifurcation analysis. Specifically, we obtain tipping diagrams in the plane of the magnitude and rate of a parameter shift to uncover nontrivial R-tipping phenomena.

In the second part of the talk, we develop a general mathematical framework for R-tipping based on the concepts of thresholds, edge states and suitable compactification of the nonautonomous system. This allows us to define R-tipping in terms of connecting heteroclinic orbits in the compactified system, which greatly simplifies the analysis. We explain the key concept of threshold instability and give rigorous testable criteria for R-tipping to occur in arbitrary dimension.

AM **Thursday, September 05, 2019, 14:45 – 15:30**

Control of pedestrian flows: Social dynamics beyond modelling

Wolfram Just
Queen Mary University of London, UK

Manoeuvring of pedestrians around obstacles is very relevant for evacuations of mass events or daily commuting problems in densely populated regions. To avoid severe accidents it is relevant to get some general understanding of pedestrian behaviour. Pedestrian flows typically represent a challenging research area as they consist of a discrete structure with many degrees of freedom where well accepted models do not exist. A carefully constructed experiment is studied which represents a simplified evacuation scenario and permits the isolation and investigation of the relevant effects. For this, a long corridor with a triangular obstacle and a well defined pedestrian influx is investigated where the pedestrians have to reach the end of the corridor. The obstacle position is slowly moved under quasi-stationary conditions so that the symmetry of the problem is changed, and the flux difference of pedestrians left and right of the obstacle is investigated depending on the position of the obstacle. The experiments clearly show nonlinear effects, namely bistability and a hysteresis behaviour of the flux difference depending on the position of the obstacle. In addition to the stable states, this indicates the existence of unstable pedestrian flow states which separate the two stable states. Mathematical methods to analyze these states directly in the experiment will be discussed. This is a model-free approach to analyze the social dynamics which is entirely data driven and uses concepts from control and analysis of complex dynamical systems. Based on experimental observations, this provides quantitative benchmarks to judge the quality of mathematical models for pedestrian motion.

This is joint work with Ilias Panagiotopoulos (University of Rostock) and Jens Starke (University of Rostock).

AM **Friday, September 06, 2019, 09:00 – 09:45**

On solving ill-posed problems

Eduard Feireisl
Czech Academy of Sciences, Prag, Czech Republic

Certain problems in fluid dynamics concerning inviscid fluids are desperately ill-posed. We discuss solvability of the compressible Euler system, several concepts of generalized solutions, and their numerical approximations. In particular, we propose a new method of computing oscillatory solutions based on the concept of K-convergence.

Friday, September 06, 2019, 09:45 – 10:30 AM

Imaging ultrafast dynamics in helium nanodroplets

Daniela Rupp
ETH Zürich, Switzerland
and
Max-Born-Institute Berlin, Germany

With the extremely intense short-wavelength pulses of free-electron lasers (FELs) and high harmonic sources (HHG) novel experiments with highest spatial and temporal resolution become possible. One key example is diffraction imaging of individual nanoparticles. Here, the elastically scattered photons form an interference pattern which encodes structural information. This enables the in-situ study of such fragile structures as combustion aerosols or superfluid helium nanodroplets and time-resolved investigations of ultrafast dynamics like e.g. laser induced ultrafast melting in metal nanoparticles. Even the changes in the electronic structure due to excitation and ionization alter the scattering response and can therefore in principle be traced [1]. While electron dynamics occur on a timescale shorter than the typical tens of femtosecond pulse durations, an exciting development can be expected from the current progress at both FEL and HHG sources towards high-intensity attosecond pulses.

In my talk I will present static and time-resolved diffraction experiments on helium nanodroplets using extreme ultraviolet (XUV) pulses. The comparably long wavelengths allow for the measurement of wide-angle diffraction patterns that contain three-dimensional information [2], thus enabling the structural characterization of superfluid spinning droplets [3,4]. To trace the XUV induced dynamics in helium nanodroplets, we have developed a novel concept using two XUV pulses of different wavelengths for capturing consecutive images of the same droplet. Further, ultrafast bleaching effects were observed in helium nanodroplets irradiated with moderately intense infrared laser pulses (10^{11} W/cm^2) and imaged with near-resonant HHG pulses. Both results exemplify the capability of diffraction imaging to visualize ultrafast nanoscale dynamics in highly excited matter.

[1] C. Bostedt et al. *Ultrafast X-ray scattering of xenon nanoparticles: imaging transient states of matter*, Phys. Rev. Lett. **108**, 093401(2012)

[2] I. Barke et al. *The 3D-architecture of individual free silver nanoparticles captured by X-ray scattering*, Nat. Commun. **6**, 6187 (2015)

[3] D. Rupp et al. *Coherent diffractive imaging of single helium nanodroplets with a high harmonic generation source*, Nat. Commun. **8**, 493 (2017)

[4] B. Langbehn et al. *Three-dimensional shapes of spinning helium nanodroplets*, Phys. Rev. Lett. **121**, 255301 (2018)

AM **Friday, September 06, 2019, 11:40 – 12:20**

Robust chaos: a tale of blenders, their computation, and their destruction

Hinke Osinga
The University of Auckland, Department of Mathematics, New Zealand

Joint work with Stephanie Hittmeyer and Bernd Krauskopf (University of Auckland) and Katsutoshi Shinohara (Hitotsubashi University).

A blender is an intricate geometric structure of a three- or higher-dimensional diffeomorphism. Its characterising feature is that its invariant manifolds behave as geometric objects of a dimension that is larger than expected from the dimensions of the manifolds themselves. We introduce a family of three-dimensional Hénon-like maps and study how it gives rise to an explicit example of a blender. The map has two saddle fixed points. Their associated stable and unstable manifolds consist of points for which the sequence of images or pre-images converges to one of the saddle points; such points lie on curves or surfaces, depending on the number of stable eigenvalues of the Jacobian at the saddle points. We employ advanced numerical techniques to compute one-dimensional stable and unstable manifolds to very considerable arclengths. In this way, we not only present the first images of an actual blender but also obtain a convincing numerical test for the blender property. This allows us to present strong numerical evidence for the existence of the blender over a larger parameter range, as well as its disappearance and geometric properties beyond this range. We will also discuss the relevance of the blender property for chaotic attractors.

2 Mini-Symposia

M1-AM: Nonlinearities and self-organization in musical acoustics

Organizer:

Rolf Bader, *Institute of Systematic Musicology, University of Hamburg, Germany*

Speaker:

Jost Leonhardt Fischer, *Institute of Systematic Musicology, University of Hamburg, Germany*
Rolf Bader, *Institute of Systematic Musicology, University of Hamburg, Germany*
Simon Linke, *Hamburg University of Applied Sciences, Germany*

Outline of minisymposium:

Most musical instruments are self-organizing systems, which cause harmonic overtone spectra of wind or bowed string instruments. Further, it is essential for the slaving of a resonance box by a string, which can be observed when examining string instruments. Thus, self-organization is crucial for making musical instruments usable at all. Additionally, many nonlinearities contribute to musical salient features, like bifurcations and multiphonics with wind instruments leading to large articulatory possibilities, nonlineardistortion due to viscoelasticity and nonlinear material behavior leading to roughness and brightness, or chaoticity in initial transients leading tomusical instrument identification. The Minisymposium discusses examples and presents general models, simulations and experimental results in this field.

M1-AM.1 **Monday, September 02, 2019, 11:00 – 11:20**

Shock wave characteristics in the initial transient of wind instruments

Jost Leonhardt Fischer
Institute of Systematic Musicology, University of Hamburg, Germany

In this comparative study we investigate the initial transients of different wind instruments. The instruments, bass instruments, are built by the manufacture Vogt Instruments in Leipzig. The instruments are the piccolo trumpet, the trumpet, the trombone, the French horn, the baritone horn and the tuba. The high precision measurements of the initial transient show propagating wave fronts with special characteristics. The speed of the wave front maxima are slightly but significant higher than the speed of sound. The phase portraits of the measured time series show a nonlinear behavior in the initial transient. The SPL-spectra show the mix of higher harmonics as well as their damping behavior along the mic-array. The results of the measurements lead to a new model of sound field generation in wind instruments.

M1-AM.2 **Monday, September 02, 2019, 11:20 – 11:40**

Viscoelastic memory effect as cause of musical instrument spectral flux and musical liveliness

Rolf Bader
Institute of Systematic Musicology, University of Hamburg, Germany

The internal damping of materials used for musical instruments, like wood, leather, or artificial polymers is highly complex, both in time and frequency. Here the measured spectral flux, like amplitude fluctuations, side bands, or mode couplings contributes strongly to the liveliness and character of the instruments. The main cause of such internal damping is viscoelasticity. Existing physical models of musical instruments, used for computational sound production as well as analysis for researchers and instrument builders are not able to model complex damping spectra. As a novel approach a Viscoelastic Finite-Difference Time Domain (FDTD) physical model of a drum and a piano soundboard is implemented on a Graphics Processing Unit (GPU), which models musical instruments with complex damping behaviour. A Laplace transform is used to integrate the acceleration of the complex Young's modulus and complex tension in time. The model shows that it is the acceleration memory intrinsic to viscoelasticity that leads to amplitude fluctuations, side bands, as well as to a highly nonlinear dependency of the fitted damping exponent with the input Laplace parameter.

Monday, September 02, 2019, 11:40 – 12:00 M1-AM.3

Describing minimum bow force using Impulse Pattern Formulation (IPF) – an empirical validation

Simon Linke
Hamburg University of Applied Sciences, Germany

In the acoustics of bowed string instruments, the necessary minimum bow force has been an often-discussed question in the last hundred years. If the bowing force is too small (or the bowing velocity too large) no stable tone production is possible and bifurcations or noise occur due to the restoring force of the string. The Impulse Pattern Formulation (IPF) is a top-down method proposed previously (Bader, R.: Nonlinearities and Synchronization in Musical Acoustics and Music Psychology, 2013) which can explain such transitions between regular periodicity at nominal pitch, bifurcation scenarios, and noise. This recursive equation assumes musical instruments to work with impulses which are produced at a generator, travel through the instrument, are reflected at various positions, are exponentially damped and finally trigger or at least interact with succeeding impulses produced by the generator.

A self-organised bowing pendulum is used to measure transitions from bifurcation to stable tone production as well as the underlying bowing pressure and velocity. Further the IPF is used to reproduce this behaviour. Here its input-parameters in respect of the measured bowing pressure and velocity are determined using simulated annealing. Thus, a dynamical model of the complex transient behaviour of a bowed string is obtained, rather than an analytical expression for a quasi-stationary minimum bow force.

M2-AE1: Chaotic and nonlinear dynamics for ICT

Organizer:

Satoshi Ebisawa, *Institute of Technology, Niigata Institute of Technology*
Fumiyoshi Kuwashima, *Fukui University Technology*

Speaker:

Fumiyoshi Kuwashima, *Fukui Univ. of Tech., Japan*
Satoshi Ebisawa, *Niigata Institute of Technology, Japan*
K. I. Amila Sampath, *Tokyo University of Science, Japan*
Takashi Isoshima, *RIKEN-CPR, Japan*

Outline of minisymposium:

The proposed mini-symposium aims at presenting some recent theoretical and experimental progresses on chaotic and nonlinear dynamics related to information and communication technology (ICT).

Instability and nonlinear dynamics have received a lot of attention in recent years because of their potential application to ICT. Various unstable or nonlinear behaviors have been studied to modify stable or controllable systems for improvement of properties and creation of emergent novel functionalities. Understanding of similarities and differences among those nonlinearities will stimulate further studies in these research fields.

In this mini-symposium, we focus on ICT and make cross-sectoral discussions on chaos, randomness, bistability and nonlinearity in their dynamics including the following topics; nonlinear dynamics of semiconductor lasers for chaos generation and its application to THz wave generation and chaos synchronization for telecommunication; nonlinearity of Brillouin scattering; chaotic and random dynamics; optical bistability for natural computing.

M2-AE1.1 **Monday, September 02, 2019, 11:00 – 11:20**

Stable THz wave generation using laser chaos

Fumiyoshi Kuwashima
Fukui Univ. of Tech., Japan

Stable and wide range THz waves are obtained from the chaotically oscillated multimode-laser diode excited photoconductive antennas. This system is a cheap system, and this THz wave is suitable for spectroscopy.

Monday, September 02, 2019, 11:20 – 11:40 M2-AE1.2

Chaotic oscillation of laser diode with optical injection and pseudorandom drive current

Satoshi Ebisawa
Niigata Institute of Technology, Japan

We numerically studied the chaotic dynamics of a laser diode (LD) system with optical injection and drive current modulated by a pseudorandom signal, and found that the orbital instability is enhanced by applying a pseudorandom signal to the master and slave LDs when the inherent system without the applied signal is a "window". Then, we also described the response of the orbital instability to the frequency range of the applied signal to show the proper spectra of the signal for enhancing the orbital instability.

Monday, September 02, 2019, 11:40 – 12:00 M2-AE1.3

Electrically wavelength-tunable light source by means of stimulated Brillouin scattering in single-mode fibers

K. I. Amila Sampath
Tokyo University of Science, Japan

Recently, wavelength tunable light sources have gained a considerable research interest because of their potential applications in a number of fields such as information and communication technology, biomedical engineering, meteorology, etc. Conventionally, a tunable light source is a fragile device because it relies on mechanical wave-selective elements such as an external grating or Fabry-Perot etalon. We proposed an electrically-tunable three-wavelength light source which consists of an optical intensity modulator and a fiber loop.

In the presentation, we will discuss the performances of the proposed light source for data transmission.

Monday, September 02, 2019, 12:00 – 12:20 M2-AE1.4

Control of wavefront propagation properties for natural computing in two-dimensional optical bistable devices

Takashi Isoshima
RIKEN-CPR, Japan

Bistable system with a spatial expanse can support traveling wavefronts, i.e. interfaces between two stable states (ex. "on" and "off"). We investigate a two-dimensional optical bistable device (2DOBD) for natural computing including maze exploration. We have reported that our device can present not only extension of "on"-state area, but also reduction mode in which "on"-state area retreats from a dead-end path by controlling the light intensity. In this presentation, we will report a 'phase map' of wavefront propagation, showing controllability of propagation properties by the light intensity and the path width.

M3-AM: Structure and dynamics of future power grids

Organizer:

Simona Olmi, *INRIA Sophia Antipolis, France & CNR, Sesto Fiorentino, Italy*
Katrin Schmietendorf, *ForWind Universität Oldenburg & Universität Münster, Germany*
Oliver Kamps, *Center for Nonlinear Science Universität Münster, Germany*
Eckehard Schöll, *TU Berlin, Institut für Theoretische Physik, Germany*

Speaker:

Marc Timme, *Network Dynamics / TU Dresden, Germany*
Michael Fette, *Fette – Competence in Energy GmbH, Paderborn, Germany*
Philipp Maaß, *Osnabrück University, Department of Physics, Germany*
Pere Colet, *Instituto de Física Interdisciplinar y Sistemas Complejos, iFISC (CSIC-UIB), Spain*
Christian Beck, *Queen Mary, University of London, School of Mathematical Sciences, UK*
Benjamin Schäfer, *TU Dresden & Queen Mary, University of London, School of Mathematical Sciences, United Kingdom*
Philippe Jacquod, *University of Geneva / University of Applied Sciences of Western Switzerland, Switzerland*
Leonardo Rydin, *Institute for Theoretical Physics, Uni. Köln / Forschungszentrum Jülich - IEK-STE, Germany*
Carl Hendrik Totz, *TU Berlin, Germany*
Anton Plietzsch, *Potsdam Institute for Climate Impact Research, Germany*
Johannes Schiffer, *Brandenburgische Technische Universität Cottbus-Senftenberg, Fachgebiet Regelungssysteme und Netzleittechnik, Germany*
Melvyn Tyloo, *Univesity of Applied Science of Western Switzerland, HES-SO Valais/Wallis and Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland*
Martin Greiner, *Aarhus University, Department of Engineering, Denmark*
Stefan Kettemann, *Jacobs University Bremen, Germany*
Franz Kaiser, *Forschungszentrum Jülich, Institute of Energy and Climate Research, Systems Analysis and Technology Evaluation, Germany*
Halgurd Taher, *Inria Sophia Antipolis Méditerranée Research Centre, France*
Philipp Böttcher, *DLR-Institut für Vernetzte Energiesysteme, Oldenburg, Germany*

Outline of minisymposium:

The Paris Conference in 2015 set a path to limit climate change below 2 degrees: to reach this goal, integrating renewable and sustainable energy sources into the electrical power grid is essential. Wind and solar power are the most promising contributors to reach a sustainable energy supply but their integration into the existing electric power system remains an enormous challenge.

The central observable in power grid monitoring, operation, and control is the grid frequency: primary control on short time scales to stabilize the grid frequency and secondary control on longer time scales to restore the nominal grid frequency are both fundamental. The increase of renewable energy challenges this central control paradigm, as generation becomes more volatile and the spinning reserve decreases. How to provide additional effective inertia is an open question. In addition, fluctuating demand and fixed trading intervals already contribute to frequency deviations.

In this minisymposium we focus on recent developments with future promising perspectives, e.g., how the collective grid dynamics is driven by fluctuations originating from varying power demands, fluctuating power input, and trading; how the dynamics changes according to decentralization, topological modification, patterns in the network topology and how power quality and grid stability can be improved by novel storage and control concepts.

Monday, September 02, 2019, 14:50 – 15:10 M3-AM.01

Detecting state space dimensionality (and network size) from time series of few variables

Marc Timme

Network Dynamics / TU Dresden, Germany

Knowing the interaction topology and state of a network dynamical system crucially underlies its collective function [1]. Specifically, the number N of dynamical variables making up a system arguably constitutes one of its most fundamental properties. Typically, however, N is unknown, because only a small subset of $n \ll N$ variables is perceptible. For instance, in power grids in which switches can be open or closed, the size of its connected components reveal information about switch states. Here we introduce a detection matrix that suitably arranges repeatedly observed time series to detect N via matching rank constraints [2]. The proposed method relies on basic linear algebra and as such is model-free, applicable across system types and interaction topologies, and nonstationary dynamics near fixed points. We further offer extensions to periodic and chaotic collective motion. Even if only a small minority of variables is observable and for systems simultaneously exhibiting nonlinearities, heterogeneities, and noise, exact detection is feasible.

[1] Marc Timme & Jose Casadiego, Revealing networks from dynamics: an introduction, J. Phys. A: Math. Theor. **47**:343001 (2014).

[2] Hauke Haehne et al., Detecting Hidden Units and Network Size from Perceptible Dynamics, Phys. Rev. Lett. **122**:158301 (2019).

M3-AM.02 **Monday, September 02, 2019, 15:10 – 15:30**

Bifurcational analysis of power system characteristics – Comparison to measurements in practical applications

Michael Fette
Fette – Competence in Energy GmbH, Paderborn, Germany

Power Systems are highly nonlinear systems, which are capable to exhibit complex dynamics like collapse and swing phenomena. In recent years, many efforts have been made by researchers and operators in order to prevent and control these effects. It is well known that parameter variations may change the structural behavior of a system, which changes the behavior of a system in time and its stability.

Nevertheless, the decarbonization of power industry leads to the situation, that renewable sources will be used in combination with storages and intelligent load control much more. Big power plants will be shut down due to political and economic reasons.

With that, power systems will be changed in behavior and characteristics, more dramatically than ever known. Classical electric machines are substituted by converter driven sources. To ensure the operability of these systems, e.g. in Europe new grid codes are established in the last years, which take the changing process into account. The most important change in comparison to the "old" rules is, that now the small plants – located in medium and low voltage level, must take the lead and be an active part in grid operation to ensure stability and quality parameters.

Intensive analysis of nonlinear power system models had been done, to find out, what is different to the past situation and what must be done to guide this transition process. At the moment we have both, bulk power systems in combination with "stupid" decentralized sources.

As a result of our research, we defined new classes of grid analysis measurement devices, manufactured them to compare theoretical results with measurements of real systems. Analyses of grid dynamics in the frequency range from 5 mHz up to 9 kHz in very small steps in a period of more than 10 years. We can measure the "frequency patterns", which received by theoretical research formerly. Up to now, measurements in more than 300 cases, grid dynamics in power systems, industrial areas, households, in all voltage areas, including HVDC-systems, analyzed them, mostly to overcome formerly unknown failure behavior or to develop new control strategies.

The contribution will show some theoretical results from bifurcational analysis, associated measurements and will give an outlook of the second generation of measurement and rating system based on Key Reliability Indicators (KRI).

Monday, September 02, 2019, 15:30 – 16:00 M3-AM.03

Short-term power grid stability under stochastic feed-in of renewable energy sources

Philipp Maaß
Osnabrück University, Department of Physics, Germany

We present recent results of the short-term stability of power grids under stochastic feed-in of renewable energy sources. The focus will be on the questions how the grid modeling level and how spatial correlations of the stochastic energy input affect statistical measures for the frequency stability, and for risks of transmission line overloading and cascading failures. Our analysis is based on the swing equations for the voltage phase angles, whose time evolution is driven by the instantaneous imbalance of mechanical and electrical powers. Heterogeneities in transmission line and node properties are taken into account as well as reactances between points of power production/consumption (internal nodes) and power injection/ejection (terminal nodes). These reactances leads to a coupling matrix of a complete graph with linkages between all node pairs. It is shown that the assessment of grid stability is strongly influenced by the grid modeling level and that simplifications, as, e.g., implied by assuming homogeneous line and node properties, can lead to misleading conclusions [1]. Spatial correlations of the power input are a relevant stability factor and could be utilized for a smart integration of renewables [2].

This is joint work with Pedro G. Lind (Department of Physics, Osnabrück University, Germany; Department of Computer Science, Oslo Metropolitan University, Norway) and Matthias F. Wolff (Department of Computer Science, Oslo Metropolitan University, Norway).

[1] M. F. Wolff, P. G. Lind, and P. Maass, Chaos **28**, 103120 (2018)

[2] [2] C. Schiel, P. G. Lind, and P. Maass, Sci. Rep. **7**, 11562 (2017)

M3-AM.04 **Tuesday, September 03, 2019, 11:00 – 11:20**

Power grid frequency fluctuations and smart devices with dynamic demand control

Pere Colet
Instituto de Física Interdisciplinar y Sistemas Complejos, iFISC (CSIC-UIB), Spain

Power grid frequency control is a demanding task requiring expensive idle power plants to adapt the supply to the fluctuating demand. An alternative approach is controlling the demand side in such a way that certain appliances modify their operation to adapt to the power availability. This is especially important to achieve a high penetration of renewable energy sources. A number of methods to manage the demand side have been proposed. In this work we focus on dynamic demand control (DDC), where smart appliances can delay their switchings depending on the frequency of the system. We introduce a simple model to study the effects of DDC on the frequency of the power grid. This includes the power plant equations, a stochastic model for the demand that reproduces, adjusting a single parameter, the statistical properties of frequency fluctuations measured experimentally, and a generic DDC protocol. We find that DDC can reduce small and medium-size fluctuations but it can also increase the probability of observing large frequency peaks due to the necessity of recovering pending task. Although these events are very rare they can potentially trigger a failure of the system and therefore strategies to avoid them have to be addressed. Therefore we also introduce a protocol for communication among DDC devices belonging to a given group, such that they can coordinate opposite actions to keep the group demand more stable. We show that this protocol reduces the amount of pending tasks by a factor 10 while large frequency fluctuations are significantly reduced or even completely avoided. We also study the influence of the grid topology in the shape of the power spectrum of the electrical frequency fluctuations.

M3-AM.05 **Tuesday, September 03, 2019, 11:20 – 11:40**

Superstatistical methods for power grids

Christian Beck
Queen Mary, University of London, School of Mathematical Sciences, UK

The superstatistics concept is a very general concept for driven nonequilibrium systems in statistical physics and hydrodynamic turbulence, but it can also be usefully applied to experimental time series that are relevant to understand the changing demand and production patterns in power grids. In this talk I will concentrate on how to extract relevant superstatistical parameters from a given experimentally measured time series. Main examples considered will be measured frequency fluctuations in various European power grids, wind velocity fluctuations, and pollution statistics.

Tuesday, September 03, 2019, 11:40 – 12:00 M3-AM.06

Power grid frequency: data-driven and statistical analysis

Benjamin Schäfer
TU Dresden & Queen Mary, University of London, School of Mathematical Sciences, United Kingdom

The Paris conference 2015 set a path to limit climate change to 'well below 2°C'. To reach this goal, integrating renewable energy sources into the electrical power grid is essential but poses an enormous challenge to the existing system, demanding new conceptional approaches. In this talk, I will stress the need for data-driven approaches to understand the energy system. In particular, I present our latest research on power grid fluctuations and how they threaten robust grid operation. For our analysis, we collected frequency recordings from power grids in North America, Europe and Japan, noticing significant deviations from Gaussianity. We developed a coarse framework to analytically characterize the impact of arbitrary noise distributions as well as a superstatistical approach. Overall, we identified energy trading as a significant contribution to today's frequency fluctuation and effective damping of the grid as a controlling factor enabling reduction of fluctuation risks.

