IP1

Advances on the Control of Nonlinear Network Dynamics

An increasing number of complex systems are now modeled as networks of coupled dynamical entities. Nonlinearity and high-dimensionality are hallmarks of the dynamics of such networks but have generally been regarded as obstacles to control. In this talk, I will discuss recent advances on mathematical and computational approaches to control high-dimensional nonlinear network dynamics under general constraints on the admissible interventions. I will present applications to the stabilization of power grids, identification of new therapeutic targets, mitigation of extinctions in food webs, and control of systemic failures in socio-economic systems. These examples will illustrate the potential and limitations of existing methods to address a broad class of problems, ranging from cascade control and transient stability to network reprogramming in general.

Adilson E. Motter
Northwestern University
motter@northwestern.edu

IP2

Mathematics of Crime

There is an extensive applied mathematics literature developed for problems in the biological and physical sciences. Our understanding of social science problems from a mathematical standpoint is less developed, but also presents some very interesting problems, especially for young researchers. This lecture uses crime as a case study for using applied mathematical techniques in a social science application and covers a variety of mathematical methods that are applicable to such problems. We will review recent work on agent based models, methods in linear and nonlinear partial differential equations, variational methods for inverse problems and statistical point process models. From an application standpoint we will look at problems in residential burglaries and gang crimes. Examples will consider both "bottom up' and "top down' approaches to understanding the mathematics of crime, and how the two approaches could converge to a unifying theory.

Andrea L. Bertozzi
UCLA Department of Mathematics
bertozzi@math.ucla.edu

IP3

Filtering Partially Observed Chaotic Deterministic Dynamical Systems

This talk is concerned with determining the state of a chaotic dynamical system, for which the initial condition is only known probabilisticlly, given partial and noisy observations. In particular it is of interest to study this problem in the limit of a large number of such observations, over a long time interval. A key question is to determine which observations are sufficient in order to accurately recover the signal, and thereby overcome the lack of predictability caused by sensitive dependence on initial conditions. A canonical application is the development of probabilistic weather forecasts. In order to study this problem concretely, we will focus on a wide class of dissipative differential equations with quadratic energy-conserving nonlinearity, including the Navier-Stokes equation on a two dimensional torus. The work presented is contained in the paper D. Sanz-Alonso and A.M.Stuart, "Long-time asymptotics of the filtering distribution for partially observed chaotic deterministic dynamical systems" (http://arxiv.org/abs/1411.6510); see also the paper K.J.H. Law, A. Shukla and A.M. Stuart, "Analysis of the 3DVAR filter for the partially observed Lorenz '63 model,'" Discrete and Continuous Dynamical Systems A, 34(2014), and the book K.J.H. Law, A.M.Stuart and K. Zygalalkis, "Data Assimilation: A Mathematical Introduction" (in preparation, 2015) for further background references.

Andrew Stuart
Mathematics Institute,
University of Warwick
a.m.stuart@warwick.ac.uk

IP4

Fields of Dreams: Modeling and Analysis of Large Scale Activity in the Brain

With the advent of optogenetics and the ability to record large numbers of neurons with high temporal resolution, there is now a great deal of interest in both the temporal and spatial activity of neurons in the brain. In this talk, I will discuss a number of old and new developments in the study of these nonlinear integro-differential equations and how they apply to some new biological findings. Topics that I will discuss include the role of noise on spatio-temporal activity, the interaction between extrinsic and intrinsic activity, interactions between multiple spatial networks, and finally some recent applications of Filippov theory to discontinuous neural field models.

Bard Ermentrout
University of Pittsburgh
Department of Mathematics
bard@pitt.edu

IP5

Cooperation, Cheating, and Collapse in Biological Populations

Natural populations can suffer catastrophic collapse in response to small changes in environmental conditions as a result of a bifurcation in the dynamics of the system. We have used laboratory microbial ecosystems to directly measure theoretically proposed early warning signals of impending population collapse based on critical slowing down. Our experimental yeast populations cooperatively break down sugar, meaning that below a critical size the population cannot sustain itself. The cooperative nature of yeast growth on sucrose makes the population susceptible to "cheater" cells, which do not contribute to the public good and reduce the resilience of the population.

Jeff Gore
Massachusetts Institute of Technology
gore@mit.edu

IP6

Brain Control - It's Not Just for Mad Scientists

The brain is an amazing organ - and dynamical system - which is responsible for a number of important functions including cognition, attention, emotion, perception, memory, and motor control. Some brain disorders are hypothesized to have a dynamical origin; in particular, it has been been hypothesized that some symptoms of Parkinson's disease are due to pathologically synchronized neural activity in the motor control region of the brain. We have developed a procedure for determining an optimal electrical deep brain stimulus which desynchronizes the activity of a group of neurons by maximizing the Lyapunov exponent associated with their phase dynamics, work that could lead to an improved "brain control" method for treating Parkinson's disease. The use of related control methods for treating other medical disorders, including cardiac arrhythmias, will also be discussed.

Jeff Moehlis
Dept. of Mechanical Engineering
University of California – Santa Barbara
moehlis@engineering.ucsb.edu

IP7

The Robotic Scientist: Distilling Natural Laws from Raw Data, from Robotics to Biology and Physics

Can machines discover scientific laws automatically? Despite the prevalence of computing power, the process of finding natural laws and their corresponding equations has resisted automation. This talk will outline a series of recent research projects, starting with self-reflecting robotic systems, and ending with machines that can formulate hypotheses, design experiments, and interpret the results, to discover new scientific laws. We will see examples from psychology to cosmology, from classical physics to modern physics, from big science to small science.

Hod Lipson
Cornell University, USA
hod.lipson@cornell.edu

SP1

Juergen Moser Lecture - Dynamics and Data

This lecture highlights interdisciplinary interactions of dynamical systems theory. Experimental data and computer simulation have inspired mathematical discoveries, while resulting theory has made successful predictions and created new scientific perspectives. Nonlinear dynamics has unified diverse fields of science and revealed deep mathematical phenomena. Examples involving

- One dimensional maps
- Numerical bifurcation analysis
- Multiple time scales
- Bursting and MMOs in neuroscience and chemistry
- Locomotion

are described, along with emerging areas having public impact.

John Guckenheimer
Cornell University
jmg16@cornell.edu

CP1

Morse-Floer Homology for Travelling Waves in Reaction-Diffusion Equations

This talk is about heteroclinic solutions u of

$$\partial_t^2 u - c\partial_t u + \Delta_x u + f(u) = 0.$$

For suitable (nonlocal) perturbations of this equation solutions can be assigned an index, and solutions with a fixed index form a finite dimensional manifold. Furthermore, for a large class of nonlinearities f we can count index 1 solutions. This allows us to define Morse-Floer homology groups, which are invariant with respect to continuation of f.

Berry Bakker, Jan Bouwe Van Den Berg, Robert van Der Vorst
VU University Amsterdam
b.bakker@vu.nl, janbouwe.vanden.berg@vu.nl, vd-vorst@few.vu.nl

CP1

Reaction-Diffusion Equations with Spatially Distributed Hysteresis in Higher Spatial Dimensions

Many chemical and biological processes are modelled by reaction-diffusion equations with a nonlinearity involving hysteresis. In such problems each spatial point can be in one of two configurations and the configuration changes in time via a hysteresis law. Points in different configurations segregate the domain into several subdomains and switching implies that these subdomains are separated by free boundaries. We will discuss how the hysteresis gives rise to a novel type of free boundary evolution.

Mark J. Curran
Free University of Berlin
mark.curran@fu-berlin.de

CP1

Existence of Periodic Solutions of the FitzHugh-Nagumo Equations for An Explicit Range of the Small Parameter

We consider the FitzHugh-Nagumo system describing nerve impulse propagation in an axon. With aid of computer-assisted rigorous computations we are able to show the existence of the periodic pulse for an explicit range of singular perturbation parameter $\epsilon \in (0, \epsilon_0]$. Our right bound ϵ_0 is large enough to be reached by validated continuation methods designed for ODEs without time scale separation.

