Dynamics Days Europe

Exeter, UK
6-10 September 2015

Book of Abstracts

Contents

About this booklet:

This is the book of abstracts for the XXXV Dynamics Days Europe 2015, held at the University of Exeter, UK from 6th-10th September 2015. For past and future Dynamics Days Europe, see:

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Booklet produced 21st August 2015

Schedule

Sunday 6th Sept

Public lecture: 17.00-18.00

- PL00: (Public lecture) 17.00–18.00 (Newman Blue LT (A))
- Michael Field **Illuminating Chaos - Art (and Science) on Average** (P 22)

Monday 7th Sept

Plenary 1: 8.45-9.35

- PL01 (Plenary 1): 08.45–09.35 (Newman Blue LT (A))
- Sandra Chapman **Large-scale astrophysical and laboratory plasmas as testbeds for fundamental multiscale non-linear processes** (P 23)

Session 1: 10.00-12.00

MS01 (MS Controlling, synchronizing and modelling complex systems): 10.00–12.00 (PCC 1.4-1.6)

- Ezequiel Bianco-Martinez **Symbolic computations of non-linear observability** (P 41), 10.00–10.25
- Irene Sendiña-Nadal **Interlayer synchronisation and the problem of targeting in multiplex networks** (P 106), 10.30–10.55
- Luis Aguirre **Controllability and synchronizability: are they related?** (P 31), 11.00–11.17
- Erivelton Nepomuceno **Reduction of required vaccination level by means an integrated control with isolation** (P 91), 11.20–11.37
- Sylvain Mangiarotti **Chaotic models for the plague in Bombay by the end of the 19th century** (P 88), 11.40–11.57

MS02 (MS Laser and complex dynamics): 10.00–12.00 (PCC 2.1-2.3)

- Junji Ohtsubo **Dynamics and synchrony in coupled semiconductor laser networks** (P 92), 10.00–10.25
- Antonio Hurtado **Spiking Patterns in Vertical Cavity Surface Emitting Lasers for Neuromorphic Photonic Systems** (P 70), 10.30–10.55
- Atsushi Uchida **Recent advances in ultra-fast random number generation with chaotic lasers** (P 121), 11.00–11.17
- Miguel Cornelles Soriano **Consistency and chaos synchronization in delay-coupled semiconductor lasers** (P 48), 11.20–11.37
- Takahisa Harayama **Nonlinear dynamics and wave chaos in two-dimensional microcavity** (P 67), 11.40–11.57

MS03 (MS Pattern formation): 10.00–12.00 (PCC 2.4-2.6)

- Jonathan Dawes **Pattern formation in a model for dryland vegetation** (P 52), 10.00–10.25
- Cedric Beaume **Spatial localization in three-dimensional doubly diffusive convection** (P 39), 10.30–10.55
- Nicolas Verschueren van Rees **Localised Solutions in a Non-Conservative Cell Polarization Model** (P 125), 11.00–11.17
- Steffen Härting **Stable patterns with jump discontinuity in systems with Turing instability and hysteresis** (P 66), 11.20–11.37
- Delora Gaskins **Experimental Pattern to Pattern transitions in the Chlorine Dioxide-Iodine- Malonic Acid reaction with Halide Addition** (P 62), 11.40–11.57

MS04 (MS Astrophysical and laboratory plasmas as testbeds for fundamental multiscale nonlinear processes): 10.00–12.00 (PCC 1.1-1.3)

- Anthony Yeates **Impact of Magnetic Topology on Plasma Dynamics** (P 131), 10.00–10.25
- Angela Busse **Single- and multi-particle statistics of magnetohydrodynamic turbulence** (P 47), 10.30–10.55
- Robert Tautz **Cosmic-Ray Diffusion in Magnetized Turbulence** (P 117), 11.00–11.17
- Heli Hietala **Ion heating in magnetotail reconnection jets** (P 69), 11.20–11.37
- Mykola Gordovskyy **Magnetic reconnection and particle acceleration in twisted coronal loops** (P 65), 11.40–11.57

Lunch/Poster session: 12.00-13.30

P01 (Posters 01): 12.00–13.30 (PCC Foyer)

- Milan Krbalek **On a link between novel ensembles of random matrices and systems of self-driven particles** (P 243), 12.00–13.30
- Pietro Tierno **Depinning and collective dynamics of magnetically driven colloidal monolayers** (P 269)
- Peter Ashwin **Restricted Conley Index** (P 219)
- Magnus Dam **Bifurcation Analysis of Isolated Structures in a Nonuniformly Magnetized Plasma** (P 225)
- Gerrit Ansmann **A highly specific test for periodicity** (P 218)

- Angel Daniel Garaboa-Paz **Atmospheric Rivers and Lagrangian Coherent Structures.** (P 234)
- Fumiyoshi Kuwashima **High efficent THz-TDS system using laser chaos and super focusing with metal V grooved wave guide** (P 244)
- Michiko Shimokawa **Deformation and breakup of a droplet** (P 263)
- Vilmos Gáspár **Experimental Study of the Dynamics of Pattern Formation in the Ferrocyanide - Iodate - Sulphite Reaction in a Gel Reactor** (P 233)
- Sebastian Stein **Dynamics and Synchronisation of Viscoelastically Coupled Van der Pol Oscillators** (P 266)
- Takahito Mitsui **Abrupt millennial-scale paleoclimate changes: a statistical modelling study based on forced stochast** (P 249)
- Yusuke Uchiyama **Fractional generalized Cauchy process** (P 271)
- Toshiya Takami **Multiscale descriptions for nonlinear dynamics** (P 268)
- Andrea Fortini **Superadiabatic Forces in Brownian Many-Body Dynamics** (P 232)
- Valerio Lucarini **Equivalence of Non-Equilibrium Ensembles and Representation of Friction in Turbulent Flows: The Lorenz 96 Model** (P 247)
- Jose A. Reinoso **Analysis of spike correlations in neuronal models via symbolic ordinal patterns** (P 256)
- Frank Kwasniok **Analysis and modelling of rapid glacial climate transitions using simple dynamical systems** (P 245)
- Xingrong Fan **A Knowledge-and-Data-Driven Modeling Approach for Simulating Plant Growth: A Case Study on Tomato Growth** (P 231)
- Satoshi Sunada **Experimental observation of common-noise-induced phase synchronization in semiconductor lasers** (P 267)
- Stefan Ruschel **Delay-coupled oscillators on random networks.** (P 259)
- Peter Ashwin **Parameter shifts, pullback attractors and tipping points** (P 220)
- Ines P. Mariño **A nonlinear population Monte Carlo algorithm for parameter estimation in intercellular networks** (P 252)
- Jannes Quer **Estimating exit rates in rare event dynamical systems via extrapolation** (P 253)
- Juliano A. de Oliveira **Relaxation to asymptotic steady state in one-dimensional logistic-like mappings** (P 227)

- James Rankin **Auditory bistable perception in a neural competition model with periodic inputs** (P 255)
- Carlos Quintero **Analysis of the effects of periodic forcing in the spike rate and spike correlations in semiconductor lasers with optical feedback** (P 254)

Penary 2: 13.30-14.20

- PL02 (Plenary 2): 13.30–14.20 (Newman Blue LT (A))
- Barbara Niethammer **Dynamic scaling in kinetic models for coarsening and coagulation** (P 28)

Session 2: 14.30-16.00

CTAM (CT Active matter): 14.30–16.00 (PCC 1.1-1.3)

- Tobias Sprodowski **Collaboration of autonomous vehicles using the MPC-algorithm with a shortened solution space** (P 198), 14.30–14.45
- Alejandro Martínez **Superdiffusive Transport and Energy Localization in Disordered Granular Crystals** (P 174), 14.48–15.03
- Burhan Bezekci **Analytical and Numerical Approaches to Initiation of Excitation Waves** (P 143), 15.06–15.21
- Lachlan Smith **Mixing of Discontinuously Deforming Media** (P 197), 15.24–15.39

CTAP (CT Astro and plasma physics): 14.30–16.00 (PCC 1.4-1.6)

- Carl Dettmann **How sticky is the chaos/order boundary?** (P 150), 14.30–14.45
- Yue-Kin Tsang **Particle diffusion in magnetohydrodynamic turbulence: effects of a guiding magnetic field** (P 206), 14.48–15.03
- Giovanni Rastelli **Warped product of Hamiltonians** (P 189), 15.06–15.21
- Sarah Jabbari **Formation of intense bipolar regions in spherical dynamo simulations with stratification** (P 160), 15.24–15.39

CTBI (CT Biophysics): 14.30–16.00 (PCC 2.1-2.3)

- Ilya Potapov **Bayes forest: a framework for realistic modeling of plant shapes** (P 186), 14.30–14.45
- Christophe Letellier **How the growth rate of host cells affects cancer risk in a deterministic way** (P 172), 14.48–15.03
- Michael Stich **Oscillations and symmetry breaking in simple models for homochirality** (P 202), 15.06–15.21

- Konstantin Novikov **Different scale method for early endosome dynamics analysis** (P 179), 15.24–15.39
- Shambhavi Srivastava **The stochastic and the deterministic nature of recurrence in the DNA and throughout its evolutionary history** (P 200), 15.42–15.57

CTF1 (CT Fluids I): 14.30–16.00 (PCC 2.4-2.6)

- Vicente Pérez-Muñuzuri **Clustering of inertial particles and FTLE in compressible chaotic flows** (P 183), 14.30–14.45
- Hiroyuki Kitahata **Spontaneous motion of an elliptic particles induced by surface tension gradient** (P 163), 14.48–15.03
- Ben Devenish **A model for temperature fluctuations in a buoyant plume** (P 151), 15.06–15.21
- Victor Krylov **Aquatic propulsion by propagating flexural waves and the role of nonlinearity** (P 168), 15.24–15.39
- Sergey Sergeyev **Harnessing vector rogue waves** (P 194), 15.42–15.57

Session 3: 16.30-18.30

MS05 (MS Delay-equations for optoelectronic systems): 16.30–18.30 (PCC 1.1-1.3)

- Laurent Larger **Patchy Space with Diffusion** (P 81), 16.30–16.55
- Gaetan Friart **New trends for lasers subject to a delayed optical feedback** (P 61), 17.00–17.25
- Ingo Fischer **State-dependent delay dynamics in a semiconductor laser system** (P 60), 17.30–17.55
- Serhiy Yanchuk **Dynamical jittering and exponentially large number of periodic spiking solutions in oscillators with pulsatile delayed feedback** (P 130), 18.00–18.25

MS06 (MS Nonlinear dynamics on lattices): 16.30–18.30 (PCC 1.4-1.6)

- Guillaume James **Solitary waves in the Burridge-Knopoff model** (P 74), 16.30–16.55
- Michael Herrmann **Asymptotic formulas for the high-energy limit of FPU-type chains** (P 68), 17.00–17.25
- Hadi Susanto **Snaking in the discrete Swift-Hohenberg equation** (P 116), 17.30–17.55

MS07 (MS Structural model error in applied dynamics): 16.30–18.30 (PCC 2.4-2.6)

- Leonard Smith **Pragmatic Bayes: Embracing with Model Inadequacy in Nonlinear Dynamical Systems** (P 109), 16.30–16.55
- Matthew Smith **Planetary intelligence** (P 110), 17.00–17.25
- E Wheatcroft **On the chance of rain: Probability forecasts in an operational setting** (P 127), 17.30–17.55
- Hailiang Du **Data Assimilation Designed for Imperfect Model(s)** (P 56), 18.00–18.25

MS08 (MS Problems when inferring networks from data): 16.30–18.30 (PCC 2.1-2.3)

- Ralph Andrzejak **Tracing the temporal evolution of coherence in networks of non-locally coupled oscillators** (P 35), 16.30–16.55
- Andreas Daffertshofer **Partial synchronization in oscillatory networks - estimating the (multi-dimensional) dynamics from data** (P 50), 17.00–17.25
- Henning Dickten **Unsolved issues in the data-driven inference of weighted and directed networks** (P 54), 17.30–17.55
- Bjoern Schelter **Multivariate network analysis: causality or correlation** (P 105), 18.00–18.25

Tuesday 8th September

Plenary 3: 8.45-9.35

- PL03 (Plenary 3): 08.45–09.35 (Newman Blue LT (A))
- Bjorn Hof **The universality class of the transition to turbulence** (P 27)

Session 4: 10.00-12.00

MS09 (MS Localisation mechanisms in shear flows): 10.00–12.00 (PCC 1.4-1.6)

- Bruno Eckhardt **Localized transitions to turbulence in shear flows** (P 57), 10.00–10.25
- Ashley Willis **Streamwise localisation mechanism of exact solutions in pipe flow** (P 129), 10.30–10.55
- Fernando Mellibovsky **Open shear flow archetypal streamwise localization** (P 89), 11.00–11.25
- Sebastian Altmeyer **From localised exact solutions to localised turbulence in pipe flow** (P 34), 11.30–11.55

MS10 (MS Mathematical models of anomalous diffusion): 10.00–12.00 (PCC 2.1-2.3)

- Igor Sokolov **Continuous time random walks and their close relatives** (P 112), 10.00–10.25
- Sergei Fedotov **Anomalous random walk and nonlinear fractional PDE's** (P 59), 10.30–10.55
- Santos B. Yuste **Subdiffusive CTRWers that disappear: where, when, how fast?** (P 132), 11.00–11.25
- Alexander Nepomnyashchy **Propagation of phase-transition boundaries in systems with subdiffusion** (P 90), 11.30–11.55

MS11 (MS Extreme events): 10.00–12.00 (PCC 1.1-1.3)

- Gerrit Ansmann **Extreme events and pattern switching on small-world networks of excitable units** (P 36), 10.00–10.25
- Jose A. Reinoso **Extreme intensity pulses in laser systems generated by the interplay of nonlinearity, noise and delay.** (P 101), 10.30–10.55
- Stephan Bialonski **Predicting and preventing extreme events in a spatially extended excitable system** (P 40), 11.00–11.25
- Marco Thiel **Reconstruction of networks and extreme events** (P 118), 11.30–11.55

MS12 (MS Nonlinear dynamical aspect of data assimilation): 10.00–12.00 (PCC 2.4-2.6)

- Marc Bocquet **Can one track the unstable space with the iterative ensemble Kalman smoother?** (P 44), 10.00–10.25
- Ehouarn Simon **Observation thinning in data assimilation computations** (P 107), 10.30–10.55
- Dan Crisan **Towards a Stable Particle Filter in High-Dimensions** (P 49), 11.00–11.25
- Leonard Smith **Data Assimilation: What is the Point?** (P 111), 11.30–11.55

Lunch/Posters: 12.00-13.30

Poster session continued from Monday.

Plenary 4: 13.30-14.20

- PL04 (Plenary 4): 13.30–14.20 (Newman Blue LT (A))
- Marc Timme **Collective Nonlinear Dynamics of Power Grids – (In-)stability, Braess' Paradox and Nonlocal Rerouting** (P 30)

Session 5: 14.30-16.00

CTF2 (CT Fluids II): 14.30–16.00 (PCC 1.1-1.3)

- Yuki Koyano **Rotation and Oscillation of a Self-Propelled particle in a Two-Dimensional Axisymmetric System** (P 166), 14.30–14.45
- Benedict C.-W. Tan **New phenomena observed following the entry of rigid spheres into a two-layer system of immiscible liquids** (P 204), 14.48–15.03
- Andrea Fortini **Non-equilibrium size segregation in evaporating films of colloidal mixtures** (P 153), 15.06–15.21
- Moritz Linkmann **Sudden relaminarisation and lifetimes in forced isotropic turbulence** (P 173), 15.24–15.39
- Jens Starke **Pattern formation in systems of repulsive particles** (P 201), 15.42–15.57

CTIA1 (CT Interdisciplinary Applications I): 14.30–16.00 (PCC 1.4-1.6)

- Tjeerd olde Scheper **Homeostasis is a Critical Illusion of Harmony** (P 192), 14.30–14.45
- Hildegard Meyer-Ortmanns **Games within games: a dynamical generation of multiple scales in space and time** (P 176), 14.48–15.03
- Uta Naether **Compact nonlinear localized modes in sawtooth lattices** (P 178), 15.06–15.21

- José Sartorelli **Dynamics of a pendulum under tilted parametric excitations** (P 190), 15.24–15.39

- Edmund Barter **Abundance and distribution of food chains in a patch dynamic model of metacommunites** (P 141), 15.42–15.57

CTIA2 (CT Interdisciplinary Applications II): 14.30–16.00 (PCC 2.4-2.6)

- Mirko Schaefer **Tracing the flow in complex renewable energy networks** (P 191), 14.30–14.45

- Amit Apte **Rank deficiency of Kalman filter and assimilation in unstable subspace** (P 136), 14.48–15.03

- Fabian Böhm **Exploiting multistabilities to achieve stable chimera states in globally coupled small laser networks** (P 138), 15.06–15.21

- Shigefumi Hata **Advection equation for network-organized systems** (P 156), 15.24–15.39

- Tamas Bansagi **Dynamic behaviour in an enzyme reaction** (P 139), 15.42–15.57

CTPA (CT Patterns): 14.30–16.00 (PCC 2.1-2.3)

- Daeyoung Choi **Experimental Route to Chaos of an External-Cavity Semiconductor Laser** (P 145), 14.30–14.45

- Dezso Horvath **Dynamics of self-organized precipitate patterns driven by gravity current** (P 157), 14.48–15.03

- James Rankin **Localised states in a neural field model of the primary visual cortex** (P 188), 15.06–15.21

- Jaime Cisternas **Explosive dissipative solitons and their anomalous diffusion** (P 146), 15.24–15.39

- Sándor Kovács **Turing Bifurcation in an Epidemic Model in Patchy Space with Diffusion** (P 164), 15.42–15.57

Wednesday 9th September

Plenary 5: 8.45-9.35

- PL05 (Plenary 5): 08.45–09.35 (Newman Blue LT (A))
- Suzanne Fielding **Hydrodynamics and phase behaviour of biologically active suspensions** (P 26)

Session 6: 10.00–12.00

MS13 (MS Controlling complex networks: interplay of structure, noise, and delay): 10.00–12.00 (PCC 1.1-1.3)

- Christian Bick **Controlling Chimeras** (P 42), 10.00–10.25
- Oleh Omel'chenko **Creative control of chimera states** (P 93), 10.30–10.55
- Laurent Larger **Chimera states in laser delay dynamics: experiment and modeling** (P 82), 11.00–11.25
- Anna Zakharova **Controlling coherence/incoherence patterns by noise and delay** (P 133), 11.30–11.55

MS14 (MS Response, variability and transitions in geophysical systems): 10.00–12.00 (PCC 2.1-2.3)

- David Stainforth **On quantifying the local climate response in observations and models** (P 113), 10.00–10.25
- Anna von der Heydt **A stochastic dynamical systems view on climate sensitivity** (P 126), 10.30–10.55
- Valerio Lucarini **Response Theory in Geophysical Fluid Dynamics: Climate Change Prediction and Parametrizations** (P 87), 11.00–11.25
- Stéphane Vannitsem **Dynamical properties of a hierarchy of low-order coupled ocean-atmosphere models.** (P 124), 11.30–11.55

MS15 (MS Time series, causality, networks and applications I): 10.00–12.00 PCC 2.4-2.6)

- Cees Diks **Time Series, Causality, Networks and Applications** (P 55), 10.00–10.25
- Dimitris Kugiumtzis **Discrimination of dynamical states from causality networks** (P 78), 10.30–10.55
- Max Little **Approximate maximum a-posteriori inference for the infinite hidden Markov model (iHMM)** (P 86), 11.00–11.25
- Milan Palus **Long-term seizure dynamics** (P 95), 11.30–11.55

MS16 (MS Nonlinear dynamics of movement coordination and interpersonal interactions): 10.00–12.00 (PCC 1.4-1.6)

- Julien Lagarde **Looking for patterns in dyads movements: Direct and less direct application of the HKB model** (P 80), 10.00–10.25
- Piotr Slowinski **Bifurcation analysis of the HKB model with time delays** (P 108), 10.30–10.55
- Andreas Daffertshofer **Phase to phase - how phase entrainment can affect amplitude in weakly nonlinear systems** (P 51), 11.00–11.25
- Francesco Alderisio **Modelling and control of interpersonal motor coordination in joint action tasks** (P 32), 11.30–11.55

Lunch/Posters: 12.00-13.30

P02 (Posters 02): 12.00–13.30 (PCC Foyer)

- Jonathan Dawes **Derivation of mass action laws: issues and questions** (P 226)
- Suman Acharyya **Maximal synchronizability of networks and the role of edges** (P 217)
- Pietro Tierno **Excluded Volume Causes Integer and Fractional Plateaus in Colloidal Ratchet Currents** (P 270)
- Vadim Biktashev **Evaluating Exponential Integrators for Markov Chain Ion Channel Models** (P 222)
- Daniel Wetzel **PDEpath** (P 272)
- Uta Naether **Stationary localization in Bose-Hubbard chains with gain and losses** (P 251)
- Daniel Jung **Long-range Response in AC Electricity Grids** (P 238)
- Martin Rohden **A systematic study of Limit Cycles in Kuramoto like models** (P 258)
- Atsunari Katsuki **Size Distribution of Barchan Dunes by Coarse-grained Dune Model** (P 239)
- Masanobu Inubushi **Memory capacity and time scales in delay dynamical systems for reservoir computing** (P 237)
- Kai Morino **Complex Phase Diagram of Coupled Heterogeneous Phase Oscillators** (P 250)
- Petroula Laiou **Equality and equivalency in interdependence of non-identical bidirectionally coupled dynamics** (P 246)

- Nobutoshi Ikeda **Inequality in competition for links by randomly chosen intermediaries in excessive supply of edges** (P 236)
- Alberto Carrassi **Advanced nudging method for data assimilation using time-delayed coordinates** (P 223)
- Taizo Kobayashi **Vortex Sound from a wavy jet and Howe's energy corollary** (P 241)
- Svetlana Khrisanfova **The dynamics of two coupled phase oscillators** (P 240)
- Sergey Sergeyev **Vector Self-pulsing Scenarios** (P 262)
- Peter Ditlevsen **The Middle Pleistocene transition as a generic bifurcation on a slow manifold** (P 230)
- Valerio Lucarini **Global Instability in the Ghil-Sellers Model: Climates vs. Melancholia States** (P 248)
- Paul Schultz **Survivability: A Unifiying Concept for the Transient Resilience of Deterministic Dynamical Systems** (P 261)
- Constantinos Siettos **Equation-Free Computation of Center Manifolds for Black-Box/ Large-Scale Simulators** (P 264)
- Dario Zappalá **Investigating phase dynamics and synchronisation in climate data** (P 273)
- Juliano A. de Oliveira **Phase transition for a family of Hamiltonian mappings: finding critical exponents** (P 228)
- Juliano A. de Oliveira **Convergence to a transcritical bifurcation in the logistic mapping** (P 229)
- Paul Ritchie **Interactions between noise and rate-induced tipping** (P 257)
- Harun Baldemir **Complex oscillation patterns in immature inner hair cells** (P 221)
- Alberto Saa **Optimal synchronization of Kuramoto oscillators: a dimensional reduction approach** (P 260)
- Dong-Uk Hwang **The influence of shortcut in directed ring of oscillators** (P 235)
- Jens Christian Claussen **Oscillations and intrinsic fluctuations in evolutionary dynamics: how payoffs, dynamics and population sizes control the stability, and implementation of global feedback** (P 224)

Plenary 6: 13.30-14.20

- PL06 (Plenary 6): 13.30–14.20 (Newman Blue LT (A))
- Alberto Pinto **Dynamics of human decisions** (P 29)

Session 7: 14.30-16.00

CTCH (CT Chaos): 14.30–16.00 (PCC 1.1-1.3)

- Oliver Pfante **Coarse-Grainings Induced by Non-Generating Partitions of Unimodular Maps** (P 185), 14.30–14.45
- Lawrie Virgin **Experimental study of regular and chaotic transients in a nonsmooth system** (P 209), 14.48–15.03
- Andreas Karsaklian Dal Bosco **Bifurcation to chaos in a Photonic Integrated Circuit: the intermittency route** (P 148), 15.06–15.21
- Jens Christian Claussen **Remarks on possible extensions of definitions of fractal dimensions to no-metric spaces** (P 147), 15.24–15.39
- Carlos Quintero **Numerical and experimental study of the effects of noise on the permutation entropy** (P 187), 15.42–15.57

CTMA (CT Mathematical aspects): 14.30–16.00 (PCC 1.4-1.6)

- Gaetano Zampieri **On local and nonlocal variational constants of motion** (P 215), 14.30–14.45
- Murilo S. Baptista **The topology and timing of causality** (P 140), 14.48–15.03
- Tamas Kovacs **Escape dynamics through continuously growing leak** (P 165), 15.06–15.21
- Tatsuo Yanagita **Applications of Extended Ensemble Monte Carlo for Dynamical Systems** (P 213), 15.24–15.39
- Andrew Gilbert **Transport and instabiliities in some MHD shear flows** (P 154), 15.42–15.57

CTNE (CT Networks): 14.30–16.00 (PCC 2.1-2.3)

- Eve Armstrong **From the complex nonlinear behavior of a single neuron to the robust pattern of a network: Using data assimilation to probe this transformation** (P 137), 14.30–14.45
- Stefan Kettemann **Delocalization of Phase Fluctuations and the Stability of AC Electricity Grids** (P 162), 14.48–15.03
- Darka Labavic **Coherent collective behavior in networks of coupled circuits with a zoom into the transition regime** (P 169), 15.06–15.21
- G. Ambika **Complex networks from chaotic time series** (P 135), 15.24–15.39
- Judith Lehnert **Adaptive control of synchronization in complex networks** (P 171), 15.42–15.57

CTSP (CT Stochastic processes): 14.30–16.00 (PCC 2.4-2.6)

- Milan Krbalek **On a link between novel ensembles of random matrices and systems of self-driven particles** (P 167), 14.30–14.45
- Masanobu Inubushi **Noise-robustness of physical random bit generation** (P 158), 14.48–15.03
- Kazusa Ugajin **Fast physical random number generation using a photonic integrated circuit and a differential method** (P 207), 15.06–15.21
- Mozhdeh Massah **Study of LDP for correlated Gaussian stochastic processes and intermittent dynamical systems, stimulated by a climate science problem** (P 175), 15.24–15.39

Session 8: 16.30-18.30

MS17 (MS Soft matter under control: pattern formation and transport): 16.30–18.30 (PCC 2.1-2.3)

- Markus Bär **Modelling Pattern Formation and Waves in Active Biological Fluids** (P 38), 16.30–16.55
- Pietro Tierno **Colloidal Microworms Propelling via a Cooperative Hydrodynamic Conveyor-Belt** (P 120), 17.00–17.25
- Andrew Archer **Patterns formed in soft matter after a quench** (P 37), 17.30–17.55
- Sabine Klapp **Feedback control of one-dimensional colloidal transport** (P 76), 18.00–18.25

MS18 (MS Time series, causality, networks and applications II): 16.30–18.30 (PCC 2.4-2.6)

- Radek Janca **Dynamical profile of connectivity changes of ictal epileptic networks** (P 75), 16.30–16.55
- Christian Geier **Identifying important nodes in epileptic brain networks** (P 63), 17.00–17.25
- Ernesto Pereda **Magnetic or electric? Studying functional brain networks of alcoholic patients from simultaneously recorded MEG and EEG data** (P 96), 17.30–17.55
- Christian Rummel **Resected brain tissue, seizure onset zone and quantitative EEG measures: Towards prediction of post-surgical seizure control** (P 103), 18.00–18.25

MS19 (MS Self-organizing effects in complex (dusty) plasmas): 16.30–18.30 (PCC 1.4-1.6)

- Markus Thoma **Phase transitions in electrorheological plasmas** (P 119), 16.30–16.55
- Christoph Raeth **Wave turbulence observed in an auto-oscillating complex (dusty) plasma** (P 98), 17.00–17.25
- Couedel Lenaic **Synchronization in two-dimensional plasma crystals** (P 83), 17.30–17.55
- Alexei Ivlev **Statistical mechanics for nonreciprocal forces** (P 73), 18.00–18.25

MS20 (MS Nonlinear and stochastic dynamics in weather and climate science): 16.30–18.30 (PCC 1.1-1.3)

- Frank Kwasniok **Data-driven stochastic modelling of unresolved scales in weather and climate science** (P 79), 16.30–16.55
- Paul Williams **Noise-induced regime transitions in atmospheric flow** (P 128), 17.00–17.25
- Laure Zanna **Energy backscatter and parametrization of sub-grid scale ocean eddies** (P 134), 17.30–17.55
- Michael Ghil **The Wind-Driven Ocean Circulation: Bifurcations, Simulations and Observations** (P 64), 18.00–18.25

Thursday 10th September

Plenary 7: 8.45-9.35

- PL07 (Plenary 7): 10 Sep 08.45–09.35 (Newman Blue LT (A))
- Blas Echebarria **Critical behaviour of intracellular calcium dynamics in cardiac cells** (P 25)

Session 9: 10.00-12.00

CTNO (CT Nonlinear optics): 10 Sep 10.00–12.00 (PCC 1.1-1.3)

- Takashi Isoshima **Wavefront Propagation in Two-dimensional Optical Bistable Device** (P 159), 10.00–10.15
- Shoma Ohara **Frequency dependence of chaos synchronization of low-frequency fluctuations in a photonic integrated circuit with mutually-coupled semiconductor laser** (P 181), 10.18–10.33
- Nobumitsu Suzuki **Effect of the bandwidth limitation of an optical noise signal used for common-signal induced synchronization in chaotic semiconductor lasers** (P 203), 10.36–10.51
- Lina Jaurigue **Dynamics of passively mode-locked lasers under the influence of optical feedback and optical coupling** (P 161), 10.54–11.09
- Chien-Yuan Chang **Extreme events in the chaotic dynamics of external-cavity semiconductor lasers** (P 144), 11.12–11.27

MS21 (MS Cardiac dynamics): 10 Sep 10.00–12.00 (PCC 1.4-1.6)

- Jean Bragard **Comparison of two and four electrode defibrillators through a simple cardiac dynamical model** (P 46), 10.00–10.25
- Sergio Alonso **Modeling ectopic beats and arrhythmias generated by diffuse fibrosis in cardiac tissue** (P 33), 10.30–10.55
- Vadim Biktashev **Drift of Scroll Waves in Thin Layers Caused by Thickness Features** (P 43), 11.00–11.25
- Niels Otani **Unification of electrical restitution dynamics with ion channel dynamics as a description of action potential propagation in the heart** (P 94), 11.30–11.55

MS22 (MS Source buoyancy effects on plume and thermal flow): 10 Sep 10.00–12.00 (PCC 2.4-2.6)

- Matthew Scase **Unsteady plumes and explosive volcanism** (P 104), 10.00–10.25
- M Delichatsios **Transient development of a thermal and a fire plume using integral models** (P 53), 10.30–10.55
- Maarten van Reeuwijk **An energy-based framework for unsteady turbulent plumes** (P 123), 11.00–11.25
- Gabriel Rooney **propagation of turbulent downdraughts** (P 102), 11.30–11.55

MS23 (MS Coupling functions - theories and applications): 10 Sep 10.00–12.00 (PCC 2.1-2.3)

- Antonio Politi **On the equivalence of phase-oscillator and integrate-and-fire models: how the coupling functions matter** (P 97), 10.00–10.25
- Tomislav Stankovski **Coupling functions: Universal insights into dynamical interactions** (P 114), 10.30–10.55
- Zoran Levnajic **Reconstructing coupling functions vs. reconstructing interaction strengths** (P 85), 11.00–11.25
- Lal Hussain **Coupling functions between brain waves: Significance of opened/closed eyes** (P 72), 11.30–11.55

Lunch/Posters: 12.00-13.30

(Poster session continued from Wednesday)

Plenary 8: 13.30-14.20

- PL08 (Plenary 8): 10 Sep 13.30–14.20 (Newman Blue LT (A))
- Michel Crucifix **Ten challenges for ice age dynamics: a dynamical system perspective** (P 24)

Session 10: 14.30-16.30

CTCL (CT Climate): 10 Sep 14.30–16.30 (PCC 1.1-1.3)

- Mark Williamson **New early warning signals of tipping points in periodically forced systems** (P 211), 14.30–14.45
- Takahito Mitsui **Nonsmooth saddle-node bifurcations and strange nonchaotic attractors in a phase oscillator model of glacial cycles** (P 177), 14.48–15.03
- Annette Witt **Analysis and Modelling of a 9.3 ky Palaeoflood Record** (P 212), 15.06–15.21

- Peter Ditlevsen **Predictability, waiting times and tipping points in the climate** (P 152), 15.24–15.39
- Sebastian Bathiany **Climate tipping points triggered by changes in periodic forcing** (P 142), 15.42–15.57

CTNP (CT Networks and Patterns): 10 Sep 14.30–16.30 (PCC 1.4-1.6)

- Hui Yang **Large epidemic thresholds emerge in heterogeneous networks of heterogeneous nodes** (P 214), 14.30–14.45
- Holly Silk **Exploring network dynamics with a mathematical triple jump** (P 196), 14.48–15.03
- Mitsuyoshi Tomiya **Traveling Wavepacket and Scar States** (P 205), 15.06–15.21
- Michal Pecelerowicz **(In)stability of Laplacian growth** (P 184), 15.24–15.39
- Chengwei Wang **An approximate solution and stability determination for the finite-size Kuramoto mode** (P 210), 15.42–15.57
- Walter Zimmerman **Emergence and Coexistence of stable branched patterns in anisotropic systems** (P 216), 16.00–16.15

CTTS (CT Time series): 10 Sep 14.30–16.30 (PCC 2.1-2.3)

- Ingo Laut **Phase correlations in leptokurtic time series** (P 170), 14.30–14.45
- Marc Höll **Analytical investigation on the detrended fluctuation analysis** (P 155), 14.48–15.03
- Elsa Siggiridou **Restricted linear Granger causality measures** (P 195), 15.06–15.21

MS24 (MS Turbulent dispersion): 10 Sep 14.30–16.30 (PCC 2.4-2.6)

- Michael Borgas **The dispersive nature of a meandering atmospheric plume and its impact on our sense of smell** (P 45), 14.30–14.55
- Mike Reeks **The concept of particle pressure in a suspension of particles in a turbulent flow** (P 100), 15.00–15.25
- Gavin Esler **Adaptive stochastic trajectory modelling** (P 58), 15.30–15.55
- Lukas Konstandin **Supersonic, compressible turbulence - The influence of a varying density field** (P 77), 16.00–16.25

Public lecture

Public lecture (PL00)
6 September 17.00–18.00 (Newman Blue LT (A))

Time: 17.05 – 17.55

Illuminating Chaos - Art (and Science) on Average

Michael Field (Rice University, Houston)

Abstract: The theory of chaos and sensitive dependence on initial conditions, or "the butterfly effect", has attracted a lot of attention outside mathematics and science. For example, ideas about chaos underpin the play Arcadia by Tom Stoppard and there is a series of popular movies named after the butterfly effect. So, what are chaos and the butterfly effect and how do we know when they are there and, if they are, what do we do with them? In this talk, which is for a general audience, we describe what chaos is (and is not), how we visualise chaos, and how all of this fits into the general framework of science: what is the experiment and what are we trying to measure? One of the seeming paradoxes of chaos is that chaos can often lead to order. We illustrate with some striking visual examples of structure in chaos from mathematics and science.

Plenary talks

Plenary 1 (PL01)
7 September 08.45–09.35 (Newman Blue LT (A))

Time: 08.45 – 09.30

Large-scale astrophysical and laboratory plasmas as testbeds for fundamental multiscale non-linear processes

Sandra Chapman (University of Warwick)

Abstract: Fully non-linear processes which couple across spatio-temporal scales, such as reconnection and turbulence are ubiquitous in astrophysical fields and flows. They are key mechanisms for plasma heating and particle acceleration from the energy contained in large scale plasma flows and magnetic fields. Turbulence and the formation and propagation of coherent structures are also central to anomalous transport and diffusion seen in large-scale confined plasmas for magnetically confined fusion (MCF). These driven, dissipative confined plasmas exhibit transitions between confinement states with emergence of large-scale flows which are non-linearly coupled to the background turbulence. Turbulence and reconnection can be observed in-situ at first hand in our solar system using satellite-borne instrumentation. We now have a rich collection of such observations and in particular, multi-point and high time resolution observations spanning magnetohydrodynamic and kinetic scales. Large scale MCF experiments are also comprehensively diagnosed. Alongside this, it is now becoming feasible to perform numerical simulations that capture the full non-linear physics self-consistently down to kinetic scales, in three dimensions. Comparing theory and simulations with data requires us to be quantitative, under the somewhat difficult circumstances of a finite sized observed system with limited time-stationarity. Methods to address these challenges have potential cross-over between laboratory and space plasmas, and wider application, in both the simulations and the data analysis tools.

Plenary 8 (PL08)
10 September 13.30–14.20 (Newman Blue LT (A))

Time: 13.30 – 14.15

Ten challenges for ice age dynamics: a dynamical system perspective

Michel Crucifix (Université catholique de Louvain)

Abstract: This presentation focuses on the slow dynamics of the climate system, at time scales of one thousand to one million years. We focus specifically on the phenomenon of ice ages that has characterised the slow evolution of climate over the Quaternary, and our objective is to show how mathematical theories and concepts have improved our capacity to articulate simulation and observations, provide predictions, and identify research questions. In particular, we identify three useful paradigms: 1. Dynamical system theory provides the basic framework to approach questions associated with system stability, predictability, abrupt change and early-warning signals. Dynamical system application are nowadays often associated with probabilistic theory. In particular, stochastic dynamical system provide a powerful framework to articulate effects associated with different times scales. 2. Numerical simulation is an essential aspect of climate system modelling. We review the now classical classification distinguishing conceptual models, Earth Systems Models of Intermediate Complexity, and Global Climate Models. The distinction between the latter two categories can be approached from different points of view. The criteria used here is based on level of parameterisation of weather statistics. 3. Statistical inference provides a framework for model selection, parameter and state estimation in presence of limited data and uncertain model error.
The discussion in structured around a list of 10 challenges, which are introduced here as an attempt to rationalise the research agenda and clarify synergies between the three approaches mentioned above. The 10 challenges are further divided into three general research objectives: provide a seamless climate theory across time scales, understand and predict climate states across climate transitions, statistical concepts and methods of model selection and calibration adapted to the palaeoclimate constraints. The focus is set on questions that will, on the one hand, generate collaboration between mathematicians and palaeoclimate experts and, on the other hand, have far-reaching applications in other areas.

Plenary 7 (PL07)
10 September 08.45–09.35 (Newman Blue LT (A))

Time: 08.45 – 09.30

Critical behaviour of intracellular calcium dynamics in cardiac cells

Blas Echebarria (Universitat Politècnica de Catalunya)

Abstract: In the heart, electrical wave propagation signals the contraction of cardiac tissue. The voltage difference across the cell membrane of cardiomyocytes changes abruptly in response to an external stimulus, in a manner typical of an excitable system. Thus, in cardiac tissue, theories developed for general reaction diffusion systems have found a relevant application. Instabilities of periodic pulses, spirals, scroll waves, and spiral break-up all have their clinical equivalent, in terms of different arrhythmias, tachycardia or fibrillation. In the last years big progress has been done in the modelling of cardiac arrhythmias. A better knowledge of the heartâĂŹs morphology and electrophysiology, as well as its mechanical properties has allowed to construct realistic models able to reproduce situations of clinical importance. However, much can also be learnt from the study of simplified cardiac models. An important example that I will discuss in this talk is that of cardiac alternans, a beat-to-beat alternation in the strength of cardiac contraction that has been shown to be related to sudden cardiac death. In particular, I will consider the mechanisms underlying the appearance of electromechanical alternans, in which the instability ensues from the dynamics of intracellular calcium. At a global level, this instability appears as a period doubling bifurcation of the periodic rhythm. However, within the cell, calcium is released in thousands of microdomains, where release is regulated by the stochastic opening and closing of ion channels and receptors. At the subcellular level, thus, the cardiac cell behaves as a noisy nonequilibrium system. Surprisingly (or not) we found that the transition to calcium alternans shares the characteristics of an order disorder phase transition in equilibrium systems, including critical behaviour, with critical exponents that are consistent with the Ising universality class. These findings highlight the important role of noise and cooperativity in biological cells, and suggest novel approaches to investigate the onset of the alternans instability in the heart.

Plenary 5 (PL05)
9 September 08.45–09.35 (Newman Blue LT (A))

Time: 08.45 – 09.30

Hydrodynamics and phase behaviour of biologically active suspensions

Suzanne Fielding (Durham University)

Abstract: Following a brief pedagogical introduction to the field of biologically active suspensions, we discuss recent research results for the phase behaviour and rheology of these fluids. In the first part of the talk we report simulations of a continuum model for active fluids in two dimensions (2D). We focus on extensile materials and find that steady shear bands, previously shown to arise ubiquitously in 1D for the active nematic phase at small (or indeed zero) shear rate, are generally replaced in 2D by more complex flow patterns that can be stationary, oscillatory, or apparently chaotic. The consequences of these flow patterns for time-averaged steady-state rheology are examined. In the second part we discuss particle based simulations with hydrodynamics of a suspension of active disks squirming through a Newtonian fluid. We explore numerically the full range of squirmer area fractions from dilute to close packed and show that "motility induced phase separation" (MIPS), which was recently proposed to arise generically in active matter, and which has been seen in simulations of active Brownian disks, is strongly suppressed by hydrodynamic interactions. We give an argument for why this should be the case and support it with counterpart simulations of active Brownian disks in a parameter regime that provides a closer counterpart to hydrodynamic suspensions than in previous studies.

Plenary 3 (PL03)
8 September 08.45–09.35 (Newman Blue LT (A))

Time: 08.45 – 09.30

The universality class of the transition to turbulence

Bjorn Hof (IST)

Abstract: How turbulence arises in simple shear flows, such as pipes and channels has been an open question for over a century. In these cases turbulence sets in despite the linear stability of the laminar flow and transition is caused by finite amplitude perturbations. Despite numerous experimental and theoretical studies it has not been possible to determine the nature of this transition. It will be shown for the examples of pipe and Couette flow that the onset of sustained turbulence is a nonequilibrium phase transition. The critical point is determined by resolving the extremely long time scales of the underlying growth and decay processes. In detailed experiments and direct numerical simulations close to the transition point we explicitly measure the critical exponents and show that this transition falls into the directed percolation universality class.

Plenary 2 (PL02)
7 September 13.30–14.20 (Newman Blue LT (A))

Time: 13.30 – 14.15

Dynamic scaling in kinetic models for coarsening and coagulation

Barbara Niethammer (University of Bonn)

Abstract: Coarsening, that is the increase of typical length scales in a microstructure, is a fundamental process in numerous phenomena in physics or materials science. Typical examples include Ostwald Ripening in binary alloys or grain growth in polycrystalline materials. It is intriguing that such systems typically evolve after some transient stage in a universal statistically self-similar fashion. Often kinetic mean-field type equations are used in order to try to capture this universal long-time behaviour, but despite looking typically rather simple, their analysis turns out to be a challenge. In this talk I will review some progress of recent years in the analysis of such equations and will also discuss major open problems.

Plenary 6 (PL06)
9 September 13.30–14.20 (Newman Blue LT (A))

Time: 13.30 – 14.15

Dynamics of human decisions

Alberto Pinto (University of Porto)

Abstract: We study a decision model where both the set of individuals and the set of possible alternatives are finite. Individuals make their choices according to an utility function that is an additive combination of a personal valuation component and an interaction component. We will study the dynamics associated to the individual decisions from a game theoretical perspective.

Plenary 4 (PL04)
8 September 13.30–14.20 (Newman Blue LT (A))

Time: 13.30 – 14.15

Collective Nonlinear Dynamics of Power Grids – (In-)stability, Braess' Paradox and Nonlocal Rerouting

Marc Timme (MPIDS, Göttingen)

Abstract: Robust energy supply and distribution fundamentally underlies our economy, industry and daily life.The ongoing switch of energy sources from fossil to renewable creates a multitude of challenges for operation of modern power grids. Renewable-source generation is intrinsically smaller, more distributed, more heterogeneous, fluctuating, correlated and thus requires system-wide planning, balance and control. In this talk I highlight some of the challenges from the perspective of network dynamical systems. In particular, I show why collective aspects of network dynamics as emerging through a multitude of co-acting nonlinearities play a crucial role in the existence of relevant invariant dynamics, their (in)stability, the prediction of critical links and non-local rerouting of flows. A mechanistic understanding of the collective power grid dynamics is thus crucial to design, plan, operate and control them.
References: 1) Decentral Smart Grid Control: Schäffer et al., New J. Phys. 17:015002 (2015).2) Impact of network topology: Rohden et al., Phys. Rev. Lett. 109:064101; Chaos 24: 013123 (2014).3) Braess' Paradox: Witthaut & Timme, New J. Phys. 14:083036 (2012)4) Supply Network Stability: Manik et al., EPJ Special Topics 02274-y-1:1 (2014).This is joint work with Dirk Witthaut, Debsankha Manik, Martin Rohden, Andreas Sorge, Xiaozhu Zhang, Levke Johanna Deutsch, Malte Schroeder, Moritz Matthiae, Nora Molkenthin, Jose Casadiego and Sarah Hallerberg.

