Patterns of Dynamics

Conference in Honor of Bernold Fiedler

Berlin, July 25-29, 2016

Venue

Free University of Berlin
Takustraße 9

Book of Abstracts and Program

Berlin

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Isabelle Schneider, Hannes Stuke, Yuya Tokuta,
Nicola Vassena, Martin Väth
Konstantinos Zemas

	Monday, July 25th
	LECTURE HALL
8:00-9:30	Registration
9:30-9:45	Opening
9:45-10:30	**Willi Jäger** Mathematical modelling and simulation of the evolution of plaques in blood vessels
10:30-11:00	Coffee break
	LECTURE HALL
11:00-11:45	**Hiroshi Matano** Front propagation in predator-prey type reaction-diffusion systems
11:45-12:30	**Konstantin Mischaikow** Dynamics signatures generated by regulatory networks
12:30-14:00	Lunch

Monday, July 25th		
	LECTURE HALL	ROOM A
14:00-14:30	**Wolf-Jürgen Beyn** Computation and stability of patterns in second order evolution equations	**Hiroshi Kokubu** Morse decompositions of global dynamics from image data
14:30-15:00	**Yannis G. Kevrekidis** No equations, no variables, no parameters: data, and the modeling of complex systems	**Stefan Liebscher** Every circle touches infinity twice!
15:00-15:30	**Andreas Schuppert** “Big data and dynamics” – the key to model-driven personalized medicine?	**Vassili Gelfreich** Particle acceleration in non-autonomous billiards
15:30-16:00	Coffee break	

Monday, July 25th			
	LECTURE HALL	ROOM A	ROOM B
16:00-16:20	**Paolo Gidoni** Locomotion of a bio-inspired crawler: stasis domains and sweeping processes	**Jens Starke** Analysis of macroscopic behaviour in complex particle systems	**Andrey Afendikov** Patterns of dynamics in cosymmetric problems and theory of bifurcations without parameter
16:20-16:40	**Stephan van Gils** A biophysical model for cytotoxic edema	**Florin Diacu** Relative equilibria of the curved N-body problem	**Valery Gaiko** Global bifurcations in low-dimensional dynamical systems
16:40-17:00	**Daniel Wetzel** Pattern analysis in a benthic bacteria-nutrient system	**Giorgi Khimshiashvili** Geometry and control of constrained electrostatic equilibria	**Samira Mohagheghi** Dynamics of pattern formation in In-Bi-Sn eutectic system in quasi-2D sample
17:00-17:20	**Robert MacKay** Ideas about Riemann's hypothesis		

Tuesday, July 26th		
	LECTURE HALL	
9:00-9:45	**Yasumasa Nishiura** On the interplay between intrinsic and extrinsic instabilities of spatially localized patterns	
9:45-10:30	**Eckehard Schöll** Tweezers for chimeras in small networks	
10:30-11:00	**Group photo** & Coffee break	
	LECTURE HALL	ROOM A
11:00-11:30	**Jörg Schmeling** Fourier dimension and its modification	**Lutz Recke & Klaus Schneider** An implicit function theorem for singularly perturbed problems
11:30-12:00	**Jürgen Scheurle** Patterns in Fourier space	**Abderrahim Azouani** Use of finite number of determining parameters and continuous data assimilation into feedback control
12:00-12:30	**Romain Joly** How opening a hole affects the sound of a flute	**Katharina Krischer** From a classification scheme for chimera states to novel coexistence patterns in isotropic oscillatory media
12:30-14:00	Lunch	

Tuesday, July 26th		
	LECTURE HALL	
14:00-14:45	**Sabine Klapp** Spatiotemporal patterns and hysteresis in colloidal suspensions under shear	
	LECTURE HALL	ROOM A
15:00-15:30	**Alan D. Rendall** Dynamics of the Calvin cycle	**Carlos Rocha** A permutation characterizing unbounded attractors of slowly nondissipative systems
15:30-15:50	**Sebastian Ruszkowski** Ważewski type theorem for non-autonomous systems of equations	**Pablo Castañeda** The tortoise method and a new linear algorithm for rainbow meanders
15:50-16:50	**Poster session**[1] & Coffee break **Sylvain Mazas**' exposition "Polymatics"[2]	

[1] See section "List of posters", p. 13.
[2] It will take place in Rooms D & E.

Tuesday, July 26th		
	LECTURE HALL	ROOM A
16:50-17:20	**Claudia Wulff** Exponential estimates of symplectic slow manifolds	**Anna Zakharova** Noise-induced chimera states in a neural network
17:20-17:40	**Lev Lerman** Geometry and dynamics of slow fast Hamiltonian systems	**Philipp Hövel** Controlling chimera states by a block of excitable units
17:40-18:00	**Björn Sandstede** Canard-like transitions from 1- to 2-pulses in the FitzHugh-Nagumo system	**Bastian Pietras** Ott-Antonsen attractiveness for parameter-dependent oscillatory networks

	Wednesday, July 27th	
	LECTURE HALL	
9:00-9:45	**Sjoerd Verduyn Lunel** Wasserstein distances in the analysis of time series and dynamical systems	
9:45-10:30	**Angela Stevens** Homogenization of weakly connected structures in 2D: Combining stripes, traps, and sieves	
10:30-11:00	Coffee break	
	LECTURE HALL	ROOM A
11:00-11:30	**Klaus Böhmer** Dew drops on spider webs: a symmetry breaking bifurcation for a parabolic differential-algebraic equation	**Dmitry Turaev** Quantum acceleration
11:30-12:00	**Messoud Efendiyev** Why not?	**Karsten Matthies** Asymptotics and stability of solitary waves in the high-energy limit of FPU-type chains
12:00-12:30	**Reiner Lauterbach** Recent progress on Ize's conjecture	**Sergey Tikhomirov** Rattling in spatially discrete reaction-diffusion equations with hysteresis
12:30-14:00	Lunch	
14:00-19:00	Excursion	
19:00-22:00	Dinner talk: **André Vanderbauwhede** & Conference dinner	

	Thursday, July 28th	
	LECTURE HALL	
9:00-9:45	**Sigurd Angenent** Non self similar solutions from cones in mean curvature flow	
9:45-10:30	**Klaus Ecker** Local monotonicity and mean value formulas for some nonlinear diffusion equations	
10:30-11:00	Coffee break	
	LECTURE HALL	ROOM A
11:00-11:30	**Peter Szmolyan** Blow-up analysis of regularizations of nonsmooth systems	**Jens Rademacher** Samples of pattern formation under advection
11:30-11:50	**Nikita Begun** Dynamics of discrete time systems with the hysteresis stop operator	**Denny Otten** Spatial decay and spectral properties of rotating waves in evolution equations
11:50-12:10	**Mark Curran** Reaction-diffusion equations with hysteresis in higher spatial dimensions	**Vassilios Rothos** Dynamics of localized structures in dissipative nonlinear lattices
12:10-14:00	Lunch	

	Thursday, July 28th	
	LECTURE HALL	ROOM A
14:00-14:30	**Pavel Brunovský** BF as učenik and the speculator HJB equation	**Isabelle Schneider** Spatio-temporal feedback control of partial differential equations
14:30-15:00	**Angela Fiedler** Macroeconomic dynamics	**Serhiy Yanchuk** Self-organized resistance to noise of neuronal networks with plasticity
15:00-15:20	**Philipp Strack** On the speed of social learning	**Felicia Magpantay** Lyapunov-Razumikhin techniques for state-dependent delay differential equations
15:20-15:40	**Johannes Buchner** Complexity and critical mathematical economics	**Dmitry Puzyrev** Modulational instability and zigzagging of dissipative solitons induced by delayed feedback
15:40-16:10	Coffee break	
16:10-16:40	**Mohamed Belhaq** Analytical approximation of heteroclinic bifurcation near 1:3 and 1:4 resonances	**Peter Polacik** Propagating terraces in the dynamics of parabolic equations
16:40-17:10	**Alexander Mielke** Exponential decay into thermodynamical equilibrium for reaction-diffusion systems with detailed balance	**Martin Väth** Recent results for Turing bifurcation with unilateral obstacles

	Friday, July 29th	
	LECTURE HALL	
9:00-9:45	**John Mallet-Paret** Genericity, analyticity, and global bifurcation of periodic solutions of delay equations	
9:45-10:30	**Arnd Scheel** Growth and patterns	
10:30-11:00	Coffee break	
	LECTURE HALL	ROOM A
11:00-11:30	**Marek Fila** Non-uniqueness of solutions of a semilinear heat equation with singular initial data	**Ale Jan Homburg** Random interval maps
11:30-11:50	**Hannes Stuke** Blow-up and complex time	**Dongchen Li** Homoclinic bifurcations that give rise to heterodimensional cycles near a saddle-focus equilibrium
11:50-12:10	**Sinisa Slijepcevic** Surprising applications of the zero number: phase transitions, DNA replication, and twist maps	**Ivan Ovsyannikov** Global bifurcations and discrete Lorenz attractors
12:10-13:40	Lunch	

Friday, July 29th			
	LECTURE HALL	ROOM A	ROOM B
13:40-14:00	**Christos Sourdis** Interface layer of a two-component Bose-Einstein condensate		**Bernhard Brehm** Sensitivity of metabolic reaction networks
14:00-14:20	**Roman Grigoriev** Spiral wave chaos: Tiling, local symmetries, and asymptotic freedom	**Oleh Omel'chenko** Patterns of coherence and incoherence	**Nicola Vassena** Monomolecular reaction networks: flux-influenced sets and balloons
14:20-14:40	**Jia-Yuan Dai** Existence of rotating spiral patterns of the complex Ginzburg-Landau equation on 2-spheres	**Claude Baesens** Simplest bifurcation diagrams for monotone families of vector fields on a torus	**Aleksander Cwiszewski** Dynamics of perturbed p-Laplace problems
14:40-15:00	**Phillipo Lappicy** Einstein constraints: A dynamical approach	**Robert Skiba** Homotopy invariants in bifurcation theory for dynamical systems	
15:00	Closing remarks and farewell coffee		

List of posters

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Patterns of dynamics in cosymmetric problems and theory of bifurcations without parameter

Andrey Afendikov[1]*

In the early 1990s V.Yudovich introduced the notion of cosymmetry. He discovered that in this case steady states are generically non-isolated and investigated some bifurcation problems. We consider recently several hydrodynamic problems in unbounded domains where in a vicinity of the instability threshold, the dynamics is governed by generalized Cahn-Hilliard equation. For the time independent solutions of this equation, Bogdanov-Takens bifurcation without parameter in the 3-dimensional reversible system with a line of equilibria were recovered. This line of equilibria is neither induced by symmetries, nor by first integrals. At isolated points, normal hyperbolicity of the line fails due to a transverse double eigenvalue zero. The bi-reversible problem and its small perturbation with only one symmetry left was studied in [1, 2]. Our aim is to relate Yudovich theory to these results and to discuss hydrodynamic problems, where the reversibility breaking perturbation cannt be considered as small.
Supported by RFBR 14-01-00566 A

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[1] A. Afendikov, B. Fiedler, and S. Liebscher. Plane Kolmogorov flows and Takens-Bogdanov bifurcation without parameters: The doubly reversible case.Asymptotic Analysis, 60 (3,4), (2008), 185211.

[2] A. Afendikov, B. Fiedler, and S. Liebscher. Plane Kolmogorov flows and Takens-Bogdanov bifurcation without parameters: The singly reversible case. Asymptotic Analysis, 72, n. 1-2, (2011), 3176

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Stability for integro-differential equations using fixed point theory

Kamel Ali khelil[1*], Ahcene Djoudi[1†]

In this work, we use a fixed point method to establish an asymptotic stability theorem with a necessary and sufficient condition of the zero solution for a class of integro-differential equations with variable delays.

References

[1] C. Jin and J. Luo, Stability of an integro-differential equation Comput. Math. Appl.57(7), 1080-1088 (2009).

[2] D. S. Smart, Fixed point theorems; Cambridge Tracts in Mathematics, No. 66. Cambridge University Press, London-new York 1974.