Tuesday, September 03, 2019, 12:00 – 12:20 M3-AM.07

Optimal placement of inertia and primary control in high voltage power grids

Philippe Jacquod
University of Geneva / University of Applied Sciences of Western Switzerland, Switzerland

The increasing penetration of inertialess new renewable energy sources raises a number of issues of power grid stability over short to medium time scales. It has been suggested that the resulting reduction of overall inertia can be compensated to some extent by the deployment of substitution inertia - synthetic inertia, flywheels or synchronous condensers. Of particular importance is to optimize the placement of the limited available substitution inertia, to mitigate voltage angle and frequency disturbances following a fault such as an abrupt power loss. Performance measures in the form of H_2-norms have been recently introduced to evaluate the overall magnitude of such disturbances on an electric power grid. However, despite the mathematical convenience of these measures, analytical results can be obtained only under rather restrictive assumptions of uniform damping ratio, or homogeneous distribution of inertia and/or primary control in the system. Here, we introduce matrix perturbation theory to obtain analytical results for optimal inertia and primary control placement under the assumption that both are moderately heterogeneous. Armed with that efficient tool, we construct two simple algorithms that independently determine the optimal geographical distribution of inertia and primary control. These algorithms are then implemented on a model of the synchronous transmission grid of continental Europe.

M3-AM.08 **Tuesday, September 03, 2019, 16:00 – 16:20**

Tackling stability for conventional and inverter-based power grids in the presence of resistive terms

Leonardo Rydin
Institute for Theoretical Physics, Uni. Köln / Forschungszentrum Jülich - IEK-STE, Germany

Electrical power-grid system stability is essential to provide a robust power supply to all consumers. Dynamic stability is assessed for generator models of different levels of detail and complexity, coupled via the electric power grid. Higher-order models can describe the voltage and rotor-angle dynamics with great accuracy, but can typically only be tackled computationally due to the dimensionality of the equations and the size of the networks. A common assumption is to ignore the resistive terms, i.e., line losses and other ohmic elements. We derive strict mathematical criteria for the stability of the dynamics of power grids comprised of synchronous machines, without any assumptions on line losses or the topological structure of the network. These criteria entail a greater detail on the fundamental criteria required to safely operate power grids, in particular not discarding the influence of dissipative effects. The generality of the results also permits a flexible application of the criteria to systems of similar nature, for example, inverter-based power systems, which are particularly relevant for microgrid systems where resistivity is non-negligible. These results are particularly important for the ongoing transition into a more renewable-energy based power system, incorporating a growing number of zero-inertial generators in the power grid. The stability criteria obtained for the conventional and inverter-based power grids can uncover weaknesses and bottlenecks in this transition to a environment of growing renewable generation.

M3-AM.09 **Tuesday, September 03, 2019, 16:20 – 16:40**

Control of synchronization in two-layer power grids

Carl Hendrik Totz
TU Berlin, Germany

The dynamics of a two-layer network modeling the Italian high voltage power grid is investigated: the first layer represents the generators and consumers, while the second layer represents a dynamic communication network between generators that serves as controller of the first layer. The dynamics of the power grid is modeled by the Kuramoto model with inertia, while the second layer provides a control signal for each generator to improve frequency synchronization within the power grid.

We investigate different realizations of the communication layer topology and different control methods. The two-layer system is tested for different perturbation scenarios (disconnecting some generators, increasing demand of consumers, generators with stochastic output) and, irrespectively of the applied perturbation, we find that the control scheme aimed to synchronize the frequency of the generators with the consumers is very efficient against almost all perturbation scenarios.

Tuesday, September 03, 2019, 16:40 – 17:00 M3-AM.10

A generalized linear response theory for renewable fluctuations in lossy microgrids

Anton Plietzsch
Potsdam Institute for Climate Impact Research, Germany

A central requirement in the operation of power grids is the stability of the grid frequency at 50 or 60Hz. In the language of theoretical physics this can be phrased as the question whether a networked system of inertial oscillators stays close to synchrony in the presence of disturbances or fluctuating energy infeed at the nodes.

In this talk I will present a generalised linear response theory for network dynamical systems. It is shown how external fluctuations with arbitrary power spectra couple to the eigenmodes of the system.

This theory can then be applied to the example case of renewable power fluctuations in AC microgrids to calculate the variance of the frequency deviations from the nominal frequency. I will show that in midvoltage grids the power flow losses on resistive lines play an important role in creating certain response patterns that mainly depent on the network structure of the grid.

Especially the slowest network mode reveals a strong asymmetry of the response dynamics that yields classes of nodes with enhanced vulnerability to external fluctuations (troublemaker nodes). It is shown that for microgrids with low inertia and radial structure this particular mode is dominant and the vulnerability is strongly connected to the power flow in the grid.

Tuesday, September 03, 2019, 17:00 – 17:20 M3-AM.11

Almost global synchronization in droop-controlled microgrids - a multivariable cell structure approach

Johannes Schiffer
Brandenburgische Technische Universität Cottbus-Senftenberg, Fachgebiet Regelungssysteme und Netzleittechnik, Germany

Conditions for existence of invariant solutions and almost global synchronization in droop-controlled microgrids with radial electrical network topology are provided. This is achieved by first establishing a necessary and sufficient condition for existence of equilibria as well as characterizing their local stability properties. Subsequently, sufficient conditions for almost global synchronization are derived by means of the recently proposed multivariable cell structure approach. The latter is an extension of the powerful cell structure principle developed by Leonov and Noldus to nonlinear systems that are periodic with respect to several state variables and possess multiple invariant solutions. The analysis is illustrated via a numerical example.

M3-AM.12 **Tuesday, September 03, 2019, 17:20 – 17:40**

The key player problem in realistic large-scale power grids

Melvyn Tyloo

Univesity of Applied Science of Western Switzerland, HES-SO Valais/Wallis and Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Identifying key players in a set of coupled individual systems is a fundamental problem in network theory. Its origin can be traced back to social sciences, where the problem led to ranking algorithms based on graph theoretic centralities. Coupled dynamical systems differ from social networks in that, first, they are characterized by degrees of freedom with a deterministic dynamics and second the coupling between individual systems is a well-defined function of those degrees of freedom. Additionally focusing on high voltage electric power grids, dynamical parameters such as the inertia and the damping parameters widely vary between different individual systems. One therefore expects the coupled dynamics as well as these dynamical parameters, and not only the network topology, to determine the key players. In this talk, I investigate synchronizable network-coupled dynamical systems, focusing on high voltage electric power grids. I search for network nodes which, once perturbed by a local noisy disturbance, generate the largest overall transient excursion away from synchrony. A spectral decomposition of the network coupling matrix leads to an elegant, concise, yet accurate solution to this identification problem. We show that these key players are peripheral in the sense of a centrality measure defined from effective resistance distances. The latter depend on various network matrices which, according to the situation considered, are weighted by the inertia or the damping parameters.

Tuesday, September 03, 2019, 17:40 – 18:00   M3-AM.13

Renewable energy networks

Martin Greiner
Aarhus University, Department of Engineering, Denmark

In view of climate change and a limited remaining CO_2 emission budget, a fast transformation towards a sustainable energy system is needed. The physics of networked dynamical systems is able to contribute to the solution of this grand challenge. We discuss a simple network model, which describes a future European electricity system with a high share of wind and solar power generation. The weather acts as the fluctuating driving force. Weather data covering multiple years are converted into prospective wind and solar power generation with good spatial and temporal resolution. The weather-driven network modelling represents a direct approach to obtain fundamental estimates on the required backup infrastructure of highly renewable large-scale energy systems. Estimates on the required amount of conventional backup power plants, transmission lines and storage will be given. The optimization of energy system costs will be addressed, leading to new design concepts like the optimal heterogeneity and the benefit of cooperation. Related to diffusion processes on networks, flow tracing algorithms are described, which help to clarify the nodal cost allocations. More physics-related topics like the storage singularity and the power flow renormalization will also be shortly addressed. An outlook about current research on the coupling of the different energy sectors, the design of investment roadmaps into the future as well as the impact of climate change will be given.

M3-AM.14 **Wednesday, September 04, 2019, 11:00 – 11:20**

Propagation of disturbances in power grids

Stefan Kettemann
Jacobs University Bremen, Germany

We present results on the propagation of disturbances in power grids by solving nonlinear swing equations describing coupled rotating masses of synchronous generators and motors on different grid topologies. We identify ranges of parameters with different transient dynamics: the disturbance decays exponentially in time, superimposed by oscillations with the fast decay rate of a single node, or with a smaller decay rate without oscillations [1]. Most remarkably, as the grid inertia is lowered, nodes may become correlated, slowing down the propagation from ballistic to diffusive motion, decaying with a power law in time. Applying linear response theory we show that tree grids have a spectral gap leading to exponential relaxation as protected by topology and independent on grid size. Meshed grids are found to have a spectral gap which decreases with increasing grid size, leading to slow power law relaxation and collective diffusive propagation of disturbances. We next apply the linear response theory to obtain analytical results for the variance of frequency increment distributions [2]. We find that the variance of short-term fluctuations decays, for large inertia, exponentially with distance to the feed-in node, in agreement with numerical results both for a linear chain of nodes and the German transmission grid topology. In sharp contrast, the kurtosis of frequency increments is numerically found to decay only slowly, not exponentially, in both systems, indicating that the non-Gaussian shape of frequency fluctuations persists over long ranges.

[1] Tamrakar, S. R., Conrath, M., Kettemann, S. Scientific Reports **8**, 6459 (2018).

[2] Haehne, H., Schmietendorf, K., Tamrakar, S., Peinke, J., Kettemann, S. Phys. Rev. E Rapid Communications **99**, 050301 (2019).

M3-AM.15 **Wednesday, September 04, 2019, 11:20 – 11:40**

The impact of network topology on failure spreading in power grids

Franz Kaiser
Forschungszentrum Jülich, Institute of Energy and Climate Research, Systems Analysis and Technology Evaluation, Germany

Structural perturbations can impair the stable operation of supply networks such as power grids up to the point of complete collapse. However, the role of network topology for the response to such damages is poorly understood. Here, we examine the interplay between network structure and failure spreading in detail with a special focus on power grids. We analyze the localization of failures by studying the impact of distance on the spreading and derive results on the importance of certain paths on the effect a perturbation exerts on the overall network. Our results show that it is possible to predict failure spreading in supply networks to a large extent based on purely topological measures.

Wednesday, September 04, 2019, 11:40 – 12:00 M3-AM.16

Enhancing power grid synchronization and stability through time delayed feedback control

Halgurd Taher
Inria Sophia Antipolis Méditerranée Research Centre, France

The increase of the inclusion of renewable energy sources into the power grid is rather a paradigm change for the entire European power grid, bringing new challenges for power grid operation, due to the presence of different perturbation forms into the network thus possibly harming stability and synchronization. In this talk asynchrony of single nodes in power grids is investigated using the sparsely connected German transmission grid. Based on time delayed feedback control, different control strategies are defined and compared. The strategies not only take into account solitary states, but also the Lyapunov vector corresponding to the largest Lyapunov exponent. Starting from an unstable state, lead out of synchrony, we are able to frequency synchronize and stabilize power grids by just controlling a small set of nodes. Numerical calculation of the Lyapunov spectrum allows to explore the mechanism behind the synchronization transition occurring due to the control.

Wednesday, September 04, 2019, 12:00 – 12:20 M3-AM.17

Time delay effects in the control of synchronous electricity grids

Philipp Böttcher
DLR-Institut für Vernetzte Energiesysteme, Oldenburg, Germany

The expansion of inverter connected generation facilities (i.e. wind and photovoltaics) and the removal of conventional power plants is necessary to mitigate the impacts of climate change.

Whereas conventional generation with large rotating generator masses provides stabilizing inertia, inverter connected generation does not. Since the underlying power system and the control mechanisms that keep it close to a desired reference state, were not designed for such a low inertia system, this might make the system vulnerable to disturbances.

We investigate whether the currently used control mechanisms are able to keep a low inertia system stable and how this is affected by the time delay of control.

To this end, we integrate the control mechanisms used in continental Europe into a model of coupled oscillators which resembles the second order Kuramoto model. This model is then used to investigate how the interplay of network topology, delayed control and remaining system parameters effect the stability of the interconnected power system. To identify regions in parameter space that make stable grid operation possible, the linearized system is analyzed to create the system's stability chart. We show that lower and distributed inertia could have a beneficial effect on the stability of the desired synchronous state.

M4-AE2: Phase space geometry of Hamiltonian systems and applications

Organizer:

Makrina Agaoglou, *University of Bristol, UK*

Speaker:

Francisco Gonzalez Montoya, *University of Bristol, School of Mathematics, United Kingdom*
Jezabel Curbelo, *Universidad Autónoma de Madrid - ICMAT, Spain*
Dmitry Zhdanov, *University of Bristol, School of Mathematics, United Kingdom*
Mariya Trukhanova, *M. V. Lomonosov Moscow State University, Faculty of Physics, Russia*

Outline of minisymposium:

This minisymposium is focused on the structure of the phase space and the associated transport mechanisms in Hamiltonian systems that arise in many fields of Nonlinear Dynamics like classical and quantum chemical reactions dynamics, geophysical dynamics etc.

The aim of the minisymposium is to encourage the interdisciplinary research and collaboration. For this reason, the talks will be equally focused on pedagogical examples, and practical methods. This should provide participants more opportunities to exchange methods and ideas.

We especially welcome applied mathematicians, physicists, chemists etc.

M4-AE2.1 **Tuesday, September 03, 2019, 11:00 – 11:20**

Revealing roaming on the double Morse potential energy surface with Lagrangian descriptors

Francisco Gonzalez Montoya
University of Bristol, School of Mathematics, United Kingdom

In this work we analyse the phase space structure of the roaming dynamics in a two degree of freedom potential energy surface consisting of two identical planar Morse potentials separated by a distance. This potential energy surface has two potential wells surrounded by an unbounded flat region containing no critical points. We study the phase space mechanism for transference between the wells using the method of Lagrangian descriptors.

Tuesday, September 03, 2019, 11:20 – 11:40 M4-AE2.2

Lagrangian study of phase space geometrical structures in 3D vector fields

Jezabel Curbelo
Universidad Autónoma de Madrid - ICMAT, Spain

We explore the capability of Lagrangian descriptors (LDs) [1], a tool that has been successfully applied to 2D vector fields, to reveal phase space geometrical structures in time-dependent three-dimensional vector fields. In particular, we show how LDs can be used to reveal phase space structures that govern and mediate phase space transport. We specially highlight the identification of normally hyperbolic invariant manifolds (NHIMs) and tori [2]. We will show that LDs successfully identify and recover the template of invariant manifolds that define the dynamics in phase space for several examples of the stratospheric dynamics [3, 4, 5].

Support was provided by the ONR Grant no. N00014-17-1-3003.

[1] A. M. Mancho, S. Wiggins, J. Curbelo, and C. Mendoza. (2013) Comm. Nonlinear Sci. Num. Sim., **18**(12):3530-3557.

[2] V. J. García-Garrido, J. Curbelo, A.M. Mancho, S. Wiggins, C. Mechoso.(2018) Regul. Chaot. Dyn. **23**: 551

[3] J. Curbelo, V. J. García-Garrido, C. R. Mechoso, A. M. Mancho, S. Wiggins, C. Niang, (2017). Nonlinear Processes in Geophysics, **24**(3), 379–392.

[4] J. Curbelo, C. R. Mechoso, A. M. Mancho, S. Wiggins, (2019a) Lagrangian study of the final warming in the southern stratosphere during 2002: Part I. The Vortex Splitting at Upper Levels. Climate Dynamics

[5] J. Curbelo, C. R. Mechoso, A. M. Mancho, S. Wiggins, (2019b) Lagrangian study of the final warming in the southern stratosphere during 2002: Part II. 3D structure. Climate Dynamics.

Tuesday, September 03, 2019, 11:40 – 12:00 M4-AE2.3

Phase space representation of quantum dynamics using squeezed coherent states

Dmitry Zhdanov
University of Bristol, School of Mathematics, United Kingdom

Solving time-dependent Schrödinger equation is a tremendous challenge for quantum systems with many degrees of freedom. One of the semiclassical approaches (proven effective to model chemical dynamics) is to expand the total wavefunction as a linear combination of time-dependent multidimensional squeezed coherent states. Various ideas were tested to evolve this time dependent ansatz including variational methods, Newtonian mechanics, and Bohmian trajectories.

I will introduce a family of methods to propagate coherent states basis based on hydrodynamic treatment of Wigner quasiprobability formalism. I will show how it ties together several existing approaches; and also reveals the classical geometric origins of such seemingly quantum objects as quantum potential in Bohmian mechanics.

M4-AE2.4 **Tuesday, September 03, 2019, 12:00 – 12:20**

The gauge field theory in condensed matter physics

Mariya Trukhanova
M. V. Lomonosov Moscow State University, Faculty of Physics, Russia

The gauge field theory is extensively used in the condensed matter physics, in particular for the systems with Rashba or Dresselhaus spin-orbit couplings description. We have expanded the four-dimensional SU(2) U(1) gauge theory, with U(1) being the Maxwell field and SU(2) being the Yang-Mills field. We derive forces acting on the spin and current induced by the Yang-Mills fields. The Berry gauge field associated with adiabatic quantum evolution represents a very interesting area of research. We construct the quantum hydrodynamics model (QHD) that describes the electron-skyrmion interactions, with separate description of spin-up and spin-down electrons. The electrons acquire opposite Berry phases and we regard the electrons with different projections of spin on the preferable direction as two different species of particles. The quantum effects, represented by the quantum Bohm potential, are taken into account. We investigate the electron gas moving in a smooth magnetic texture, where the magnetic moments adjust to the local magnetization direction of skyrmion. Applying the separated spin evolution quantum hydrodynamics to the two-dimensional electron gas traveling on the background of Berry gauge field in plane samples located in external magnetic field we find a wave of a new kind in the electron gas. This wave appears as an influence of emergent fields. We find the modified spin-electron acoustic wave.

M5-AE2: PDEs and dynamics with symmetries

Organizer:

Reiner Lauterbach, *Department of Mathematics, University of Hamburg, Germany*
Jochen Merker, *HTWK Leipzig, Germany*

Speaker:

Timo Hofmann, *Leipzig University of Applied Sciences, Leipzig, Germany*
Alexander Lohse, *Universität Hamburg, Germany*
Mara Sommerfeld, *Universität Hamburg, Fachbereich Mathematik, Deutschland*
Isabelle Schneider, *Freie Universität Berlin, Deutschland*
Björn Gebhard, *Universität Leipzig, Germany*

Outline of minisymposium:

Dynamics with symmetries are in many aspects different from dynamics without symmetries. For example, heteroclinic cycles occur robustly in many equivariant dynamical systems but do not generally occur in systems without symmetries, and symmetries may enforce a certain structure of the linearization of a dynamical system. Particularly, this happens for PDEs generating infinite-dimensional dynamical systems, and to handle this case rigorously, advanced functional analytic methods have to be used. The aim of the minisymposium is to bring experts from different areas of dynamical systems, whose research is concerned with infinite- dimensional systems having additional symmetries.

Tuesday, September 03, 2019, 16:00 – 16:20 M5-AE2.1

Symplectic local Lyapunov exponents are symmetric

Timo Hofmann
Leipzig University of Applied Sciences, Leipzig, Germany

Due to symplectic symmetries, chaos in finite- and infinite-dimensional Hamiltonian systems is rather special. For example, the global Lyapunov exponents of Hamiltonian systems occur in pairs $(\lambda, -\lambda)$. For local Lyapunov exponents, whose time averages converge to the global Lyapunov exponents, the pairing property depends on the precise definition. We show that symplectic local Lyapunov exponents defined using the Iwasawa decomposition of the real symplectic group $Sp(2n)$ occur in pairs, indicate, why covariant local Lyapunov exponents have the same pairing property, and provide numerical examples.

This is joint presentation with Jochen Merker (HTWK Leipzig, Germany).

M5-AE2.2 **Tuesday, September 03, 2019, 16:20 – 16:40**

Symmetry effects on non-asymptotic attraction

Alexander Lohse
Universität Hamburg, Germany

In this talk we discuss some notions of non-asymptotic attraction/stability with a focus on heteroclinic structures in equivariant systems of ODEs. Through some recent results we illustrate how different symmetry groups influence the possible stability configurations of so-called simple and pseudo-simple heteroclinic cycles that have the same topological architecture.

M5-AE2.3 **Tuesday, September 03, 2019, 16:40 – 17:00**

Hamiltonian relative equilibria in symplectic representations of compact connected groups

Mara Sommerfeld
Universität Hamburg, Fachbereich Mathematik, Deutschland

I will present an approach to investigate the structure of relative equilibria in a Hamiltonian system with a connected compact symmetry group near a completely symmetric equilibrium. This problem is closely related to bifurcation theory of equivariant vector fields.

The approach relies on an adaption of a method to investigate bifurcation problems with symmetry developed by Mike Field and his coauthors. This method is combined with the representation theory of connected compact groups: From the weights of a given representation, we can deduce the existence of certain manifolds of relative equilibria. Moreover, we obtain information about the symmetry of these solutions.

M5-AE2.4 **Tuesday, September 03, 2019, 17:00 – 17:20**

Symmetry-breaking control of reaction-diffusion equations

Isabelle Schneider
Freie Universität Berlin, Deutschland

Noninvasive time-delayed feedback control (“Pyragas control”) has been investigated theoretically, numerically and experimentally during the last twenty years, mostly for ordinary differential equations. In this talk, we introduce new noninvasive symmetry-breaking control terms scalar reaction-diffusion equations with the purpose to stabilize unstable equilibria and periodic orbits.

Control terms which are directly inspired by Pyragas control fail their task of stabilization. Therefore, we construct successful new control terms, by introducing the notion of control triples. The control triple defines how we transform the output signal, space, and time in the control term. This ansatz incorporates the spatio-temporal patterns of the equilibria and periodic orbits into the control term and breaks the symmetry, thereby allowing for stabilization.

Tuesday, September 03, 2019, 17:20 – 17:40 M5-AE2.5

An equivariant degree and periodic solutions of the N-vortex problem

Björn Gebhard
Universität Leipzig, Germany

The N-vortex problem is a first order Hamiltonian system arising as a singular limit (not only) in two-dimensional fluid dynamics. The Hamiltonian contains logarithmic singularities and is except for some special domains not explicitly known. In this talk we will discuss the existence of global continua of periodic solutions in general domains. The main tool in the proof is a S^1-equivariant degree theory for the H^1-gradient of the action functional of a first order Hamiltonian system.

M6-AE1: Solvability and qualitative behavior of solutions for viscoelastic fluids dynamics models

Organizer:

Victor Zvyagin, *Voronezh State University, Russia*

Speaker:

Vladimir Orlov, *Voronezh State University, Russia*
Andrei Zviagin, *Voronezh State University, Russia*
Aleksandr Boldyrev, *Voronezh State University, Russia*
Victor Zvyagin, *Voronezh State University, Russia*

Outline of minisymposium:

The scope of the minisymposium covers theoretical aspects of mathematical hydrodynamics for non-Newtonian fluids. New methods of weak solvability will be presented at this minisymposium. The areas of interest include but are not restricted to:

- Initial boundary value problems for non-Newtonian fluid dynamics models
- Attractors of hydrodynamic models
- Thermoviscoelastic problems of fluid dynamics

M6-AE1.1 **Wednesday, September 04, 2019, 11:00 – 11:20**

On some fractional models of viscoelastic mediums

Vladimir Orlov
Voronezh State University, Russia

The fractional mathematical models of viscoelastic fluids are under consideration. We establish the existence of weak solutions of the corresponding initial-boundary value problems for Voigt and anti-Zener type models. The investigation is based on the theory of fractional powers of positive operators, fractional calculus and classical results on Navier-Stokes equations. In the planar case we establish some both uniqueness and strong solvability results.

This is joint work with Victor Zvyagin.

Wednesday, September 04, 2019, 11:20 – 11:40 M6-AE1.2

Weak solvability of thermo-model for one viscoelastic fluid

Andrei Zviagin
Voronezh State University, Russia

The initial-boundary value problem under consideration describes the weakly concentrated water polymer solutions motion. This problem is considered with constitutive law which is frame indifferent, i.e. that do not change under the Galilean transformation. Also in this mathematical model the viscosity depends on a temperature, which leads to emergence of additional heat balance equation (it is a parabolic equation with nonsmooth coefficients and with right part from $L_1(0, T; L_1(\Omega))$. For the initial-boundary value problem under consideration the existence theorem of weak solutions is proved. For this the topological approximation approach for hydrodynamic problems is used.

This research was supported by the Ministry of Education and Science of the Russian Federation (Grant 14.Z50.31.0037).