Minisymposium talks

MS Controlling, synchronizing and modelling complex systems (MS01)

7 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.00 – 11.17

Controllability and synchronizability: are they related?

Luis Aguirre (Universidade Federal de Minas Gerais) Christophe Letellier CORIA-UMR 6614 Normandie Université, CNRS-Université et INSA de Rouen, Campus Universitaire du Madrillet, F-76800 Saint-Etienne du Rouvray, France

Abstract: In the two last decades the concept of observability has been formally linked to that of embedding in the context of nonlinear dynamics. Such a concept has been shown to play important roles in global modelling, data analysis and filtering, to mention a few examples. Preliminary results suggested that observability, at least in some cases, has some influence in synchronization problems. It is usually assumed that the dual concept of controllability should also be important in such problems. However, in the context of synchronization, in general, the role played by controllability properties may not be as relevant as observability is for data analysis. In this paper we compute controllability coefficients analogous to the observability ones, now established in the literature, and evaluate their importance in synchronization problems. The results concern the synchronization to external forces of two benchmarks, the Rössler system and the cord system. Also for these two benchmarks bidirectional coupling synchronization is considered. The results discussed in this paper show that controllability and synchronizability may not be so closely related as thought before.

MS Nonlinear dynamics of movement coordination and interpersonal interactions (MS16)
9 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.30 – 11.55

Modelling and control of interpersonal motor coordination in joint action tasks

Francesco Alderisio (University of Bristol) Zhai, C (University of Bristol) Slowinski, P (University of Exeter) Tsaneva-Atanasova, K (University of Exeter) di Bernardo, M (University of Bristol)

Abstract: It is of great significance to model interpersonal motor coordination due to its potential applications in human motor rehabilitation, humanoid robot and human-robot interaction. In this talk, we will present our work on modelling and control of socio-motor coordination carried out in the context of the European ‘AlterEgo’ project. Specifically, we create a virtual player (VP) able to play the mirror game with a human player (HP) in different experimental conditions. Haken-Kelso-Bunz (HKB) model is employed to describe the nonlinear dynamics of the human end effector, and a feedback control approach based on optimal control has been developed, which allows the VP to interact with the HP in real time. Moreover, our approach succeeds in reconciling the motor signature of the VP with the temporal correspondence with its human partner. The proposed model has been validated by matching experimental data and reproducing experimentally observed phenomena.

MS Cardiac dynamics (MS21)
10 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.30 – 10.55

Modeling ectopic beats and arrhythmias generated by diffuse fibrosis in cardiac tissue

Sergio Alonso (Universitat Politècnica de Catalunya) Bär, Markus (Physikalisch-Technische Bundesanstalt)

Abstract: Arrhythmias in cardiac tissue are related to irregular electrical wave propagation in the heart. Some types of arrhythmias have been frequently related with fibrosis and ischemia of the tissue. Cardiac tissue is typically model with the continuous cable equations. However, tissues are formed by a discrete network of cells, which, normally, are far to be homogeneous. The inclusion of non-conducting media among the cells, mimicking cardiac fibrosis, in models of cardiac tissue may lead to the formation of reentries and other dangerous arrhythmias. The fraction of non-conducting media in comparison with the fraction of healthy myocytes and the topological distribution of the cells determines the probability of ectopic beat generation. A localized region with a fraction of non-conducting media surrounded by homogeneous conducting tissue can become a source of reentry and ectopic beats. Extensive simulations in discrete models of cardiac tissue with different topologies show that a wave crossing a heterogeneous region of cardiac tissue can disintegrate into irregular patterns.

MS Localisation mechanisms in shear flows (MS09)
8 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.30 – 11.55

From localised exact solutions to localised turbulence in pipe flow

Sebastian Altmeyer (Institute of Science and Technology Austria) Mellibovsky, F. (Universitat Politecnica de Catalunya), Willis, A. (University of Sheffield), Hof, B. (Institute of Science and Technology Austria)

Abstract: It has been proposed in recent years that turbulence is organized around unstable invariant solutions, which provide the building blocks of the chaotic dynamics. In direct numerical simulations of pipe flow we show that when imposing a minimal symmetry constraint (reflection in an axial plane only) the formation of turbulence can indeed be explained by dynamical systems concepts. The hypersurface separating laminar from turbulent motion, the edge of turbulence, is spanned by the stable manifolds of an exact invariant solution, a periodic orbit of a spatially localized structure. The turbulent states themselves (turbulent puffs in this case) are shown to arise in a bifurcation sequence from a related localized solution (the upper branch orbit). The rather complex bifurcation sequence involves secondary Hopf bifurcations, frequency locking and a period doubling cascade until eventually chaotic motion arises. Furthermore we identify several coherent structures - travelling waves - and illustrate their connection to the found localized solutions.

MS Problems when inferring networks from data (MS08)
7 September 16.30–18.30 (PCC 2.1-2.3)

Time: 16.30 – 16.55

Tracing the temporal evolution of coherence in networks of nonlocally coupled oscillators

Ralph Andrzejak (Universitat Pompeu Fabra, Barcelona) Kaspar Schindler (qEEG group, Department of Neurology, Inselspital, Bern, Switzerland) Christian Rummel (Support Center for Advanced Neuroimaging, University Institute for Diagnostic and Interventional Neuroradiology, Inselspital, Bern, Switzerland)

Abstract: We use a data-driven approach to study the dynamics of a ring of identical phase oscillators with nonlocal coupling. Such networks can segregate into two opposing subpopulations, one with simple harmonic and mutually synchronous oscillations and the other with an irregular asynchronous motion. Accordingly, the symmetry of the network architecture is broken by the network's dynamics - a so-called chimera state is formed. While chimera states are stable in the thermodynamic limit of infinitely many oscillators [3], they can collapse after long lifetimes to a fully synchronized state for networks of finite size. We at first study the influence of the shape and broadness of the coupling kernel function on the dynamics. Features that are investigated include the probability that a chimera state is formed after initializing the network with random phases and the mean lifetime of chimera states once they are formed. We then set the coupling kernel such that chimera states are formed for approximately 95% of the realizations and the mean lifetimes are comparable to maximal lifetimes reported in previous studies [4, 5]. Finally, we study the temporal evolution of the local order parameter derived from the phases of the oscillators [1]. We show how the information extracted from this order parameter can be used to provoke or counteract the collapse of chimera states to the fully synchronized state using a control scheme similar to the one proposed in [4]. Accordingly, we show how data measured from a network of phase oscillators can be used to not only infer the current state of the network but also to control its dynamics.
References: [1] Kuramoto, Y., & Battogtokh, D. Coexistence of Coherence and Incoherence in Nonlocally Coupled Phase Oscillators. Nonlinear phenomena in complex systems, 5, 380-385, 2002. [2] Abrams, Daniel M., & Steven H. Strogatz. Chimera states for coupled oscillators. Physical Review Letters 93, 174102, 2004. [3] Panaggio, M.J. & Abrams, D.M. Chimera states: coexistence of coherence and incoherence in networks of coupled oscillators. Nonlinearity, 28, R67-R87, 2015. [4] Wolfrum, M., & Omel'chenko, E. Chimera states are chaotic transients. Physical Review E, 84, 015201, 2011. [5] Sieber, J., Omel'chenko, E., & Wolfrum, M. Controlling unstable chaos: stabilizing chimera states by feedback. Physical Review Letters, 112, 054102, 2014. [6] Wolfrum, M., & Omel'chenko, E. Chimera states are chaotic transients. Physical Review E, 84, 015201, 2011.

MS Extreme events (MS11)
8 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.00 – 10.25

Extreme events and pattern switching on small-world networks of excitable units

Gerrit Ansmann (University of Bonn) Lehnertz, K (University of Bonn) Feudel, U (University of Oldenburg)

Abstract: We study systems of FitzHugh–Nagumo units coupled on small-world networks that can exhibit self-induced, seemingly random switchings between three different collective dynamical patterns. One of these patterns are rare events, during which the whole system becomes excited and an aggregated observable becomes unusually high. In contrast to the other patterns, these events are short-lived and can thus be considered extreme events. We discuss the mechanisms behind the switchings to and from extreme events as well as the impact of aspects of the coupling topology on the observed phenomena. This work was supported by the Volkswagen Foundation (Grant Nos. 85388 and 85392)

MS Soft matter under control: pattern formation and transport (MS17)
9 September 16.30–18.30 (PCC 2.1-2.3)

Time: 17.30 – 17.55

Patterns formed in soft matter after a quench

Andrew Archer (Loughborough University) Walters, M (Loughborough), Rucklidge, A (Leeds), Thiele, U (Muenster), Knobloch, E (Berkeley)

Abstract: Results will be presented for two-dimensional systems of soft particles interacting via soft potentials that may be considered to be simple models for the effective interaction between dendrimers and other such polymeric macromolecules in solution. Density functional theory and Dynamical Density Functional Theory (DDFT) are used to study the structures that are formed from quenching the uniform liquid to a state where it is unstable with respect to freezing. The systems that we study all have a common feature: there are two lengths and two energy scales in the interaction potential(s). The systems we study include both binary mixtures and one-component systems. The interplay of the different length and energy scales during the solidification process can lead to a variety of different equilibrium and metastable structures (i.e. global and local minima of the free energy), including crystals, disordered solids, quasicrystals (QC) and a so-called 'crystal-liquid'. The latter is an exotic periodic state with a sizeable fraction of highly mobile particles. The QC structures may be created by a competition between linear instability at one scale and nonlinear selection of the other. This dynamic mechanism for forming QCs is qualitatively different from mechanisms observed previously. The system first forms a small length scale crystal. Only when this phase is almost fully formed (i.e., the dynamics is far into the nonlinear regime) does the longer length scale start to appear, leading to the formation of QCs.

MS Soft matter under control: pattern formation and transport (MS17)
9 September 16.30–18.30 (PCC 2.1-2.3)

Time: 16.30 – 16.55

Modelling Pattern Formation and Waves in Active Biological Fluids

Markus Bär (PTB)

Abstract: Active fluids are complex fluids wherein energy is injected by active internal units. In this talk I consider as example for an active biological fluids - a dense suspension of swimming bacteria (e. g. Bacillus subtilis). A simple macroscopic phenomenological model will be introduced, that predicts regular and turbulent vortex lattices and reproduces recent experimental findings of mesoscale turbulence in two- and three-dimensional suspensions of Bacillus subtilis quantitatively [1,2]. Moreover, we have been able to recover qualitatively the observed behavior in a minimal 'microscopic' model based on the competition between short-range and long-range antialignment of self-propelled particles representing bacterial swimmers [3].
References: [1] J. Dunkel, S. Heidenreich, M. Bär and R. E. Goldstein (2013). Minimal continuum theories of structure formation in dense active fluids. New. J. Phys., 045016. [2] J. Dunkel, S. Heidenreich, K. Drescher, H. H. Wensink, M. Bär and R. E. Goldstein (2013). Fluid dynamics of bacterial turbulence. Phys. Rev. Lett. 110, 228102. [3] R. Großmann, P. Romanczuk, M. Bär, and L. Schimansky-Geier (2014). Vortex Arrays and Mesoscale Turbulence of Self-Propelled Particles. Phys. Rev. Lett. 113, 258104.

MS Pattern formation (MS03)
7 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.30 – 10.55

Spatial localization in three-dimensional doubly diffusive convection

Cedric Beaume (Imperial College London) Knobloch, E (UC Berkeley) Bergeon, A (University of Toulouse)

Abstract: Doubly diffusive convection arises frequently in natural phenomena and industrial processes, and occurs in systems characterized by competing fields that diffuse at different rates. Well-known examples are provided by thermohaline convection and the salt-finger instability. Recent work has led to the realization that subcritical instabilities of this type can lead to stable but spatially localized convection. In this talk, I will present the occurrence of such solutions in three-dimensional thermohaline convection where a salt-water mixture is confined between vertical walls maintained at different temperatures and concentrations. The spatially localized solutions consist in spots of convection embedded in a background conduction state and give rise to an intricate bifurcation diagram. I will also discuss how such solution are linked to the chaotic dynamics observed right above the onset of the linear instability.

MS Extreme events (MS11)
8 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.00 – 11.25

Predicting and preventing extreme events in a spatially extended excitable system

Stephan Bialonski (Max-Planck-Institute for the Physics of Complex Systems)

Abstract: Extreme events occur in many spatially extended systems and can threaten human life. Their reliable prediction and prevention is thus highly desirable. We study the prediction and prevention of extreme events in a spatially extended system, a network of FitzHugh-Nagumo units, in which events occur in a spatially and temporally irregular way. Despite being challenged by the rareness of events and without knowing the governing equations of motion, we can predict - with a data-driven method - the beginning, propagation, and termination of extreme events in this system remarkably well. We suppress extreme events via tiny and spatiotemporally localized perturbations which are guided by our predictions. We discuss how symmetries in the system could be exploited for better forecast performance.

MS Controlling, synchronizing and modelling complex systems (MS01)
7 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.00 – 10.25

Symbolic computations of non-linear observability

Ezequiel Bianco-Martinez (University of Aberdeen) Murilo S. Baptista (Institute for Complex Systems and Mathematical Biology, SUPA, University of Aberdeen)

Abstract: Nature offers abundant manifestations of collective motion phenomena in self-propelled living systems at all scales, from biomolecular micromotors, migrating cells and growing bacteria colonies, to insect swarms, fish schools, bird flocks, mammal herds and even human crowds. Instead of focusing on the specific details that make each of these biological systems unique, statistical physicists have been studying the general patterns of biological collective motion, aiming to identify the general laws and underlying principles that may govern their behaviour. A simple but useful description of these systems can be achieved with the so-called standard Vicsek model (SVM), which assumes that neighbouring individuals tend to align their direction of movement when they are placed within a certain interaction range. This alignment rule, which would trivially lead to fully ordered collective motion, is complemented by a second one that introduces noise in the communications among individuals. Along this work we analized the critical behaviour of the SVM showing that for topological interactions (instead of the geometric ones usually considered) the universality class of the model remains unchanged, point out its robustness. (ezequielalbyahoo.com.ar)

MS Controlling complex networks: interplay of structure, noise, and delay (MS13)
9 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.00 – 10.25

Controlling Chimeras

Christian Bick (University of Exeter) Martens, Erik A (University of Copenhagen)

Abstract: A curious feature of non-locally coupled phase oscillator is the emergence of chimera states. These localized pattern are characterized by localized phase synchrony while the remaining oscillators move incoherently. The position of synchronized region however depends strongly on the initial condition and is subject to pseudo-random fluctuations. Here we apply the idea of control to chimera states; through a new dynamic control scheme that exploits drift, a chimera will attain any desired target position. Our control approach extends beyond chimera states as it may also be used to optimize more general objective functions.

MS Cardiac dynamics (MS21)
10 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.00 – 11.25

Drift of Scroll Waves in Thin Layers Caused by Thickness Features

Vadim Biktashev (University of Exeter) Biktasheva, IV (University of Liverpool); Dierckx, H (University of Ghent)

Abstract: A scroll wave in a thin layer of excitable medium is similar to a spiral wave, but may drift depending on layer geometry. Effects of sharp thickness variations are distinct from filament tension and curvature-induced drifts described earlier. We describe these effects asymptotically, with the layer thickness and its relative variation as small parameters. Asymptotic predictions agree with numerical simulations for drift of scrolls along thickness steps, ridges, ditches, and disk-shaped thickness variations. This explains drift of scroll waves in geometrically realistic models of heart atria which was been unclear otherwise.

MS Nonlinear dynamical aspect of data assimilation (MS12)
8 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.00 – 10.25

Can one track the unstable space with the iterative ensemble Kalman smoother?

Marc Bocquet (Ecole des Ponts ParisTech) Marc Bocquet, CEREA joint laboratory Ecole des Ponts ParisTech and EdF R&D, Université Paris-Est, France Alberto Carrassi, Nansen Environmental and Remote Sensing Center, Bergen, Norway

Abstract: The iterative ensemble Kalman smoother (IEnKS) is an ensemble variational data assimilation method. It seamlessly combines an ensemble of states to represent forecast errors with a 4D-variational analysis in the space of the ensemble. Because it accounts for the flow dependency of the errors and because it relies on a nonlinear variational analysis, it was shown to outperform 4D-Var, the ensemble Kalman filter and smoother with chaotic low-order models in a wider range of dynamical regimes. A peculiar feature of the IEnKS is its performance behaviour as a function of the ensemble size. The skill abruptly improves as soon as the number of members exceeds the number of asymptotical unstable modes, the backward Lyapunov vectors, of the dynamics. This behaviour is characteristic of methods based on the assimilation in the unstable subspace (AUS) in which the unstable modes are explicitly used in the analysis update. Yet, the backward Lyapunov vectors are not computed in the scheme of the IEnKS. This talk focuses on the connection between the IEnKS and AUS.The performance of the IEnKS will be analysed in relation with its ability to capture and use the unstable subspace.

MS Turbulent dispersion (MS24)
10 September 14.30–16.30 (PCC 2.4-2.6)

Time: 14.30 – 14.55

The dispersive nature of a meandering atmospheric plume and its impact on our sense of smell

Michael Borgas (CSIRO)

Abstract: An odour plume is often most important in light wind stable atmospheric boundary layers, whether the issue is an odour nuisance downwind of an industry or for an insect tracking pheromone plumes in a field. Our common practical models for turbulent dispersion are least suited to such conditions and poor estimates of impacts of chemical releases to the atmosphere are a consequence. Here we describe simple new models of Lagrangian dispersion which have meandering due to broken reflectional symmetry causing coupling of horizontal motions of turbulence and decoupling from much weaker vertical motions appropriate for stable conditions. We further input fluctuating Eulerian winds at the source to generate fine-scale plume fluctuations downwind. Energy spectra appropriate for a stable boundary layer but still with high Reynolds number are used. Model statistics like concentration distributions and complex images of meandering dispersion as well as the identification of a new control parameter for atmospheric dispersion are useful outputs.

MS Cardiac dynamics (MS21)
10 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.00 – 10.25

Comparison of two and four electrode defibrillators through a simple cardiac dynamical model

Jean Bragard (University of Navarra) Ana Simic (UNAV), Jorge Elorza (UNAV)

Abstract: Defibrillation is the standard clinical treatment used to terminate ventricular fibrillation. An electrical device delivers via a pair of electrodes a controlled amount of electrical energy in order to reestablish the normal heart rate. However, in order for the shock to be successful it is necessary to apply high energies, typically around 150 Joules for the transthoracic defibrillation. These high energy shocks have several side effects. There have been numerous attempts to reduce the defibrillation thresholds by, e.g., reversing the polarity of the shock during the defibrillation and optimizing the reversal time, waveform and duration of the shock. In this work we propose a new technique that is a combination of biphasic shocks applied with a four electrode system rather than the standard two electrode system. Here, we have used a numerical model to test and evaluate the gain that such new technique offers. The model consists of a one-dimensional ring of cardiac tissue. The electrical behavior of the cardiac tissue is modeled through the standard bidomain model and a modified Beeler-Reuter system of differential equations are used for modeling the active properties of the cell membrane. Here we have compared three different shock types, i.e., monophasic and two types of biphasic shocks. The results obtained by using a four electrode system are quantitatively compared with those obtained with the standard two electrode system. A drastic reduction in defibrillation threshold is achieved with the four electrode system. The mechanisms of successful defibrillation are also analyzed and they revealed that the advantage of biphasic shocks for the case of the four electrodes system lies behind the interplay of the duration of the cathodal and anodal phase of the shock.

MS Astrophysical and laboratory plasmas as testbeds for fundamental multiscale nonlinear processes (MS04)
7 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.30 – 10.55

Single- and multi-particle statistics of magnetohydrodynamic turbulence

Angela Busse (University of Glasgow) Jane Pratt (University of Exeter) and Wolf-Christian Müller (Technische Universität Berlin)

Abstract: Turbulence plays a fundamental role in many astrophysical flows such as convection in stars, stellar winds and the interstellar medium. Most astrophysical objects are composed of magnetised plasma. Astrophysical turbulence is thus characterised by the complex nonlinear interaction of flows with magnetic fields. Magnetohydrodynamic turbulence is known to differ significantly from standard hydrodynamic turbulence, especially in the presence of strong mean magnetic fields. The changes in the turbulence induced by the presence of magnetic fields can be observed in standard Eulerian diagnostics such as the energy spectra and the structure functions of the velocity field. They are even more clearly revealed in the Lagrangian statistics, which provide insight into the diffusive and dispersive flow dynamics and the relevant time scales in a turbulent flow. In this talk, statistical properties of homogeneous magnetohydrodynamic turbulence will be discussed with a focus on the Lagrangian perspective. New results will be presented for Lagrangian statistics based on both the motion of individual tracers as well as the relative motion of groups of particles.

MS Laser and complex dynamics (MS02)
7 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.20 – 11.37

Consistency and chaos synchronization in delay-coupled semiconductor lasers

Miguel Cornelles Soriano (IFISC (CSIC-UIB), University of the Balearic Islands)

Abstract: Semiconductor lasers are extremely sensitive to external perturbations and, as a result of the perturbations, these devices can exhibit complex nonlinear dynamics. In particular, delayed optical feedback or coupling is a common way to induce and/or control chaotic laser emission. The rich dynamical behaviour of delay-coupled semiconductor lasers has led to the development of novel applications ranging from secure communications to random bit generation [1]. In practice, several secure key distribution and communication protocols rely on the synchronization of two or more lasers operating in the chaotic regime. The major improvement in the quality of the experimental characterization of the chaotic emission of these devices has led to a better understanding of their synchronisation properties. In this contribution, I will present the existence of a clear link between the properties of chaos synchronization and consistency in the dynamics of semiconductor lasers with delayed optical feedback and delayed-coupling [2,3]. Importantly, I will show that the link between consistency and chaos synchronization boils down to the identification of strong and weak chaos regimes. For the strong chaos regime, the lasers do not respond consistently and synchronization cannot be reached. In contrast, for the weak chaos regime, the lasers are consistent and chaos synchronization is possible. Thus, weak chaos regime with a high degree of synchronization is desired for secure applications.
References: [1] M. C. Soriano, J. García-Ojalvo, C. R. Mirasso, and I. Fischer, "Complex photonics: Dynamics and applications of delay-coupled semiconductors lasers", Rev. Mod. Phys. 85, 421-470 (2013). [2] S. Heiligenthal, T. Jüngling, O. D'Huys, D. A. Arroyo-Almanza, M. C. Soriano, I. Fischer, I. Kanter, and W. Kinzel, "Strong and weak chaos in networks of semiconductor lasers with time-delayed couplings", Phys. Rev. E 88, 012902 (2013). [3] N. Oliver, T. Jüngling, and I. Fischer. "Consistency Properties of a Chaotic Semiconductor Laser Driven by Optical Feedback." Phys. Rev. Lett. 114, 123902 (2015).

MS Nonlinear dynamical aspect of data assimilation (MS12)
8 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.00 – 11.25

Towards a Stable Particle Filter in High-Dimensions

Dan Crisan (Imperial College London) Beskos, E (University College London) Jasra, A (National University of Singapore) Kamatani, K (Osaka University) Zhou, Y (National University of Singapore)

Abstract: I will discuss some variants of the standard bootstrap particle filter suitable for the numerical resolution of the filtering problem in high dimensions.

MS Problems when inferring networks from data (MS08)
7 September 16.30–18.30 (PCC 2.1-2.3)

Time: 17.00 – 17.25

Partial synchronization in oscillatory networks - estimating the (multi-dimensional) dynamics from data

Andreas Daffertshofer (VU University Amsterdam)

Abstract: The analysis of partial synchronization is a challenge. Partial synchronization is seminal for spatial heterogeneity and often implies ongoing, transient behavior. We approach this challenge by pre-clustering the node dynamics of large oscillatory networks. For this, a hierarchical clustering based on a distance measure for multivariate phases will be employed. Time series of the so-determined phase clusters will further serve to estimate their generating, usually multi-dimensional, nonlinear dynamics. Provided this dynamics obeys Markov properties, this estimate can be realized by determining Kramer-Moyal coefficients via the phase clusters' transition probability. This is illustrate using simulated Kuramoto-like networks with multi-modal frequency distributions, for which the clustering and its dynamics can be derived analytically, at least to great extent. As will be shown the approach can reveal these analytical results from the simulated data. Finally, we apply this approach to encephalographic with likewise multi-modal frequency distributions.
References: Hutt, Daffertshofer, & Steinmetz (2003) Physical Review E 68: 036219; doi: 10.1103/PhysRevE.68.036219 Anderson, Tenzer, Barlev, Girvan, Antonsen, & Ott (2012) Chaos 22: 013102; doi: 10.1063/1.3672513 Van Mourik, Daffertshofer, & Beek (2006) Physics Letters A 351: 13; doi: 10.1016/j.physleta.2005.10.066

MS Nonlinear dynamics of movement coordination and interpersonal interactions (MS16)
9 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.00 – 11.25

Phase to phase - how phase entrainment can affect amplitude in weakly nonlinear systems

Andreas Daffertshofer (VU University Amsterdam)

Abstract: The effect of amplitude on the phase dynamics in networks of (self-sustaining) oscillators has been well documented. In contrast, the effect of phase on the amplitude dynamics has largely been ignored. We briefly sketch the derivation of amplitude and phase dynamics in weakly nonlinear systems using conventional averaging techniques. As will be shown, the coupling between amplitudes is typically modulated by the relative phase between the oscillator units. We illustrate this using examples of coupled neural oscillators (Wilson-Cowan models and Freeman models) and link it to results of experimental observations in encephalographic studies. We also discuss implications of our results on crowd dynamics like walking in synchrony.
References: Daffertshofer & van Wijk, (2011) Front. Hum. Neurosci. 5: 6; doi: 10.3389/fn-inf.2011.00006 Ton, Deco, & Daffetshofer (2014), PLoS Comp. Biol. 10(7): e1003736; doi: 10.1371/journal.pcbi.1003736 Strogatz, Abrams, McRobie, Bruno Eckhardt, & Edward Ott (2005) Nature 438:43; doi:10.1038/438043a

MS Pattern formation (MS03)
7 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.00 – 10.25

Pattern formation in a model for dryland vegetation

Jonathan Dawes (University of Bath) J.L.M. Williams (University of Bath)

Abstract: We analyse the model for vegetation growth in a semi-arid landscape proposed by von Hardenberg et al [Phys. Rev. Lett. 87:198101, 2001], which consists of two parabolic partial differential equations that describe the evolution of the soil water content and the vegetation level. This model is a generalisation of one proposed by Klausmeier but it contains additional terms that capture additional physical effects. By considering the limit in which the diffusion of water in the soil is much faster than the spread of vegetation, we asymptotically reduce the system to a simpler parabolic- elliptic system of equations that describes small amplitude instabilities of the uniform vegetated state. We carry out a thorough weakly nonlinear analysis to investigate bifurcations and pattern formation in the reduced model. Pattern forming instabilities are subcritical except in a small region of parameter space. In the original model we find localised solutions, organised by homoclinic snaking bifurcations as is well known in other models for pattern forming systems. Together, our results describe how the von Hardenberg model displays a sequence of (often hysteretic) transi- tions from a non-vegetated state, to localised vegetation patches, to periodic patterns, to uniform vegetation, as the precipitation parameter increases.

MS Source buoyancy effects on plume and thermal flow (MS22)
10 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.30 – 10.55

Transient development of a thermal and a fire plume using integral models

M Delichatsios (Ulster University)

Abstract: We discuss the relevant integral conservation equations for a transient thermal plume amending a an earlier paper of mine (JFM pp 241-250,1979) and in light of the corrections and comparisons with that paper recently appeared in the Journal of Fluid Mechanics (Scase et.al and Van Reeuwijk et al, JFM 2012-2014). The critically discussed equation in the recent publications is the transient continuity equation which appears difficult to integrate over the radial direction because the transient term diverges. A plausible assumption made in the original paper appears to be not rigorous even though the results for similarity are still valid. We correct the derivation of the integral continuity equation by subtracting from it the derivative of the ambient density which is constant in a non-stratified ambient environment. This way there is no divergence of the transient term in the continuity equation. Subsequently by adding the integral continuity equation to the transient buoyancy (thermal energy) equation the transient terms of these equations are cancelled so that the transient continuity equation can be replace by an equation not containing transient terms whereas the momentum and buoyancy equation remain the same. We compare this development with the results in the recent publications where the continuity equation is replace by the mechanical energy equation (following Priestley and Ball . Q.J. of the Royal Meteorological society 1955). Finally we extend the analysis for a thermal plume by modifying the thermal energy equation either assuming that the heat of reaction is proportional to the air entrained or by using an additional equation of the conserved scalar mixture fraction together with its pdf distribution.

MS Problems when inferring networks from data (MS08)
7 September 16.30–18.30 (PCC 2.1-2.3)

Time: 17.30 – 17.55

Unsolved issues in the data-driven inference of weighted and directed networks

Henning Dickten (Department of Epileptology, University of Bonn) Christian E. Elger [1], Klaus Lehnertz [1,2,3] [1] Department of Epileptology, University of Bonn, Bonn, Germany [2] Helmholtz Institute for Radiation and Nuclear Physics, University of Bonn, Bonn, Germany [3] Interdisciplinary Center for Complex Systems, University of Bonn, Bonn, Germany

Abstract: Over the past decade, network theory has contributed significantly to improving our understanding of spatially extended, complex dynamical systems, with wide applications in diverse fields, ranging from physics to biology and medicine. For the inference of the functional network, knowing the properties of interactions between network constituents is essential. A large number of bivariate linear and nonlinear analysis techniques is available to characterize couplings from passive observations of the system's behavior, thus allowing a data-driven quantification of the strength and direction of an interaction. Nevertheless, there is a number of open issues that can lead to misinterpretations when inferring weighted and directed networks. We discuss some of these issues using the example of characterizing time-evolving interactions between brain regions using information-theoretic time series analysis techniques and point to possible solutions.
Supported by the Deutsche Forschungsgemeinschaft (Grant No: LE 660/5-2)

MS Time series, causality, networks and applications I (MS15)
9 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.00 – 10.25

Time Series, Causality, Networks and Applications

Cees Diks (University of Amsterdam) Wolski, M. (European Investment Bank)

Abstract: We propose an extension of the bivariate nonparametric Diks-Panchenko Granger causality test to multivariate settings. We first show that a direct generalization of the bivariate test statistic lacks consistency in the multivariate setting. This is the result of the kernel density estimator bias, which does not converge to zero at a sufficiently fast rate when the number of conditioning variables is larger than one. To overcome this difficulty we propose to apply data-sharpening for bias reduction prior to calculating the test statistic. We derive the asymptotic properties of the 'sharpened' test statistic and investigate its performance numerically. We conclude with an empirical application to the US grain market, using the price of futures on heating degree days as additional conditioning variable.

MS Structural model error in applied dynamics (MS07)
7 September 16.30–18.30 (PCC 2.4-2.6)

Time: 18.00 – 18.25

Data Assimilation Designed for Imperfect Model(s)

Hailiang Du (University of Chicago) L.A. Smith (London School of Ecomomics)

Abstract: Data assimilation and state estimation for nonlinear dynamical models is a challenging task mathematically. Performing this task in real time is even more challenging as the models are imperfect: the mathematical system that generated the observations (if such a thing exists) is not a member of the available model class. To the extent that traditional approaches address structural model error at all, most fail to produce consistent treatments. This results in questionable estimates both of the model state and of its uncertainty. Pseudo-orbit based data assimilation (PDA) provides an attractive, alternative approach to produce more consistent estimates of the model state and to estimate the (state-dependent) model error simultaneously. Empirical results demonstrate improved performance over that of the two main traditional approaches of data assimilation (Ensemble Kalman Filter and four-dimensional variational assimilation). Applications of PDA in delay coordinates based model as well as in the partial observations cases are explored. The potential use of PDA for locating longer shadowing trajectories (model trajectories being consistent with observations) and integrating dynamical information from multiple models in time are discussed.

MS Localisation mechanisms in shear flows (MS09)
8 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.00 – 10.25

Localized transitions to turbulence in shear flows

Bruno Eckhardt (Philipps-University Marburg) Zammert, S (U Marburg) Duguet, Y (LIMSI Paris) Khapko, T (KTH Stockholm) Kreilos, T (EPF Lausanne) Schlatter, P (KTH Stockholm) Henningson, DS (KTH Stockholm)

Abstract: Much of our understanding of the transition to turbulence in flows without a linear instability came with the discovery and characterization of fully three-dimensional solutions to the Navier-Stokes equation. The first examples in plane Couette flow were periodic in both spanwise and streamwise direction, and could explain the transitions in small domains only. The presence of localized turbulent spots in larger domains, the spatio-temporal decoherence on larger scales and the ability to trigger turbulence with pointwise perturbations requires solutions that are localized in both directions. By now, we have numerous examples of states that are localized in the downstream or spanwise or both directions, in pipe flow and other internal flows, as well as boundary layers. Building on this ensemble of states common features can be identified and open questions formulated.

MS Turbulent dispersion (MS24)
10 September 14.30–16.30 (PCC 2.4-2.6)

Time: 15.30 – 15.55

Adaptive stochastic trajectory modelling

Gavin Esler (University College London)

Abstract: Lagrangian models of aerosol, trace gas and pollutant dispersion are tools of great importance in many branches of climate science. The effects of unresolved atmospheric (or oceanic) turbulence can be represented in such models by a stochastic term. The subject of this talk will be to investigate the extent to which, if such models are formulated as stochastic differential equations, importance sampling techniques from mathematical finance and stochastic physics can be adapted to enhance their efficiency. Specifically, a practical importance sampling algorithm, based on Grassberger's 'go-with-the-winners' branching process is described in detail. A model transport problem in a chaotic advection flow is investigated, and it is demonstrated that the algorithm can improve the efficiency of a transport calculation, in the case where the direct flow between the source and receptor locations is weak, by two orders of magnitude or more. The key to success is to use information from a back trajectory calculation to help select the 'winners' (i.e. chosen particles) in the forward calculation. Applications to realistic transport problems in boundary layers are discussed.

MS Mathematical models of anomalous diffusion (MS10)
8 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.30 – 10.55

Anomalous random walk and nonlinear fractional PDE's

Sergei Fedotov (The University of Manchester)

Abstract: Linear fractional equation involving a Riemann-Liouville derivatives is the standard model for the description of anomalous subdiffusive and superdiffusive transport of particles. The question arises as to how to extend this fractional PDE for the nonlinear case involving particles interactions. The talk will be concerned with the nonlinear fractional PDE's and aggregation phenomenon.

MS Delay-equations for optoelectronic systems (MS05)
7 September 16.30–18.30 (PCC 1.1-1.3)

Time: 17.30 – 17.55

State-dependent delay dynamics in a semiconductor laser system

Ingo Fischer (IFISC (UIB-CSIC)) Jade Marínez-Llinàs, IFISC (UIB-CSIC) Xavier Porte, IFISC (UIB-CSIC) Miguel C. Soriano, IFISC (UIB-CSIC) Pere Colet, IFISC (UIB-CSIC)

Abstract: Optical systems, and in particular semiconductor laser systems, have proven excellent to study the influence of delays in feedback and coupling under well-controlled conditions [1]. Such studies have actually boosted the interest in delay systems. Moreover, the gained insights and the good control over such systems have in recent years been inspiring applications, harnessing delay-induced properties. In a number of systems, the delays can depend on the state of the system. Although there have been a number of mathematical investigations, the understanding of the impact of state-dependent delays remains poor with a particular lack of systematic experimental studies. In this contribution, we present a semiconductor laser system, allowing to study the influence of state-dependent delay [2]. We introduce a conceptually simple semiconductor laser system exhibiting dynamics of self-organised switching between two delay loops with different delay times, depending on the system's state. We present experiments and modelling, characterizing the state-dependent switching. Finally, we provide perspectives for the study of state-dependent delay systems.
References: [1] M.C. Soriano, J. García-Ojalvo, C.R. Mirasso, I. Fischer, Rev. Mod. Phys. 85, 421-470 (2013). [2] Jade Martínez-Llinàs, Xavier Porte, Miguel C. Soriano, Pere Colet, and Ingo Fischer, accepted for publication in Nature Communications (2015).

MS Delay-equations for optoelectronic systems (MS05)
7 September 16.30–18.30 (PCC 1.1-1.3)

Time: 17.00 – 17.25

New trends for lasers subject to a delayed optical feedback

Gaetan Friart (Université Libre de Bruxelles) Thomas Erneux (Université Libre de Bruxelles)

Abstract: Nonlinear delay dynamics have found during the last decade a prolific area of research in the field of photonic devices. The popular external cavity semiconductor laser (SL) where the light coming from the laser is reflected back into the laser after a substantial delay is a particularly attractive dynamical system. It has led to a variety of applications including all-optical, high-frequency, sources of light, new imaging techniques based on its sensitivity to feedback, and secure communication schemes based on chaos. Two new setups have recently appeared, namely, SLs subject to Polarization Rotated Optical Feedback (PROF) and Quantum Cascade Lasers (QCL). In a laser subject to PROF, light is re-injected in the weak TM mode leaving the TE mode free of perturbations. The laser exhibits square-wave oscillations which we investigate both theoretically and experimentally. They emerge from distinct Hopf bifurcation points and are characterized by period close to $P_n = 2\tau/(1+2n)$ $(n = 0, 1, 2, ..)$ where τ is the delay of the feedback. By contrast, QCLs are known to be highly tolerant to optical feedback and are used as new sensing devices. From the laser rate equations, we determine the first Hopf bifurcation in the limit of large delays. As a result, we obtain a simple expression that provides a useful threshold for instabilities in terms of the feedback rate.

MS Pattern formation (MS03)
7 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.40 – 11.57

Experimental Pattern to Pattern transitions in the Chlorine Dioxide-Iodine- Malonic Acid reaction with Halide Addition

Delora Gaskins (Brandeis University) Pruc, E. E. (Brandeis University) Dolnik, M. (Brandeis University) Epstein, I.R. (Brandeis University)

Abstract: Alan Turing predicted that stationary patterns with finite wavelength could form as a result of the processes of reaction and diffusion breaking the symmetry of a uniform unstable steady state. Turing patterns can have different morphologies and beyond the Turing instability, there exist spatially periodic states with different wavelengths. Pattern to pattern transitions are of interest in reaction-diffusion systems including ecological systems with patterned biomass prone to desertification. We investigate pattern transitions experimentally in the chlorine dioxide-iodine-malonic acid (CDIMA) system which is the prototypical system for the study of Turing patterns in chemical systems. Additions of selected halides have led to increases in pattern wavelengths by up to a factor of four greater than the original pattern wavelength. Spatiotemporal patterns achieved via this perturbation can transition back to shorter wavelength patterns when the perturbation is removed. In the quasi two dimensional reactor, superlattice structure formation is observed as a result of the transition from larger wavelength to smaller wavelength patterns. We report our progress in investigating the pattern to pattern transitions that are due to halide addition, including the formation of superlattice structures.

MS Time series, causality, networks and applications II (MS18)
9 September 16.30–18.30 (PCC 2.4-2.6)

Time: 17.00 – 17.25

Identifying important nodes in epileptic brain networks

Christian Geier (University of Bonn) Christian E. Elger (University of Bonn, Germany) Klaus Lehnertz (University of Bonn, Germany)

Abstract: Network analysis has recently emerged as a powerful tool for investigating extended dynamical systems in diverse scientific fields. Previous studies have successfully utilized network analysis for an improved characterization of functional networks in the human epileptic brain. Here, we investigate the importance of various nodes in epileptic brain networks for initiation, maintenance, and termination of seizures. For this purpose we derive weighted, functional networks from intracranial, multi-channel, long-term, electroencephalographic data in a time resolved manner with a sliding window approach. We then assess importance of brain regions (considered as nodes) via different centrality metrics. We will show when and under which network construction parameters different nodes can be regarded as most important for seizure dynamics.

MS Nonlinear and stochastic dynamics in weather and climate science (MS20)
9 September 16.30–18.30 (PCC 1.1-1.3)

Time: 18.00 – 18.25

The Wind-Driven Ocean Circulation: Bifurcations, Simulations and Observations

Michael Ghil (Ecole Normale Supérieure, Paris, and University of California, Los Angeles)

Abstract: The large-scale, near-surface flow of the mid-latitude oceans is dominated by the presence of a larger, anticyclonic and a smaller, cyclonic gyre. The two gyres share the eastward extension of western boundary currents, such as the Gulf Stream or Kuroshio, and are induced by the shear in the winds that cross the respective ocean basins. The boundary currents and eastward jets carry substantial amounts of heat and momentum; the jets also contribute to mixing in the oceans by their "whiplashing" oscillations and the detachment of eddies from them. We study the low-frequency variability of the wind-driven, double-gyre circulation in mid-latitude ocean basins, subject to time-constant or purely periodic wind stress. Both analytical and numerical methods of nonlinear dynamics are applied in this study. Symmetry-breaking bifurcations occur, from steady to periodic and aperiodic flows, as wind stress increases or dissipation decreases. The first bifurcation is of pitchfork or perturbed-pitchfork type, depending on the model's degree of realism. Oscillatory instabilities arise by supercritical Hopf bifurcation, with periods from a few months to a few years. Numerical evidence points to homoclinic orbits that connect high- and low-energy branches of steady-state solutions and induce interdecadal variability. These results are shown to be robust across a full hierarchy of models - quasi-geostrophic, shallow-water, and primitive-equation ones - including multi-layer and eddy-resolving ocean models. Coupled ocean-atmosphere models show the basin-scale variability to be still dominated by the intrinsic ocean variability. High resolution is necessary in the atmospheric component of these models in order to allow for proper coupling of the intraseasonal variability with the interannual one. Given such resolution, we obtain a promising explanation of the North Atlantic Oscillation. The results are compared with decade-long in situ and more recent, satellite observations of three ocean basins, the North and South Atlantic, and the North Pacific. Based on this comparison, we discuss what is and isn't known about the role of the oceans in climate variability. This talk reflects collaborative work with a large and still increasing number of people. Please visit http://www.atmos.ucla.edu/tcd/ for their names, affiliations, and respective contributions.

MS Astrophysical and laboratory plasmas as testbeds for fundamental multiscale non-linear processes (MS04)

7 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.40 – 11.57

Magnetic reconnection and particle acceleration in twisted coronal loops

Mykola Gordovskyy (University of Manchester) P.K.Browning (University of Manchester), R.Pinto (Paris Observatory, Meudon), M.Bareford (University of Edinburgh, and E.P.Kontar (University of Glasgow)

Abstract: Consistent modelling of solar flares involving both thermal and non-thermal aspects is essential for interpretation of multi-spectral observational data. We discuss our recent results on the energy release and particle acceleration during magnetic reconnection in unstable twisted coronal loops. Evolution of various helical structures is described in terms of resistive MHD, including heat conduction and radiation. We consider the effects of field topology and photospheric motions on the energy accumulation and release. In particular, we focus on scenarios with continuous helicity injection, leading to recurrent explosive events. Using the obtained MHD models, ion and electron acceleration is investigated, taking into account Coulomb collisions. We derive time-dependent energy spectra and spatial distribution for these species, and calculate resulting non-thermal radiation intensities. Based on the developed numerical models, we investigate observational implications of particle acceleration in helical magnetic structures. Thus, we compare temporal variations of thermal and non-thermal emission in different configurations. Furthermore, we consider spatial distributions of the non-thermal hard X-ray emission and compare them with observational data.

MS Pattern formation (MS03)
7 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.20 – 11.37

Stable patterns with jump discontinuity in systems with Turing instability and hysteresis

Steffen Härting (University of Heidelberg)

Abstract: Classical models of pattern formation are based on diffusion-driven instability (DDI) of constant stationary solutions of reaction-diffusion equations, which leads to emergence of stable, regular Turing patterns formed around that equilibrium. In this talk we show that coupling reaction-diffusion equations with ordinary differential equations (ODE) may lead to a novel pattern formation phenomenon, in which DDI causes destabilization of both constant solutions and Turing patterns. Bistability and hysteresis effects in the null sets of model nonlinearities yield formation of patterns with jump discontinuity far from the equilibrium. Specifically, we investigate the hysteresis-driven pattern formation in a model with DDI using an example of two-component model of receptor-ligand binding. We give conditions for stability of stationary solutions with jump discontinuity in a suitable topology. The proposed model provides an example of a mechanism of de novo formation of patterns far from the equilibrium in reaction-diffusion-ODE models involving co-existence of DDI and hysteresis. The talk is based on joint research with A. Marciniak-Czochra (University of Heidelberg) and I. Takagi (Tohoku University).