[3] J. J. Levin and J. A. Nohel, On a system of integrodifferential equations occurring in reactor dynamics, J. Math. Mech. 9, 347368 (1960).

[4] T. A. Burton, Fixed points and stability of a nonconvolution equation, Proc. Am. Math. Soc. 132, 36793687 (2004).

[5] T. A. Burton, The case for stability by fixed point theory, Dyn. Contin. Discrete Impulsive Syst.: Ser. A - Math. Anal. 13B(Suppl.), 253263 (2006).

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Non self similar solutions from cones in mean curvature flow

Sigurd Angenent[1*]

It is known that for certain cones in $\mathbf{R}^n$ more than one smooth self similar solution to MCF exists. I will discuss a number of such examples, and show how to construct many more non-self similar solutions from the same conical initial data.

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Use of finite number of determining parameters and continuous data assimilation into feedback control

Abderrahim Azouani[1*], Edriss S. Titi[2], Eric Olson[3], Masakazu Gesho[4]

We introduce a feedback control scheme for stabilizing solutions of infinite-dimensional dissipative dynamical systems. For more reaching applications, we present a new continuous data assimilation algorithm based on our feedback controls ideas in the context of the incompressible two-dimensional Navier-Stokes equations. This algorithm allows the use of any type of measurement data for which a general type of approximation interpolation operator exists. Our main result provides conditions, on the finite-dimensional spatial resolution of the collected data, sufficient to guarantee that the approximating solution, obtained by our algorithm from the measurement data, converges to the unknown reference solution over time.

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Simplest bifurcation diagrams for monotone families of vector fields on a torus

Claude Baesens[1]*, Robert MacKay[1]†

We prove that the bifurcation diagram proposed in [1] as the simplest possibility for a monotone two-parameter family of vector fields on a torus is indeed representative of the simplest possible cases. To achieve this we define "simplest" by minimising sequentially the numbers of equilibria, Bogdanov-Takens points, closed curves of centre and of neutral saddle, Reeb components, arcs of rotational homoclinic bifurcation of horizontal homotopy type, necklace points, points of neutral horizontal homoclinic bifurcation, half-plane fan points, points of coexistence of centre and neutral saddle, and degenerate Hopf points. We obtain a variety of simplest cases, including that initially proposed. We provide an example of a family satisfying our definition of simplest. Fiedler's index plays a role in this analysis.

References

[1] Baesens C, Guckenheimer J, Kim S, MacKay RS, Three coupled oscillators: mode-locking, global bifurcations and toroidal chaos, Physica D 49 (1991) 387–475.

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Dynamics of discrete time systems with the hysteresis stop operator

Nikita Begun[1*]

Joint result with M. Arnold, P. Gurevich, E. Kwame, H. Lamba, D. Rachinskii. We consider a piecewise linear two-dimensional dynamical system that couples a linear equation with the so-called stop operator. Global dynamics and bifurcations of this system are studied depending on two parameters. The system is motivated by general-equilibrium macroeconomic models with sticky information.

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Analytical approximation of heteroclinic bifurcation near 1:3 and 1:4 resonances

Mohamed Belhaq[1*]

In this work, the method of nonlinear time transformation is applied to obtain analytical approximation of heteroclinic connections in the problem of stability loss of self-oscillations near resonances of order 3 and 4. As an example, we explore this problem in the slow flow (normal form) of a parametric and self-excited nonlinear oscillator near these resonances. The method mainly uses the unperturbed heteroclinic connection in the Hamiltonian system in the slow flow and determines conditions under which the heteroclinic connections persist in the perturbed system. The results show that for small perturbation of the Hamiltonian system, the nonlinear time transformation method predicts well the heteroclinic connections near the resonance of order 3 and 4.

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Computation and stability of patterns in second order evolution equations

Wolf-Jürgen Beyn[1*], Denny Otten[1†], Jens Rottmann-Matthes[2‡]

As a model example we consider in this talk traveling waves of a semilinear damped wave equation. We show how the freezing method generalizes from first to second order evolution equations by transforming the original PDE into a partial differential algebraic equation (PDAE). Solving a Cauchy problem via the PDAE generates a comoving frame in which the solution becomes stationary, and an additional variable which converges to the speed of the wave, provided the original wave has suitable stability properties. A rigorous theory of this effect is presented in one space dimension, building on recent nonlinear stability results for waves in first order hyperbolic systems. Numerical examples demonstrate the applicability of the method, and generalizations to rotating patterns in several space dimensions indicate its scope.

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Dew drops on spider webs: a symmetry breaking bifurcation for a parabolic differential-algebraic equation

Klaus Böhmer[1]*

Lines of dew drops on spider webs are frequently observed on cold mornings. I have chosen it for a presentation requested by the Hessian TV as an example known to everybody, demonstrating aspects of modern mathematical problems. In this lecture I present a model explaining their generation. Although dew is supposed to condense somehow evenly along the thread, only lines of drops are observed along the spider thread. What are the reasons for this difference? I give an explanation by concentrating on some essential aspects only. This every-day observation is an example for one of the fascinating scenarios of nonlinear problems, *symmetry breaking bifurcation.* Despite many simplifications the model still provides very interesting mathematical challenges. In fact the necessary mathematical model and the corresponding numerical methods for this problem are so complicated that it never has been studied before. We analyse and numerically study symmetry breaking bifurcations for a free boundary value problem of a degenerate parabolic differential-algebraic equation employing a combination of analytical and numerical tools. In Marburg Karlheinz Schild, Bernhard Schmitt and I have solved this problem.

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Existence of periodic solutions for delay differential equations on time scales

Fayçal Bouchelaghem[1*], Abdelouaheb Ardjouni[1†]

In this work, we use the fixed-point theorem to prove the existence of periodic solutions of differential equtions with delay on time scales. We present some conditions which our solutions are positive and periodic. The main results are illustrated with several examples.

References

[1] D.R. Smart, Fixed Point Theorems, in: Cambridge Tracts in Mathematics, vol. 66, Cambridge University Press, London, New York, 1974.

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[3] Z. Jin, H.Wang, A note on positive periodic solutions of delayed differential equations, Appl. Math. Lett. 23 (2010) 581584.

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Sensitivity of metabolic reaction networks

Bernhard Brehm[1*], Bernold Fiedler[1†]

We study the influence of rate perturbations on reaction fluxes, at steady state, in general metabolic networks. In particular, we establish transitivity of flux influence in the presence of multimolecular reactions. We illustrate our results for several variants of the tricarboxylic citric acid cycle (TCAC).

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BF as učenik and the speculator HJB equation

Pavel Brunovský[1]*

Secret even for the speaker.

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Complexity and critical mathematical economics

Johannes Buchner[1]*

The aim of my talk is to present elements and discuss the potential of a research program in the intersection between mathematics and heterodox economics, which we call Criticial Mathematical Economics (CME). We identify two key parts of CME, which leads to a natural structure of the talk: The first focusses on an analysis and critique of mathematical models used in mainstream economics, like e.g. the Dynamic Stochastic General Equilibrium (DSGE) in Macroeconomics. We will focus on the latter, including a discussion of the so-called "Sonnenschein-Mantel-Debreu"-Theorems that deal with the aggregaton of the Micro- to the Macro-Level in economics and point to some mathematical difficulties in DSGE models. The aim of the second part of CME is to improve and extend heterodox models using ingredients from modern mathenmatics and computer science, a method with strong relation to Complexity Economics. We will exemplify this idea by describing how methods from Non-Linear Dynamics have been used what could be called "The Dynamical Systems approach to Post-Keynesian Macroeconomics", and also discuss possible Micro- and Mesofoundations. We conclude by giving an outlook in which areas a collaboration between mathematicians and heterodox economists could be most promising. This includes the mathematical and model-theoretic foundations of controversies in economic policy.

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The tortoise method and a new linear algorithm for rainbow meanders

Pablo Castañeda[1*]

The 1991 groundbreaking work of Fusco and Rocha “A permutation related to the dynamics of a scalar parabolic PDE” shows the close relation of detailed dynamics of *Sturm global attractors* with *open meanders configurations*. The 2012 joint work with Bernold Fiedler shows the strict relation between a variant of *closed meanders* and *Cartesian billiards*. Another few works relate *Temperey-Lieb algebras* and several other objects from diverse areas of mathematics. In this work I will present another two approaches: one is a geometrical algorithm with log-complexity, the second one presents a strong matrix structure that we can analyse, however it is linear.

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The structure of global attractors for non-autonomous perturbations of discrete gradient-like dynamical systems

David Cheban[1*], Cristiana Mammana[2†], Elisabetta Michetti[2‡]

In this talk we give the complete description of the structure of compact global (forward) attractors for non-autonomous perturbations of discrete autonomous gradient-like dynamical systems under the assumption that the original discrete autonomous system has a finite number of hyperbolic stationary solutions. We prove that the perturbed non-autonomous (in particular τ-periodic, quasi-periodic, Bohr almost periodic, almost automorphic, recurrent in the sense of Birkhoff) system has exactly the same number of invariant sections (in particular the perturbed systems has the same number of τ-periodic, quasi-periodic, Bohr almost periodic, almost automorphic, recurrent in the sense of Birkhoff) solutions). It is shown the compact global (forward) attractor of non-autonomous perturbed system coincides with the union of unstable manifolds of this finite number of invariant sections.

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Reaction-diffusion equations with hysteresis in higher spatial dimensions

Mark Curran[1*]

In this talk, I will treat the equation

$$u_t = \Delta u + f(u, \mathcal{H}(u)), \tag{1}$$

where u represents a diffusing substance and $\mathcal{H}(u)$ is a hysteresis operator defined at every spatial point. Such equations model processes where the non-diffusing substance $\mathcal{H}(u)$ can be in one of two states, and the switching mechanism between states is determined by a hysteresis law. These equations model a variety of biological and chemical processes that exhibit spatio-temporal patterns. Numerical simulations of such models are in agreement with experiment, however questions of the existence and uniqueness of solutions, as well as a rigorous explanation of the mechanisms for pattern formation remain largely open. Well-posedness only recently been addressed on one-dimensional domains. The set of points where $\mathcal{H}(u)$ is in one state or the other naturally segregates the domain into two subdomains. Moreover, a switching mechanism implies that these subdomains are separated by free boundaries. I will consider (1) on a higher dimensional domain and present conditions on the free boundary and initial data that guarantee the existence and uniqueness of solutions. I will also give a description of how the hysteresis gives rise to a novel type of free boundary evolution.

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Dynamics of perturbed p-Laplace problems

Aleksander Cwiszewski[1]*, Mateusz Maciejewski[1]

Stationary solutions, connecting orbits and periodic solutions for a class of evolution equations with p-Laplace operator shall be studied. We shall use the theory of evolution equations involving m-accretive and monotone operators to construct semiflows and evolution systems. We shall also examine the continuity and compactness properties of the translation along trajectories operator in order to apply topological methods based on homotopy invariants such as Conley homotopy and fixed point indices. As a result, we obtain effective criteria for the existence of stationary solutions and connecting orbits as well as co-bifurcations of periodic solutions.

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Existence of rotating spiral patterns of the complex Ginzburg-Landau equation on 2-spheres

Jia-Yuan Dai[1*]

We show the existence of rotating spiral patterns, defined by a spiral ansatz, of the complex Ginzburg-Landau equation on 2-spheres. In the proof we apply equivariant bifurcation results and study the kernel of the linear variational equation along each bifurcating solution.

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Relative equilibria of the curved N-body problem

Florin Diacu[1]*

We generalize the Newtonian N-body problem to spaces of constant curvature, as done in [1], and study its relative equilibria, i.e. orbits that maintain constant mutual distances during the motion [2,3,4,5]. We provide a complete description of these solutions, prove criteria for finding them, and present several examples for various values of N. Finally we introduce the concept of central configuration and show how it can simplify the study of relative equilibria. The core of the talk is paper [5], for which the author was awarded the J.D. Crawford Prize from SIAM in 2015.

References

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[2] F. Diacu, On the singularities of the curved N-body problem, Trans. Amer. Math. Soc. 363, 4 (2011), 2249–2264.