Wednesday, September 04, 2019, 11:40 – 12:00 M6-AE1.3

Uniform attractors for weak solutions to viscoelastic media with memory

Aleksandr Boldyrev
Voronezh State University, Russia

We study attractors existence of weak solutions to model of viscoelastic media with memory motion in non-autonomous case. We can't used attractors theory for dynamical systems because the uniqueness of a weak solution for this model hasn't been established. In this connection, the theory of trajectory attractors for non-invariant trajectory spaces is applied and the existence of uniform trajectory attractor and uniform global attractor for this system is proved. The proof of existence theorems is based on the approximation-topological method.

This research was supported by the Ministry of Science and Higher Education of the Russian Federation (grant 14.Z50.31.0037).

Wednesday, September 04, 2019, 12:00 – 12:20 M6-AE1.4

On the weak solvability of initial-boundary value problems for a class of integro-differential equations with memory

Victor Zvyagin
Voronezh State University, Russia

The report proves the existence of weak solutions of integro-differential systems with memory on the trajectories of the motions of points of the system. These systems are consequences of the Oldroyd model and the Voigt model of non-Newtonian hydrodynamics.

M7-AM: Spectral methods in applied mathematics

Organizer:

Wolfram Just, *Queen Mary University of London, UK*

Speaker:

Wolfram Just, *Queen Mary University of London, UK*
Martin Richter, *University of Nottingham, School of Mathematical Sciences, United Kingdom*
Julia Slipantschuk, *Queen Mary University of London, UK*

Outline of minisymposium:

The minisymposium reviews recent approaches to dynamical systems based on spectral properties of the dyanamics. The talks cover the theoretical background, e.g., spectra of transfer operators as well as applications such as billiard dynamics.

M7-AM.1 **Thursday, September 05, 2019, 11:00 – 11:20**

Transfer operator technique for analytic maps Or: Chaos in the Hilbert space

Wolfram Just
Queen Mary University of London, UK

The talk reviews recent advances on the understanding of simple one dimensional chaotic maps. A family of analytic interval maps is introduced for which complete spectral data of the Perron Frobenius operator is available.

M7-AM.2 **Thursday, September 05, 2019, 11:20 – 11:40**

Convergence properties of transfer operators for billiards with a mixed phase-space

Martin Richter
University of Nottingham, School of Mathematical Sciences, United Kingdom

We analyse the convergence properties of a ray-tracing approach via transfer operators. The investigation focuses on a two-dimensional Hamiltonian system with a mixed-phase space, i.e. coexisting integrable and chaotic dynamics. As we focus on mid- to high-frequency regimes of the corresponding wave problem, we construct the transfer operator by means of a ray-tracing approach. We then solve the propagation problem numerically and investigate the rate of convergence. We accompany this with an investigation of the dynamics in phase space in terms of the boundary map. We compare our findings with recent rigorous proofs carried out for a circular domain and conclude with an outlook about its applicability to real-world problems.

Thursday, September 05, 2019, 11:40 – 12:00 M7-AM.3

Transfer operator approach to ray tracing in circular domains

Julia Slipantschuk
Queen Mary University of London, UK

This talk is about ongoing work on proving convergence results for algorithms that use transfer operator methods for computing vibrational energy distributions in mechanical structures. These algorithms reduce the problem to numerical approximation of suitable transfer operators for billiard dynamics. For circular billiards we prove convergence of finite rank approximations, with the polynomial convergence rate depending on the smoothness of the energy source.

M8-AE1: Dynamics of delay differential equations and applications

Organizer:

Jan Sieber, *University of Exeter, Department of Mathematics, United Kingdom*
Matthias Wolfrum, *Weierstrass Institute, Berlin, Germany*
Serhiy Yanchuk, *Technical University of Berlin, Institute of Mathematics, Germany*

Speaker:

Fatihcan Atay, *Bilkent University, Department of Mathematics, Turkey*
Konstantin Blyuss, *University of Sussex, Department of Mathematics, United Kingdom*
Maikel Bosschaert, *Hasselt University, Belgium*
Isabelle Schneider, *Freie Universität Berlin, Deutschland*

Outline of minisymposium:

Dynamical behavior of many real world systems can be properly described by the mathematical models, which include delay differential equations. Examples of such systems are neural networks, interacting semiconductor lasers, time-delay reservoir computing. The minisymposium “Dynamics of delay differential equations and applications” is devoted to analysis, modeling, and numerical study of such systems.

M8-AE1.1 **Thursday, September 05, 2019, 11:00 – 11:20**

Consensus-type problems on networks with time delays

Fatihcan Atay
Bilkent University, Department of Mathematics, Turkey

Consensus and synchronization dynamics are characterized by the presence of the difference of states of agents as the main driving force moving the network to an agreement state. Geometrically, consensus behavior is described by the convergence of the dynamics to a low-dimensional subspace associated with the null space of the coupling matrix. Algebraically, the presence of a zero eigenvalue suggests a conserved quantity. In this talk, we consider a general setting of networks of coupled nonlinear and possibly time-varying systems whose dynamics are subject to time delays, and derive a general formula for the conserved quantity. We apply the results to coordination and agreement problems with a generalized consensus subspace and calculate the consensus value in the presence of arbitrary multiple time delays. An interesting consequence is that sometimes the actual ’network’ that enters the dynamics is different from the static connection topology. As a particular application, we present a network model of anticipating agents and derive its consensus value.

Thursday, September 05, 2019, 11:20 – 11:40 M8-AE1.2

Mathematical modelling of awareness-based disease control

Konstantin Blyuss
University of Sussex, Department of Mathematics, United Kingdom

In this talk I will discuss a model for control of disease depending on the level of population awareness. Specific attention is paid to the time delay in population response. Analytical and numerical results provide an understanding of different dynamical scenarios that can be observed in the model. I will also discuss how a similar modelling approach can be used for the analysis of plant diseases.

Thursday, September 05, 2019, 11:40 – 12:00 M8-AE1.3

Initialization of homoclinic solutions near Bogdanov-Takens points in delay differential equations

Maikel Bosschaert
Hasselt University, Belgium

Great interest has been shown in the continuation of homoclinic bifurcation curves emanating from codimension 2 Bogdanov-Takens bifurcation points in ordinary differential equations. In this talk, the parameter-dependent center manifold reduction near the generic and transcritical codimension 2 Bogdanov-Takens bifurcation in delay differential equations (DDEs) with finitely many constant delays is presented. Using a generalization of the Lindstedt-Poincaré method to approximate a homoclinic solution allows us to initialize the continuation of the homoclinic bifurcation curves emanating from these points in DDEs. The normal form coefficients are derived in the functional analytic perturbation framework for dual semigroups (sun-star calculus) using a normalization technique based on the Fredholm alternative. The obtained expressions give explicit formulas, which have been implemented in the freely available numerical software package DDE-BifTool. The effectiveness is demonstrated on two models.

Thursday, September 05, 2019, 12:00 – 12:20 M8-AE1.4

Mechanisms of delayed feedback control

Isabelle Schneider
Freie Universität Berlin, Deutschland

By extending the well-known Pyragas control scheme to include spatio-temporal patterns, it is now possible to target the selected periodic orbits and stabilize them by a noninvasive control scheme. In this talk, we give an illustrated step-by step instruction on how to apply equivariant Pyragas control networks of coupled oscillators, explaining the mechanisms behind the control scheme.

M9-AE2: Synchronization patterns in networks

Organizer:

Iryna Omelchenko, *Institut für Theoretische Physik, Technische Universität Berlin, Germany*
Giulia Ruzzene, *Universitat Pompeu Fabra, Barcelona, Spain, España*

Speaker:

Eckehard Schöll, *TU Berlin, Institut für Theoretische Physik, Germany*
Giulia Ruzzene, *Universitat Pompeu Fabra, Barcelona, Spain, España*
Oleh Omel'chenko, *University of Potsdam, Deutschland*
Anna Zakharova, *Technische Universität Berlin, Institut für Theoretische Physik, Germany*
Astero Provata, *National Center for Scientific Research 'Demokritos', Institute of Nanoscience and Nanotechnology, Greece*
Rico Berner, *TU Berlin, Institute of Theoretical Physics, Germany*
Iryna Omelchenko, *Institut für Theoretische Physik, Technische Universität Berlin, Germany*

Outline of minisymposium:

Synchronization in complex networks is a topic of high interest in nonlinear dynamics, network science, and statistical physics, with a plethora of applications in physics, biology, and technology. Fascinating dynamical scenarios and patterns, which emerge for coupled systems, have attracted much attention in the scientific community recently. An interplay of nonlinear dynamics of individual nodes and complex topology of the networks results in diverse types of dynamics such as asymmetric clusters, chimera states, and solitary states. They are a manifestation of spontaneous symmetry-breaking in systems of oscillators, and occur in a variety of physical, chemical, biological, technological, or socio-economic systems. We focus on recent developments in the studies of synchronization patterns in complex networks with future promising perspectives that go beyond simple oscillator dynamics and regular network topologies. We will pay attention to the stability of nontrivial patterns, role of the time delay and noise in the dynamics of complex networks, as well as new approaches allowing for control of patterns in networks.

Thursday, September 05, 2019, 11:00 – 11:20 M9-AE2.1

Partial synchronization in complex networks

Eckehard Schöll
TU Berlin, Institut für Theoretische Physik, Germany

We study remote (or relay) synchronization in multilayer networks between parts of one layer and their counterparts in a second layer, where these two layers are not directly connected. A simple realization of such a system is a triplex network where a relay layer in the middle, which is generally not synchronized, acts as a transmitter between two outer layers; an example is provided by the hippocampus connecting distant parts of the brain.

We find various partial synchronization patterns, in particular chimera states, i.e., complex patterns of coexisting coherent and incoherent domains, and establish time delay in the inter-layer coupling as a powerful tool of control [1]. We demonstrate that the three-layer structure of the network allows for synchronization of the coherent domains of chimera states in the first layer with their counterparts in the third layer, whereas the incoherent domains either remain desynchronized or synchronized. As model dynamics we use the paradigmatic FitzHugh-Nagumo system.

[1] J. Sawicki, I. Omelchenko, A. Zakharova, and E. Schöll, Phys. Rev. E **98**, 062224 (2018).

Thursday, September 05, 2019, 11:20 – 11:40 M9-AE2.2

Minimal action to control chimera states

Giulia Ruzzene
Universitat Pompeu Fabra, Barcelona, Spain, España

In networks of oscillators, a chimera states is formed when the oscillators spontaneously split into two groups, one synchronized and the other showing an erratic motion. In finite-size networks chimeras are unstable, since they coexist with the fully synchronous solution. Furthermore, the two groups drift along the network, showing a Brownian motion. We present a method to control these instabilities in ring networks of nonlocally coupled oscillators, and we use this mechanism to investigate which is the minimal action needed to control chimeras. Turning one oscillator into a pacemaker, we are able to prevent chimeras from collapsing to the synchronous state, to generate chimeras from initial conditions for which they do not form spontaneously and to stabilize the position of the incoherent group within the network. Having a pacemaker in the network corresponds to setting to zero the coefficients of an entire row of the connectivity matrix. We found that modifying fewer coefficients produces effects similar to the ones obtained with the full pacemaker. In particular, even changing the strength of a single coefficient allows controlling the chimera position.

This is joint work with I. Omelchenko, E. Schöll, A. Zakharova and R.G. Andrzejak.

M9-AE2.3 **Thursday, September 05, 2019, 11:40 – 12:00**

Quasiperiodic Chimera states

Oleh Omel'chenko
University of Potsdam, Deutschland

In this talk we will describe recent work on quasiperiodic chimera states in a ring of non-locally coupled phase oscillators. In the continuum limit such chimera states appear as quasiperiodic solutions (more precisely, as relative periodic orbits) of the corresponding Ott-Antonsen equation. We will show how to perform numerical continuation of these solutions and analyze their stability. Thereby we will focus on mathematical problems concerned with the solution non-smoothness and the presence of neutral continuous spectrum in the corresponding linearized problem.

M9-AE2.4 **Thursday, September 05, 2019, 12:00 – 12:20**

Control of synchronization patterns in multilayer networks

Anna Zakharova
Technische Universität Berlin, Institut für Theoretische Physik, Germany

We investigate a multilayer network of coupled FitzHugh-Nagumo neurons and focus on the case of weak multiplexing, i.e., when the coupling between the layers is smaller than that inside the layers. It turns out that weak multiplexing has an essential impact on the dynamical patterns observed in the system and can be used for controlling in both oscillatory and excitable regimes. In the oscillatory regime, we show that different types of chimera states can be induced and suppressed. Moreover, we report the occurrence of solitary states for small intra-layer coupling strength mismatch between the layers [1]. For the excitable regime with noise, we find that weak multiplexing induces coherence resonance in networks that do not demonstrate this phenomenon in isolation [2]. Examples are provided by deterministic networks and networks where the strength of interaction between the elements is not optimal for coherence resonance. In both cases, we show that the control strategy based on multiplexing can be successfully applied. The advantage of multiplexing control we discuss here is that it allows to achieve the desired state in a certain layer without manipulating its parameters, and it works for weak inter-layer coupling.

[1] M. Mikhaylenko, L. Ramlow, S. Jalan, and A. Zakharova,
Weak multiplexing in neural networks: Switching between chimera and solitary states, Chaos **29**, 023122 (2019)

[2] N. Semenova, A. Zakharova,
Weak multiplexing induces coherence resonance, Chaos **28**, 051104 (2018) *Selected as Editor's Pick

Thursday, September 05, 2019, 16:00 – 16:20 M9-AE2.5

Mechanisms underlying the formation of Chimera states in brain dynamics

Astero Provata
National Center for Scientific Research 'Demokritos', Institute of Nanoscience and Nanotechnology, Greece

We explore the formation of chimera states and possible mechanisms giving rise to partial synchronization, in an effort to clarify the conditions under which chimeras are manifested and to address their presence in brain dynamics. We also discuss the influence of the form of the coupling matrix and the other system parameters in the chimera pattern and multiplicity. To this purpose, nonlocal and hierarchical connectivities will be presented in 2 and 3 spatial dimensions, as well as connectivities recorded experimentally, in vivo.

[1] A. Schmidt, T. Kasimatis, J. Hizanidis, A. Provata and P. Hoevel, Chimera patterns in two-dimensional networks of coupled neurons, Physical Review E, **95**, 032224 (2017).

[2] G. Argyropoulos, T. Kasimatis and A. Provata, Chimera patterns and subthreshold oscillations in two-dimensional networks of fractally coupled leaky integrate-and-fire neurons, Physical Review E, **99**, 022208 (2019).

[3] J. Sawicki, I. Omelchenko, A. Zakharova and E. Schoell, Delay-induced chimeras in neural networks with fractal topology, European Physical Journal B, **92**, 54 (2019).

Thursday, September 05, 2019, 16:20 – 16:40 M9-AE2.6

Self-organization on complex oscillator networks with adaptive coupling

Rico Berner
TU Berlin, Institute of Theoretical Physics, Germany

Dynamical systems on networks with adaptive couplings appear naturally in real-world systems such as power grid, social or neuronal networks. We investigate the collective behaviour of a network of adaptively coupled phase oscillators. Due to a slow adaptation of couplings, the network topology evolves on a slower time-scale than the oscillators. The considered system give rise to numerous complex dynamics, including relative equilibria and hierarchical multi-cluster states. We provide analytic arguments for existence as well as the stability of these states and describe the natural appearance of network motifs due to frequency synchronization. The interplay between the self-organized structure formation and complex networks is studied numerically. Moreover, the interactions between different clusters are investigated in the framework of multiplex networks. Our results allow for the interpretation of special types of relative equilibria as functional units in multi-cluster structures. The results contribute to the understanding of the mechanisms for self-organized pattern formation in adaptive networks, such as neural systems with plasticity.

M9-AE2.7 **Thursday, September 05, 2019, 16:40 – 17:00**

Chimera control in small networks

Iryna Omelchenko
Institut für Theoretische Physik, Technische Universität Berlin, Germany

Chimera states are complex spatio-temporal patterns of coexisting coherent and incoherent domains, which can often be observed in networks with nonlocal coupling topology. In small-size nonlocally coupled networks, chimera states usually exhibit short lifetimes and erratic drifting of the spatial position of the incoherent domain. This problem can be solved with a tweezer feedback control which can stabilize and fix the position of chimera states [1; 2]. We analyse the action of the tweezer control in two-layer networks, where each layer is a small nonlocally coupled ring of Van der Pol oscillators. We demonstrate that tweezer control, applied to only one layer, successfully stabilizes chimera patterns in the other, uncontrolled layer, even in the case of nonidentical layers [3]. These results might be useful for applications in multilayer networks, where one of the layers cannot be directly accessed, thus it can be effectively controlled via a neighbouring layer.

[1] PRL **116**, 114101 (2016)

[2] PRE **97**, 012216 (2018)

[3] Front. Appl. Math. Stat. **4**:67 (2019)

M10-AM: Recent advances in slow-fast dynamics

Organizer:

Daniele Avitabile, *VU Amsterdam, The Netherlands*
Mathieu Desroches, *Inria Sophia Antipolis Méditerranée, France*

Speaker:

Stéphane Barland, *Université Cote d'Azur - CNRS, Institut de Physique de Nice, France*
Jan Rombouts, *KU Leuven, Belgium*
Ilona Kosiuk, *Vienna University of Technology, Austria*
Daniele Avitabile, *VU Amsterdam, The Netherlands*
Mathieu Desroches, *Inria Sophia Antipolis, France*
Panagiotis Kaklamanos, *University of Edinburgh, United Kingdom*

Outline of minisymposium:

Multiple timescales are underpinning complex oscillatory dynamics in many application areas, including and especially in the biosciences. Dynamical systems with multiple timescales are able to display a vast repertoire of complex oscillations: spikes, bursts, mixed-mode oscillations, as well as combinations of them. This mini-symposium will present recent results on multi- timescale dynamics in ODEs and network systems with a clear focus towards biological applications. In these examples, phenomena such as canards and dynamic bifurcations are key to understand and control non-trivial behaviours near the boundaries between different activity regimes at many scales ranging from single neurons to micro-circuits and populations.

Thursday, September 05, 2019, 16:00 – 16:20 M10-AM.1

Experimental observation of low dimensional dynamics in a fully connected network of spiking lasers

Stéphane Barland
Université Cote d'Azur - CNRS, Institut de Physique de Nice, France

Low dimensional dynamics of large networks is the focus of many theoretical works, but controlled laboratory experiments are comparatively very few. Here, we discuss experimental observations on a fully connected network of several hundreds of semiconductor lasers, which collectively display effectively low-dimensional mixed mode oscillations and chaotic spiking typical of slow-fast systems. We explain our observations by demonstrating analytically that the critical manifold of the network is at leading order very close to that of a single node. Experimental measurement of the bifurcation parameter for different network sizes corroborate the theory.

M10-AM.2 **Thursday, September 05, 2019, 16:20 – 16:40**

Dynamically changing bistable switches in the cell cycle

Jan Rombouts
KU Leuven, Belgium

How does the cell robustly switch from one state to another? One way to ensure such robustness in cellular decisions is to make use of underlying bistability, where the cell can end up in one of two stable states, depending on where it comes from. These states can correspond to low and high protein concentration or activity, for example. Such bistability has been shown to play a crucial role in the cell cycle, where irreversible transitions from one cell cycle phase to the next correspond to going from one branch of the bistable system to the other. These transitions are essential for healthy progression of the cell cycle, and it is therefore no surprise that a large number of bistable switches have been experimentally identified. Generally, these switches are the result of positive feedback loops between proteins.

Bistability can also serve as a crucial building block for other cellular processes. On the one hand, when adding a negative feedback loop to such a bistable system, an autonomously oscillating system with robust amplitude can result, driving the cell through its cycle. These relaxation oscillations are reminiscent of Fitzhugh-Nagumo type systems, where the system slowly proceeds along the stable branches and abruptly switches from one to the other. On the other hand, when coupled in space, bistable systems can show propagation of one state into another one. The states are linked by a front which moves at a constant speed. In large cells, this mechanism is important to synchronize the cell's internal state.

One aspect that is not often looked at, is how the bistable response curve itself changes during the cell cycle. Existing models have usually assumed that the shape of the response curve remains the same, and that the system proceeds along its branches. However, the bistable curve can depend on a number of parameters which themselves may vary in time and/or space. Here I will discuss how such dynamical changes in bistable switches can play an important role in cell biology. I will also illustrate some of these findings using experiments related to the cell cycle in early frog embryos carried out by others in our lab.

This is joint work with Lendert Gelens.

Thursday, September 05, 2019, 16:40 – 17:00 M10-AM.3

Geometric singular perturbation theory meets cell biology: new challenges and recent advances

Ilona Kosiuk
Vienna University of Technology, Austria

During the last decades geometric singular perturbation theory (GSPT) and the blow-up method have become powerful tools for analyzing slow-fast systems in standard form and have been successfully used in many areas of mathematical biology. However, GSPT of mathematical models arising in molecular cell biology is much less established. The main reason for this seems to be that the corresponding models typically do not have an obvious slow-fast structure of the standard form. Nevertheless, many of these models exhibit some form of hidden slow-fast dynamics, which can be utilized in the analysis.

In this talk I will survey recent advances in GSPT beyond the standard form in the context of prototypical examples from cell biology. I will show that geometric methods based on the blow-up method provide a systematic approach to problems of this type.

Thursday, September 05, 2019, 17:00 – 17:20 M10-AM.4

Canards and slow passage through bifurcations in infinite-dimensional dynamical systems

Daniele Avitabile
VU Amsterdam, The Netherlands

I will present a rigorous framework for the local analysis of canards and slow passages through bifurcations in a large class of infinite-dimensional dynamical systems with time- scale separation. The framework is applicable to models where an infinite-dimensional dynamical system for fast variables is coupled to a finite-dimensional dynamical system for slow variables. I will discuss examples where the fast variables evolve according to systems of local and nonlocal reaction-diffusion PDEs, integro-differential equations, or delay-differential equations. This approach opens up the possibility of studying spatio-temporal canards and slow passages through bifurcations in spatially-extended systems, and it provides an analytical foundation for several numerical observations recently reported in literature.

This is joint work with Mathieu Desroches and Martin Wechselberger.

M10-AM.5 **Thursday, September 05, 2019, 17:20 – 17:40**

Canards in excitatory networks and their mean-field limits

Mathieu Desroches
Inria Sophia Antipolis, France

In this talk, I will present recent results on slow-fast dynamics in mean-field limits of networks of quadratic-integrate-and-fire (QIF) neurons using the Ott-Antonsen ansatz. We find that the excitable structure of one QIF neuron under slow periodic forcing, which is organised by so-called folded-saddle canards, persist in large networks of QIF neurons and up to the mean-field limit. We give theoretical arguments and numerical evidence for the existence of such canards underpinning the excitability threshold of these large networks as well as in their mean-field limits.

This is joint work with Daniele Avitabile (VU Amsterdam, The Netherlands) and Bard Ermentrout (University of Pittsburgh, USA).

M10-AM.6 **Thursday, September 05, 2019, 17:40 – 18:00**

Geometry of an extended prototypical three-timescale system: bifurcations of mixed-mode oscillations

Panagiotis Kaklamanos
University of Edinburgh, United Kingdom

In this talk we will discuss the geometry of a multi-parameter three-dimensional system of ordinary differential equations that exhibits dynamics on three distinct timescales. This system is a generalization of the prototypical system introduced by Krupa et al. in 2008 and has a one-dimensional S-shaped supercritical manifold that is embedded into a two-dimensional S-shaped critical manifold in a symmetric fashion. We will explore the effects of varying the different parameters on the geometry of the system and on its local and global dynamics, with a particular focus on mixed-mode oscillations and their bifurcations. We will demonstrate our results for the Koper model from chemical kinetics, which represents one particular realization of our prototypical system. Finally, we will extend some of our results to more general systems with similar geometric properties, such as a three-dimensional reduction of the Hodgkin-Huxley equations derived by Rubin and Wechselberger in 2007.

M11-AE1: Recent advances in time-delayed systems

Organizer:

Yuliya Kyrychko, *University of Sussex, Department of Mathematics, United Kingdom*
Konstantin Blyuss, *University of Sussex, Department of Mathematics, United Kingdom*

Speaker:

Anna Zakharova, *Technische Universität Berlin, Institut für Theoretische Physik, Germany*
Eckehard Schöll, *TU Berlin, Institut für Theoretische Physik, Germany*
Jens Christian Claussen, *Aston University, Department of Mathematics, Birmingham, UK*
Florian Stelzer, *Humboldt-Universität zu Berlin, Germany*
Jan Sieber, *University of Exeter, Department of Mathematics, United Kingdom*

Outline of minisymposium:

Time-delayed systems have attracted a lot of attention in the last few decades, and have opened new avenues for modelling and understanding of real-world processes. Time delays arise naturally in a variety of contexts, and often result in a rich catalogue of dynamical behaviour. This mini-symposium will present a diverse range of applications of such systems, as well as analytical and numerical methods for their analysis.