MS Laser and complex dynamics (MS02)
7 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.40 – 11.57

Nonlinear dynamics and wave chaos in two-dimensional microcavity

Takahisa Harayama (Waseda University) Satoshi Sunada(Kanazawa University), Susumu Shinohara(NTT Communication Science Laboratories), and Takehiro Fukushima(Okayama Prefectural University)

Abstract: Around these two decades, morphological effects of optical microcavities on their optical properties have been investigated both theoretically and experimentally. Actually, arbitrary shapes of optical microcavities can be made by technologies developed for semiconductor and plastic devices. Ray and wave dynamics in microcavities are similar to particle dynamics in billiards, which have extensively been studied as ergodic and quantum theories in mathematics and physics. It has been shown that particle dynamics in certain shapes of billiards is chaotic and eigenfunctions of quantum stationary states are very complex like turbulence and uniformly distributed. Those microcavity lasers in which ray dynamics is chaotic are called chaotic billiard lasers, two-dimensional (2D) microcavity lasers, deformed microcavity lasers, or asymmetric resonant cavity lasers. In addition to the nonlinearity of the cavity shape, chaotic billiard lasers have the nonlinearity of the active lasing media which cause the interaction among resonance wave functions. We show a rich variety of complex dynamical behaviors of interacting resonance wave functions as well as chaotic ray trajectories and turbulent wave functions. We also show that chaotic billiard lasers are useful for compact design of optical delay line and make it possible to implement delayed feedback laser chaos systems in small optical circuits.

MS Nonlinear dynamics on lattices (MS06)
7 September 16.30–18.30 (PCC 1.4-1.6)

Time: 17.00 – 17.25

Asymptotic formulas for the high-energy limit of FPU-type chains

Michael Herrmann (University of Muenster) Karsten Matthies (University of Bath)

Abstract: It is well established that the high-energy limit of FPU 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. We also discuss the implications concerning the uniqueness and the stability of traveling waves.

MS Astrophysical and laboratory plasmas as testbeds for fundamental multiscale non-linear processes (MS04)

7 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.20 – 11.37

Ion heating in magnetotail reconnection jets

Heli Hietala (Imperial College London) Drake, J. F. (University of Maryland, USA); Phan, T. D. (Space Science Laboratory, University of California, Berkeley, USA); Eastwood, J. P. (Imperial College London, UK); McFadden, J. P. (Space Science Laboratory, University of California, Berkeley, USA)

Abstract: Magnetic reconnection redistributes energy by releasing magnetic energy into plasma kinetic energy - high speed bulk flows, heating, and particle acceleration. Fast jets are a key signature of reconnection in *in situ* observations, while remote observations concentrate on energetic particles. To understand the energy budget, though, we need to consider heating as well. A significant portion of the energy released by reconnection in the Earth's magnetotail appears to go into ion heating. Furthermore, the heating is anisotropic with the plasma temperature parallel to the magnetic field generally increasing more than the perpendicular temperature. Simulations and theory indicate that this temperature anisotropy can balance part of the magnetic tension force that accelerates the jet, and may even exceed it leading to firehose instability. We examine ARTEMIS dual-spacecraft observations of a long-duration magnetotail exhaust generated by anti-parallel reconnection in conjunction with Particle-In-Cell simulations, showing spatial variations in the anisotropy across the outflow far downstream (> 100 ion inertial lengths) of the X-line. A consistent pattern is found in both the spacecraft data and the simulations: whilst the total temperature across the exhaust is rather constant, near the boundaries the parallel temperature dominates. The plasma is well-above the firehose threshold in portions of the exhaust, suggesting that the drive for the instability is strong and the instability is too weak to relax the anisotropy. In contrast, the perpendicular temperature dominates at the mid-plane, indicating that (1) the increase in perpendicular heating is not simply the result of scattering, and (2) despite the large distance to the X-line, particles undergo Speiser-like motion. We also analyse the characteristics of the particle distributions leading to these anisotropies at different distances from the mid-plane.

MS Laser and complex dynamics (MS02)
7 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.30 – 10.55

Spiking Patterns in Vertical Cavity Surface Emitting Lasers for Neuromorphic Photonic Systems

Antonio Hurtado (University of Strathclyde)

Abstract: Photonic approaches emulating the powerful computational features of biological neurons are receiving increasing research interest for novel ultrafast neuromorphic information processing systems [1-4]. One of these techniques considers the use of Semiconductor Lasers (SLs), as these devices can produce a rich variety of dynamical responses similar to those observed in biological neurons but at much faster time-scales [5-7] (up to 9 orders of magnitude faster). Amongst SLs, Vertical Cavity Surface Emitting Lasers (VCSELs) are ideal candidates for novel photonic neuronal models given their inherent advantages, i.e. lower manufacturing costs, ease to integrate in 2D arrays, etc. Nevertheless, in spite of these interesting features, it is only recently that the use of VCSELs for neuromorphic photonic systems has started to receive attention. The emulation of neuronal responses using the polarization switching dynamics in optically-injected VCSELs has been recently reported [1]. Also, the firing of self-generated [6] and controllable [7] excitable spikes has been observed in VCSELs and the use of these features for all-optical data storage has been proposed [2]. Furthermore, controllable spike firing in a VCSEL under different polarized optical injection scenarios has been predicted theoretically [4]. In this work, we report a first experimental observation of the controlled firing of different spiking patterns at sub-nanosecond operation speeds, including single and multiple spiking and bursting responses in a long-wavelength VCSEL subject to either parallel- or orthogonally-polarized optical injection in response to induced perturbations. The achievement of controllable spiking responses in VCSELs operating at 1310 nm, a very important wavelength in optical communications over silica fibers, offers exciting prospects for the use of these devices in novel ultrafast neuromorphic photonic systems for applications in non-traditional computing paradigms and optical communication networks.
References: 1. A. Hurtado, K. Schires, I.D. Henning and M.J. Adams, Investigation of vertical cavity surface emitting laser dynamics for neuromorphic photonic systems, in Appl. Phys. Letts. 100, 103703 (2012) 2. B. Garbin, J. Javaloyes, G. Tissoni and S. Barland, Topological solitons as addressable phase bits in a driven laser, in Nat. Commun., 6, 5915 (2015) 3. R. Al-Seyab, I.D. Henning, M.J. Adams and A. Hurtado, Controlled single-and multiple-pulse excitability in VCSELs for novel spiking photonic neurons, IEEE International Semiconductor Laser Conference, 165-166 (2014) 4. A.N. Tait, M.A. Nahmias, Y. Tian, B.J. Shastri and P.R. Prucnal, Photonic neuromorphic signal processing and computing, Nanophotonic Information Physics, Springer, 183-222 (2014) 5. S. Wieczorek, B. Krauskopf and D. Lenstra, Multipulse excitability in a semiconductor laser with optical injection, Phys. Rev. Lett. 88, 063901 (2002) 6. K. Schires, A. Hurtado, I.D. Henning and M.J. Adams, Rare disruptive events in the polarisation-resolved dy-

namics of optically-injected 1550nm-VCSELs, in Electron. Letts., 48, 872 (2012) 7. M Turconi, B Garbin, M Feyereisen, M Giudici, S Barland, Control of excitable pulses in an injection-locked semiconductor laser, Phys. Rev. E 88, 022923 (2013)

MS Coupling functions - theories and applications (MS23)
10 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.30 – 11.55

Coupling functions between brain waves: Significance of opened/closed eyes

Lal Hussain (University of Azad Jammu and Kashmir)

Abstract: The complex neuronal oscillations can be investigated using nonlinear dynamical analysis. The intrinsic brain dynamics in Electroencephalography (EEG) with eye - closed (EC) and eye open (EO) during resting states can be used to investigate the changes in brain complexity i.e. simple visual processing which are associated with increase in global dimension complexity. In order to study these changes in EEG, we will compute the coupling to see the inhibitory interneurons response and inter-regions functional connectivity differences between the eye conditions. The alpha activity i.e. predominant posterior oscillations are prominent characteristics in human EEG during the resting state. As the information promulgate in different brain regions through convergence and divergence of oscillatory behaviour. This information flow can be processed and analysed in form of Cross-frequency Coupling (CFC) and multi-frequency behaviour. Our aim is to compute different CFC and to check their applicability in multichannel resting state EEG to determine that which brain regions are affected by power modulations of alpha rhythms and CFC. We will investigate the fluctuations in EEG activities in low and high frequency brain oscillations. Coupling will be estimated using Dynamic Bayesian inference approach which can effectively detect the phase connectivity subject to the noise within a network of time varying coupled phase oscillators. Using this approach, we will see that which CFC measure will be dominant in resting state EEG and applicable to multivariate network oscillator.

MS Self-organizing effects in complex (dusty) plasmas (MS19)
9 September 16.30–18.30 (PCC 1.4-1.6)

Time: 18.00 – 18.25

Statistical mechanics for nonreciprocal forces

Alexei Ivlev (Max Planck Institute) Bartnick, J (Heinrich-Heine-Universitaet, Duesseldorf, Germany), Heinen, M (Heinrich-Heine-Universitaet, Duesseldorf, Germany), Du, C-R (Donghua University, Shanghai, People's Republic of China), Nosenko, V (Deutsches Zentrum für Luft- und Raumfahrt, Wessling, Germany), Loewen, H (Heinrich-Heine-Universitaet, Duesseldorf, Germany)

Abstract: There is a variety of situations in which Newton's third law is violated. Generally, the action-reaction symmetry can be broken for mesoscopic particles, when their effective interactions are mediated by a nonequilibrium environment - prominent examples include complex plasmas and colloidal dispersions. We have investigated different classes of nonreciprocal interactions relevant to real experimental situations, and performed their basic statistical mechanics analysis [1]. We rigorously showed that in certain cases systems with nonreciprocal interactions, being intrinsically nonequilibrium, can nevertheless be described in terms of equilibrium statistical mechanics and exhibit detailed balance with distinct temperatures for each species. Our results have profound implications, in particular, demonstrating the possibility to generate extreme temperature gradients on the particle scale. We verify the principal theoretical predictions in experimental tests performed with two-dimensional binary complex plasmas.
Reference: [1] A. V. Ivlev, J. Bartnick, M. Heinen, C.-R. Du, V. Nosenko, and H. Löwen, Statistical Mechanics where Newton's Third Law is Broken, Phys. Rev. X 5, 011035 (2015).

MS Nonlinear dynamics on lattices (MS06)
7 September 16.30–18.30 (PCC 1.4-1.6)

Time: 16.30 – 16.55

Solitary waves in the Burridge-Knopoff model

Guillaume James (INRIA Grenoble Rhône-Alpes) Morales, J.E. (INRIA Grenoble Rhône-Alpes) Tonnelier, A. (INRIA Grenoble Rhône-Alpes)

Abstract: The Burridge-Knopoff model is a lattice differential equation describing a chain of blocks connected by springs and pulled over a surface. This model incorporates a nonlinear velocity-dependent friction force between the blocks and the fixed surface. For some classes of non-monotonic friction forces, this system displays a large response to perturbations above a threshold, which is characteristic of excitable dynamics. In some parameter regimes, this response corresponds to the propagation of a solitary wave. We introduce a simplified piecewise linear friction law (reminiscent of the McKean nonlinearity in spiking neuron models) which allows us to prove the existence of large amplitude solitary waves and study their qualitative properties.

MS Time series, causality, networks and applications II (MS18)
9 September 16.30–18.30 (PCC 2.4-2.6)

Time: 16.30 – 16.55

Dynamical profile of connectivity changes of ictal epileptic networks

Radek Janca (Czech Technical University in Prague) Cmejla, R (Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic), Jezdik, P (Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic), Palus, M (Institute of Computer Science, Czech Academy of Science, Czech Republic), Hlinka, J (Institute of Computer Science, Czech Academy of Science, Czech Republic), Krsek, P (2nd Faculty of Medicine, Charles University in Prague, Motol University Hospital, Czech Republic), Marusic, P (2nd Faculty of Medicine, Charles University in Prague, Motol University Hospital, Czech Republic) and Jiruska, P (Institute of Physiology, Czech Academy of Science, Czech Republic)

Abstract: How seizures emerge from the abnormal dynamics of epileptic networks is still not clear. To elucidate the mechanisms of seizure initiation and progression it is necessary to understand the complex interaction between the individual network components and to identify the critical ones. Recent studies have demonstrated dynamical reconfiguration of functional network connectivity at the onset of the seizure, particularly within the seizure onset area. In this study we have explored the functional connectivity changes in invasive recordings from candidates of epilepsy surgery who were implanted with intracranial electrodes. For the purpose of this study we have developed a novel method based on multivariate directed transfer function (DTF) estimation, which is characterized by higher temporal resolution and improved statistical reliability when compared to traditional DTF techniques. Application to intracranial data enabled determination of the a priori probability of seizure connectivity and information flow changes in respect to the pre-seizure state. Seizure onset and early parts of the seizures were associated with a decrease in average connectivity mainly in the gamma and fast gamma frequency bands. These changes were observed mainly in channels which were marked by clinicians as seizure onset zones. Seizure onset was also accompanied by a mild increase of in-flow energy from the areas surrounding the seizure onset zone. During advanced seizure stages, areas outside seizure onset zone were characterized by an increase in connectivity strength and spatial coherence. The observed results suggest that seizure onset is characterized by disconnection of the seizure onset zone from the rest of the network. Activation of the surrounding network areas may represent the feedback mechanism to control the pathological seizure activity and its spatial expansion. In addition, connectivity metrics may be utilized to better localize the seizure onset zone during the presurgical examination. Supported by grants from Neuron Fund for Support of Science (NFKJ 001/2012), Ministry of Health of the Czech Republic (IGA MZ CR NT/14489-3, NT/13357-4) and Czech Science Foundation (14-02634S).

MS Soft matter under control: pattern formation and transport (MS17)
9 September 16.30–18.30 (PCC 2.1-2.3)

Time: 18.00 – 18.25

Feedback control of one-dimensional colloidal transport

Sabine Klapp (Institute of Theoretical Physics, Technical University Berlin) Gernert, R. (TU Berlin) Loos, S. (TU Berlin) Lichtner, K. (TU Berlin)

Abstract: Within the last year, feedback control of colloidal transport has become a focus of growing interest. Here we present recent work on feedback control of one-dimensional colloidal systems, both with instantaneous feedback and with time delay. Topics include the reversal of current and the emergence of current oscillations, the enhancement of transport in ratchet systems, and the supression of density fluctuations by a co-moving trap. We also discuss the treatment of interactions between the colloidal particles via (dynamical) density functional theory. Finally, we make contact to recent work on the (non-equilibrium) thermodynamics of systems under feedback control.

MS Turbulent dispersion (MS24)
10 September 14.30–16.30 (PCC 2.4-2.6)

Time: 16.00 – 16.25

Supersonic, compressible turbulence - The influence of a varying density field

Lukas Konstandin (University of Exeter) Schmidt, W. (University of Goettingen) Girichidis, P. (Max-Planck Institute for Astrophysics, Garchingen) Federrath, C. (The Australian National University) Klessen, R. S. (University of Heidelberg)

Abstract: The space in between stars is filled with a dilute mixture of charged particles, atoms, molecules and dust, called the interstellar medium (ISM). Observations reveal that the ISM is highly turbulent and characterised by complex structure on all resolvable spatial scales. The ISM is the primary galactic repository out of which stars are born and into which they deposit energy, momentum and enriched material as they die. While common terrestrial flows are incompressible, astrophysical flows are highly supersonic and compressible. We present a systematic study of the influence of different forcing types on the statistical properties of supersonic, isothermal turbulence in both the Lagrangian and Eulerian frameworks. We analyse a series of high-resolution, hydrodynamical grid simulations with Lagrangian tracer particles and examine the effects of solenoidal (divergence-free) and compressive (curl-free) forcing on structure functions, their scaling exponents, and the probability density functions of the gas density.

MS Time series, causality, networks and applications I (MS15)
9 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.30 – 10.55

Discrimination of dynamical states from causality networks

Dimitris Kugiumtzis (Aristotle University of Thessaloniki) Elsa Siggiridou, Christos Koutlis and Alkiviadis Tsimpiris

Abstract: The detection of structural changes in time series is a timely research topic in many different areas ranging from neuroscience to finance. In the recent years, the interest has been focused on multivariate time series, and the structural change is investigated in the coupling structure of the observed variables. The rationale is that the coupling structure determines the dynamical state of the multivariate system. The study deals with the problem of identifying changes in the coupling structure in three stages. In the first stage, the Granger causality for each couple of variables, accounting for the presence of the other observed variables, is estimated. Among different measures, we found that the most appropriate is an information based measure for Granger causality called partial mutual information from mixed embedding (PMIME) [1,2]. PMIME has the advantage of being able to detect direct causal effects in the presence of many inter-related variables. In the second stage, the causality network is formed, where the nodes are the observed variables and the directed connections are the PMIME values (or the zero-one values for zero or positive PMIME). Further, different characteristics of the network (of binary or weighted connections) are quantified by network indices [3]. In the third stage, the network indices are computed for different multivariate time series, typically obtained from sliding windows on a time series record. Statistical tools are then used to assess the presence of structural change and thus discriminate different dynamical states of the underlying system. We demonstrate this procedure on a synthetic example, the coupled Mackey-Glass system of many variables, and two real examples, scalp multi-channel epileptic EEG records and records of many indices of the US stock market.
References: [1] I. Vlachos and D. Kugiumtzis. Non-uniform state space reconstruction and coupling detection. Physical Review E, 82:016207, 2010. [2] D. Kugiumtzis. Direct-coupling information measure from nonuniform embedding. Physical Review E, 87:062918, 2013. [3] D. Kugiumtzis and V. K. Kimiskidis. Direct causal networks for the study of transcranial magnetic stimulation effects on focal epileptiform discharges. International Journal of Neural Systems, 25:1550006, 2015.

MS Nonlinear and stochastic dynamics in weather and climate science (MS20)
9 September 16.30–18.30 (PCC 1.1-1.3)

Time: 16.30 – 16.55

Data-driven stochastic modelling of unresolved scales in weather and climate science

Frank Kwasniok (University of Exeter)

Abstract: The dynamics of weather and climate encompass a wide range of spatial and temporal scales. Owing to the nonlinear nature of the governing equations the different scales are dynamically coupled with each other. Finite computational resources limit the spatial resolution of weather and climate prediction models; small-scale processes such as convection, clouds or mesoscale ocean eddies are not properly represented. The necessity arises to account for unresolved scales and processes through the use of some form of subgrid modelling. This is usually referred to as a closure in fluid dynamics and theoretical physics, and as a parametrization in meteorology and climate science. A data-based stochastic modelling strategy for parametrization of unresolved scales and processes is used. The subgrid-scale model is conditional on the state of the resolved scales, consisting of a collection of local models. A clustering algorithm in the space of the resolved variables is combined with statistical modelling of the impact of the unresolved variables. The clusters and the parameters of the associated subgrid models are estimated simultaneously from data. The ideas are explored in a hierarchy of systems ranging from the Kac-Zwanzig model to the Lorenz 1996 system, to a realistic model of large-scale atmospheric flow. The stochastic low-order models exhibit high predictive skill and are able to reproduce in a long-term simulation important summary statistics of the full system.

MS Nonlinear dynamics of movement coordination and interpersonal interactions (MS16)
9 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.00 – 10.25

Looking for patterns in dyads movements: Direct and less direct application of the HKB model

Julien Lagarde (Euromov M2H, University Montpellier)

Abstract: The aim of this talk is to present an experimentalist vision of the research that has been given momentum by the the HKB model and its empirical origin, the discovery of phase transitions in human brain and behavior. I will introduce milestones introduced since the HKB model was first proposed. The talk will cover some of those developments that emphasize human brain plasticity and its capacity to produce a multiplicity of responses. This relates to results obtained in the study of learning. In addition, the recently observed limitations to basic capacity like synchronization of movement to a beat, may call into question the assumed architecture(s) behind once thought generic phenomena. My conclusions may drive me to point at the need of theoretically driven taxonomies of human behaviour.

MS Delay-equations for optoelectronic systems (MS05)
7 September 16.30–18.30 (PCC 1.1-1.3)

Time: 16.30 – 16.55

Patchy Space with Diffusion

Laurent Larger (FEMTO-ST / Univ. Franche-Comte) Chembo, Y.K (FEMTO-ST, CNRS) Jacquot, M. (FEMTO-ST, Univ. Franche-Comte) Erneux, T. (Univ. Libre Bruxelles) Maistrenko, Y. (NAS Kiev)

Abstract: In this talk we will propose to describe various experiments, togeher with their modeling from a signal processing viewpoint. Particular emphasis will be given to specific modeling features, which have been initially driven by technological constrains imposed by application driven research, which have however also led to new fundamental phenomena. The talk will scan various applications (emphaiszing on the modeling issues essentially) which have been explored during the past 20 years, from optical chaos communications to currenty emerging brain-inspired computing approaches, through ultra-pure microwave generation for Radar applications. We also report in each how the applications have led to the finding of novel dynamical phenomena in delay systems, such as chaotic breathers, Neymark-Sacker bifurcation, and more recently chimera states.

MS Controlling complex networks: interplay of structure, noise, and delay (MS13)
9 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.00 – 11.25

Chimera states in laser delay dynamics: experiment and modeling

Laurent Larger (University of Franche-Comte, FEMTO-ST / Optics Dept.) Bogdan Penkovsky Franche-Comte, France) and Yuri Maistrenko (Institute of Mathematics and Center for Medical and Biotechnical Research, Ukraine)

Abstract: Chimera states is essentially explored in spatio-temporal dynamical systems made of usually non-locally coupled identical oscillators. Through the space-time analogy of delay dynamics, we have extended the occurrence of these chimera states to delay differential equations. Sustained complex spatio-temporal patterns showing stable coexistence of chaotic oscillation next to constant amplitudes have been observed, both numerically and experimentally under particular configurations (integro-differential delay dynamics, and positive delayed feedback with asymmetric non linearities). A particularly rich and organized structure of the parameter space has been also found for the domain of existence for multiple-headed chimera states. Finally, a finer analysis of the model through tools picked from signal theory, even allowed to formulate the equation of motion in a very similar way compared to the well known of coupled Kuramoto oscillator configuration.

MS Self-organizing effects in complex (dusty) plasmas (MS19)
9 September 16.30–18.30 (PCC 1.4-1.6)

Time: 17.30 – 17.55

Synchronization in two-dimensional plasma crystals

Couedel Lenaic (CNRS, AMU, PIIM) I. Laut (Deutsches Zentrum fur Luft- und Raumfahrt, Forschungsgruppe Komplexe Plasmen), C. Rath (Deutsches Zentrum fur Luft- und Raumfahrt, Forschungsgruppe Komplexe Plasmen), S. Zhdanov (Max Planck Institute for extraterrestrial Physics), V. Nosenko (Deutsches Zentrum fur Luft- und Raumfahrt, Forschungsgruppe Komplexe Plasmen), and H. M. Thomas (Deutsches Zentrum fur Luft- und Raumfahrt, Forschungsgruppe Komplexe Plasmen)

Abstract: In two-dimensional plasma crystals, wake-mediated interactions between the particles result in the coupling of the crystal in-plane and out-of-plane modes into a shear-free hybrid mode of the lattice layer. Localised 'hot spots' in the lattice phonon spectra are a typical signature of this mode [1]. The theory of mode-coupling instability [2, 3, 4] gives a detailed picture of a plasma-specific melting scenario operating in 2D plasma crystals. The mode coupling induced melting can only be triggered if (i) the modes intersect, and (ii) the neutral gas damping is sufficiently low. The kinematics of dust particles during the early stage of mode-coupling induced melting is explored [5]. The formation of the hybrid mode induces the partial synchronisation of the particle oscillations at the hybrid frequency. Phase- and frequency-locked hybrid particle motion in both vertical and horizontal directions (hybrid mode) is evidenced. A rhythmic pattern of alternating in-phase and anti-phase oscillating chains of particles is observed. The spatial orientation of the synchronisation pattern correlates well with the directions of the maximal increment of the shear-free hybrid mode. Asymetries are observed in the current fluctuation spectra and seem to originate from an inhomogeneity of the horizontal confinement. To investigate this hypothesis, experimental results are compared to molecular dynamics simulations [6]. The crystal is compressed horizontally by an anisotropic confinement. This compression leads to an asymmetric triggering of the mode-coupling instability which is accompanied by alternating chains of in-phase and anti-phase oscillating particles. A new order parameter is proposed to quantify the synchronization in different directions of the crystal. Depending on the orientation of the confinement anisotropy, mode-coupling instability and synchronized motion are observed in one or two directions. The good agreement of the simulations with the experiments of Ref. [5] suggests that the confinement anisotropy can be used to explain the observed synchronization process.
References: [1] L. Couedel, V. Nosenko, A. V. Ivlev, S. K. Zhdanov, H. M. Thomas, and G. E. Morfill, Phys. Rev. Lett. 104, 195001 (2010). [2] A. V. Ivlev and G. Morfill, Phys. Rev. E 63, 016409 (2001). [3] S. K. Zhdanov, A. V. Ivlev, and G. E. Morfill, Phys. Plasmas 16, 083706 (2009). [4] L. Couedel, S. K. Zhdanov, A. V. Ivlev, V. Nosenko, H. M. Thomas, and G. E. Morfill, Phys. Plasmas 18, 083707 (2011) [5] L. Couedel, S. Zhdanov, V. Nosenko, A.V. Ivlev, H.M. Thomas, G.E. Morfill, Phys Rev E 89 053108 (2014) [6] I. Laut, C. Rath, S. Zhdanov,

V. Nosenko, L. Couedel, and H. M. Thomas, "Synchronization of particle motion in compressed two-dimensional plasma crystals", Submitted to EPL (2015)

MS Coupling functions - theories and applications (MS23)
10 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.00 – 11.25

Reconstructing coupling functions vs. reconstructing interaction strengths

Zoran Levnajic (Faculty of Information Studies in Novo mesto)

Abstract: We present a method of reconstructing the interaction strengths in a general dynamical network from the observable time series. The method relies on examining the correlations between the values of the derivatives and the variables associated with different dynamical units. We discuss the reconstruction precision depending on the properties of the dynamics, and in particular depending on how much information on the inter-unit coupling functions is available.

MS Time series, causality, networks and applications I (MS15)
9 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.00 – 11.25

Approximate maximum a-posteriori inference for the infinite hidden Markov model (iHMM)

Max Little (MIT/Aston University) Raykov, Y.P. (Aston University) Boukouvalas, A. (Aston University)

Abstract: The hidden Markov model (HMM) is a mainstay of nonlinear time series modelling and has significant value in applications across science and engineering. One of the limitations of this model is that the number of hidden states must be fixed in advance. This is problematic as these models are 'nested' making the selection of the number of hidden states difficult. An alternative model, the infinite HMM, can be considered as 'nonparametric' in that the number of hidden states is effectively infinite, and, for any finite data set, takes on a finite value which grows to accommodate increasingly complex data sets. iHMMs have significant potential but while inference in HMMs is straightforward, iHMM inference is computationally heavy. In this talk I will detail a novel method for iHMM inference based on sequential maximization of the conditional distributions of the underlying probabilistic graphical model. This algorithm finds an approximate maximum a-posteriori estimate of the joint distribution of the model in a few iterations and is therefore useful in practice.

MS Response, variability and transitions in geophysical systems (MS14)
9 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.00 – 11.25

Response Theory in Geophysical Fluid Dynamics: Climate Change Prediction and Parametrizations

Valerio Lucarini (University of Hamburg/University of Reading)

Abstract: The climate is a complex, chaotic, non-equilibrium system featuring a limited horizon of predictability, variability on a vast range of temporal and spatial scales, instabilities resulting into energy transformations, and mixing and dissipative processes resulting into entropy production. Despite great progresses, we still do not have a complete theory of climate dynamics able to encompass instabilities, equilibration processes, and response to changing parameters of the system. We will outline some possible applications of the response theory developed by Ruelle for non-equilibrium statistical mechanical systems, showing how it allows for setting on firm ground and on a coherent framework concepts like climate sensitivity, climate response, and climate tipping points. We will show results for comprehensive global circulation models. The results are promising in terms of suggesting new ways for approaching the problem of climate change prediction and for using more efficiently the enormous amounts of data produced by modeling groups around the world. We will then show how response theory can be used for constructing parametrizations for multiscale systems, providing explicit formulas for the effective dynamics identical to what can be obtained using a perturbative Mori-Zwanzig approach. This might be relevant for constructing practical parametrizations for weather and climate models.
V. Lucarini, R. Blender, C. Herbert, F. Ragone, S. Pascale, J. Wouters, Mathematical and Physical Ideas for Climate Science, Reviews of Geophysics 52, 809-859 (2014)

MS Controlling, synchronizing and modelling complex systems (MS01)
7 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.40 – 11.57

Chaotic models for the plague in Bombay by the end of the 19th century

Sylvain Mangiarotti (Centre d'Etudes Spatiales de la Biosphère)

Abstract: An epidemic of plague took place in Bombay by the end of the 19th century. Its evolution was carefully monitored by several plague committees. Numerous records were gathered, analyzed and published for the period starting from the breakout of the epidemic in August 1896 to December 1911. This historical dataset is revisited with the aim to obtain models of ordinary differential equations directly based on the original records of human deaths caused by plague, and populations of infected rodents.
Two types of analyses are performed: (1) Univariate global modeling is applied to records of plague death for different time windows. (2) Multivariate modeling is applied to retrieve the dynamical coupling between the epidemic and the epizootics of two main species of rodents in Bombay. Several models are obtained from these two analyses. These are either chaotic or close to chaos. Validation is performed by considering the models' forecasting ability which shows that multivariate models have horizons of predictability near to four times longer than univariate models. The algebraic structure of multivariate models is analyzed and an interpretation is proposed for it.

MS Localisation mechanisms in shear flows (MS09)
8 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.00 – 11.25

Open shear flow archetypal streamwise localization

Fernando Mellibovsky (Universitat Politecnica de Catalunya) Meseguer, A. (Universitat Politecnica de Catalunya)

Abstract: In this talk we present recent numerical explorations carried out in a canonical shear flow (plane Poiseuille) were it is revealed how localized and periodically modulated travelling waves connect with the classical TS-waves. Subharmonic linear stability analyses combined with Newton-Poincaré-Krylov continuation methods allow to find the connections of these families of solutions in the (k_0, Re) parameter space, $\Lambda = 2\pi/k_0$ being the length of the computational box. These connections are found to be intricated and no simple mechanisms of localization and de-localization have yet been identified.

MS Mathematical models of anomalous diffusion (MS10)
8 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.30 – 11.55

Propagation of phase-transition boundaries in systems with subdiffusion

Alexander Nepomnyashchy (Technion - Israel Institute of Technology) Volpert, V (Northwestern University)

Abstract: Subdiffusion transport has been detected in numerous physical and biological systems, specifically in gels. Propagation of phase-transition boundaries in systems with subdiffusion has some specific features that are discussed in the present talk. As the first example, we consider the growth of a solid nucleus inside a supersaturated gel. The growth is due to precipitation governed by subdiffusion of the dissolved component towards the nucleus surface. We obtain an exact self-similar solution describing propagation of the phase-transition front, and discuss its stability. The second example is the description of the glass-gel transition which is in some sense an opposite process. The transition from glass to gel takes place with the growth of the concentration of a solvent which is transported to the transition front by subdiffusion. An exact self-similar solution describing the front propagation is obtained, and its non-trivial analytical properties are investigated.

MS Controlling, synchronizing and modelling complex systems (MS01)
7 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.20 – 11.37

Reduction of required vaccination level by means an integrated control with isolation

Erivelton Nepomuceno (Federal University of São João del-Rei) Takahashi, R. C. H. (Federal University of Minas Gerais) and Aguirre, L. A. (Federal University of Minas Gerais)

Abstract: SIR models have been highly studied as a very simple model to explain basic dynamics of epidemiological systems. There are also many works that apply control theories, such as vaccination (continuous or pulsed). Usually vaccination is a preferable control action. Of course, it is used when a vaccine has been already developed, otherwise, a isolation procedure, in which infected individual are kept away from other individuals. In this paper, we show a possibility to use isolation, not only as replacing strategy, but as a way to decrease the level of vaccination required to eradicate a disease. We believe that this approach can be useful in many situations, which are difficult to vaccinate high levels of the population due economical or geographical reasons. We give an example showing that by means an integrated isolation action we are able to decrease the required vaccination from 95% to 57%.

MS Laser and complex dynamics (MS02)
7 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.00 – 10.25

Dynamics and synchrony in coupled semiconductor laser networks

Junji Ohtsubo (Shizuoka University)

Abstract: In common nonlinear networks, synchronization between distant elements is of particular importance. For example, zero-lag synchronization of neurons in distant space plays an important role for information processing in brain. There are many nonlinear network elements similar to synaptic neurons. In this talk, we focus on chaotic semiconductor lasers as nonlinear elements and discuss the dynamics and the synchronization properties in coupled semiconductor laser networks with rather small number of elements. First, we briefly discuss chaotic semiconductor lasers as nonlinear elements and, then, investigate the synchronization properties up to four network elements. We also focus on the conditions for zero-lag synchronization of the networks. The greatest common divisor (GCD) rule with relation to the number of network nodes and the connections of network loops is one of measures to infer the number of synchronization clusters in coupled nonlinear networks. Indeed, the GCD rule well applies to small number of nodes in semiconductor laser networks. We further discuss the prospects for the synchronization properties for larger number of nodes in semiconductor laser networks.

MS Controlling complex networks: interplay of structure, noise, and delay (MS13)
9 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.30 – 10.55

Creative control of chimera states

Oleh Omel'chenko (WIAS, Berlin) Wolfrum, M (WIAS, Berlin) and Sieber, J (University of Exeter)

Abstract: Chimera states are self-organized patterns of coherence and incoherence in large, macroscopically homogeneous systems of coupled oscillators. Usually, such patterns occur for a relatively narrow range of parameter values that significantly restricts their appearance and variability of their characteristics. In this talk we describe a control scheme, which permits us to observe chimera states in regions of the phase and parameter space that are inaccessible in conventional simulations and experiments. In particular, the control makes chimera states observable close to coherence, for small number of oscillators, and for random initial conditions.

MS Cardiac dynamics (MS21)
10 September 10.00–12.00 (PCC 1.4-1.6)

Time: 11.30 – 11.55

Unification of electrical restitution dynamics with ion channel dynamics as a description of action potential propagation in the heart

Niels Otani (Rochester Institute of Technology)

Abstract: The characterization of action potential dynamics in cardiac tissue has traditionally followed two parallel tracks: use of the dependence of action potential duration and wave propagation speed on the preceding diastolic interval (called electrical restitution theory), and use of intricate ion channel models. In our work, we unify these two approaches by applying eigenmode theory to the mapping of perturbations of both sets of dynamical variables from one action potential to the next. This link between the two approaches provides us with an important foundation on which we can discuss in a rigorous manner how drugs and electrical interventions impact the onset and control of fibrillation in the heart.

MS Time series, causality, networks and applications I (MS15)
9 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.30 – 11.55

Long-term seizure dynamics

Milan Palus (Instite of Computer Science CAS) Kudlacek J. (Institute of Physiology CAS and Faculty of Electrical Engineering, Czech Technical University in Prague) Vlk P. (Institute of Physiology CAS and Faculty of Electrical Engineering, Czech Technical University in Prague) Hlinka J. (Institute of Computer Science CAS, Prague) Cmejla R. (Faculty of Electrical Engineering, Czech Technical University in Prague) Demeterova L. (Department of Neurology, 2nd Faculty of Medicine, Charles University in Prague) Marusic P. (Department of Neurology, 2nd Faculty of Medicine, Charles University in Prague) Otahal J. (Institute of Physiology CAS, Prague) Jefferys J.G.R. (University of Birmingham) Jiruska P. (Institute of Physiology CAS, Prague)

Abstract: Epileptic seizures are traditionally described as sudden and unpredictable events. The inability to predict the occurrence of the next seizure represents the main disabling factor of epilepsy. Recent studies have demonstrated that seizures do not occur randomly, nor are they uniformly distributed in time. Periods of increased and decreased probability of seizure occurrence were observed in patients and in chronic models of epilepsy. Power-law behaviour has been discovered in distributions of seizure energy and inter-seizure intervals (ISI). In the present study, we examined long-term seizure dynamics in the tetanus toxin model of temporal lobe epilepsy in eight adult rats. In all animals seizures did not occur randomly and periods of high seizure frequency (clusters) were interspersed with periods of seizure absence or low seizure frequency. Concatenated data from all clusters confirm scale-free behavior, especially the increase of the conditional waiting time until the next event (CWT) with increasing the waiting time for the preceding event was detected. The CWT increase, however, did not correspond to those of well-known scale-free processes, including a nonparametic multifractal model (multifractal surrogate data, see M. Palus, Phys. Rev. Lett. 101, 134101, 2008). A closer look at the dynamics of individual clusters revealed a coexistence of scale-specific memoryless dynamics for small ISI followed by a long-memory dynamics with characteristic CWT behavior and a progressive change in the seizure parameters marked an approaching termination of the seizure clustering. Understanding the mechanisms behind changes in seizure dynamics and occurrence probability, especially in terms of changing connectivity and information flows in epileptogenic networks can open new ways for the development of techniques for seizure forecasting and prevention. Support by the Czech Science Foundation (GACR 14-02634S) is gratefully acknowledged.

MS Time series, causality, networks and applications II (MS18)
9 September 16.30–18.30 (PCC 2.4-2.6)

Time: 17.30 – 17.55

Magnetic or electric? Studying functional brain networks of alcoholic patients from simultaneously recorded MEG and EEG data

Ernesto Pereda (University of La Laguna) Bruña, R (Politechnic University of Madrid) Jurado, R (Teaching Hospital 12 de Occtubre)

Abstract: The analysis of complex brain networks from neural data has become a very active area of research. Neuroimaging techniques such as fMRI provide excellent spatial resolution but poor temporal one, whereas neurophysiological data such as EEG or MEG have very good temporal resolution yet do not give detailed spatial location. Source reconstruction is a suitable way of combining both techniques to get a good localization of neural activity with excellent temporal resolution. For this purpose, one extract the information about subject's anatomy included in his/her MRI and use it to constrain the chosen algorithm to solve the inverse problem of finding the sources from the recorded electrode/sensors. Here, we address the issue of whether the complex brain network of cortical sources reconstructed using either MEG sensors or simultaneously recorded EEG electrodes present the same structural properties by comparing both set of networks in the same group of healthy subjects in resting state with closed eyes. Moreover, we also check the statistical power of different complex network measures obtained from both MEG and EEG-reconstructed sources when analysing the differences between this group of healthy subjects and an age-matched group of alcoholic subjects. The results show that, whereas the networks reconstructed from the two neurophysiological modalities are mostly coincident, there are also some differences in the information they provide, which suggests the convenience, whenever possible, of analysing both types of data to get a comprehensive picture of complex brain network activity.

MS Coupling functions - theories and applications (MS23)
10 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.00 – 10.25

On the equivalence of phase-oscillator and integrate-and-fire models: how the coupling functions matter

Antonio Politi (University of Aberdeen)

Abstract: The algebraic structure of multivariate models is analyzed and an interpretation is proposed for it.

MS Self-organizing effects in complex (dusty) plasmas (MS19)
9 September 16.30–18.30 (PCC 1.4-1.6)

Time: 17.00 – 17.25

Wave turbulence observed in an auto-oscillating complex (dusty) plasma

Christoph Raeth (Max-Planck-Institute for extraterrestrial Physics, Garching, Germany) S. Zhdanov (1), M. Schwabe (1,2), H. M. Thomas (2), and G. E.Morfill (1): (1) Max-Planck-Institute for extraterrestrial Physics, Garching, Germany (2) Research Group Complex Plasmas, DLR, Oberpfaffenhofen, Germany

Abstract: Complex plasmas consist of micrometer-sized particles embedded in a low-temperature plasma and are ideal model systems for nanofluids, phase transitions and transport processes [1,2]. The microparticles can be visualized individually in real time, thus providing a kinetic level of observations of vortices, self-propelling, particle pairing, tunneling and channeling [3-8]. For instance, vortices in complex plasmas are an ideal test bed for studying the onset of turbulence and collective effects on the microcanonical level. Specifically, driven turbulence in complex plasmas is of low Reynolds numbers. The opportunity to study turbulence in fluids with low Reynolds numbers at the kinetic level is especially interesting in many other physical, biophysical, and industrial applications as diverse as water flow through porous media, viscoelastic liquid polymer flows, chaotic mixers, self-propelled stochastic microdevices, and bacterial quasiturbulence. Simulations of vortices in a typical laboratory setup allowed us to investigate the onset of turbulence and collective effects in complex plasmas [6]. Velocity structure functions and the energy and enstrophy spectra show that vortex flow turbulence is present that is in essence of the "classical" Kolmogorov type. We report also on a complex plasma under microgravity conditions that is auto-oscillating due to a heartbeat instability and contains quasi-solitary wave ridges: oscillons [9]. We demonstrate that this system can serve as a nearly ideal model system to mimic weak Kolmogorov-Zakharov type wave turbulence. The slopes of the structure functions agree reasonably well with power laws assuming extended self-similarity. The energy spectrum displays multiple cascades, which we attribute to the influence of friction, the heartbeat instability and a modulational instability.
References: [1] P. K. Shukla and A. A. Mamun, Introduction to Dusty Plasma Physics (Institute of Physics Publishing, Bristol) 2002. [2] G. E.Morfill and A. V. Ivlev, Rev. Mod. Phys. 81, 1353 (2009). [3] M. R. Akdim and W. J. Goedheer, Phys. Rev. E 67, (2003) 056405. [4] G. E. Morfill, U. Konopka, M. Kretschmer, M. Rubin-Zuzic, H. M. Thomas, S. K. Zhdanov, and V. Tsytovich, New J. Phys. 8, 7 (2006). [5] I. Laut, C. Raeth, L. Woerner, V. Nosenko, S. K. Zhdanov, J. Schablinski, D. Block, H. M. Thomas and G. E. Morfill, Phys. Rev. E 89, 023104 (2014). [6] M. Schwabe, S. Zhdanov, C. Raeth, D. B. Graves, H. M.Thomas, and G. E. Morfill, Phys. Rev. Lett. 112, 115002 (2014). [7] Ch. Du, V. Nosenko, S. Zhdanov, H. M. Thomas, and G. E. Morfill, Phys. Rev. E 89, 021101(R) (2014). [8] S. K. Zhdanov, L. Couedel, V. Nosenko, H. M. Thomas, and G. E. Morfill, Physics of Plasmas 22, 053703 (2015). [9] S. Zhdanov, M. Schwabe, C. Raeth, H. M. Thomas, and G. E.Morfill, EPL 110, 35001 (2015).

MS Turbulent dispersion (MS24)
10 September 14.30–16.30 (PCC 2.4-2.6)

Time: 15.00 – 15.25

The concept of particle pressure in a suspension of particles in a turbulent flow

Mike Reeks (Newcastle University)

Abstract: The Clausius Virial theorem of Classical Kinetic Theory is used to evaluate the pressure of a suspension of small particles at equilibrium in an isotropic homogeneous and stationary turbulent flow. It then follows a similar approach to the way Einstein [1] evaluated the diffusion coefficient of Brownian particles (leading to the Stokes-Einstein relation) to similarly evaluate the long term diffusion coefficient of the suspended particles. In contrast to Brownian motion, the analogue of temperature in the equation of state which relates pressure to particle density is not the kinetic energy per unit particle mass except when the particle equation of motion approximates to a Langevin Equation.
References: [1] A. Einstein. On the theory of Brownian motion. Ann, d. Physik, IV:549, 1905

MS Extreme events (MS11)
8 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.30 – 10.55

Extreme intensity pulses in laser systems generated by the interplay of nonlinearity, noise and delay.

Jose A. Reinoso (Universidad Pompeu Fabra) Jordi Zamora-Munt and Cristina Masoller (Universidad Politécnica de Barcelona)

Abstract: We present a numerical study of the pulses displayed by a semiconductor laser with optical feedback in the short-cavity regime, such that the external cavity round-trip time is shorter than the laser relaxation oscillation period. For certain parameters there are occasional pulses, which are high enough to be considered extreme events. We characterize the bifurcation scenario that gives rise to such extreme pulses and study the influence of noise. We demonstrate intermittency when the extreme pulses appear and hysteresis when the attractor that sustains these pulses is destroyed. We also show that this scenario is robust under the inclusion of noise.