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Local monotonicity and mean value formulas for some nonlinear diffusion equations

Klaus Ecker[1*]

We present methods for construction of global and local quantities (Lyapunov type functionals) for certain nonlinear diffusion equations. These quantities behave monotonically with respect to time or a space-time scaling parameter.

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Why not?

Messoud Efendiyev[1*]

We study the asymptotic behaviour of solutions of nonlinear elliptic equations in asymptotically symmetric unbounded domains. We are interested in how the asymptotic symmetry of the domain is inherited to the symmetry of appropriate global attractor. To this end we use a dynamical systems approach and new Liouville type results which are of independent interest as well. It is worth noting that this study was initiated many years ago via discussions in the Fachbereich Kolloquium at the Free University Berlin.

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Macroeconomic dynamics

Angela Fiedler[1]*

Modeling expectations is at the heart of modeling macroeconomic dynamics. The past decades of macroeconomic research have been dominated by so-called unique rational expectations equilibrium models. Recently, this class of models has been called into question for two reasons. Firstly, experimental evidence suggests that, for a broad class of models, agents fail to coordinate on unique rational expectations equilibria. Secondly, we see ourselves confronted with phenomena as house price bubbles, financial crises, and stock market price crashes, which are hard to reconcile with the unique rational expectations paradigm. Several alternative modeling approaches are therefore presented and discussed.

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Non-uniqueness of solutions of a semilinear heat equation with singular initial data

Marek Fila[1]*, Eiji Yanagida[2]†

We construct new examples of non-uniqueness of positive solutions of the Cauchy problem for the Fujita equation. The solutions we find are not self-similar and some of them blow up in finite time. Connecting orbits and ancient solutions of a rescaled equation play a key role in our constructions.

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Global bifurcations in low-dimensional dynamical systems

Valery Gaiko[1]*

We carry out the global bifurcation analysis of low-dimensional polynomial dynamical systems. First, using new bifurcational and topological methods, we solve Hilbert's Sixteenth Problem on the maximum number of limit cycles and their distribution for the 2D general Liénard polynomial system and Holling-type quartic dynamical system. Then, applying a similar approach, we study 3D polynomial systems and complete the strange attractor bifurcation scenario for the classical Lorenz system connecting globally the homoclinic, period-doubling, Andronov–Shilnikov, and period-halving bifurcations of its limit cycles which is related to Smale's Fourteenth Problem.

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Particle acceleration in non-autonomous billiards

Vassili Gelfreich[1 *]

This talk presents a survey of recent results on the evolution of particle energy in a mathematical billiard inside a time-dependent domain. Assuming that the particle moves much faster than the boundary, we discuss sufficient conditions for the exponential growth of the energy. If the dynamics in the frozen domain is ergodic the evolution of the energy can be described by the adiabatic theory, which leads to conclusions similar to the adiabatic theory of an ideal gas. The ergodic adiabatic theory can be extended to systems with mixed phase space where the ergodicity condition is violated, this extension leads to a probabilistic model for the particles dynamics. This approach takes into account transition of the phase volume between ergodic components of the frozen billiard and leads to a quantitative prediction for the acceleration rate. This rate is in good agreement with results of numerical simulations. Finally, we discuss the problem of energy equilibration. This is a joint work with V. Rom-Kedar, K. Shah and D. Turaev.

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Locomotion of a bio-inspired crawler: stasis domains and sweeping processes

Paolo Gidoni[1*], Antonio DeSimone[1†]

The modelling of crawling locomotors is receiving increasing attention with the development of bio-inspired soft robots. In this talk we see how, in case of dry friction, the locomotion problem for a N-segments crawler can be restated and solved in the framework of rate-independent systems. This formulation emphasizes hysteresis, expressed by the presence of stasis domains, and provides an intuitive description of the motility properties of the systems, such as the key role of a directionality in the friction.

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Spiral wave chaos: Tiling, local symmetries, and asymptotic freedom

Roman Grigoriev[1*], Chris Marcotte[1†]

Excitable systems can generate dynamics ranging from solitary waves in 1D to spiral/scroll wave chaos in 2D/3D. Complex spatiotemporally chaotic dynamics featuring spiral waves are associated with phenomena such as cardiac arrhythmias (e.g., fibrillation) and seizures (epilepsy). Understanding the nature of spatiotemporal chaos in excitable systems therefore is not only of fundamental interest, but also of high practical importance. This talk will give an overview of recent progress in understanding the dynamical mechanisms that initiate and maintain spiral wave chaos featuring multiple interacting spiral waves that repeatedly break up and merge. Periodic orbit theory, which aims to describe chaotic dynamics using the properties of unstable periodic solutions embedded in the chaotic attractor, produced a lot of insight into the dynamics of low-dimensional systems, starting with the work of Poincare on celestial mechanics. Recently, a similar approach has been applied rather successfully to spatiotemporal chaos in a range of systems (complex Ginzburg-Landau, Kuramoto-Sivashinsky, and Navier-Stokes equation). In excitable systems, however, it fails rather spectacularly due to a special property of spiral waves: they have extremely short spatial correlations. Although it is tempting to associate the relevant length scale with the wavelength of a spiral wave, the former is instead defined by the width of the adjoint eigenfunctions associated with the dominant modes of the linearization. For typical models of excitable dynamics these eigenfunctions are exponentially localized around the spiral core, with the width much smaller than the wavelength. Hence, interaction between two spiral waves falls off exponentially, and the dynamics of individual spirals become effectively independent once the separation between the spiral cores exceeds this length scale (spiral waves become asymptotically free). As a result, typical multi-spiral states break the global Euclidean symmetry of the problem, but respect local symmetries (translations and rotations in 2D). Local symmetries imply that time-periodic solutions are extremely rare due to the slow relative drift in the position and orientation of individual spirals. This drift can be understood by partitioning the domain into tiles, each of which supports a single spiral wave. The dynamics of each spiral can then be understood completely based on the shape of the corresponding tile and the position of the spiral core. This formalism produces a number of specific predictions that are fully supported by numerical simulations and offers a novel way to understand and describe spiral wave chaos.

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Random interval maps

Ale Jan Homburg[1*], Masoumeh Gharaei[1†], Neda Abbasi[2‡]

I will consider skew product systems of intervals maps (diffeomorphisms and unimodal maps) over shifts on symbol spaces. The emphasis will be on intermittency and synchronization.

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Controlling chimera states by a block of excitable units

Philipp Hövel[1*], Thomas Isele[1], Johanne Hizanidis[2], Astero Provata[3]

Systems of nonlocally coupled oscillators can exhibit complex spatio-temporal patterns, called chimera states, that consist of coexisting domains of spatially coherent (synchronized) and incoherent (desynchronized) dynamics. First observed in systems of identical elements with symmetric coupling topology, these hybrid states have been intensively studied during the last decade. We explore the influence of a block of excitable units on the existence and behavior of chimera states in a nonlocally coupled ring-network of FitzHugh-Nagumo elements. The FitzHugh-Nagumo system, a paradigmatic model in many fields from neuroscience to chemical pattern formation and nonlinear electronics, exhibits oscillatory or excitable behavior depending on the values of its parameters. Until now, chimera states have been studied in networks of coupled oscillatory FitzHugh-Nagumo elements. In the present work, we find that introducing a block of excitable units into the network may lead to several interesting effects. It allows for controlling the position of a chimera state as well as for generating a chimera state directly from the synchronous state.

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Mathematical modelling and simulation of the evolution of plaques in blood vessels

Willi Jäger[1]*

This lecture deals with the mathematical modelling of formation and evolution of plaques in arteries, one of the main causes for the blockage of blood flow. Plaque rupture and spread of torn-off material may cause closures in the down-stream vessel system and lead to ischaemic brain or myocardial infarctions. The arising system of biochemical and biophysical processes is huge and complex. We focus on an important sub-system: the transport of immune cells in large blood vessels, their transition through the endothelial layer and their interactions with the vessel walls, causing changes of the volume and mechanical properties and leading to plaque formation. The following topics will be covered in this talk:

- Derivation of the model system as a mechano-chemical fluid-structure interaction problem
- Numerical algorithms developed and used to simulate the dynamics of this interaction: The arbitrary Lagrangian Eulerian method (ALE) is chosen to solve the systems numerically.
- Results of simulations of the plaque formation for realistic systems parameters: The evolving structures are matching clinical observations: The time scale of the formation is in the simulation of comparable order as in reality. Simulations of plaques demonstrate pattern formation, which was not expected, but can be observed.

Changes of the blood perfusion is also leading to changes in the supply in particular with oxygen, which is an important factor in the dynamics of inflammation. Hypoxia is responsible for changes in water permeability of cell walls, leading to osmotic effects and as a consequence to swelling of cells and of tissue. A survey on results for swelling of a single cell is presented. The reported results are based on joint research of the authors of the following references.

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How opening a hole affects the sound of a flute

Romain Joly[1*]

Consider the wave equation in a thin three-dimensional tube. The "thin domains" methods easily show that this situation can be approximated by a one-dimensional wave equation. But what happens when a hole is open on the side of the tube? In the case of old flutes, the approximation by a simple 1D wave equation is inaccurate. In this talk, we use a work of J. Casado-Díaz, M. Luna-Laynez and F. Murat to mathematically derive a suitable model.

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Pattern formation on a two-dimensional flame front during thermoacoustic instability

Lipika Kabiraj[1*], Aditya Saurabh[1†], Christian Oliver Paschereit[1‡]

Thermoacoustic instability is an undesirable phenomenon observed in a system where confined combustion takes place. It is most commonly seen in system such as land based gas turbine and aero-engine combustors. It occurs due to nonlinear interaction between the unsteady combustion process and the acoustic field of the confinement and is manifested as self-excited acoustic and heat release rate oscillations. Such oscillations can be fatal for the structural integrity of the entire system. Nonlinear dynamics of thermoacoustic oscillationsbifurcations, bistability, and chaosoriginates from the flame. Accordingly, flame front dynamics, particularly in the presence of an acoustic field, is an important ongoing study. We conducted experiments on self-excited thermoacoustic instability involving a ducted two dimensional premixed flame stabilized on a perforated burner plate. On changing the fuel flow rates in the system we found that system undergoes subcritical Hopf bifurcation to limit cycle oscillations. On further variation in the parameter changes in the dynamical nature of the oscillations were observed. Interestingly, these changes were accompanied by pattern formation on this thin flame front; the appearance of the pattern resembles Faraday instability. We investigate the pattern formation to identify responsible mechanisms.

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Meanders: Sturm global attractors, seaweed Lie algebras and classical Yang-Baxter equation

Anna Karnauhova[1*]

Our aim is to give an overview on recent results obtained in our Ph.D. thesis. Meanders are closed Jordan curves in the plane intersecting the straight horizontal line transversely and without self-intersections. By the Jordan Curve Theorem and vertex-gluing we introduce the *collapse* of meanders and furthermore the *multiple collapse*. Both, the collapse and the multiple collapse introduced for meanders yield sufficient arguments in order to prove the *Obstruction-Theorem*, which ensures that it is not possible to find any closed expression in terms of the greatest common divisor of homogeneous polynomials of arbitrary degrees with integer coefficients for the number of connected components of seaweed meanders with at least four upper rainbow blocks. Moreover, the collapse yields the relation between the seaweed Lie algebras and seaweed meanders by using the results of A. Kirillov and V. Dergachev on representing a seaweed Lie algebra by *meander graphs*. As we will see meander graphs are collapsed seaweed meanders. By introducing right and left one-shift maps applied to meanders we describe different classes of Morse meanders, which we call of *type I, II, III, and IV*. By using combinatorial description of Sturm global attractors of

$$\text{(PDE)}, \text{(N)} \begin{cases} u_t = a(x)u_{xx} + f(x,u,u_x),\ 0 < x < 1 \\ u_x = 0,\ x = 0 \ or \ x = 1. \end{cases} \tag{1}$$

established by Bernold Fiedler and Carlos Rocha we study the corresponding *connection graphs* with respect to the graph isomorphy. Here, we show some results for connection graphs expressed in terms of the group action on canonical trees corresponding to blocks of *Morse meanders of type I.*

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No equations, no variables, no parameters: data, and the modeling of complex systems

Yannis G. Kevrekidis[1*]

In mathematical modeling one typically progresses from observations of the world (and some serious thinking!) to equations for a model, and then to the analysis of the model to make predictions. Good mathematical models give good predictions (and inaccurate ones do not) - but the computational tools for analyzing them are the same: algorithms that are typically based on closed form equations. While the skeleton of the process remains the same, today we witness the development of mathematical techniques that operate directly on observations -data-, and “circumvent” the serious thinking that goes into selecting variables and parameters and writing equations. The process then may appear to the user a little like making predictions by “looking into a crystal ball”. Yet the “serious thinking” is still there and uses the same -and some new- mathematics: it goes into building algorithms that “jump directly” from data to the analysis of the model (which is never available in closed form) so as to make predictions. I will present a couple of efforts that illustrate this new path from data to predictions. It really is the same old path, but it is travelled by new means.