M11-AE1.1 **Thursday, September 05, 2019, 16:00 – 16:20**

Designing solitary states by time delays

Anna Zakharova
Technische Universität Berlin, Institut für Theoretische Physik, Germany

Understanding mechanisms of desynchronization plays a significant role in the study of neural networks. Dynamical scenario of transition from pathological neural synchrony to a healthy state can involve partial synchronization patterns, such as chimera states or solitary states. The term "solitary" comes from the Latin "solitarius" and can be understood as "alone", "lonely", or "isolated". In the case of chimera states, a network spontaneously splits into coexisting domains of synchronized and desynchronized behavior, which are localized in space. For solitary states, on the contrary, it is typical that individual "solitary" oscillators split off from the synchronized cluster at random positions in space [1].

Here we discuss the formation of solitary states and, in particular, the conditions under which these patterns occur in one-layer [2] and two-layer [3] networks of oscillatory FitzHugh-Nagumo neurons.

Furthermore, we present a technique that allows to engineer solitary states. By delaying links of selected nodes we are able to control their position and displacement with respect to the synchronized cluster [4].

[1] P. Jaros, S. Brezetsky, R. Levchenko, D. Dudkowski, T. Kapitaniak, and Y. Maistrenko, Solitary states for coupled oscillators with inertia, Chaos **28**, 011103 (2018).

[2] E. Rybalova, V. Anishchenko, G. Strelkova, and A. Zakharova,
Solitary states and solitary state chimera in neural networks, Chaos (2019) accepted.

[3] M. Mikhaylenko, L. Ramlow, S. Jalan, and A. Zakharova,
Weak multiplexing in neural networks: Switching between chimera and solitary states, Chaos **29**, 023122 (2019).

[4] L. Schülen, S. Ghosh, A.D. Kachhvah, A. Zakharova, and S. Jalan,
Delay engineered solitary states in complex networks (in preparation).

Thursday, September 05, 2019, 16:20 – 16:40 M11-AE1.2

Delay-induced chimeras in neural networks with fractal topology

Eckehard Schöll
TU Berlin, Institut für Theoretische Physik, Germany

We study chimera states, which are partial synchronization patterns consisting of spatially coexisting domains of coherent (synchronized) and incoherent (desynchronized) dynamics, in ring networks of FitzHugh-Nagumo oscillators with fractal connectivities [1]. In particular, we focus on the interplay of time delay in the coupling term and the network topology. In the parameter plane of coupling strength and delay time we find tongue-like regions of existence of chimera states alternating with regions of coherent dynamics. We show analytically and numerically that the period of the synchronized dynamics as a function of delay is characterized by a sequence of piecewise linear branches. In between these branches various chimera states and other partial synchronization patterns are induced by the time delay. By varying the time delay one can deliberately choose and stabilize desired spatio-temporal patterns.

[1] J. Sawicki, I. Omelchenko, A. Zakharova, and E. Schöll, Eur. Phys. J. B **92**, 54 (2019).

M11-AE1.3 **Thursday, September 05, 2019, 16:40 – 17:00**

Sleep bout statistics from sleep depth diffusion models: including a REM step and its influence on the distributions

Jens Christian Claussen
Aston University, Department of Mathematics, Birmingham, UK

Sleep stages switch dynamically, where the deterministic part of the dynamics is governed by the sleep-regulating processes, and stochasticity arises on all scales, leading to switching between sleep stages at shorter timescales. This leads to a time microstructure of the sleep-wake pattern down to the 1 - 10 second scale. Interestingly, the wake and sleep durations follow different statistics. Sleep durations have been reported exponentially-distributed thus random, while wake periods appear power-law distributed in some studies, while deviations are observed elsewhere. We extend a recent sleep stage diffusion model to account for these deviations. A pure Markov analysis [1] assuming random switching however ignores any deterministic components in the dynamics which are manifest in time correlations. The phenomenological model proposed in [2] describes sleep depth by a one-dimensional diffusion process with a reflecting border for sleep and a restoring force for wake. We extend this model [3] to account for the REM state and modify the restoring force law to account for deviations to the power law that are observed in data from some (but not all) labs and obtain a better fit to data. We conclude that such a refined model is necessary to account for the different experimental results, but significantly larger cohorts of sleep studies would be needed to distinguish between the two-regime and the one-regime distributions. This concerns only the wake to sleep transition, the sleep to wake transition remains consistent with a random process homogeneous in time.

[1] Kim et al, Phys Rev Lett **102**, 178104, 2009

[2] Lo et al, EPL **57**, 631, 2002

[3] Barkentien and Claussen, in preparation

M11-AE1.4 **Thursday, September 05, 2019, 17:00 – 17:20**

Performance boost of time-delay reservoir computing by non-resonant clock cycle

Florian Stelzer
Humboldt-Universität zu Berlin, Germany

We consider a reservoir computing setup based on a time-delay system. Such a setup has been used previously and successfully implemented in experiments. In this presentation, we discuss the effects of a mismatch between two main timescales of this system: time-delay and a clock cycle given by the modulation period of the input. Usually, these two times are considered to be equal. Here we show that the case of equal or rationally related time-delay and the clock cycle leads to an increase of the approximation error of the reservoir. We show that non-resonant ratios of these times have maximal memory capacities. From the point of view of nonlinear dynamics, the loss of memory capacity is related to an interplay between the period of an external periodic forcing and time-delay.

Thursday, September 05, 2019, 17:20 – 17:40 M11-AE1.5

Temporal dissipative solitons and their spectrum

Jan Sieber

University of Exeter, Department of Mathematics, United Kingdom

Localized states are a universal phenomenon observed in spatially distributed dissipative nonlinear systems. Known as dissipative solitons, auto-solitons, spot or pulse solutions, these states play an important role in data transmission using optical pulses, neural signal propagation, and other processes. While this phenomenon was thoroughly studied in spatially extended systems, temporally localized states are gaining attention only recently, driven primarily by applications from fiber or semiconductor lasers. Here we present a theory for temporal dissipative solitons (TDS) in systems with time-delayed feedback. In particular, we derive a system with an advanced argument, which determines the profile of the TDS. We also provide a complete classification of the spectrum of TDS into interface and pseudo-continuous spectrum. We illustrate our theory with two examples: a generic delayed phase oscillator, which is a reduced model for an injected laser with feedback, and the FitzHugh-Nagumo neuron with delayed feedback. Finally, we discuss possible destabilization mechanisms of TDS and show an example where the TDS delocalizes and its pseudo-continuous spectrum develops a modulational instability.

This is joint work with Serhiy Yanchuk, Stefan Ruschel and Matthias Wolfrum.

3 Contributed Talks

Monday, September 02, 2019, 12:00 – 12:20 C1-AM.4

The Painlevé paradox in 3D

Noah Cheesman
University of Bristol, United Kingdom

Every mathematician knows all too well that chalk can squeal when pushed along a blackboard. Similarly, robotic manipulators may judder when picking up objects from conveyor belts.

These phenomena are linked to the Painlevé paradox, where no unique forward solutions exist to certain rigid body problems with unilateral constraints in the presence of friction. Whilst the Painlevé paradox has been a curiosity of mathematicians and engineers alike for over a century, it is only recently that many of the developments have been made, both experimentally and theoretically. In this contribution, we consider a stiff and slender rod, slipping along a rough surface. Results from developments in the 2D "classical Painlevé problem" are generalised to the full 3D problem. We show analytically how the planar case is singular, that the introduction of the other spatial dimension complicates the dynamics and that, whilst in 2D no trajectories can enter the inconsistent region, in the 3D system trajectories can enter the inconsistent region in finite time. In order to "resolve" this paradox, one approach is regularize (smooth) the system. The method here is to relax the rigidity of the system through the incorporation of compliance. This allows the rod tip to enter the surface and restores uniqueness of forward solutions. Due to the high stiffness involved, this regularization introduces a small parameter, leading to a slow-fast system. The blowup method is used to deal with the resulting system.

C1-AE2.2 **Monday, September 02, 2019, 11:00 – 11:20**

Cross frequency coupling in next generation inhibitory neural mass models

Simona Olmi
Inria Sophia Antipolis Mediterranee Research Centre, France

Coupling between neural rhythms is one of the most important mechanisms for information processing in the brain. In this study we show that a neural mass model, rigorously obtained from the microscopic dynamics of an inhibitory spiking network, is able to autonomously generate oscillations. These oscillations emerge via a super-critical Hopf bifurcation, and their frequencies are controlled by the synaptic time scales, the synaptic coupling and the average excitability of the neural population. Furthermore, we demonstrate that a two population neural mass model with unidirectional coupling can display various dynamical regimes including periodic motion, quasi-periodicity and chaos. Finally, we show that the interaction of two bidirectionally coupled populations with different synaptic time scales can reproduce two types of $\theta - \gamma$ cross-frequency coupling in the form of phase synchronization and nested oscillations, which can be enhanced via the addition of a slowly modulating signal, reminiscent of the type of modulation observed in Hippocampal circuits.

C1-AE2.2 **Monday, September 02, 2019, 11:20 – 11:40**

The brain activity at rest as self-sustained collective irregular dynamics in spiking networks

Ekkehard Ullner
University of Aberdeen, Department of Physics, United Kingdom

The origin of the self-sustained brain activity in the resting state is not fully understood. We propose the collective irregular dynamics (CID) as a possible mechanism. Collective irregular dynamics (CID) is stochastic-like behavior on macroscopic scales. We study two very different neuronal network types expressing CID: (i) we investigate fully coupled networks of spiking neurones with a dispersion of their natural frequencies and (ii) we discuss the emergence of CID in random networks of spiking neurons with quasi-balanced activity.

Our analysis is based on the computation of a suitable order parameter, typically used to characterize synchronization phenomena. A detailed investigation of the thermodynamic limit for fixed density of connections shows that the asymptotic regime is characterized by self-sustained irregular, macroscopic (collective) dynamics. As long as the connectivity is massive, this regime is found in many different setups. The irregularity of the collective dynamics is justified by the power spectra of the neural activity, a fractal-dimension analysis and standard synchronisation measures.

As a result, we can conclude that CID is a true thermodynamic phase, intrinsically different from the standard asynchronous regime.

Monday, September 02, 2019, 12:00 – 12:20 C1-AE2.4

Dynamics of synchronization measures between autonomous regulation processes of heart rate and blood pressure

Vladimir Ponomarenko
Saratov Branch of the Institute of Radioengineering and Electronics of RAS, Russia
and
Saratov State University, Russia

The processes of autonomous regulation of heart rate and blood pressure with a frequency of about 0.1 Hz are the subject of investigation of many researchers. The results are applicable in clinical practice [1]. As has been shown, the synchronization of these two processes is an important diagnostic factor. Most studies have been performed previously with 10-minute records of electrocardiogram and photoplethysmogram signals. The total percent of phase synchronization index for healthy subjects and patients with myocardial infarction was estimated [2]. However, from the point of view of time series analysis, the studied 10-minute records are rather short, since they contain only about 60 characteristic periods of oscillations.

In this work, the processes of autonomous regulation of heart rate and blood pressure were studied in healthy volunteers using long (with duration of 2-4 hours) electrocardiogram and photoplethysmogram records. The correlation and statistical properties of the signals were estimated, the synchronization of regulation processes with a frequency of about 0.1 Hz was investigated. The phase synchronization index, the total percent of phase synchronization, and the synchrograms of the signals were calculated. The dynamics of the calculated measures was studied in time. An estimation of the statistical significance of the results was obtained.

This is joint work with Skazkina V.V. (Saratov State University, Russia), Kiselev A.R. (Saratov State University, Russia and Saratov State Medical University n.a. V.I. Razumovsky, Russia), Borovkova Ye.I. and Karavaev A.S. (Saratov Branch of the Institute of Radioengineering and Electronics of RAS, Russia and Saratov State University, Russia) and Prokhorov M.D. (Saratov Branch of the Institute of Radioengineering and Electronics of RAS, Russia).

This research was funded by the Russian Science Foundation, Grant No. 19-12-00201.

[1] Heart rate variability: Standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology // Circulation, 1996, vol. **93**, no. 5, pp. 1043–1065.

[2] Karavaev A.S., Prokhorov M.D., Ponomarenko V.I., Kiselev A.R., Gridnev V.I., Ruban E.I., Bezruchko B.P. Synchronization of low-frequency oscillations in the human cardiovascular system // Chaos, 2009, vol. **19**, no. 3, 033112.

C1-H1.1 **Monday, September 02, 2019, 11:00 – 11:20**

Discontinuous Galerkin methods for Keller-Segel chemotaxis system with general chemotactic sensitivity and cross-diffusion

Arumugam Gurusamy
Indian Institute of Technology Gandhinagar, India

In this paper, both symmetric and nonsymmetric interior penalty discontinuous hp-Galerkin methods are applied to the Keller-Segel chemotaxis system with cross-diffusion. In particular, the spatial discretizations of the system are based on the discontinuous Galerkin method. Then the existence of solutions to the semidiscrete problem is proved by using Schauder's fixed point theorem. Moreover a priori error estimates are derived. Finally numerical experiments illustrating the theoretical results are provided.

C1-H1.2 **Monday, September 02, 2019, 11:20 – 11:40**

Breakup of falling droplets by instability of vortex ring

Michiko Shimokawa
Fukuoka Institute of Technology, Japan

When a droplet with a relatively high density falls into a miscible solution with a relatively low density, the droplet deforms into a vortex ring and the instability of the vortex ring leads to the droplet breaking up spontaneously. Although it is easy to observe this phenomenon with such things as ink and water, it is difficult to clarify the dynamics as the phenomenon occurs in an unsteady state where the falling velocity and the shape of the droplet and vortex ring changes with time. In a previous paper, we showed that Rayleigh-Taylor instability was an important factor for the instability of the vortex ring derived from the droplet breakup. In this presentation, we focus on the number of the breakup and discuss the physical parameters to determine the number through a consideration of the dynamics.

We investigated the number m of the breakup in experiments with several density differences $\Delta\rho$ between two solutions, viscosities μ, and droplet radii r when a droplet starts to fall. The mode number m has a distribution even under the same experimental conditions. We propose a simple model of mode-selection based on the linear Rayleigh-Taylor instability and the growing radius of the vortex ring deformed from the droplet. The model provides the probability distribution $p = (m)$ and a relationship between the non-dimensional parameter $G = \Delta\rho g r^3/\mu^2$ and the average value of m. The theoretical arguments are consistent with experimental results.

Monday, September 02, 2019, 11:40 – 12:00 C1-H1.3

Numerical simulation of convection of a phase change material in a rectangular cavity

Marlene Crumeyrolle-Smieszek
Université Le Havre Normandie, Laboratoire Ondes et Milieux Complexes, France

Convective flows with phase change material (PCM) is observed not only in nature e.g. melting of sea ice or basal melting [3] but also in built environment such as underfloor heating, ceiling cooling, Trombe wall [1] or thermal storage systems [6], when such equipment features a PCM layer.

For the horizontal case heated from below, non-trivial effects have been reported at the interface between the liquid and the solid domain. The mathematical Stefan condition have been proven to lead to complex pattern dynamics [5] and the critical Rayleigh number depends on the thickness of the solid layer [3]. Experiments [2] exhibit either roll or hexagonal patterns at steady state. The vertical case is both of interest for energy storage and geophysics [4, 6].

In the present work we take into account the temperature dependence of density and thermal conductivity of heptadecane, a widely used PCM in experimental investigations. Finite thickness effects are taken into account by investigating numerically both the liquid domain and the solid domain.

We perform the study in COMSOL Multiphysics with a front tracking or the effective heat capacity method. The latter defines a modified heat capacity cp over the melting temperature range of the PCM that implies cp as well as its latent heat of fusion. A 2d vertical geometry in agreement with the experimental setup is chosen. We also investigate the horizontal case. Nusselt numbers at boundaries and flow patterns are reported. Thermal imbalance is compared to solidification front displacement. The influence of the thickness on the stability is reported. The results are compared to preliminary experimental investigations.

This work is part of the RIN-FIVATHE project, funded by the Région Normandie.

This is joint work with I. Mutabazi and O. Crumeyrolle (Université Le Havre Normandie, Laboratoire Ondes et Milieux Complexes, France).

[1] Anisur, M.R., Kibria; M.A., Mahfuz, M.H., Saidur; R., Metselaar, I.H.S.C. (2014). Cooling of air using heptadecane phase change material in shell and tube arrangement: Analytical and experimental study. Energy and Buildings, **85**, 98-106

[2] Davis, S., Müller, U., & Dietsche, C. (1984). Pattern selection in single-component systems coupling Bénard convection and solidification. Journal of Fluid Mechanics, **144**, 133-151

[3] Favier, B., Purseed, J., & Duchemin, L. (2019). Rayleigh–Bénard convection with a melting boundary. Journal of Fluid Mechanics, **858**, 437-473

[4] Kerr, R., & McConnochie, C. (2015). Dissolution of a vertical solid surface by turbulent compositional convection. Journal of Fluid Mechanics, **765**, 211-228. doi:10.1017/jfm.2014.722

[5] Vasil, G., & Proctor, M. (2011). Dynamic bifurcations and pattern formation in melting-boundary convection. Journal of Fluid Mechanics, **686**, 77-108

[6] Zeinelabdeina, R., Omera, S., Gana, G. (2018). Critical review of latent heat storage systems for free cooling in buildings. Renewable and Sustainable Energy Reviews **82**, 2843-2868

C1-H1.4 **Monday, September 02, 2019, 12:00 – 12:20**

Entropy production rate of diffusivity fluctuations of RNA-protein particles

Yuichi Itto
Aichi Institute of Technology, Japan

A recent experimental study [1] has revealed that the RNA-protein particles exhibit anomalous diffusion in cytoplasm of a living cell. Unexpectedly, the experimental results have shown, for two different types of cell, that the distribution of diffusivity fluctuations (i.e., fluctuating diffusion coefficient) over the cytoplasm obeys the exponential law. Then, it has been pointed out [1] that this is the maximal entropy distribution. Here, time evolution of entropy associated with the fluctuations is discussed [2]. The entropy production rate under the diffusing diffusivity equation [3] describing the dynamical behavior of the fluctuations is explicitly shown to become positive. The rate with the time-dependent solution of the equation tells us how the entropy approaches its maximum value. Thus, the present result is expected to offer a dynamical foundation of diffusivity fluctuations as the maximum entropy distribution.

[1] T. J. Lampo, S. Stylianidou, M. P. Backlund, P. A. Wiggins, and A. J. Spakowitz, Biophys. J. **112**, 532 (2017).

[2] Y. Itto, e-print arXiv: 1901.05291.

[3] M. V. Chubynsky and G. W. Slater, Phys. Rev. Lett. **113**, 098302 (2014).

Monday, September 02, 2019, 14:50 – 15:10 C2-AE1.1

Event-based model for digital oscillators

Sara Ameli Kalkhouran
Max Planck Institute for Physics of Complex Systems, Dresden, Germany

Networks of coupled oscillators are ubiquitous in natural and artificial systems. In large electronic systems, for example, the coordination in time of spatially distributed components is essential for reliable operations. At high frequency or large spatial distribution, such coordination becomes a challenging task, e.g., due to inevitable signal transmission delays and crosstalk between signal transmission lines.

Here we study so-called digital phase-locked loops (DPLLs), electronic feedback-loop circuits that can frequency lock to external periodic signals. DPLLs can, therefore, be entrained by a precise reference clock via a clock tree and play an essential role in the distribution of a time-reference in state-of-the-art electronics, e.g., mobile communications, indoor-navigation, and Systems-on-a-Chip. However, such hierarchical approaches to synchronization become complicated, or even impossible for large system sizes. Recently, the possibility to use mutually delay-coupled DPLL units has been explored, using a continuous phase-model description and an experimental prototype setup. This work has shown that self-organized synchronization is possible in such mutually delay-coupled DPLL networks. It is not clear however whether synchronization can also be achieved in the presence of noise. Therefore it is essential to understand how noise affects the dynamics in networks of coupled DPLLs.

We introduce a discrete dynamical model for delay-coupled DPLL networks. The digital signals of the DPLLs are therein represented by sets of discrete event-times. In this framework the introduction of noise in the form of timing-jitter comes in a natural way, as it can be directly implemented as the uncertainty of the signals' edgetimes. Time-delays in the system leads to simply shifts of these discrete event-times. This enables the application of the tools of discrete dynamical systems theory.

The model is not restricted to the study of electronic oscillators as it governs the dynamics of coupled digital oscillators with signal transmission and processing delays in general. Due to its generic formulation it may be useful for studying the collective dynamics in a variety of analog-digital systems.

C2-AE1.2 **Monday, September 02, 2019, 15:10 – 15:30**

Topological steps toward walking colloidal bipeds

Mahla Mirzaee Kakhki
University of Bayreuth, Department of Physics, Germany

Paramagnetic colloidal spheres assemble to colloidal bipeds of various length in an external magnetic field. When the bipeds reside above a magnetic pattern and we modulate the direction of the external magnetic field, the rods perform topologically distinct classes of protected motion above the pattern. The topological protection allows each class to be robust against small continuously deformations of the driving loop of the external field. We observe motion of the rod from a passive central sliding and rolling motion for short bipeds toward a walking motion with both ends of the rod alternately touching down on the pattern for long bipeds. The change of character of the motion occurs in form of discrete topological transitions. The topological protection makes walking a form of motion robust against the breaking of the non symmorphic symmetry. In symmorphic patterns walking is reversible. In non symmorphic patterns the walking can be irreversible or reversible involving or not involving ratchet jumps.

C2-AE2.1 **Monday, September 02, 2019, 14:50 – 15:10**

Non-Gaussian states: a first sign of complex events

Antonina N. Fedorova
Mathematical Methods in Mechanics Group, IPME RAS, St. Petersburg, Russia

A number of the important in a various areas of physics phenomena demonstrate non-gaussian and even non–gibbsian behaviour, most of them are related to non-maxwellian regimes in statistical physics, plasma physics, (global) astrophysics.

Formally, on the math level, the existence of such partition functions is the first sign of emergence of complicated internal structures like (well-known in fundamental areas of physics) hidden symmetries and as an immediate consequence appearance of the non-trivial complex spectral nature of all these phenomena.

Here, we sketch some features of our general approach, whose core, formally, is rather simple: it based on the representation theory of internal hidden symmetries and on analysis of proper orbits and dynamics along them together with 'interference phenomenon', which lead to the full description of evolution dynamics. Roughly speaking, it is the only way to introduce into the game the hidden multiscale dynamics of the full exact set of internal nonlinear (corresponding to non-abelian nature of group structure motivated by a proper description of physical behaviour) (eigen)modes.

In the most simple cases of affine or Weyl–Heisenberg groups in multiresolution framework, we demonstrate as emergence of non-gaussian/maxwellian partitions as well their dominance in the most important for us (nontrivial) cases. A general approach is illustrated by a number of examples related to fusion schemes in plasma physics and the description of post–inflation spectra in astrophysics.

This is joint work with Michael G. Zeitlin.

Monday, September 02, 2019, 15:10 – 15:30 C2-AE2.2

Sheaves, schemes, and all that: new looking glass for quantum phenomena

Michael G. Zeitlin
Mathematical Methods in Mechanics Group, IPME RAS, St. Petersburg, Russia

It is a short introduction to our program of the revisiting of some basic points of 'orthodox' Quantum Mechanics together with some subset of facts covering the routine quantum folklore ('self–interference', hidden parameters, nonlocality, contextuality, and all that).

The reason for that is obvious: the recent experimental breakthrough in the wide area of the so-called 'Quantum Computing' together with well-known success in related areas like Quantum Cryptography, Algorithms, etc. demand the more deep understanding of this area as a whole and, first of all, the basic statements, because in spite of some success, we are still far away from the main goals- the construction of the real quantum CPU on the pragmatic side of Quantum Physics and unification of all existing zoo of phenomena (mostly 'under-described' mathematically on the pretty low level) on the solid Math background on the theoretical side. In a good case it can provide the long waiting success in this very important area.

Our program in this direction is based on the so-called 'categorification' of Quantum Physics: instead of functions, manifolds and well-known old machinery we introduce sheaves, schemes and the corresponding new methods based on algebraic-geometrical constructions appeared in Math since the pioneering work of Alexander Grothendieck. It seems that such powerful machinery allows us to unify all existing phenomena via such a modern looking glass. Also, we consider the bridge of such an approach to other one, based on deformation quantization and related Wigner–Moyal–Weyl-von Neumann framework considered by us previously.

This is joint work with Antonina N. Fedorova.

C2-H1.1 **Monday, September 02, 2019, 14:50 – 15:10**

Flickering candle flames and their emergent synchronization. An experimental and dynamical systems approach.

Zoltán Néda
Babeș-Bolyai University, Department of Physics, Romania

Single candles tend to have a stable flame. For candles coupled in bundles, the flame oscillates with a frequency around 10-12 Hz [1,2]. The oscillation frequency decreases with the size of the bundle depending also on the topology in which the candles are grouped. Emergent in-phase and anti-phase synchronization was observed for the flames of nearby bundles. For short distances in-phase synchronization appears. For large distances first an anti-phase synchronization is observed, then synchrony disappears.