Aleksander Czechowski, Piotr Zgliczyński
Jagiellonian University, Poland
czechows@ii.uj.edu.pl, umzglicz@cyf-kr.edu.pl

CP1

Spatio-Temporal Dynamics of Heterogeneous Excitable Media

The propagation of electrical waves in biological tissue or concentration waves in chemical reactions are examples for complex dynamics in excitable media. Already simple homogeneous reaction-diffusion systems reveal a rich diversity of dynamical patterns, including spiral waves and spatio-temporal chaos. Here we consider excitable media including heterogeneities and study their (transient) dynamics in numerical simulations employing (covariant) Lypaunov Vectors, (linear) mode decompositions, and diffusion-mapped delay coordinates.

Thomas Lilienkamp
Max Planck Institute for Dynamics and Self-Organization
Biomedical Physics Research Group
Thomas.Lilienkamp@ds.mpg.de

Ulrich Parlitz, Stefan Luther

Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
ulrich.parlitz@ds.mpg.de, stefan.luther@ds.mpg.de

CP1

Low Dimensional Models of Diffusion and Reaction in Stratified Micro Flows

We develop a low dimensional model of simultaneous interphase mass transfer and reaction in two-phase stratified flows through microchannels. Here, diffusion quickly equilibrates the distribution of species in the lateral direction. This singularly perturbed dynamical system has a *slow invariant manifold*, which is parameterized by a suitably weighted laterally averaged concentration. The *Lyapunov-Schmidt reduction* of bifurcation theory is used to compute this manifold and derive reduced order models for arbitrary reaction kinetics.

Jason R. Picardo, Subramaniam Pushpavanam
Department of Chemical Engineering
Indian Institute of Technology Madras
picardo21@gmail.com, spush@iitm.ac.in

CP1

Defect Solutions in Reaction-Diffusion Equations

In this talk, I will discuss the effect a heterogeneity can have on the pattern formation process for two different types of reaction-diffusion equations. These heterogeneities for example arise in models where a particular species is only produced in a particular part of the domain of interest. I will mainly focus on the pinning of solutions near and away from the heterogeneity.

Peter van Heijster
Mathematical Sciences School
Queensland University of Technology
petrus.vanheijster@qut.edu.au

CP2

Generalized Behavior of the Two-phase System in (1+1) D

The two-phase model is well known for its applications in gel-dynamics. A network made of an extracellular polymeric substance (EPS) is immersed in a fluid solvent. The network provides a layer of protection for bacterial growth. We find a general reduction in the two-phase system for an arbitrary growth in (1+1) D to a system of a single variable. This system emits several solutions. The first two solutions show that in the presence of logistic growth in a frictionless environment, osmotic pressure has a negligible effect. The third solutions shows that the inviscid two-phase system emits shocks and rarefactions.

David A. Ekrut, Nicholas Cogan
Florida State University
ekrut@math.fsu.edu, cogan@math.fsu.edu

CP2

Scaling and Robustness of Two Component Morphogen Patterning Systems

Embryonic development requires highly reproducible mechanisms of pattern formation so that cell fate is assigned at the right time and location. To identify the mechanisms of pattern regulation, we developed a Two Component System (TCS) model of morphogen (m) and modulator (M) that interact and spatially alter the biochemical properties of each other. We identified a number of network motifs that confer scaling and robustness of morphogen patterning including bilateral repression and others.

Md. Shahriar Karim
Purdue University
mkarim@purdue.edu

Hans G. Othmer
University of Minnesota
Department of Mathematics
othmer@math.umn.edu

David Umulis
Dept. of Ag. and Biological Engineering, Purdue University
West Lafayette, IN-47904, USA
dumulis@purdue.edu

CP2

Solitary Waves in the Excitable Discrete Burridge-Knopoff Model

The Burridge-Knopoff model describes the dynamics of an elastic chain of blocks pulled over a surface. This model accounts for nonlinear friction phenomena and displays excitability when the velocity-dependent friction force is nonmonotone. We introduce a simplified piecewise linear friction law (reminiscent of the McKean nonlinearity in spiking neuron models) which allows us to analyze the existence of large amplitude solitary waves. Propagation failure is shown to occur for weakly coupled oscillators.

Jose Eduardo Morales Morales
INRIA Rhone Alpes
jose-eduardo.morales-morales@inria.fr

Guillaume James, Arnaud Tonnelier
INRIA - Rhône Alpes
guillaume.james@inria.fr, arnaud.tonnelier@inria.fr

CP2

Aspects and Applications of Generalized Synchronization

Different concepts of generalized synchronization of coupled (chaotic) dynamical systems and corresponding time series analysis methods are revisited and compared. Furthermore, we address the relation to snapshot attractors as well as potential applications of generalized synchronization for state estimation and data assimilation. For all topics representative examples will be given to illustrate the main statements.

Ulrich Parlitz
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
ulrich.parlitz@ds.mpg.de

CP2

Discrete Synchronization of Massively Connected Systems Using Hierarchical Couplings

We study the synchronization of massively connected networks of which interactions come from successive hierar-

chical couplings. Motivations of this work come from the growing necessity of understanding properties of complex systems that often exhibit a hierarchical structure. Starting with a set of 2^n coupled maps, we obtain synchronization results for infinitely many, i.e for a Cantor set of maps. We also prove synchronization happens when the network is still massively connected but with an infinite number of broken links inside the hierarchical structure.

Camille Poignard
Doctor
camille.poignard@gmail.com

CP2

Nonlinear Dynamics of Two-Colored Filaments

Propagation of light filaments is a highly nonlinear process that results from light-matter interactions. It is important area in nonlinear optics with much ongoing theoretical and experimental research efforts. While there has been much progress in both fronts, there remain many challenges to produce long-lived filaments. Modeling requires good understanding of light matter interactions with a particular objective of determining conditions that limits spatio-temporal instabilities thus producing quasi-stable dynamics. While typical studies concentrate on optical filaments at a single frequency, mostly in the infrared (IR) and the ultraviolet (UV) wavelengths, under suitable conditions nonlinear wave-mixing can lead to multicolored filaments. In this talk I will present new results that consider the coexistence of UV/IR filaments under a variety of spatial configurations

Alexey Sukhinin, Alejandro Aceves
Southern Methodist University
asukhinin@smu.edu, aaceves@smu.edu

CP3

Heterogeneities in Temporal Networks Emerging from Adaptive Social Interactions

Recent studies on social empirical data have revealed heterogeneities in human dynamics, which are signs of the distinctive mechanism underlying the dynamical behaviors of societies. It is known that human activity is bursty, and the social interactions have scale-free structures. To facilitate unified understanding of social dynamics and networks, we propose a model of adaptive temporal networks. Under suitable conditions, this model exhibits heterogeneous temporal and structural behaviors even from a completely homogenous initial condition.

Takaaki Aoki
Faculty of Education
Kagawa university
aoki@ed.kagawa-u.ac.jp

Luis Rocha
Department of Public Health Sciences
Karolinska Institutet, Solna, Sweden
lecrocha@yahoo.com

Thilo Gross
Department of Engineering Mathematics and Bristol Centre for
University of Bristol, Bristol, UK
thilo@biond.org

CP3

Analysis of Connected Vehicle Networks with Non-trivial Connectivity, a Modal Decomposition Approach

Connected vehicles that communicate via wireless vehicle-to-vehicle communication are gaining increasing attention due to their potential in improving traffic safety, mobility, and efficiency. As connected vehicle systems become more complex, the analysis of the arising networked dynamical systems becomes more challenging. We present a novel method to analyze the network modes by expansion around a network of simple connectivity, and demonstrate that unstable traffic flow can be stabilized using long-range interactions.

Sergei S. Avedisov
University of Michigan, Ann Arbor
savedisov@gmail.com

Gabor Orosz
University of Michigan, Ann Arbor
Department of Mechanical Engineering
orosz@umich.edu

CP3

Simulating the Dynamics of College Drinking

Heavy episodic or binge drinking is among the most difficult public health challenges on college campuses. Integrating peer influence models from public health and identity verification from social psychology as mechanisms that influence drinking behavior, we develop an agent-based simulation to examine the dynamics of drinking events, as students group together and interact. We also consider the conditions necessary for widely-used social norms interventions to be effective.