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Geometry and control of constrained electrostatic equilibria

Giorgi Khimshiashvili[1 *]

We deal with equilibrium configurations of points with Coulomb interaction confined to a compact submanifold of Euclidean space. The first aim is to obtain a geometric characterization of configurations which can serve as stable equilibrium configurations of certain point charges placed at the given points. We will present such a characterization in certain cases where the number of charges does not exceed five. The next aim is to describe the dynamics of such equilibria under the change of values of stabilizing charges and identify arising typical bifurcations. It will be shown that, in particular, the pitchfork bifurcation is typical in the case of the so-called charged necklace in the sense of P.Exner, i.e., for point charges confined to a flexible contour of fixed length. Finally, we will show that in many cases the set of constrained equilibria is path-connected and one may achieve a robust control of stable equilibria by properly changing the values of stabilizing charges. Some applications to the control of vertex-charged mechanical linkages and Coulomb control of satellite swarms will be also outlined. The presentation is based on a few recent joint papers with G.Panina and D.Siersma.

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Spatiotemporal patterns and hysteresis in colloidal suspensions under shear

Sabine Klapp[1]*

Shearing a fluid is a paradigmatic example of driving a soft-matter system out of equilibrium. Indeed, it is now well established that shear flow can induce a variety of complex dynamical effects such as spatial symmetry–breaking in polymeric and colloidal systems, spontaneous oscillations in systems of anisotropic particles, and even chaotic states. Understanding and controlling these effects is not only of strong fundamental interest, but also crucial for many applications. Here we focus on soft–matter systems under the combined influence of shear flow and restricted geometry. We first consider confined suspensions of interacting spherical colloids, analyzed by many-particle computer simulations and effective single-particles models. By varying the externally applied shear rate these colloidal films can display sequences of states characterized by pinning, shear-induced melting, laning, and moving crystalline order with synchronized oscillations of the particles. The transitions between these states are accompanied by pronounced nonlinearities and hysteresis in the corresponding flow curve. We also discuss the appearance of moving density heterogeneities (kinks and antikinks). In the second part, we discuss the nonlinear flow-behavior and the emergence of shear-bands in systems of anisotropic particles. Based on a continuum model involving the (five-dimensional) orientational order parameter and the flow profile we explore systems with different boundary conditions and different spatial correlation lengths. Our results reveal new types of shear-banded states characterized by coexistence of oscillatory motion and steady states.

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Morse decompositions of global dynamics from image data

Hiroshi Kokubu[1]*

In experimental studies, changes of spatial patterns are understood as a manifestation of dynamics. However, there is no method that directly connects changes of patterns with dynamics. In this talk, I shall discuss the use of persistent homology as time-series of the time-varying image data in order to extract dynamical information, especially Morse decomposition. I will apply the idea to numerically simulated data of spatial patterns of PDEs, such as the Swift-Hohenberg equation, and show how the persistent homology data can recover the dynamics on the global attractor of the PDE. This is a joint work with Miroslav Kramar (Tohoku U), Marcio Gameiro (USP-Sao Carlos, Brazil) and Hiroe Oka (Ryukoku, Japan).

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From a classification scheme for chimera states to novel coexistence patterns in isotropic oscillatory media

Felix Kemeth[1*], Sindre Haugland[1†], Lennart Schmidt[1‡], Yannis Kevrekidis[2§], Katharina Krischer[1¶]

Chimera states, the counterintuitive coexistence of synchronized and desynchronized regions in an otherwise isotropic system, have received considerable interest during the last decade. Meanwhile, many different chimera states have been reported in experiment and theories of different mechanisms leading to their emergence are known. In the talk, I will first present a universal characterization scheme for chimera states applicable to both numerical and experimental data sets. The scheme is based on two correlation measures that enable a meaningful definition of chimera states as well as their classification into three categories: stationary, turbulent and breathing. In addition, the categories can be further subdivided according to the time-stationarity of these two measures. In the second part of the talk I will present experiments and simulations that suggest that chimera states are just one realization of a multitude of related coexistence patterns, showing a similar level of seemingly contradictory behavior in the coexisting regions. In a wider sense, the coexistence of such disparate patterns can be seen as diversification of the dynamical behavior of a system with uniform parameters.

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Einstein constraints: A dynamical approach

Phillipo Lappicy[1*]

The Einstein constraint equations describe the space of initial data for the evolution equations, dictating how space should curve within spacetime. Under certain assumptions, the constraints reduce to a scalar quasilinear parabolic equation on the sphere with various singularities, and nonlinearity being the prescribed scalar curvature of space. We focus on self-similar solutions of Schwarzschild type. Those describe, for example, the initial data of black holes. We give a detailed study of the axially symmetric solutions, since the domain is now one dimensional and nodal properties can be used to describe certain asymptotics of the rescaled self-similar solutions. In particular, we mention examples for certain prescribed scalar curvatures.

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Recent progress on Ize's conjecture

Reiner Lauterbach[1]*

The Ize conjecture goes back a long time and addresses an algebraic question which has direct applications to generic equivariant bifurcations. Although quite a few counterexamples to this conjecture are presently known, there are some new conjectures open questions and some partial answers relating to algebra, equivariant bifurcations and dynamics. In this talk we would like to present some of these issues and try to provide some answers.

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Geometry and dynamics of slow fast Hamiltonian systems

Lev Lerman[1*]

We introduce some geometric tools needed to describe slow-fast Hamiltonian systems on smooth manifolds. We start with a smooth bundle $p : M \to B$ where (M, ω) is a C^∞-smooth presymplectic manifold with a closed constant rank 2-form ω and (B, λ) is a smooth symplectic manifold. The 2-form ω is supposed to be compatible with the structure of the bundle, that is, the bundle fibers are symplectic manifolds with respect to the 2-form ω, the distribution on M generated by kernels of ω is transverse to the tangent spaces of the leaves and the dimensions of the kernels and of the leaves are supplementary. This allows one to define a symplectic structure $\Omega_\varepsilon = \omega + \varepsilon^{-1} p^*\lambda$ on M for any positive small ε, where $p^*\lambda$ is the lift of the 2-form λ to M. Given a smooth Hamiltonian H on M one gets a slow-fast Hamiltonian system with respect to Ω_ε. We define a slow manifold SM for this system. Assuming SM is a smooth submanifold, we define a slow Hamiltonian flow on SM. After that we consider singularities of the restriction of p to SM. We show that if $\dim M = 4$, $\dim B = 2$ and the Hamilton function H is generic, then the behavior of the system near a singularity of fold type is described, to the main order, by the equation Painlevé-I, and if this singularity is a cusp, then the related equation is Painlevé-II. The dynamical patterns will be illustrated for the case of the Duffing type equation with slow periodically varying parameters.

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Homoclinic bifurcations that give rise to heterodimensional cycles near a saddle-focus equilibrium

Dongchen Li[1*]

We show that heterodimensional cycles can be born at the bifurcations of a pair of homoclinic loops to a saddle-focus equilibrium for flows in dimension 4 and higher. In addition to the classical heterodimensional connection between two periodic orbits, we found, in intermediate steps, two new types of heterodimensional connections: one is a heteroclinic between a homoclinic loop and a periodic orbit with a 2-dimensional unstable manifold, and the other connects a saddle-focus equilibrium to a periodic orbit with a 3-dimensional unstable manifold.

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Every circle touches infinity twice!

Stefan Liebscher[1*]

A circle in perspective becomes an ellipse, or a general conic section. Is it possible, however, to detect those conic section which have been circles before? The answer is: yes! And it goes back to the Erlangen Program of Felix Klein to embed the Euclidean and non-Euclidean geometries into the projective plane. We take the horizon, i.e. the points at infinity, as a conic section. Its type defines the geometry - and, indeed, circles touch this absolute conic section twice. This can be seen (almost) without calculations, improves our geometric intuition, and provides beautiful examples of cosmology, differential geometry, and dynamical systems. I will uses this to discuss the geodesic flow from a little unusual perspective.

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Ideas about Riemann's hypothesis

Robert MacKay[1*]

Riemann's hypothesis, made on the occasion of his election to the Berlin Academy of Sciences, is the conjecture that all the zeroes of his ξ function are real. As he proved ξ is even, the conjecture is equivalent to saying that the zeroes of $\Xi(E) = \xi(2\sqrt{E})$ are real and non-negative. Extending a suggestion of Polya and Hilbert, we seek a Hermitian operator H such that the functional determinant of $H - E$ is $\Xi(E)$, which would prove Riemann's hypothesis. I haven't solved it but propose to describe where I have got to.

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Lyapunov-Razumikhin techniques for state-dependent delay differential equations

Felicia Magpantay[1*]

We present theorems for the Lyapunov and asymptotic stability of the steady state solutions to general state-dependent delay differential equations (DDEs) using Lyapunov-Razumikhin methods. These theorems build upon the previous work of Hale and Verduyn Lunel (1993), and Barnea (1969) which were mainly aimed at equations with simpler delay terms (e.g. constant and time-dependent delays), and are less applicable to state-dependent DDEs such as the following model equation,

$$\dot{u}(t) = \mu u(t) + \sigma u\big(t - a - cu(t)\big).$$

For fixed a and c, the stability region Σ_* of the zero solution to this model problem is known, and it is the same for both the constant delay ($c = 0$) and state-dependent delay ($c \neq 0$) cases. Using our results we can prove the asymptotic stability of the zero solution to this model problem in parts of Σ_*, considerably expanding upon the work of Barnea, who proved Lyapunov stability for the simpler $\mu = c = 0$ constant delay case. Similar techniques are used to derive a condition for global asymptotic stability of the zero solution to the model problem, and bounds on periodic solutions when the zero solution is unstable. This is joint work with A.R. Humphries.

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Genericity, analyticity, and global bifurcation of periodic solutions of delay equations

John Mallet-Paret[1]*

We study the global bifurcation of periodic solutions for a class of delay-differential equations of Mackey-Glass type. In particular, the presence of a period-doubling cascade of periodic solutions is established. The proof relies on generic properties (in the sense of Kupka-Smale) for classes of such equations. We also discuss some open questions related to generic properties and analyticity of the solution branches.

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Front propagation in predator-prey type reaction-diffusion systems

Hiroshi Matano[1*]

In this talk I will discuss the spreading properties of solutions of a certain class of predator-prey type reaction-diffusion systems. Here, by a spreading property, we mean the way the solution front propagates to infinity when starting from compactly supported initial data. There is extensive literature on front propagation in various reaction-diffusion equations, but, as far as front spreading (from compactly supported initial data) is concerned, few rigorous results are known for systems for which the comparison principle does not hold, such as our predator-prey systems. Among other things we show that both the prey and the predator spread to infinity with definite spreading speeds, which could be different between the two species. This means that two separate fronts may appear, and they divide the space into three regions; the leading edge, the intermediate zone and the final zone. The final zone is where the two species are both uniformly positive and interact with each other most intensively. If the corresponding ODE system has a special type of Lyapunov function and if the diffusion coefficients of the two species are equal, then the solution in the final zone converges uniformly to a spatially homogeneous positive steady-state as time goes to infinity. However, in a more general situation, the dynamics in the final zone is largely unknown. If I have time, I will also mention briefly the extension of the above work to the following two cases:

(1) spreading in spatially periodic environments;

(2) spreading in the hyperbolic space.