A dynamical system approach where the temperature and the oxygen concentration are the main variables was recently considered in order to understand the dynamical aspects of the problem [1]. We modify these evolution equations in order to be in agreement with novel experimental results. Furthermore the evolution equations for single bundles are coupled in an original manner to reproduce the experimentally observed facts. Results of carefully designed experiments support the validity of the considered coupling.

This is joint work with A. Gergely and B. Sandor.

[1] H. Kitahata et. al, J. Phys. Chem. A, vol. **113**, 8164 (2009)

[2] K. Okamoto et. al, Scientific Reports, vol. **6**, 36145 (2016)

C2-H1.2 **Monday, September 02, 2019, 15:10 – 15:30**

Mathematical model for the nonlinear dynamics of valve spring

Majdi Gzal
Technion, Israel Institute of Technology, Israel

The nonlinear dynamics of the valve spring of an internal combustion engine is mathematically modeled and investigated. Exact solutions in the form of time-periodic and spatially localized edge states are derived. The stability of the system is analyzed using the Floquet theory. Comparison of the analytical solution with numerical simulations and experimental test results conducted on an actual valve spring yields an excellent agreement.

Tuesday, September 03, 2019, 11:00 – 11:20 C3-AE1.1

Non-Markovianity and subdiffusion of volcanic seismicity

Norikazu Suzuki
Nihon University, College of Science and Technology, Japan

Volcanic seismicity is a special type of earthquake clustering that occurs not only during but also prior to eruption, indicating its significance as a precursor to such an event. Geophysical approaches to volcanic earthquakes involve high-level complexity regarding stress accumulation on faults: dynamics of dikes (propagating, inflating or being magma-filled), nontrivial geometry of the shape of magma migration (such as branching), transport of groundwater through porous media, etc. [1]. Thus, one inevitably faces with complex dynamics on complex architecture.

However, as we will see, volcanic seismicity itself can actually be characterized by a set of surprisingly simple empirical laws. In this talk, we focus our attention on the statistical-mechanical properties of volcanic seismicity at Mt. Etna. In particular, we perform an analysis in connection with the diffusion phenomenon of volcanic earthquakes, that is, growth of a region in time where earthquakes occur. We report several remarkable findings including the subdiffusive nature, the power-law waiting-time distribution and the exponential-law jump distribution [2, 3]. Although these results would seem to suggest that the phenomenon could be described by temporally-fractional kinetic theory based on the viewpoint of continuous-time random walks [4, 5], the exponent of the power-law waiting-time distribution actually lies outside of the range allowed in the theory. In addition, there exists the aging phenomenon in the event-time averaged mean squared displacement, in contrast to the picture of fractional Brownian motion [6, 7]. We also comment on possible relevances of random walks on fractals [8] as well as nonlinear kinetics [9] and (non-)Markovianity of the process [10, 11]. Thus, problems of volcanic seismicity are highly challenging for science of complex systems.

[1] D. L. Turcotte, Fractals and Chaos inn Geology and Geophysics, 2nd edition (Cambridge University Press, Cambridge) 1997.

[2] S. Abe and N. Suzuki, EPL, **110** (2015) 59001.

[3] S. Abe and N. Suzuki, Acta Geophysica, **65** (2017) 481.

[4] E. W. Montroll and G. H. Weiss, J. Math. Phys., **6** (1965) 167.

[5] R. Metzler and J. Klafter, Phys. Rep., **339** (2000) 1.

[6] B. B. Mandelbrot and J. W. Van Ness, SIAM Review, **10** (1968) 422.

[7] I. Goychuk and V. O. Kharchenko, Math. Model. Nat. Phenom., **8** (2013) 144.

[8] J. F. Lutsko and J. P. Boon, Phys. Rev. E, **77** (2008) 051103.

[9] D. Ben-Avraham and S. Havlin, Diffusion and Reactions in Fractals and Disordered Systems (Cambridge University Press, Cambridge) 2000.

[10] F. Bardou, J.P. Bouchaud, A. Aspect, C. Cohen-Tannoudji, Lévy statistics and laser cooling: how rare events bring atoms to rest (Cambridge University Press, Cambridge) (2002).

[11] S. Abe and N. Suzuki, Physica A, **338** (2009) 1917.

C3-AE1.3 **Tuesday, September 03, 2019, 11:40 – 12:00**

Signatures of low-dimensional intraseasonal motion in the data of a German climate station

Peter Carl
ASWEX - Applied Water Research, Germany

Climatic motions during the extended boreal summer season (256 days, from March 1 to November 11) have been studied in daily resolution using the surface air temperature (SAT) series of climate station Lindenberg (Mark) since the beginning of the record in 1906. It was surprising to see signals in these local data that sometimes closely correspond to the global behavior of a tropospheric General Circulation Model (GCM) of very low spatial resolution (i.e., a model of "intermediate complexity") – which nevertheless shows a qualitatively correct intraseasonal motion of the planetary-scale monsoon system, notably its 30-60 day activity cycle. In attractor studies of the GCM, this cycle was shown to represent the minor (poloidal) circumference of a torus segment in phase space. It displays a complete yet backwards running "route to chaos" in global integrals of motion, starting from out of fixpoint dynamics in spring via the passage of a subcritical Hopf bifurcation in early summer, with a hard jump into a chaotic July regime that is left then as the season advances into period doubling and period-one cycles. The latter stretches further toward a lately degenerate, very slow motion that develops from a fault into a 'scar' on the torus mantle and disappears to give way to the autumn fixpoint.

Though it is well-known that the monsoons on Earth are representatives of a global climatic subsystem, it was not expected to see even details of this GCM-scenario in local data at European midlatitudes. The year 2013 shows an archetypal example of period doubling in the station's SAT data, with a strong heat wave in midsummer flanked by weaker ones about 50 days apart each. Chaotic motions in the time-frequency plane, period doubling and stretching were also part in 2018 of the system's evolution into the strong heat wave that could be foreshadowed more than 30 days in advance, based in part on the qualitative, topological knowledge drawn from the GCM simulations. In addition to a couple of historical case studies, the contribution announced here displays analyses and projections of the evolving boreal summer 2019. The present abstract is written at the height of the heat wave end of June, which is speculated to be the stronger one in another period doubling regime and to be followed by a weaker pulse around about mid-August. If the major monsoon activity cycle is maintained this summer, the phase relation to the seasonal cycle reached might result in a relatively early termination of the 2019 boreal summer season. Two further, intriguing scenarios appear to be borne in the data by end of June, however. We shall better see by the date of the conference which one the system has chosen, and how the seasonal transition might proceed . . .

Tuesday, September 03, 2019, 12:00 – 12:20 C3-AE1.4

Topological universality of ride-sharing efficiency and the impact of asymmetric request distributions

Verena Krall
TU Dresden, Germany

Current mobility is highly inefficient, implying immense ecological and economical damages. Public ride-sharing buses that offer on-demand transportation from door to door while optimally combining the routes of several passengers provide options to make mobility more efficient and sustainable. Considering the large topological differences between street networks, for example between rural and urban regions, one important question is how efficient and feasible ride-sharing can be depending on the area in which it is introduced. Here, we present a class of efficiency measures for ride-sharing where the influence of network topology is captured by a single topological factor, thus indicating topological universality [N. Molkenthin, M. Schröder, M.Timme, Topological universality of on-demand ride-sharing efficiency (in prep., 2019)]. These insights enable us to quantify ride-sharing feasibility across networks. Differences in network topologies are often closely related to asymmetries in request distributions. As an example, a larger number of people is traveling daily towards an urban area than to the countryside. We discuss the influence of such asymmetries for ride-sharing efficiency and how they can be summarized in the context of a model we propose.

Tuesday, September 03, 2019, 11:00 – 11:20 C3-H1.1

On the $\mathfrak{sl}_2$-representation near the triple-zero bifurcation

Fahimeh Mokhtari
Vrije Universiteit (VU University Amsterdam), Department of Mathematics, Faculteit der Exacte Wetenschappen, NL

This work generalizes the work on the Bogdanov-Takens bifurcation and its unique normal form, which took off with the papers of Baider and Sanders (1991-92). Here the application of the Jacobson-Morozov theorem led to a systematic approach to computing the unique normal form in a number of cases.

One can imagine that the complications of analyzing the 3D triple-zero bifurcation are rather challenging. Nevertheless, progress has been made in the last decade and it is time to list what has been done and what still needs to be done.

We apply the Jacobson–Morozov theorem to embed this class of three dimensional vector fields into an $\mathfrak{sl}_2$-triple. Three irreducible families are produced this way. In this presentation, we will introduce these families with several geometrical properties of them.

The first step is to find the structure constants of these families. In this talk, we also show how the Clebsch-Gordan formula is employed to find explicit formulas for the structure constants. We demonstrate that these families can generate some Lie sub-algebras with respect to the triple-zero bifurcation point, thereby creating smaller subproblems that can be studied independently in their own right (like the Hamiltonian case in the 2D analysis).

C3-H1.2 **Tuesday, September 03, 2019, 11:20 – 11:40**

Dipolar chains and their hidden branches of equilibria

Jaime Cisternas

Universidad de los Andes, Facultad de Ingeniería y Ciencias Aplicadas, Chile

We use a small number of magnetic dipoles hinged on a plane and subject to an external magnetic field for studying more complex metamaterials and hysteresis loops. Depending on the intensity of the applied field and other details as the number of dipoles and their distances, several stable equilibria can coexist [PRL 120, 157202 (2018)]. Using bifurcation theory we have found the nature of the transitions and the relevance of the unstable solutions that reveal the symmetries of the system. In the case of more than one stable solution, their basins of attraction in the space of initial configurations show surprising rich structure. In the last part of the presentation, I will show how the unstable solutions can be stabilized and thus observed in experiments by using a high-frequency excitation (as it was originally shown for the inverted pendulum by Kapitza).

In collaboration with Paula Mellado and Andrés Concha.

C3-H1.3 **Tuesday, September 03, 2019, 11:40 – 12:00**

Global bifurcations of limit cycles and strange attractors in multi-parameter dynamical systems

Valery Gaiko

United Institute of Informatics Problems, National Academy of Sciences of Belarus, Belarus

We carry out a global bifurcation analysis of multi-parameter polynomial dynamical systems. To control the global bifurcations of limit cycles in planar systems, it is necessary to know the properties and combine the effects of all their rotation parameters. It can be done by means of the development of new bifurcational geometric methods based on the Wintner-Perko termination principle. Using these methods, we present, e.g., a solution of Hilbert's Sixteenth Problem on the maximum number and distribution of limit cycles for the Kukles cubic-linear system, the general Lienard polynomial system with an arbitrary number of singular points, Leslie-Gower systems which model the population dynamics in real ecological or biomedical systems and a reduced planar quartic Topp system which models the dynamics of diabetes. Applying a similar approach, we study also three-dimensional polynomial dynamical systems and, in particular, complete the strange attractor bifurcation scenarios in Lorenz type systems connecting globally the homoclinic, period-doubling, Andronov-Shilnikov, and period-halving bifurcations of limit cycles.

Tuesday, September 03, 2019, 12:00 – 12:20 C3-H1.4

Phase-sensitive excitability of a limit cycle

Matthias Wolfrum
Weierstrass Institute, Berlin, Germany

The classical notion of excitability refers to an equilibrium state that shows under the influence of perturbations a nonlinear threshold-like behavior. We extend this concept by demonstrating how periodic orbits can exhibit a specific form of excitable behavior where the nonlinear threshold-like response appears only after perturbations applied within a certain part of the periodic orbit, i.e the excitability happens to be phase-sensitive. We demonstrate this concept using the relaxation oscillations of the FitzHugh-Nagumo system. Triggering the phase-sensitive excitability by noise leads to a characteristic non-monotone dependence of the mean spiking rate of the relaxation oscillation on the noise level. In a system of two mutually coupled FitzHugh-Nagumo oscillators the phase sensitive excitability can induce a dynamical regime with alternating spiking order, called leap-frogging.

Tuesday, September 03, 2019, 16:00 – 16:20 C4-AE1.1

Jump intermittency near the boundary of generalized synchronization in systems with complex topology of attractor

Olga Moskalenko
Saratov State University, Russian Federation

The transition from asynchronous dynamics to generalized chaotic synchronization and then to completely synchronous dynamics is known to be accompanied by on-off intermittency. We show that there is another type of the transition called as jump intermittency which occurs near the boundary of generalized synchronization in chaotic systems with complex topology of attractor. Although this transient behavior also exhibits intermittent dynamics, it sufficiently differs from on-off intermittency supposed hitherto to be the only one type of motion corresponding to the transition to generalized synchronization. This type of transition is demonstrated in both unidirectionally and mutually coupled chaotic Lorenz and Chen oscillators.

C4-AE1.2 **Tuesday, September 03, 2019, 16:20 – 16:40**

Dimensional reduction in coupled heteroclinic cycles

Maximilian Voit
Jacobs University Bremen, Germany

Modeling complex systems as networks has recently received much attention, as real world systems usually consist of many coupled units. The dynamics of such coupled systems generically differs from the individual dynamics of single units and collective effects are in the focus of interest. Although heteroclinic cycles emerge robustly in various scenarios (e.g. in biology, fluid dynamics, or game theory), systems of coupled heteroclinic cycles have not been extensively studied up to now. Here, we present results on small systems of coupled heteroclinic cycles. In spite of their simple structure, these systems show rich dynamics. In particular, we explain the emergence of different kinds of dimensional reduction, especially toward a synchronized state, and the multistability between them. Furthermore, we find transient chaos and investigate its scaling behaviour.

C4-AE1.3 **Tuesday, September 03, 2019, 16:40 – 17:00**

Repulsively coupled Kuramoto-Sakaguchi phase oscillators ensemble subject to common noise

Chen Gong
Universität Potsdam, Deutschland

We consider the Kuramoto-Sakaguchi model of identical coupled phase oscillators with a common noisy forcing. While common noise always tends to synchronize the oscillators, a strong repulsive coupling prevents the fully synchronous state and leads to a nontrivial distribution of oscillator phases. In previous numerical simulations, a formation of stable multicluster states has been observed in this regime. However we argue here, that because identical phase oscillators in the Kuramoto-Sakaguchi model form a partially integrable system according to the Watanabe-Strogatz theory, the formation of clusters is impossible. Integrating with various time steps reveals that clustering is a numerical artifact, explained by the existence of higher order Fourier terms in the errors of the employed numerical integration schemes. Monitoring the induced change in certain integrals of motion we quantify these errors. We support these observations by showing, on the basis of the analysis of the corresponding Fokker-Planck equation, that two-cluster states are non-attractive. On the other hand, in ensembles of general limit cycle oscillators, such as Van der Pol oscillators, due to an anharmonic phase response function, as well as additional amplitude dynamics, multiclusters can occur naturally.

Tuesday, September 03, 2019, 17:00 – 17:20 C4-AE1.4

Transitions in random dynamical systems with bounded uncertainty

Kalle Timperi
Imperial College London, United Kingdom

As an alternative to stochastic differential equations, the assumption of bounded noise can offer a flexible and transparent paradigm for modelling systems with uncertainty. In particular, it offers an avenue for carrying out stability and bifurcation analysis in random dynamical systems, using a set-valued dynamics approach. The system under study is assumed to be a discrete time dynamical system in a low-dimensional Euclidian space, with bounded random kicks at each time step. The collective behaviour of all future trajectories is then represented by a set-valued map, whose minimal invariant sets represent the stable state-space regions of the system, including the effect of the noise/randomness.

We describe in the 2-dimensional case the geometric properties of minimal invariant sets, and provide a classification result for the singularity points on their boundaries. The geometry is quite well understood in this case, but becomes increasingly more complicated in higher dimensions. The geometric picture obtained serves as a stepping stone for further dynamical analysis of the systems.

In order to illuminate the loss of stability near a set-valued bifurcation, we will discuss the boundary dynamics of the minimal invariant sets, and present a numerical scheme for tracking the boundaries for changing parameter values and noise amplitudes.

Tuesday, September 03, 2019, 17:20 – 17:40 C4-AE1.5

A Bayesian nonparametric approach to the approximation of the global stable manifold

Konstantinos Kaloudis
Department of Mathematics, Nazarbayev University, Kazakhstan

In this work, a Bayesian nonparametric approach to the approximation of the global stable manifold is presented. Specifically, we introduce the Backward GSBR (BGSBR) model, in order to estimate past unobserved observations, namely performing prediction in reversed time, given dynamically noisy corrupted chaotic time series. The BGSBR sampler can be applied multiple times over proper subsets of the noisy observations, each time generating posterior samples for the various initial conditions. Then, the global stable manifold of the associated deterministic map can be stochastically approximated as the union of the supports, or the regions of higher probability, of the posterior marginal distributions. The proposed method is parsimonious and we demonstrate its efficiency in cases of both invertible and non-invertible maps. We are currently applying these ideas to the dynamics of coupled semiconductor laser arrays.

C4-AE1.6 **Tuesday, September 03, 2019, 17:40 – 18:00**

Symmetry and bifurcations in ring networks with periodically switched connections

Lucia Russo
Consiglio Nazionale delle Ricerche, Italy

We analyse transitions between symmetric and asymmetric regimes in a ring network with periodically forced connections. In particular, the connections of the network are periodically switched in a circular way. We analyse the symmetry-breaking phenomena which emerge due to the interaction between the natural and external forcing action. The system exhibits Neimark-Saicker bifurcations, where the periods are exact multiples of the period of the forcing or quasi-periodic regimes. In addition to frequency locking, we observe symmetry-breaking transitions. We found that symmetry breaks when the rotational number of the limit cycle, which arises from the Neimark-Saicker bifurcation, has a specific ratio. Finally, symmetry locking and resonance regions are computed through the bifurcation analysis to detect the critical parameters which mark the symmetry-breaking transitions.

C4-AE2.6 **Tuesday, September 03, 2019, 17:40 – 18:00**

Uniqueness of the trivial solution for some quasilinear inequalities

Olga Salieva
Moscow State Technological University 'Stankin', Russia

We consider the quasilinear elliptic inequality

$$-\Delta_p u \geq a(x)u_+^{q_1} + b(x)u_-^{q_2} \quad (x \in \mathbb{R}^n),$$

where $p > 1$, q_1, $q_2 \in \mathbb{R}$, $u_+ = \max\{u, 0\}$, $u_- = -\min\{u, 0\}$, and the functions $a(x)$ and $b(x)$ satisfy power-like lower bounds.

We obtain sufficient conditions for the uniqueness of the trivial weak solution of this inequality.

This is joint work with Evgeny Galakhov, RUDN University, Russia.

C4-H1.1 **Tuesday, September 03, 2019, 16:00 – 16:20**

Emergence of quasi-equilibrium in Hamiltonian systems

Tatsuo Yanagita
Osaka Electro-Communication University, Japan

We study relaxation to equipartition in a slow-fast Hamiltonian system. By using the so-called bead-spring model which is one of the most popular polymer models, we report on the relaxation to equilibrium. When the system has two distinct time scales, i.e, the fast vibration of bonds between beads and the slow interaction between the beads and solvent, the relaxation time takes extremely long, and which obeys Boltzmann-Jeans law. In the course of the relaxation to equipartition, we report an emergence of quasi-equilibrium state due to the effect of 'freezing' for the high-frequency degrees of freedom.

Tuesday, September 03, 2019, 16:40 – 17:00 C4-H1.3

An investigation of chaotic diffusion in a family of Hamiltonian mappings whose angles diverge in the limit of vanishingly action

Edson Leonel
Department of Physics - UNESP, Univ Estadual Paulista, Brazil

The chaotic diffusion for a family of Hamiltonian mappings whose angles diverge in the limit of vanishingly action is investigated by using the solution of the diffusion equation. The system is described by a two-dimensional mapping for the variables action, I, and angle, θ and controlled by two control parameters:

(i) ϵ, controlling the nonlinearity of the system, particularly a transition from integrable for $\epsilon = 0$ to non-integrable for $\epsilon \neq 0$ and

(ii) γ denoting the power of the action in the equation defining the angle. For $\epsilon \neq 0$ the phase space is mixed and chaos is present in the system leading to a finite diffusion in the action characterized by the solution of the diffusion equation. The analytical solution is then compared to the numerical simulations showing a remarkable agreement between the two procedures.

Tuesday, September 03, 2019, 17:00 – 17:20 C4-H1.4

Structure, size and statistical properties of chaotic components in Hamiltonian systems with divided phase space

Crt Lozej
CAMTP - Center for Applied Mathematics and Theoretical Physics, Slovenia

Generic Hamiltonian dynamical systems are neither integrable nor fully chaotic. Whether the motion is chaotic or not depends on the initial condition. The phase space is divided into various invariant components. Typically, the chaotic component, known as the chaotic sea, surrounds an infinite number of Kolmogorov-Arnold-Moser (KAM) islands. Invariant fractal sets known as cantori may also be present and limit transport in the phase space causing the phenomenon known as stickiness. In the talk we will present the statistical properties of the largest chaotic component in a family of billiards introduced by Robnik as well as the family of Lemon billiards. By changing the value of the billiard parameters, we may acquire anything from a fully regular (integrable) to fully chaotic (ergodic) Hamiltonian systems. We divide the phase space into a grid of cells and determine which of them belong to the chaotic component by the iteration of a chaotic orbit. We compare the dynamics of the cell filling with the so-called random model, that assumes completely uncorrelated cell visits and accurately describes the filling of cells for ergodic systems. We will show that due to stickiness the random model fails to describe the cell filling in systems where stickiness is present. The statistics of cell recurrence times provide a way of quantifying the stickiness of the structures in the phase space.

C4-H1.5 **Tuesday, September 03, 2019, 17:20 – 17:40**

Coexistence of Hamiltonian-like and dissipative dynamics in chains of coupled oscillators with skew-symmetric coupling

Serhiy Yanchuk

Technical University of Berlin, Institute of Mathematics, Germany

We consider rings of coupled phase oscillators with anisotropic coupling. When the coupling is skew-symmetric, i.e., when the anisotropy is balanced in a specific way, the system shows robustly a coexistence of Hamiltonian-like and dissipative dynamics in the phase space. We relate this phenomenon to the time-reversibility of the system. The geometry of low-dimensional systems up to five oscillators is described in detail. In particular, we show that the boundary between the dissipative and Hamiltonian-like regions consists of families of heteroclinic connections. In the limit of $N \to \infty$ oscillators, we formally derive an amplitude equation for solutions close to synchrony. It has the form of a nonlinear Schrödinger equation and describes the Hamiltonian-like region.

C4-H1.6 **Tuesday, September 03, 2019, 17:40 – 18:00**

Integrable dynamical systems with dissipation

Maxim V. Shamolin

Lomonosov Moscow State University, Institute of Mechanics, Russian Federation

We study nonconservative systems for which the usual methods of the study, e.g., Hamiltonian systems, are inapplicable. Thus, for such systems, we must “directly” integrate the main equation of dynamics. We generalize previously known cases and obtain new cases of the complete integrability in transcendental functions of the equation of dynamics of a lower- and multi-dimensional rigid bodies in a nonconservative force fields.

Of course, in the general case, the construction of a theory of integration of nonconservative systems (even of low dimension) is a quite difficult task. In a number of cases, where the systems considered have additional symmetries, we succeed in finding first integrals through finite combinations of elementary functions.

We obtain a series of complete integrable nonconservative dynamical systems with nontrivial symmetries. Moreover, in almost all cases, all first integrals are expressed through finite combinations of elementary functions; these first integrals are transcendental functions of their variables. In this case, the transcendence is understood in the sense of complex analysis, when the analytic continuation of a function into the complex plane has essentially singular points. This fact is caused by the existence of attracting and repelling limit sets in the system (for example, attracting and repelling focuses).

Wednesday, September 04, 2019, 11:00 – 11:20 C5-AE2.1

Adaptive delayed feedback control to stabilize in-phase synchronization in complex oscillator networks

Viktor Novičenko
Vilnius University, Lithuania

In-phase synchronization is a special case of synchronous behavior when coupled oscillators have the same phases for any time moments. Such behavior appears naturally for nearly identical coupled limit-cycle oscillators when the coupling strength is greatly above the synchronization threshold. We investigate the general class of nearly identical complex oscillators connected into network in a context of a phase reduction approach. By treating each oscillator as a black-box possessing a single-input single-output, we provide a practical and simply realizable control algorithm to attain the in-phase synchrony of the network [1]. For a general diffusive-type coupling law and any value of a coupling strength (even greatly below the synchronization threshold) the delayed feedback control with a specially adjusted time-delays can provide in-phase synchronization [2]. Such adjustment of the delay times performed in an automatic fashion by the use of an adaptive version of the delayed feedback algorithm [3] when time-delays become time-dependent slowly varying control parameters. Analytical results show that there are many arrangements of the time-delays for the in-phase synchronization, therefore we supplement the algorithm by an additional requirement to choose appropriate set of the time-delays, which minimize power of a control force. Performed numerical validations of the predictions highlights the usefulness of our approach.