Ben G. Fitzpatrick, Jason Martinez, Elizabeth Polidan
Tempest Technologies
fitzpatrick@tempest-tech.com, martinez@tempest-tech.com, polidan@tempest-tech.com

CP3

Integrating Hydrological and Waterborne Disease Network Models

Mechanistic drivers of the seasonal patterns of cholera in Bangladesh remain poorly understood. A community network model for cholera dynamics is developed. A hydrological model for the Ganges-Brahmaputra-Meghna river basin is integrated into the disease network model to account for seasonality of surface water connectivity and contamination. We demonstrate that the integrated model can contribute to the understanding of disease dynamics and potentially to the development of disease forecasting tools.

Karly Jacobsen
Mathematical Biosciences Institute
The Ohio State University
jacobsen.50@osu.edu

Michael Kelly
The Ohio State University
kelly.1156@osu.edu

Faisal Hossain
University of Washington
fhossain@uw.edu

Joseph H. Tien
Ohio State University
Department of Mathematics
jtien@math.ohio-state.edu

CP3

Phase Response Properties of Collective Rhythms in Networks of Coupled Dynamical Systems

Phase response property of a network of diffusively coupled dynamical units undergoing collective oscillations is studied. Each unit can possess arbitrary local dynamics as long as the whole coupled system exhibits stable limit-cycle oscillations. The phase response property of the system can be decomposed into Laplacian eigenmodes of the coupling network, which reveals how each individual mode contributes to the total phase response. Phase synchronization of simple dynamical networks is analyzed as an example.

Hiroya Nakao
Graduate School of Information Science and Engineering, Tokyo Institute of Technology
nakao@mei.titech.ac.jp

Sho Yasui
Graduate School of Information Science and Engineering
Tokyo Institute of Technology
yasui.s.af@m.titech.ac.jp

CP4

Prediction in Projection

Full and accurate reconstruction of dynamics from time-series data—e.g., via delay-coordinate embedding—is a real challenge in practice. For the purposes of forecasting, however, reconstructions that do not satisfy the dimension conditions of the embedding theorems can still be quite useful. Despite the lack of topological conjugacy, near-neighbor forecast methods working in these reduced-order spaces are as (or more) effective than in complete embeddings. We demonstrate this using both synthetic and experimental time series data.

Joshua Garland
University of Colorado at Boulder
garland.joshua@gmail.com

Elizabeth Bradley
University of Colorado
Department of Computer Science
Elizabeth.Bradley@Colorado.EDU

CP4

Sparse Sensing Based Detection of Dynamical Phenomena and Flow Transitions

Reduced order models for fluid dynamics are often sensitive to changes in flow topology and require some information about the dynamical regime of operation. Using sparse sensing and reconstruction techniques, we present a framework to detect dynamical phenomena such as bifurcations and changes in flow topology in a variety of thermo-fluid dynamical systems. This framework can be combined with adaptive reduced order models for improved observation and control. We present some numerical results for the case of Navier Stokes and Boussinesq equations.

Piyush Grover
Mitsubishi Electric Research Laboratories
grover@merl.com

Boris Kramer
Virginia Tech
bokr@vt.edu

Petros Boufounos, Mouhacine Benosman
Mitsubishi Electric Research Laboratories
petrosb@merl.com, benosman@merl.com

CP4

Bifold Visualization of Dynamic Networks

We consider binary datasets arising from bipartite data, where the data describes the relationships between two types of entities (such as a user "liking' a certain movie). Comparing the binary patterns between entities provides a dissimilarity measure which allows projecting that data in a Euclidean representation. We apply our algorithm to datasets of US senators and their voting records. By simultaneously representing intergroup and intragroup relationships, significant additional insight is provided by the visualization.

Yazhen Jiang, Joseph Skufca, Jie Sun
Clarkson University
yajiang@clarkson.edu, jskufca@clarkson.edu, sunj@clarkson.edu

CP4

An Algorithmic Approach to Computing Lattice Structures of Attractors

We describe the lifting of sublattices of attractors, which are computationally less accessible, to lattices of forward invariant sets and attracting neighborhoods, which are computationally accessible. We provide necessary and sufficient conditions for such a lift to exist along with algorithms to check whether such conditions are met or not and to construct the lift if met. We illustrate the algorithms with some examples.

Dinesh Kasti
Florida Atlantic University
dkasti@fau.edu

William D. Kalies
Florida Atlantic University
Department of Mathematical Sciences
wkalies@fau.edu

Robertus Vandervorst
Vrije Universiteit Amsterdam
vdvorst@few.vu.nl

CP4

Expanded Mixed Finite Element Method for Generalized Forchheimer Flows

We study the expanded mixed finite element method applied to the Forchheimer fluid flow in porous media. The bounds for the solutions are established. Utilizing the spe-

cial properties of Forchheimer equation and boundedness of solutions we prove the optimal error estimates in L^2-norm for solution. The error bounds are established for the solution and divergence of the vector variable in Lebesgue norms and Sobolev norms. A numerical example using the lowest order Raviart-Thomas (RT_0) mixed element are provided agreement with our theoretical analysis.

Thinh T. Kieu
University of North Georgia
thinh.kieu@ung.edu

Akif Ibraguimov
Department of Mathematics and Statistics.
Texas Tech University
akif.ibraguimov@ttu.edu

CP4

A Method for Identification of Spatially-Varying Parameters Despite Missing Data with Application to Remote SensingA Method for Identification of Spatially-Varying Parameters Despite Missing Data with Application to Remote Sensing

Remote sensing data allows for ecological inferences over large-scale oceanic regions. Proposed models require parameter tuning to match data observations, including synchronization and filtering methods. A major hindrance in applying synchronization methods to remote sensing data is the frequency with which clouds hide parts of a satellite image. A synchronization method is discussed to infer unknown model parameters and states, despite hidden data. We treat a PDE as a temporally-varying network to prove the method.

Sean Kramer, Erik Bollt
Clarkson University
skramer@norwich.edu, bolltem@clarkson.edu

CP5

A Mathematical Model for the Sexual Selection of Extravagant and Costly Mating Displays

The evolution of extravagant and costly ornaments on animals has intrigued biologists and mathematicians since Darwin suggested that female preference for exaggerated courtship displays drives the sexual selection of these ornaments. We propose a minimal mathematical model that incorporates two components of ornament evolution: an intrinsic cost and/or benefit of ornamentation to an individual, and a social benefit of relatively large ornaments within a population. Using bifurcation analysis and perturbation theory, we show that on an evolutionary time scale, identically healthy animals will split into two niches, one with large ornaments and one with small. This result may explain why ecologists have observed bimodal distributions of ornament size in several species.

Sara Clifton
Northwestern University, USA
sclifton@u.northwestern.edu

Daniel Abrams, Daniel Thomas
Northwestern University
dmabrams@northwestern.edu,
danielthomas2014@u.northwestern.edu

CP5

Mathematical Models of Seasonally Migrating Populations

Predator-prey systems that allow for one or more species to undergo mass migration open up a range of new possibilities from a dynamical point of view. We consider two different approaches to modelling problems of this type, namely, ordinary and partial differential equations. In both cases the inclusion of time switches is key to understanding their behaviour and allows us to consider the effects of timing mismatches brought about by changing climatic conditions.

John G. Donohue
National University of Ireland, Galway
johndonohue555@hotmail.com

Petri T. Piiroinen
School of Mathematics, Statistics and Applied Mathematics
National University of Ireland, Galway
petri.piiroinen@nuigalway.ie

CP5

A Model for Mountain Pine Beetle Outbreaks in An Age Structured Forest: Approximating Severity and Outbreak-Recovery Cycle Period

We develop a system of difference equations to model (temperature-driven) mountain pine beetle infestation in an age-structured forest. Equilibrium stability analysis indicates the existence of periodic outbreaks that intensify as growth rates increase. Analytical methods are devised to predict outbreak severity, duration, and frequency. The model predicts cycle periods that fall within observed outbreak period ranges. To assess future beetle impact on forests, we predict severity of outbreaks in the face of changing climate.

Jacob P. Duncan, James Powell, Luis Gordillo
Utah State University
jacob.duncan@aggiemail.usu.edu, jim.powell@usu.edu, luis.gordillo@usu.edu

Joseph Eason
University of Utah
eason@math.utah.edu

CP5

Host-Mediated Responses on the Dynamics of Host-Parasite Interaction

The regulation of helminth populations within hosts depends on host age, immunity and density-dependent constraints. Laboratory infections reveal that rabbit immunity limits worm growth and reduces fecundity. Continuous natural exposure of rabbits to worms generates a negative relationship between rabbit age and worm fecundity. Using an age-structured population model we show how these regulatory factors stabilize the dynamical behaviour of between-host transmission via egg shedding through maintaining a self-sustained oscillation in rabbit generations.