MS Source buoyancy effects on plume and thermal flow (MS22)
10 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.30 – 11.55

propagation of turbulent downdraughts

Gabriel Rooney (Met Office)

Abstract: Deep convection in the atmosphere is associated with strong in-cloud updraughts as well as turbulent downdraughts. These downdraughts are initiated by the descent of hydrometeors within the cloud. The details of the initial conditions of the descent, and the processes that sustain it, are not well understood. The subsequent 'cold pool' of air which it creates at the surface is a topic of current interest in meteorology, because of its possible role in triggering and sustaining convection, acting as a 'memory' of the system. This talk will examine the initiation and descent of downdraughts, and the spreading of turbulent cold pools, in terms of the dynamics of turbulent plumes, thermals and gravity currents, as well as the effect of hydrometeors on sustaining convection in a stratified background.

MS Time series, causality, networks and applications II (MS18)
9 September 16.30–18.30 (PCC 2.4-2.6)

Time: 18.00 – 18.25

Resected brain tissue, seizure onset zone and quantitative EEG measures: Towards prediction of post-surgical seizure control

Christian Rummel (Support Center for Advanced Neuroimaging (SCAN), University Institute for Diagnostic and Intervention) Abela, E (Inselspital Bern), Andrzejak, RG (Universityt Pampeu Fabra, Barcelona), Wiest, R (Inselspital Bern) and Schindler, K (Inselspital Bern)

Abstract: Epilepsy surgery is a potentially curative treatment option for pharmacoresistent patients. Visual analysis of intracranial electroencephalographic recordings (EEG) is the current gold standard to identify the seizure onset zone for targeted resection. Despite of its great potential to assess the epileptogenicty of brain tissue, application of signal analysis techniques to EEG ('quantitative EEG', qEEG) has not yet found its way into routine clinical practice. To demonstrate that qEEG may yield clinically highly relevant information we retrospectively investigated how post-operative seizure control is associated with four qEEG measures evaluated in the resected brain tissue and the seizure onset zone. The studied measures were representative for each of the four categories: - univariate linear - univariate nonlinear - bivariate linear - bivariate nonlinear The exact spatial location of the intracranial electrodes was determined by coregistration of pre-operative MRI and post-implantation CT. Coregistration with post-resection MRI was used to delineate the extent of tissue resection. Using data-driven thresholding, qEEG results were separated into normally contributing and salient channels. In patients with favorable post-surgical seizure control a significantly larger fraction of salient channels in three of the four qEEG measures was resected than in patients with unfavorable outcome in terms of seizure control. In the pre-ictal and early ictal phase the overlap between the resected brain tissue and the salient channels in two qEEG measures reached statistical significance in patients with good outcome. The same statistics revealed smaller association with post-operative seizure control when EEG channels contributing to the seizure onset zone were studied. We conclude that qEEG may provide clinically relevant and objective markers of target tissue, which may be used to optimize epilepsy surgery. The finding that differentiation between favorable and unfavorable outcome was better for the fraction of salient values in the resected brain tissue than in the seizure onset zone is consistent with growing evidence that spatially extended networks might be more relevant for seizure generation, evolution and termination than a single highly localized brain region (i.e. a 'focus') where seizures start.

MS Source buoyancy effects on plume and thermal flow (MS22)
10 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.00 – 10.25

Unsteady plumes and explosive volcanism

Matthew Scase (University of Nottingham) Phillips, J. C. (Bristol University) Watson, I. M. (Bristol University)

Abstract: Vulcanian eruptions are a common, and extremely hazardous, form of volcanic activity that produce plumes of hot volcanic gas and ash. Such eruptions can produce significant eruption volumes, as recent VEI3 eruptions at Montserrat and Sakurajima demonstrate. The vent conditions are not well described by approximation to either steady or instantaneous sources. The eruptions are of short duration, typically seconds-minutes, and are characterized by unsteady source conditions. The classical steady state 'plume equations' due to Morton, Taylor & Turner are developed to allow for use in unsteady multiphase flow, including Vulcanian eruptions. New measurement techniques allow field observations from Santiaguito Volcano, Guatemala to be used as input boundary conditions to the developed model enabling comparison with plume rise-height observations. Large errors in eruption parameters are shown to occur if steady models are incorrectly used to invert, for example, deposit measurements to infer source conditions for historic or unobserved eruptions.

MS Problems when inferring networks from data (MS08)
7 September 16.30–18.30 (PCC 2.1-2.3)

Time: 18.00 – 18.25

Multivariate network analysis: causality or correlation

Bjoern Schelter (University of Aberdeen) Schelter, B (University of Aberdeen) and Thiel, M (University of Aberdeen)

Abstract: Recent years have seen a large increase in the availability of data. Increasing amounts of data play a key role in every aspect of our lives. Dealing with these data sets efficiently determines the success of projects, treatments, assessments, and analyses. This necessity to better understand and analyze data has led to an outburst of research into advanced methods of data based modeling. We address various approaches to network inference based on time series data. We will focus in particular on issues of various multivariate network inference techniques that arise when interpreting links in a network as causal.

MS Controlling, synchronizing and modelling complex systems (MS01)
7 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.30 – 10.55

Interlayer synchronisation and the problem of targeting in multiplex networks

Irene Sendiña-Nadal (Universidad Rey Juan Carlos) Sevilla-Escoboza, R (Universidad de Guadalajara) Gutierrez, R (The University of Nottingham) Leyva, I (Universidad Rey Juan Carlos & CTB-UPM) Zanin, M (Innaxis Foundation) Papo, D Buldú, JM (Universidad Rey Juan Carlos & CTB-UPM) Boccaletti, S (CNR- Institute of Complex Systems)

Abstract: In the past years, the emergence of synchronised states has been extensively reported and studied for the case of mono-layer networks, with the emphasis focusing on how the complexity of the layer topology influences the propensity of the coupled units to synchronise. A completely different scenario is that of networking dynamical units with coexisting layers. In this case, indeed, the different layers determine as a whole the overall coupling structure through which the system components interact. We concentrate on a specific case, involving a two-layer network in a master-slave configuration, in view of the relevance of this situation that extends the very concept of synchronisation and provides practical tools to target the dynamics of complex networks toward any desired collective behaviour (not necessarily synchronous). The problem is here tackled through a Master Stability Function approach, assessing the stability of the aimed dynamics, and through a selection of nodes to be targeted. We show that the degree of a node is a crucial element in this selection process, and that the targeting mechanism is most effective in heterogeneous scale-free architectures. This makes the proposed approach applicable to the large majority of natural and man-made networked systems. We also present some preliminary results on a more general case of interlayer synchronisation in bidirectional coupled multiplexes assessing the stability conditions of the interlayer synchronised solution for both identical and non-identical layers.

MS Nonlinear dynamical aspect of data assimilation (MS12)
8 September 10.00–12.00 (PCC 2.4-2.6)

Time: 10.30 – 10.55

Observation thinning in data assimilation computations

Ehouarn Simon (INPT/IRIT) Gratton, S. (INPT/IRIT and Cerfacs); Rincon-Camacho, M. (Cerfacs), Toint P. (University of Namur)

Abstract: 4D variational data assimilation problems in geophysical fluids consist in solving nonlinear least square problems. The incremental 4D-Var method is a popular technique to tackle high dimensional problems as it is equivalent to applying a truncated Gauss-Newton iteration. The development of efficient numerical techniques, like the restricted preconditioned conjugate gradient (RPCG) method, allow to solve the embedded quadratic optimization subproblem (also called inner loop) in observation space. This approach becomes computationally attractive when the number of observations is much smaller than the dimension of the control space (for instance the dimension of the initial state vector). However, the amount of observations to assimilate can still be large even in this favorable case. In order to reduce the computing costs of the Incremental 4D-Var in observation space, we proposed an observation-thinning strategy that exploits an adaptive structure of the observations in the spirit of multigrid techniques. The thinned observation set is defined using a hierarchy of observations, from coarsest to finest level. Starting from the coarsest set of observations, observations from the next level will be included in the observation set according to the influence they have on the solution, as measured by an estimate on the solution variation between two consecutive levels. Numerical experiments performed in toy models highlighted the benefits of this approach considering both the reductions in the computing costs/time and the amount of assimilated observations.

MS Nonlinear dynamics of movement coordination and interpersonal interactions (MS16)
9 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.30 – 10.55

Bifurcation analysis of the HKB model with time delays

Piotr Slowinski (University of Exeter)

Abstract: Recently, simulations of the the Haken-Kelso-Bunz (HKB) model of interpersonal coordination have been successfully used to explain coordination patterns observed in the interaction between schizophrenic patients and healthy participants. In this talk, we use bifurcation analysis to explain the results of the simulations of the HKB model with time delays. In particular, we use numerical continuation to systematically study effects of time delays, and other parameters, on stability of coordination patterns of the two coupled HKB oscillators. The mathematical model takes the form of four dimensional system of delay differential equations for the two coupled oscillators. The two time delays present in the system are associated with delays in processing sensory information and human reaction times. Presented bifurcation analysis provides a deeper understanding of the experimental results and allows us to make experimentally testable predictions.

MS Structural model error in applied dynamics (MS07)
7 September 16.30–18.30 (PCC 2.4-2.6)

Time: 16.30 – 16.55

Pragmatic Bayes: Embracing with Model Inadequacy in Nonlinear Dynamical Systems

Leonard Smith (LSE CATS, London/ Pembroke College, Oxford)

Abstract: The probability calculus provides the tools needed to propagate imprecisely known initial conditions through nonlinear models given imprecisely know parameters and successfully arrive at probability forecasts more informative than the prior information. Inasmuch as all models of physical dynamical systems are structurally flawed, however, there is a sense in which all these successful forecast problems provide merely tautological probabilities: the probability obtained having been defined completely in the problem statement itself (so we are doing no more than when computing the probability that a fair coin will come up heads h times in n tosses; mere bookkeeping given that the coin is fair.). A probability distribution is conditioned on the information available, and when that information includes the fact our model class is inadequate then the Bayesian goal, the impersonally 'subjective' probabilities of IJ Good's Infinite Rational Org, are beyond reach. Assuming such things exist. Indeed the more precise the observations and the more exact the model, the more the discriminatory power of (all traditional) Bayes can lead to disaster. Pragmatic Bayes accepts the premise that, in fact, we are not dealing with probability distributions of the forecast variable, or equivalently, that the information set our forecasts are conditioned upon is 'False' with certainty. Pragmatic Bayes focuses on the information content of the forecast distributions. By accepting that decision-relevant probabilities cannot be obtained, Pragmatic Bayes helps one formulate the problem By accepting that decision-relevant probabilities cannot be obtained, Pragmatic Bayes using a the insights of the Bayesian way to formulate the problem, while accepting its limitations in the world. Given today's 'best available' forecast distributions, whether they are model-based or reflect a forecaster's subjective beliefs, Pragmatic Bayes asks if they are mature: if they are expected to change without either additional observations or new theoretical insight. A mature distribution will not, while IJ Good's 'Dynamic Probability' will with probability one. Secondly, Pragmatic Bayes insists that a probability forecast is incomplete unless it contains an explicit estimate of the probability of a big surprise, P(BS), which quantifies the forecast issuer's subjective probability that, after the fact, the forecast strategy will be seen as untenable. Pragmatic Bayes accepts that a cooperative insurer, seeking only to break even in the long run, must effectively issue odds that do not correspond to probabilities (as the implied probabilities sum to more than one). Fair odds do not correspond to probability. Quantitative decision aides which insist on extracting probabilities from an imperfect model have a large, unquantified risk of ruin. In that case: traditional Bayes goes bust. Ideally, Pragmatic Bayes remains solvent.

MS Structural model error in applied dynamics (MS07)
7 September 16.30–18.30 (PCC 2.4-2.6)

Time: 17.00 – 17.25

Planetary intelligence

Matthew Smith (Microsoft Research) Purves, D. W. P Emmott, S.

Abstract: Advances in computation and data enable us to challenge our models like never before. While before you needed substantial resource commitment (scientists+money) to deploy models that have well characterised predictive performance now it seems anyone can throw a deep neural network at a bunch of factors and verify it leads to a skilful model. Do we even need to account for causality any more? My team have been advancing our understanding of how predictive performance varies with different degrees of abstraction and data constraints, predominantly in the domain of ecology. Our realisation is that the long established process based models for ecological dynamics can show remarkably accurate predictive performance if combined with a bit of machine learning. Improvement in the realism of the model can lead to longer or further forecast horizons, or it can make it worse. We're now looking at a new era of planetary intelligence in which governments, individuals and businesses make better decisions for themselves and the planet by having access to an ecosystem of demonstrably accurate predictive models for all sectors.

MS Nonlinear dynamical aspect of data assimilation (MS12)
8 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.30 – 11.55

Data Assimilation: What is the Point?

Leonard Smith (LSE CATS, London/ Pembroke College, Oxford)

Abstract: What defines successful data assimilation? Is the goal to obtain the most accurate analysis, a point in the model state space 'representative' of reality at the instant the forecast cast is launched? Or is the goal to construct an n_{ens} member ensemble, or better still a distribution from which an ensemble of any size can be drawn, which will yield the best probability forecast of future states of the system. Are either of those aims well-defined mathematically, when real-world forecasts are to be made and flaws in the structural formational of the model will exist? How are resources best balanced between accounting for nonlinearities of the model and coping with model inadequacy? Following Teller, it is argued that Perfect Model Model should be rejected at the outset, that the traditional aims of data assimilation are untenable outside the perfect model scenario, and a transparent data assimilation strategy that embraces model inadequacy from the outset is to be preferred, especially by those using the forecast for decision support. Illustrations outside the perfect model scenario are provided to support this argument. Pseudo-orbit Data Assimilation attempts to embrace model inadequacy form the beginning rather than perturbing off 'perfect model' schemes; it strengths and shortcomings are noted (Du, H. and Smith, L.A. (2014) 'Pseudo-orbit data assimilation part II', Journal of the Atmospheric Sciences, 71 (2), 483-495. ISSN 0022-4928. DOI: 10.1175/JAS-D-13-033.1). This contribution follows the outline of a presentation of the same title given in North Carolina in SAMSI ten years ago. The formulation of the questions has improved significantly in the meantime.

MS Mathematical models of anomalous diffusion (MS10)
8 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.00 – 10.25

Continuous time random walks and their close relatives

Igor Sokolov (Humboldt University) Sokolov, I (Humboldt University Berlin)

Abstract: Continuous time random walks (CTRW) are a popular model of anomalous diffusion. The model has a clear physical interpretation as an approximate description of trapping in high dimensions, and a clear mathematical structure as a process subordinated to simple random walks, and, in the corresponding limit, to Brownian motion. We discuss several models closely related to CTRW. Thus, we show that the scaled Brownian motion (sBm) as described by the Bachelor's equation (in the subdiffusive case) is a mean field (Gaussian) approximation of CTRW, and discuss the similarities and the differences between these models. Both models are non-stationary and share the same aging properties, but differ in the finer characteristics of their behavior. Thus the sBm is weakly ergodic [1] while CTRW shows weak ergodicity breaking. We moreover consider other situations corresponding to more general models of motion in random potentials [2] and to models subordinated to fractional Brownian motion [3]. In cases when the behavior can be described by subordination, we discuss which properties are dominated by the parent process and which ones (like the ergodicity breaking parameter) by the directing one.
References: [1] F. Thiel and I.M. Sokolov, Phys. Rev. E v. 89, 012115 (2014) [2] F. Thiel, F. Flegel, and I.M. Sokolov, Phys. Rev. Lett. v. 111, 010601 (2013) [3] F. Thiel and I.M. Sokolov, Phys. Rev. E v. 89, 012136 (2014)

MS Response, variability and transitions in geophysical systems (MS14)
9 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.00 – 10.25

On quantifying the local climate response in observations and models

David Stainforth (London School of Economics)

Abstract: Traditionally the response of the climate system to increasing atmospheric greenhouses gases has been quantified in terms of changes in global mean surface temperature and encapsulated in concepts such as equilibrium climate sensitivity, transient climate sensitivity and earth system sensitivity. More recently the focus has shifted to how we quantify regional and local changes; changes which relate to individuals' experiences and decision-relevant impacts. On these spatial scales climate variability both limits our ability to quantify climatic changes from observations, and fundamentally impacts how we should design modelling experiments to understand future responses to climate perturbations. This talk will demonstrate how the timescales of climatic perturbations associated with anthropogenic climate change provide intrinsic limits to the quantification of local change. Despite such limits, it is nevertheless sometimes possible to identify changes in distribution; this will be illustrated with an exploration of local temperature and precipitation changes across Europe. The same intrinsic limits require us to use initial condition ensembles when exploring the climate response to potential future greenhouse gas concentration scenarios within complicated global climate models. The design of such ensembles is, however, far from trivial. How the design influences the probabilistic accuracy one can expect and the role of what has been termed macro c.f. micro initial condition uncertainty in the experimental setup will be illustrated.

MS Coupling functions - theories and applications (MS23)
10 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.30 – 10.55

Coupling functions: Universal insights into dynamical interactions

Tomislav Stankovski (Faculty of Medicine, University Ss. Cyril and Methodius, Skopje 1000) McClintock, PVE (Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom) Stefanovska, A (Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom)

Abstract: Interacting dynamical systems abound in nature and science attempts to understand them as much as possible. Often, the interest is not only to understand the structure of systems, but also the functions and mechanisms that define and connect them. This is facilitated by coupling functions which contain detailed information about the functional mechanisms underlying the interactions and prescribe the physical rule specifying how an interaction occurs. We developed a method for time-evolving dynamical Bayesian inference of coupled systems in the presence of noise [1]. By decomposing the dynamics into base functions, the method is able to infer and reconstruct the coupling functions from data. We applied it to better understand the biomedical oscillatory interactions under time-varying conditions. The reconstructed cardio-respiratory coupling functions showed in detail how the heart oscillations accelerate or decelerate due to the coupling influence from the lungs [1]. Furthermore, we studied how the cardio-respiratory coupling functions are affected by ageing [2]. It was found that such coupling functions reduce and become more varying and unstable with age. Similarly, recently we inferred the cross-frequency coupling functions of multivariate neuronal oscillations [3]. The strength and the form of neuronal coupling functions were also quantified for spatially distributed brain electrodes. Moreover, we found that the forms of biological i.e. cardio-respiratory coupling functions are time-varying processes for themselves. Then we used this knowledge of time-varying coupling functions and applied it to build a new improved secure encryption protocol [4, 5]. We encode the information signals as modulating scales of plurality of coupling functions between two dynamical systems at the transmitter. Knowing the exact form of coupling functions in use (eventually forming the encryption key) we were able to decrypt the information signals by use of the time-evolving dynamical Bayesian inference. In this way, we showed that the coupling function protocol has unbounded encryption possibilities, allows multiplexing inherently and is extremely noise resistant. Being a theoretical construct, the coupling function describes the interaction between dynamical systems in general, no matter whether if they are chemical, biological, mechanical or communication systems. Because of this property of universality we were able to connect two seemingly very different areas - biology and communications. Needless to say, the methodology and the theoretical concepts have wide implications for interacting dynamical systems in general.
References: [1] Stankovski, T., Duggento, A., McClintock, P. V., & Stefanovska, A. (2012). Inference of time-evolving coupled dynamical systems in the presence of noise. Physical Review Letters, 109(2),024101. [2] Iatsenko, D., et al. (2013). Evolution of cardiorespiratory inter-

actions with age. Philosophical Transactions of the Royal Society A, 371(1997), 20110622. [3] Stankovski, T., Ticcinelli, V., McClintock, P. V., & Stefanovska, A. (2015). Coupling functions in networks of oscillators. New Journal of Physics, 17(3), 035002. [4] Stankovski, T., McClintock, P. V., & Stefanovska, A. (2014). Coupling functions enable secure communications. Physical Review X, 4(1),011026. [5] Subject to patent application No. WO2015019054A1.

MS Nonlinear dynamics on lattices (MS06)
7 September 16.30–18.30 (PCC 1.4-1.6)

Time: 17.30 – 17.55

Snaking in the discrete Swift-Hohenberg equation

Hadi Susanto (University of Essex, UK)

Abstract: The discrete Swift-Hohenberg equation with cubic and quintic nonlinearities is introduced. Through numerical continuations, it is shown that the system exhibits a remarkable wealth of stable spatially localized states, that are even richer than their continuous counterparts. Starting from the periodic solutions, it is shown that snaking may already appear, which does not occur in the equivalent continuum equation. Spatially localised states may even have complicated structures. The appearance of isolas at particular parameter values by the detachment of parts of the snaking will also be discussed. The evolution of the localized states once they lose stability is illustrated using direct simulations in time.

MS Astrophysical and laboratory plasmas as testbeds for fundamental multiscale nonlinear processes (MS04)
7 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.00 – 11.17

Cosmic-Ray Diffusion in Magnetized Turbulence

Robert Tautz (Technische Universität Berlin)

Abstract: Understanding the origin and the propagation of charged particles has been an important problem in both plasma astrophysics and astroparticle physics. Examples are diffusive shock acceleration, galactic and extra-galactic cosmic rays, and, in the solar system, the arrival of coronal mass ejections on Earth. In the talk, an overview will be presented of the complicated interaction processes between cosmic rays and turbulent electromagnetic fields. In particular, numerical Monte-Carlo approaches and the need for nonlinear theories will be discussed. For the example of the solar wind, the impact of realistic anisotropic and dynamical turbulence models will be demonstrated.

MS Extreme events (MS11)
8 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.30 – 11.55

Reconstruction of networks and extreme events

Marco Thiel (University of Aberdeen) Schelter, B. (University of Aberdeen)

Abstract: Interacting systems can lead to emergent collective behaviour and extreme events. To predict these, or at least their likelihood, the estimation of their interaction structure is crucial. We will present a Granger Causality based approach to infer the network structure of interacting systems; this structure will then be used to develop a data based predictive model. We will show that extreme events are predicted much more reliably based on this model.

MS Self-organizing effects in complex (dusty) plasmas (MS19)
9 September 16.30–18.30 (PCC 1.4-1.6)

Time: 16.30 – 16.55

Phase transitions in electrorheological plasmas

Markus Thoma (Univ. Giessen) A.V. Ivlev (MPE Garching), M. H. Thoma (Univ. Giessen), C. Raeth (DLR Oberpfaffenhofen), C. Dietz (Univ. Giessen), G. E. Morfill(MPE Garching)

Abstract: Electrorheological fluids are suspensions of non-conducting liquids containing nano- or microparticles. Applying an electric field can change properties of these fluids, such as the viscosity, drastically by string formation of the nano- or microparticles. These fluids are used, for example, for brakes or shock absorbers. Similarly, electrorheological plasmas are complex (dusty) plasmas containing microparticles in a low-temperature discharge plasma. Applying an AC field string formation of the microparticles has been observed under microgravity conditions. First observations of an electrorheological plasma were made with the PK-3 Plus experiment onboard the International Space Station (ISS). Here we discuss experiments performed with the complex plasma facility PK-4 in parabolic flights. It is argued that the observed phase transition from an isotropic system in the DC case to an anisotropic, electrorheological system, analysed by the scaling index method, corresponds to a transition from a non-Hamiltonian system with non-reciprocal particle interaction to a Hamiltonian system with reciprocal interaction. Also preliminary parabolic flight experiments in which the duty cycle of the AC field was varied from 50% (symmetric AC) to 100% (DC) are discussed. These experiments show the onset of the phase transition from an electrorheological to an isotropic system, using the peak distance of the anisotropic scaling index distributions as an order parameter. Future electrorheological experiments with PK-4, launched to the ISS in October 2014, improving and extending the parabolic flight results are planned. A. V. Ivlev, M. H. Thoma, C. Räth, G. Joyce, and G. E. Morfill, Complex Plasmas in External Fields: The Role of Non-Hamiltonian Interactions, PRL 106, 155001 (2011)

MS Soft matter under control: pattern formation and transport (MS17)
9 September 16.30–18.30 (PCC 2.1-2.3)

Time: 17.00 – 17.25

Colloidal Microworms Propelling via a Cooperative Hydrodynamic Conveyor-Belt

Pietro Tierno (Universitat de Barcelona) Fernando-Martinez Pedrero, Antonio Ortiz, Ignacio Pagonabarraga

Abstract: We study propulsion arising from microscopic colloidal rotors dynamically assembled and driven in a viscous fluid upon application of an elliptically polarized rotating magnetic field. Close to a confining plate, the motion of this self assembled microscopic "worm" results from the cooperative flow generated by the spinning particles such as an hydrodynamic "conveyor-belt" effect. Chains of rotors propels faster than individual ones, until reaching a saturation speed at distances where flow additivity vanishes. By combining experiments with theoretical arguments, we eluci date the underlying mechanism of motion and fully characterize the propulsion speed in terms of the external field parameters.

MS Laser and complex dynamics (MS02)
7 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.00 – 11.17

Recent advances in ultra-fast random number generation with chaotic lasers

Atsushi Uchida (Saitama University)

Abstract: Physical random number generators are key technologies for information security applications due to their unpredictability. Optical physical random number generators based on chaotic lasers have been developed intensively in recent years [1-6]. One of the advantages of chaotic-laser based random number generators is the speed of random bit generation, over Gigabit per second (Gb/s), due to the fast dynamics of chaotic laser output. Fast physical random number generators are key technologies for applications of a new type of security systems and parallel computation. The development of random number generators based on chaotic laser dynamics has been progressing recently in terms of generation rate. A number of new schemes for random number generation have been proposed since the first demonstration in 2008 [1], and the generation rate of random bits has been increasing very rapidly, exceeding Tb/s [3]. Most laser-chaos-based random number generators reported in the literature utilize commercially available semiconductor lasers and photodetectors, which require large space on an optical table for experimental apparatus. To overcome this issue, photonic integrated circuits (PICs) are promising devices to minimize the size of random number generators for practical implementation. Several PICs with optical feedback have been fabricated and reported as suitable chaotic laser sources for random number generators [4-6]. We report on the speed and the miniaturization of physical random number generators based on chaotic lasers. We first experimentally demonstrate ultra-fast physical random bit generation from bandwidth-enhanced chaos by using three-cascaded semiconductor lasers. The three semiconductor lasers are unidirectionally coupled from Laser 1 to 2 and from Laser 2 to 3 with positive optical frequency detuning. We obtain bandwidth-enhanced chaos in Laser 3 with a bandwidth of 35.2 GHz and a flatness of 5.6 dB. We use the bandwidth-enhanced chaos for physical random bit generation. We introduce a multi-bit extraction method for random bit generation to evaluate the maximum random bit generation rate. We achieve the maximum generation rate at 1.2 Tb/s for physical random bit sequences whose randomness is verified by using both NIST Special Publication 800-22 and TestU01 [3]. In order to perform miniaturization of physical random number generators, we fabricate PICs with short external cavity lengths (1 10 mm) for fast chaos generation and random number generation. We use a single-bit generation method to evaluate the condition on chaotic signals for generating good-quality random bit sequences. It is found that random bit sequences can pass all the statistical tests of randomness when the sampling rate is set to the delay time for which the autocorrelation function of the two chaotic signals shows a local minimum. We also use PICs with different external cavity lengths to generate random bit sequences. The selection of the cavity length is important to generate broad spectra of the chaotic laser output, which results in high-quality

random bit generation. The highest rate of random bit generation of 5.6 Gb/s is obtained by using the chaotic signals generated from the PIC with 4-mm-long external cavity [6]. These PICs are promising miniature entropy sources for the integration of random number generators for applications in information security and numerical computations.

References: [1] A. Uchida, et al., Nature Photonics, Vol. 2, No. 12, pp. 728-732 (2008). [2] I. Reidler, et al., Physical Review Letters, Vol. 103, No. 2, pp. 024102 (2009). [3] R. Sakuraba, et al., Optics Express, Vol. 23, No. 2, pp. 1470-1490 (2015). [4] A. Argyris, et al., Optics Express, Vol. 18, No. 18, pp. 18763-18768 (2010). [5] T. Harayama, et al., Physical Review A, Vol. 83, No. 3, pp. 031803 (2011). [6] R. Takahashi, et. al., Optics Express, Vol. 22, No. 10, pp. 11727-11740 (2014).

MS Source buoyancy effects on plume and thermal flow (MS22)
10 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.00 – 11.25

An energy-based framework for unsteady turbulent plumes

Maarten van Reeuwijk (Imperial College London) John Craske (Imperial)

Abstract: In this seminar we will discuss an energy-based framework for unsteady turbulent plumes, which generalises previous models and exposes several fundamental aspects of their physics. Drawing on the results of direct numerical simulation (DNS) of a plume subjected to an instantaneous step change in its source buoyancy, we use the framework in a diagnostic capacity to investigate the properties of the resulting travelling wave. In general the governing integral equations are hyperbolic, becoming parabolic in the limiting case of a 'top-hat' model, and the travelling wave can be classified as lazy, pure or forced according to the particular assumptions that are invoked to close the integral equations. Guided by observations from the DNS data, we use the framework in a prognostic capacity to develop an accurate and well-posed model of unsteady plumes, based on the assumption of a Gaussian velocity profile. To account for higher-order transport terms, the model utilises the shear-flow dispersion closure developed in Craske & van Reeuwijk (J. Fluid Mech., vol. 763 2015a, p. 538). An analytical solution is presented for a pure straight-sided plume, which is in good agreement with the DNS observations.

MS Response, variability and transitions in geophysical systems (MS14)
9 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.30 – 11.55

Dynamical properties of a hierarchy of low-order coupled ocean-atmosphere models.

Stéphane Vannitsem (Royal Meteorological Institute of Belgium)

Abstract: The statistical and dynamical properties of the atmosphere are considerably affected by the presence of the other components of the climate system, namely the hydrosphere, the cryosphere, the biosphere, and the lithosphere. In particular, the oceans play a particularly crucial role on the dynamics of the atmosphere at seasonal, inter-annual and decadal time scales in the tropical regions. At mid-latitudes, the role of the oceans on the dynamics and predictability of the atmosphere is much less clear and is subject to debates. This question is currently central in the climate and atmospheric communities in view of the potential impact of the ocean on long term forecasts. Recently we have developed a hierarchy of low-order coupled ocean-atmosphere models of different complexity [1, 2, 3]. These low-order models provide important information on the potential impact of the mechanical coupling and radiative and heat fluxes between the ocean and the atmosphere on the dynamics and predictability of this coupled system. In this talk we review past and recent results obtained with this type of low-order models. In particular we will show that slow coupled modes can emerge for large mechanical couplings, provided a radiative and heat flux coupling scheme is present between the two components. This slow dynamics is characterized by strong modification of the mean meridional temperature gradient in the atmosphere and the ocean, associated with the transport of heat within the ocean. This in turn modifies drastically the instability properties of the coupled flow.
References: 1. Vannitsem S., Dynamics and predictability of a low-order wind-driven ocean-atmosphere coupled model. Climate Dynamics, 42, 1981-1998, 2014. 2. Vannitsem S. & L. De Cruz, A 24-variable low-order coupled ocean-atmosphere model: OA-QG-WS v2. Geoscientific Model Development, 7, 649-662, 2014. 3. Vannitsem, S., J. Demaeyer, L. De Cruz, & M Ghil: Low-frequency variability and heat transport in a low-order nonlinear coupled ocean-atmosphere model. Submitted to Physica D, 2014. http://arxiv.org/pdf/1412.0621.pdf

MS Pattern formation (MS03)
7 September 10.00–12.00 (PCC 2.4-2.6)

Time: 11.00 – 11.17

Localised Solutions in a Non-Conservative Cell Polarization Model

Nicolas Verschueren van Rees (University of Bristol) Alan Champneys(University of Bristol)

Abstract: We study a reaction-diffusion model for cell polarization, which exhibits pinned front solutions as a consequence of mass conservation. When a source and a sink term are added to the model, the front solutions vanish. This gives rise to spike solutions and the snaking scenario. Using numerical and analytical tools, we characterize these behaviours. Finally we investigate the connection between the snaking and front solutions, when the non-conservative terms tend to zero.

MS Response, variability and transitions in geophysical systems (MS14)
9 September 10.00–12.00 (PCC 2.1-2.3)

Time: 10.30 – 10.55

A stochastic dynamical systems view on climate sensitivity

Anna von der Heydt (Utrecht University)

Abstract: The concept of equilibrium climate sensitivity has been introduced with the aim to provide a transparent measure of the response of the climate system to 'external' perturbations. In practice, it is the equilibrium change in global mean surface temperature due to a doubling of the atmospheric CO_2 concentration. This quantity can be determined in climate models and derived from observations. Despite much research over the last decades, large uncertainties remain in the value of climate sensitivity and its potential variation in time or depending on the background climate. One reason for this is the fact that the climate has a strong internal variability on many time scales, is subject to a non-stationary forcing and mostly out of equilibrium with the changes in the radiative forcing. Palaeo records of past climate variations can give insight into how the climate system responds to various forcings although care must be taken of the *slow* feedback processes at comparing palaeo climate sensitivity estimates with estimates from (short time scale) model simulations. In addition, for the late Pleistocene ice age cycles it has been shown from both proxy data and a conceptual climate model that climate sensitivity varies considerably between the cold and warm phases because the *fast* feedback processes change their relative strength over one cycle. Another type of 'background state dependency' may be present in systems that involve bifurcation points or tipping elements: The processes determining the background climate state may change across a bifurcation point, and consequently the response to doubling the CO_2 concentration may change as well. Here we formulate a more general concept of climate sensitivity, which is based on the theory of stochastic dynamical systems and is able to quantify the system response in the presence of bimodal behaviour.

MS Structural model error in applied dynamics (MS07)
7 September 16.30–18.30 (PCC 2.4-2.6)

Time: 17.30 – 17.55

On the chance of rain: Probability forecasts in an operational setting

E Wheatcroft (London School of Economics) Leonard Smith

Abstract: In the forecasting of nonlinear dynamical systems, ensembles of model simulations are often used to account for initial condition uncertainty, For example, in weather forecasting, ensembles of around 50 members are launched every 6 or 12 hours, with each simulation extending a week or more from its launch time. It is often convenient to interpret the information contained in ensembles at any given time by using them to form predictive distribution functions called forecast densities. Applying traditional density formation techniques such as kernel density estimation would aim to recover the distribution of the ensemble. This, however is not satisfactory when the model is imperfect since our aim is to estimate the distribution of the outcome which is necessarily different to that of the ensemble. We show how an approach called kernel dressing can be used to account for model error and can yield more skillful forecast densities when measured using a logarithmic scoring rule. In the second part of the talk, we ask whether the information contained in forecasts of the same target time but launched sequentially in time can be combined in some way to yield improved forecast skill. We argue that, if the forecast densities could be considered to represent probabilities of the predictand, a Bayesian approach would be expected to yield optimal skill. We show, however, that this is not the case, casting doubt on the validity of treating forecast probabilities in this way. The ideas in this talk are demonstrated using both low dimensional chaotic systems such as Lorenz '63 and using a high dimensional model of real-world weather observations.

MS Nonlinear and stochastic dynamics in weather and climate science (MS20)
9 September 16.30–18.30 (PCC 1.1-1.3)

Time: 17.00 – 17.25

Noise-induced regime transitions in atmospheric flow

Paul Williams (University of Reading)

Abstract: Several aspects of atmospheric flow are thought to exhibit regime behaviour. Regimes are a set of preferred circulation patterns that are qualitatively different from each other. When the flow is in one regime, it will persist there for an extended period of time, before undergoing a rapid transition to another regime. An example of atmospheric regimes is sudden stratospheric warmings, which occur when the stratospheric polar vortex undergoes a sudden transition from an axisymmetric state to a split or displaced state. Another example is the North Atlantic jet stream, which appears to have three preferred regimes that correspond to northern, southern, and central jet positions, and which are closely related to the North Atlantic Oscillation. This talk will show that useful insights into atmospheric regimes - and the transitions between them - may be gained by studying experiments on rotating fluids in the laboratory. In this simple setting, regimes may be studied without the often ad-hoc approximations of numerical and theoretical approaches. In experiments with a two-layer rotating annulus, we have found that transitions between large-scale flow regimes may be triggered by small-scale gravity waves. These transitions may be mimicked in a numerical model via the injection of stochastic noise, motivating stochastic parameterisations in atmospheric models. The laboratory experiments have also inspired a new interpretation of sudden stratospheric warmings, as being gravity wave noise-induced transitions.

MS Localisation mechanisms in shear flows (MS09)
8 September 10.00–12.00 (PCC 1.4-1.6)

Time: 10.30 – 10.55

Streamwise localisation mechanism of exact solutions in pipe flow

Ashley Willis (University of Sheffield) Chantry, M. (ESPCI, Paris), Kerswell, R.R. (University of Bristol)

Abstract: The dynamical systems approach has enabled significant progress in our understanding of transition to turbulence over the last ten years. Much of this progress took place through the study of properties of spatially periodic waves, the discovery of many of which occurred in the early 2000s. With improved computational facilities, localised solutions are now slowly being identified. For extension of the relationships established between turbulence and periodic waves, a fundamental for taking this approach step towards more realistic flows was to establish a connection between the spatially periodic and localised solutions. In shear flows, the spanwise flow is substantially weaker than the streamwise flow, with relative magnitudes as low as a few percent. Coupling of neighbouring 'rolls' is therefore relatively weak, and streamwise periodic waves with a single or pair of rolls in the spanwise direction could be isolated. Strongly sheared layers in the streamwise direction, however, strongly couples the structures in that direction. The question of the existence of a link with streamwise localised solutions was therefore non-trivial. Attempts to construct localised solutions from periodic solutions, by 'windowing' and numerical continuation to greater wavelength, had failed. In this talk it is shown that a simple generic connection exists. Continuation from the localised solution to finite short wavelengths reveals that localised solutions originate from spatially sub-harmonic bifurcations. The change from periodic to localised, including the key structures (energy generating features) of the localised structures are easily captured in small domains, corresponding to only a few wavelengths of the periodic counterparts.

MS Delay-equations for optoelectronic systems (MS05)
7 September 16.30–18.30 (PCC 1.1-1.3)

Time: 18.00 – 18.25

Dynamical jittering and exponentially large number of periodic spiking solutions in oscillators with pulsatile delayed feedback

Serhiy Yanchuk (Weierstrass Institute for Applied Analysis and Stochastics) Leonhard Luecken (Weierstrass Institute for Applied Analysis and Stochastics, Berlin), Vladimir Klinshov, Dmitry Shchapin, Vladimir Nekorkin (Institute of Applied Physics, Nizhny Novgorod)

Abstract: Oscillatory systems with time-delayed feedback appear in various applied and theoretical research areas, and received a growing interest in recent years. For such systems with pulse-like feedback type, we report a remarkable scenario of thedestabilization of a periodic regular spiking regime. At the bifurcation point numerous periodic solutions with nonequal interspike intervals emerge. We show that the number of the emerging, so-called 'jittering' regimes grows exponentially with the delay. Although this appears as highly degenerate from a dynamical systems viewpoint, such bifurcation occurs robustly in a large class of systems. We observe it not only in a paradigmatic phase-reduced model, but also in a simulated Hodgkin-Huxley neuron model and in an experiment with an electronic circuit.

MS Astrophysical and laboratory plasmas as testbeds for fundamental multiscale non-linear processes (MS04)
7 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.00 – 10.25

Impact of Magnetic Topology on Plasma Dynamics

Anthony Yeates (Durham University) Hornig, G (University of Dundee) Russell, A.J.B. (University of Dundee)

Abstract: How is a plasma's evolution affected by its global magnetic field structure? I will focus on trying to understand the self-organisation of turbulently relaxing plasma - a phenomenon observed in laboratory devices and hypothesised to occur in astrophysical plasmas such as stellar atmospheres. If these plasmas were perfect electrical conductors, their magnetic topology (linkage and connectivity of their magnetic field lines) would be perfectly frozen-in for all time. In reality, the turbulent flows lead to very sharp layers of electric current where even a very small resistivity allows for field-line reconnection. Nevertheless, it is well-known that the total magnetic helicity - an overall measure of the topology - remains a robust invariant. Thus the magnetic energy released during the relaxation may be limited by the conservation of total magnetic helicity. Our work goes further: we focus on the possible relevance of additional topological constraints beyond total magnetic helicity. In a turbulently relaxing plasma, we propose that the leading order behaviour is a re-organisation of field-line helicity, which in general will put additional constraints on the dynamics. If the region of turbulent reconnection is localised, one such constraint may be expressed as conservation of the topological degree of the magnetic field-line mapping.

MS Mathematical models of anomalous diffusion (MS10)
8 September 10.00–12.00 (PCC 2.1-2.3)

Time: 11.00 – 11.25

Subdiffusive CTRWers that disappear: where, when, how fast?

Santos B. Yuste (Dpt. Fisica, Univ. Extremadura) Abad, E. (Univ. Extremadura) Lindenberg, K (Univ. California-San Diego)

Abstract: Diffusion processes where diffusive entities (walkers) disappear in the course of their motion are ubiquitous. These walkers may disappear due to an intrinsic process (finite lifetime of the walker) and/or to some extrinsic processes such as the encounter with a predator or reaction site. Our goal is the characterization of the region explored by subdiffusive mortal walkers (size of the region and the way in which it is occupied) and their survival probability. In order to address this problem we consider random walkers (i) in the continuum limit by means of fractional diffusion equations with reactive terms and/or reactive boundary conditions, and (ii) on d-dimensional lattices by means of the generating function formalism. The interplay between mortality and subdiffusion leads to interesting and, in some cases, unexpected results.

MS Controlling complex networks: interplay of structure, noise, and delay (MS13)
9 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.30 – 11.55

Controlling coherence/incoherence patterns by noise and delay

Anna Zakharova (TU Berlin) Sarah Loos (TU Berlin) Julien Siebert (TU Berlin) Vladimir Semenov (Saratov State University) Alexandar Gjurchinovski (Cyril and Methodius University, Skopje) Eckehard Schöll (TU Berlin)

Abstract: Chimera states are complex partially synchronized dynamical patterns in a network of identical oscillators composed of coexisting domains of coherent (synchronized) and incoherent (desynchronized) behavior. We investigate amplitude chimera states in nonlocally coupled ring networks of Stuart-Landau oscillators with S^1 symmetry breaking coupling [1]. Here, we analyze the role of time delay and stochastic perturbations for these synchronization-desynchronization patterns. We address the question of robustness and control of chimera states in the presence of time delay and noise. In particular, we calculate the dependence of the dynamic regimes in the plane of the coupling range and the coupling strength upon the noise intensity and the coupling delay. Also, we determine the transient lifetimes of amplitude chimeras as a function of noise strength and coupling delay. [1] A. Zakharova, M. Kapeller, E. Schöll, Phys. Rev. Lett. 112, 154101 (2014)

MS Nonlinear and stochastic dynamics in weather and climate science (MS20)
9 September 16.30–18.30 (PCC 1.1-1.3)

Time: 17.30 – 17.55

Energy backscatter and parametrization of sub-grid scale ocean eddies

Laure Zanna (University of Oxford) Porta Mana L (University of Oxford)

Abstract: The new generation of climate models is starting to resolve parts of the ocean mesoscale spectrum. Yet, despite their increased resolution, these models which allow for the presence do not adequately resolve the mesoscale eddies and the energy transfer between scales. A representation of the mesoscale eddy forcing as function of the straining and shearing of the resolved flow, wind forcing, stratification and model resolution is developed using probability distribution functions (PDFs) diagnosed from high-resolution quasigeostrophic eddy-resolving runs. The PDFs represent the eddy-eddy and eddy-mean flow interactions and associated Reynolds stresses necessary to mimic the effects of the eddies. The reconstructed PDFs are used as a parametrization of sub-grid eddy effects, leading to improvements in the mean and variability of the coarse-resolution parametrized simulation over the unparametrized version. The effects of the parametrizations are shown to allow for energy backscattery, therefore respecting the inverse energy cascade of quasi-geostrophic turbulence.

Contributed talks

CT Networks (CTNE)

9 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.24 – 15.39

Complex networks from chaotic time series

G. Ambika (Indian Institute of Science Education and Research, Pune) Rinku Jacob and K. P. Harikrishnan (The Cochin College, Cochin-682 002, India) R. Misra(Inter University Centre for Astronomy and Astrophysics, Pune-411 007, India)

Abstract: We present a uniform frame work for analyzing chaotic systems using the unweighted e -recurrence networks constructed from their time series. Our scheme prescribes how to choose the correct range of e that can map the relevant information from the time series to the constructed network. We discuss the computed characteristic measures of the constructed network like degree distribution, characteristic path length link density, and clustering coefficient etc. for standard low dimensional chaotic systems. We show that the degree distribution is a characteristic measure of the structure of the attractor and display statistical scale invariance with respect to increase in N. We apply the scheme to real data and compare with scale free and Erdos-Renyi networks.