[1] V. Novičenko, I. Ratas: In-phase synchronization in complex oscillator networks by adaptive delayed feedback control, Phys. Rev. E **98**, 042302 (2018)

[2] V. Novičenko: Delayed feedback control of synchronization in weakly coupled oscillator networks, Phys. Rev. E **92**, 022919 (2015)

[3] V. Pyragas and K. Pyragas: Adaptive modification of the delayed feedback control algorithm with a continuously varying time delay, Phys. Lett. A **375**, 3866 (2011)

Wednesday, September 04, 2019, 11:20 – 11:40 C5-AE2.2

Target waves and new chimera structures in a 2D lattice of nonlocally coupled Van der Pol oscillators

Vadim Anishchenko
Saratov State University, Russia

The dynamics of a two-dimensional lattice of nonlocally coupled Van der Pol oscillators is studied using a numerical simulation method. The possibility of realizing regular spiral and target waves has been established. We demonstrate the emergence of a new type of chimera structure which is realized on the base of target waves in the considered network. This chimera structure is called a “target wave chimera”. The characteristics of target wave chimeras are compared with those for spiral wave chimeras.

C5-AE2.3 **Wednesday, September 04, 2019, 11:40 – 12:00**

Formation mechanisms of spiral and double-well chimeras in a 2D lattice of coupled bistable FitzHugh-Nagumo oscillators

Igor Shepelev
Saratov State University, Russia

We study the dynamics of a 2D lattice of nonlocally coupled FitzHugh-Nagumo oscillators in the bistable regime. Special attention is paid to the research of influence both of a type of boundary conditions and of features of the oscillator interaction on a formation of wave regimes and of spatiotemporal structures. It is shown that a shift of effective values of the control parameters of partial oscillators under influence of the coupling significantly changes the oscillator dynamics and can lead to switching the dynamical regimes of the whole system. A regime of the spiral chimera has been found in the lattice under study. It is revealed that the system is in the hyperchaotic regime for this chimera state. We also explain the mechanisms of emergence both of the double-well and spiral chimera states realizing in the lattice.

C5-AE2.4 **Wednesday, September 04, 2019, 12:00 – 12:20**

Forced synchronization of a heterogeneous multilayer network of nonlocally coupled maps

Galina Strelkova
Saratov State University, Russia

We study numerically forced synchronization of a heterogeneous multilayer network of nonlocally coupled chaotic maps. Transmission of chimera states in the first (master) layer is considered for the cases of unidirectional and asymmetric mutual inter-layer coupling. It is shown that there is a threshold of forced synchronization for different chimera types (phase and amplitude chimeras) in the master layer. It is established that the presence of backward inter-layer coupling is a significant obstacle for global synchronization across the considered network. We also analyze and compare the impact of heterogeneity in the control and coupling parameters on the degree of forced synchronization.

Wednesday, September 04, 2019, 11:00 – 11:20 C5-H1.1

Solitary waves in a non-integrable chain with double-well potentials

Shmuel Katz
Technion – Israel Institute of Technology, Israel

We study solitary waves in a 1-D lattice of identical masses that are connected in series by nonlinear springs. The potential of each spring is nonconvex, where two disjoint convex regions, Phase I and Phase II, are separated by a concave, spinodal region. Consequently, the force-strain relation of the spring is non-monotonous, which gives rise to a bistable behavior. Based on analytical treatment, with some approximations, combined with extensive numerical simulations, we are able to reveal important insights. For example, we find that the solitary wave solution is indifferent to the energy barrier that separates the two energy wells associated with Phase I and Phase II, and that the shape of the wave can be described by means of merely two scalar properties of the potential of the springs, namely the ratio of stiffness in Phase II and Phase I, and the ratio between the Maxwell's force and corresponding transition strain. The latter ratio provides a useful measure for the significance of the spinodal region. Linear stability of the solitary-wave solution is studied analytically using the Vakhitov-Kolokolov criterion applied to the approximate solutions obtained in the first part. These results are validated by numerical simulations. We find that the solitary wave solution is stable provided that its velocity is higher than some critical value. It is shown that, practically, the solitary waves are stable for almost the entire range of possible wave velocities. This is also manifested in the interaction between two solitary waves or between a solitary wave and a wall (rigid boundary). Such interaction results in a minor change of height and shape of the solitary wave along with the formation of a trail of small undulations that follow the wave, as expected in a non-integrable system. Even after a significant number of interactions the changes in the wave height and shape are minor, suggesting that the bistable chain may be a useful platform for delivering information over long distances, even in concurrent with additional information (other solitary waves) passing through the chain.

C5-H1.2 **Wednesday, September 04, 2019, 11:20 – 11:40**

Investigation of Turing structures formation under the influence of wave instability

Maxim Kuznetsov
1) P. N. Lebedev Physical Institute of the Russian Academy of Sciences
2) Peoples' Friendship University of Russia, Russia

The classical nonlinear model Brusselator is considered, being augmented by addition of a third variable, which plays the role of a fast-diffusing inhibitor. The model is investigated in one-dimensional case in the parametric domain, where both wave instability and Turing instability are manifested, the former leading to spontaneous formation of autowaves and the latter leading to the spontaneous formation of stationary dissipative structures. It is shown that, due to the subcritical nature of Turing bifurcation, the interaction of two instabilities in this system results in spontaneous formation of stationary dissipative structures already before the passage of Turing bifurcation. In response to different perturbations of the spatially uniform stationary state, various combinations of stationary and autowave dissipative structures can be formed in the parametric domain under study. At that, the system is multistable and exhibits high sensitivity to the initial conditions, which leads to the blurring of boundaries between qualitatively different regimes in the parametric region. In two-dimensional case, mixed modes turn out to be only transient — upon the appearance of localized Turing structures under the influence of wave regime, they eventually occupy all available space.

C5-H1.3 **Wednesday, September 04, 2019, 11:40 – 12:00**

Existence and stability of periodic travelling waves: who will prevail in a Rock-Paper-Scissors game?

Cris Ragheb Hasan
University of Auckland, Department of Mathematics, New Zealand

We study a Rock-Paper-Scissors model that describes the spatiotemporal evolution of three competing populations in ecology, or strategies in evolutionary game theory. The dynamics of the model is determined by a set of partial differential equations (PDEs) that features travelling waves (TWs) in one spatial dimension and spiral waves in two spatial dimensions. We focus on periodic TWs, and the closely-related spiral-wave patterns in this model. A characteristic feature of this model is the present of a robust heteroclinic cycle that plays a key role in the organization of periodic TW. The existence of periodic TWs can be established via the transformation of the PDE model into a system of ordinary differential equations (ODEs) under the assumption that wave speed is constant. We explore the bifurcation diagram of the ODE system and investigate the existence of TWs as different parameters are varied. Determining the stability of periodic TWs is more challenging and requires a study of the essential spectrum of the linear operator of the periodic TWs. We compute this spectrum and the curve of instability with the continuation method developed in [Rademacher et al., Physica D, 2007]. We also develop a method for computing what we call belts of instability, which are indicators of the temporal expansion rates of unstable TWs. We finally show how our results from the stability analysis are verified by direct simulation of the PDE model and how the computed growth rates accurately quantify the instabilities of the travelling waves.

Wednesday, September 04, 2019, 12:00 – 12:20 C5-H1.4

Convective nano-flow in self-assembled precipitate membranes

Silvana Cardoso
University of Cambridge, Department of Chemical Engineering & Biotechnology, United Kingdom

We demonstrate experimentally and theoretically that self-assembled precipitate membranes with dual permeability can initiate and maintain exchange nano-flows using the chemical-potential gradient of a dissolving solute. Moreover, we show how such chemical energy can drive stable, oscillatory and explosive convective motions.

Thursday, September 05, 2019, 12:00 – 12:20 C6-AM.4

New type of oscillation death in coupled counter-rotating identical nonlinear oscillators

Jung-Wan Ryu
Institute for Basic Science, South Korea

We study oscillatory and oscillation suppressed phases in coupled counter-rotating nonlinear oscillators. We demonstrate the existence of limit cycle, amplitude death, and oscillation death, and also clarify the Hopf, pitchfork, and infinite period bifurcations between them. Especially, the oscillation death is a new type of oscillation suppressions of which the inhomogeneous steady states are neutrally stable. We discuss the robust neutral stability of the oscillation death in non-conservative systems via the anti-PT-symmetric phase transitions at exceptional points in terms of non-Hermitian systems.

C6-H1.1 **Thursday, September 05, 2019, 11:00 – 11:20**

Predicting spatio-temporal time series using dimension reduced local states

Jonas Isensee
Institute for the Dynamics of Complex Systems, Georg August University Göttingen
Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Understanding spatio-temporal dynamics is central to describing many physical and biological systems in nature that exhibit behaviour such as turbulence and wave propagation.

For cases where no mathematical model based on first principles is available data driven approaches may provide an interesting and useful alternative for describing the process of interest.

We present a method for both, cross estimation and iterated time series prediction of spatio-temporal dynamics based on reconstructed local states and local modeling using nearest neighbour methods. Typical computational problems that arise from complex high-dimensional data sets are addressed by dimension reduction based on principal component analysis and symmetry considerations of the underlying dynamics. The efficacy of this approach is shown for (noisy) chaotic spatio-temporal data from a cubic Barkley model, the Bueno-Orovio-Cherry-Fenton model, the Kuramoto Sivashinsky equation, and the Lorenz-96 model.

This is joint work with George Datseris and Ulrich Parlitz.

C6-H1.2 **Thursday, September 05, 2019, 11:20 – 11:40**

Predicting high dimensional chaos using machine learning

Ulrich Parlitz
Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

Methods from Machine Learning provide powerful tools for data driven modeling of dynamical processes. We shall demonstrate how Reservoir Computing [1] and a combination of Convolutional Autoencoders and Conditional Random Fields [2] can very efficiently (cross-) predict time series from spatially extended, hyperchaotic systems. Using different examples performance and (data) requirements of these and other methods will be compared and assessed.

[1] R. Zimmermann and U. Parlitz, Observing spatio-temporal dynamics of excitable media using reservoir computing, Chaos **28**, 043118 (2018)

[2] S. Herzog, F. Wörgötter and U. Parlitz, Data-Driven Modeling and Prediction of Complex Spatio-Temporal Dynamics in Excitable Media, Frontiers in Applied Mathematics and Statistics 4, **60** (2018)

Thursday, September 05, 2019, 11:40 – 12:00 C6-H1.3

Measuring Lyapunov spectrum of large chaotic systems with global coupling by time series analysis

Taro Shimizu

Department of Physics, Tokyo Institute Technology, Japan

Although the Lyapunov exponents are essential to characterizing chaos, it still remains a challenge to measure them for large experimental systems, mainly due to the lack of recurrences in time series analysis. Here, we develop a method to overcome this difficulty, valid for systems determined by a few variables such as systems with global coupling, for which the dimensionality of recurrence analysis can be reduced drastically [1]. We test our method numerically with two globally coupled systems, namely, logistic maps and limit-cycle oscillators with global coupling. The evaluated exponent values are successfully compared with the true ones obtained by the standard numerical method.

[1] T. P. Shimizu and K. A. Takeuchi, Chaos **28**, 121103 (2018).

C6-H1.4 **Thursday, September 05, 2019, 12:00 – 12:20**

Control of multistability in harmonically driven nonlinear oscillators via a temporary addition of a second harmonic component to the driving

Ferenc Hegedűs
Budapest University of Technology and Economics, Department of Hydrodynamic Systems, Hungary

Multistability is a very common feature of nonlinear systems. It occurs when multiple stable states coexist at fixed parameter sets. It is present in many fields of sciences from hydrodynamics, mechanical engineering, chemistry, neuroscience to social sciences. The different stable states represent different system performances (e.g. chemical output); thus, driving the system into a desirable stable state is of paramount importance. This is the main objective of the research area called "Control of Multistability". There are three major control strategies presented in the literature. Nonfeedback techniques are easy to use (e.g. kick the system) but direct attractor selection is not possible. Applying a feedback control strategy, this disadvantage can be solved; however, in certain systems, the employment of a feedback control is impossible. The third category, stochastic control, operates by adding external noise to the system resulting in the annihilation of some attractors. In this way, control of multistability can be achieved by reducing the number of coexisting stable states. As a drawback of this technique, direct attractor selection is also not possible. The main aim of the present study is to propose a control technique in which direct attractor selection is possible without using feedback to the system. Our method works for harmonically driven nonlinear oscillators via a temporary addition of a second harmonic component to the driving. It is tested on several systems: on the Keller—Miksis equation well-known in bubble dynamics and sonochemistry, and on the classical Duffing, Morse and Toda nonlinear oscillators.

This is a joint work with Péter Krähling (Department of Hydrodynamics Systems, Budapest University of Technology and Economics), with Prof. Dr. Werner Lauterborn and Dr. Robert Mettin (Drittes Physikalisches Institut, Georg-August-Universität Göttingen) and with Prof. Dr. Ulrich Parlitz and Marcel Aron (Research Group Biomedical Physics, Max Planck Institute for Dynamics and Self-Organization, Göttingen).

Thursday, September 05, 2019, 17:00 – 17:20 C7-AE2.4

Intralayer synchronization in evolving multiplex hypernetworks

Sarbendu Rakshit
Indian Statistical Institute, Kolkata, INDIA

Complex network theory is an appropriate tool to characterize the large variety of interacting systems. While the interactional organization may consist with multiple types of interactions among the inter-connected systems, which are not always static, rather they are varying in space and time. This study is concerned with the intralayer synchronization of multiplex networks where nodes in each layer interact through diverse types of coupling functions associated with different time-varying network topologies, referred as multiplex hypernetworks. Here all types of intralayer connections are evolving with respect to time, and interlayer connections are stagnant. Now an interesting problem is how to analyze the stability of the intralayer synchronization in such temporal networks. We prove that if the dynamical multiplex hypernetwork for the static time-average topology possesses intralayer synchronization, then each layer of the time-varying multiplex hypernetwork will be synchronized, for sufficiently fast switching. Then through master stability function formalism, we analytically derive the necessary and sufficient stability condition of intralayer synchronous states for such temporal architecture in terms of time-average dynamical network. The generalization of our stability approach is articulated. Finally, theoretical findings are verified numerically by taking the network of paradigmatic chaotic Rössler oscillators.

C7-AE2.5 **Thursday, September 05, 2019, 17:20 – 17:40**

Impact of multiplexing on spatiotemporal dynamical patterns in networks: Role of inhibition

Sarika Jalan
Professor, Complex Systems Lab, Disciplines of Physics, Indian Institute of Technology Indore, Indore, India

In the past few decades, the study of networks has been catapulted into the limelight due to their booming applications in various branches of science and engineering. One of the aspects of network science is to study the collective output of a system arising due to complex interactions between its constituents. The interactions (edges) between the constituents (nodes) often result in fascinating spatiotemporal phenomena, among which synchronization of coupled phase oscillators has proven to be important in understanding the collective behaviors of a variety of real-world complex systems ranging from physical to biological systems. Furthermore, multiplex networks frameworks incorporating existence of various types of interactions between the same pair of nodes by categorizing them in different layers with each layer reflecting a specific type of interaction have provided a new dimension to complex systems research. Few examples of multiplex networks are transport systems (with different means of travel as different layers), biochemical networks (with different signaling channels representing different layers), etc. The influence of multiple types of interactions on the dynamical behavior of an individual layer has been one of the principal objectives of the studies on multiplex networks.

We investigate the impact of inhibition in one layer on the collective behavior of the entire multiplex networks and that of other layers. We report that there exists an enhancement in the appearance of the chimera state in one layer of the multiplex network in the presence of repulsive coupling in the other layer. Furthermore, we show that a small amount of inhibition or repulsive coupling in one layer is sufficient to yield the chimera state in another layer by destroying its synchronized behavior. These results can be used to obtain insight into dynamical behaviors of those systems where both attractive and repulsive couplings exist among their constituents. Additionally, explosive synchronization (ES) in a network is shown to be originated from considering either degree-frequency correlation, frequency-coupling strength correlation, inertia or adaptively-controlled phase oscillators. We show that ES is a generic phenomenon and can occur in any network by multiplexing it with an appropriate layer without considering any prerequisite for the emergence of ES. We devise a technique which leads to the occurrence of ES with hysteresis loop in a network upon its multiplexing with a negatively coupled (or inhibitory) layer. This investigation is a step forward in highlighting the importance of multiplex framework not only in bringing novel phenomena which are not possible in an isolated network but also in providing more structural control over the induced phenomena.

[1] Sarika Jalan, Saptarshi Ghosh, Bibhabasu Patra, Is repulsion good for the health of chimeras? Chaos (Fast Track) **27** (10), 101104 (2017)

[2] Sarika Jalan, Vasundhara Rathore, Ajay Deep Kachhvah and Alok Yadav, Inhibition induced explosive synchronization in multiplex networks. arXiv:1904.01801 [nlin.AO]

[3] Saptarshi Ghosh, and Sarika Jalan. (2018). Engineering chimera patterns in networks using heterogeneous delays. Chaos (Fast Track), **28**, 071103 (Editors Pick Article).

Thursday, September 05, 2019, 17:40 – 18:00 C7-AE2.6

Taming chimera state using heterogeneous delays

Saptarshi Ghosh
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Coupled nonlinear systems can exhibit a plethora of complex interaction patterns and novel emergent phenomena, among which partial synchronization patterns of chimera state has recently attracted considerable attention. The chimera state refers to a hybrid state in which coherent and incoherent dynamics coexist in a coupled network of identical oscillators. Recent literature has indicated a strong connection between the occurrence of chimera and various responses of neurons in brain networks. For example, the chimera state has been related to the uni-hemispheric sleep in mammals where half of the brain remains asleep, while the other half remains active. Various brain diseases have been linked to chimera states such as spatio-temporal correlation profiles, obtained from Electroencephalogram readings of ecliptic seizures, bore striking similarities with hybrid patterns of the chimera state. Due to potential applicability as well as fundamental significance of the study of chimera state, there have been persistent efforts to control the chimera states, one of which is to introduce delayed interaction between the nodes of the network. We present a method to engineer a chimera state by using an appropriate distribution of heterogeneous time delays on the edges of a network. Using a coupled chaotic map with the identical coupling environment, we demonstrate that control over the spatial location of the incoherent region of a chimera state in a network can be achieved. We show that in the coherent regime, the position of the incoherent region can be controlled by suitably placing the delayed nodes in a preferred spatial location. By appropriate distribution of the heterogeneous delays, it is possible to engineer both the single-cluster and the multi-cluster chimera state. This investigation also indicates that the partial heterogeneous delays play a crucial role in the emergence of the chimera states. The influence of delayed nodes in the engineering of the chimera state can be explained by comparing the time evolution of the delayed with those of the undelayed nodes. At high coupling values, the undelayed nodes reach to a coherent state and the delayed nodes lag behind due to the existence of the heterogeneous delays. Thus, at a particular time, the undelayed nodes form the coherent bulk whereas the delayed nodes show a scattered spatial profile, giving rise to the chimera state.

[1] Saptarshi Ghosh and Sarika Jalan. (2018). Engineering chimera patterns in networks using heterogeneous delays. Chaos (Fast Track), **28**, 071103 (Editors Pick Article).

[2] Sarika Jalan, Saptarshi Ghosh, Bibhabasu Patra. (2017). Is repulsion good for the health of chimeras? Chaos (Fast Track) **27** (10), 101104.

C7-H1.1 **Thursday, September 05, 2019, 16:00 – 16:20**

The bee Trigona builds its comb like a crystal

Julyan Cartwright
CSIC, Spain

Bees of the genus Trigona construct a brood comb with a spiral or a target pattern architecture in three dimensions. Crystals possess these same patterns on the molecular scale. Here we show that the same excitable-medium dynamics governs both crystal nucleation and growth and comb construction in Trigona, so that a minimal coupled-map lattice model based on crystal growth explains how bees produce the structures seen in the bee combs.

C7-H1.2 **Thursday, September 05, 2019, 16:20 – 16:40**

Complete synchronization emergence under advection

Maximiliano Contreras
German Cancer Research Center (DKFZ) Heidelberg, Germany

Synchronization is a paradigmatic type of emerging collective behavior in complex systems. It is characterized by the rhythm adjustment and the coordinated action of the system's components. This phenomenon is very ubiquitous in several systems; circadian rhythm, microwave generators, Josephson junctions, coupled lasers, cooperative behavior of insects and neuronal firing, among others.

One way to study complex systems, and in particular synchronization, is using Coupled Map Lattices (CML) models. For this type of mathematical models, mainly symmetric (diffusive) and instantaneous (no delay) interactions have been considered. For antisymmetric interactions (advection), there are key studies on transport phenomena; gradient flows, the velocity of patterns and pattern evolution.

In our work we investigate the effect of advection on completely synchronized states (CSS) for a ring lattice, with and without time delay. We found that advection mainly reduces the number of stable CSS without affecting the nature of the orbits in phase space. When the model has both, delay and advection, the interplay shows that delays lessen the effect of advection, allowing CSS in the short-range. For long range interactions, delays dominates the dynamics, regardless the intensity of the advection, hindering its global effect.

Thursday, September 05, 2019, 16:40 – 17:00 C7-H1.3

Diagnostics of fs-laser induced plasma formation in bulk fused silica with the help of low-order harmonic emission

Alexandre Mermillod-Blondin
Max-Born-Institute Berlin, Germany

Focusing an ultrashort laser pulse in the volume of a transparent solid dielectric results in a permanent alteration of the refractive index of the target material. Based on that simple scheme, direct laser writing of integrated optical microstructures has become a standard procedure to fabricate complex optical chips routinely used in telecommunications, quantum simulations, or (bio-)sensing, to name but a few. The structural modifications leading to a permanent refractive index change are a direct consequence of the formation and relaxation of a laser-induced electron-hole plasma. The laser-induced plasma formation proceeds through the two distinct mechanisms of strong field ionization and impact (electron-electron) ionization. Because these two mechanisms happen concomitantly and on a short timescale (during the laser irradiation), their experimental study is arduous. Our current understanding (and control) of the plasma formation remains therefore elusive. For instance, the relative importance of strong field ionization and impact ionization to the total plasma formation remains an open question. In this presentation, we study numerically and experimentally the emission of low-order harmonics produced upon irradiation with an intense (1-10 TW/cm^2, i.e. close to the threshold for the permanent material modification), mid-IR (central wavelength at ca. 2100 nm) ultrashort laser pulse (ca. 140 fs duration) in a fused silica sample. Our experimental approach relies on a two-color, pump-probe scheme offering spectrally- and temporally-resolved measurements. We show that the sources of nonlinearities usually invoked to explain the formation of harmonics (i.e. intraband, interband, Brunel and Kerr) play a marginal role in our irradiation conditions. Instead, we establish that the low-order harmonic emission observed arises from the displacement of the electrons across the bandgap as they are injected from the valence to the conduction band. Our results offer an important pathway to understand, control, and optimize laser-induced plasma formation close to the material modification threshold as well as precious insights to study strong field ionization in solid dielectrics.

This is joint work with P. Jürgens, A. Husakou, and M. J. J. Vrakking from the Max-Born-Institute, as well as B. Liewehr, B. Kruse, C. Peltz, and T. Fennel from the University of Rostock.

C7-H1.4 **Thursday, September 05, 2019, 17:00 – 17:20**

Josephson junctions for signal detection

Giovanni Filatrella

Dept. of Sciences and Technologies, University of Sannio, Italy

Josephson junction electrical behavior is governed by a quantum variable, the gauge invariant phase difference between the macroscopic phases of the two superconductors forming the junction. Therefore, the dynamics, as described by the celebrated Josephson equations, is equivalent to a damped and force pendulum affected by noise. The quantum phase dynamics is accessible, albeit through indirect electrical measurements, essentially the current and the voltage. In particular, it is possible to retrieve the current at which occurs the passage from the superconducting, zero voltage, state to the finite voltage.

Repeating the measurements in the presence of a random disturbance, or because of quantum effects, the passage to the finite voltage occurs at slightly different current levels, thus producing a distribution of switching currents. The deviations from the expected distribution can be used as a clue on the type of disturbance that affects the junction, and thus to analyze the signal applied to the junction, for instance a sinusoidal drive embedded in the noise. In doing so the nonlinear analysis of the escape processes is essential for the application of the detection scheme, that is based on the indirect information available. Most importantly, the output shows a nonlinear relation with the input noise, as in stochastic resonance.

The analysis of the escape times can be extended to other systems, such as a quasi-Hamiltonian pendular Fabry-Perot interferometer. Placed inside one of the minimum of the optomechanical potential an escape can be revealed by the sudden change of reflectivity near the top of the potential well. Finally, the detector can be used to reveal the features of the noise itself, for instance the presence of non-Gaussian fluctuations characterized by the so-called Lévy flights.