Suma Ghosh, Matthew Ferrari

The Pennsylvania State University
sug25@psu.edu, mferrari@psu.edu

CP5

Geometric Dissection of a Model for the Dynamics of Bipolar Disorders

We study a model for the dynamics of bipolar disorders developed by A. Goldbeter. The model is four-dimensional and not in the standard form of slow-fast systems. The geometric analysis of the model is based on identifying and using hierarchies of local approximations based on various - hidden – forms of time scale separation. A central tool in the analysis is the blow-up method which allows the identification of a complicated singular cycle.

Ilona Kosiuk
MPI MiS
Inselstrasse 22, 04103 Leipzig Germany
ilona.kosiuk@mis.mpg.de

Ekaterina Kutafina
AGH University of Science and Technology
Cracow, Poland
ekaterina.kutafina@gmail.com

Peter Szmolyan
Vienna University of Technology
Vienna, Austria
peter@asc.tuwien.ac.at

CP6

Continuation of Bifurcations in Physical Experiments

A good mathematical model for a specific physical system can be hard to create. Fortunately, the low cost and easy availability of high-speed electronics now enables real-time integration of numerical methods and physical experiments. This opens up a wide range of new possibilities in experimental nonlinear dynamics. Here we outline the current state-of-the-art in control-based continuation, a method for tracking the solutions and bifurcations directly in a physical experiment.

David A. Barton
University of Bristol, U.K.
david.barton@bristol.ac.uk

CP6

Structuring and Stability of Solutions of the Static Cahn-Hilliard Equation

We use the variational form of the 2D Cahn-Hilliard equation to obtain numerically the steady non-linear solutions of films of confined polymer blends with a free deformable surface. Varying the average composition and geometry of the films we find a rich morphology of solutions in the form of laterally structured films, layered, droplets over the substrate and free surface, and checkerboard structures. We show that laterally structured films are energetically favorable and that most of the solutions appear through pitchfork bifurcations.

Santiago Madruga
Aerospace Engineering School
Universidad Politécnica de Madrid
smadruga@gmail.com

Fathi Bribesh
Department of Mathematics
Zawia University, Zawia, Libya
f.bribesh@gmail.com

Uwe Thiele
Institute of Theoretical Physics
University of Muenster
u.thiele@uni-muenster.de

CP6

Escape from Potential Wells in Multi-Degree of Freedom Systems: Phase Space Geometry and Partial Control

Predicting the escape from a potential energy well is a universal exercise, governing myriad engineering and natural systems, e.g., buckling phenomena, ship capsize, and human balance. For such systems, tube dynamics provides the phase space criteria for escape. We consider a control problem where the goal is to avoid escape in the presence of large disturbances which are greater in magnitude than the controls by implementing a safe-set-sculpting algorithm which explicitly incorporates tube dynamics.

Shibabrat Naik
Engineering Science and Mechanics
Virginia Tech
shiba@vt.edu

Shane D. Ross
Virginia Tech
Engineering Science and Mechanics
sdross@vt.edu

CP6

Periodic Social Niche Construction

Social niche construction describes the creation of social networks and institutions that influence individual fitness. Niche construction involves multiple timescales, including the relatively short time required to build a niche, and the longer time required to learn how to build a niche. We explore a number of learning rules for niche construction in relation to competition between constructing species or agents, in particular the dynamics of institutional switching, as the system undergoes a Hopf-bifurcation. Hysteresis in key competition parameters provides evidence of top-down causal memory from the institutions, leading to increased resistance to change between states. This is due to the different stability criteria for a periodic solution as dictated by Floquets theory. We also find evidence for greater stability in a two-institution than a single institution setting. We relate these results to prior discussion of stability induced in bi-polar versus unipolar social systems.

Philip Poon
Department of Mathematics
ppoon@discovery.wisc.edu

David Krakauer, Jessica Flack
Center for Complexity & Collective Computation
Wisconsin Institute for Discovery
krakauer2@wisc.edu, jcflack@wisc.edu

CP6

Experimental Verification of Criteria for Escape from a Potential Well in a Multi-degree of Free-

dom System

Criteria and routes of escape from a potential well have previously been determined for 1 degree of freedom (DOF) mechanical systems with time-varying forcing, with reasonable agreement with experiments. When there are 2 or more DOF, the situation becomes more complicated, but there is still a method, tube dynamics, for determining the phase space states which will escape. Here, we verify tube dynamics for a 2 DOF experiment of a ball rolling on a surface.

Shane D. Ross
Virginia Tech
Engineering Science and Mechanics
sdross@vt.edu

Amir BozorgMagham
University of Maryland, College Park
amirb@atmos.umd.edu

Lawrence Virgin
Cntr for Nonlinear and Complex Systems
Duke University
l.virgin@duke.edu

CP6

Sensitivity of the Dynamics of the General Rosenzweig-MacArthur Model to the Mathematical Form of the Functional Response: a Bifurcation Theory Approach

We revisit the Rosenzweig-MacArthur predator-prey model to help explain sensitivity to the mathematical forms of three functional responses (Holling type II, Ivlev, and Trigonometric). We consider both local and global dynamics and determine possible bifurcations with respect to variation of the carrying capacity of the prey. We provide an analytic expression that determines the criticality of a Hopf bifurcation and revisit the ranking of the functional responses, according to their potential to destabilize the dynamics of the model.

Gunog Seo
Colgate University
gseo@colgate.edu

Gail Wolkowicz
McMaster University
wolkowic@mcmaster.ca

CP7

Numerical Simulations of Nonlinear Dynamics of Beams, Plates, and Shells

Solution of nonlinear structural dynamics poses a challenging problem and often requires the use of computers in order to obtain a quantitative solution. Such simulations are usually computationally expensive and are typically performed only as academic research. The current study serves two purposes: i) it presents simple semi-implicit numerical formulations, which are computationally efficient, simple to use, and can be used in nonlinear dynamics and chaos simulations ii) it serves as a good introduction to numerical studies of nonlinear structural dynamics for graduate students and upper division undergraduate students. Numerical formulations along with results are presented for nonlinear oscillators, beams, von Karman plates, and thin shells.

Timur Alexeev
University of California, Davis
talexeev@ucdavis.edu

CP7

A New Mathematical Explanation of What Triggered the Catastrophic Torsional Mode of the Tacoma Narrows Bridge

We suggest a mathematical model for the study of the dynamical behavior of suspension bridges which provides a new explanation for the appearance of torsional oscillations during the Tacoma collapse.

Gianni Arioli
Dipartimento di Matematica
Politecnico di Milano
gianni.arioli@polimi.it

CP7

Global Attractors for Quasilinear Parabolic-Hyperbolic Equations Governing Longitudinal Motions of Nonlinearly Viscoelastic Rods

We prove the existence of a global attractor and estimate its dimension for a general family of third-order quasilinear parabolic-hyperbolic equations governing the longitudinal motion of nonlinearly viscoelastic rods subject to interesting body forces and end conditions. The simplest version of the equations has the form $w_{tt} = n(w_x, w_{xt})_x$ where n is defined on $(0, \infty) \times \mathbb{R}$ and is a strictly increasing function of each of its arguments, and with $n \to -\infty$ as its first argument goes to 0. This limit characterizes a total compression, a source of technical difficulty, which delicate a priori estimates prevent. (These estimates simplify and generalize earlier versions.) We determine how the dimension of the attractor varies with the several parameters of the problem, giving conditions ensuring that it is small. These estimates illuminate asymptotic analyses of the governing equation as parameters approach limits.

Suleyman Ulusoy
Zirve University
suleyman.ulusoy@zirve.edu.tr

Stuart S Antman
University of Maryland
ssa@math.umd.edu

CP7

Revision on the Equation of Nonlinear Vibration of the Cable with Large Sag

The problem in the conventional cable theory about the relation between the chord-line component of dynamical cable tension and the deflection is discussed. The expression of the chord-line component of dynamical cable tension is rationally revised based on the proposed compatibility equation. The equation of motion of cable in time and space is then formulated with the corrected expression of chord-line component of cable internal force and reduced to nonlinear multi-degree-of-freedom system with Galerkin's method. Some numerical results are presented and discussed. The upper limit of the sag-span ratio for which the conventional equation of cable motion can give acceptable

results is investigated.