Most of this talk is based on the joint work with Arnaud Ducrot and Thomas Giletti.

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Asymptotics and stability of solitary waves in the high-energy limit of FPU-type chains

Karsten Matthies[1]*, Michael Herrmann[2]†

The high-energy limit of travelling waves in Fermi-Pasta-Ulam type chains is governed by the hard-sphere model provided that the atomic interaction potential grows sufficiently fast. In this talk we briefly review the existing convergence results for solitary waves and present a refined asymptotic analysis which provides almost explicit expressions up to high accuracy. This enables us to study the linearisation around such waves. We discuss the implications concerning the uniqueness and the stability of travelling waves.

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Polymatics

Sylvain Mazas[1]*

Polymatics grew from an idea to visualize mathematical concepts, especially prime and composite numbers. It started with doodles on a sketchbook that eventually became 6 meters wide drawings. Being a hobby musician, I looked further into the relation between music and mathematics, and –almost without noticing it– into algorithmic composition. My research is focused on the confrontation of prime numbers and chaos on the one side, composite numbers and harmony on the other side. I consider myself more an illustrator than a mathematician and my research should be considered an experimental playground. However, unlike many Artists working with mathematics, my goal is not to use mathematics to create Art, but to understand artistic creation. The drawings and music presented is the result of a one month Artist-residency at GEMAK, The Hague in 2015.

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Exponential decay into thermodynamical equilibrium for reaction-diffusion systems with detailed balance

Alexander Mielke[1*]

We consider reaction-diffusion systems on a bounded domain with no-flux boundary conditions. All reactions are given by the mass-action law and are assumed to be reversible and satisfy the detailed balance condition. In that case the whole system can be understood as a gradient system, where the relative entropy is the driving functional. We also give a version of the fact for energy-reaction-diffusion systems, where the internal energy is used as a state variable instead of the temperature. Using this structure we study the decay into equilibrium by using the energy-dissipation relation or the entropy entropy-production relation, respectively. This part even works for reaction systems satisfying a complex-balanced condition. We discuss three different methods to derive exponential decay estimates: (i) a compactness argument of Glitzky and Huenlich, (ii) a convexification argument, and (iii) a series of analytical estimates derived by Desvillettes, Fellner, and Tang. This is joint work with Jan Haskovec, Sabine Hittmeir, Peter Markowich, and Markus Mittnenzweig.

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Dynamics signatures generated by regulatory networks

Konstantin Mischaikow[1]*

The results presented in this talk are strongly motivated by attempts to characterize the dynamics of regulatory networks in biological systems. There are three fundamental questions that we attempt to address are: (1) given a time series of gene expression, e.g. RNA-Seq, can one determine regulatory networks that can generate such a time series, (2) given a regulatory network can one determine the types of dynamics that it is capable of generating in a robust manner, and (3) how robust are these networks with respect to expression of particular dynamic phenotypes? There are obvious challenges to answering these questions: (1) biological data tends to be extremely noisy and typically imprecisely measured, (2) the associated mathematical models are derived using heuristic arguments as opposed to first principles, (3) the associated parameter spaces are high dimensional and most parameters are either poorly measured or unknown, and (4) answers to many relevant questions require characterizing global dynamics. We will discuss the mathematical ideas and software associate with the Dynamics Signatures Generated by Regulatory Networks (DSGRN) project. This is based on a combinatorial approximation of dynamics that leads to a natural decomposition of parameter space into semi-algebraic sets. We will discuss how this approach leads to efficient computations and mathematically rigorous results that address the four challenges. We will show how these techniques can be applied to questions related to Malaria and Cancer networks. Finally, if time remains we will discuss related open mathematical questions.

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Dynamics of pattern formation in In-Bi-Sn eutectic system in quasi-2D sample

Samira Mohagheghi[1*], Melis Serefoğlu[1†]

Solidification microstructure is a trace in the solid imprinted by the propagating solid/liquid interface. The formation of solidification patterns is essentially out-of-equilibrium phenomena and the study of this pattern formation has been fostered by nonlinear physics approaches since the 1980s. Recent experimental and numerical works were dedicated to characterize the microstructures of multiphase systems; in particular, alloys with eutectic composition are studied due to their practical importance. In well-controlled experimental conditions, the micro-scale pattern, formed during unidirectional solidification exhibits self-organized array of lamellar or rod structures on a quite large scale. In a 2D three-phased system, one can expect diverse phase configurations; for instance, ABC, ABAC or ABABC repeating units, where A, B, and C are three crystalline phases at equilibrium with the liquid. In this work, we present an in situ experimental study on the microstructure formed during directional solidification of an In-Bi-Sn ternary eutectic alloy. Quasi-2D samples at eutectic composition were directionally solidified using a horizontal Bridgman setup. The dynamics of microstructure formation were examined in real time using a computer controlled high resolution motor and a special optical microscopy system, which enables observation of the solidification front from top and bottom simultaneously. We first map the morphological stability diagram for quasi-2D samples and characterize the instabilities occurring beyond the limits of stability. Second, using recorded image sequences from both sides of the sample, we are able to determine the dynamics of eutectic spacing adjustment mechanisms. We report that beyond the upper limit of the stability, lamellae splitting takes place with phase invasion and exchange, and beyond the lower limit of the stability lamellae termination takes place. Finally we discuss how the system reveals the complex mechanisms to come back to the basic state.

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On the interplay between intrinsic and extrinsic instabilities of spatially localized patterns

Yasumasa Nishiura[1]*

Spatially localized dissipative structures are observed in various fields, such as neural signaling, chemical reactions, discharge patterns, granular materials, vegetated landscapes and binary convection. These patterns are much simpler than single living cells, however they seem to inherit several characteristic living state feature, such as self-replication, self-healing and robustness as a system. Adaptive switching of dynamics can also be observed when these patterns collide with each other, or when they encounter heterogeneities or environmental changes in the media. These behaviors stem from an interplay between the intrinsic instability of each localized pattern and the strength of external signals. To understand such an interplay, we explore the global geometric interrelation amongst all relevant solution branches of a corresponding system with approximate unfolding parameters. For instance, it has been uncovered that large deformations at strong collisions are mapped into the network of unstable patterns called scattors, and that an organizing center for 1D pulse generators is a double homoclinic orbit of butterfly type. We will illustrate the impact of this approach by presenting its application in relation to the decision making process of amoeboid locomotion and hierarchical structures of ordered patterns arising in reaction diffusion systems and binary fluids.

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Patterns of coherence and incoherence

Oleh Omel'chenko[1*]

Arrays of coupled limit-cycle oscillators are used to model a variety of pattern-forming systems in neuroscience, biochemistry, physics and engineering. One of the most striking discoveries made recently in this field, are so-called 'chimera states', or coherence-incoherence patterns emerging spontaneously in systems of identical non-locally coupled oscillators. Despite the nontrivial dynamical nature of such patterns, one can effectively study them using methods of nonequilibrium statistical physics. In this talk, we discuss a continuum limit integro-differential equation describing the evolution of the local order parameter representing chimera states. We overview typical bifurcation scenarios leading to the appearance of chimera states and provide their natural classification.

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Spatial decay and spectral properties of rotating waves in evolution equations

Denny Otten[1]*, Wolf-Jürgen Beyn[1]†

Rotating waves are special solutions of reaction-diffusion systems which rotate at constant velocity while maintaining their shape. Nonlinear stability results for such waves are usually based on spatial behavior of the wave profile and on spectral properties of the linearization. In this talk we present suitable conditions guaranteeing that the rotating wave decays exponentially in space. We also derive an upper bound for the decay rate and extend our results to complex-valued cases. The proof utilizes resolvent estimates for perturbed Ornstein-Uhlenbeck operators, abstract semigroup theory, and sharp heat-kernel estimates. A key step is to solve the identification problem via a dissipativity condition which is equivalent to bounding the first antieigenvalue of the diffusion matrix. For the linearized operator we determine the essential spectrum and a specific part of the point spectrum including their associated eigenfunctions. Some extensions to second-order evolution equations will be briefly discussed. Finally, we present numerical results for spinning solitons that appear in the cubic-quintic complex Ginzburg-Landau equation.

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Global bifurcations and discrete Lorenz attractors

Ivan Ovsyannikov[1*]

A presence of non-transversal homoclinic or heteroclinic orbits (tangencies) in a dynamical system is regarded as a universal criterion of existence of a complex dynamics. However, it does not immediately lead to the emergence of genuine strange attractors (i.e. those preserving their "strangeness" under small perturbations) such as the Lorenz attractors. In the talk the list of three-dimensional diffeomorphisms with quadratic homoclinic and heteroclinic tangencies is presented in which discrete Lorenz attractors are born in bifurcations. For some of them a stronger result was also proved: in any neighbourhood there exist residual sets in which systems possess a countable number of coexisting discrete Lorenz attractors. Note that the bifurcations under consideration can be of codimension three, two and even one. In order to get Lorenz attractors one needs to have the effective dimension of the problem to be not less than three. For 3D diffeomorphisms this means that there should be no global contraction/expansion and no global center manifolds. To fulfill the first condition the Jacobian at the saddle fixed point should be close to 1 in the homoclinic case, and in the heteroclinic case it is enough to have the so-called contracting-expanding configuration, when the Jacobian at one saddle is less than one and greater than one at another saddle. The following conditions prevent the appearance of center manifolds: 1. At least one of the saddle fixed point is a saddle-focus; 2. All the fixed points are saddles but one of the homoclinic/heteroclinic orbits is non-simple; 3. A saddle is resonant (two stable eigenvalues either coincide or have opposite signs).

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Ott-Antonsen attractiveness for parameter-dependent oscillatory networks

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The Ott-Antonsen (OA) ansatz [1] has been widely used to describe large networks of coupled phase oscillators. If the coupling is sinusoidal and if the phase dynamics does not depend on the specific oscillator, then the macroscopic behavior of the network can be fully described by a low-dimensional system. Does the OA manifold remain attractive, when introducing an intrinsic dependence between an oscillator's phase and its dynamics by additional, oscillator specific parameters? To answer this we extended the OA ansatz and proved that parameter-dependent oscillatory networks continue to converge to the OA manifold under certain conditions. Our proof confirms recent numerical findings that hint at this convergence. It also provides a thorough mathematical underpinning for networks of theta neurons, where the OA ansatz has just been applied.

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Propagating terraces in the dynamics of parabolic equations

Peter Polacik[1 *]

We will present a recent result on the approach of front-like solutions of one-dimensional parabolic equations to propagating terraces, or, stacked families of traveling fronts. We will then show some applications of the theorem in multidimensional problems.

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Modulational instability and zigzagging of dissipative solitons induced by delayed feedback

Dmitry Puzyrev[1]*, Andrei Vladimirov[2], Svetlana Gurevich[3], Serhiy Yanchuk[1]

We report a destabilization mechanism of localized solutions in spatially extended systems which is induced by delayed feedback. Considering a model of a wide-aperture laser with a saturable absorber and delayed optical feedback, we demonstrate the appearance of multiple coexistent laser cavity solitons. We show that at large delays apart from the drift and phase instabilities the soliton can exhibit a delay-induced modulational instability associated with the translational neutral mode. The combination of drift and modulational instabilities produces a zigzagging motion of the solitons, which are either periodic, with the period close to the delay time, or chaotic, with low-frequency fluctuations in the direction of the soliton motion. The same type of modulational instability is demonstrated for localized solutions of the cubic-quintic complex Ginzburg-Landau equation.

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Samples of pattern formation under advection

Jens Rademacher[1]*

Advection terms break symmetry and cause pattern formation to come with transport. We present some results on the influence of constant advection terms in one component of the system on the onset of pattern formation. In reaction diffusion systems, stripes in the direction of advection are in a certain sense preferred over the otherwise dominant hexagons. In a specific system class the onset in parameter space monotonically moves with advection. Numerically, increasing advection brings stability region of wavetrains in 2D closer to that in 1D. In a fluid model for plasma, we show that only moderate advection destabilizes, while the basic state is globally stable for large and small advection. Numerically, decreasing diffusion increases the complexity of secondary bifurcations. This is drawn from joint work with several collaborators over the past few years.