CT Interdisciplinary Applications II (CTIA2)
8 September 14.30–16.00 (PCC 2.4-2.6)

Time: 14.48 – 15.03

Rank deficiency of Kalman filter and assimilation in unstable subspace

Amit Apte (ICTS-TIFR) Karthik Gurumoorthy (ICTS-TIFR), Colin Grudzien (UNC Chapel hill), Alberto Carrassi (NERSC, Bergen, Norway, Chris Jones (UNC Chapel Hill)

Abstract: Kalman filters have been successfully used for low dimensional state estimation problems, e.g., in engineering. One of the main reasons that make it difficult to use them in geosciences is, apart from the obvious problem of nonlinearity of the systems involved, the high dimensionality of these problems. A set of techniques collectively called "assimilation in unstable subspace" (AUS), proposed by Trevisan et al., try to overcome this restriction by proposing a reduced rank approximation of many assimilation techniques including Kalman filter. We prove that for linear, deterministic systems, the support of these error covariance matrices is confined to the space spanned by the unstable-neutral backward Lyapunov vectors, providing the theoretical justification for the AUS methodology.

CT Networks (CTNE)
9 September 14.30–16.00 (PCC 2.1-2.3)

Time: 14.30 – 14.45

From the complex nonlinear behavior of a single neuron to the robust pattern of a network: Using data assimilation to probe this transformation

Eve Armstrong (University of California, San Diego) Abarbanel, Henry (University of California, San Diego: Department of Physics); Daniel Margoliash (University of Chicago: Department of Organismal Biology and Anatomy); Michael Long (New York University: Neuroscience Institute and Department of Otolaryngology)

Abstract: We are developing a biophysical model of neural circuitry in the sensory-motor junction (HVC) of the songbird vocalization network. In this effort, we have created methods addressing the problem of sparse measurements that pervades analysis of functional circuits in neuroscience and complex systems in general. A neuron is a nonlinear system that, in isolation, exhibits highly variable and often chaotic behavior. When placed within a functional circuit, however, there often emerges patterned behavior with high coherence over thousands of participating cells, and which demonstrates robustness to noise and mild trauma. The way this transformation is achieved - and the connectivity that achieves it - is largely unknown, mainly because most of the variables governing the system dynamics are unmeasurable. We are adapting an approach to data assimilation that has demonstrated success in chaotic systems such as meteorology, and has been applied rarely to biological neural networks. These methods are designed to maximally utilize the information in sparse data sets. Data assimilation is likely to make a transformative impact in neuroscience, where sparse measurements present a great obstacle, and where the community remains largely uninformed that methods exist to address that problem. Our close collaborations with experimental neurobiologists offers us an unusual platform for demonstrating and disseminating our results. We are working with the laboratories of Daniel Margoliash at the University of Chicago and Michael Long at New York University Medical School, to first characterize each cell type in terms of distinct biophysical cellular properties, and secondly to design and assist in the analysis of experiments to ascertain the functional connectivity of the HVC network. Our approach involves a systematic probe of the question: What is the role of the complex nonlinear properties of individual cells in producing the robust patterns of a network?

CT Interdisciplinary Applications II (CTIA2)
8 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.06 – 15.21

Exploiting multistabilities to achieve stable chimera states in globally coupled small laser networks

Fabian Böhm (Technische Universität Berlin) Lüdge, K. (Freie Universität Berlin)

Abstract: Advancements in fabrication techniques of photonic circuits allow for the realization of large networks of optically coupled semiconductor lasers as on-chip solutions. These small devices are promising for the study of complex network dynamics and new methods in signal processing. Our work focuses on arrays of identical semiconductor lasers where the individual untis are globally coupled by a common mirror in a short external cavity. Using the Lang-Kobayashi model for the local laser dynamics, we investigate the bifurcation structure, multistabilities and the occurring rich variety of dynamics . We identify the material parameters of the lasers, e.g. the amplitude-phase-coupling and the time scale separation between electrons and photons as driving forces for multistability and complex synchronization phenomena. We show that regions of multistability between the synchronous steady state and asynchronous periodic solutions allow for the formation of tiny chimera states. The domains of coherence and incoherence that are typical for chimera states are found to exist simultaneously for the amplitude, phase, and inversion of the coupled lasers. These tiny chimera states are interesting in regards to established existence criteria. While chimera states in phase oscillators generally demand nonlocal coupling, large system sizes, and specially prepared initial conditions, we find chimera states that are stable for global coupling in a network of only four coupled lasers for random initial conditions.

CT Interdisciplinary Applications II (CTIA2)
8 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.42 – 15.57

Dynamic behaviour in an enzyme reaction

Tamas Bansagi (Department of Chemical and Biological Engineering, University of Sheffield)
Taylor A.F. (Department of Chemical and Biological Engineering, University of Sheffield)

Abstract: The rate-pH dependence of enzyme-catalysed reactions in membranes was proposed as a possible source of dynamical behaviour including bistability, oscillations and waves in biology; however, a robust experimental example of such a system is still lacking. Recent investigations with the urea-urease reaction suggest this reaction may provide such an example: the reaction has shown bistability in pH in a CSTR and alginate beads, and propagating pH fronts which has been successfully utilized in isothermal frontal hydrogel formation. The urea-urease system may also exhibit oscillations in beads or membranes provided the transport of acid is sufficiently faster than that of urea.

CT Mathematical aspects (CTMA)
9 September 14.30–16.00 (PCC 1.4-1.6)

Time: 14.48 – 15.03

The topology and timing of causality

Murilo S. Baptista (University of Aberdeen) E.B. Martinez (Institute for Complex Systems and Mathematical Biology, University of Aberdeen, SUPA, AB24 3UE Aberdeen, UK)

Abstract: In a causal world the direction of the time arrow dictates how past causal events produce future effects. In this talk, we will show how to easily construct a space partition from observational time-series, whose topological features - quantified by a new measure, named future mutual information (FMI) - provide not only how time-series are causally connected, but also details such as when and where information is mostly or least transmitted, how much time one needs to observe a time-series in the effecting system to extract full information about the causing system. Moreover, it can be applied to quantify causality in networks of both discrete and continuous systems, in experimental time-series measures, and all this can be calculated with very little computation effort as compared to similar quantities such as the Transfer Entropy. Finally, we will explain the relationship of our proposed approach with other causality measures, and show that conditional probabilities are not necessary to calculate causality, nowadays the largest inconvenience in its detection.

CT Interdisciplinary Applications I (CTIA1)
8 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.42 – 15.57

Abundance and distribution of food chains in a patch dynamic model of metacommunites

Edmund Barter (Bristol University) Thilo Gross (University of Bristol)

Abstract: In ecological systems several different types of networks appear. One of these types is food webs, the networks of who eats whom. Another is dispersal networks, the networks on which animals travel between different locations, called patches. Current efforts focus on understanding ecology at the meta-community level, which combines food webs with dispersal networks. The meta-community can be depicted as a network, where the nodes are spatial patches and links are avenues of dispersal between these patches. Every patch is occupied by a set of species which can change in time due to colonization from neighbouring patches, and local extinction of species. This meta-community approach offers a potential reconciliation between expectations of food webs arising from stability analysis and properties of empirically observed food webs. Analysis suggests that stable food webs should be small, with no, or few, loops, while empirically observed food webs are often large and complex. In a meta-community description the food web on each patch is small, and thus stable, the observed food web is the aggregation of all of the interactions observed across all of the patches. A simple modelling framework for food web dynamics at the meta-community level has been proposed by Pillai et al[1]. This model combines SIS type species dispersal between patches with feeding interactions between species at each patch. Feeding interactions are modelled by certain patches being inaccessible to certain species. We have focussed on predator-prey interactions, which are reflected in the model by the constraint that a species can only inhabit patches which its prey also inhabits. For this model we construct equations for the rate of change of the generating function for the degree distribution of the network of patches inhabited by each species. We find the solution for the steady state of these equations, and hence for the degree distributions of the networks inhabited by each species in the endemic state. We present the consequences of this analysis for the viability of species at high levels of the food chain. We find the variation in abundance and viability dependent on the form of the patch network. [1] Pillai, P., Loreau, M. & Gonzalez, A. (2010), A patch-dynamic framework for food web metacommunities, Theoretical Ecology 3(4), 223-237

CT Climate (CTCL)
10 September 14.30–16.30 (PCC 1.1-1.3)

Time: 15.42 – 15.57

Climate tipping points triggered by changes in periodic forcing

Sebastian Bathiany (Wageningen University) Scheffer, M (Wageningen University) Williamson, M (University of Exeter), Lenton, TM (University of Exeter), van Nes, EH (Wageningen University)

Abstract: Some ecosystems and parts of the climate system are suspected to have catastrophic bifurcation points: When an external condition is changed beyond a threshold, the present equilibrium state of the system suddenly ceases to exist. As a consequence, an abrupt and irreversible shift to a different state can occur, a behaviour often referred to as a tipping point. However, natural systems are not in equilibrium with their external conditions as these conditions usually change faster than the system can respond. In particular, many systems are forced by (quasi-)periodic drivers such as the annual cycle or internal modes of climate variability. Using a very simple bistable system with a periodic driver we demonstrate that tipping points can be triggered not only by a change in the mean of the driver but also by changes in its amplitude or frequency. Such tipping points can consist in an irreversible and abrupt change of the system's mean state, but also in an abrupt change of its amplitude. We show that such phenomena occur in conceptual models of savannah ecosystems, Arctic sea ice and tropical monsoons. Our results imply that abrupt and irreversible change may occur in these and other natural systems due to only small shifts in the magnitude or time scale of environmental fluctuations. While our results are based on previous mechanistic studies of particular systems, we suggest that these systems can be seen in a common framework. We therefore call for a broader perspective on abrupt change and a generalised view on tipping points in the Earth system.

CT Active matter (CTAM)
7 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.06 – 15.21

Analytical and Numerical Approaches to Initiation of Excitation Waves

Burhan Bezekci (College of Engineering, Mathematics and Physical Sciences, University of Exeter) Prof Vadim N Biktashev

Abstract: We consider the problem of initiation of excitation waves, that is, classification of initial conditions in an excitable medium, that in the long run will either lead to a propagating wave solution or fail to do that and converge to the resting state. We consider one-dimensional excitable reaction-diffusion systems with the aim of finding "critical curves" characterising initial conditions, separating domains in the space of the parameters that correspond to initiation from domains corresponding to failure. We consider idealized initial conditions where the resting stated perturbed by a rectangular perturbation of a certain magnitude and width. The resulting critical curve is called "strength-extent" curve. The key idea of our approach is based on the observation that the basins of attractions of the initiation and failure states in the phase space of the system are separated by the centre-stable manifold of a certain critical solution, which may be "critical nucleus", "critical front" or "critical pulse", depending on the model. Our analytical approach to this problem is based on the idea of approximating the center-unstable manifold with the corresponding centre-stable space. We also demonstrate the possibility of a second-order approximation of the centre-stable manifold. This results in a hybrid analytical-numerical description, where the analytical expression for the critical curves is obtained, which is based on numerical calculations of the critical solutions and associated eigenvalue problems. We illustrate the efficacy of our approach in some spatially-extended excitable systems, including McKean, FitzHugh-Nagumo and Beeler-Reuter models.

CT Nonlinear optics (CTNO)
10 September 10.00–12.00 (PCC 1.1-1.3)

Time: 11.12 – 11.27

Extreme events in the chaotic dynamics of external-cavity semiconductor lasers

Chien-Yuan Chang (Georgia Institute of Technology) J. Barnoud, Daeyoung Choi, J. Wishon, Y. Bouazizi, A. Locquet, D.S. Citrin (Georgia Institute of Technology, School of Electrical and Computer Engineering, Atlanta, Georgia 30332-0250 USA) and (UMI 2958 Georgia Tech-CNRS, Georgia Tech Lorraine, 2 Rue Marconi F-57070, Metz, France)

Abstract: Extreme events (EE) are rare events of unusually high amplitude. An common example exists as rogue wave in the ocean, which until recently were not well documented and often considered mythical. We focus on EEs in the time-dependent optical intensity output from chaotic external-cavity semiconductor lasers (ECL), and relate the frequency of EEs to the dynamical regime in which the ECL operates. More specifically, we present a series of experimental studies of the occurrence of extreme events in the optical intensity in various chaotic regimes of a time-delayed dynamical system. Our system is an external-cavity laser composed of a laser diode subjected to an external feedback forming an external cavity. The injection current and the feedback strength are used to control the dynamical regime of the ECL. We observe a drastic increase (approximately a hundred fold) in the number of EEs as the ECL transitions from a coherence collapse (CC) to a low-frequency-frequency fluctuations (LFF) regime. We determine, using all the common criteria, that the EEs observed in the LFF regime qualify as rogue waves. We confirm experimentally the robustness of this result by changing the operational parameters, i.e., feedback strength. We identify that some of these EEs are separately by approximately the time delay of the ECL. Moreover, we find that throughout the low-frequency fluctuation regime, that the extreme events occur in bursts immediately following a dropout.

CT Patterns (CTPA)
8 September 14.30–16.00 (PCC 2.1-2.3)

Time: 14.30 – 14.45

Experimental Route to Chaos of an External-Cavity Semiconductor Laser

Daeyoung Choi (Georgia Institute of Technology) Byungchil Kim, J. Wishon, C. Y. Chang, Alexandre Locquet and D. S. Citrin (Georgia Institute of Technology, School of Electrical and Computer Engineering, Atlanta, Georgia 30332-0250 USA) and (UMI 2958 Georgia Tech-CNRS, Georgia Tech Lorraine, 2 Rue Marconi F-57070, Metz, France)

Abstract: We report experimental bifurcation diagrams based on the optical intensity of an external-cavity laser (ECL) biased well-above threshold. ECL dynamics are widely used in applications such as physical-layer security, random number generation, laser sensing, and reservoir computing, though the bifurcations that lead to the various dynamical regimes have only been partially confirmed experimentally. The bifurcation diagrams we present provide a detailed and systematic study of the route to chaos of an ECL, for various operating conditions, as the feedback strength is increased. We observe that the route to fully developed coherence collapse of the ECL is typically interrupted by several windows corresponding to periodic or quasi-periodic attractors that have developed around one or modes of the external-cavity, and that can be located in different regions of phase space. In addition, we observe experimentally for the first time the transition between different limit cycles originating from the same ECM as well as transitions between limit cycles of different but neighboring ECMS. We also show that the widely-used Lang and Kobayashi model of ECL dynamics is qualitatively consistent with the experimental observations.

CT Patterns (CTPA)
8 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.24 – 15.39

Explosive dissipative solitons and their anomalous diffusion

Jaime Cisternas (Universidad de los Andes) Albers, T (TU Chemnitz) Radons, G (TU Chemnitz)

Abstract: Dissipative solitons show a variety of behaviors not exhibited by their conservative counterparts. For instance a dissipative soliton can remain localized for a long period of time without major profile changes, then, unexpectedly, grow and become broader for a short time —suffer an explosion—, returning to the original spatial profile afterward. This behaviour has been reported in experiments in the context of nonlinear optics. In this presentation we consider the dynamics of dissipative solitons and the onset of explosions in detail, inspired by a model of mode-locked lasers based in the complex Ginzburg-Landau equation. Now the spatial jumps induced by the explosions are random, even in the absence of noise, and in the long run the trajectory of the soliton will follow a diffusive behavior that shows several interesting features of anomalous diffusion. Using slightly different initial conditions one can find: large trajectory-to-trajectory variations, in particular the time-averaged mean squared displacements seem to obey a scaling behaviour but with a wide range of exponents; the mean squared displacement (averaged over an ensemble) shows a power-law scaling, different from the one of single trajectories, indicating a weak ergodicity breaking; and ageing, as ensemble averages depend on the time between preparation of the initial soliton and the start of measurements. All these signatures find their explanation in the long-term memory exhibited by the chaotic attractor of the dissipative soliton.

CT Chaos (CTCH)
9 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.24 – 15.39

Remarks on possible extensions of definitions of fractal dimensions to no-metric spaces

Jens Christian Claussen (Jacobs University Bremen)

Abstract: In the context of fractal sets, different definitions of dimensions are used, namely the topological dimension, the Hausdorff-Besikovic dimension, and generalized dimensions. The latter two require a metric space to define scaling with respect to a length scale grasped from diameters of covering elements. Immediate generalizations of the topological dimension definition seem difficult unless one at least requires a measurable space. However utilizing elements of both Hausdorff-Besikovic and generalized dimension definitions one can replace scaling with respect to length by scaling with respect to the number of covering elements.

CT Chaos (CTCH)
9 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.06 – 15.21

Bifurcation to chaos in a Photonic Integrated Circuit: the intermittency route

Andreas Karsaklian Dal Bosco (Saitama University) Yasuhiro Akizawa (Saitama University, Japan), Kazusa Ugajin (Saitama University, Japan), Kazutaka Kanno (Fukuoka University, Japan), Atsushi Uchida (Saitama University, Japan), Takahisa Harayama (Waseda University, Japan), Kazuyuki Yoshimura (NTT Corporation, Japan)

Abstract: Photonic integrated circuits (PICs) are micro-scale semiconductor laser devices commonly used in various fields of optics such as fast random bit generation [1] and telecommunications [2]. Although they are currently the subject of intensive research for high-speed data transmission and laser coupling, studies specifically addressing the question of the dynamics of lasers with optical feedback embedded in PICs remain few. Yet, due to their reduced spatial extension, PICs are typical examples of laser systems operating in short cavity regimes, i.e. where the feedback delay is shorter than the relaxation oscillation period (sub-nanosecond timescale). As predicted in the theory, the dynamical scenarios that can be expected in a laser with a short cavity totally differ from the long-cavity case [3, 4, 5]. We present here a route to chaos showing intermittency in a PIC laser with optical feedback. The intermittency route is characterized by short bursts rising irregularly above the oscillating laminar background of the laser temporal waveform when a transition to chaos is undergone [6, 7] by increasing the feedback strength. We bring experimental and numerical illustration of a bifurcation scenario showing a route to chaos through intermittency in a laser which external cavity length is a few millimetres, at the limit between short and long cavity regimes. As the feedback strength is increased, the systematic mechanism first shows the destabilization of a limit cycle into a complex attractor which size grows on in the phase space. Then a second attractor is created and jumps between the two attractors occur at irregular time intervals. We explain the intermittency phenomenon by these irregular jumps which act as connections between the two attractors of different size and dynamics, one corresponding to the bursts and the other to the laminar regions seen in the temporal waveform. We present the evolution of the intermittencies and how their typical dynamics made of bursts and laminar regions ends up by disappearing and giving way to a fully developed coherence collapse state as the feedback strength is gradually increased. Numerical simulations bring theoretical support to the experimental observations and give insight into the dynamical mechanism specific to intermittency. The influence of some parameters on the scenario's features such as the external cavity length is discussed as well. [1] Harayama et al., Physical Review A, 83, 031803 (2011) [2] Argyris et al., Physical Review Letters, 100, 194101 (2008) [3] Tager et al., IEEE J. Quant. Electr. 30, 1553 (1994) [4] Heil et al., Physical Review Letters, 87, 243901-1 (2001) [5] Erneux et al., Physical Review A, 66, 033809 (2002) [6] Tang et al., Physical Review A, 46, 676 (1992) [7] Manffra et al., Nonlinear Dynamics, 27, 185 (2002)

CT Astro and plasma physics (CTAP)
7 September 14.30–16.00 (PCC 1.4-1.6)

Time: 14.30 – 14.45

How sticky is the chaos/order boundary?

Carl Dettmann (University of Bristol) Orestis Georgiou (University of Bristol and Toshiba)

Abstract: Hamiltonian dynamical systems with mixed phase space are ubiquitous, but poorly understood due to complicated structure of the boundary between chaotic and ordered regions. Mushroom billiards were introduced by Bunimovich in 2001 as an example of sharply divided phase space. A billiard comprises a point particle moving uniformly in a specified region except for mirror-like reflections from the boundary, here shaped like a mushroom with a semicircular cap and polygonal stem. Later, Altmann and others pointed out that almost all mushroom billiards have parabolic orbits embedded in the chaotic region leading to 'stickiness', algebraic slowing of the chaotic expansion and mixing properties. A zero measure set of mushroom parameters for which these orbits are absent, and the remaining stickiness, originating from the boundary of the chaotic region itself, will be characterised using Diophantine approximation methods. The results may shed light on the parameter dependence of stickiness in more general Hamiltonian systems.

CT Fluids I (CTF1)
7 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.06 – 15.21

A model for temperature fluctuations in a buoyant plume

Ben Devenish (University of Exeter) A. Bisignano

Abstract: We present a hybrid Lagrangian stochastic model for buoyant plume rise from an isolated source that includes the effects of temperature fluctuations. The model is based on that of Webster and Thomson (Atmospheric Environment, 2002, Vol.36, 5031-5042) in that it is a coupling of a classical plume model in a cross flow with stochastic differential equations (sdes) for the vertical velocity and temperature (which are themselves coupled). The novelty lies in the addition of the latter sde. Parameterisations of the plume turbulence are presented which are used as inputs to the model. The root-mean-square temperature is assumed to be proportional to the temperature difference between the centre line temperature of the plume and the ambient temperature. The constant of proportionality is tuned by comparison with equivalent statistics from large-eddy simulations (LES) of buoyant plumes in a uniform crossflow and linear stratification. We compare plume trajectories for a wide range of crossflow velocities and find that the model generally compares well with the equivalent LES results particularly when added mass is included in the model. The exception occurs when the crossflow velocity becomes very weak. Comparison of the scalar concentration, both in terms of the height of the maximum concentration and its vertical spread, shows similar behaviour. The model is extended to allow for realistic profiles of ambient wind and temperature and the results are compared with LES of the plume that emanated from the explosion and fire at the Buncefield oil depot in 2005.

CT Climate (CTCL)
10 September 14.30–16.30 (PCC 1.1-1.3)

Time: 15.24 – 15.39

Predictability, waiting times and tipping points in the climate

Peter Ditlevsen (University of Copenhagen)

Abstract: It is taken for granted that the limited predictability in the initial value problem, the weather prediction, and the predictability of the statistics are two distinct problems. Predictability of the first kind in a chaotic dynamical system is limited due to critical dependence on initial conditions. Predictability of the second kind is possible in an ergodic system, where either the dynamics is known and the phase space attractor can be characterized by simulation or the system can be observed for such long times that the statistics can be obtained from temporal averaging, assuming that the attractor does not change in time. For the climate system the distinction between predictability of the first and the second kind is fuzzy. On the one hand, weather prediction is not related to the inverse of the Lyapunov exponent of the system, determined by the much shorter times in the turbulent boundary layer. These time scales are effectively averaged on the time scales of the flow in the free atmosphere. On the other hand, turning to climate change predictions, the time scales on which the system is considered quasi-stationary, such that the statistics can be predicted as a function of an external parameter, say atmospheric CO2, is still short in comparison to slow oceanic dynamics. On these time scales the state of these slow variables still depends on the initial conditions. This fuzzy distinction between predictability of the first and of the second kind is related to the lack of scale separation between fast and slow components of the climate system. The non-linear nature of the problem furthermore opens the possibility of multiple attractors, or multiple quasi-steady states. As the paleoclimatic record shows, the climate has been jumping between different quasi-stationary climates. The question is: Can such tipping points be predicted? This is a new kind of predictability (the third kind). The Dansgaard-Oeschger climate events observed in ice core records are analyzed in order to answer some of these questions. The result of the analysis points to a fundamental limitation in predictability of the third kind.

CT Fluids II (CTF2)
8 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.06 – 15.21

Non-equilibrium size segregation in evaporating films of colloidal mixtures

Andrea Fortini (University of Surrey) Ignacio Martin-Fabiani, (University of Surrey) Joseph L. Keddie (University of Surrey) Richard P. Sear (University of Surrey)

Abstract: Paints start as a thin layer of a colloidal suspension on a substrate. The water then evaporates, concentrating the suspension until a dry layer of packed particles is deposited. We use Brownian Dynamics simulations in combination with experiments to investigate this process for a binary mixture of colloidal particles. In simulations, we find that solvent evaporation can induce non-equilibrium size segregation. The big particles are depleted from the region close to the air-water interface, while a layer of small particles accumulate at that interface. This depletion of the large particles occurs over a wide range of size ratios and evaporation velocities. At low concentrations of small particles, this depletion effect disappears and the big particles accumulate at the air-water interface in either a crystalline or disordered structure. In this regime, the small particles fill the interstitial spaces of the large particles. The experimental results agree qualitatively with the simulation findings. This segregation is a novel example of non-equilibrium phase separation. It may also be useful if stratified coatings are needed. For example, if the smaller particles are harder, they will form a scratch-resistant upper layer to the coating.

CT Mathematical aspects (CTMA)
9 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.42 – 15.57

Transport and instabiliities in some MHD shear flows

Andrew Gilbert (University of Exeter) Durston, S. (University of Exeter)

Abstract: Forced 2-d flows are known to show instabilities leading to large-scale flows, following from classic studies of the instability of the Kolmogorov flow $u = (0, \sin x)$. More recently there has been much work on randomly forced two-dimensional flows on beta-planes, to model the formation of jet structures in geophysical and astrophysical fluid flows, the most famous example being the banded flows on Jupiter. These can often be understood in terms of transport effects, in particular negative eddy diffusion that can counter normal diffusion and destabilise a large-scale flow, so-called zonostrophic instability. In this talk we discuss calculations of diffusivities using a quasi-linear model. Our particular interest is in the addition of further physical effects. First, when there is an overall uniform shear flow $u = (\Lambda y, 0)$ applied to the system, and where a magnetic field $B = (B(y), 0)$ is present, leading to Alfven waves.

CT Time series (CTTS)
10 September 14.30–16.30 (PCC 2.1-2.3)

Time: 14.48 – 15.03

Analytical investigation on the detrended fluctuation analysis

Marc Höll (Max Planck Institute for the Physics of Complex Physics) Kantz, H (MPI Dresden)

Abstract: The detrended fluctuation analysis (DFA) is a widely used method for detecting long-range correlations in non-stationary time series. In this talk we present analytic results of the relationship between the fluctuation function of the DFA and the autocorrelation function. With this result we can investigate the well-known scaling of the fluctuation function for stationary short-range and long-range correlated processes. Furthermore we show that short-range correlated process always exhibit a crossover between regions of different scaling. We calculate this crossover point and compare it with the characteristic correlation time of the process. We conclude that DFA is data consuming and requires one to two orders of magnitude more data than the estimation of the autocorrelation function.

CT Interdisciplinary Applications II (CTIA2)
8 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.24 – 15.39

Advection equation for network-organized systems

Shigefumi Hata (Japan Agency for Marine-Earth Science and Technology) Hiroya Nakao (Tokyo Institute of Technology), Alexander S. Mikhailov (Fritz Haber Institute of the Max Planck Society)

Abstract: Advection is a transport mechanism where substances are passively conveyed by bulk flows. It plays important roles in a wide range of research fields, such as physics, biology, engineering and earth sciences. The flow pattern is generally given and not influenced by variations in particles' concentration. Statistical aspects of advection of a passive particle by flows have attracted much attention. Advective phenomena have been studied mainly for continuous media by employing the classical advection equation, however, there are also many situations where flows are passing over connections between discrete nodes constituting a network. Obvious example is provided by pipelines, which is used for delivery of gas, oil, or pollutant to a set of destinations. Another example should be given by the transportation. Traffic flows are established by trains, ships or aircraft on a regular scheduled service between rail stations, ocean harbours or airports. It is however remarkable that advection equation for networks have not been so far mathematically formulated. Transport of particles over networks is generally described in terms of random Markov processes. The time evolution of the concentration u_i of particles at node i is given by

$$\frac{d}{dt}u_i = \sum_{j=1}^{N} \left(\nu_{ij} A_{ij} u_j - \nu_{ji} A_{ji} u_i\right), \qquad (1)$$

where $\{A_{ij}\}$ is the adjacency matrix which specifies the network topology and, ν_{ij} is the probability rate for the transition from node j to i. Properties of the transport process are determined by ν_{ij}, e.g. the diffusion process is given by $\nu_{ij} = 1$ for all $\{i, j\}$. In this talk, we present a mathematical formulation of the advection equation for network-organized systems. The transition rates for advection processes $\nu_{ij} = \nu_{ij}^{\mathrm{adv}}$ in Eq. (1) are determined under two assumptions: (i) The flow pattern is stationary and, for each node, total incoming and outgoing flows are equal. (ii) The particles can be only transported together with a flow, so that the probability of transition from one node to another is proportional to the intensity of the flow passing through the respective link. As a demonstration of advective phenomena in networks, we show equilibration (mixing process) of passive particles. Concentrations of particles at equilibrium in all nodes are the same and, the steady state is always uniform. Equilibration of particle concentrations begins in the subset of nodes, representing flow hubs, and spreads gradually to the periphery, where only weak flows are present. These characteristics can be explained by using eigenvectors of the flow matrix $M_{ij} = \nu_{ij}^{\mathrm{adv}} - \sum_{l=1}^{N} \nu_{li}^{\mathrm{adv}} \delta_{ij}$.

CT Patterns (CTPA)
8 September 14.30–16.00 (PCC 2.1-2.3)

Time: 14.48 – 15.03

Dynamics of self-organized precipitate patterns driven by gravity current

Dezso Horvath (University of Szeged) Gabor Potari, Eszter Toth-Szeles, Agota Toth

Abstract: In our experiments we generate a gravity current around an inlet by pumping a dense solution into a liquid layer. When the reaction between the two solutions leading to precipitate formation is characterized by slow kinetics, the spatial distribution of the precipitate is governed by the fluid flow. With sufficient density difference the resultant pattern shows angular variation in the form of precipitate-rich filaments oriented radially. Our numerical study based on the Navier-Stokes equation in a three-dimensional medium reveals that a hydrodynamically unstable zone evolves behind the tip of the gravity current, generating flows in transverse direction, which in turn are responsible for the angular alternation of precipitate-rich and -lean segments. The results of the calculations are in good agreement with experimental observations.

CT Stochastic processes (CTSP)
9 September 14.30–16.00 (PCC 2.4-2.6)

Time: 14.48 – 15.03

Noise-robustness of physical random bit generation

Masanobu Inubushi (NTT Communication Science Laboratories, NTT Corporation) Yoshimura, K (NTT CS lab), and Davis, P (Telecognix Corp.)

Abstract: We are all familiar with throwing dice to get random numbers. How can we be sure that they are truly random and unpredictable? And how can we be sure that their randomness properties are reliable? Our study focuses on this fundamental problem. The ability to create random and unpredictable bits from random physical processes in optoelectronic devices is essential to security and privacy in modern IT systems. These devices are called physical random bit generators (RBGs). They are also known as true random number generators (TRNGs) or nondeterministic random bit generators (NRBGs). Recent works have focused on methods for fast physical RBG using physical devices such as chaotic semiconductor lasers and superluminescent LED. However, little is known about how to evaluate and guarantee the reliability of the unpredictability of such devices. In our study, we introduce a new property of physical RBGs, called 'noise robustness' [1]. In general, any physical RBG uses some kind of microscopic noise source, such as thermal or quantum noise. We say that a physical RBG has noise-robustness with respect to a randomness property such as unpredictability if the randomness property of the bits does not depend on microscopic noise properties. It is important that unpredictability of a physical RBG be robust with respect to variations of the noise properties, which may occur due to the intrinsic difficulty of specifying or controlling the noise, or due to malicious attack. To describe the noise-robustness more concretely, we give a formal definition of noise-robustness by considering the parameter space of a stochastic model of a microscopic noise source. Furthermore, we show that a chaotic laser RBG is an example of a promising physical RBG that has noise-robustness with respect to changes in bias of noise source [2]. Finally, we compare the noise-robustness of the chaotic laser RBG with that of bistable (or metastable) RBGs which are commonly used in computer chips.
References: [1] M. Inubushi, K. Yoshimura, P. Davis, Noise robustness of unpredictability in a chaotic laser system: Toward reliable physical random bit generation, Phys. Rev. E, Vol. 91, 022918, 2015. [2] M. Inubushi, K. Yoshimura, Kenichi Arai, Peter Davis, Physical random bit generators and their reliability: focusing on chaotic laser systems, Nonlinear Theory and Its Applications (NOLTA), IEICE, Vol. 6, no. 2, 2015.

CT Nonlinear optics (CTNO)
10 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.00 – 10.15

Wavefront Propagation in Two-dimensional Optical Bistable Device

Takashi Isoshima (RIKEN) Ito, Y. (RIKEN)

Abstract: Wavefront propagation in a nonequilibrium system is attracting attentions in the field of natural computing. For example, Belousov-Zhabotinsky (BZ) reaction system with a two-dimensional spatial expanse is one of the famous system for wave propagation. We are investigating a two-dimensional thermo-optical bistable device for wave propagation, because of their controllability and stability. In this type of devices, optical bistability is realized through positive feedback between heat generated by photoabsorption and change in optical absorbance induced by temperature-dependent absorption coefficient. With a bias light irradiation at an intensity below the turn-on threshold (in the bistable region), the whole area remains "off" without any perturbation. Once the light intensity is increased above the turn-on threshold at a location, the medium is locally triggered to turn on, and the "turn-on" wavefront extends two-dimensionally due to thermal diffusion in lateral direction. We have fabricated devices composed of a liquid crystal as a temperature-sensitive transmission-changing material combined with a black optical absorption layer below it, and experimentally demonstrated wavefront propagation. The wavefront propagation properties were analyzed and compared with theoretical calculation based on the nonlinear opto-thermal diffusion equation. Preliminary maze-exploration experiment was also performed.

CT Astro and plasma physics (CTAP)
7 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.24 – 15.39

Formation of intense bipolar regions in spherical dynamo simulations with stratification

Sarah Jabbari (Stockholm University) Brandenburg, A. (Nordita and Stockholm university)

Abstract: Recent studies have suggested a new mechanism that can be used to explain the formation of magnetic spots or bipolar regions in highly stratified turbulent plasmas. According to this model, when the magnetic Reynolds number is large enough, a large-scale magnetic field suppresses the turbulent pressure, which leads to a negative contribution of turbu- lence to the effective magnetic pressure. Direct numerical simulations (DNS) have confirmed that the negative contribution is large enough so that the effective magnetic pressure becomes negative and leads to a large- scale instability, which we refer to as negative effective magnetic pressure Instability (NEMPI). NEMPI was used to explain the formation of active regions and sunspots on the solar surface. One step toward improving this model was to combine dynamo in- stability with NEMPI. The dynamo is known to be responsible for the solar large-scale magnetic field and to play a role in solar activity. In this context, we studied stratified turbulent plasmas in spherical geometry, where the background field was generated by alpha squared dynamo. For NEMPI to be excited, the initial magnetic field should be in a proper range, so we used quenching function for alpha. Using the Pencil Code and mean field simulations (MFS), we showed that in the presence of dynamo-generated magnetic fields, we deal with a coupled system, where both instabilities, dynamo and NEMPI, work together and lead to the formation of magnetic structures (Jabbari et al. 2013). We also studied a similar system in plane geometry in the presence of rotation and confirmed that for slow rotation NEMPI works, but as the Coriolis number increases, the rotation suppresses NEMPI. By increasing the Coriolis number even further, the combination of fast rotation and high stratification excites a dynamo, which leads again to a coupled system of dynamo and NEMPI (Jabbari et al. 2014). In our recent study, we use DNS to investigate a similar system. The turbulence is forced in the entire spherical shell, but the forcing is made helical in the lower 30% of the shell, similar to the model of Mitra et al. (2014). We perform simulations using the Pencil Code for different density contrasts and other input parameters. We applied vertical field boundary conditions in the r direction. The results show that, when the stratification is high enough, intense bipolar regions form and as time passes, they expand, merge and create giant structures. At the same time, the new structures appear at different latitudes. By extending in f direction, the size of the bipolar regions decreases. When the helical zone is thinner, the structures appear at a later time (for more detail see Jabbari et al. 2015).

CT Nonlinear optics (CTNO)
10 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.54 – 11.09

Dynamics of passively mode-locked lasers under the influence of optical feedback and optical coupling

Lina Jaurigue (Technical University Berlin) Schöll, E (Technische Universität Berlin) Lüdge, K (Freie Universität Berlin)

Abstract: High-repetition rate ultra-short light sources are essential for optical data communication and all-optical computing. Promising candidates, particularly for on-chip optical data communication, are semiconductor passively mode-locked lasers. Such devices produce light pulses through the interplay between an absorbing and an amplifying section. We study the dynamics of these devices under the influence of time-delayed optical feedback and optical coupling to a second mode-locked laser. By means of numerical bifurcation analysis we determine the different regimes of operation, ranging from stable mode-locking regimes with short pulses to quasi-periodic and chaotic pulse trains. For the aforementioned applications highly regular pulse trains are required, however spontaneous emission noise significantly degrades the regularity of the emitted pulse trains in semiconductor passively mode-locked lasers. This pulse train regularity is quantified by the so called timing jitter. For both the feedback and coupled laser schemes we find parameter regimes within which the timing jitter is decreased compared with the solitary laser. In addition, these setups allow for post fabrication tuning of the pulse repetition rate via the feedback, or coupling, delay time.

CT Networks (CTNE)
9 September 14.30–16.00 (PCC 2.1-2.3)

Time: 14.48 – 15.03

Delocalization of Phase Fluctuations and the Stability of AC Electricity Grids

Stefan Kettemann (Jacobs University Bremen)

Abstract: The energy transition towards an increased supply of renewable energy raises concerns that existing electricity grids, built to connect few centralized large power plants with consumers, may become more difficult to control and stabilized with a rising number of decentralized small scale generators. Here, we aim to study therefore, how local phase fluctuations affect the AC grid stability. To this end, we start from a model of nonlinear dynamic power balance equations. We map them to complex linear wave equations and find stationary solutions for the distribution of phases fi at the generator and consumer sites i. Next, we derive differential equations for deviations from these stationary solutions. Starting with an initially localized phase perturbation, it is found to spread in a periodic grid diffusively throughout the grid. We derive the parametric dependence of diffusion constant D. We apply the same solution strategy to general grid topologies and analyse their stability against local fluctuations. The fluctuation remains either localized or becomes delocalized, depending on grid topology and distribution of consumers and generators Pi. Delocalization is found to increase the lifetime of phase fluctuations and thereby their influence on grid stability, while localization results in an exponentially fast decay of phase fluctuations at all grid sites[1]. [1] S. Kettemann, subm. to Phys. Rev. Lett. (2015), arXiv:1504.05525

CT Fluids I (CTF1)
7 September 14.30–16.00 (PCC 2.4-2.6)

Time: 14.48 – 15.03

Spontaneous motion of an elliptic particles induced by surface tension gradient

Hiroyuki Kitahata (Chiba University) Iida, K (Tohoku University) Nagayama, M (Hokkaido University)

Abstract: When a circular camphor disk is put onto water surface, it diffuses camphor molecules onto water surface and reduces surface tension. It is known that the symmetric surface tension profile can be unstabilized and that the camphor particle can be driven by the asymmetric surface tension profile. In this sense, the camphor disk has been studied as a good model for self-propelled particles. Recently, the coupling between deformation and direction of motion of self-propelled particles has been investigated. In order to study the effect of the shape to the motion, we used a camphor with an elliptic shape. We constructed and reduced a mathematical model for the surface-tension-driven motion of an elliptic camphor particles, and discussed the direction of motion from the standpoint of bifurcation analysis.
References: [1] H. Kitahata, K. Iida, and M. Nagayama, Phys. Rev. E, 87, 010901 (2013). [2] K. Iida, H. Kitahata, and M. Nagayama, Physica D, 272, 39-50 (2014).

CT Patterns (CTPA)
8 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.42 – 15.57

Turing Bifurcation in an Epidemic Model in Patchy Space with Diffusion

Sándor Kovács (Eötvös Loránd Tudományegyetem)

Abstract: In this talk we propose an epidemic model in order to simulate the dynamics of disease transmission under the influence of population migration among patches. Our interest is to study a SIS epidemiological model in two patches in which the per capita migration rate of each species is influenced only by its own density, i.e. there is no response to the density of the other one. We will prove that at a critical value of the bifurcation parameter the system undergoes a so called Turing bifurcation, in addition as one of the diffusion coefficients is increased and passes through critical value, the spatially homogeneous equilibrium loses its stability and two new equilibria arise.

CT Mathematical aspects (CTMA)
9 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.06 – 15.21

Escape dynamics through continuously growing leak

Tamas Kovacs (Konkoly Observatory, Budapest) Vanyo J (Eszterhazy Karoly University)

Abstract: Simple nonlinear dynamical systems in which trajectories may escape through an artificial leak, called leaky systems, play an important role in recent studies. In this work we present the escape rate of the trajectories through continuously growing leak where the size of the hole depends on the number of the particles felt in. The motivation of this study comes from the application of leaky systems to dynamical astronomy. More precisely, the early stage of planet formation during the forming planetesimals, that can be thought as of holes in the phase space, accrete the particles from their neighborhood, and therefore, their size is growing. In numerical simulations we consider the standard map demonstrating that the results can be used in case of fully hyperbolic dynamics as well as in mixed phase space. An analytic derivation of the escape rate which is valid during the hole's expansion is also present. Additionally, we show that this analytic expression tends to the classical exponential decay, known from the theory of transient chaos, in the limit when the escaping particles do not affect the hole size.

CT Fluids II (CTF2)
8 September 14.30–16.00 (PCC 1.1-1.3)

Time: 14.30 – 14.45

Rotation and Oscillation of a Self-Propelled particle in a Two-Dimensional Axisymmetric System

Yuki Koyano (Chiba University) Koyano, Y (Chiba University) Yoshinaga, N (Tohoku University) Kitahata, H (Chiba University)

Abstract: The particles or droplets moving through energy gain and dissipation from/to the surroundings are called self-propelled particles. In terms of symmetry, self-propulsion is classified into two types. The first type involves the direction of motion being determined by the asymmetry originally embedded in the system, while the second type is the motion of a symmetric particle that arises via spontaneous symmetry breaking. In the latter case, the rest state consistent with symmetric properties of the system becomes unstable and motion with lower symmetry is realized. Here, we focus on symmetric particles. In one dimensional systems with inversion symmetry, oscillatory motions are produced through bifurcation from the rest state at the system center by breaking inversion and time-translation symmetries. In this study, we consider two-dimensional systems with inversion and rotational symmetries as an extension of the one-dimensional system. Such axisymmetric systems are exemplified by a particle in a central force field or that confined in a circular region. In those systems, the self-propelled particle may show rotational or oscillatory motion. We propose a generic model for a self-propelled particle in a two-dimensional axisymmetric system. A weakly nonlinear analysis establishes criteria for determining rotational or oscillatory motion. In numerical calculation, we confirmed the validity of the analytical results, and we found the trajectories converge to quasi-periodic orbits under the condition beyond the weakly nonlinear limit.

CT Stochastic processes (CTSP)
9 September 14.30–16.00 (PCC 2.4-2.6)

Time: 14.30 – 14.45

On a link between novel ensembles of random matrices and systems of self-driven particles

Milan Krbalek (Czech Technical University)

Abstract: Stochastic analysis of individual quantities measured in various systems of self-driven particles (agents: walkers, drivers, birds) reveals many common features. Indeed, statistical distributions of headways among succeeding agents as well as the statistical rigidity in those systems show significant mathematical similarities. Such a striking resemblance is not accidental, although each of those systems is ruled by a different level of mutual agent repulsions/attractions or a different level of stochasticity. Thus, to what extent are these distributions affected by the interaction rules? We will present (by means of novel classes of random matrices) a general scheme of agent dynamics producing the same statistical micro-distributions as those revealed in empirical data. Non-triviality of that correspondence will be confirmed by testing of associated statistical rigidities.

CT Fluids I (CTF1)
7 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.24 – 15.39

Aquatic propulsion by propagating flexural waves and the role of nonlinearity

Victor Krylov (Loughborough University)

Abstract: In the present work, some initial results of the research into the theory of wave-like aquatic propulsion of marine craft are reported. Recent experimental investigations of small model boats propelled by propagating flexural waves that have been carried out by the present author and his co-workers demonstrated viability of this type of propulsion as an alternative to a well-known screw propeller. In the attempts of theoretical explanation of the obtained experimental results, it was found that Lighthill's theory of fish locomotion predicts zero thrust for such model boats, which is in contradiction with the results of the experiments. One should note in this connection that Lighthill's theory of fish locomotion assumes that the amplitudes of propulsive waves created by fish body motion grow from zero on the front (at fish heads) to their maximum values at the tails. This is consistent with fish body motion in nature, but is not compatible with the behaviour of localised flexural waves used for propulsion in the experimental model vessels. To overcome the problem of predicting zero thrust for the above vessels, it was suggested that nonlinear distortion of localised flexural waves may be responsible for generation of thrust. This hypothesis has been explored in the present work by adding nonlinear harmonics of propulsive flexural waves to the Lighthill's equations for thrust and efficiency. For simplicity, only the lowest (third) harmonic growing linearly with the distance of propagation was used. The resulting formula for the averaged thrust shows that, due to the effect of the third harmonic, the thrust is no longer zero, thereby demonstrating that nonlinear distortion of the propulsive flexural waves is crucial for the existence of wave-like aquatic propulsion of small marine craft employing freely propagating flexural waves.