Kun Wang
University of Macau
yb37402@umac.mo

CP7

Control Strategies for Electrically Driven Flapping of a Flexible Cantilever Perturbed by Low Speed Wind

Control parameters for the effect of low speed wind perturbations to the electrically driven flapping of a flexible cantilevered beam are studied both experimentally and numerically. The experiments consist of varying the applied potential (1kV-9kV) between the gap (15mm-35mm) separating a conducting plastic cantilever and a rigid ground electrode. Other inputs are the frequency (1Hz-8Hz), the input signal type (sine, square and triangle) and wind speed (1mph-8mph). Numerical data is produced using the dynamic Euler-Bernoulli beam equation with viscous damping and gravitational effects. The electrical load appears as a non-linear term in the otherwise linear equation. The numerical and experimental data for the effects of electrical load, frequency and wind speed on vibrational amplitude of the cantilever will be used to introduce control strategies for these systems.

Thomas Ward
Department of Mechanical and Aerospace Engineering
NC State University
thomasw@iastate.edu

CP8

Coexistence of Multiannual Attractors in a Disease Interaction Model: Whooping Cough Revisited

Incidence of whooping cough (WC) exhibits variable dynamics with periodicity 2-5 years. We propose an alternative model of WC as interacting strains via age-dependent convalescence. The model exhibits several stable multiannual coexisting attractors. Also, perturbation due to case-importation and noise in transmission switches the system from one dynamical regime to the other. This study suggests that variable dynamics of WC could be an emergent property of the interacting system, which is not observed earlier.

Samit Bhattacharyya
NBHM, DAE, Research Fellow
Department of Pure Mathematics, University of Calcutta
szb16@psu.edu

Matthew Ferrari, Ottar Bjornstad
Penn State University
mjf283@psu.edu, onb1@psu.edu

CP8

Examining Ebola Transmission Dynamics and Forecasting Using Identifiability and Parameter Estimation

The ongoing Ebola epidemic in West Africa is larger than all previous Ebola outbreaks combined. Here I will discuss our ongoing work developing mathematical models of the Ebola epidemic, using a range of identifiability and parameter estimation approaches. We used these models to examine uncertainty in forecasting disease dynamics, and evaluated a range of questions involving spatial spread, alternative intervention strategies, and contributions to transmission by different infectious stages (early-stage, late-stage, and funeral transmission).

Marisa Eisenberg
University of Michigan
marisae@umich.edu

CP8

How Radiation-Induced Dedifferentation Influences Tumor Hierarchy

Evidence indicates solid tumors exhibit cellular hierarchy where only a fraction of cells are able to maintain and regrow the tumor. Recent discoveries indicate that, besides these inherent cancer stem cells, other cells can dedifferentiate to a stem-like state after radiation exposure. We modify an ODE lineage model to include feedback, radiation, and dedifferentiation. Setting parameters with experimental data, we observe an elevated dedifferentiation rate for irradiated cells that can profoundly impact long-term population size.

Kimberly Fessel
Mathematical Biosciences Institute
fessel.6@mbi.osu.edu

John Lowengrub
Department of Mathematics
University of California at Irvine
lowengrb@math.uci.edu

CP8

Order Reduction and Efficient Implementation of Nonlinear Nonlocal Cochlear Response Models

The cochlea is shown to exhibit active nonlinear spatiotemporal response dynamics. To model such phenomena, it is often necessary to incorporate cochlear fluid-membrane interactions. This results in both high-order model formulations and computationally-intensive solutions that limit their practical use (for psychoacoustic audio signal processing) even for simple single-tone brief inputs. In this paper, we reformulate an existing nonlinear cochlear model into sparse state-space (SS) models that are of considerably lower order (factor of 8) and are computationally simpler (factor of 25) with little reduction in accuracy.

Maurice G. Filo
PhD Student at UC Santa Barbara
filo@umail.ucsb.edu

CP8

Periodic Outbreaks in Models of Disease Transmission with a Behavioral Response

Recently there has been increasing interest in the effects of behavioral responses to information on outbreaks of infectious diseases. Such a response can drive the infection to low endemic levels even if it wanes over time and the infection does not confer immunity upon recovery. This talk will report on recent results on the question whether a waning behavioral response provides sufficient protection against subsequent flare-ups of the infection.

Winfried Just
Department of Mathematics
Ohio University

just@math.ohiou.edu

Joan Saldana
Departament d'Informàtica, Matemàtica Aplicada i Estadstica
Universitat de Girona
jsaldana@imae.udg.edu

CP8

Competition and Invasion of Dengue Viruses in Vaccinated Populations

The complex competitive landscape that exists between the four dengue serotypes will change in unforeseeable ways with the soon-to-be released commercial vaccines. Here, we use a compartmental dengue transmission model incorporating mass vaccination to investigate the possibility of serotype reintroduction in locations where one or more serotypes are absent. We show that the widespread application of fully sterilizing vaccines can have the unintended effect of facilitating the reintroduction of missing serotypes.

Luis Mier-y-Teran, Isabel Rodriguez-Barraquer
Johns Hopkins Bloomberg School of Public Health
lmier-y@jhsph.edu, irodrigu@jhsph.edu

Ira B. Schwartz
Naval Research Laboratory
Nonlinear Dynamical Systems Section
ira.schwartz@nrl.navy.mil

Derek Cummings
Johns Hopkins Bloomberg School of Public Health
dcummings@jhsph.edu

CP9

$\mathcal{C}^\infty$ Regularisation of Local Singularities of Filippov Systems

We study the Sotomayor-Teixeira regularization of a general visible fold singularity of a Filippov system. In the case that the regularized system is $\mathcal{C}^{p-1}$ the deviation from the Fenichel manifold is $O(\varepsilon^{\frac{p}{2p-1}})$. We extend these results to the case where the regularized vector field is analytic. In this case the regularized vector field and the Filippov one are different in the whole phase space, but this is just a technical problem that will not change the final result.

Carles Bonet
Universitat Politecnica de catalunya
carles.bonet@upc.edu

Tere M. Seara-Alonso
Universitat Politecnica de Catalunya
tere.m-seara@upc.edu

CP9

Filippov Unplugged - Part 2

Following on from Filippov Unplugged part 1, we will present results from "Differential equations with discontinuous righthand sides" that hold in n-dimensional nonsmooth systems. Focussing on issues of topological equivalence and structural stability, we will identify basic topological classes of singularities that can occur, as well as the bifurcations that ensue. Practical examples, rooted in real applications, will be given to illustrate the talk.

John Hogan
Bristol Centre for Applied Nonlinear Mathematics
Department of Engineering Mathematics, University of Bristol
s.j.hogan@bristol.ac.uk

Martin Homer
University of Bristol
Department of Engineering Mathematics
martin.homer@bristol.ac.uk

Mike R. Jeffrey, Robert Szalai
University of Bristol
mike.jeffrey@bristol.ac.uk, r.szalai@bristol.ac.uk

CP9

Filippov Unplugged — Part 1

Almost every paper on nonsmooth systems references the book by Filippov "Differential equations with discontinuous righthand sides' (Kluwer, 1988). The aim of this talk is to direct attention toward results therein that are relevant to the modern audience, yet do not appear to be widely known. In particular, we will focus on two-dimensional flows, and discuss how we must fundamentally revise our notions of singularities, codimension, separatrices, structural stability, topological equivalence and bifurcations.

John Hogan
Bristol Centre for Applied Nonlinear Mathematics
Department of Engineering Mathematics, University of Bristol
s.j.hogan@bristol.ac.uk

Martin Homer
University of Bristol
Department of Engineering Mathematics
martin.homer@bristol.ac.uk

Mike R. Jeffrey, Robert Szalai
University of Bristol
mike.jeffrey@bristol.ac.uk, r.szalai@bristol.ac.uk

CP9

On the Use of Blow Up to Study Regularizations of Singularities of Piecewise Smooth Dynamical Systems

This talk will demonstrate the use of the blow up method of Krupa and Szmolyan to study the regularization of singularities of piecewise smooth dynamical systems. We will primarily focus on the regularization of the two-fold bifurcation and the perturbation of associated limit cycles, pseudo-equilibria, and canard-like orbits connecting stable sliding with unstable sliding. We will also present results on how the regularization function can introduce additional bifurcation.