This is joint work with P. Addesso (Dept. DIEM, University of Salerno, Italy), with C. Guarcello (Centro de Física de Materiales, Centro Mixto CSIC-UPV/EHU, San Sebastián, Spain), with V. Pierro (Dept. of Engineering, University of Sannio, Italy), and with B. Spagnolo and D. Valenti (Dept. of Physics and Chemistry, Interdisciplinary Theoretical Physics Group, University of Palermo, Italy).

Thursday, September 05, 2019, 17:20 – 17:40 C7-H1.5

AB initio study of superconductivity and electron-phonon interaction in the tetragonal BiLi

Ertuğrul Karaca

Sakarya Üniversitesi and BİMAYAM (Biyomedikal, Manyetik ve Yarıiletken Araştırma Merkezi), Türkiye

First principles pseudopotential calculations have been performed to explore the effect of spin-orbit coupling on the electronical, mechanical, vibrational and electron-phonon interaction properties of Tetragonal BiLi. Our electron–phonon interaction calculations reveals that the mechanism for superconductivity in BiLi is mainly governed by the interactions of electrons with acoustic phonon modes and low–frequency optical phonon modes. The average electron-phonon coupling parameter increases from 0.611 without spin-orbit coupling to 0.665 with spin-orbit coupling, resulting in the corresponding changes to the superconducting transition temperature from 1.596 to 2.227 K. The latter value of superconducting transition temperature compares very well with its experimental value of 2.470 K.

C7-H1.6 **Thursday, September 05, 2019, 17:40 – 18:00**

Dimensional coupling induced current reversal in two-dimensional driven lattices

Aritra K. Mukhopadhyay

Center for Optical Quantum Technologies, Department of Physics, University of Hamburg, Germany

Time driven lattice setups, i.e., particles in a lattice which is shaken by external time-dependent forces of zero mean, have been shown to exhibit directed transport for an ensemble of particles - a phenomenon more commonly called 'ratchet' effect. Due to its ability to convert random particle motion into an unidirectional transport in an unbiased non-equilibrium environment, the ratchet effect has found widespread application across various disciplines like biological, atomic and condensed matter physics leading to many intriguing effects and applications like on-site particle trapping, particle sorting and efficient velocity filters. While the underlying symmetries of a system allow to predict the presence or absence of such directed transport, the difficulty to predict the resulting transport direction has evoked broad interests and efforts to control the directed particle current. A key focus in this direction has been current reversal, where it has been shown that the transport can often be reverted by changing the value of certain system parameters or particle properties, and is extremely useful since it allows segregation of particle mixtures based on the physical properties of the constituents. Although there has been substantial success concerning the control of directed transport in various systems with one spatial dimension, very little is known about two dimensional setups especially those operating in the Hamiltonian regime.

We demonstrate that the direction of particle transport, in a two-dimensional ac-driven lattice of Gaussian barriers operating in a purely Hamiltonian regime, can be dynamically reversed by changing the structure of the lattice in the direction perpendicular to the applied driving force [1]. These structural changes introduce dimensional coupling effects and we show via statistical analysis that the current reversal timescale depends on the coupling strength according to an inverse power law. The underlying mechanism is based on the fact that dimensional coupling allows the particles to explore regions of phase space which are inaccessible otherwise. This dependence exclusively on generic phase space structures promises the possibility to realize it in a wide class of systems such as cold atoms or colloidal particles in driven lattices and accordingly should be of broad interest to researchers working on directed transport in non-linear dynamics, cold atom physics and soft matter physics.

[1] Aritra K. Mukhopadhyay, Tianting Xie, Benno Liebchen, and Peter Schmelcher, "Dimensional coupling-induced current reversal in two-dimensional driven lattices," Phys. Rev. E **97**, 050202 (R) (2018).

Friday, September 06, 2019, 11:00 – 11:20 C8-AM.1

The dynamics of equation with large state-dependent delay

Ilia Kashchenko
Yaroslavl State University, Russia

The nonlinear differential equation with large state depended delay is considered and its local (i.e., in a small neighborhood of the zero equilibrium) dynamics is studied. It was shown that the critical cases in the equilibrium stability problem have an infinite dimension (i.e., it is unbounded as delay time grows). As the main results, special nonlinear boundary value problems of the parabolic type were constructed whose nonlocal dynamics determine the behavior of the solutions of initial problem.

Friday, September 06, 2019, 11:20 – 11:40 C8-AM.2

Chaoticity of the non-Abelian gauge field theory on lattice considering the complexity

Agnes Fülöp
Eötvös Loránd University, Hungary

The Yang-Mills fields have an important role in the non-Abelian gauge field theory which describes the properties of the quark-gluon plasma. The real time evolution of the classical fields is given by the equations of motion which are derived from the Hamiltonians to contain the term of the SU(2) gauge field tensor. This system has chaotic behaviour.

The homogeneous Yang-Mills contains the quadratic part of the gauge field strength tensor in the Minkowski space, it is expressed by gauge fields fulfilling the continuous Lie group. The equation of motion can be expressed by covariant derivative in the adjoin representation.

The real time evolution of the classical Yang-Mills fields equations is derived by the Hamiltonian for SU(2) gauge field tensor to constraint the total energy and it satisfies the Gauss law. The microcanonical equations of motion is solved on 3 dimensional lattice and chaotic dynamics is studied by the entropy-energy relation, which is presented by Kolmogorov-Sinai entropy considering the complexity.

C8-AE1.1 **Friday, September 06, 2019, 11:00 – 11:20**

Decentralized topology optimization implemented as a self-organization of multi-agent systems

Tatsuya Iwase
Sorbonne University, on leave from Toyota Central R & D Labs., France

Topology optimization is a general technique of structure designs, which has broad range of applications [1]. While traditional studies in topology optimization mainly focused on centralized computation with single CPU, we focus on a problem of decentralized optimization where a swarm of multi agents self-organizes a designated structure with their ability to move and connect to each other. We propose a distributed optimization method of structure design based on an extension of ESO method [2].

[1] Bendsøe, Martin Philip, and Noboru Kikuchi. 'Generating optimal topologies in structural design using a homogenization method.' Computer methods in applied mechanics and engineering **71**.2 (1988): 197-224.

[2] Huang, Xiaodong, and Yi-Min Xie. 'A further review of ESO type methods for topology optimization.' Structural and Multidisciplinary Optimization **41**.5 (2010): 671-683.

C8-AE1.2 **Friday, September 06, 2019, 11:20 – 11:40**

Collective motion pattern analysis on self-propelled particles using Rayleigh-Morse models

Atsushi Kawamoto
Frontier Research Center, Toyota Motor Corporation, Japan

This research deals with collective motion patterns seen in self-propelled particle systems such as schooling fish[1]. Rayleigh-Morse equations are used to model the collective schooling fish[2]. This model well captures the milling and swarm states of schooling fish. This talk focuses on the collective dynamics of the center of the school. In order to classify the dynamics, we propose a new analysis method based on the parametrized Morse potential.

[1] Tunstrøm et.al. Collective states, multistability and transitional behavior in schooling fish. PLOS. Comp. Bio., 2013.

[2] D' Orsogna MR, Chuang YL, Bertozzi AL, Chayes LS. Self-propelled particles with soft-core interactions: patterns, stability, and collapse. Phys Rev Lett. 2006 Mar 17; **96**(10):104302. (2006).

Friday, September 06, 2019, 11:00 – 11:20 C8-AE2.1

Noisy oscillator populations beyond the Ott-Antonsen theory - circular cumulant approach

Denis Goldobin
Institute of Continuous Media Mechanics UB RAS (Perm, Russia), Russia

We develop an approach for the description of the dynamics of large populations of phase oscillators based on "circular cumulants" instead of the Kuramoto-Daido order parameters [1]. In the thermodynamic limit, these variables yield a simple representation of the Ott-Antonsen invariant solution [2] and appear appropriate for constructing perturbation theory on top of the Ott-Antonsen ansatz. First, on the basis of this approach, we report a generalization of the Ott-Antonsen solution for ideal Ott-Antonsen systems [3]. Second, we employ this approach to study the impact of intrinsic noise on the dynamics. As a result, a closed system of equations for the two leading cumulants, describing the dynamics of noisy ensembles, is derived. Third, we consider physical constrains on the truncation of circular cumulant expansions and demonstrate remarkable convergence of these expansions for experimental data of different natures [4].

The work was supported by Russian Science Foundation (Grant # 19-42-04120).

[1] I.V. Tyulkina et al., PRL **120**, 264101 (2018)

[2] E. Ott, T. M. Antonsen, Chaos **18**, 037113 (2008)

[3] Tyulkina et al., Radiophys. Quantum Electron. **61**, 640 (2019)

[4] arXiv:1908.00230

Friday, September 06, 2019, 11:20 – 11:40 C8-AE2.2

Mode-locked solutions in systems of globally-coupled phase oscillators

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In systems of globally-coupled phase oscillators with equidistant natural frequencies, one can observe an interesting collective phenomenon below the synchronization threshold. The collective behavior is characterized by sharp pulses in the mean-field amplitude and therefore appropriately called mode locked. We discuss the emergence of this particular type of solution as well as the typical bifurcation scenarios at the stability boundaries. In large ensembles, where the natural frequencies are drawn from a multi-modal frequency distribution, mode-locked solutions are observed as a macroscopic phenomenon.

The breakdown of the pulsation due to less ordered natural frequencies is explored and a connection between mode locking and an echo-type response phenomenon the so-called coherence echo is revealed.

4 Poster Presentations

A kinematic model for the dynamics of passive tracers in laboratory experiments of atmospheric baroclinic waves **P 1**

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In this work, we study the Lagrangian footprint of the atmospheric baroclinic waves in laboratory experiments. Our focus is on constructing a simple kinematic model that retains the fundamental mechanisms responsible for complex parcel evolution. The study of Lagrangian transport phenomena highlights hyperbolic trajectories, and these trajectories are Lagrangian objects that are the kinematic mechanism for the observed filamentation phenomena. Our analysis utilizes fundamental ideas from dynamical systems theory which search for sharper insights. In particular we exploit Poincaré's idea of determining the geometrical structures in the phase space (for this problem, the atmosphere) that define regions where particle trajectories have qualitatively different behaviors. The boundaries, or barriers, between these regions are mathematically realized as objects called manifolds, also known as Lagrangian coherent structures (LCS). Lagrangian tools have provided in the past interesting insights. In this work we illustrate the power of a recent dynamical systems tool, Lagrangian descriptors (LD), also known as the function M.

Invariant manifolds mediating reaction dynamics **P 2**

Mohammed Alharthi
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We discuss the phase space structure for the collinear hydrogen exchange system crossesan energy barrier. Above the reaction threshold, the system must pass through a Symmetric Stretch Periodic Orbit (SSPO) where the dynamics are structuring a Dividing Surface (DS), that separates reactants and products. At low energy, the SSPO can serve as a dividing surface that satisfies the no-recrossing assumption of Transition State Theory (TST). As the energy increases, saddle-node bifurcations occur on both sides of the SSPO. Above the bifurcation energy, trajectories appear that recross the central DS. The region of recrossing trajectories is bounded by the stable manifolds of the additional Unstable Periodic Orbits (UPOs). We investigate the fractal structure of the TST violating islands of the DS and how it is determined by the invariant manifolds of the UPOs. We demonstrate that the various layers are all bounded by the same stable manifold.

P 3

Quasiperiodically forced nonlinear oscillator models

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Nonlinear oscillator models can exhibit relaxation oscillations that consists of alternating fast-slow motions. These models have been used to explain a variety of physical and biological systems. We present a study of a nonlinear oscillator model, namely the van der Pol oscillator. Ashwin et al. (2018) find significant regions of chaotic responses to periodic forcing and quasiperiodic forcing in the van der Pol-Duffing oscillator. We illustrate responses of the unforced asymmetric van der Pol and van der Pol duffing oscillators. We aim to understand the analysis of the forced asymmetric van der Pol oscillator under quasiperiodic forcing. To achieve this aim, we use geometric singular perturbation theory and numerical simulations to investigate forced relaxation oscillations. In particular, we follow the analysis of Guckenheimer et al. (2003) for the periodically forced symmetric van der Pol oscillator and discuss how this can be extended to other quasiperiodically forced oscillations. We present a hybrid reduced system that models the forced van der Pol oscillator in a singular limit, and that leads to an understanding of the bifurcations in the periodically forced van der Pol oscillator.

P 4

Conservative perturbation theory and the Hannay angle for dissipative oscillatory systems with limit cycle

Rohitashwa Chattopadhyay
Indian Institute of Technology, Kanpur, India

Hamiltonian for the van der Pol oscillator (vdPO) – a paradigm for nonlinear dissipative systems with limit cycle – is formulated by extending the degrees of freedom of the system with the addition of an auxiliary equation. Furthermore, with this process, we also find the Hamiltonian structure for an important subset of the Liénard system. Taking the example of the vdPO, we show how to use the canonical perturbation theory and the Lie transform Hamiltonian perturbation theory to find the perturbative solutions and the frequency corrections for dissipative dynamical systems capable of showing limit cycle oscillations. Finally, we use Lie transform Hamiltonian perturbation theory to analytically calculate the Hannay angle for the vdPO's limit cycle trajectory when its parameters – the strength of the nonlinearity and the frequency of the linear part – evolve periodically and adiabatically. We also numerically compute the corresponding geometric phase for this vdPO, and establish its equivalence with the Hannay angle.

The rocking can

P 5

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This work examines the rocking of an axially symmetric can (a special case of which is Euler's disc). Experimental evidence has shown that upon rocking, the can generically tilts downwards towards the flat and level state, avoids impact and then tilts back up again. However, the final state is not opposite that of the initial state. Instead the can rotates through an angle greater than π. This problem was originally studied by Srinivasan and Ruina [1], using a formal analysis. Here we employ geometric singular perturbation theory and blow-up to examine the fast dynamics of the can as it avoids impact. To do so, equations of motion are derived in a constrained Lagrangian approach. The system is then reduced to a singularly perturbed second order ODE. Applying the blow-up technique yields the same angle of turn as calculated by Srinivasan and Ruina [1], together with additional information about the sign of the angle of turn.

[1] Srinivasan, M. and Ruina, A., 2008. Rocking and rolling: a can that appears to rock might actually roll. Physical Review E, **78**(6), p.066609.

Bifurcations in systems of Kuramoto oscillators with delayed coupling

P 6

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Pattern formation is studied in a system of locally coupled identical Kuramoto rotators. Continuing our recent study[1], here the considered interaction is time delayed: each oscillator is coupled to the past state of their neighbors. The presence of time delay induces transcritical bifurcations on phase-locked states, meaning that states being unstable in the non-delayed case become stable and vice versa. After a proper rescaling of the relevant parameters, the number of stable/unstable states exhibit periodic behavior. The size of the attraction basins changes also with the system parameters resulting in a periodic shift for the most probable state from in-phase synchronization to anti-phase ordering. The average time length needed for the system to select an ordered state (see for example [2]) increases for those time delay values where the probability distributions of the allowed states suffer drastic changes. This suggests similarities with phase-transition like phenomena.

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[1] Dénes K, Sándor B, Néda Z. Pattern selection in a ring of Kuramoto oscillators. Commun Nonlinear Sci Numer Simulat, **78**:104868, 2019

[2] Dénes K, Sándor B, Néda Z. On the predictability of the final state in a ring of Kuramoto rotators, Rom. Rep. Phys. (in press)

P 7 Bifurcation analysis of a neural network in the olfactory bulb using equation-free methods

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The olfactory bulb's (OB) neural network with individually firing neurons in the olfactory bulb, which is responsible for odour recognition, is a good model system to study the brain's performance because of its well-defined input and output.

For the direct interaction among cells in high-dimensional biological neural networks exist detailed models. We use a Spike and Response Model (SRM) to simulate numerically the OB. If one considers the distinction of two different odours, both, biological measurements in mammals and direct simulation, show the same macroscopic behaviour. If one odour is dominant and the concentration ratio for the two odours is slightly changed, the first one's respective area is longer dominantly active as if the other odour was first dominant. Therefore, we consider the difference of the fire rates of their different appendant areas as the macroscopic variable. Hence, the detection of an odour depends on the fire rates in different areas of the neural network. By direct simulation, one can already get the stable branches of the fire rates. In an odour concentration/fire rate difference-diagram, hysteresis behaviour can be observed.

In order to track the unstable branches by implicit equation-free methods, we use an altered Newton method, which deals with noisy derivative information due to the quasi-chaotic fire rates close to equal concentration.

P 8 Monte Carlo basin bifurcation analysis

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Many high-dimensional complex systems exhibit an enormously complex landscape of possible asymptotic states. Here, we present a numerical method geared towards analyzing such systems. It is situated between the classical analysis with macroscopic order parameters and a more thorough, detailed bifurcation analysis. Based on random sampling and clustering methods, we are able to characterize the different asymptotic states or classes thereof and its basins of attraction. In order to due this suitable, easy to compute, statistics of trajectories with randomly generated initial conditions and parameters are clustered by an algorithm such as DBSCAN. Due to the modular and flexible nature of the method, it has a wide range of possible applications. Typical applications are oscillator networks, but it is not limited only to ordinary differential equation systems, every complex systems yielding trajectories, such as maps or agent-based models, can be analyzed, as we show by applying it the Dodds-Watts model, a generalized SIRS-model. A second order Kuramoto model and a Stuart-Landau oscillator network, each exhibiting a complex multistable regime, are shown as well. The method is available to use as a package for the Julia language.

Phase reconstruction with iterative Hilbert transform embeddings **P 9**

Erik Gengel
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The Hilbert transform is in the heart of nonlinear time series analysis for oscillatory processes. If the deviation from the limit cycle of the underlying dynamic system is small, it is in principle possible to extract the phase dynamics from the data. However, a single application of the Hilbert transform and subsequent construction of the analytic signal and its amplitude and phase are not sufficient to obtain the phase of the dynamic system even though the raw signal is a function of this (unknown) true phase.

The first problem to be solved is: Given an arbitrarily complex wave form with constant amplitude and an arbitrarily complex but monotonous phase, construct this phase from the data.

The second problem to be solved is: Given a time series from a weakly perturbed oscillatory system, reconstruct the phase of the system. In both situations. the problem is solved by iterative reuse of previously calculated phases of the analytic signals. For constant amplitude signal the accuracy of the method is limited only by the sampling rate and the length of the time series. For dynamic systems, the method yields major improvements in the phase reconstruction if the phase dynamics dominates. Situations with larger amplitude modulations have to be treated with more caution.

Macroscopic reductions for oscillator populations beyond Ott-Antonsen ansatz **P 10**

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Macroscopic dynamics of large ensembles of phase elements can be characterised by the order parameters – the mean fields. Quite often the evolution of these collective variables is surprisingly simple, which makes a description with only a few order parameters feasible. Hence, one tries to construct closed low-dimensional mathematical models for the dynamics of a few principal order parameters. These models represent useful tools for gaining insight into the underlying mechanisms of some sophisticated collective phenomena: for example, one describes coupled populations by virtue of coupled equations for the relevant order parameters. For a certain class of ideal paradigmatic systems of coupled phase oscillators, the Ott-Antonsen ansatz yields an exact equation for the main order parameter [1]. Recently, a regular approach was suggested for dealing with situations where the Ott-Antonsen ansatz is not admitted – 'circular cumulant' approach [2; 3]. We demonstrate application of this approach for diverse physical systems.

The work was supported by Russian Science Foundation (Grant # 19-42-04120).

[1] E. Ott, T.M. Antonsen, Chaos **18**, 037113 (2008)

[2] I.V. Tyulkina et al., PRL **120**, 264101 (2018)

[3] D.S. Goldobin et al., Chaos **28**, 101101 (2018)

P 11 On the edge: Extinction thresholds and the periphery of pollination networks

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Unravelling the interrelationship between structure and stability of ecological networks is an important issue in theoretical biology. We contribute to this subject by identifying and analyzing the most endangered species in plant-pollinator systems. To this end, we assume a pollination network to be a multistable system in which one desired dynamical regime, enabling the largest number of coexisting species, competes with several 'undesired' regimes of partial extinction. Accordingly, an extinction threshold corresponds to an initial condition just outside the basin of attraction of the desired regime. We use our approach of minimal thresholds as well as an random perturbation scheme to locate weak points in various pollination networks and examine how the core-periphery structure of a network affects its stability. In this context, we are particularly interested in the relationship between the network position of a species and its risk of extinction.

P 12 MPGOS: A GPU accelerated, general purpose program package to solve a large number of indented ODE systems

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In many fields of science, the physical processes can be described by ordinary differential equation systems (ODEs). One possible way to accelerate their investigation is the application of the massively parallel environment of professional graphics processing units (GPUs). However, it is a highly nontrivial task as an initial value problem is serial in nature. Nevertheless, if one intends to perform large parameter studies (bifurcation analysis) or to investigate the effect of the employed initial conditions (multistability, basin of attraction), the overall problem can be decomposed into a large number of decoupled sub-problems where each parameter combination and/or initial conditions represent an individual and independent task. In this way, the whole computational problem became suitable for GPUs. The main aim of the present study is to introduce a modular and general purpose program package capable to efficiently handle the aforementioned problem. The name of the package is Massively Parallel GPU-ODE Solver (MPGOS) and it is free to use under an MIT license, for details see the official website www.gpuode.com.

We paid close attention for modularity, flexibility and user-friendliness without losing performance. Although the package is written in C++, it can be used similarly as the MATLAB built-in ODE solver. The available numerical schemes are the 4th order Runge–Kutta algorithm with fixed time step and the adaptive Runge–Kutta-Cash–Karp method with embedded 5th order error estimation. The package has important features such as event handling, efficient treatment of non-smooth dynamical systems (e.g. impact dynamics) and many others that shall be introduced during the presentation. The performance of the code shall be demonstrated via several test cases: on the classical Duffing oscillator, on the Keller—Miksis equation well-known in sonochemistry and on a model of a pressure relief valve that can exhibit non-smooth impact dynamics.

Flee the toxins: autotoxicity-induced traveling vegetation spots in a biomass-water-toxicity model

P 13

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In recent years it has become increasingly clear that one factor that can serve as an indicator to critical climate changes, and how resilient a given ecosystem is to such changes, is the dynamics of vegetation. This realization has made the understanding of the underlying mechanisms regulating these dynamics extremely important to explore. Motivated by this direction of investigation, a new ecological theory has recently emerged, which identifies the toxic compounds that are produced by the decomposition of organic material as an essential element in the behaviour of local vegetation. The introduction of a new model component modeling biomass autotoxicity induces novel spatiotemporal behaviour of vegetation patterns. In particular, autotoxicity is seen to induce movement and deformation of spot patterns. Our aim is to analytically quantify this novel phenomenon, by considering the model reduced to one spatial dimension. We use geometric singular perturbation theory to obtain an explicit expression for the corresponding asymmetric traveling pulse solution, by constructing a homoclinic orbit in the associated 5-dimensional dynamical system. The temporal stability of this pulse is determined using Evans function techniques. We find that both the plant's sensitivity to toxins and the toxin decay rate significantly influence the behaviour and shape of the biomass pulse.

Annihilation mechanism for chimera states in coupled dynamical flows through linear augmentation

P 14

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In this paper we propose a scheme for the creation and annihilation of chimera states through linear augmentation. These states are hybrid dynamical patterns consisting of coexisting coherent and incoherent dynamics present in a network of coupled oscillators. We create chimeras in globally coupled oscillators through induced multistability. Earlier studies have shown that multistability in a dynamical system can be controlled through linear augmentation. We, therefore, couple individual oscillators to linear system and observe that the dynamics of a given oscillator can be engineered in a controlled way. We consider an ensemble of Lorenz oscillators under the influence of various drives and observe that the resulting chimera states can be annihilated in a desired way. The resulting dynamics can be desynchronized, completely synchronized or a chimera state in which only desired oscillators can participate. Annihilation of these states is characterized by exploring their basin of attraction. We also verify the stability of different states present in the coupled systems before and after linear augmentation by calculating the transverse Lyapunov exponent and master stability function. We observed that annihilation of chimera states is independent of the coupling mechanism and also on the initial conditions chosen for the creation of chimera states.

P 15 Coherent diffractive imaging of population dynamics in a helium droplet

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Only recently, coherent single-shot diffractive imaging (CDI) of individual free nanoparticles has been demonstrated with a laser-based source using high harmonic generation [1], promising new applications and unprecedented insights into the ultrafast dynamics induced or probed via the single-shot scattering process. So far, CDI experiments have been analyzed via an effective classical linear response description, e.g. to reconstruct the shape and orientation of nanoparticles [2]. For strong laser fields and in particular for resonant excitations, both the linear and the classical description may no longer be valid as population depletion and stimulated emission become important. To what extent such processes may influence CDI scattering images is currently largely unknown. In our theoretical analysis, we describe the quantum-mechanical few-level bound state dynamics using a density matrix formalism and incorporate this into a 3D Maxwell solver based on the finite-difference time-domain method (FDTD). We discuss how and to which extend the spatio-temporal population dynamics influences the scattering images and analyze the observed trends.