CT Networks (CTNE)
9 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.06 – 15.21

Coherent collective behavior in networks of coupled circuits with a zoom into the transition regime

Darka Labavic (Jacobs University Bremen) Hildegard Meyer-Ortmanns (Jacobs University Bremen)

Abstract: We study the versatile performance of networks of coupled circuits. Each of these circuits is composed of a positive and a negative feedback loop in a motif that is frequently found in genetic and neural networks. When two of these circuits are coupled with mutual repression, the system can function as a toggle switch. The variety of its states can be controlled by two parameters as we demonstrate by a detailed bifurcation analysis. In the bistable regimes, switches between the coexisting attractors can be induced by noise. When we couple larger sets of these units, we numerically observe collective coherent modes of individual fixed-point and limit-cycle behavior. It is there that the monotonic change of a single bifurcation parameter allows one to control the onset and arrest of the synchronized oscillations. This mechanism may play a role in biological applications, in particular, in connection with the segmentation clock. While tuning the bifurcation parameter a variety of transient patterns emerges upon approaching the stationary states, in particular, a self-organized pacemaker in a completely uniformly equipped ensemble, so that the symmetry breaking happens dynamically. A change of a single bifurcation parameter also triggers the mutual conversion of regimes of collective fixed-point behavior and collective synchronized oscillations. Of particular interest is the arrest of oscillations. We identify the criterion that determines the seeds of arrest and the propagation of arrest fronts in terms of the vicinity to the future attractor. Due to a high degree of multistability we observe versatile patterns of phase locked motion in the oscillatory regime. Quenching the system into the regime, where oscillatory states are metastable, we observe qualitatively distinct approaches of the fixed-point attractor, depending on the initial seeds. If the seeds of arrest are isolated single sites of the lattice, the arrest propagates via bubble formation, visually similar to nucleation processes; if the seed is extended along a line of lowest amplitudes, the freezing follows the spatial patterns of phase-locked motion with long interfaces between arrested and oscillating units. For spiral patterns of oscillator phases these interfaces are arranged along the arms of the spirals. [1] D. Labavic and H. Meyer-Ortmanns, Chaos **24** (2014) 043118 [2] D. Labavic and H. Meyer-Ortmanns, EPL **109** (2015) 10001

CT Time series (CTTS)
10 September 14.30–16.30 (PCC 2.1-2.3)

Time: 14.30 – 14.45

Phase correlations in leptokurtic time series

Ingo Laut (Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)) Raeth, C. (DLR), Schreiber K. (DLR)

Abstract: Many time series of nonlinear origin, like turbulence or financial markets not only exhibit leptokurtic (also called heavy-tailed or fat-tailed) probability distribution functions (PDF) but are also classified or characterized by them. In the Fourier representation of these time series these nonlinearities must be contained in the phase information. Here, we demonstrate how to exploit this information to both synthesize and analyze leptokurtic time series. We first show that empirical data of market indices show linear phase correlations. Based on these findings we impose a set of linear phase correlations on white Gaussian noise and demonstrate that the so-obtained time series can reproduce the scaling properties of the PDF and volatility often observed in financial data remarkably well [1]. Next we introduce a novel nonlinear statistic called phase walk statistics (PWS), which measures – in close analogy to random walk analyses – the deviation from randomness of the phases. Applying this statistic to a number of empirical and synthetic leptokurtic time series reveals that nonlinearities can be detected with unprecedented significance. A surrogate-assisted analysis further shows that PWS is able to disentangle different classes of nonlinearities, which have indistinguishable PDFs [2]. In summary, the study of Fourier phases offers new and refined insights into nonlinearities in time series. Thus, this approach opens new ways for better understanding and modelling the underlying nonlinear processes. [1] C. Raeth and I. Laut, PRL, (submitted) [2] K. Schreiber and C. Raeth, PRE, (submitted)

CT Networks (CTNE)
9 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.42 – 15.57

Adaptive control of synchronization in complex networks

Judith Lehnert (Institut für Theoretische Physik, TU Berlin) Hövel, P. (TU Berlin) Selivanov, A. (Tel Aviv University) Fradkov, A. (Sankt Peterburg State University) Schöll, E. (TU Berlin)

Abstract: We suggest an adaptive control scheme for the control of zero-lag and cluster synchronization in delay-coupled networks. Based on the speed gradient method, our scheme adapts the topology of a network such that the target state is realized. The emerging topology is characterized by a delicate interplay of excitatory and inhibitory links leading to the stabilization of the desired cluster state. As a crucial parameter determining this interplay we identify the delay time. Furthermore, we show that it is not necessary to control all links of the network but that it suffices to control a subset of links. We discuss the conditions under which the control of a subset of links fails. We apply our method to coupled Stuart-Landau oscillators, a paradigmatic normal form that naturally arises in an expansion of systems close to a Hopf bifurcation. The successful and robust control of this generic model opens up possible applications in a wide range of systems in physics, chemistry, technology, and life science.

CT Biophysics (CTBI)
7 September 14.30–16.00 (PCC 2.1-2.3)

Time: 14.48 – 15.03

How the growth rate of host cells affects cancer risk in a deterministic way

Christophe Letellier (CORIA - Universitè de Rouen) Draghi C. (CORIA - Université de Rouen) Viger L. (CORIA - Université de Rouen) Denis F. (Centre Jean Bernard - CORIA)

Abstract: Cancer incidence depends strongly on the tissue considered and, for instance, the probability to have a colorectal cancer can be up to 7 times greater than the probability for a thyroid cancer, or ten times the one for a glioma. It was recently asserted that the variation in cancer risk was mostly due to "bad luck". Based on a deterministic model describing the interactions between the host, immune and tumor cells and allowing to simulate spatial growth of tumor, we show that the probability for a clinically significant tumor increases with growth rate of host cells. This is mainly due to the fact that malignant cells have a growth rate being, at least, twice the growth rate of the host cells from which they are issued (mutated). More active the tissue, smaller the number of possibilities the parameter values for which the microenvironment can resist against tumor proliferation. The deleterous issue of a tumor growth is indeed mainly driven by parameter values of our model, that is, by the conditions under which the different populations of cells interact. Such a feature is in agreement with the largest cancer risk found in tissue with a high regeneration rate. Moreover, the nature of cellular interactions is thus clearly driven by the status of the tissue considered, a degraded tissue thus being not a tissue with a reduced growth rate, but rather a tissue whose interactions with the immune system and tumor cells do not longer prevent from a tumor growth. Dynamically speaking, it is also shown that a chaotic regime at the tumor site scale (roughly 100 μm^3 in our simulations) leads to a less agressive (active) tumor at the tissue scale (greater than 1 mm^3).

CT Fluids II (CTF2)
8 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.24 – 15.39

Sudden relaminarisation and lifetimes in forced isotropic turbulence

Moritz Linkmann (School of Physics and Astronomy, University of Edinburgh) Alexander Morozov

Abstract: We demonstrate an unexpected connection between isotropic turbulence and wall-bounded shear flows. We perform direct numerical simulations of isotropic turbulence forced at large scales at moderate Reynolds numbers and observe sudden transitions from chaotic dynamics to a spatially simple flow, analogous to the laminar state in wall bounded shear flows. We find that the survival probabilities of turbulence are exponential and the typical lifetimes increase super-exponentially with the Reynolds number, similar to results on relaminarisation of localised turbulence in pipe and plane Couette flow. Results from simulations subjecting the observed large-scale flow to random perturbations of variable amplitude demonstrate that it is a linearly stable simple exact solution that can be destabilised by a finite-amplitude perturbation. Our results suggest that both isotropic turbulence and wall-bounded shear flows share the same phase-space dynamics.

CT Active matter (CTAM)
7 September 14.30–16.00 (PCC 1.1-1.3)

Time: 14.48 – 15.03

Superdiffusive Transport and Energy Localization in Disordered Granular Crystals

Alejandro Martínez (University of Oxford) Kevrekidis, P. G. (University of Massachusetts), and Porter, Mason A. (University of Oxford)

Abstract: We study spreading processes of initially localized excitations in one-dimensional disordered granular crystals. We thereby investigate localization phenomena in strongly nonlinear systems, which we demonstrate to be fundamentally different from localization in linear and weakly nonlinear systems. We conduct a thorough comparison of wave dynamics in chains with three different types of disorder: an uncorrelated (Anderson-like) disorder and two types of correlated disorders (which are produced by random dimer arrangements).

CT Stochastic processes (CTSP)
9 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.24 – 15.39

Study of LDP for correlated Gaussian stochastic processes and intermittent dynamical systems, stimulated by a climate science problem

Mozhdeh Massah (MPIPKS, Dresden) Leonard Smith (LSE CATS, London / Pembroke College, Oxford) and Holger Kantz (MPIPKS, Dresden, Germany)

Abstract: As we have one and only one earth and no replicas, climate characteristics are usually computed as time averages from a single time series. For understanding climate variability, it is essential to understand how closely a single time average will typically be to an ensemble average. To answer this question, we study large deviation probabilities (LDP) of stochastic processes and characterize them by their dependence on the time window. In contrast to iid variables for which this dependence is exponential and where there exists an analytic expression for the rate function, the correlated variables such as auto-regressive and auto-regressive fractionally integrated moving average processes, have not an analytic LDP. We study LDP for these processes, in order to see how correlation affects this probability in comparison to iid data. We then take a look at the LDP of maps such as the logistic map and the Pomeau-Manneville map, as intermittent dynamical systems, to see how comparable this probability for such maps is to LDP of the stochastic processes that we studied.

CT Interdisciplinary Applications I (CTIA1)
8 September 14.30–16.00 (PCC 1.4-1.6)

Time: 14.48 – 15.03

Games within games: a dynamical generation of multiple scales in space and time

Hildegard Meyer-Ortmanns (Jacobs University Bremen) Darka Labavic (Jacobs University Bremen)

Abstract: We consider (N, r) games of competition with N species and $r < N$ prey and predators. The competition is realized as predation. Further basic reactions include reproduction, decay and diffusion over a one- or two-dimensional grid, without a hard constraint on the occupation number per site. For special combinations of N and r we observe the option to see games within games for an appropriate choice of parameters. As concrete example we analyze a (6,3)- game. Once the players segregate from a random initial distribution, domains on a coarse scale emerge, which play a (2,1)-game at their boundaries, while agents inside the domains play rock-paper-scissors (that is (3,1)), leading to spiral formation with species chasing each other. The (2,1)-game has a winner in the end, so that the coexistence of domains is transient, while agents inside the remaining domain coexist, until demographic fluctuations let a single species survive in the very end. This means that we observe a dynamical generation of multiple space and time scales with emerging re-organizations of players, starting from a simple set of rules on the scale of the unit grid size. These observations are based on Gillespie simulations. We derive the deterministic limit within a van Kampen expansion. A linear stability analysis of the deterministic equations reproduces the number of forming domains, their composition in terms of species, leaving the very type of patterns unexplained. In the vicinity of a nearby bifurcation, the bifurcation analysis of the deterministic limit also explains the occurrence of transient patterns that are hints to the stable fixed points on the other side of the bifurcation point. The comparison with Gillespie simulations also reveals the impact that the various sources of stochastic fluctuations have even on qualitative features of the dynamics.

CT Climate (CTCL)
10 September 14.30–16.30 (PCC 1.1-1.3)

Time: 14.48 – 15.03

Nonsmooth saddle-node bifurcations and strange nonchaotic attractors in a phase oscillator model of glacial cycles

Takahito Mitsui (Université Catholique de Louvain) Crucifix, M (Université catholique de Louvain), Aihara, K (University of Tokyo)

Abstract: The Quaternary ice age is characterized by large variations of continental ice sheet mass and greenhouse gases (the glacial-interglacial cycles). The Earth is currently in an interglacial period started from ∼11,700 years ago. The average period of the cycles is ∼41 kilo-years (kyr) before the so-called middle Pleistocene transition (MPT) between 1.2 and 0.7 Myr ago, and it is ∼100 kyr after the MPT. It is now widely accepted that the glacial cycles are paced by the astronomical forcing, which is the long term variations of seasonal and spacial distributions of incoming-solar radiation (insolation) due to the Earth's orbital and obliquity changes. In the time scale of the Quaternary, the astronomical forcing is well approximated by a quasiperiodic function of time [Berger and Loutre, 1991], and as a result, many models of glacial cycles are written as quasiperiodically forced dynamical systems. Recently, the authors showed that several models of glacial cycles exhibit strange nonchaotic attractors (SNAs) [1,2] (see [3] for SNAs). That is, the relationship from the phase of astronomical forcing to the climate state is represented by a geometrically strange set. However, so far, the birth mechanism of SNAs has not been elucidated in the models of glacial cycles. In this study [4], we introduce a phase oscillator model of glacial cycles, and show that SNAs appear through nonsmooth saddle-node bifurcations [3] in the model. When a model of glacial cycles exhibits an SNA, the sequences of glacial cycles synchronize under the same astronomical forcing, but simultaneously they can be sensitive to parameter changes. Based on the bifurcation analysis, we suggest that the 41-kyr oscillations, typical before the MPT, are little sensitive to parameter changes, but the 100-kyr oscillations after the MPT can be strongly sensitive to parameter changes.

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CT Interdisciplinary Applications I (CTIA1)
8 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.06 – 15.21

Compact nonlinear localized modes in sawtooth lattices

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Abstract: We discuss the properties of nonlinear localized modes in sawtooth lattices, in the framework of a discrete nonlinear Schrödinger model with general on-site nonlinearity. Analytic conditions for existence of exact compact three-site solutions are obtained, and explicitly illustrated for the cases of power-law (cubic) and saturable nonlinearities. The compact states of the linear lattices belong to an isolated flat band, we show how they may be continued into compact nonlinear modes. For the linear system a compact mode exists only for one specific ratio of coupling constants, whereas for nearly any coupling ratio a compact localized modes can be found at some specific cubic nonlinearity. Furthermore, these modes are stable for wide parameter regimes. In saturable lattices, the compactification nonlinearity can be also tuned by varying the power. Further explored possibilities for the manipulation of compactness are different onsite energies and anisotropic couplings. Also, strongly localized modes of different forms and their stability are investigated numerically, in particular their possible connection to the compact modes is considered.

CT Biophysics (CTBI)

7 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.24 – 15.39

Different scale method for early endosome dynamics analysis

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Abstract: Endocytosis is a vital intracellular process, providing nutrient uptake, signaling and disease resistance [1]. Molecular motors represent one of the main components of endocytic system, fulfilling transport and some regulatory functions. Molecular motor dysfunctions may cause diseases of nervous system, kidney diseases, and chronic infection of respiratory tract [2]. Our study focuses on establishment of involvement of different molecular motors in endocytosis. Straightforward way to examine molecular motor participation in endocytosis is to compare endosome (membrane-bounded cargo container) speed in experiments with or without motor knockdown. The problem of this approach is that tens of motor species participate in endocytosis and functions of some of them may be partially replaced by functions of other ones. Moreover, motors often have specific impact on endosome trafficking (for example, they may transport subpopulation of endosomes). Apparently, that is why precise results about roles of specific minus-end directed kinesins do not exist still. Therefore, it takes whether more observations to get significant difference or applying new approaches revealing effect. We propose a method utilizing dynamic nature of endocytic system. Endosomes undergo maturation process, during which endosome characteristics evolve. Here we address only early stage of it, i.e. so called early endosomes. Roughly speaking during this process endosomes grow in size (through endosome fusion), increase rab5 surface density (most of the early maturation stage) [3]. Therefore, we consider endosome characteristic trends as maturation-linked factors. Thus, endosome characteristic as a function of another characteristic reflects properties of maturation process on a large scale, while function values on some small domains reflect local scale properties or particular maturation stage features. Endosome motility is essential for maturation, since it provides fusion/fission events. Molecular motors, fulfilling endosome trafficking, thus, influence maturation. However, endosome characteristics in turn determine endosome behavior and endosome-motor interactions in particular. Thus, motor activity and maturation are strongly coupled mutually dependent processes. Therefore, motor knock-down may have both local and large scale impact on endosome characteristic dependences. Our approach uses numerical description of these dependences. We used MotionTracking [1,2] software to quantify motor knockdown experiments in HeLa cells

and acquired endosome characteristics (size, surface rab5 density, speed, minus- and plus-end directed speed and distance to nucleus). For each pair of characteristics we depicted dataset on a scatter plot with characteristic values on x and y-axes. First, x-axis characteristics was binned and mean y-axis characteristic value was computed for each bin. Second, every dependency was fitted with analytical function; choice of the exact function was based on cross-correlation error. Mean bin values and analytical function coefficients were used as statistics, which were compared with corresponding control experiment statistics using Mann-Whitney test. Difference between mean values in some bin catches local scale motor impact, while difference between function coefficients should reflect large scale maturation alteration. These statistics allowed revealing local effects of some motors, which cannot be distinguished from control using straightforward approach. For example, kif16b is a molecular motor known to transport phosphatidylinositol 3-phosphate-containing early endosomes in HeLa cells [4]. There are local scale(i.e. in some x-axis bins) differences in size-surface rab5 density dependency exhibiting high significance level as well as high significance level large scale difference between powers of exponents, fitted to surface rab5 density-speed dependency. We are going to add track-describing statistics soon, which would allow us to determine some motor properties as, for example, whether motor participates mainly on long or short range transport.

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CT Nonlinear optics (CTNO)
10 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.18 – 10.33

Frequency dependence of chaos synchronization of low-frequency fluctuations in a photonic integrated circuit with mutually-coupled semiconductor laser

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Abstract: Coupled nonlinear systems show a large variety of dynamics. Recently, chaos synchronization in semiconductor lasers with delayed optical feedback has been studied for applications in secure key distribution [1, 2]. When two semiconductor lasers are mutually coupled, the output of these lasers show chaotic temporal oscillations whose dominant frequency corresponds to the inverse of twice the coupling time delay [3]. The chaotic temporal waveforms can be synchronized to each other with the time lag of the coupling delay time. The dynamics and synchronization in mutually-coupled semiconductor lasers have been investigated intensively for long coupling lengths ($>$ 100 mm). Recently, photonic integrated circuits (PICs) have been proposed as monolithically integrated optical systems suitable for physical random number generation [4, 5]. However, nonlinear dynamics and chaos synchronization in a PIC with two mutually-coupled semiconductor lasers with short coupling length (10 mm) have not been reported yet. We experimentally investigate chaos synchronization in a PIC with two mutually-coupled semiconductor lasers. The PIC consists of two semiconductor lasers, two semiconductor optical amplifiers, two photodetectors, and one mirror. The semiconductor lasers are mutually coupled via the mirror. In addition, each laser is subjected to it own optical feedback, and the corresponding external cavity lengths are 10 mm. We focus on chaos synchronization when both lasers exhibit low-frequency fluctuations (LFFs). The LFF dynamics consists of high-frequency chaotic oscillations and low-frequency intensity dropouts. We apply a low pass filter to the laser output signals to separate these two dynamics. We calculate the cross correlation between the temporal waveforms after filtering of the two laser outputs to evaluate the synchronization quality for different cut-off frequency values of the filter. We investigate the dependence of the synchronization quality on different frequency components by using the low-pass filter in the LFF regime. We find that the cross correlation between the two lasers shows a negative value for the filtered signals while for the unfiltered signals this value is positive. We discuss the dependence of the synchronization of LFF dynamics between the two lasers on the cut-off frequency of the low-pass filter. This phenomenon can be observed for intermediate level of injection currents of the two semiconductor lasers.
References: [1] K. Yoshimura, et al., Phys. Rev. Lett, Vol. 108, pp. 070602 (2012). [2] E. Klein, et al., Phys. Rev. E, Vol. 73, pp. 066214 (2006). [3] T. Heil, et al., Phys. Rev. Lett, Vol. 86, pp. 795 (2001). [4] R. Takahashi, et. al., Opt. Express, Vol. 22, pp. 11727 (2014). [5]

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CT Fluids I (CTF1)
7 September 14.30–16.00 (PCC 2.4-2.6)

Time: 14.30 – 14.45

Clustering of inertial particles and FTLE in compressible chaotic flows

Vicente Pérez-Muñuzuri (University of Santiago de Compostela) D. Garaboa

Abstract: Clustering of inertial particles is analyzed in chaotic compressible flows. A simplified dynamical model for the motion of inertial particles in a compressible flow has been derived. Clustering enhancement has been observed for intermediate Stokes times and characterized in terms of the Finite-Time Lyapunov Exponents (FTLE). To that end, a new method to calculate these exponents that takes into account not only the initial position of the particles, but their initial velocities, has been proposed. Cluster formation has been observed to depend on the nature of the flow; vortical or shear one. The motion of heavy and light particles is analyzed in terms of the compressibility and correlation length of the density field. Results will be illustrated for different numerical flows. [1] V. Pérez-Muñuzuri. Phys. Rev. E 89, 022917, 2014. [2] V. Pérez-Muñuzuri. Phys. Rev. E 91, 052906, 2015. [3] D. Garaboa and Pérez-Muñuzuri, Submitted to Nonlin. Proc. Geophys. 2015.

CT Networks and Patterns (CTNP)
10 September 14.30–16.30 (PCC 1.4-1.6)

Time: 15.24 – 15.39

(In)stability of Laplacian growth

Michal Pecelerowicz (Institute of Theoretical Physics, Faculty of Physics, University of Warsaw)
Szymczak, P (University of Warsaw)

Abstract: Laplacian growth is one of the fundamental mechanisms of pattern formation, driving such natural processes like electrodeposition, dielectric breakdown or viscous fingering. A characteristic feature of these processes is a strong instability of the interface motion: if the interface is an isoline of the harmonic field and the growth rate is proportional to the gradient of the field, small perturbations of the interface have a tendency to grow and eventually get transformed into fingers. At short wavelengths, the interface growth is stabilized by regularization mechanisms such as surface tension or kinetic undercooling, but the longer wavelengths are generally unstable. In this communication, we show that - if the fingers produced as a result of the instability are long and thin - then globally the pattern continues to grow in a stable way, with its envelope expanding with nearly a constant velocity thus forming highly regular geometric shapes. We show that the stabilizing mechanism here is connected with the splitting of the fingers. Whenever the growth velocity becomes too large, the finger splits in two branches. In this way the system can absorb an increased flux and thus damp the instability. The quantitative analysis of these effect is provided by means of the Loewner equation, which allows us to reduce the problem of the interface motion to that of the evolution of the conformal mapping onto the complex plane. This allows us for an effective analysis of the the multi-fingered growth in a variety of different geometries. We show how the geometry impacts the shape of the envelope of the growing pattern and compare the results with those observed in natural systems.

CT Chaos (CTCH)
9 September 14.30–16.00 (PCC 1.1-1.3)

Time: 14.30 – 14.45

Coarse-Grainings Induced by Non-Generating Partitions of Unimodular Maps

Oliver Pfante (Max Planck Institute for Mathematics in the Sciences) Jost, J. (Max Planck Institute for Mathematics in the Sciences)

Abstract: In order to deal with chaotic dynamical systems induced by unimodular maps one often converts an analog time series into a binary sequence by introducing a threshold. The choice of the maximum of the unimodular map provides the generating partition, i.e., the one with maximal topological entropy, and the powerful techniques of kneading theory are available. Nearly nothing is known if the choice of the threshold differs from the maximum. The induced partitions have been simply considered as "misplaced". Our approach to the symbol vs. analog time series problem is entirely different because we do not consider the symbol sequence merely as a vehicle to get information about the original, analog time series. We think of the symbol dynamics as new, macroscopic ones in their own right which are derived from a microscopic time series - the initial analog signal - by means of an aggregation which assigns the same symbol to all elements in a cell of the partition. Due to this new point of view, we enter the realm of multilevel dynamical systems in general and the problem how one can identify emergent levels in particular. Choices of the threshold different from the maximum lead to interesting macroscopic dynamics. They exhibit a rich structure which can be captured by information theoretical measures proposed by the author and others. The explicit study of these measures provides not only insights into them but also new and deep results on the relations between the analog and the symbol dynamics of unimodular maps. Keywords: Chaotic Dynamics, Information Theory, Statistical Physics, Aggregation, Time-Discrete Dynamics, Ergodicity

CT Biophysics (CTBI)
7 September 14.30–16.00 (PCC 2.1-2.3)

Time: 14.30 – 14.45

Bayes forest: a framework for realistic modeling of plant shapes

Ilya Potapov (Tampere University of Technology) Järvenpää, M. (Tampere University of Technology), Raumonen, P. (Tampere University of Technology), Kaasalainen, M. (Tampere University of Technology),

Abstract: Modeling of the plant architecture accounting for the real shapes facilitates many applications: ecology (realistic assessments in the photosynthetic production, biomass, community interactions etc.), forestry (resources management and predictions), society (urban planning) and others. Majority of the plant models use the experimental data partially, considering only several most representable conditions for growth and development. Here, we propose a framework to combine models and data in a highly throughput stochastic procedure, where the two supplement each other in the Bayesian sense. On the one hand, the theoretical and computational functional-structural growth models with their analytic rules of growth serve as *a priori* information. On the other hand, the complex quantitative architectural models obtained directly from data act as the *likelihood* component. In this junction, data dictates the parameter choice of the models, while the models filter out the spurious and outlier results of the experiments. To show the feasibility of the approach, we used the most advanced models for reconstruction of geometry and topology of trees using Terrestrial Laser Scanning (TLS) data and the function-structural plant growth model LIGNUM for pine tree growth (*Pinus sylvestris L.*). The latter was further modified for the faster calculation and augmented with the stochastic rules of growth. Therefore, the LIGNUM allows for generation of the distribution functions (various stochastic entities describing the geometry and topology of trees) and their comparison to the corresponding distribution functions of the TLS generated data. The analysis embodies finding of a choice of the stochastic LIGNUM parameters that fit the experimental distribution functions best. We found that only partial structural information and moderate parameter set (< 20) lead to the realistic tree forms observed in real conditions.

CT Chaos (CTCH)
9 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.42 – 15.57

Numerical and experimental study of the effects of noise on the permutation entropy

Carlos Quintero (Universitat Politècnica de Catalunya) Simone Pigolotti (Universitat Politècnica de Catalunya), M. C. Torrent (Universitat Politècnica de Catalunya) and Cristina Masoller (Universitat Politècnica de Catalunya)

Abstract: We analyze the effects of noise on the permutation entropy of dynamical systems. We take as numerical examples the logistic map and the Rössler system. Upon varying the noise strength faster, we find a transition from an almost-deterministic regime, where the permutation entropy grows slower than linearly with the pattern dimension, to a noise-dominated regime, where the permutation entropy grows faster than linearly with the pattern dimension. We perform the same analysis on experimental time-series by considering the stochastic spiking output of a semiconductor laser with optical feedback. Because of the experimental conditions, the dynamics is found to be always in the noise-dominated regime. Nevertheless, the analysis allows to detect regularities of the underlying dynamics. By comparing the results of these three different examples, we discuss the possibility of determining from a time series whether the underlying dynamics is dominated by noise or not

CT Patterns (CTPA)
8 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.06 – 15.21

Localised states in a neural field model of the primary visual cortex

James Rankin (New York University) Avitabile, D (University of Nottingham), Chavane, F (INT, CNRS & Aix-Marseille University), Faye, G (EHESS) and Lloyd, D (University of Surrey)

Abstract: We study localised states in the neural field equation (NFE) posed on the Euclidean plane. The resulting nonlocal integro-differential equation has been widely used to model the mean firing rates of neurons across a spatially continuous domain. Existing studies of localised states in the NFE exploited a PDE approximation of the full integral model (IM), which is only applicable without inputs and for certain choices of the connectivity function. We developed a numerical scheme using FFTs and Matrix-free Newton-Krylov solvers to perform numerical continuation directly on the IM. The tools developed allow for localised states in the NFE to be characterised and the effectiveness of PDE approximations to be evaluated. Furthermore, we are no longer restricted in the choice of connectivity function and can study the NFE with inputs. Primary visual cortex features a quasiperiodic orientation preference map with a regular length scale. Voltage imaging experiments have shown that local, oriented visual stimuli elicit activation that is orientation-selective and patchy within the stimulus footprint but non-selective outside the footprint. We study the dynamics of these input-driven states in a model with a biologically-motivated radial connectivity profile and sub-populations encoding different orientations. We argue that the observed patchy cortical activation patterns are pre-encoded by the connectivity profile and that the orientation preference map fixes the spatial phase of such patterns.

CT Astro and plasma physics (CTAP)
7 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.06 – 15.21

Warped product of Hamiltonians

Giovanni Rastelli (University of Turin) C. Chanu (University of Turin), L. Degiovanni (University of Turin)

Abstract: Two, or more, Hamiltonian functions defined on different phase spaces can be combined together to obtain a Hamiltonian on the product of those spaces. The new Hamiltonian is called the warped product of its factors. We show how the idea of warped product of Hamiltonians can be employed both to analyze given Hamiltonian systems (for example the Jacobi-Calogero and Wolfes three-body systems on a line) and to build integrable or superintegrable systems (Tremblay-Turbiner-Winternitz system, extensions of Hamiltonian systems).
References: C. Chanu, L. Degiovanni and G. Rastelli, "Warped product of Hamiltonians and extensions of Hamiltonian systems", J. Phys.: Conf. Ser. 597 012024 doi:10.1088/1742-6596/597/1/012024 (2015)

CT Interdisciplinary Applications I (CTIA1)

8 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.24 – 15.39

Dynamics of a pendulum under tilted parametric excitations

José Sartorelli (Universidade de São Paulo) Depetri G (Universidade Estadual de Campinas) Marin B (Universidade de São Paulo) Saa, A (Universidade Estadual de Campinas) Baptista, MS (University of Aberdeen)

Abstract: Experimental investigations and numerical simulations on the dynamics of a simple planar pendulum, under tilted parametric excitations are presented. The excitations are applied by letting the pivot oscillate harmonically $S(t) = A\cos(2\pi f_p t)$ on a trail making an angle $\phi = \frac{\pi}{8}$ with the vertical direction, where the amplitude A and frequency f_p are the control parameters of the system. The equations of motion are given by differential equations with time-varying coefficients due to the excitation acceleration given by $\ddot{S}$. For $\phi = 0$, in the parameter space (f_p,A) there are regions of stabilized angular positions while for $\phi \neq 0$, they no longer exist and new regions appear in which stable periodic oscillations take place. The experimental data are the time series of the absolute value of the angular speed ω, which are analyzed through Poincaré section $S = 0$. These maps give origin to first return maps $|\omega_{n+1}| \times |\omega_n|$, so the map periodicity is given by $n = f_p/f_{osc}$. The bifurcations loci in the parameter space (f_p,A) were obtained by direct integration of the equations of motion by keeping fixed the initial conditions $(\theta(0), \omega(0)) = (\frac{\pi}{5.7}, 0)$. Due to attractors coexistence, to apply the numerical continuation technique to classify the bifurcation types, period doubling, saddle node, etc we need to take different initial conditions for different periodicity n. For the vertical case, through simulations we observed even resonances n=2 and 4, related respectively to period doubling and saddle-node bifurcations. The non verticality of the excitation breaks the symmetry inducing a direct horizontal base-excitation component generating in addition to the primary resonances previously observed, the odd resonances n = 1, 3, and 5, related to saddle node bifurcations. Our results agree with those proposed by the Melnikov method, which guarantees the existence of only the even subharmonic resonances for the tilted case, but guarantees the existence of the all resonances in the tilted case.

CT Interdisciplinary Applications II (CTIA2)
8 September 14.30–16.00 (PCC 2.4-2.6)

Time: 14.30 – 14.45

Tracing the flow in complex renewable energy networks

Mirko Schaefer (FIAS) Hörsch, J (FIAS) Schramm, S (FIAS) Greiner, M (Aarhus University)

Abstract: Renewable energy networks are defined as power grids with a large penetration of fluctuating renewable power generation. Flow tracing algorithms track the renewable power as it flows from the generation nodes through the network to the consumption nodes. This allows for fair pricing schemes of future transmission investments. We compare different methods of flow tracing by applying them to both abstract network models and a model of the pan-European transmission grid.

CT Interdisciplinary Applications I (CTIA1)
8 September 14.30–16.00 (PCC 1.4-1.6)

Time: 14.30 – 14.45

Homeostasis is a Critical Illusion of Harmony

Tjeerd olde Scheper (Oxford Brookes University)

Abstract: The concept of homeostasis has been always been a convenient principle to describe the experimentally observed stability of an organism or process. This stable state seems to underpin the balance of nature, reaching back to the ideas of a body in harmony and under control . Control mechanisms that enable this harmonic state are comparable to plant control processes, relying on feedback and error estimates to determine the control needed to maintain this stable stat. Unfortunately, for the poetic beauty of the concept, homeostatic systems are in fact not stable in the dynamic sense, nor has any relevant biological mechanism been identified that may function as the supervisory controller. Occasionally, alternative variants for homeostatic control are proposed. These encompass allostasis and similar mechanisms, which can be interpret as multi-state homeostatic control. None of the existing feedback loop and multi-state proposals of homeostatic control are capable of explaining the multi-scale dynamic emerging semi-stable state associated with homeostasis. To understand homeostasis as a dynamic process, one needs to have a dynamic system with the ability to change state without losing stability, respond flexibly to small and large perturbations, and have the ability to respond in a mostly scale-free manner. Assuming that a homeostatic system is an epiphenomenon, i.e. it is an apparent result of underlying stabilising mechanisms rather than the mechanism itself, it may be possible to explain the concept and its failings in a consistent dynamic systems manner. This will allow for a better understanding of the underlying mechanisms, and point towards possible ways to resolve the failings that currently cannot be addressed with the homeostatic paradigm. Rate Control of Chaos (RCC) is a non-linear method of control, derived from metabolic processes. Its main features are the ability to control chaotic systems into unstable periodic orbits, maintaining stability across bifurcations, yet allowing the controlled chaotic system to remain slightly chaotic (in terms of small positive Lyapunov exponents). This property permits a set of RCC controlled chaotic systems to become connected into a stable periodic system, whose behaviour is not merely the result of the cumulative underlying dynamics. Nevertheless, such a combined system is still based on stable individual systems, and can be scale-free as demonstrated by a strong power law relation evident in its dynamic behaviour. The emergent dynamics and scale-free property of a connected rate controlled chaotic system demonstrates similar properties to a critical system. To demonstrate the strengths of criticality for homeostatic control, a set of RCC controlled Roessler oscillators are connected to show the ability of the combined system to be scale invariant, and maintain a stable oscillation despite perturbations. Nevertheless, the system can still change state on by oscillating in different mulit-orbits depending on connectivity and underlying dynamics. Furthermore, a model of extracellular matrix formation, allows more complex dynamics and the demonstration of the power law relation between the number of connected units and the total

system oscillation amplitude. These emerging critical systems demonstrate that seemingly stable systems can be scale-free. They can respond rapidly to varying scaled input, maintain stability, and show that interacting non-linear systems are controllable without the need for set points and linear control methods. The illiusion of harmony of a homeostatic system is maintained by an emergent critical system, but is not limited to the many failings of a homeostatic control method applied to complex, high order biological systems. Enticingly, it may also be that seemingly homeostatic biological systems are merely demonstrating their underlying emerging criticality.

CT Fluids I (CTF1)
7 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.42 – 15.57

Harnessing vector rogue waves

Sergey Sergeyev (Aston University) Kolpakov, S A (Aston University), Mou, Ch (Aston University), Jacobsen, G (Acreo, Sweden), and Popov, S (KTH, Sweden)

Abstract: Extreme wave events with destructive impact in nature and society (rogue waves) have been studied for decades to get insight on their origin. With a short pulse width of 1 ps range, pulsed lasers provided an excellent opportunity to find conditions for rogue wave's emergence based on ability to collect more data in a short time and under laboratory controlled conditions. Here, we report for the first time on the new type of vector rogue waves emerging in mode-locked fibre laser. Our approach is based on a new vector model accounting for vector nature of the interaction between an optical field and an Er-doped active medium, birefringence in fibre, slow relaxation dynamics of erbium ions, and light-induced anisotropy caused by the pump field. We apply saddle index analysis to find conditions for emerging complex vector attractors including rogue waves as a function of laser parameters such as power, ellipticity of the pump wave and cavity birefringence. We demonstrate that by tuning the laser parameters we can harnessing vector rogue waves and so stabilise laser output power. Analysis validated by extensive numerical simulations demonstrates good correspondence to our experimental results. The observed phenomena will provide a base for advancing lasers in the context of increased output power and access to the variety of previously unexplored waveforms and will also affect research on rogue waves in numerous disciplines beyond the scope of photonics.

CT Time series (CTTS)
10 September 14.30–16.30 (PCC 2.1-2.3)

Time: 15.06 – 15.21

Restricted linear Granger causality measures

Elsa Siggiridou (Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki) Kugiumtzis, Dimitris (Aristotle University of Thessaloniki)

Abstract: Granger causality is a statistical concept, initially based on prediction models, and reads that if a time series X_1 "Granger-causes" a time series X_2, then the past values of X_1 should contain information that improves the prediction of X_2. In the case of multivariate time series, the Granger causality has to account for the presence of the other observed variables and is quantified by the conditional Granger causality index (CGCI). The CGCI from a driving variable X_i to a response variable X_j is built on the basis of two VAR models, the unrestricted VAR model containing all lagged variables including X_i, and the restricted VAR model containing all lagged variables but the lags of X_i. When there are many observed time series (variables) and short time series, a setting often met in the study of complex systems, the estimation of the unrestricted VAR model may not be stable due to the large number of coefficients of lagged variables to be estimated. For this, restrictions on the lagged variables have been suggested. In our recent study [1], we proposed the restricted CGCI (RCGCI), deriving the unrestricted VAR model by the backward-in-time selection method (BTS) [2]. Moreover, we proposed this restriction in the estimation of the generalized partial directed coherence (GPDC) [3], computed on the basis of the coefficients of VAR, termed as restricted GPDC (RGPDC). In this study, we exploit the canonical correlation analysis (CCA) to develop a similar index to RCGCI, but on the basis of (linear) correlation rather than VAR models. The CCA quantifies the correlation between vector variables. A simulation study is conducted to evaluate the proposed CCA-CGCI and compare it to CGCI and GPDC and their restricted analogues RCGCI and RGPDC using time series from linear stochastic multivariate systems and nonlinear coupled systems of many variables. The performance of the measures is evaluated in terms of their ability to detect the true causal effects (sensitivity) and not detect causal effects when there are not present in the system (specificity). Further, the measures are applied to small sliding segments of multi-channel scalp electroencephalograms (EEG) before, during and after epileptiform discharges, in order to assess the changes in brain connectivity.
References: [1] E. Siggiridou and D. Kugiumtzis. Granger Causality in Multi-variate Time Series using a Time Ordered Restricted Vector Autoregressive Model, *submitted*, 2015, [2] I. Vlachos and D. Kugiumtzis. Backward-in-Time Selection of the Order of Dynamic Regression Prediction Model, *Journal of Forecasting*, 32(8):685-701, 2013. [3] L.A. Baccalá and F. de Medicina. Generalized partial directed coherence, *Proceedings 15th International Conference on Digital Signal Processing*, 163–166, 2007.

CT Networks and Patterns (CTNP)
10 September 14.30–16.30 (PCC 1.4-1.6)

Time: 14.48 – 15.03

Exploring network dynamics with a mathematical triple jump

Holly Silk (University of Bristol) Demirel, G(Max-Planck-Institute for the Physics of Complex Systems) Homer, M(University of Bristol) Gross,T(University of Bristol)

Abstract: Heterogeneous moment expansions have recently emerged as an effective approximation in the study of adaptive networks. Until now, the resulting infinite dimensional system of ordinary differential equations (ODEs) could only be solved using numerical methods. Using the example of the adaptive voter model, we present the first analytical solution to a heterogeneous expansion by introducing a widely applicable methodology. In athletics a triple-jump uses three different techniques in order to cover as much distance as possible: hop, step and jump. Here we perform a mathematical triple-jump in order to analyse an adaptive network model. Using a heterogeneous moment expansion we approximate an agent-based model by an infinite-dimensional system of ODEs. Then, using generating functions we convert the infinite-dimensional system ODEs into a low-dimensional system of partial differential equations (PDEs). Finally, we solve the PDEs using tools from PDE-theory. We therefore demonstrate that the infinite-dimensional system of ODEs resulting from the heterogeneous approximation can be solved analytically by using generating functions and a suitable PDE technique. We expect the methodology to prove valuable in providing analytical solutions for many existing network models that the heterogeneous expansion accurately describes.

CT Active matter (CTAM)
7 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.24 – 15.39

Mixing of Discontinuously Deforming Media

Lachlan Smith (Monash University) Rudman, M (Monash University) Lester, DR (RMIT University) Metcalfe, G (CSIRO)

Abstract: Over the past 30 years, the mechanisms which govern mixing of materials have been uncovered using tools of dynamical systems theory. Whilst this approach - termed chaotic advection - is applicable to materials that deform smoothly, there also exists a wide class of materials that deform discontinuously via e.g. shear banding, wall or bulk slip. For smooth systems the theory has been extensively developed, focusing on stretching and folding as the key mechanism for mixing, however there is little theory for systems which undergo discontinuous deformations. The theory that does exist focuses on systems where solely cutting and shuffling occurs, such as for granular materials. When highly localised discontinuous deformations are added to an otherwise smooth fluid flow additional freedom for fluid transport is created, such as sporadic jumping between streamlines. We show that a number of the structures associated with smooth dynamical systems are preserved in the presence of discontinuous deformation, while others are destroyed. Furthermore, the freedom created by discontinuous deformations enables the creation of new types of transport structures. In particular, we uncover a novel mixing mechanism that can only arise under combined stretching and folding and cutting and shuffling. The mechanism is fundamentally different to both classical smoothly deforming systems and systems with only cutting and shuffling as it exhibits exponential mixing rates in the absence of folding. These insights provide a set of tools and techniques to understand mixing in the presence of discontinuous deformations in natural and engineered systems.

CT Active matter (CTAM)
7 September 14.30–16.00 (PCC 1.1-1.3)

Time: 14.30 – 14.45

Collaboration of autonomous vehicles using the MPC-algorithm with a shortened solution space

Tobias Sprodowski (University of Bremen, Faculty of Production Engineering) Jürgen Pannek (University of Bremen)

Abstract: The research topic of autonomous cars and the communication among them has attained much attention in the last years and is developing fast. This research includes interdisciplinary components from associated fields such as image recognition, mathematical control theory, communication networks, sen- sor fusion and others. Most papers focus on equipped scenarios which often exclude certain disturbing factors. For instance these are non-communicating participants such as cyclists, pedestrians or cars which behaves either selfishly or are unable to support coordinative communication. Moreover, the research has to follow communication between cars considering non-communicating par- ticipants with regard to reliability and certainty. We consider an intersection scenario where we divide the road space in differ- ent cells. These cells form a grid [1]. In this scenario we model autonomous cars as a multi-agent-system. Each car uses a feedback controller based on the model predictive control-algorithm (MPC), see [2] for details, to control its own behaviour. Every car follows its own cost function to cross the intersection as fast as possible and to avoid any collision. Therefore the cars behave non- cooperative, but they have to collaborate to handle the intersection as shared space. Furthermore, the cars themselves should calculate a path through the intersection using cost-based graph-search-algorithms. Each of these paths con- tain list items. These list items consists of the coordinates referring to the grid cells and the reservation time when the car plans to occupy the intersection cell. The paths should be collision-free which is guaranteed by an observer monitoring all calculated paths. Our motivation is to eliminate the necessity of the observer as the centralized unit to avoid additional infrastructure in the considered scenario. To achieve this goal, we propose a three stage plan. First, path planning is done locally and subject to observer coordination. Secondly, the observer is substituted by integrated communication. And last, non-participating cars are treated via cooperative sensing. In the first step the calculated paths should be collision-free, which is guaran- teed by an observer instance for the first realization step. Therefore we predict a solution pattern that each car prefers to restrict the possible solution space and to reduce the complexity. The observer instance combines the calculated paths and creates virtual obstacles to prevent different cars to take the same path. Expanding the scenario, we introduce non-participating cars which are not com- municating. Beyond that, we assume that every car may deviate from its cal- culated path. Hence, our implemented observer has to give alerts if a collision is imminent. In the second step we assume that the cars incorporate the planned trajectories from the other cars via communicating the own paths to each other. To reduce the communication effort the cars have to utilize the distance as a metric system to decide which car shall be integrated for

communication. In the third step each car predicts routes using nonlinear optimization methods for non-participating cars. Integrated the sensed data into respective path cal- culations allow us to dispose of the observer instance. In summary with this restricted communication model we will show an effi- cient usage of the intersection scenario with autonomous cars is possible with reduced comunication costs. Furthermore, using MPC for the prediction of the behaviour of non-participating cars and a shortened solution space for own path calculation, we will illustrate that additional infrastructure is not necessary to achieve a certain and collision-free throughput.