Kristian Uldall Kristiansen
Technical University of Denmark
Department of Applied Mathematics and Computer Science
krkri@dtu.dk

John Hogan
Bristol Centre for Applied Nonlinear Mathematics

Department of Engineering Mathematics, University of Bristol
s.j.hogan@bristol.ac.uk

CP10

Curve Evolution in Second-Order Lagrangian Systems

A second-order Lagrangian system is a generalization of a classical mechanical system for which the Lagrangian action depends on the second derivative of the state variable. Recent work has shown that the dynamics of such systems can be substantially richer than for classical Lagrangian systems. In particular, topological properties of the planar curves obtained by projection onto the lower-order derivatives play a key role in forcing certain types of dynamics. However, the application of these techniques requires an analytic restriction on the Lagrangian that it satisfy a twist property. Here we approach this problem from the point of view of curve shortening in an effort to remove the twist condition.We prove the existence of simple periodic solutions for a general class of systems without requiring the twist condition. Further, our results provide a framework in which to try to further extend the topological forcing theorems to systems without the twist condition.

Ronald Adams
Florida Atlantic University
radams22@fau.edu

William D. Kalies
Florida Atlantic University
Department of Mathematical Sciences
wkalies@fau.edu

R.C.A.M van Der Vorst
Vrije Universiteit
vdvorst@few.vu.nl

CP10

Tensor of Green of Coupled Thermoelastodynamics

Some problems of coupled thermoelastodynamics are considered. Method of boundary integral equations is used for solution of system of integral equations, fundamental tensors of stresses received by using of apparate of generalized functions.

Bakhyt Alipova
University of Kentucky
bakhyt.alipova@uky.edu

CP10

Periodic Eigendecomposition and Its Application in Nonlinear Dynamics

As an extension of periodic Schur decomposition, periodic eigendecomposition is capable of calculating Floquet spectrum and Floquet vectors along periodic orbits in chaotic systems accurately. Its effectiveness, and in particular its ability to resolve eigenvalues whose magnitude differs by hundreds of orders, is demonstrated by applying the algorithm to computation of the full linear stability spectrum of periodic solutions of Kuramoto-Sivashinsky system. Also, its efficiency is compared with the existing covariant vectors algorithm.

Xiong Ding
School of Physics, Georgia Institute of Technology
xding@gatech.edu

Predrag Cvitanovic
Center for Nonlinear Science
Georgia Institute of Technology
predrag.cvitanovic@physics.gatech.edu

CP10

Error Assessment of the Local Statistical Linearization Method

We determine probability density functions of multidimensional stochastic differential equations by means of the Local Statistical Linearization method. The core of this method is the approximation of a non-Gaussian probability density by superposition of Gaussian densities. For this, the evolutions of local Gaussian densities are calculated and used in a time stepping scheme. Moreover, we provide error evolutions using accurate Monte Carlo simulations, Stochastic Averaging and available analytical solutions.

Leo Dostal
Hamburg University of Technology
Institute of Mechanics and Ocean Engineering
dostal@tuhh.de

Edwin Kreuzer
Institute of Mechanics and Ocean Engineering
Hamburg University of Technology
kreuzer@tuhh.de

CP10

Geometric Phase in the Hopf Bundle and the Sability of Non-Linear Waves

Building on the Evans function, we have proven a related, alternative form of analysis that uses the Hopf bundle to determine the stability of traveling waves. The total space of the Hopf bundle is S^{2n-1} and it is naturally embedded in C^n. The dynamical system associated with the linearized operator for a PDE induces a winding number through parallel transport in the fibre, S^1. Our method uses parallel transport to count the multiplicity of eigenvalues.

Colin J. Grudzien
University of North Carolina at Chapel Hill
Mathematics Department
cgrudz@gmail.com

Christopher Krt Jones
University of North Carolina at Chapel Hill
ckrtj@email.unc.edu

CP10

Computation of Cauchy-Green Strain Tensor Using Local Regression

The Cauchy-Green strain tensor provides an effective tool for understanding unsteady flows. We propose a new method for computing the CG strain tensor using a local quadratic regression (LOESS) technique. We compare this LOESS method with several classical methods using closed form flows, noisy flows, and simulated time series. In each case the CG strain tensor produced by the LOESS method is remarkably accurate and robust compared to classical

methods.

Shane D. Kepley
Florida Atlantic University
skepley@fau.edu

Bill Kalies
Florida Atlantic University
Department of Mathematical Sciences
wkalies@fau.edu

CP11

Odd-Number Limitation for Extended Time-Delayed Feedback Control

Time-delayed feedback control is a simple and established method to stabilize unstable periodic orbits within a chaotic attractor. Here we prove a generalization of the well-known odd-number limitation of this control method to the case of autonomous systems. This result is further generalized to the extended version of time-delayed feedback control. We uncover the important role played by the period of the orbit that is induced by mismatching the delay time of the control scheme.

Andreas Amann, Edward Hooton
School of Mathematical Sciences
University College Cork
a.amann@ucc.ie, 105426740@umail.ucc.ie

CP11

Approximate Controllability of An Impulsive Neutral Fractional Stochastic Differential Equation With Deviated Argument and Infinite Delay

We proved the approximate controllability of an impulsive fractional stochastic neutral integro-differential equation with deviated argument and infinite delay. We used Schauder fixed point theorem and fundamental assumptions on system operators. The inverse of controllability operator fails to exist in infinite dimensional space in case generated semigroup is compact. Therefore, the need to assume the invertibility of controllability operator is removed. Lipschitz continuity is also not required. Specifically we studied the following remote control dynamical system

$$\begin{aligned} {}^cD_t^q[x(t)+g(t,x_t)] &= A[x(t)+g(t,x_t)] + Bu(t) + f(t, x(a(x(t),t)), u(t)) \\ &+ \int_{-\infty}^{t} G(x_s)dW(s), t \in J = [0,T], t \neq t_k, k = 1, \dots, m \\ x_0(t) &= \phi(t), \qquad t \in J_1 = (-\infty, 0] \\ x(t_k^+) - x(t_k^-) &= I_k(x(t_k)), \qquad k = 1, ..., m, \end{aligned}$$

Sanjukta Das
Indian Institute of Technology, Roorkee,
sanjukta_das44@yahoo.com

Dwijendra Pandey
Indian Institute of Technology, Roorkee
dwijfma@iitr.ernet.in

CP11

Chaos in Biological Systems with Memory and Its Controllability

Biological systems, a neuron, the brain, the heart, a human being, a society .., are systems with memory (in many cases power-law). This implies a possibility of their description by fractional differential equations or maps with power-law memory. Nonlinear systems with power-law memory demonstrate new features, including cascade of bifurcations type behavior (with fixed parameters). This behavior could be related to the evolution of chronic diseases, epileptic seizures, and evolution of the human society. In nonlinear systems with power-law memory chaos can be controlled by changing nonlinearity parameter and also by changing a memory parameter of a system.

Mark Edelman
Stern College for Women and Courant Institute
edelman@cims.nyu.edu

CP11

Discrete-Time Structure-Preserving Optimal Ergodic Control

Trajectories are ergodic with respect to a measure when the amount of time spent in a neighborhood is proportional to the measure evaluated over the neighborhood, making ergodicity an appropriate metric for searching a domain. Ergodic control in higher dimensional configuration spaces requires discretization of the optimal control formulation. Recent works have shown advantages of structure-preserving variational integrators in control and estimation of mechanical systems. Here we develop a discrete-time variational optimal ergodic control scheme.