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Homogenization of Cahn-Hilliard-type equations via evolutionary Gamma-convergence

Matthias Liero[1*], Sina Reichelt[1†]

We discuss two approaches to evolutionary Γ-convergence of gradient systems in Hilbert spaces. The formulation of the gradient system is based on two functionals, namely the energy functional and the dissipation potential, which allows us to employ Γ-convergence methods. In the first approach we consider families of uniformly convex energy functionals such that the limit passage of the time-dependent problems can be based on the theory of evolutionary variational inequalities as developed by Daneri and Savaré 2010. The second approach uses the equivalent formulation of the gradient system via the energy-dissipation principle and follows the ideas of Sandier and Serfaty 2004. We apply both approaches to rigorously derive homogenization limits for Cahn–Hilliard-type equations. Using the method of weak and strong two-scale convergence via periodic unfolding, we show that the energy and dissipation functionals Γ-converge. In conclusion, we will give specific examples for the applicability of each of the two approaches.

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Dynamics of the Calvin cycle

Alan D. Rendall[1]*

The Calvin cycle is a central part of photosynthesis where carbon fixation takes place. There are various models for this process in the literature which consist of ordinary differential equations. They differ in the number of chemical species included and the assumptions made on the kinetics of the reactions involved. I will discuss the dynamical properties of solutions of some of these models. Issues addressed include whether concentrations may tend to zero at late times (which might be caused by too much inorganic phosphate in the cytosol) and the multiplicity and stability of steady states. I will also discuss how techniques which have proved useful in analysing this problem might be applied to other models in molecular biology.

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A permutation characterizing unbounded attractors of slowly nondissipative systems

Carlos Rocha[1*], Juliana Pimentel[2†]

We consider scalar reaction-diffusion equations generating global semiflows which exhibit blow-up in infinite time. The associated maximal attractor is unbounded as it contains all blow-up solutions. The introduction of objects interpreted as equilibria at infinity, allows for the description of these unbounded solutions as heteroclinic orbits. By extending the Sturm permutation characterization of heteroclinic orbits which holds in the dissipative case we obtain a description of the connecting orbit structure for the noncompact global attractors. We then characterize the permutations realizable by the slowly nondissipative problems considered here. Using this permutation characterization we also discuss orbit equivalence of the noncompact global attractors. This is based on a joint work with J. Pimentel.

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Dynamics of localized structures in dissipative nonlinear lattices

Vassilios Rothos[1*]

This talk reviews results about the existence of spatially localized waves in nonlinear chains of coupled oscillators, and provides new results for a model of a one-dimensional magnetic metamaterial formed by a discrete array of nonlinear resonators. Localized solutions include solitary waves of permanent form and traveling breathers which appear time periodic in a system of reference moving at constant velocity. For KG lattices of magnetic metamaterials, we obtain a general criterion for spectral stability of multi-site breathers for a small coupling constant. For the metamaterial lattices we focus on periodic traveling wave due to the presence of periodic force. We employ topological and variational methods to study the existence and the stability of periodic waves. These localized structures are also computed and discussed numerically.

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Ważewski type theorem for non-autonomous systems of equations

Sebastian Ruszkowski[1*]

I will present Ważewski type theorem for non-autonomous systems of equations with a disconnected set of egress points. During the talk I will study solutions of nonlinear dynamic systems on time scales of the form $y^{\Delta}(t) = f(t, y(t))$, where $f\colon \mathbb{T} \times \mathbb{R}^n \to \mathbb{R}^n$, and $\mathbb{T}$ is the time scale. For a given set $\Omega \subset \mathbb{T} \times \mathbb{R}^n$, I will formulate conditions for functions f which guarantee that at least one solution y of the above system stays in Ω. It is worth noting that the results are new also for non-autonomous systems of difference equations $\Delta y(n) = f(n, y(n))$ and impulsive differential equations. The talk is based on paper [1].

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Canard-like transitions from 1- to 2-pulses in the FitzHugh-Nagumo system

Björn Sandstede[1]*

The FitzHugh-Nagumo system is a paradigm for singularly perturbed PDEs that supports stable localized pulses with both monotone and oscillatory tails. These pulses cease to exist in certain parameter regions: we show rigorously that the mechanism behind this phenomenon is a continuous transition from localized 1-pulses to 2-pulses, where the second pulse in the wake of the first pulses appears through a canard-like explosion. This is joint work with Paul Carter.

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Growth and patterns

Arnd Scheel[1*], Ryan Goh[1†]

I will motivate and explain results that give universal scaling laws and quantitative predictions for patterns observed in systems posed on growing domains. Examples are the SwiftHohenberg equation, the CahnHilliard and the GinzburgLandau equations, and reaction-diffusion systems.

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Patterns in Fourier space

Jürgen Scheurle[1] *

We consider periodic as well as quasiperiodic functions which are invariant under the action of some symmetry group. Motivated by crystallography and other applications we discuss consequences concerning the structure of the representation of those functions in Fourier space. Also, equivariant vector fields are considered.

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Fourier dimension and its modification

Jörg Schmeling[1]*

This is joint work with Fredrik Ekstrm and Tomas Persson. We investigate how one can modify the Fourier dimension in order to fulfil the standard requirements of a dimension-lie quantity. We found a way to keep all the data obtained from the original definition but can prove that our modification behaves more regularly. In particular our definition really defines a dimension and measures of a given dimension are classified by their 0-sets.

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Spatio-temporal feedback control of partial differential equations

Isabelle Schneider[1*]

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 spatio-temporal control terms to a particular type of partial differential equations (scalar reaction-diffusion equations on the circle) with the purpose of stabilizing unstable equilibria and periodic orbits. The 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, especially well suited for the control of partial differential equations, does not exist in the literature so far. It incorporates the spatio-temporal patterns of the equilibria and periodic orbits into the control term.

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An implicit function theorem for singularly perturbed problems

Lutz Recke[1*], Klaus Schneider[2†]

Many analytical treatments of singularly perturbed problems fit into the following scheme: First one constructs, in a rather formal and ad hoc manner, a family (parametrized by the singular perturbation parameter) of so-called approximate solutions, i.e. of functions which solve the problem approximately. Usually those functions have a certain structure (internal and boundary layers, spikes etc.) which is interesting for applications, and one believes that for all sufficiently small singular perturbation parameters there exists an exact solution to the problem close to the approximate solution. And second, one proves that really for all sufficiently small perturbation parameters there exists an exact solution to the problem close to the approximate solution. In this talk we will present sufficient conditions in terms of the problem data and of the approximate solutions which guarantee existence and local uniqueness of an exact solution close to an approximate solution. Moreover, we derive an a priori estimate for the distance between the exact and the approximate solutions. We will work in a completely abstract setting, but we will mention applications of our abstract results to singularly perturbed semilinear elliptic and parabolic problems with (probably non-monotone) boundary layer solutions and spike solutions as well as to problems with multidimensional singular perturbation parameter. This is joint work with V. F. Butuzov, N. N. Nefedov and O. E. Omel'chenko.

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Tweezers for chimeras in small networks

Eckehard Schöll[1*], Iryna Omelchenko[1†], Oleh Omel'chenko[2‡], Anna Zakharova[1§], Matthias Wolfrum[2¶]

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

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"Big data and dynamics" – the key to model-driven personalized medicine?

Andreas Schuppert[1]*

Bridging the gap between the highly focused research strategies in drug R&D, with tight control of the experimental protocols, and the "real world" in clinics is a major challenge on the route to sustainable health care systems. Hence, "Big Data" analysis on real world data offers great promises to industry, clinics and society. However, the system to be analyzed, namely the patients, is not only extremely complex in terms of its entities, it is controlled by multi-scale mutual control mechanisms and exobiotic impact factors which are unexplored in detail. Moreover, biological systems can change their structure in response to stress, thus they exhibit complex dynamic features. To tackle this challenge requires systematic analysis of very large, heterogeneous and multi-variate data sets, which fortunately have become available today. It requires the development of new computational methods and workflows enabling one to extract the information on the mechanisms controlling the respective diseases and therapies. Moreover, they have to tackle the inherent "biological noise" in order to cope with the heterogeneity of clinical practice. We demonstrate on examples that integrated data analysis and dynamic hybrids allows the unsupervised identification of biological mechanisms from heterogeneous, MIMO-data sets and allows the utilization of the biological noise.

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Effects of grazing on patterned ecosystems

Eric Siero[1]*

Vegetation patterns in drylands are ubiquitous. They serve as an early warning signal for upcoming desertification. We model grazing in existing reaction-diffusion models through a nonlocal (global) reaction term, and study the effects on the desertification scenario: pattern formation, coarsening, critical transitions.

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Homotopy invariants in bifurcation theory for dynamical systems

Robert Skiba[1*]

In the talk we will shortly discuss two approaches to bifurcation theory. The first one is based on the index bundle from topological K-theory. On illustration, we will present an application to bifurcation of homoclinic solutions of discrete non-autonomous dynamical systems bifurcating from the trivial branch of stationary solutions.

The second approach is based on the cohomological index of Fuller type which extends the notion of the classical fixed point index for single-valued maps. In particular, we will present how it can be applied to study bifurcation of periodic orbits of dynamical systems generated by differential equations without uniqueness of solutions.

New open problems will be also discussed.

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Surprising applications of the zero number: phase transitions, DNA replication, and twist maps

Sinisa Slijepcevic[1*]

Bernold Fiedler developed the zero-number in a number of seminal papers as the main tool in describing dynamics of scalar semi-linear parabolic differential equations on bounded domains. We show that this tool can be adapted to study of such equations on unbounded domains, their discrete-space analogues (the Frenkel-Kontorova models), as well as these equations with a random force. The idea is to consider the expectation of the zero number with respect to a measure on the phase space, and its evolution. We show that this tool can be used to describe invariant probability measures of the considered equations, which leads to rigorous results on phase transitions. This could be applied to various physical phenomena modeled with these equations, including Charge Density Waves, Josephson Junction Arrays, and DNA replication. Finally, we outline a line of attack to solving one of the key open conjectures of Hamiltonian dynamics: positive metric entropy of twist maps, by using the same tool.

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Interface layer of a two-component Bose-Einstein condensate

Christos Sourdis[1*], Amandine Aftalion[2†]

We study the behaviour of the wave functions of a two-component Bose-Einstein condensate near the interface, in the case of segregation, in the Thomas-Fermi limit. In the direction orthogonal to the interface, possibly after a rescaling, this should be governed by an energy minimizing solution of the problem:

$$\begin{cases} -av_1'' + v_1^3 - v_1 + \Lambda v_2^2 v_1 = 0, \\ \\ -v_2'' + v_2^3 - v_2 + \Lambda v_1^2 v_2 = 0, \end{cases} \tag{1}$$

$$(v_1, v_2) \to (0, 1) \text{ as } z \to -\infty, \quad (v_1, v_2) \to (1, 0) \text{ as } z \to +\infty, \tag{2}$$

where $\Lambda > 1$ represents the intercomponent repulsive strength and $a > 0$ is a fixed parameter. Using singular perturbation arguments, we construct a solution to the above problem with monotone components, while providing a very detailed componentwise description of the limiting behaviour $v_1 v_2 \to 0$ in the case of the strong segragation regime, that is $\Lambda \to \infty$. Our analysis is based on the nondegeneracy of the inner (or blow-up) profile which is a special entire solution of

$$aV_1'' = V_1 V_2^2, \quad V_2'' = V_2 V_1^2, \tag{3}$$

as well as on the nondeneracy of the outer profiles which satisfy the Allen-Cahn type of problems that give the leading order behaviour of solutions to (1)-(2) as $\Lambda \to \infty$. Furtheremore, we prove that the constructed solution is nondegenerate in the natural sense: the linearized operator of (1)-(2) about the solution, in $L^2(\mathbb{R}) \times L^2(\mathbb{R})$, has zero as a simple eigenvalue at the bottom of its spectrum and the rest of the spectrum is contained in an interval of the form $[c, \infty)$ with $c > 0$ independent of $\Lambda \gg 1$. Moreover, we prove that there is a unique solution (modulo translations) to (1)-(2) with positive components such that at least one is monotone. In turn, this implies that the constructed solution is a minimizer of the associated energy to (1)-(2). We can then exploit our detailed estimates from the singular perturbation analysis and provide an asymptotic expression for its energy, which is in agreement with that predicted in the physics literature. Finally, our existence and uniqueness results for (1)-(2) can be combined to give a new proof of the uniqueness (modulo translations and scalings) of the blow-up profile in (3). This is a joint work with A. Aftalion.