CT Biophysics (CTBI)
7 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.42 – 15.57

The stochastic and the deterministic nature of recurrence in the DNA and throughout its evolutionary history

Shambhavi Srivastava (University of Aberdeen) Baptista, M (University of Aberdeen)

Abstract: In this talk, I will show how to create a Markov model for the DNA that allows us to analytically calculate the statistics of recurrence of many group of words. This model is constructed by encoding the DNA nucleotides into symbolic sequences (words) and creating a 2D symbolic map for the DNA. We then partition the symbolic map or space in sub-regions, each sub-region representing a group of words that share symbolic similarities. A partition of order -T of the symbolic space of the DNA is done by verifying information-theoretical quantities that specify that this partition, composed of many subregions, has Markov properties, in the sense that for some sub-regions, representing some groups of words, words belonging to a group will repeat again after T nucleotides, and the correlation between two words belonging to one of these groups will be approximately zero. These sub-regions that provide the Markov properties of the DNA are responsible for the stochastic nature of the DNA and provide a simple way to analytically calculate the statistics of recurrence of many group of words. The remaining sub-regions, representing other group of words whose correlation between words does not decay after T nucleotides represent the group of words that provide the dynamical deterministic nature of the DNA. In this presentation, I will show how the stochastic and the deterministic nature of the DNA contributes to the genes, coding and non-coding regions of the DNA, and provide an explanation for the evolution of the DNA from simple organisms to the Human genome in terms of how the recurrence of the DNA has become more or less memoryless.

CT Fluids II (CTF2)
8 September 14.30–16.00 (PCC 1.1-1.3)

Time: 15.42 – 15.57

Pattern formation in systems of repulsive particles

Jens Starke (Technical University of Denmark) Christian Marschler (Technical University of Denmark), Yuri Gaididei (Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine), Peter Leth Christiansen (Technical University of Denmark), Mads Peter Sørensen (Technical University of Denmark)

Abstract: Particle systems with symmetric and asymmetric repulsion are studied. The models are motivated by pedestrian flow in a corridor where the asymmetry describes that pedestrians in front, i.e. in walking direction, have a bigger influence on the pedestrian behavior than those behind. Transitions from one-lane to different types of multi-lane behavior including multi-stability and a peristaltic motion are investigated.

CT Biophysics (CTBI)
7 September 14.30–16.00 (PCC 2.1-2.3)

Time: 15.06 – 15.21

Oscillations and symmetry breaking in simple models for homochirality

Michael Stich (Aston University) Blanco, C (University of California Santa Barbara); Hochberg, D (Centro de Astrobiologia, Madrid)

Abstract: Some fundamental building blocks of living matter, such as amino acids and sugars show the preference of one of the two chiral states of an otherwise chemically identical molecule. The origin of this so-called biological homochirality is still a matter of debate, even after decades of intense theoretical and experimental work. At the heart of many theoretical approaches lies a mechanism responsible for spontaneous mirror symmetry breaking, leading finally to stable stationary states of given chirality, i.e., states with nonvanishing enantiomeric excess. Here, we discuss a model purporting to describe general chiral polymerization processes, devised for explaining the appearance of homochirality. We observe the onset of stable chemical oscillations in this model which are in fact related to the appearance of oscillations in the enantiomeric excess, the so-called chiral oscillations. We compare this to the phenomenon of chiral excursions, found in similar systems, but which do not show permanent symmetry breaking. We discuss the importance of the results in light of recent experiments on amino acids reporting chiral oscillations.

CT Nonlinear optics (CTNO)
10 September 10.00–12.00 (PCC 1.1-1.3)

Time: 10.36 – 10.51

Effect of the bandwidth limitation of an optical noise signal used for common-signal induced synchronization in chaotic semiconductor lasers

Nobumitsu Suzuki (Saitama University) Hida, T (Saitama University, Japan) Kakesu, I (Saitama University, Japan) Uchida, A (Saitama University, Japan) Yoshimura, K (NTT Communication Science Laboratories, Japan) Arai, K (NTT Communication Science Laboratories, Japan)

Abstract: Secure key distribution is an important technique for information security and cryptography. Recently, a novel secure key distribution scheme has been proposed based on generation of correlated random bits using synchronization of semiconductor lasers [1, 2]. The information theoretic framework of this scheme has been developed in [3]. In this scheme, when a drive signal is unidirectionally injected into two identical semiconductor lasers, the outputs of these two lasers are synchronized, but are different from the drive signal. An important condition in this scheme is the fact that it must not be possible to record the drive signal [2, 4]. Indeed, if the drive signal can be recorded, an eavesdropper could reuse it in order to estimate the output signal of the two synchronized lasers, breaking thus the security of the system. In order to prevent eavesdropping, the drive signal must have a broad bandwidth. It has been demonstrated that broadband optical noise signal could be used as a common drive signal, and common-signal-induced synchronization has been observed in semiconductor lasers driven by the output signal of a super-luminescent diode [5, 6]. However, the effect of the bandwidth limitation of the optical noise signal on the synchronization quality has not been investigated experimentally yet, although it has been studied numerically [7]. We experimentally observe common-signal-induced synchronization between two chaotic semiconductor lasers to which a bandwidth-limited optical noise signal is injected. We use a super-luminescent diode as a source of the optical noise signal. The bandwidth of the super-luminescent diode is about 5 THz. We apply an optical band-pass-filter to change the bandwidth of the noise signal, and investigate the synchronization quality. We find that good synchronization can be achieved when the bandwidth of the optical noise signal is larger than the linewidth of the optical spectrum of the semiconductor lasers. In addition, the synchronization quality gradually increases as the bandwidth of the optical noise signal is increased.
References: [1] K. Yoshimura, et al., Physical Review Letters, Vol. 108, No. 7, pp. 070602 (2012). [2] H. Koizumi, et al., Optics Express, Vol. 21, No. 15, pp. 17869 (2013). [3] J. Muramatsu, et al., Information Theoretic Security, vol. 5973, Springer-Verlag, 2010, pp. 128-139 ser. Lecture Notes on Computer Science. [4] H. Aida, et al., Optics Express Vol.20, No. 11, pp.11813 (2012). [5] S. Sunada, et al., Physical Review Letters, Vol. 112, pp. 204101 (2014). [6] K. Arai, et al., Proc. of 2014 International Symposium on Nonlinear theory and its Applications (NOLTA2014), pp.472-477. [7] K. Yoshimura, et al., Proc. of 2014 International Symposium on Nonlinear theory and its Applications (NOLTA2014), pp.545-548.

CT Fluids II (CTF2)
8 September 14.30–16.00 (PCC 1.1-1.3)

Time: 14.48 – 15.03

New phenomena observed following the entry of rigid spheres into a two-layer system of immiscible liquids

Benedict C.-W. Tan (University of Warwick) Jozef H. A. Vlaskamp (University of Warwick), Petr Denissenko (University of Warwick) & Peter J. Thomas (University of Warwick)

Abstract: We summarise an experimental study investigating the dynamics of the cavity formed subsequent to the entry of steel spheres into a stratified, two-layer system of immiscible liquids comprising a thin layer of oil floating on a deep pool of water. The observations could be classified into four distinct phenomena, two of which were neither previously mentioned in literatures nor studied in detail. The results obtained from analysing the high-speed video recordings are compared to existing data for the dynamics associated with spheres entering a single, homogeneous liquid. It has been found that the oil coating acquired by the spheres while passing through the thin oil layer substantially affects qualitative and quantitative aspects of the developing cavity. In particular, a new type of ripple instability develops on the wall of the cavity formed by the spheres in the two-layer system, the phenomenon not observed when spheres enter homogeneous liquids.

CT Networks and Patterns (CTNP)
10 September 14.30–16.30 (PCC 1.4-1.6)

Time: 15.06 – 15.21

Traveling Wavepacket and Scar States

Mitsuyoshi Tomiya (Seikei University) Tsuyuki, H(Seikei University) Sakamoto, S(Seikei University) Heller, E. J.(Harvard University)

Abstract: In chaotic billiard systems, scar-like localisation has been found on traveling wavepacket. We may call it the 'dynamical scar' to separate it to the original scar in stationary states. It also comes out along the vicinity of classical unstable periodic orbits, when the wavepackets are launched along the orbits, against the hypothesis that the waves become homogenous all around the billiard. Expanding the wavepackets by the eigenstates of the system, it can be easily shown that the wavepackets with 'dynamical scar' states have larger coefficients for the scar states. The histogram of the square of the coefficients have the similar pattern to the weighted spectrum, however, relatively smaller amount of selected eigenstates which usually have the scar have dominant contribution to the histogram. And simultaneously it also lets the "dynamical scars" emerge. Furthermore, the semi-classical approximation shows that the weighted spectrum function plays crucial role to evaluate the wave function.

CT Astro and plasma physics (CTAP)
7 September 14.30–16.00 (PCC 1.4-1.6)

Time: 14.48 – 15.03

Particle diffusion in magnetohydrodynamic turbulence: effects of a guiding magnetic field

Yue-Kin Tsang (University of Exeter) Joanne Mason (University of Exeter)

Abstract: Previous numerical studies demonstrated that in two dimensions, the presence of a background guiding field can suppress turbulent transport in the field-perpendicular direction. The situation in three dimensions is less clear. Motivated by the many applications of magnetohydrodynamic (MHD) turbulent transport, we examine the Lagrangian statistics in three dimensional field-guided MHD turbulence. We measure the single-particle diffusion along different directions with respect to the background magnetic field in high-resolution simulations and interpret the results in terms of the Lagrangian velocity function.

CT Stochastic processes (CTSP)
9 September 14.30–16.00 (PCC 2.4-2.6)

Time: 15.06 – 15.21

Fast physical random number generation using a photonic integrated circuit and a differential method

Kazusa Ugajin (Saitama University) Terashima, Y (Saitama University, Japan) Uchida, A (Saitama University, Japan) Harayama, T (NTT Communication Science Laboratories, Japan; Waseda University, Japan) Yoshimura, K (NTT Communication Science Laboratories, Japan)

Abstract: Random number generation based on physical phenomena is useful for information security and cryptographic communication. Recently, fast physical random number generation using chaotic semiconductor lasers has been intensively investigated [1-6]. In these systems, chaotic generators are usually composed of many devices such as a laser, a photodetector, and a mirror. Therefore, photonic integrated circuits (PICs) have been proposed to reduce the size of physical random number generators [2, 3]. However, the statistical histogram of chaotic signals typically shows asymmetric distribution. As a consequence, the quality of the randomness is degraded. To solve this problem, a differential method has been proposed to produce symmetric statistical distribution of the chaotic signals [4, 5]. We propose a scheme for fast random number generation using a PIC and a differential method. Our PIC consists of a semiconductor laser, two semiconductor optical amplifiers, a 5-mm-long waveguide, a mirror, and a photodetector. A chaotic laser output is generated by the optical feedback from the mirror. The feedback strength can be tuned by varying the injection currents of the optical amplifiers. The chaotic optical signal of the laser is converted into an electrical signal by the photodetector. This electrical signal is then sampled by a digital oscilloscope with an analog-to-digital converter of 8-bit resolution. To prevent the undesired asymmetric distribution of the laser histogram, we apply a differential method to the chaotic signal. First, we generate three time-delayed 8-bit signals (called D1, D2, and D3) from the original signal (called D0). Then, we generate two differential signals (called DS1 and DS2) by calculating the differences between D0 and D1, and between D2 and D3 respectively. In this case, we find that the statistical histograms of DS1 and DS2 show symmetric distributions. Next, the bit order of DS2 is reversed, i.e., the most significant bit (MSB) changes to the least significant bit (LSB), the second MSB changes to the second LSB and so on [6]. Bitwise exclusive-OR (XOR) operation is then carried out between the reversed DS2 and the original DS1. Finally, a certain number of LSBs are extracted from the 8-bit signal resulting from the XOR operation and are used as a random bit sequence. Its randomness is evaluated by NIST Special Publication 800-22 [7]. We achieve fast random number generation at the rate of 350 Gb/s (= 50 GSample/s Œ 7 LSBs) from this scheme. This rate is higher than the random bit sequence rate of 50 Gb/s obtained without the differential method.
References: [1] A. Uchida, et al., Nature Photonics, Vol. 2, pp. 728 (2008). [2] R. Takahashi, et. al., Opt. Express, Vol. 22, pp. 11727 (2014). [3] A. Argyris, et al., Opt. Express, Vol. 18, pp. 18763 (2010). [4] I. Reidler, et al., Phys. Rev. Lett, Vol. 103, pp. 024102 (2009). [5] J.

Zhang, et al., Opt. Express, Vol. 20, pp. 7496 (2012). [6] Y. Akizawa, et al., IEEE Photon. Tech. Lett, Vol. 24, pp. 1042 (2012). [7] A. Rukhin, et al., National Institute of Standards and Technology, Special Publication 800-22, Revision 1a (2010).

CT Chaos (CTCH)
9 September 14.30–16.00 (PCC 1.1-1.3)

Time: 14.48 – 15.03

Experimental study of regular and chaotic transients in a nonsmooth system

Lawrie Virgin (Duke University) Christopher George (Duke University) Thomas Witelski (Duke University)

Abstract: This presentation will focus attention on transient behavior in a non-smooth dynamical system. Prior to settling down onto some kind of long-term recurrent behavior, such as a periodic steady-state or chaos, a nonlinear system may exhibit a variety of transient behavior involving hysteresis, attraction to isolated remote solutions, and super-persistent chaotic transients. Some of this behavior is closely linked to grazing bifurcations - a subtle feature common to non-smooth systems. A relatively simple mechanical system is used to demonstrate generic transient behavior in an experimental setting. Specifically, we consider a rigid-arm pendulum system that encounters an inclined impact barrier. An important feature of this study is the generation of random initial conditions allowing a full investigation of basins of attraction, together with some sensitive features associated with the sudden onset or loss of contact.

CT Networks and Patterns (CTNP)
10 September 14.30–16.30 (PCC 1.4-1.6)

Time: 15.42 – 15.57

An approximate solution and stability determination for the finite-size Kuramoto mode

Chengwei Wang (University of Aberdeen) Nicolas Rubido (Universidad de la Republica); Celso Grebogi (University of Aberdeen); Murilo S. Baptista (University of Aberdeen).

Abstract: Synchronization phenomenon of coupled phase oscillators has aroused general interest recently, because it provides an explanation about how collective behaviours appear in natural and technological complex systems. Scientists have considered using the Kuramoto model with a finite number of oscillators to study the real-world networks, especially for the frequency synchronisation (FS) problem. However, an analytical solution for the finite-size Kuramoto model in FS is still missing. We propose a novel analytical method to trivially calculate the stable solution for the finite-size Kuramoto model in FS, approximately. In our calculation, we impose no restriction on the distribution of the natural frequencies of oscillators. Numerical experiments verified that our method is effective for networks constructed by different number of oscillators with different distributions of natural frequencies. Further, we present an approximate criterion to state about the stability of the FS state of the finite-size Kuramoto model without knowing its solution. This allows one to quickly study the relationship between the structure of the network and its stable behaviours.

CT Climate (CTCL)
10 September 14.30–16.30 (PCC 1.1-1.3)

Time: 14.30 – 14.45

New early warning signals of tipping points in periodically forced systems

Mark Williamson (University of Exeter) T. Lenton (Exeter) S. Bathiany (Wageningen) M. Scheffer (Wageningen)

Abstract: The usual methods of early warnings of an approaching tipping point require one to be able to partition the system in to three widely separated timescales, that of a fast, random noisy forcing, a very slow drift in the equilibrium manifold modelled by a control paramater while the system of study has overdamped behaviour with a time scale much larger than the fast forcing and much smaller than the slow drift. When these assumptions are valid, one finds the a rising trend in the autocorrelation (effectively a measure of the linearized dynamics timescale) is a good early warning indicator. However, for many systems of interest one may not be able to make these assumptions. In particular, many systems in the climate are forced periodically by the diurnal, annual or longer time scale orbital (Milankovitch) cycles. Here we find early warnings of bifurcations in systems subjected to periodic forcing whose time scale is similar to the period of the forcing. That is, these are systems that are not in, or close to a fixed point and their steady state is described by a periodic attractor. These are systems in which one cannot place the periodic forcing in either the slow drift or the fast, noisy partitions. We find early warnings in the system response phase lag and system response amplification based on a linear dynamics approximation. We also demonstrate that by looking at the power spectrum of the system's time series, one finds harmonics of the forcing period generated, the size of which are proportional to how nonlinear the system's response is becoming. Note that closer to a bifurcation, a system's response becomes more nonlinear.

CT Climate (CTCL)

10 September 14.30–16.30 (PCC 1.1-1.3)

Time: 15.06 – 15.21

Analysis and Modelling of a 9.3 ky Palaeoflood Record

Annette Witt (Max-Planck Institute for Dynamics and Self-Organization) Bruce D. Malamud (King's College London) Achim Brauer (GeoResearchCenter Potsdam) Clara Mangili (GeoResearchCenter Potsdam)

Abstract: Palaeoflood sequences represent a promising source for understanding the long-term dynamics of hydrogeological hazards. We examine both correlations and clustering in a 9360 y record of palaeofloods using varved (annual) sediments from Palaeolake Piànico (Southern Alps). We find clustering in the succession of palaeofloods which is caused by by long-term correlations and by a low-frequent climate cycle. We construct a model that is based on peaks over thresholds of correlated noises, fit the corresponding model parameters by employing Bayesian statistics and show that the model captures the observed correlation and clustering behaviour.

CT Mathematical aspects (CTMA)
9 September 14.30–16.00 (PCC 1.4-1.6)

Time: 15.24 – 15.39

Applications of Extended Ensemble Monte Carlo for Dynamical Systems

Tatsuo Yanagita (Osaka Electro-Communication University)

Abstract: The structures both in phase and parameter spaces of nonlinear dynamical system are usually very complex. Invariant manifolds, fixed points, periodic orbits and their basin structures are examples of them. It is difficult to capture these global structures by usual time evolution method because most of them are unstable and some of them are very rare. To analyze these structures, we will introduce Markov Chain Monte Carlo (MCMC) as an anatomical tool for nonlinear dynamical systems. Monte Carlo methods are very important in computational physics, physical chemistry, and related applied fields, and have diverse applications. In statistical mechanics, sampling of microscopic states from Gibbs distributions is used to calculate physical quantities. For example, a microscopic state corresponds to a spin configuration for Ising model. Instead, we consider initial condition of dynamical system as microscopic state, and extract trajectories that have a certain "atypical" property by MCMC. An extension of sampling to parameter space enables us to investigate global bifurcation structures. The several examples of finding a set of "special" initial conditions will be shown, i.e., unstable periodic orbits and its bifurcation structure of Lorenz system by using MCMC. Further, we can also design a dynamical system by finding a special parameter set. The MCMC techniques have been applied to the design of network architecture of coupled oscillator systems. Using a measure of the performance of the system which implements certain desired dynamical behaviors, i.e., synchronizability, as an energy for MCMC algorithm, we will show statistical characteristics of network structure and discuss the robustness against the change of network structure.

CT Networks and Patterns (CTNP)
10 September 14.30–16.30 (PCC 1.4-1.6)

Time: 14.30 – 14.45

Large epidemic thresholds emerge in heterogeneous networks of heterogeneous nodes

Hui Yang (University of Electronic Science and Technology of China, University of Bristol) Tang, M (University of Electronic Science and Technology of China) Gross, T (University of Bristol)

Abstract: One of the famous results of network science states that networks with heterogeneous connectivity are more susceptible to epidemic spreading than their more homogeneous counterparts. In particular, in networks of identical nodes it has been shown that heterogeneity can lower the epidemic threshold at which epidemics can invade the system. Network heterogeneity can thus allow diseases with lower transmission probabilities to persist and spread. Here, we point out that for real world applications, this result should not be regarded independently of the intra-individual heterogeneity between people. Our results show that, if heterogeneity among people is taken into account, networks that are more heterogeneous in connectivity can be more resistant to epidemic spreading. We study a susceptible-infected-susceptible model with adaptive disease avoidance. Results from this model suggest that this reversal of the effect of network heterogeneity is likely to occur in populations in which the individuals are aware of their subjective disease risk. For epidemiology, this implies that network heterogeneity should not be studied in isolation.

CT Mathematical aspects (CTMA)

9 September 14.30–16.00 (PCC 1.4-1.6)

Time: 14.30 – 14.45

On local and nonlocal variational constants of motion

Gaetano Zampieri (University of Verona) Gianluca Gorni, University of Udine

Abstract: Let $q(t)$ be a solution to Euler-Lagrange equation for a smooth Lagrangian $L(t, q, \dot{q})$, with q in an open set of R^n, and let $q_\lambda(t)$, $\lambda \in R$, be a smooth family of perturbed motions, such that $q_0(t) \equiv q(t)$. Then the following function is constant:

$$t \mapsto \partial_{\dot{q}} L(t, q(t), \dot{q}(t)) \cdot \partial_\lambda q_\lambda(t)|_{\lambda=0} - \int_{t_0}^{t} \frac{\partial}{\partial \lambda} L(s, q_\lambda(s), \dot{q}_\lambda(s))\Big|_{\lambda=0} ds$$

($\partial_{\dot{q}}$ gradient with respect to the vector $\dot{q}$ and $\cdot$ scalar product in R^n). This constant of motion is generally *nonlocal*, and while it is often trivial or of no apparent practical value, there are cases when it is interesting and useful. We can get genuine first integrals for $L = \frac{1}{2}\|\dot{q}\|^2 - U(q)$ with U homogeneous of degree -2, in particular Calogero's potential, and $q_\lambda(t) = e^\lambda\, q(e^{-2\lambda} t)$. We also find nonlocal constants of motion which give global existence and estimates for the solutions of the dissipative equation $\ddot{q} = -k\dot{q} - \partial_q U(q)$, when $k > 0$ and $U : R^n \to R$ is bounded from below. In this case the Lagrangian is $L = e^{kt}(\frac{1}{2}\,|\dot{q}|^2 - U(q))$ and the family is $q_\lambda(t) = q(t + \lambda\, e^{kt})$. Finally, we show a nonlocal constant of motion for the Maxwell-Bloch system in Lagrangian formulation which leads to separation of one of the variables. This is done with the Lagrangian $L = \frac{1}{2}(\dot{q}_1^2 + \dot{q}_2^2 + \dot{q}_3^2 + \dot{q}_3(q_1^2 + q_2^2))$ and the family $q_\lambda(t) = (e^\lambda q_1(t), e^\lambda q_2(t), e^{-2\lambda} q_3(t))$.

CT Networks and Patterns (CTNP)
10 September 14.30–16.30 (PCC 1.4-1.6)

Time: 16.00 – 16.15

Emergence and Coexistence of stable branched patterns in anisotropic systems

Walter Zimmerman (University of Bayreuth) B. Kaoui, A. Guckenberger, A. Krekhov, F. Ziebert

Abstract: A new class of pattern forming systems is identified and investigated: anisotropic systems that are spatially inhomogeneous along the direction perpendicular to the preferred one. By studying the generic amplitude equation and a model equation, we show that branched stripe patterns emerge, which for a given parameter set are stable within a band of different wavenumbers and different numbers of branching points (defects). Moreover, the branched patterns and unbranched ones (defect-free stripes) coexist over a finite parameter range. We propose two systems where this generic scenario can be found experimentally, surface wrinkling on elastic substrates and electroconvection in nematic liquid crystals, and relate them to the findings from the amplitude equation.

Posters

Posters 02 (P02)

9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Maximal synchronizability of networks and the role of edges

Suman Acharyya (International Centre for Theoretical Sciences (ICTS) TIFR Centre Building-IISc Campus)

Abstract: We study synchronizability of networks of coupled oscillators as a function of number of edges while the node number is fixed. In many coupled oscillators systems, the synchronization state is stable in a finite interval of coupling parameter (ε). We define this finite interval of coupling parameter as *synchronization length* (l_ε). The number of edges in a network plays a crucial role in determining its synchronization length. We observed that, in most of the networks, there exists a perfect number of edges for which the synchronization length is maximum and we call these networks as the *maximally synchronizable* networks. Too less or too many edges reduce the synchronization length leading to worse synchronization performance of the network.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

A highly specific test for periodicity

Gerrit Ansmann (University of Bonn)

Abstract: We present a method that allows for a distinction of nearly periodic and strictly periodic behaviours in time series. The investigated criterion for periodicity is that the time series can be interpolated by a periodic function whose local extrema are also present in the time series. Our method is aimed at the analysis of time series generated by deterministic dynamical systems, for which it can aid by telling periodic dynamics from chaotic or transient ones. Moreover, our method precisely yields the period length, which can be a useful characteristics to distinguish dynamical regimes. In contrast to a test based on Poincaré sections (or marker events), our method is more specific in many typical situations, does not require any adjustment to the individual time series and is computationally faster. This work was supported by the Volkswagen Foundation (Grant No. 85392).

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Restricted Conley Index

Peter Ashwin (University of Exeter) Asma Alrami (University of Benghazi, Libya)

Abstract: The Conley index is a powerful tool for the characterization of invariant sets, for global bifurcations and, in particular, for proving the existence of connect- ing orbits in flows. In this paper we present a new concept, the "Restricted Conley Index". We show theoretical results for this tool, including that it is well-defined and other properties that allow us to use it to study robustness property for some dynamics, specifically robustness of heteroclinic connections. These results are considered on systems under the constraint that they are defined on a compact manifold and the existence of the Morse function in the neighbourhood of subspace under consideration. We describe a setting where robust heteroclinic connections can appear and use a restricted Conley index to prove some necessary conditions for robustness. Although many results can be obtained using standard transversality arguments, these techniques extend to more general situations.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Parameter shifts, pullback attractors and tipping points

Peter Ashwin (University of Exeter) Clare Perryman (University of Exeter) and Sebastian Wieczorek (University College Cork)

Abstract: I will discuss the behaviour of nonlinear nonautonomous systems where there is a "parameter shift" from one asymptotically steady value of parameters to a different value. Using pullback attractors to characterise the behaviour of the system, we show that one can understand bifurcation and rate-induced tipping points in terms of properties of these pullback attractors, and apply this to some low-dimensional examples.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Complex oscillation patterns in immature inner hair cells

Harun Baldemir (CEMPS, University of Exeter) Krasimira Tsaneva-Atanasova (University of Exeter)

Abstract: Inner hair cells (IHCs) in the auditory system are responsible for converting sound-evoked vibrations into electrical signals, which in turn are passed on to the brain. During development of hearing these electrical signals manifest themselves as complex Ca+2-based action potentials observed experimentally in immature IHCs. Here we present a bifurcation analysis (co-dimension 1 and 2) of the IHC model proposed in Szalai, R., et al. (2011). In particular we study the dependence of the complex firing patterns on Ca+2 channel conductance (gCa). This analysis allows us to investigate the role that voltage-gated Ca+2 channel conductance plays for the existence and stability of specific oscillatory behaviours exhibited by the model. Furthermore, it has been previously shown, experimentally as well as theoretically, that the rate of calcium-induced calcium-release (pER) and Ca+2- activated potassium (K+) channel conductance (gK(Ca)) also have a significant effect on shaping action-potential firing in the immature IHCs. Therefore, we perform two-parameter bifurcation analysis in (gCa, pER) and (gCa, gK(Ca)) respectively. This analysis enables us to identify the stability regions for different classes of complex periodic solutions in two-parameter spaces, namely gCa - pER, and gCa - gK(Ca).

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Evaluating Exponential Integrators for Markov Chain Ion Channel Models

Vadim Biktashev (University of Exeter) Stary, T (University of Exeter)

Abstract: We evaluate the accuracy and efficiency of an exponential integrator method applied to a cardiac excitation model with numerically stiff Markov chain (MC) description of ionic channels, namely Ryanodine receptor (RyR) and L-type calcium channel ICa(L). If solved by explicit methods such as forward Euler (FE), the stability constraints for these MC models require very small time steps. We extend the idea of the Rush-Larsen method, originally developed for Hodgkin-Huxley type gate models, for MC models. The method is based on the assumption that the variation of the transitions of MC is small within one time step, so we can consider their values constant for the duration of the time step. Our method allows 30-fold increase of the time step size, while providing reasonably accurate solutions and maintaining numerical stability. The reduction of computational cost is achieved by increasing time step size of the numerical integration.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Advanced nudging method for data assimilation using time-delayed coordinates

Alberto Carrassi (Nansen Environmental and Remote Sensing Center - NERSC) Diego Pazò (Instituto de Fisica de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain) M.A. Rodriguez (Instituto de Fisica de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain) J.M. Lopez (Instituto de Fisica de Cantabria (IFCA), CSIC-Universidad de Cantabria, Santander, Spain)

Abstract: We consider the problem of assimilating sparse observations with a low computational cost. The well-known, and simple, nudging technique is modified by supplementing the standard coupling of the model to current observations with an additional coupling to past observations. Time-delayed coupling decreases the assimilation error, without accessing to additional observations. The influence in the algorithm of delay time, coupling strengths, and observational sparseness is investigated in a low-order atmospheric model. Moreover, we verify the robustness of the method under model error. Finally, we present a theoretical justification of the better performance of nudging with delayed coupling; and obtain, as a byproduct, a rough estimation of the optimal delay in relation with the maximum Lyapunov exponent of the system.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Oscillations and intrinsic fluctuations in evolutionary dynamics: how payoffs, dynamics and population sizes control the stability, and implementation of global feedback

Jens Christian Claussen (Jacobs University Bremen)

Abstract: Biological as well as socio-economic populations can exhibit oscillatory dynamics, in the simplest zero-sum case of three competing strategies in the limit of infinite populations, around a neutral fixed point as in the classical Lotka-Volterra system. In reality, populations are always finite, which can be discussed in a general framework of finite size expansion which allows to derive stochastic differential equations of Fokker-Planck type as macroscopic evolutionary dynamics from microscopic interactions.
Important applications of this concept are economic cycles for cooperate - defect - tit for tat, mating behaviour of lizards, and bacterial games which all can be described by cyclic games of rock-scissors-paper dynamics. Here one can study explicitly how the stability of coexistence is controlled by payoffs, behavioural model and population size.
In addition, bimatrix games between two populations allow for a stabilization of the coexistence fixed point if the underlying process is nonlinear and incorporates global information by the average payoffs of each sub-population. Finally, in socio-exonomic systems one is often interested to stabilize coexistence or diversity to sustain an ecosystem or society. Utilizing a diversity measure as dynamical observable, a feedback into the payoff matrix is discussed which stabilizes the coexistence state without explicit knowledge of the population size.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Bifurcation Analysis of Isolated Structures in a Nonuniformly Magnetized Plasma

Magnus Dam (Technical University of Denmark) Morten Brøns (DTU Compute, Technical University of Denmark, Kgs. Lyngby, Denmark), Jens Juul Rasmussen (Association Euratom-DTU, DTU Physics, Technical University of Denmark, Kgs. Lyngby, Denmark), and Volker Naulin (Association Euratom-DTU, DTU Physics, Technical University of Denmark, Kgs. Lyngby, Denmark).

Abstract: We investigate the convection driven evolution of isolated structures in a nonuniformly magnetized plasma. The analysis is based on numerical simulations of the evolution of two-dimensional plasma filaments. For the simulations we use a minimal model for interchange motions describing the coupling between a thermodynamic variable and the vorticity of the plasma. The analysis focuses on classification of topological changes of the structures as they develop in time. We investigate how the topological changes during time evolution depend on the Prandtl and Rayleigh numbers.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Derivation of mass action laws: issues and questions

Jonathan Dawes (University of Bath) Max Souza (UFF, Rio de Janeiro)

Abstract: There are well-trodden paths that enable one to pass from stochastic individual-based models to deterministic population-level models. In this work we have used these to (i) make a complete first- principles derivation of Holling's functional responses, and (ii) extend the Fokker–Planck Equation description of the dynamics to account for the absorbing states on phase space boundaries.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Relaxation to asymptotic steady state in one-dimensional logistic-like mappings

Juliano A. de Oliveira (Univ Estadual Paulista) Geraldo, F C (Univ Estadual Paulista, câmpus de São João da Boa Vista, SP, Brazil) Teixeira, R M (Univ Federal do Ceará, Fortaleza, CE, Brazil) Costa Filho, R N (Univ Federal do Ceará, Fortaleza, CE, Brazil) Leonel, E D (Univ Estadual Paulista, câmpus de Rio Claro, SP, Brazil)

Abstract: An analytical description of the convergence to a period one fixed point is investigated for a family of one-dimensional logistic-like mappings. The mappings are parametrized by a control parameter γ as a dynamical variable. The relaxation to the fixed point is considered near the bifurcation. The convergence to the fixed point is characterized by an exponential decay with the relaxation time given by a power law of $\mu = R - R_c$, where R_c is the bifurcation parameter. We found the exponents α, β, z and δ analytically. Thanks FAPESP (2014/18672-8) and PROPe/UNESP.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Phase transition for a family of Hamiltonian mappings: finding critical exponents

Juliano A. de Oliveira (Univ Estadual Paulista) Silva, M R (Univ Estadual Paulista, câmpus de Rio Claro, SP, Brazil) Penalva, J (Univ Estadual Paulista, câmpus de Rio Claro, SP, Brazil) Leonel, E D (Univ Estadual Paulista, câmpus de Rio Claro, SP, Brazil)

Abstract: A dynamical phase transition from integrability to non-integrability for a family of 2-D Hamiltonian mappings whose angle, θ, diverges in the limit of vanishingly action, I, is characterised. The mappings are described by two parameters: (i) ϵ, controlling the transition from integrable ($\epsilon = 0$) to non-integrable ($\epsilon \neq 0$); and (ii) γ, denoting the power of the action in the equation which defines the angle. We prove the average action is scaling invariant with respect to either ϵ or n and obtain a scaling law for the three critical exponents. Thanks FAPESP (2014/18672-8) and PROPe/UNESP.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Convergence to a transcritical bifurcation in the logistic mapping

Juliano A. de Oliveira (Univ Estadual Paulista) Fidanza, L B (Univ Estadual Paulista, câmpus de São João da Boa Vista, SP, Brazil) Gonçalves, J O (Univ Estadual Paulista, câmpus de São João da Boa Vista, SP, Brazil) Montero, L T (Univ Estadual Paulista, câmpus de São João da Boa Vista, SP, Brazil) Leonel, E D (Univ Estadual Paulista, câmpus de Rio Claro, SP, Brazil)

Abstract: Convergence to a period one fixed point is analyzed numerically to a period one fixed point in the logistic mapping. The relaxation to the fixed point is considered near a transcritical bifurcation. We confirmed that the convergence to the fixed point for a region close to the fixed point goes exponentially fast to the fixed point and with a relaxation time described by a power law of exponent -1. At the bifurcation point the exponent is not universal and depends on the type of the bifurcation as well as on the nonlinearity of the map. Thanks FAPESP (2014/18672-8) and PROPe/UNESP.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

The Middle Pleistocene transition as a generic bifurcation on a slow manifold

Peter Ditlevsen (University of Copenhagen) Ashwin, P (University of Exeter)

Abstract: The Quaternary ice ages are attributed to the change in the insolation (incoming solar radiation) from changes in the Earth's orbit around the Sun. The spectral power in the climate record is very different from that of the orbital forcing: Prior to 1000 kyr before present (BP) most of the spectral power is in the 41 kyr band while since then the power has been in the 100 kyr band. The change defines the middle Pleistocene transition (MPT). The MPT does not indicate any noticeable difference in the orbital forcing. The climate response to the insolation is thus far from linear, and appears to be structurally different before and after the MPT. We present a low order conceptual model for the oscillatory dynamics of the ice sheets in terms of a relaxation oscillator with multiple levels subject to the Milankovitch forcing. The model exhibits smooth transitions between three different climate states; an interglacial (i), a mild glacial (g) and a deep glacial (G) as proposed by Paillard (1998). The model suggests a dynamical explanation in terms of the structure of a slow manifold for the observed allowed and 'forbidden' transitions between the three climate states. With the model we propose that the synchrony of the climate oscillations with the astronomical forcing is through the mechanism of phase-resetting oscillation in which the internal frequency of oscillation is increased to match the frequency of the forcing, while the opposite possibility of a faster internal oscillation cannot be slowed down to match a longer period forcing.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

A Knowledge-and-Data-Driven Modeling Approach for Simulating Plant Growth: A Case Study on Tomato Growth

Xingrong Fan (Institute of Automation, Chinese Academy of Sciences) Mengzhen Kang (Institute of Automation, Chinese Academy of Sciences), Baogang Hu (Institute of Automation, Chinese Academy of Sciences)

Abstract: This paper proposes a novel knowledge-and-data-driven modeling (KDDM) approach for simulating plant growth that primarily consists of two submodels. One submodel is derived from all available domain knowledge, including all known relationships from physically based or mechanistic models; the other is constructed solely from data without using any domain knowledge. In this work, a GreenLab model was adopted as the knowledge-driven (KD) submodel and the radial basis function network (RBFN) as the data-driven (DD) submodel. A tomato crop was taken as a case study on plant growth modeling. Tomato growth data sets from twelve greenhouse experiments over five years were used to calibrate and test the models. In comparison with the existing knowledge-driven model (KDM, BIC = 1215.67) and data-driven model (DDM, BIC = 1150.86), the proposed KDDM approach (BIC = 1144.36) presented several benefits in predicting tomato yields. In particular, the KDDM approach is able to provide strong predictions of yields from different types of organs, including leaves, stems, and fruits, even when observational data on the organs are unavailable. The case study confirms that the KDDM approach inherits advantages from both the KDM and DDM approaches. Two cases of superposition and composition coupling operators in the KDDM approach are also discussed.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Superadiabatic Forces in Brownian Many-Body Dynamics

Andrea Fortini (University of Surrey) Daniel de las Heras, (University of Bayreuth) Joseph M. Brader,(University of Fribourg) Matthias Schmidt (University of Bayreuth)

Abstract: Theoretical approaches to nonequilibrium many-body dynamics generally rest upon an adiabatic assumption, whereby the true dynamics is represented as a sequence of equilibrium states. Going beyond this simple approximation is a notoriously difficult problem. For the case of classical Brownian many-body dynamics, we present a simulation method that allows us to isolate and precisely evaluate superadiabatic correlations and the resulting forces. Application of the method to a system of one-dimensional hard particles reveals the importance for the dynamics, as well as the complexity, of these nontrivial out-of-equilibrium contributions [Phys. Rev. Lett. 113, 167801]. Our findings help clarify the status of dynamical density functional theory and provide a rational basis for the development of improved theories.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Experimental Study of the Dynamics of Pattern Formation in the Ferrocyanide - Iodate - Sulphite Reaction in a Gel Reactor

Vilmos Gáspár (University of Debrecen) István Pontos (University of Debrecen) Szilágyi, O.; Gáspár, V. (University of Debrecen, Hungary)

Abstract: We have studied the dynamics of pattern formation in the ferrocyanide-iodate-sulphite reaction [1] using a one-side fed unstirred spatial gel reactor. We have investigated the effect of changing some parameters, such as gel thickness, Na-polyacrylate concentration (added to affect the diffusion of the activator species H^+), and the residence time of the connected continuous flow stirred tank reactor. The formation and development of patterns were recorded by a digital camera, and the images have been analyzed by a computer program. The emergence mechanism of the patterns and the characteristics of the final stage allowed us to distinguish different parameter regions. The experimental results show strong similarity with the results of simulations by Asgari et al. using FitzHugh-Nagumo model [2].
References [1] Gáspár, V. and Showalter, K.: The Oscillatory Landolt Reaction. Empirical Rate Law Model and Detailed Mechanism, J. Am. Chem. Soc., 109, 4869-4876 (1987) [2] Asgari, Y., Ghaemi, M. and Mahjani, M. G.: Pattern Formation of the FitzHugh-Nagumo Model: Cellular Automata Approach, Iran. J. Chem. Eng., 30, 1, 135- 142 (2011)

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Atmospheric Rivers and Lagrangian Coherent Structures.

Angel Daniel Garaboa-Paz (Group of Nonlinear Physics, University of Santiago de Compostela) Eiras-Barca, J. (Group of Nonlinear Physics, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain), Huhn, F. (Institute of Mechanical Systems, Department of Mechanical and Process Engineering, ETH Zurich, Leonhardtstrasse 21, CH-8092 Zurich Switzerland) Perez-Muñuzuri, V. (Group of Nonlinear Physics, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain)

Abstract: Atmospheric Rivers (ARs) are narrow and elongated structures of intense water vapor flux accounting for more than 90% of the poleward latent energy transport. These dynamical structures are commonly defined as areas of Integrated Water Vapor (IWV) column > 2 cm and strong winds in the lower troposphere, their length-scale exceeding the width-scale several times [1]. Since most AR show a coherent behavior having a timescale of a few days, here, we attempt to characterize them as Lagrangian Coherent Structures (LCS) [2]. To that end, an existing database documenting AR-arrivals at the western Iberian Peninsula was considered which relies on column integrated water vapor and water vapour flux [3], as well as on zonal and meridional wind fields, as provided by the ECMWF ERA-Interim reanalysis at full resolution. For each AR event in this database, the LCS was extracted using backward-forward advection for 5 days to find the main involved dynamical structures. We assessed the coherence of these events and tried to classify the LCS patterns. As the main finding, we found that the most coherent and filamentous AR events are associated with an attracting hyperbolic LCS in front of the AR axis. It acts as a lateral boundary to the ARs which helps to address water vapor transport from tropics to mid-latitudes. This fact will help to improve the actual definition of ARs.
References: [1] Gimeno, L., Nieto, R., Vázquez, M., & Lavers, D.. Atmospheric rivers: a mini-review. Frontiers of Earth Science, 2, 2. (2014) [2] Garaboa-Paz,D., Eiras-Barca,J., Huhn, F., Pérez-Muñuzuri, V., Lagrangian Coherent Structures Along Atmospheric Rivers, Chaos, (2015) [3] Eiras-Barca, J., Brands, S., Migue-Macho, J., Seasonal Variations in North Atlantic Atmospheric River Activity and Associations with Anomalous Precipitation over the Iberian Atlantic Margin. Under revision, JGR, (2015).