Kathrin Flakamp, Todd Murphey
Northwestern University
kathrin.flasskamp@northwestern.edu, t-murphey@northwestern.edu

CP11

Mathematical Study of the Effects of Travel Costs on Optimal Dispersal in a Two-Patch Model

How might organisms constrained by perceptual limitations or imperfect information use resource information optimally in habitat selection? We analyze a general ordinary differential equation model of a single species in a two-patch heterogeneous environment. Global stability analysis yields an evolutionarily stable information use strategy that depends on the magnitude of the constraints and the heterogeneity of the resources. Incorporating travel costs into the model yields a different strategy that is locally convergent stable

Theodore E. Galanthay
University of Colorado
tgalanthay@ithaca.edu

CP11

Computing Bisimulation Functions Using SoS Optimization and δ-Decidability over the Reals

We present BFComp, an automated framework based on Sum-Of-Squares (SOS) optimization and δ-decidability over the reals to compute Bisimulation Functions (BFs) that characterize input-to-output stability (IOS) of dynamical systems. BFs are Lyapunov-like functions that decay along the trajectories of a given pair of systems, and can be used to establish the stability of the outputs with respect to bounded input deviations. In addition to establishing IOS, BFComp is designed to provide tight bounds on the squared output errors between systems whenever

possible. For this purpose, two SOS optimization formulations and δ-decidability-based Satisfiability Modulo Theory are employed. We illustrate the utility of BFComp on a feedback-based canonical cardiac-cell model, showing that the four-variable Markovian model for the slow Potassium current I_{Ks} can be safely replaced by an approximately one-variable Hodgkin-Huxley-type approximation.

Abhishek Murthy
Philips Research North America
amurthy.sunysb@gmail.com

Md. Ariful Islam, Scott Smolka
Computer Science
Stony Brook University
mdaislam@cs.stonybrook.edu, sas@cs.stonybrook.edu

Radu Grosu
Vienna University of Technology
radu.grosu@tuwien.ac.at

CP12

Empirical Validation of Conceptual Climate Models

Conceptual climate models are useful for testing hypotheses regarding the processes underlying observations; but they generally can only qualitatively match the empirical records. Models based on substantially different underlying physics can have comparable correlations with any given observation; more robust model validation procedures are needed. Using the Mid-Pleistocene Transition as a test case, we will show how modern time-series-analysis techniques can improve validation by extracting subtler features of the observations and models.

Charles D. Camp, Ryan Smith, Andrew Gallatin
California Polytechnic State University
camp@calpoly.edu, rsmith49@calpoly.edu, agallati@calpoly.edu

CP12

Modified Lorenz Equations for Rotating Convection

We derive and examine systems of nonlinear differential equations similar to the Lorenz equations. In particular, starting from the partial differential equations describing two-dimensional Rayleigh-Benard convection we derive systems of ordinary differential equations that are slight modifications of Lorenz' original system. These new systems of equations incorporate the effects of rigid body rotation. We investigate the role that rotation has on the dynamics of these reduced models.

Jessica Layton
BYU
j-layton@cox.net

Jared P. Whitehead, Shane McQuarrie
Brigham Young University
whitehead@mathematics.byu.edu,
shanemcq18@gmail.com

CP12

On the Geometry of Attractors in Ageostrophic Flows with Viscoelastic-Type Reynolds Stress

Progress utilizing other closure protocols appear in this research and innovation. Although this article is motivated by challenges in partial differential equations, we consider a two-mode Faedo-Galerkin approximation(Ed Lorenz ansatz sense) given by a system of singularly perturbed ordinary differential equations in R^4:

$$Ro\frac{dX}{dt} = Y - EkX - \lambda EkW,$$

$$\frac{dY}{dt} = \varepsilon X + X - Y - XZ,$$

$$\frac{dZ}{dt} = -bZ + XY,$$

$$We\frac{dW}{dt} = r(\delta\lambda X - W).$$

It is shown that the equilibrium point at the origin is asymptotically stable and attractive by the LaSalle invariance principle. Utilizing center manifold calculations, we show existence of supercritical pitchfork bifurcation and Poincare-Andronov-Hopf bifurcation. In order to utilize geometric singular perturbation theory and Melnikov techniques, we perturb the problem and carry the nonlinear analysis further to the question of the persistence of inclination-flip homoclinic solutions. We present a geometric approach to the problem which gives more refined a priori energy type estimates on the position of the invariant manifold and its tangent planes as the manifold passes close to a normally hyperbolic piece of a slow manifold. The main object of this result enables detection of chaotic attractors in singularly perturbed dynamical systems as depicted using the DsTool(Dynamical systems Tool) package program of Worfolk *et al.*

Maleafisha Stephen Tladi
University of Limpopo, South Africa
Stephen.Tladi@ul.ac.za

CP12

Baroclinic Instability in An Initially Stratified Rotating Fluid

Motivated by the large-scale atmospheric and oceanic circulation, we study the characteristics of density-driven convective flow in an annular, tabletop-size rotating laboratory tank, filled with water. Horizontal and vertical density gradients are induced by differential heating at the sidewalls and salinity stratification, respectively. These boundary conditions, together with the rotation of the tank, yield an interesting interplay between double-diffusive convection and baroclinic instability.

Miklos P. Vincze
HAS ELTE Theoretical Physics Research Group
vincze.m@lecso.elte.hu

Patrice Le Gal
IRPHE, CNRS-Aix Marseille
legal@irphe.univ-mrs.fr

Uwe Harlander
BTU Cottbus, Department of Aerodynamics and Fluid Mechanics

uwe.harlander@tu-cottbus.de

CP12
Gradual and Abrupt Regime Shifts in Drylands

The response of ecosystems to climatic changes and anthropogenic disturbances are crucial to our understanding of these systems. Transitions in drylands due to these perturbations may take various forms, in particular due to the patterned nature of patchy vegetation. I will discuss multistability in these systems, owing to localized states and patterns with various wavelength, and possible transitions in them. A case study of fairy circles in Namibia will be presented as a concrete example.

Yuval Zelnik
Ben-Gurion University of the Negev
zelnik@post.bgu.ac.il

Ehud Meron
Ben-Gurion University
ehud@bgu.ac.il

Golan Bel
Department of Solar Energy and Environmental Physics
Ben-Gurion University
bel@bgu.ac.il

CP13
Localized States in Periodically Forced Systems

The generalized Swift–Hohenberg equation with a quadratic-cubic nonlinearity is used to study localized pattern formation in the presence of time-periodic parametric forcing. Regions of parameter space with distinct dynamics result from resonances between the period of the forcing and the time it takes the state to nucleate/annihilate wavelengths of the pattern. The non-trivial structure of these regions can be understood qualitatively, and in some cases quantitatively, by asymptotic arguments.

Punit R. Gandhi
Department of Physics
University of California, Berkeley
punit_gandhi@berkeley.edu

Cedric Beaume
Imperial College London
ced.beaume@gmail.com

Edgar Knobloch
University of California at Berkeley
Dept of Physics
knobloch@berkeley.edu

CP13
Multicluster and Traveling Chimera States in Nonlocal Phase-Coupled Oscillators

We study a nonlocal phase-coupled oscillator model in which chimera states develop from random initial conditions. Several classes of chimera states have been found: (a) stationary multi-cluster states with evenly or unevenly distributed coherent clusters (b) a coherent state traveling with a constant speed or in a stick-slip fashion (c) chimera states traveling with a constant speed. A self-consistent continuum description of these states is provided and their stability properties are analyzed through a combination of linear stability analysis, numerical continuation, and direct numerical simulation. Heterogeneities in the natural frequency of the oscillators select the location of the coherent clusters and may lead to their breakup. Pinning of traveling states by heterogeneities may occur, followed by depinning as the heterogeneity decreases.

Hsien-Ching Kao
Wolfram Research Inc.
sp000088@gmail.com

Jianbo Xie
Department of Physics
University of California at Berkeley
swordwave@berkeley.edu

Edgar Knobloch
University of California at Berkeley
Dept of Physics
knobloch@berkeley.edu

CP13
Chimera States on the Route from Coherent State to a Rotating Wave

We discuss the occurrence of chimera states on the route from coherent via solitary states to the rotating wave in the networks of non-locally coupled pendulum-like nodes. We identify the wide region in parameter space, in which a new type chimera state, imperfect chimera state, which is characterized by a certain number of oscillators escaped from synchronized chimeras cluster appears. We describe a novel mechanism for the creation of chimera states via the appearance of the so-called solitary states. Our findings reveal that imperfect chimera states represent characteristic spatio-temporal patterns at the transition from coherence to incoherence.