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Analysis of macroscopic behaviour in complex particle systems

Jens Starke[1]*

Complex particle systems are, due to their many degrees of freedom difficult to analyze with standard methods, but often do not contain enough particles to perform a limit to a continuum description. It will be shown how the collective behaviour of these type of systems can be analyzed by so-called equation-free methods. These allow one to perform numerical investigations of the collective behaviour for which no explicit equations are available. This includes continuation and bifurcation analysis of the collective behaviour depending on system parameters. The methods are motivated and demonstrated with models and experiments from car and pedestrian traffic.

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Homogenization of weakly connected structures in 2D: Combining stripes, traps, and sieves

Angela Stevens[1*], Benedikt Jost[1†]

In this talk the heat equation with homogeneous Neumann boundary conditions on a two-dimensional weakly connected structure made of stripes, traps, and sieves is homogenized. In the limit two one-dimensional equations arise, which are coupled via a memory term in the bulk and a possible concentration gap at the boundary.

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On the speed of social learning

Matan Harel[1*], Elchanan Mossel[2†], Philipp Strack[3‡], Omer Tamuz[4§]

We consider two Bayesian agents who learn from exogenously provided private signals, as well as the actions of the other. Our main finding is that increased interaction between the agents can lower the speed of learning: when both agents observe each other, learning is significantly slower than it is when one only observes the other. This slowdown is driven by a process in which a consensus on the wrong action causes the agents to discount new contrary evidence.

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Blow-up and complex time

Hannes Stuke[1]*

In my talk I want to study blow-up of partial differential equations from the perspective of complex time. The main example will be the semilinear heat equation

$$u_t = u_{xx} + u^2 \quad (1)$$

on a bounded or unbounded interval. For real u, x and real time t, this equation has already been well-studied in the literature. It has been shown, that solutions can blow-up in finite time. Bounded solutions are analytic in time and admit an analytic continuation into the complex plane. Following an idea of Masuda [1] and Guo [2] I construct the extensions of solutions to (1) to complex time.
In a first step I prove boundedness of solutions along proper complex time paths circumventing the blow-up point at time T. Then I study their properties, e.g. can they be continued back to the real time axis, do they agree as analytic continuation along different paths, what is their limit behaviour for complex times with large real part?

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Blow-up analysis of regularizations of nonsmooth systems

Peter Szmolyan[1*]

Nonsmooth vector fields X_0 arise frequently in applications. Many results and methods from the theory of smooth dynamical systems do not directly carry over to these more singular situations. One possible remedy is to consider nonsmooth problems as $\varepsilon \to 0$ limits of smooth vector fields X_ε. The regularized problems X_ε are typically obtained by either including regularizing effects in the underlying model or by some suitable mathematical regularization procedure. A prototypical class of such problems are piecewise smooth vector fields which are smooth except on a co-dimension one hypersurface S_0. The main issues are how to properly define the dynamics on S_0 and to classify dynamical effects associated with the discontinuity. A well known phenomenon in these systems is "sliding", that is motion along S_0 if the vector field X_0 points towards S_0 on both sides of that hypersurface. More recently, interesting links between regularizations of piecewise smooth vector fields and fast–slow systems have emerged. It has been established by several authors that in certain situations sliding is closely related to the existence of a slow manifold S_ε of X_ε close to S_0. It became apparent that some well known phenomena in fast–slow systems, e.g. folds and canards associated with loss of normal hyperbolicity, have certain close analogs in piecewise smooth problems. In the talk I will survey some of these results and show that the blow-up method – which has proven to be a powerful tool in the context of fast-slow systems – can also be used effectively in the analysis of regularizations of nonsmooth problems.

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Rattling in spatially discrete reaction-diffusion equations with hysteresis

Sergey Tikhomirov[1*], Pavel Gurevich[2†]

Hysteresis naturally appears as a mechanism of self-organization and is often used in control theory. Important features of hysteresis are discontinuity and memory. We consider reaction-diffusion equations with hysteresis. Such equations describe processes in which diffusive and non-diffusive instances interacts according to a hysteresis law. Due to the discontinuity of hysteresis, these equations are not always well-posed. We consider a spatial discretization of the problem and present a new mechanism of pattern formation, which we call rattling. The profile of the solution forms two hills propagating with non-constant velocity. The profile of hysteresis forms a highly oscillating quasiperiodic pattern, which explains mechanism of ill-posedness of the original problem and suggests a possible regularization. Rattling is very robust and persists in arbitrary dimension and in systems acting on different time scales.

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Synchronization patterns in Stuart-Landau networks: a reduced system approach

Liudmila Tumash[1*], Elena Panteley[2], Anna Zakharova[1†], Eckehard Schöll[1‡]

We study networks with coupled phase and amplitude dynamics. In particular, we investigate a ring network of Stuart-Landau oscillators with two types of coupling: S^1 symmetry-breaking and S^1 symmetry-conserving. Symmetry-breaking coupling enables the appearance of nontrivial spatio-temporal patterns, such as amplitude chimeras, which exhibit domains of coherent (synchronized) and incoherent (desynchronized) dynamics with respect to the amplitude, but the phases are always correlated. These states are long-living transients. We show that amplitude chimeras can arise even in small networks of only 12 elements. For symmetry-preserving coupling we find cluster synchronization. We show that the dimension of the dynamical system can be substantially reduced, which facilitates the simulations, by projecting the system onto the subspace corresponding to the unstable eigenvalues of the linear part of the network dynamics. First, we decompose the dynamic variables into a mean-field part corresponding to motion on the synchronization manifold $\mathbf{z_s}$ and a synchronization error $\mathbf{e}$. The linear part of the network dynamics, after transforming to Jordan normal form, can be split into a low-dimensional synchronization manifold which is associated with the unstable directions of the fixed point at the origin from which the synchronized limit cycle oscillations have bifurcated, (and hence with those eigenvalues which have positive real parts) and a transverse subspace of the synchronization error, (which is associated with negative real parts) leading to an asymptotically damped synchronization error. The reduced system consists of the subspace of unstable eigenvalues. We present simulations for a network of $N = 12$ nodes which can be reduced to a 3-dimensional system with this method. We show that the asymptotic collective behavior of the network is determined by the subspace of unstable eigenvalues, while the dynamics in the remaining subspace is asymptotically damped out. In this way we reduce the network of Stuart-Landau oscillators to a lower-dimensional system. To validate this method, we apply a back transformation to the reduced system, and compare the solutions with the full dynamics.

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Quantum acceleration

Dmitry Turaev[1]*

We discuss how the adiabatic evolution of a quantum-mechanical system due to the slow and periodic change of system parameters can lead to an exponential growth of the energy. This contradicts, at first glance, to the quantum adiabatic theorem, however we show that periodic creation and destruction of an additional quantum integral leads to the adiabatic level crossing necessary for the acceleration. As an example, we consider the Schroedinger equation in a periodically divided and reconnected domain.

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A biophysical model for cytotoxic edema

Koen Dijkstra[1*], Jeanette Hofmeijer[2†], Stephan van Gils[1‡], Michel van Putten[3§]

We present a dynamical biophysical model to explain cytotoxic edema in conditions of low energy supply, as observed in cerebral ischemia. Our model contains Hodgkin-Huxley type ion currents, a recently discovered voltage-gated chloride flux through the ion exchanger SLC26A11, KCl cotransporters and ATP-dependent pumps. The model predicts changes in ion gradients and cell swelling under various conditions. We theoretically substantiate experimental observations of chloride influx generating cytotoxic edema, while sodium entry alone does not. We further show that a tipping point exists, where cell volume rapidly increases as a function of reduced activity of the Na+/K+ pump, and a Gibbs-Donnan-like equilibrium state is reached, that precludes return to physiological conditions even when pump strength returns to baseline. However, when voltage-gated sodium channels are temporarily blocked, cell swelling reverses with normalisation of the membrane potential, yielding a potential therapeutic strategy to reduce cytotoxic edema after cerebral ischemia.

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Monomolecular reaction networks: flux-influenced sets and balloons

Nicola Vassena[1*]

In the case of monomolecular reaction networks, we study the network response to perturbations of a reaction rate j^*. Following Fiedler and Mochizuki, we describe which other reaction rates j' respond with nonzero reaction flux, at steady state. Nonzero responses of j' to j^* are called flux-influence of j^* on j'. We give a structural description of the flux-influenced sets. We show a crucial property of them: if j^* flux-influences j', then the set flux-influenced by j' is contained in the one flux-influenced by j^*. Finally we derive some consequences important for chemical applications. This is a joint work in progress with Hiroshi Matano.

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Recent results for Turing bifurcation with unilateral obstacles

Martin Väth[1]*

It is well-known that in a reaction-diffusion system of two chemicals a diffusion-driven instability can arise. In particular, a small perturbution of a stationary equilibrium can lead to solutions tending to a spatially nonhomogenous stationary solution, a so-called Turing pattern. This phenomenon usually requires rather different diffusion speeds of the two chemicals. The speaker has shown that unilateral obstacles modeled by inequalities can lead to instability and even to the bifurcation of spatially nonhomogeneous stationary solutions from the equlibrium under weaker conditions. The talk gives a survey on recent results about similar bifurcation phenomena for the case that less restrictive obstacles than variational inequalities are considered. Some of these results were obtained jointly with Jan Eisner, Milan Kučera, Josef Navrátil, and Lutz Recke.

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Wasserstein distances in the analysis of time series and dynamical systems

Sjoerd Verduyn Lunel[1*]

A new approach based on Wasserstein distances, which are numerical costs of an optimal transportation problem, allows one to analyze nonlinear phenomena in a robust manner. The long-term behavior of a dynamical system represented by time series is reconstructed from time series, resulting in a probability distribution over phase space. Each pair of probability distributions is then assigned a numerical distance that quantifies the differences in their dynamical properties. From the totality of all these distances a low-dimensional representation in a Euclidean space is derived. This representation shows the functional relationships between the dynamical systems under study. It allows to assess synchronization properties and also offers a new method of numerical bifurcation analysis. Several examples are given to illustrate our results. This work is based on joint work with Michael Muskulus, see [1].

References

[1] J. Appl. Physiology 109 (2010), 1582-1591, and Phys. D 240 (2011), 45-58

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Pattern analysis in a benthic bacteria-nutrient system

Daniel Wetzel[1]*

We study steady states in a reaction-diffusion system for a benthic bacteria-nutrient model in a marine sediment over 1D and 2D domains by using Landau reductions and numerical path following methods. We point out how the system reacts to changes of the strength of food supply and ingestion. We find that the system has a stable homogeneous steady state for relatively large rates of food supply and ingestion, while this state becomes unstable if one of these rates decreases and Turing patterns such as hexagons and stripes start to exist. One of the main results of the present work is a global bifurcation diagram for solutions over a bounded 2D domain. This bifurcation diagram includes branches of stripes, hexagons, and mixed modes. Furthermore, we find a number of snaking branches of stationary states, which are spatial connections between homogeneous states and hexagons, homogeneous states and stripes as well as stripes and hexagons in parameter ranges, where both corresponding states are stable. The system under consideration originally contains some spatially varying coefficients and with these exhibits layerings of patterns. The existence of spatial connections between different steady states in bistable ranges shows that spatially varying patterns are not necessarily due to spatially varying coefficients. The present work gives another example, where these effects arise and shows how the analytical and numerical observations can be used to detect signs that a marine bacteria population is in danger to die out or on its way to recovery, respectively. We find a type of hexagon patch on a homogeneous background, which seems to be new discovery. We show the first numerically calculated solution-branch, which connects two different types of hexagons in parameter space. We check numerically for bounded domains whether the stability changes for hexagons and stripes, which are extended homogeneously into the third dimension. We find that stripes and one type of hexagons have the same stable range over bounded 2D and 3D domains. This does not hold for the other type of hexagons. Their stable range is shorter for the bounded 3D domain, which we used here. We find a snaking branch, which bifurcates when the hexagonal prisms loose their stability. Solutions on this branch connects spatially between hexagonal prisms and a genuine 3D pattern (balls).