[1] D. Rupp et al., Nat. Commun. **8**, 493 (2017)

[2] I. Barke et al., Nat. Commun. **6**, 6187 (2015)

P 16 Resumption of dynamism in damaged networks of coupled oscillators

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Deterioration in dynamical activities may come up naturally or due to environmental influences in a massive portion of biological and physical systems. Such dynamical degradation may have outright effect on the substantive network performance. This requires us to provide some proper prescriptions to overcome undesired circumstances. In this work, we present a scheme based on external feedback that can efficiently revive dynamism in damaged networks of active and inactive oscillators and thus enhance the network survivability. Both numerical and analytical investigations are performed in order to verify our claim. We also provide a comparative study on the effectiveness of this mechanism for feedbacks to the inactive group or to the active group only. Most importantly, resurrection of dynamical activity is realized even in time-delayed damaged networks, which are considered to be less persistent against deterioration in the form of inactivity in the oscillators. Furthermore, prominence in our approach is substantiated by providing evidence of enhanced network persistence in complex network topologies taking small-world and scale-free architectures, which makes the proposed remedy quite general.

On limitation of the order parameter application for the analysis of the small world network dynamics

P 17

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In the study of the transition from the asynchronous state to the synchronous one in the network dynamics the main characteristic of the degree of synchronicity of the behavior of the network elements is the order parameter. In the present work it is shown that the value of the order parameter allows obtaining reliable information about the state of random and scale-free networks, but in the study of small world network behavior in some cases the use of this tool leads to results that do not agree with the actual state of the network and does not allow to adequately detect the dynamical regime. Faced with such contradictions, some researchers introduce the concept of the phase and frequency synchronization in order to eliminate them, arguing that in the case when the order parameter value indicates the absence of phase synchronization, frequency synchronization is nevertheless diagnosed. At the same time, it is well-known that the phase and frequency synchronization for two coupled oscillators are uniquely related to each other and are, in fact, different manifestations of the same phenomenon of synchronous dynamics, and therefore, cannot exist separately. Thus, this contradiction indicates the need to clarify the conditions and limits of applicability of the order parameter as a tool for description of the state of complex networks, especially networks with the small world topology.

Existence and stability of synchronous states in the heterogeneous chains of phase oscillators

P 18

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We studied the question of robustness of synchronous states to disorder in the chain of phase oscillators with local couplings. The study combines numerical determination of the existence and stability of synchronous states with analytical investigation of the role of phase shift and the level of the disorder in the frequencies in the destruction of synchrony. We show that presence of phase shift synchronous regime became even more robust, at least up to its certain threshold value.

P 19

Diffusion of phase differences in coupled oscillators synchronized by common noise

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We investigate the diffusion of phase difference in the system of coupled oscillators with competing synchronizing effects by common noise and coupling. We analyze the Fokker-Planck equation for the phase difference distribution in the case of slightly nonidentical oscillators. The possibility of superdiffusive process was found on short time scales.

This possibility is examined with numerical simulations for (i) a pair coupled oscillators and (ii) populations of globally coupled slightly nonidentical oscillators. On large time scales, the normal diffusive behavior of phase differences, featuring an essentially intermittent character of the synchronization by common noise, also characterized.

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Mutation induced cooperation through limit cycle in delay dynamics of evolution **P 20**

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Evolutionary game theory have been successfully applied to predict evolutionary outcome in diverse fields like biology, economics, grammar learning, sociology, psychology, etc. In the simplest possible case, it is generally assumed that two player interaction in an evolutionary game is instantaneous and has an immediate effect. Nevertheless, there may exist scenarios where such an effect is not immediate. Such delays may either be attributed to the nature of interaction (social delay) or the constraint on the players' eligibility to interact (biological delay). We have considered three possible delay spectrum scenarios; one corresponding to symmetric delay case where both strategies have same non-zero delays and the other two belonging to the case where only one strategy have delay.

Here our main intention has been to study the effect of delay on the evolutionary processes that include both selection and mutation. We have considered two types of mutation in continuous replicator mutator dynamics: first one is of multiplicative type (parameterized by q) that models for the error in DNA replication, and the other one is additive mutation which is of social type (parameterized by μ). We have considered two- player-two-strategy interactions as modelled in prisoner's dilemma (PD) game, snowdrift (SD) game, stag hunt (SH) game and harmony game. These four games are the most investigated games in relation to the problem of the evolution of cooperation.

We have analytically found the criterions for which Hopf bifurcation happens, i. e., a pair of eigenvalues become purely complex for all the considered delay spectrums in our models. We have also demarcated a region in mutation parameter space (q-μ space) of all games and found the delay spectrum where central manifold theorem is applicable and stable limit cycle emerges. These findings have been backed numerically. Stable limit cycle is found in SH game for both social delay (asymmetric delay with delay being only in Defect strategy) and biological delay (symmetric delay). For PD game stable limit cycle is only found in symmetric biological delay. Stable limit cycle in SD game is found only in social delay (both symmetric and asymmetric with delay in defect strategy). Stable limit cycle is not found in Harmony game. Limit cycle behaviour is interesting as it indicates coexistence and thereby making the existence of cooperator possible in the system in presence of delay and mutation. It is clear from the results that delay in defector's strategy is a necessary condition for existence of stable limit cycle in the case of asymmetric delay. Our results for the case of no mutation have been summarised and bench marked with standard literature (where ever possible). The analysis clearly show how the mutation in delayed dynamics may induce limit cycle and what is the physical significance of these outcomes.

P 21

Spreading of disturbances in high and low inertia grids: the Nigerian 330 kV network as a case study

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The trends in the integration of Distributed Energy Resources (DERs) and other forms of Renewable Energy Resources (RES) schemes into the electrical power grids have received almost a worldwide implementation. The large integration of these schemes as well as the reduction of the conventional energy sources greatly affects the frequency dynamics and electromechanical stability of the electrical networks. This is perceived to be due to the no-rotational inertia contributions from the RES/DERs.

This paper investigates the effect of different levels of conventional power plant/grid inertia on the frequency dynamics in a view to understanding the rate/pattern at which disturbances spread in a (high and/ low Inertia) grid using a non-RES Nigerian 330 kV network as a study case.

P 22

Chaotic synchronization induced by external noise in mean-field coupled limit cycle oscillators with two native frequencies

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In uncoupled oscillatory systems, it is widely known that common noise input can induce chaotic synchronization. However, while noise can "enhance" a degree of chaotic synchronization, few studies report the chaotic synchronization "induced" by external noise in coupled oscillatory sytems. In this study, a solvable model for mean-field coupled limit cycle oscillators under the influence of independent noise is considered [1]. The model consists of the two types of limit cycle oscillators with different native frequencies. We analytically and numerically show that the model exhibits chaotic synchronization purely induced by external noise.

[1] K. Okumura, A. Ichiki, M. Shiino, Europhys. Lett. **92**, 50009 (2010).

P 23

Revisiting the decay of missing ordinal patterns in long-term correlated time series

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We revisit the decay of missing ordinal patterns in long-term correlated time series. More precisely, a stretched exponential model is proposed to describe more appropriately how the number of missing ordinal patterns decreases as a function of the time series length in the case of correlated stochastic data. Numerical analysis and experimental applications confirm that this generalized model allows a more accurate characterization of the underlying dynamics and a reliable quantification of the long-range temporal correlations.

Time-resolved X-ray imaging of anisotropic nanoplasma expansion

P 24

Christian Peltz
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We investigate the time-dependent evolution of laser-heated solid density nanoparticles via coherent diffractive x-ray imaging, theoretically and experimentally. Our microscopic particle-in-cell calculations for R = 25 nm hydrogen clusters reveal that infrared laser excitation induces continuous ion ablation on the cluster surface. This process generates an anisotropic nanoplasma expansion that can be accurately described by a simple self-similar radial density profile. It's time evolution can be reconstructed precisely by fitting the time-resolved scattering images using a simplified scattering model in Born approximation. Here we present the first successful high resolution reconstruction of corresponding experimental results, obtained at the LCLS facility with SiO2 nanoparticles (D=120 nm), and compare them to the theoretical predictions.

Applying enhanced sampling techniques and considering tunneling effects towards an experimental and theoretical agreement for the phenylisocyanate and cyclohexanol reaction

P 25

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The first principles simulation of bimolecular reactions in solution provides a challenge in cases of considerable configurational flexibility of the reactive complex and large reaction barriers requiring very long time scales for sampling the rare reactive events. In particular, there is an ongoing debate about the alcoholysis reaction between phenylisocyanate and cyclohexanol being an example for the initial step of polymerization. In general, experimental results shows that the activation energy is 6 kcal/mol [1]. However, theoretical single point calculation using density functional theory predicts a barrier that is five times higher [2]. By the use of the Nudged Elastic Band (NEB) method we have obtained in the present work a reaction path with an equally large barrier, which is, however, remarkably narrow. Free energy surfaces have also been obtained using metadynamics, in accord with the reaction path calculations. Since it is mostly the hydrogen atom which moves in the vicinity of the barrier, it is strongly suggested that the reason for the discrepancy between experiment and theory is the tunneling effect of the hydrogen atom. This conclusion is supported by a one-dimensional tunneling model for the calculation of the reaction rate.

[1] F. Kössl, M. Lisaj, V. Kozich, K. Heyne, and O. Kühn, Chem. Phys. Let. **621**, 41–45 (2015)

[2] T. Stensitzki et al., Nat. Chem. **10**, 126–131 (2018)

P 26

Dissipative quantum dynamics of an excitonic dimer under the influence of Herzberg-Teller coupling with "Hierarchical Equations of Motion" (HEOM)

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HEOM is a powerful method to treat non-Markovian and non-perturbative dissipative dynamics of a relevant system coupled to a heat bath. We formulate a description of Herzberg-Teller effects, i.e. dependencies of exitonic coupling on intramolecular vibrations, with HEOM [1]. Using a path integral approach with involvement of the Feynman-Vernon functional for the derivation [2], it turns out that Herzberg-Teller coupling leads to additional connections between the "auxiliary density operators" (ADOs) of the hierarchy. The respective terms account for dependencies of the coupling on vibrational coordinates, as reflected by structural analogies between HEOM and description in a vibronic basis, which had been reported previously in a different context [3, 4]. Application of the developed HEOM approach for the calculation of absorption spectra of a dimer system with involvement of Herzberg-Teller coupling shows excellent agreement with results obtained by density matrix propagation in a vibronic basis. It turns out that the influence of Herzberg-Teller coupling on linear absorption spectra can be captured by the concept of an effective Huang-Rhys factor. Correspondingly, the nonadiabatic effects translate into increase or decrease of importance of vibrational contributions to optical spectra.

Furthermore, we study the excited state dynamics by calculating expectation values of vibrational coordinates [5] and by extracting transfer tensor elements [6] from the numerically exact HEOM approach. The extraction of transfer tensor elements facilitates the formulation of a non-Markovian quantum master equation (QME) which leads to an equivalent description as with HEOM. For comparison with results from description with more basic rate theories, such as the standard or modified Redfield approach, we are also able to extract the respective rates from HEOM. To account for thermal equilibration in the initial state of the transfer process, selection of the respective state as the reference state leads to the requirement of a polaron transformation in HEOM space. Such polaron transformation, which is also useful for the calculation of emission spectra, can be derived in a similar way as the treatment of Herzberg-Teller coupling contributions.

Attosecond streaking in dielectrics **P 27**

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Scattering of electrons in dielectrics is at the heart of laser nanomachining, light-driven electronics, and radiation damage. Accurate theoretical predictions of the underlying dynamics require precise knowledge of the low-energy electron transport involving elastic and - even more important - inelastic collisions. Here, we demonstrate real-time access to electron scattering in isolated SiO2 nanoparticles via attosecond streaking [1]. Utilizing semiclassical Monte-Carlo trajectory simulations [2,3] we identify that the presence of the field inside the dielectric cancels the influence of elastic scattering, enabling selective characterization of the inelastic scattering time [4,5].

[1] R. Kienberger et al., Nature **427**, 817-821 (2004)

[2] F. Süßmann et al., Nat. Commun. **6**, 7944 (2015)

[3] L. Seiffert et al., Appl. Phys. B **122**, 1-9 (2016)

[4] L. Seiffert et al., Nat. Phys. **13**, 766-770 (2017)

[5] Q. Liu et al., J. Opt **20**, 024002 (2018)

Complex dynamics of non-autonomous oscillator with controlled external force **P 28**

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A non-autonomous oscillator with controlled phase and frequency of external action is studied. In the system hierarchy of chaotic oscillations and multistability were observed. Detailed study of different parameter planes was curried out. Fourier spectrums for chaotic signals were analyzed.

This work is supported by the Russian Scientific Foundation, Project 17-12-01008.

Dynamics of a two layers neuronal model: bifurcation, stability and synchronization analysis of the emergent dynamics. **P 29**

Konstantinos Spiliotis
University of Rostock, Institute of Mathematics, Germany

We study the dynamical attributes of a large scale microscopic neuronal model, which consists of two connective layers. Each of the layers forming a complex network that interact through excitatory – inhibitory synapses, forming a local circuit. Using the Equation Free Methodology, we perform Numerical Bifurcation and stability analysis with respect to the critical parameters which characterize the structure of the network. We investigate the synchronization properties between the layers as a function of interconnections and we exam the applicability of stochastic resonance theory.

P 30

Occurrence of chaos with additional zero Lyapunov exponents

Nataliya Stankevich
Yuri Gagarin State Technical of Saratov, Russia

Using an examples of a models of generators of quasiperiodic oscillations, the occurrence of chaotic dynamics with one positive and two zero Lyapunov exponents is studied. It is shown that such a dynamics arises as a result of destruction of a three-frequency torus, as well as via a sequence of two-frequency torus doubling bifurcations.

The work was carried out with the financial support of the Russian Foundation of Basic Research, grant No. 18-32-00285.

P 31

Heuristic mean-field model for short term synaptic plasticity

Halgurd Taher
Inria Sophia Antipolis Méditerranée Research Centre, France

We present a heuristic mean-field model for short-term synaptic plasticity in networks of coupled neuron populations.The model is based on recent theoretical results which allow for an exact description of the firing rate and mean membrane voltage dynamics of globally coupled quadratic integrate and fire neurons (QIF). Our extension of the mean-field model takes into account synapses with short-term depression and facilitation. It is able to resemble collective phenomena observed in the corresponding QIF network. In particular we show that a stimulus can lead a neuron population into a state in which self-sustained reoccurring population spikes (PS) rule the dynamics. This can be seen as a mechanism to store and sustain information of the stimulus. When coupling multiple neuron populations we are able to show that many competing stimuli can be stored and recalled.

This is joint work with Daniele Avitabile, Alessandro Torcini, Mathieu Desroches, and Simona Olmi.

P 32

Construction of data-driven Simulations and multi-scale analysis of complex systems

Toshiya Takami
Oita University, Japan

Data-driven simulations are constructed from numerical time series of complex systems. Several ways of representation of the time-evolution operators are obtained under constraints based on physical information. These data-driven operators are analyzed with respect to statistical methods such as principal component analysis, dynamic-mode decomposition, etc. By presenting these numerical results, we discuss applicability of data-driven ways to multi-scale analysis of complex systems.

Computational analysis of minimal invariant set for discrete dynamical systems **P 33**

Wei Hao Tey
Imperial College London, United Kingdom

The study of dynamical systems have been established since the last century and they are many theoretical insight and theorems that are built for solving real-world problems. In particular, there are many studies conducted on the discrete dynamical system and the birth of chaos from seemingly simple systems by changing the parameters. However, most studies done are on the underlying deterministic system, but realistically there exists some errors and uncertainties which should be taken into account. Hence, we aim to investigate the minimal invariant set of the system with bounded noise and its bifurcation. A numerical approach will be taken to give insight into some critical problems faced when approximating these minimal invariant sets. We also investigate the simple case of a linear map and the dynamics involved on the boundary of the minimal invariant set.

Phase and frequency response theory for hyperbolic chaotic systems **P 34**

Ralf Toenjes
University of Potsdam, Germany

We formulate a linear phase response theory for hyperbolic flows, which generalizes phase response theory for autonomous limit cycle oscillators to hyperbolic chaotic dynamics. The theory is based on a new shadowing conjecture, stating the existence of a perturbed trajectory shadowing every unperturbed trajectory on the system attractor for any small enough perturbation of arbitrary duration and a corresponding unique time diffeomorphism, which we identify as phase, such that time shifts between the unperturbed trajectory and its shadow caused by the perturbation are well defined. The shadowing trajectory and the phase can be constructed explicitly in the tangent space of an unperturbed trajectory using covariant Lyapunov vectors and can also be used to identify the limits of the regime of linear response. Even in non-hyperbolic systems such shadowing trajectories may exist over long periods of time between points of near tangencies between stable and unstable sub-spaces along trajectories. Phase averaging using the newly defined phase response function may be possible for chaotic oscillators with low chaotic phase diffusion.

P 35

Quantum resonant states and tunneling through double barrier systems of 2D in-plate graphene nanoribbon/h-BN heterojunctions

Mitsuyoshi Tomiya
Seikei University, Tokyo, Japan

The first principle calculations of the electrical properties of in-plate hetero-junctions of armchair graphene nanoribbon/hexagonal boron nitride(AGNR/h-BN)s are presented. They are carried out using the SIESTA package, which consists of numerical codes of the density functional theory(DFT) and the non-equilibrium Green's function(NEGF) method.

The central parts of the materials are made of two in-plate hetero-junctions of two transverse h-BN arrays embedded into the conductive (3n-1)-family of AGNR((3n-1)-AGNR) and remains two-dimensional. Two transverse arrays of h-BN, which is wide-gap semi-conductor, act as a double barrier system. The quantum resonant tunneling through the double barrier system is found in the transmission function(TF)s and I-V characteristics.

The simulations of in-plate hetero-junctions of zigzag graphene nanoribbon/hexagonal boron nitride(ZGNR/h-BN)s are also presented. ZGNRs are always conductive irrespective of its width, however, ZGNR/h-BNs show the spin-splitting in band structure and it makes the electrical properties far more complicated.

The quasi states in the double barrier made of two h-BN arrays play an important role in their electrical properties. We propose the one-dimensional(1D) Dirac equation model for the double barrier system and also try the explanation by the chaotic nature of the barrier systems inside.

P 36

Dynamics and topological entropy of 1D Greenberg-Hastings cellular automata

Dennis Ulbrich
Universität Bremen, Deutschland

We analyse the non-wandering set of 1D-Greenberg-Hastings cellular automata models for excitable media with $e \geq 1$ excited and $r \geq 1$ refractory states and determine its (strictly positive) topological entropy. We show that it results from a Devaney-chaotic closed invariant subset of the non-wandering set that consists of colliding and annihilating travelling waves, which is conjugate to a skew-product dynamical system of coupled shift-dynamics. Moreover, we determine the remaining part of the non-wandering set explicitly as a Markov system with strictly less topological entropy that also scales differently for large e, r.

2D versus 3D decay dynamics in transition metal dichalcogenides **P 37**

Tim Völzer
Institute of Physics, University of Rostock, Germany

Transition metal dichalcogenides feature a layered lattice structure, which allows the fabrication of two-dimensional crystals. Electronically, these monolayers differ fundamentally from the 3D bulk material, as they exhibit direct band gaps and significantly higher exciton binding energies. Hence, to shed light on how the crystal dimensionality and thickness influence the relevant excited states and their dynamics, we applied time-resolved optical pump-probe spectroscopy on flakes of molybdenum disulphide (MoS2).

We prepared a monolayer and a bulk sample via micromechanical exfoliation. The observed transient spectra originate from a red-shift of the original static absorption attributed to changes of the band structure in the presence of localized excited species. At high excitation densities, strong collisional broadening of the shifted absorption occurs. Within the first picosecond after excitation, the free carriers thermalize, while in the monolayer, electrons and holes additionally pair to form excitons. On longer time scales up to several nanoseconds, the excited populations decay. In the bulk sample, the corresponding signal reduction could be modelled in terms of a defect-assisted Auger recombination of electrons and holes.[1] For monolayer MoS2, in contrast, two-dimensional diffusion leads to trapping of the excitons.

[1] T. Völzer, M. Lütgens, F. Fennel, and S. Lochbrunner, Recombination dynamics of optically excited charge carriers in bulk MoS2, J. Phys. B: At. Mol. Opt. Phys. **50** (2017), 194003

Stochastic bursting in unidirectionally delay-coupled noisy excitable system **P 38**

Chunming Zheng
Institute of Physics and Astronomy, University of Potsdam, Germany

We show that “stochastic bursting” is observed in a ring of unidirectional delay-coupled noisy excitable systems, thanks to the combinational action of time-delayed coupling and noise. Under the approximation of timescale separation, i.e., when the time delays in each connection are much larger than the characteristic duration of the spikes, the observed rather coherent spike pattern can be described by an idealized coupled point processwith a leader–follower relationship.We derive analytically the statistics of the spikes in each unit, the pairwise correlations between any two units, and the spectrum of the total output from the network. Theory is in good agreement with the simulations with a network of theta-neurons.

P 39 Deep learning for classifying and sorting diffraction images

Julian Zimmermann
Max-Born-Institute, Berlin, Germany

Intense pulses from free-electron lasers and high-harmonic-generation sources enable diffractive imaging of individual nanoparticles in free-flight with a single short-wavelength laser shot. The size of necessary diffraction data sets with up to several million patterns represents a significant problem for data analysis.

Feature recognition, sorting, and classifying is a critical step in a subsequent data pipeline, that is still mostly carried out manually by trained researchers. Usually, hand-made algorithms are developed to approximate particular features, but such approaches do not generalize well and are time-consuming.

Recently, we have shown in [1,2] that deep neural networks can be used to classify large amounts of diffraction data if a small subset of the data is labeled by a researcher and used for the training of the network. Here, we present first results on an unsupervised deep neural network approach. A combination of training a variant of a variational auto-encoder called factorVAE [3] and a traditional clustering algorithm, namely Hierarchical Density-Based Spatial Clustering of Applications with Noise [4] are utilized. This approach allows us to find characteristic classes of patterns within a data set without any a priori knowledge about the recorded data, enabling to find common features of a dataset much faster, ultimately even during data measurement.

[1] Zimmermann et al. Phys. Rev. E **99**, 063309 (2019)

[2] Langbehn et al. Phys. Rev. Lett. **121**, 255301 (2018)

[3] Kim, H. & Mnih, A. arXiv:1802.05983 (2018)

[4] McInnes L, Healy J. (ICDMW), IEEE, pp 33-42. 2017

Social program

Various social-scientific activities will take place on Wednesday afternoon. We start the excursion with a pedestrian experiment, for which we will need as many participants as possible. Please gather in front of the conference building Audimax after the minisymposia and contributed talks session and be ready at 12:30 to participate in a 10 minutes pedestrian experiment. Try to behave like a normal pedestrian without thinking what might be behind the experiment as this would be counterproductive.

Afterwards, we offer a guided tour through the City of Rostock. The first guided tour starts from 14:00 at *Kröpeliner Tor*. To get there, you will need the ticket which you received during registration. This ticket is a *Tageskarte* (after stamping it inside the tram, inside the bus, or on the platform of S-Bahn, it is valid until 3am of the following night). The tram 3 (exit Schröderplatz) and tram 6 (exit Kröpeliner Tor) will take you to Kröpeliner Tor, and also the bus 25 (exit Doberaner Platz, and then you have to walk a bit), but not the bus 27. Walking from the Ulmencampus to Kröpeliner Tor takes about 25 minutes.

A second guided tour will start at 16:45 from the *Reisebank* near Warnemünde station. There should be enough time to attend both tours. One option is this: after the first tour, take a tram 1, 2, or 5 to *Holbeinplatz*, and then you take the S–Bahn to Warnemünde (final stop). You can also take tram 3 or 6 to Parkstraße and change to the S–Bahn there. The S-Bahn goes at least every 15 minutes and will need about 20 minutes.

There is an alternative to the city tour: we have a limited number of tickets for the *DLR Raumfahrt Show* in the Audimax. This show celebrates the 50th anniversary of the Apollo landing on the moon, with experiments on stage, fascinating videos and activities for the audience. The show is in German language, and the target audience are young children who already attend school.

The program on Wednesday will conclude with a Dinner talk by Poul Hjorth and a Social Dinner in the *Bootshalle* at the *Yachthafenresidenz Hohe Düne* (Address: Yachthafenresidenz Hohe Düne GmbH, Am Yachthafen 1, 18119 Rostock-Warnemünde). The doors will open at 18:00. To get there, take the underpass under the Warnemünde station, turn right, walk to the ferry (your *Tageskarte* is valid) and cross the water. Then walk about 300 metres in North-Eastern direction. The ferry will make at least one trip every 20 minutes till 11pm.

Please don't forget to bring your name badge to the dinner as it serves as ticket for the evening.

Keep your *Tageskarte* until you arrive back at your hotel.

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