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

The influence of shortcut in directed ring of oscillators

Dong-Uk Hwang (National Institute for Mathematical Sciences 70, Yuseong-daero 1689 beon-gil, Yuseong-gu, Daejeon, Korea 34047) Hyoungseok Chu

Abstract: Directed ring of oscillators has been considered as an pattern generator in various studies, for example, it was proven that with precisely designed delay, directed 2D lattice of oscillators can exhibit desired pattern of lattice. In this study we consider a case when shortcut is introduced in a ring of oscillators with a control parameter controlling symmetry of interaction from bidirectional interaction to unidirectional interaction. Without shortcut, tiny asymmetries of interaction lead emergence of complex eigenvalues of Laplacian matrix, that is circulating plane wave became stable. When coupling strength of shortcut is introduced, the imaginary part of eigenvalues of Laplacian matrix goes to zero, and circular traveling wave suppressed by the shortcut interaction. Interesting point is the width of range in asymmetries increases as the interaction of shortcut increases. For higher values of interaction strength in shortcut, another oscillating frequency emerge from the interaction between two circles of directed ring separated by shortcut. In this presentation, we will present diverse dynamics in directed ring with shortcut.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Inequality in competition for links by randomly chosen intermediaries in excessive supply of edges

Nobutoshi Ikeda (Tohoku Seikatsu Bunka Junior College)

Abstract: In the construction of random networks, it is natural for the continuous addition of edges between randomly chosen vertices to lead to a network with a binominal degree distribution in which all vertices are equivalent in the competition for links, resulting in a complete graph. If we consider edge additions based on local events on randomly chosen vertices, however, inequality in the competition for links can occur. In this study, we investigate a network topology constructed by the excessive addition of edges stimulated by randomly chosen vertices in a network with a fixed number of vertices. The model assumptions are: 1)At each discrete time, a vertex is randomly selected as an intermediary that encourages two randomly selected adjacent vertices to join each other, 2)If there already exists an edge between the selected adjacent vertices, the strength of the edge increases by 1. As a result, we observed some typical structures even in the excessive supply of edges. For example, a finite fraction of vertices with a large degree forms a core subgraph in which most vertices are directly connected to each other. The distribution of the strength of the edges usually follows a power law. If we take a case when the randomly selected intermediaries are encouraged to join adjacent vertices with a probability proportional to the edge strength, the strength of edges tends to condense onto the core graph. In this state, an anomalous increase in the relaxation time which forms a complete graph can be observed. The results are strongly dependent on the initial structure to which edges are added, i.e. scale-free structure, lattice structure, etc. However, by edge deletion of edges with weak strength, we can commonly find a subnetwork with degree distribution of a power law form. This fact shows that even the excessive supply of edges cannot improve the disparities between vertices competing for links.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Memory capacity and time scales in delay dynamical systems for reservoir computing

Masanobu Inubushi (NTT Communication Science Laboratories, NTT Corporation) Yoshimura, K (NTT CS lab)

Abstract: Reservoir computing (RC) is a kind of artificial neural network where only connection weights to a readout layer are trained. Recently, Appeltant et al. (2011) proposed to use delay dynamical systems (DDSs) for RC. The use of a DDS has the advantage that only a single DDS realizes a neural network with a large number of 'virtual' nodes. Moreover, they demonstrated excellent performance of the RC using DDS for information processing. Since then, implementation of RC using DDS has been attracting much attention. For instance, Paquot et al. (2012) showed an optoelectronic hardware implementation, Brunner et al. (2012) demonstrated an all-optical hardware implementation employing a semiconductor laser diode, and Haynes et al. (2015) proposed to use Boolean logic element with time-delay feedback. When a DDS is used for RC, there are at least three important time scales in the system, i.e. a delay time, a time scale of relaxation dynamics (a relaxation time to an attractor), and an interval time between the virtual nodes. So far, in studies of DDS-based RC, values of these three time scales were chosen empirically, and less attention has been paid to a relation between performances of the RC and these time scales. Here, we focus on a memory capacity of the DDS-based RC as an important performance aspect, employing the Fisher Memory Curve proposed by Ganguli et al. (2008) to measure it. We clarify how the memory capacity depends on the three time scales in the case of RC using a linear DDS. In particular, we show different behaviors of the memory capacity in two different limits of the network size, and discuss whether the DDS-based RC can have a so-called extensive memory. Furthermore, we study how the results obtained for the RC with linear DDS are affected by introducing nonlinearity in the system. Finally, we explain the existence of an optimal interval time scale between virtual nodes reported by Appeltant et al. (2011), based on the present results. The relation between the memory capacity and the time scales clarified here will give a design principle of the RC using DDS.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Long-range Response in AC Electricity Grids

Daniel Jung (Jacobs University Bremen) Kettemann, S (Jacobs University Bremen)

Abstract: Local changes in the topology of electricity grids can cause overloads far away from the disturbance [1], making the prediction of the robustness against power outages a challenging task. The impact of single-line additions on the long-range response of DC electricity grids has recently been studied [2]. By solving the static AC load flow equations, we conduct a similar investigation for AC grids. Following a recent analytical work [3], we can then also study the decay of local phase perturbations through the grid for general topologies numerically. We discuss the impact of Anderson localization on the evolution of phase perturbations in AC transmission grids. [1] D Witthaut, M Timme, Eur. Phys. J. B 86, 377 (2013). [2] D Labavic, R Suciu, H Meyer-Ortmanns, S Kettemann, Eur. Phys. J. Spec. Top. (2014). [3] S. Kettemann, submitted to Phys. Ref. Lett. (2015); arXiv:1504.05525.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Size Distribution of Barchan Dunes by Coarse-grained Dune Model

Atsunari Katsuki (Nihon University)

Abstract: Crescent sand dunes called barchan are observed in desert and on the surface of the Mars. Barchans interact with each other by collision and form barchan field. We have proposed a dune model reproducing these interactions. This model includes only saltation and avalanche as the basic sand transport processes. We have reproduced a few hundred of barchans in a numerical field and have investigated dynamics of a barchan field. We found that the size distribution of barchans is well fitted by a log-normal distribution.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

The dynamics of two coupled phase oscillators

Svetlana Khrisanfova (Lobachevsky State University of Nizhny Novgorod) Grigory V. Osipov

Abstract: The current study aimed to examine the dynamics of two coupled phase oscillators with an attractive sine connection between them. We considered a general case of two non-identical oscillators with their individual characteristics represented by parameters that appear in both equations of the system. Thus, the main object of this research was to describe possible regimes of oscillators' activity depending on their characteristics and coupling strength. The work was motivated by multiple problems of neuroscience where different types of neurons influence each other's behaviour by means of various interconnections (with exhibitory connections among them). In order to conduct a full analysis of the system's dynamics the problem was approached from different angles. Firstly, we studied steady states along with bifurcations that occur at various parameter values. The results of this part combine both numerical and analytical studies. After this, we moved on to synchronous activity. As it was discovered earlier, three possible regimes could be achieved when no equilibria exist in the system. One of the phases can increase unboundedly; both phases can do so in an asynchronous way or a synchronous activity can be observed. Accordingly, we examined each situation in order to find threshold values of the model's parameters that delimit different regimes. Finally, we obtained a complete bifurcation diagram in the parameter plane. The study revealed that coupling strength plays a crucial role in determining a possible number of steady states in the system. Whereas individual characteristics of the oscillators were proved to decide its actual behaviour (including the number of steady states). Nevertheless, depending on exact values of the oscillators' characteristics coupling strength can either facilitate an unlimited increase of one of the phases or preclude it. In line with an intuitive notion, coupling strength has a strong influence on synchronousness of the oscillators' behaviour. To conclude, in this work we found numerous regimes of oscillators' activity, formulated the conditions under which these regimes may be possible, and discussed bifurcations that occur in the system.

Posters 02 (P02)

9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Vortex Sound from a wavy jet and Howe's energy corollary

Taizo Kobayashi (Teikyo University) Iwagami, S (Kyushu Institute of Technology), Takami, T (Kyushu University), Takahashi, K (Kyushu Institute of Technology)

Abstract: We evaluated the sound generation and absorption around the mouth opening of a recorder [1,2] by applying Howe's energy corollary (HEC) [3]. In order to discuss the interaction between the jet and sound near by the mouth opening, we introduce a semi-empirical theoretical model of the wavy jet. By using HEC, we analyze the fluid acoustical interaction between the wavy jet and the plane wave of sound theoretically and numerically. The result of analysis is consistent with the results of the numerical calculation [2] and an experiment [1] qualitatively. Furthermore, it is in quantitatively good agreement with the numerical calculation [2]. For the cases of edge tone and flue instruments, the jet oscillation is induced by acoustic particle velocity (or alternating fluid current) in the vertical direction. For sake of simplicity, we can omit the existence of the edge. According to the textbook written by Fletcher and Rossing [4] and recent studies, when the jet is driven by a uniform acoustic field with the velocity $u_y = u_0 \cos \omega t$, the displacement in the y-direction of the center line of the jet is given by $\hat{y}(x,t) = \frac{u_0}{w}\left(\sin \omega t - g(\mu x) \sin \omega(t - x/u_w)\right)$, where the center line of the flue is placed along x-coordinate with its exit at the origin $(0,0)$ and the acoustic field exists in the semi-infinite space $x > 0$. The function $g(\mu x)$, which determines the shape of the wavy jet, is given by a polynomial with the degree n: $g(\mu x) = \sum_{k=0}^{n} \frac{1}{k!}(\mu x)^k$. When the jet velocity at the flue exit V is given, $u_w \approx V/2$ and $\mu \approx k = \omega/u_w$. The v_x and v_y of the 2D jet model are obtained as $v_x = V \mathrm{sech}^2((y - \hat{y}(x,t))/b)$, $v_y = u_0 \Big\{ \cos \omega t + \left[\frac{V}{u_w} \mathrm{sech}^2((y - \hat{y}(x,t))/b) - 1\right] g(\mu x) \cos \omega(t - x/u_w) - \frac{\mu}{\omega} V \mathrm{sech}^2((y - \hat{y}(x,t))/b) g'(\mu x) \sin \omega(t - x/u_w) \Big\}$, which satisfies the incompressible fluid condition. According to HEC, the local energy transfer between the acoustic field and the fluid field in 2D system is given by $\Pi_{gker} = \rho_0 (v \times \omega) \cdot u = \rho_0 \left(\frac{\partial v_x}{\partial y} - \frac{\partial v_y}{\partial x}\right) v_x u_y$, where the acoustic particle velocity u is directed in y-coordinate. Integrating Π_{gker} over a local area and taking its time average, we can estimate net acoustic energy generation and absorption in the area. The phase difference between the acoustic field and the jet motion is the key for understanding the acoustic energy generation and absorption. The acoustic energy generation occurs in the latter half of the jet close to the edge, where the jet motion is nearly out of phase with the acoustic oscillation, while the acoustic energy is consumed in the area close to the flue exit to synchronize the jet with it. This fact agrees with the experimental and numerical results.

References: [1] M. Miyamoto et al., *Acta Acustica united with Acustica* **99** 154-171 (2013). [2] T. Kobayashi et al., "Interaction between compressible fluid and sound in a flue instrument", *Fluid Dynamics Research* **46** 061411 (2014). [3] M.S. Howe, *Acoustics of Fluid-Structure Interactions* (Cambridge University Press, 1998). [4] N.S. Fletcher & T.D. Rossing, *The Physics of Musical*

Instruments (2nd edition) (Springer-Verlag, New York, 1998).

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

On a link between novel ensembles of random matrices and systems of self-driven particles

Milan Krbalek (Czech Technical University)

Abstract: Stochastic analysis of individual quantities measured in various systems of self-driven particles (agents: walkers, drivers, birds) reveals many common features. Indeed, statistical distributions of headways among succeeding agents as well as the statistical rigidity in those systems show significant mathematical similarities. Such a striking resemblance is not accidental, although each of those systems is ruled by a different level of mutual agent repulsions/attractions or a different level of stochasticity. Thus, to what extent are these distributions affected by the interaction rules? We will present (by means of novel classes of random matrices) a general scheme of agent dynamics producing the same statistical micro-distributions as those revealed in empirical data. Non-triviality of that correspondence will be confirmed by testing of associated statistical rigidities.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

High efficent THz-TDS system using laser chaos and super focusing with metal V grooved wave guide

Fumiyoshi Kuwashima (Fumiyoshi Kuwashima) Takuya Shirao (Fukui Univ. of Tech.), Toshihiro Kishibata (Fukui Univ. of Tech.), Yusuke (Fukui Univ. of Tech.), Noriyuki Iwao (Fukui Univ. of Tech.), Manatu (Fukui Univ. of Tech.), Masahiko Tani (University of Fukui), Kazuyoshi (University of Fukui), Kohji (University of Fukui), Takeshi Nagashima (Setsunan University) , Makoto Nakajima (Osaka University), Masanori Hangyo (Osaka University)

Abstract: The generation of a wide-range THz wave is investigated from a photoconductive antenna excited using a chaotic oscillation multimode semiconductor laser with optical delayed feedback by an external mirror. We compared the properties of the generated THz wave using laser chaos with those using a CW steady state laser which excited photoconductive antenna. Using a laser chaos, a stable THz wave was obtained. For a high sensitive detection, a metal V-grooved waveguide (MVG) is also used. The 1.6times larger amplitude of signal is detected using MVG compared with that using conventional Si lens system.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Analysis and modelling of rapid glacial climate transitions using simple dynamical systems

Frank Kwasniok (University of Exeter)

Abstract: Glacial climate variability is studied integrating simple nonlinear stochastic dynamical systems with palaeoclimatic records. Different models representing different dynamical mechanisms and modelling approaches are contrasted; model comparison and selection is based on a likelihood function, an information criterion as well as various long-term summary statistics. A two-dimensional stochastic relaxation oscillator model with proxy temperature as the fast variable is formulated and the system parameters and noise levels estimated from Greenland ice-core data. The deterministic part of the model is found to be close to the Hopf bifurcation, where the fixed point becomes unstable and a limit cycle appears. The system is excitable; under stochastic forcing, it exhibits noisy large-amplitude oscillations capturing the basic statistical characteristics of the transitions between the cold and the warm state. No external forcing is needed in the model. The relaxation oscillator is much better supported by the data than noise-driven motion in a one-dimensional bistable potential. Two variants of a mixture of local linear stochastic models, each associated with an unobservable dynamical regime or cluster in state space, are also considered. Three regimes are identified, corresponding to the different phases of the relaxation oscillator: (i) lingering around the cold state, (ii) rapid shift towards the warm state, (iii) slow relaxation out of the warm state back to the cold state. The mixture models have a high likelihood and are able to capture the pronounced time-reversal asymmetry in the ice-core data as well as the distribution of waiting times between onsets of Dansgaard-Oeschger events.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Equality and equivalency in interdependence of non-identical bidirectionally coupled dynamics

Petroula Laiou (Universitat Pompeu Fabra) Ralph, G. Andrzejak (Universitat Pompeu Fabra)

Abstract: Networks of interacting dynamics underlie many natural systems. Examples include the brain, the climate, financial markets etc. The elementary components of these networks are pairs of bidirectionally coupled dynamics. Therefore, the characterization of couplings between pairs of interacting dynamics is important for the understanding of such networks. For this purpose many interdependence measures have been developed. Here, we use the asymmetric state space measure L [1]. At first we verify that this measure correctly detects symmetric couplings in pairs of identical systems. However, the assessment of symmetric couplings is less straightforward once the two dynamics are non-identical. Here, we test two complementary approaches to address this open problem. In one approach we rescale the coupling values and in the other approach we normalize the values of the interdependence measure. In both approaches we use quantities derived from the energies of the signals. The aim of this approach is to introduce the notion of equivalent couplings between non-identical dynamics. We show results for a variety of different dynamics which allows us to show the strength, but also the limitations, of these approaches. [1] D. Chicharro, R.G.Andrzejak, Phys.Rev.E 80:026217(2009)

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Equivalence of Non-Equilibrium Ensembles and Representation of Friction in Turbulent Flows: The Lorenz 96 Model

Valerio Lucarini (University of Hamburg/University of Reading) G. Gallavotti (Sapienza University of Rome)

Abstract: We construct different equivalent non-equilibrium statistical ensembles in a simple yet instructive N-degrees of freedom model of atmospheric turbulence, introduced by Lorenz in 1996. The vector field can be decomposed into an energy-conserving, time-reversible part, plus a non-time reversible part, including forcing and dissipation. We construct a modified version of the model where viscosity varies with time, in such a way that energy is conserved, and the resulting dynamics is fully time-reversible. For each value of the forcing, the statistical properties of the irreversible and reversible model are in excellent agreement, if in the latter the energy is kept constant at a value equal to the time-average realized with the irreversible model. In particular, the average contraction rate of the phase space of the time-reversible model agrees with that of the irreversible model, where instead it is constant by construction. We also show that the phase space contraction rate obeys the fluctuation relation, and we relate its finite time corrections to the characteristic time scales of the system. A local version of the fluctuation relation is explored and successfully checked. The equivalence between the two non-equilibrium ensembles extends to dynamical properties such as the Lyapunov exponents, which are shown to obey to a good degree of approximation a pairing rule. These results have relevance in motivating the importance of the chaotic hypothesis. in explaining that we have the freedom to model non-equilibrium systems using different but equivalent approaches, and, in particular, that using a model of a fluid where viscosity is kept constant is just one option, and not necessarily the only option, for describing accurately its statistical and dynamical properties.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Global Instability in the Ghil-Sellers Model: Climates vs. Melancholia States

Valerio Lucarini (University of Hamburg/University of Reading) T. Bodai (University of Hamburg)

Abstract: The Ghil-Sellers energy balance model of Earth's climate, features - for a considerable range of the solar intensity - two stable climate states (a warm and a cold snowball Earth), where the bistability results from the celebrated ice-albedo feedback. The unstable solution is obtained and characterized in this paper. We find such unstable states by applying for the first time in a geophysical context the so-called edge tracking method that has been used for studying multiple coexisting states in shear flows. We examine robustness, efficiency, and accuracy properties of the edge tracking algorithm. We find that the procedure is the most efficient when taking a single bisection per cycle. Due to the strong diffusivity of the system trajectories of transient dynamics, initialized between the stable states with respect to the mean temperature, are confined to the heteroclininc trajectory, one which connects the fixed unstable and stable states, after relatively short transient times. This constraint dictates a functional relationship between observables. We characterize such a relationship between the global average temperature and a descriptor of nonequilibrium thermodynamics, the large scale temperature gradient between low and high latitudes. We find that a maximum of the temperature gradient is realized at the same value of the average temperature, about 270 K, largely independent of the strength of incoming solar radiation. We also examine the structural properties of the system defined by the equilibria depending on the solar strength. We construct new bifurcation diagrams in terms of quantities relevant for describing the thermodynamic disequilibrium, such as the temperature gradient and the material entropy production due to heat transport. We compare our results for the EBM to results for the intermediate complexity GCM PlaSim and find an interesting qualitative agreement.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Abrupt millennial-scale paleoclimate changes: a statistical modelling study based on forced stochast

Takahito Mitsui (Université Catholique de Louvain) Crucifix, M (Université Catholique de Louvain)

Abstract: Greenland Ice core records clearly show abrupt millennial-scale climate changes around the North Atlantic during the last glacial period, so-called Dansgaard-Oeschger (DO) events. Such abrupt millennial-scale climate changes seem to be pervasive in the past several glacial periods, as indicated in marine and terrestrial records. Typically, abrupt warmings occurred in a matter of decades, and they were followed by a gradual cooling with centennial-to-millennial duration and a rapid return to a cold state. The Atlantic meridional overturning circulation (AMOC) is widely considered as a key player on the DO events, but the detailed mechanism is still in debate. In this study, the influence of external forcings on DO events is investigated through a statistical modelling based on simple forced stochastic dynamical systems. Especially, we consider two classes of models: a stochastic one-dimensional potential model and a stochastic oscillator model forced by the northern hemisphere summer insolation change and the global ice volume change. The model parameters are estimated with the maximum likelihood method accompanied by the unscented Kalman filter [ex. Kwasniok 2013]. The positive evidence in favor of a stochastic oscillator model with insolation forcing and ice sheet forcing is obtained by Bayes factor analysis. The calibrated model can simulate orbital-scale frequency changes of the warming transitions in the last glacial period. Using this model, we predict the frequency of the warming transitions in the past four glacial periods. The result suggests that the abrupt climate changes might be more frequent than previously identified in Iberian margin SST records [Martrat et al. 2007].

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Complex Phase Diagram of Coupled Heterogeneous Phase Oscillators

Kai Morino (The University of Tokyo) Tanaka, G (The University of Tokyo) Aihara, K (The University of Tokyo)

Abstract: Coupled oscillator systems have been widely investigated because the oscillation is often found in real systems. Recently, the robustness of networked systems from dynamical systems viewpoint (dynamical robustness) has been analyzed based on the coupled oscillator systems. To extend studies on the dynamical robustness, we have considered a coupled system composed of heterogeneous phase oscillators represented as $\dot{\theta}_j(t) = 1 - b_j \sin(\theta_j + \alpha_j) + \frac{K}{N}\sum_{k=1}^{N} \sin(\theta_k - \theta_j)$ for $j = 1, \ldots, N$, where θ_j, b_j, and α_j are the phase, excitability, and heterogeneity of the jth oscillator, respectively. We found that the phase diagram of this system shows complex features depending on the control parameters. In the poster presentation, we will report this complex phase diagram and its characteristics such as fractal basin boundaries. This research was partially supported by JSPS KAKENHI Grant No. 24700222, 26730127 as well as the Aihara Project, the FIRST program from JSPS, initiated by CSTP.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Stationary localization in Bose-Hubbard chains with gain and losses

Uta Naether (ICMA, CSIC-Universidad de Zaragoza) F. Quijandría (ICMA, CSIC-Universidad de Zaragoza, Spain), J.J. García-Ripoll, (IFF-CSIC, Madrid, Spain) D. Zueco (ICMA, CSIC-Universidad de Zaragoza and Fundación ARAID, Zaragoza, Spain)

Abstract: In Bose-Hubbard models with and without dissipation beyond the mean-field approximation any localized state is predetermined to decay. An additional gain may be able to recover stationary and dynamically stable localized states as well as a localized oscillating solution type. We demonstrate these phases exist in one-dimensional Bose-Hubbard lattices with gain and loss in a semi-classical regime. As the full problem is intractable analytically, we will include quantum fluctuations up to second order, i.e., beyond the dissipative and driven DNLS limit and complement our study with a Gutzwiller ansatz. Stationary modes have an important advantage over exact solutions of conservative equations. If they are stable, they can be obtained via the dissipative dynamics no matter the initial state (belonging to the basins of attraction). Therefore their preparation is easier and more robust. Losses, unavoidable in experiments, are not a drawback, but a necessary ingredient for their existence. As an anti-continuous limit of discrete solitons is forbidden for quantum lattices, the appearance of localized modes has to happen differently. We find, that the symmetry-breaking transition from homogeneous to discrete periodic, the bifurcations to localized static and periodic modes, and the symmetry-breaking transition back to homogeneous mark novel phases without a counterpart in the Hamiltonian limit (zero dissipation, zero gain) of the Bose-Hubbard model.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

A nonlinear population Monte Carlo algorithm for parameter estimation in intercellular networks

Ines P. Mariño (Universidad Rey Juan Carlos) Míguez, J (Universidad Carlos III de Madrid)

Abstract: In this work we propose a nonlinear population Monte Carlo algorithm for parameter estimation in chaotic intercellular networks. The models of spontaneously active neural circuits typically exhibit chaotic dynamics. The key element of the method is that it computes nonlinear transformations of the importance weights in order to improve the efficiency of the Monte Carlo approximation and the posterior distributions of the parameters. We have applied this algorithm to a model consisting of several coupled modified repressilators with identical parameters, where the coupling is carried out through a signal that represents the fast diffusion of the autoinducer across the cell membranes.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Estimating exit rates in rare event dynamical systems via extrapolation

Jannes Quer (Konrad-Zuse-Zentrum für Informationstechnik Berlin) Weber (ZIB)

Abstract: One goal in molecular dynamics is to calculate the characteristics of a molecular system. For this it is important to know how long the molecule stays in one confimation on average (energy well). In order to calculate good estimators for the small exit rates lots of longterm trajectories are needed. The goal of this new method is to calculate estimators with lower compuational effort. For this we calculate short trajectories in an modified energy landscape. The modification of the energy landscape is given by a homopoty.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Analysis of the effects of periodic forcing in the spike rate and spike correlations in semiconductor lasers with optical feedback

Carlos Quintero (Universitat Politècnica de Catalunya) Taciano Sorrentino (Universitat Politècnica de Catalunya) M. C. Torrent (Universitat Politècnica de Catalunya) Cristina Masoller (Universitat Politècnica de Catalunya)

Abstract: Semiconductor lasers with optical feedback are excitable devices when operated in low frequency fluctuations regime. We investigate how the dynamic of a laser processes a weak forcing through a direct modulation of the pump current. We focus in understanding the influence of the modulation frequency using the method of ordinal symbolic analysis to examine how the time correlations (between several consecutive laser spikes) change with the spike rate. Our results show that higher spike rates wash-out the effects of the modulation in time correlations. The variation of the probabilities of the various symbols with the modulation frequency allows to identify different noisy phase locking regimes. Simulations using the model of Lang and Kobayashi are in good qualitative agreement with experimental observations.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Auditory bistable perception in a neural competition model with periodic inputs

James Rankin (New York University) Rinzel, J (New York University)

Abstract: Perceptual bistability leads to spontaneous switches between competing interpretations of ambiguous sensory input (e.g. binocular rivalry, necker cube). In auditory bistability sequences of interleaved high and low tones are perceived alternately as grouped into a single rhythm or as split into separate streams with perception changing every few seconds. In existing neural competition models the possible percepts are encoded by discrete units. The inclusion of mechanisms for mutual inhibition, slow adaptation (relative to a fast cortical timescale) and noise allows for many aspects of the dynamics of perceptual alternations to be captured. We incorporate similar mechanisms in a new model of auditory bistability and propose a network comprised of neuronal units distributed along a tonotopic feature space. Percepts in our model are emergent, identified in the firing patterns of the neuronal units; they are not pre-assigned to percept-specific units as in many phenomenological models. In order to deal with the periodic nature of the input tone sequences we include NMDA recurrent excitation on an intermediate timescale, which enables linkage across sound gaps in the inputs. The model is able to accurately capture the statistics of percept durations and the known perceptual organisation for stimulus parameters. Our model was developed alongside concurrent psychoacoustic experiments; model predictions about the effect of stimulus parameters are tested and confirmed. Further experiments investigate attention and an apparent conflict between its effects and stimulus parameter manipulations. Proposed mechanisms for attention are tested in a canonical competition model where bifurcation analysis and numerical continuation can be applied, before being implemented in the auditory model. Our results resolve the apparent conflict and provide insights into the mechanisms underlying attention that could generalise across sensory modalities.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Analysis of spike correlations in neuronal models via symbolic ordinal patterns

Jose A. Reinoso (Universidad Pompeu Fabra) Cristina Masoller M.C. Torrent

Abstract: Excitable neurons can encode information about input signals in the timing of their spikes. Here we analyze the effects of an stochastic input and a weak modulation representing subthreshold periodic forcing. We compare various neuronal models focusing on the serial correlations present in the sequence of inter spike intervals (ISIs) that they generate. We analyze the ISI data by using the symbolic method of ordinal patterns. We find that, while some models generate uncorrelated ISI sequences, other models generate correlated sequences. The spike correlations, which are characterized by computing the likelihood of ocurrence of various ordinal patterns, provide valuable information about the nature of the input signal.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Interactions between noise and rate-induced tipping

Paul Ritchie (University of Exeter) Jan Sieber (University of Exeter)

Abstract: A non-autonomous system is defined to pass a tipping point when gradual changes in input levels cause the output to change suddenly. We study a prototypical model for rate-induced tipping, the saddle-node normal form subject to parameter drift and noise. We determine the most likely time of escape by finding the optimal path of escape. The overall probability of escape can be approximated using the instantaneous eigenmodes of the also non-autonomous Fokker-Planck equation. Combining the timing and probability of escape can potentially give us an additional early-warning indicator for noise and rate-induced tipping.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

A systematic study of Limit Cycles in Kuramoto like models

Martin Rohden (Jacobs University Bremen) S. Kettemann (Jacobs University Bremen)

Abstract: Although the model for phase synchronization introduced by Kuramoto et al. in 1984 [1], commonly known as the Kuramoto model, has been studied extensively, much less is known about the so-called second order Kuramoto model. In recent years the so-called swing equation, which is effectively a second-order Kuramoto model, was studied extensively to model the dynamic behavior of power grids [2]. Most interestingly, the swing equation contains an area in parameter space where both stable fixed point and limit cycles coexists. Especially the exact formation of limit cycles is not yet fully understood [3]. Here we study systematically the behavior of limit cycles for this model. We analyze different topologies, starting from regular topologies to real-world power grid topologies. We use both analytical and numerical methods to study the existence and formation of limit cycles. [1] Y. Kuramoto, *Chemical Oscillations, Waves and Turbulences*. Springer (1984). [2] M. Rohden, A. Sorge, D. Witthaut and M. Timme, Chaos **24**, 013123 (2014). [3] S. Kettemann, subm. to Phys. Rev. Lett., arxiv:1504.05525.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Delay-coupled oscillators on random networks.

Stefan Ruschel (Humboldt University Berlin)

Abstract: The exploration of networks of delay-coupled oscillators has a large number of applications in nature. Based on a finite system of Kuramoto oscillators with time-delayed coupling, we impose a thermodynamic limit for an assortative scale free network with positive frequency degree correlations in order to investigate the transition towards synchronisation. Using the ansatz of Ott and Antonsen, we investigate rotating wave solutions to the resulting Fourier mode equations. We numerically relate their corresponding stability properties to previous findings of explosive synchronisation in similar settings.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Optimal synchronization of Kuramoto oscillators: a dimensional reduction approach

Alberto Saa (UNICAMP) R.S. Pinto (UNICAMP)

Abstract: The recently proposed dimensional reduction approach for the Kuramoto model [G. Gotwald, Chaos 25, 053111 (2015)] is employed to construct optimal network topologies to favor synchronization. Some explicit analytical conditions matching previous know results are obtained.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Survivability: A Unifiying Concept for the Transient Resilience of Deterministic Dynamical Systems

Paul Schultz (Potsdam Institute for Climate Impact Research (PIK)) Hellmann, P Grabow, C Heitzig, J Kurths, J

Abstract: The notion of a part of phase space containing desired (or allowed) states of a dynamical system is important in a wide range of complex systems research. It has been called the safe operating space, the viability kernel or the sunny region. In this paper we define the notion of survivability: Given a random initial condition, what is the likelihood that the transient behaviour of a deterministic system leaves the region of desirable states. In three conceptual examples we show that this basic measure captures notions of fundamental interest for climate models, transient chaos, and synchronisation. This covers applications to linear and non-linear, multistable and mono-stable systems. We also derive a semi-analytic lower bound for the survivability of linear systems with polygonal safe operating space. We then apply the concept in the case of the second order Kuramoto model, interpreted as a model of the power grid, where the type of resilience measured by survivability is of great practical interest. We show that our lower bound is a good predictor for the survivability of the power grid in realistic operating regimes. Our numerical and semi-analytic work shows that the type of resilience measured by survivability is not captured by common measures of stability such as relaxation time, basin stability, the master stability function and other asymptotic concepts.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Vector Self-pulsing Scenarios

Sergey Sergeyev (Aston University) Kolpakov, S A (Aston University), Kbashi, H (Aston University), Loika, Yu (Aston University), Zhou, K (Aston University), Turitsyn, S K (Aston University)

Abstract: Self-pulsing (self-Q-switching and self-mode-locking) in Er- and Yb-doped fibre lasers has been extensively studied for more than 20 years to unlock high power and pulsed dynamics in the context of applications ranging from fibre optic communications to biomedicine. During two decades the different mechanisms have been suggested to explain variety of self-pulsing operations: (i) multi-mode and polarization instabilities; (ii) saturable absorber effect caused by unpumped section of active fibre or the presence of clustered erbium ions; (iii) contribution of stimulated Brillouin scattering, (iv) self-phase modulation; (v) coherence and anti-coherence resonance (CR an ACR) scenario where multimode and polarization instabilities play the role of an external noise source; (vi) the pump-to-signal intensity noise transfer, (vii) power-dependent thermo-induced lensing in Er-doped fibre. Here, we present a new concept of a tunable vector self-Q-switching and self-mode-locking in Er-doped fibre laser without a saturable absorber where in addition to the pump power, the other normalized Stokes parameters are evolving on complex trajectories on the Poincare sphere. Our approach is based on a new vector model accounting for vector nature of the interaction between an optical field and an Er-doped active medium, slow relaxation dynamics of erbium ions, and light induced anisotropy caused by the pump field. We apply the saddle index analysis to find conditions for emerging complex vector attractors on the Poincare sphere as a function of the laser parameters such as power, ellipticity of the pump wave and in-cavity birefringence. Our analysis is supported by our extensive numerical simulations and experimental results.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Deformation and breakup of a droplet

Michiko Shimokawa (Fukuoka Institute of Technology) Toshiya Takami (Kyusyu University)

Abstract: When a droplet with a heavier density sinks into a lower density solution, the droplet breaks up. The observation of the breakup process from the bottom provides a horizontal deformation of the droplet as follows. (1) the spherical droplet changes into a ring shape. (2) the ring becomes deformed into a polygonal shape with singularity points. Our experiments show that the number of corners in the polygon depends on sizes of the droplet and viscosities of the lower solution. We execute fluid mechanics calculations in order to reproduce the whole process, in which we solve Navier-Stokes equations for a two-component fluid with a small interfacial force. The simulation shows similar results with the experimental ones. We would report on our experimental results and simulation results, and discuss the deformation dynamics.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Equation-Free Computation of Center Manifolds for Black-Box/ Large-Scale Simulators

Constantinos Siettos (National Technical University of Athens) Lucia Russo (Istituto di Ricerche sulla Combustione, CNR, Naples, Italy)

Abstract: The computation of center manifolds pertains particularly to the design of controllers for stabilizing large-scale systems possessing uncontrollable modes [1-4]. Restricting the dynamics of large-scale continuous and discrete systems on the center manifold allows the stability analysis and the control of the full system based on a low-scale system whose order is determined by the dimension of the generalized eigenspace associated to the eigenvalues with zero real part. However, an important assumption for the computation of center manifolds is that explicit, reasonably accurate closed form dynamical models as appearing in the form of e.g. a system of ordinary differential equations are available. However, for many contemporary complex systems, macroscopic equations are often not available in a closed form. In these circumstances, conventional continuum algorithms cannot be used. Furthermore for large-scale black-box legacy codes the computation of center manifolds is far from trivial. The Equation-Free aproach [5,6] can be used to establish a link between traditional continuum numerical analysis and large-scale legacy codes and microscopic/ stochastic simulation of complex systems. This mathematics assisted computational methodology enables large-scale black-box and microscopic-level simulators to perform system-level analysis directly, without the need to pass through an intermediate, coarse-grained, macroscopic-level, "conventional" description of the system dynamics. The backbone of the method is the 'on-demand' identification of the quantities required for continuum numerics (coarse residuals, the action of coarse slow Jacobians, eigenvalues, Hessians, etc). These are obtained by repeated, appropriately initialized calls to an existing time-stepping routine, which is treated as a black box. The key assumption is that deterministic, macroscopic, coarse models exist and close for the expected behavior of a few macroscopic system observables, yet they are unavailable in closed form. In this work the Equation-free concept is exploited for the approximation of the coarse-grained center manifold on co-dimension one bifurcations of black-box legacy simulators or microscopic/stochastic simulators. The simulator is treated as a constantly evolving experiment and the approximation of a local center manifold is provided in a polynomial form whose coefficients are computed by wrapping around the available simulator an optimization algorithm. This is a three-step protocol including [7] (a) the detection of the (coarse-grained) non-hyperbolic equilibrium, (b) the stability analysis of the critical point(s), and (c) the approximation of a local center manifold by identifying the quantities required for the optimization algorithm (coarse residuals, Hessians, etc). The proposed method is demonstrated through kinetic Monte Carlo simulations- of simple reactions taking place on catalytic surfaces- whose dynamics exhibit coarse-grained turning points and Andronov-Hopf criticalities.

References: [1] E. H. Abed, A simple proof of stability on the center manifold for Hopf bifurcation, SIAM Review, 30 (1988), 487-491. [2] H. Boumediene, K. Wei and A. J. Krener, The controlled center dynamics, Multiscale Model. Simul., 3 (2005), 838-852. [3] J. Carr, Applications of Center Manifold Theory, Springer-Verlag, New York, 1981. [4] P. Holmes, Center manifolds, normal forms and bifurcations of vector fields, Physica 2D, 2(1981), 449-481. [5] I. G. Kevrekidis, C. W. Gear, J. M. Hyman, P. G. Kevrekidis, O. Runborg and C. Theodoropoulos, Equation-free coarse-grained multiscale computation: Enabling microscopic simula- tors to perform system-level tasks, Comm. Math. Sciences, 1 (2003), 715-762. [6] I. G. Kevrekidis, C. W. Gear and G. Hummer, Equation-free: the computer-assisted analysis of complex, multiscale systems, A.I.Ch.E.J., 50 (2004), 1346-1354. [7] C. I. Siettos, Equation-Free Computation of Coarse-Grained Center Manifolds of Microscopic Simulators, Journal of Computational Dynamics, 1(2) (2104), 377-389.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Dynamics and Synchronisation of Viscoelastically Coupled Van der Pol Oscillators

Sebastian Stein (Max Planck Institute for Dynamics and Self-Organization) Parlitz, U and Luther, S

Abstract: The functional features and self-organisation processes in many biological systems critically depend on synchronisation of their oscillating components. An example for this mechanism is the heart muscle, where there it is conjectured that synchronisation due to viscoelastic coupling of cardiomyocytes is crucial for developing a functional syncytium. This example motived us to study the dynamical role of viscoelastic coupling. Although a lot of effort has been made to investigate systems of two or many elastically coupled oscillators, the effect of a viscoelastic coupling has not been analysed in detail yet. Therefore, we employ a model of two viscoelastically coupled Van der Pol Oscillators to analyse the fundamental differences between elastic and viscoelastic coupling. In particular, the impact of the viscous term on synchronisation and bifurcation scenarios will be demonstrated.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Experimental observation of common-noise-induced phase synchronization in semiconductor lasers

Satoshi Sunada (Kanazawa University) Arai, K. (NTT Communication Science Laboratories), Yoshimura, K. (NTT Communication Science Laboratories)

Abstract: Common-noise-induced synchronization (CNIS) is a phenomenon concerning nonlinear physics and various research fields such as neuronal science, laser physics, electrical engineering, and chemical dynamics. This phenomenon has been of great interest since its universality was pointed out in several theoretical studies [1,2]. However, experimental evidence is still limited. In dynamical systems point of view, lasers can be regarded as limit-cycle oscillators. The phase of oscillation can be described by the optical phase of the laser light. Thus, laser systems can offer good experimental stages for addressing fundamental issues of synchronization. In this presentation, we report an experimental result on phase synchronization in semiconductor lasers. We show that, when common broadband optical noise is injected into two uncoupled lasers, the phases of the respective laser oscillations can be successfully synchronized, i.e., CNIS is observed in the fast optical phase dynamics at terahertz regimes [3]. Moreover, we also show that there is an optimal noise intensity that maximizes the quality of the phase synchronization. These experimental results can be well reproduced by the numerical simulations based on a laser rate equation with white noise. [1] J. N. Teramae and D. Tanaka, Phys. Rev. Lett. 93 **98**, 204103 (2004). [2] K. Yoshimura, P. Davis, and A. Uchida, Prog. Theor. Phys. **120**, 621 (2008). [3] S. Sunada, K. Arai, K. Yoshimura, and M. Adachi, Phys. Rev. Lett. **112**, 204101 (2014).

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Multiscale descriptions for nonlinear dynamics

Toshiya Takami (Kyushu University) Shimokawa, M. (Fukuoka Institute of Technology), and Kobayashi, T. (Teikyo University)

Abstract: A multiscale modeling is important not only to obtain a proper description for nonlinear phenomena, but also to achieve effective performance in numerical simulations. In this presentation, we give two example systems to describe nonlinear phenomena: (1) breakup process of a drop We study motion of accelerated vortex rings to clarify basic mechanisms in the breakup process of a drop. In order to simulate the phenomenon, we utilize two different types of descriptions: mesh-based descriptions and vortex-particle ones. (2) oscillation of a jet in musical instruments Nonlinear dynamics in musical instruments can be reproduced by solving compressible Navier-Stokes equations through a computational fluid dynamics (CFD) approach. However, it is still difficult to realize its basic mechanism. Our approach is to create a reduced model to describe the phenomenon qualitatively.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Depinning and collective dynamics of magnetically driven colloidal monolayers

Pietro Tierno (Universitat de Barcelona)

Abstract: We study the collective dynamics of interacting paramagnetic colloids transported via a magnetic ratchet effect above a modulated periodic potential. Upon increasing the modulation frequency, the particles undergo a series of dynamic transitions, from a continuous smectic flow to a disorder flow, and later enter into a two phase flow regime, ending in a complete pinned state. In the disordered phase, the system organizes into density waves due to traffic jams, as in granular systems, while the two phase flow regime shows strong similarities with plastic flow in vortex matter. Finally, it is shown that induced attractive interactions between the moving colloids lead to enhancement of the particle current due to formation of condensed chains traveling along the modulated landscape.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Excluded Volume Causes Integer and Fractional Plateaus in Colloidal Ratchet Currents

Pietro Tierno (Universitat de Barcelona) Thomas M Fischer (Universität Bayreuth)

Abstract: We study the collective transport of paramagnetic colloids driven above a magnetic bubble lattice by an external rotating magnetic field. We measure a direct ratchet current which rises in integer and fractional steps with the field amplitude. The stepwise increase is caused by excluded volume interactions between the particles, which form composite clusters above the bubbles with mobile and immobile occupation sites. Transient energy minima located at the interstitials between the bubbles cause the colloids to hop from one composite cluster to the next with synchronous and period doubled modes of transport. The colloidal current may be polarized to make selective use of type up or type down interstitials.

Posters 01 (P01)
7 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Fractional generalized Cauchy process

Yusuke Uchiyama (University of Tsukuba) Konno, H (University of Tsukuba)

Abstract: Fluctuations in nature have been conventionally modeled by stochastic differential equations (SDEs) with finite variance under assumption of Markov property. One of the most famous SDEs with such properties is the Ornstein-Uhlenbeck or the Langevin equation, of which stationary probability density function (PDF) leads to the Gaussian distribution, and thus it has been applied to describe fluctuations subject to the Gaussian statistics. On the other hand, non-Gaussian statistics with fat-tails appear in many fields where the central limit theorem breaks. To identify fluctuations subject to non-Gaussian statistics, a generalized Cauchy process (GCP) with both finite and infinite variance was introduced [1]. The GCP succeeded in identifying velocity fluctuations of localized waves in spatiotemporal disorder [2], and diffusive behaviors of atoms in optical lattices [3]. Also, stochastic processes with longtime durations have been investigated in the context of subdiffusive long-memory processes. In this study we investigate a modification of GCP with longtime duration, a fractional generalized Cauchy process (FGCP), which can describe fluctuations with fat-tails and long-memory. Sample path of the FGCP is driven by subordinator with one-sided stable Lévy process, of which effect appears as time-fractional derivative in the corresponding Fokker-Planck equation. The evolution of PDF is given as form of eigenfunction expansion with the Mittag-Leffler functions giving slow relaxation of moments. The eigenvalue problem can be analytically solved with the use of scattering problem for sech-potential, where the existence of continuous eigenvalue plays dominant role. Weak ergodicity breaking of the FGCP is unveiled with the help of the fractional Feynman-Kac equation [4]. With the properties presented in the study, the FGCP can be applied to complex systems showing anomalous jumps in longtime durations. [1] H. Konno and F. Watanabe, "Maximum likelihood estimators for generalized Cauchy processes", Journal of Mathematical Physics 48, 103303 (2007). [2] Y. Uchiyama, T. Kadoya and H. Konno, Anomalous velocity fluctuation in one-dimensional defect turbulence, Physical Review E 91, 022127 (2015). [3] D. A. Kesseler and E. Barkai, Infinite covariant density for diffusion in logarithmic potentials and optical lattices, Physical Review Letters 105, 120602 (2010). [4] S. Carmi and E. Barkai, Fractional Feynman-Kac equation for weak ergodicity breaking, Physical Review E 84, 061104 (2011).

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

PDEpath

Daniel Wetzel (Carl von Ossietzky Universität Oldenburg)

Abstract: One can use the software tool AUTO to treat continuation and bifurcation problems for elliptic PDEs over 1D domains. pde2path is developed to treat such problems over 2D domains. It is based on MATLAB. Implemented are continuation and bifurcation methods, while it uses MATLAB's PDE Toolbox for finite element methods. OOPDE is an open source FEM-package, which is also based on MATLAB and works over 1D, 2D, and 3D domains. PDEpath uses the FEM routines of OOPDE and the continuation and bifurcation routines of pde2path. Thus it is independent of MATLAB's PDE Toolbox and can be used for PDEs over 1D, 2D, and 3D domains. I explain the main routines of PDEpath and show some examples combined with new results for 3D Turing patterns.

Posters 02 (P02)
9 September 12.00–13.30 (PCC Foyer)

Time: 12.00 – 13.30

Investigating phase dynamics and synchronisation in climate data

Dario Zappalá (Universitat Politècnica de Catalunya) Cristina Masoller

Abstract: In this work we investigate climate interactions from the point of view of phase synchronisation. We analyse Surface Air Temperature (SAT) time-series in ten thousand grid points over the Earth's surface [1]. By using the Hilbert transform, from each time-series we first extract a phase and then calculate phase autocorrelations. The autocorrelation map reveals the geographical regions where the phase dynamics has longer memory. In a second step, we use the cross correlation (CC) as a measure of phase synchronisation. By using a uniform threshold, from the CC matrix we build an undirected network, which is compared to the climate network constructed in the usual way from the raw SAT data (without using the Hilbert transform to extract the phases). Our work is motivated by the recent demonstration of optimal network inference when the similarity analysis is performed over phase time-series [2]. In a third step, we consider non-uniform thresholds and keep in each geographical location only the links with the highest SSM values. In this way, we build a directed climate network that allows identifying in each geographical region the most relevant inward teleconnections.
References: [1] Monthly-averaged reanalysis data from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR). [2] G. Tirabassi, R. Sevilla-Escoboza, J. M. Buldú and C. Masoller, Inferring the connectivity of coupled oscillators from time-series statistical similarity analysis, Sci. Rep. 5 10829 (2015).

Index