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Exponential estimates of symplectic slow manifolds

Kristian Kristiansen[1]*, Claudia Wulff[2]†

In this talk we present a result the existence of an almost invariant symplectic slow manifold for analytic Hamiltonian slow-fast systems with finitely many slow degrees of freedom for which the error field is exponentially small. We allow for infinitely many fast degrees of freedom. The method we use is motivated by a paper of MacKay from 2004. The method does not notice resonances, and therefore we do not pose any restrictions on the motion normal to the slow manifold other than it being fast and analytic. We also present a stability result and obtain a generalization of a result of Gelfreich and Lerman on an invariant slow manifold to (finitely) many fast degrees of freedom.

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Self-organized resistance to noise of neuronal networks with plasticity

Serhiy Yanchuk[1*], Lücken Leonhard[2], Oleksandr Popovych[3], Peter Tass[3]

One of the fundamental adaptation mechanisms of the nervous system is spike time-dependent plasticity (STDP). Depending on the spiking behavior of neural cells, plasticity regulates the coupling between individual cells and controls the network connectivity. Jointly with the Institute of Neuroscience and Medicine - Neuromodulation (Research Center Jlich) we study ensembles of synchronized spiking neurons with adaptive coupling, that are perturbed by an independent random input. For such networks, the phenomenon of self-organized resistance to noise has been reported that is characterized by an increase of the overall coupling and preservation of synchrony in the neural populations with STDP in response to the external noise growth. We studied further theoretically the influence of noise on a microscopic level by considering only two coupled neurons, where the underlying mechanism can be studied in more detail.

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Dynamics of the visual cortex

Lai-Sang Young[1]*

I will report on recent work in which my co-authors and I constructed a data-driven computational model of the monkey visual cortex as a large and complex dynamical system. I will discuss the model and its validation by many sets of experimental data, and I will explain how realistic visual functions emerge as a result of the interplay between network structure, which models neuroanatomy, and population dynamics, i.e. the dynamical interaction between local Excitatory and Inhibitory populations.

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Noise-induced chimera states in a neural network

Anna Zakharova[1*], Nadezhda Semenova[2], Vadim Anishchenko[2], Eckehard Schöll[1†]

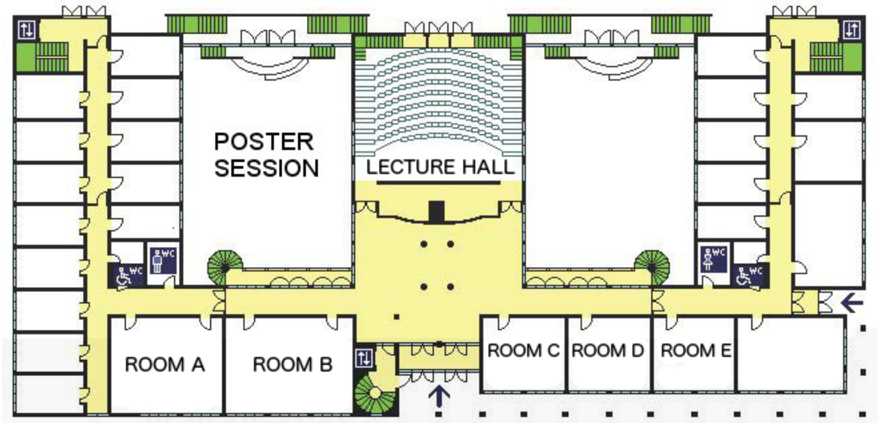
We study an effect which combines coherence resonance and chimeras states in a network of nonlocally coupled excitable elements. We demonstrate that chimera behavior can be observed in a network composed of solely excitable units and not only in oscillatory systems and show that the presence of noise is a crucial condition for this case. Moreover, we uncover the constructive role of noise for chimera states and detect a novel type of coherence resonance, which we call *coherence-resonance chimeras* [1]. In these spatio-temporal patterns coherence resonance is associated with spatially coherent and incoherent behavior, rather than purely temporal coherence or regularity measured by the correlation time. Since we consider a paradigmatic model for neural excitability in a noisy environment, we expect wide-range applications of our results to neuronal networks in general. Moreover, the noise-based control mechanism we propose here reveals an alternative direction for chimera control complementary to recent deterministic control schemes.

References

[1] N. Semenova, A. Zakharova, V. S. Anishchenko, and E. Schöll (2016), arXiv:1512.07036v2

Rooms

All the talks will take place in the Informatics building[1] in Takustraße 9. Keynote lectures will take place in the Lecture Hall and parallel sessions will be split between the Lecture Hall and Rooms A and B. Rooms D and E are available for discussions. Room C hosts the conference information desk.



Eating and drinking

Mensas

The Free University has several mensas with excellent price-value ratios. In particular[2] FU campus mensa II is reachable in about 5 minutes from the conference venue.

Restaurants[3]

1. EisZeit, ice cream and coffee.
2. La Favorita, Italian food.
3. Das Cafe in der Gartenakademie, atmosperic experience, highly recommended, easy to reach in 5 min.
4. Luise, German and international food, beer garden.
5. Alter Krug, German food, beer garden, lunch for 8,90.

[1] See “Conference Venue” on the campus plan p. 113.
[2] See “Mensa FU II” on the campus plan p. 113.
[3] See the numbered items on the campus plan p. 113.

6. Restaurant Englers, German and international food, business lunch for 9,90.
7. Ristorante Piaggio, Italian food, lunch.
8. Fabecks, German food, 9 different varieties of beer.
9. Ristorante Galileo, Italian food.
10. Ristorante Villa Rosa, Italian food.
11. eßkultur, in the ethnological museum Dahlem, international and Asian food, lunch from 11:30 to 14:00.
12. Asia Snack Dahlem.
13. Asia light, Asian food and sushi.
14. Two snack bars (at U-Bahn station Dahlem-Dorf), Döner Kebap, Bratwurst, Pommes Frites and alike.
15. Cafe Kornfeld, coffee, cakes, snacks and daily soup.
16. Cafe Cross, coffee, cakes, sandwiches and snacks.
17. Chirag, Indian food, business lunch.
18. Pesetas, Spanish food, tapas and cocktails.
19. Ko Phai, Thai food.

Internet connection

The eduroam network is available in the whole of the Free University. Moreover, the participants will be provided with a key giving them access to the WiFi network “conference” that can be used everywhere on the campus (please take into account that this is a public connection).

Conference Dinner

Date & Time:
Wednesday, 27/07
19:00 till 22:00

Dinner Speech:
André Vanderbauwhede

Location:
Harnack-Haus[4]. The Conference Venue of the Max Planck Society, Ihnestraße 16-20, 14195 Berlin, Germany.
The Harnack House is located on the campus of the Free University. The restaurant with its historic ambience is the dining room of the house. The menu will be influenced by the internationality of our conference guests.

Excursion A: Lake Wannsee - Guided walking tour

Date & Time:
Wednesday, 27/07
14:00 till 18:00

Location:
Am Großen Wannsee.
We offer a guided tour of Max-Liebermann-Villa on Lake Wannsee, and the House of the Wannsee Conference.
The excursion includes bus transfer to Lake Wannsee, guided tour (in English), coffee and cake and transfer back to the conference venue.
The bus departs from the main entrance[5] of the Seminaris hotel in the Takustraße 39 and will return there after the tour.

[4] See "Conference Dinner" on the campus plan p. 113.
[5] See "Excursions meeting point" on the campus plan p. 113.

Excursion B: Lake Wannsee - Boat trip

Date & Time:
Wednesday, 27/07
14:00 till 18:00

Location:
Landing stage: Wannsee Railway Station ("Anlegestelle Wannsee")
The boat trip will take you from Wannsee along the so called "Seven Lakes Tour" to Potsdam and back again. You will see many palaces and parks along a route between Berlin and Potsdam, that form part of a UNESCO World Heritage Site.
The excursion includes bus transfer to Lake Wannsee, guided tour (in English), coffee and cake and transfer back to the conference venue.
The bus departs from the main entrance[6] of the Seminaris hotel in the Takustraße 39 and will return there after the tour.

Emergency contact

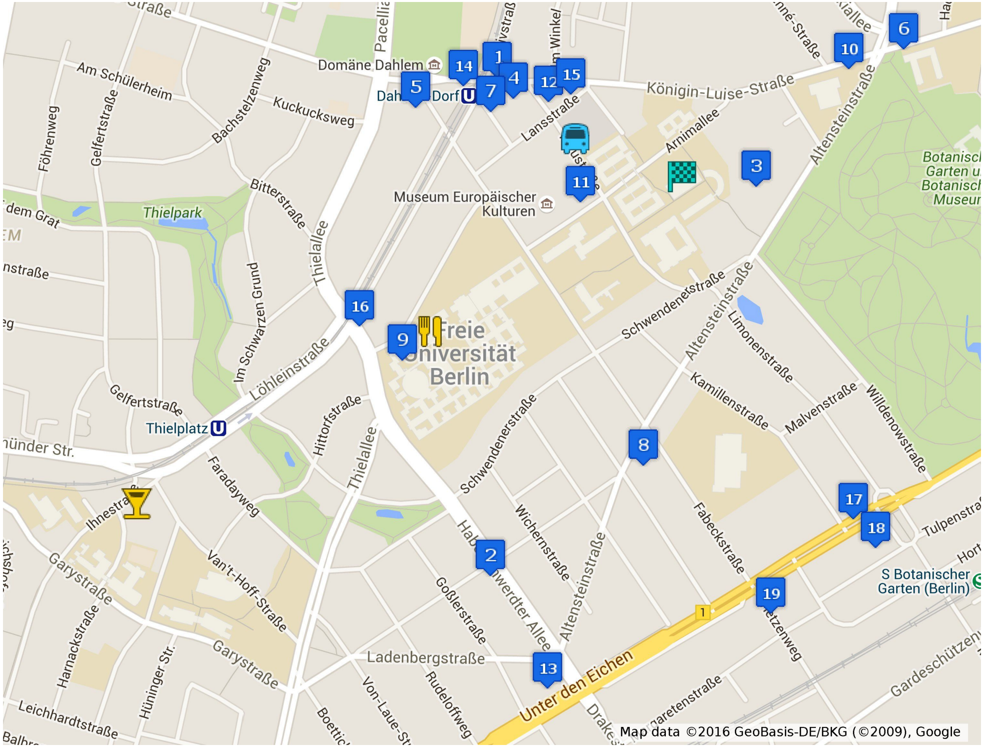
- Free University emergency number: +49 30 838 55555
- European emergency services: 112
- Police: 110

[6] See "Excursions meeting point" on the campus plan p. 113.

Campus Plan

Nearby restaurants

- Conference Venue
- Mensa FU II
- Excursions meeting point
- Conference Dinner
- 1 EisZeit
- 2 La Favorita
- 3 Café in der Gartenakademie
- 4 Luise Dahlem
- 5 Alter Krug
- 6 Restaurant Englers
- 7 Restaurant Piaggio
- 8 Fabecks Restaurant
- 9 Ristorante Galileo
- 10 Restaurant Villa Rosa
- 11 eßkultur
- 12 Asia Snack
- 13 Asia light
- 14 Snack bars
- 15 Kornfeld Dahlem Cafe
- 16 Cafe Croos
- 17 Indian Restaurant Chirag
- 18 Pesetas
- 19 Restaurant Ko Phai



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