Tomasz Kapitaniak
Technical University of Lodz
Dept of Dynamic
tomaszka@p.lodz.pl

CP13
Emergent Rhythmic Behavior of Mixed-Mode Oscillations in Pulse-Coupled Neurons

Our study is motivated by the experimental observation of fast and slow rhythms in the mammalian olfactory system. We develop a minimal model in which the interaction of three relevant populations of neurons is reduced to an effective pulse-coupling within a single population of mixed-mode oscillators. This pulse-coupling features multiple pulses with distinct propagation delays. We explore the dynamics of the system as a function of the shapes and delays of the pulses.

Avinash J. Karamchandani
Department of Engineering Sciences and Applied Mathematics
Northwestern University
avijka@u.northwestern.edu

James Graham
Northwestern University
jamesgraham2016@u.northwestern.edu

Hermann Riecke
Applied Mathematics

Northwestern University
h-riecke@northwestern.edu

CP13

Onset and Characterization of Chimera States in Coupled Nonlinear Oscillators

Role of symmetry breaking in nonlocal and global couplings of networks of identical nonlinear oscillators for the occurrence of chimera mediated transitions between desynchronized and synchronized states will be discussed. We will also distinguish between amplitude chimera and frequency chimera states in this process and identify the conditions under which chimera death states can arise. New rigorous quantitative measures to distinguish the above collective states in terms of strength of incoherence and discontinuity measure will be presented.

Lakshmanan Muthusamy
Centre for Nonlinear Dynamics, Department of Physics
Bharathidasan University, Tiruchirapalli 620024, India
lakshman.cnld@gmail.com

CP14

Reduced Modeling of Exact Coherent States in Shear Flow

In parallel shear flows, the lower branch solution follows simple streamwise dynamics. A decomposition of this solution into Fourier modes in this direction yields modes whose amplitudes scale with inverse powers of the Reynolds number. We use this scaling to derive a reduced model for exact coherent structures in general parallel shear flows. The reduced model is regularized by retaining higher order viscous terms. Both lower branch and upper branch solutions are captured and studied.

Cedric Beaume
Imperial College London
ced.beaume@gmail.com

Greg Chini
Program in Integrated Applied Mathematics
University of New Hampshire
greg.chini@unh.edu

Keith Julien
Applied Mathematics
University of Colorado, Boulder
keith.julien@colorado.edu

Edgar Knobloch
University of California at Berkeley
Dept of Physics
knobloch@berkeley.edu

CP14

Stratified Shear Turbulence Experiments

We report experiments on stratified wall-bounded shear flows in which we determine both the velocity and density fields. The flows undergo Kelvin-Helmholtz and Holmboe instabilities depending on the strength of the stratification and shear. We characterize the instabilities by the Richardson number dependence of a local Thorpe length that defines an intermittency fraction for the density interface and allows for an evaluation of the probability distribution of Thorpe length. We discuss applications to ocean overflows.

Robert E. Ecke
Center for Nonlinear Studies
Los Alamos National Laboratory
ecke@lanl.gov

Philippe Odier
ENS Lyon
philippe.odier@ens-lyon.fr

CP14

Effects of Fluid Dynamics on Experiments with Compressed/ Expanded Surfactant Monolayers

Monolayer experiments frequently measure surface rheological properties by periodically modulating surfactant concentration with two slightly immersed solid barriers that control the free surface area of a shallow liquid layer. Because the modulation is slow, most theoretical studies ignore fluid dynamics in the bulk. We present a long wave theory that also takes fluid dynamics and symmetries into account. A nonlinear diffusion equation for surfactant concentration that includes free surface deformation shows that fluid dynamics can be an important source of irreversibility and help explain experimental observations.

Maria Higuera
E. T. S. I. Aeronauticos
Univ. Politecnica de Madrid
maria@fmetsia.upm.es

Jose Perales
E. T. S. I. Aeronauticos
Universidad Politecnica de Madrid
josem.perales@upm.es

Jose Vega
E. T. S. I. Aeronáuticos
Universidad Politécnica de Madrid
josemanuel.vega@upm.es

CP15

Noisy-Bar Problem

We have all experienced the inability to hear and understand our conversation partner in a crowded room. The difficulty tends to be most apparent in a crowded bar or a club setting. Aside from presenting a social inconvenience, this problem is also closely connected to the issue of signal to noise ratio in networked electronics. In this talk I will present a simple dynamical systems model that explains the transition from a quiet to loud environment.

Korana Burke
UC Davis
kburke@ucdavis.edu

CP15

Embedology for Control and Random Dynamical Systems

We introduce a data-based approach to estimating key quantities which arise in the study of nonlinear control systems and random nonlinear dynamical systems. Our approach hinges on the observation that much of the existing linear theory may be readily extended to nonlinear systems - with a reasonable expectation of success- once the nonlinear system has been mapped into a high or infinite dimensional reproducing kernel Hilbert space. In particular, we embed a nonlinear system in a reproducing kernel Hilbert space where linear theory can be used to develop computable, nonparametric estimators approximating controllability and observability energy functions for nonlinear systems, and study the ellipsoids they induce. It is then shown that the controllability energy estimator provides a key means for approximating the invariant measure of an ergodic, stochastically forced nonlinear system. In all cases the relevant quantities are estimated from simulated or observed data.

Boumediene Hamzi
Imperial College
Department of Mathematics
b.hamzi@imperial.ac.uk

Jake Bouvrie
MIT
bouvrie@gmail.com

CP15

Faster Sensitivity Estimates for Stochastic Differential Equations

Estimating the sensitivity of model predictions to parameter variations is a common task in scientific computing. When the model in question takes the form of a stochastic differential equation, sensitivity estimates can be computationally expensive, particularly if the system at hand is chaotic. In this talk, I will describe a class of algorithms for speeding up sensitivity estimates for models of noisy, chaotic systems.

Kevin K. Lin
Department of Mathematics
University of Arizona
klin@math.arizona.edu

Jonathan C. Mattingly
Duke University
jonm@math.duke.edu

CP15

Noise Shaping and Pattern Discrimination in Recurrent Spiking Neuronal Networks

The enhancement of pattern discrimination is considered a common step in early sensory processing by the brain, often attributed to a recurrent network. It has been suggested that noise correlations arising from the common feedback within recurrent spiking networks may interfere with the intended pattern discrimination. We show that recurrent excitatory-inhibitory networks with reciprocal connections, as they arise in the olfactory system, can reshape the noise such that the network can enhance pattern discriminability efficiently.

Hermann Riecke
Applied Mathematics
Northwestern University
h-riecke@northwestern.edu

Tom Zhao, Siu Fai Chow
Northwestern University
tomzhao2014@u.northwestern.edu, siu-chow2008@u.northwestern.edu

CP15

Zero Density of Open Paths in the Lorentz Mirror Model for Arbitrary Mirror Probability

The Lorentz mirror model consists of a particle bouncing off randomly-oriented mirrors placed at integer lattice points, and is thus a key model of deterministic dynamics in a quenched random environment. We will present efficient numerical simulations to count closed and open paths in the Lorentz mirror model, and arguments based on the results of those simulations [A.S. Kraemer & D.P. Sanders, *Journal of Statistical Physics* **156**, 908–916], to show that the density of open paths in a finite box tends to 0 as the box size tends to infinity, for any probability $p > 0$ of placing a mirror at a point.

David P. Sanders
Department of Physics, Faculty of Sciences
National University of Mexico (UNAM)
dpsanders@ciencias.unam.mx

Atahualpa Kraemer
Heinrich-Hein University of Dusseldorf
ata.kraemer@gmail.com

CP15

Power System Stochastic Modeling

We develop and test recent methods in power systems simulation. A stochastic Runge-Kutta single-step solver is proposed; error coefficients and order conditions are derived. A new method of retrieving the algebraic system variables after topological changes (i.e. line tripping) in the model system is examined. The stability behavior of the system is studied under stochastic forcing and topological disturbances.

Mathew Titus, Yue Zhang, Eduardo Cotilla-Sanchez
Oregon State University
titusm@math.oregonstate.edu,
zhangyue@onid.oregonstate.edu,
ecs@eecs.oregonstate.edu

CP16

Effects of Network Structure on the Synchronization of Hamiltonian Systems

Hamiltonian systems exhibiting long-range interactions are frequently modeled using the Hamiltonian Mean Field (HMF) model. Past research on the HMF has focused on the all-to-all case where each rotor is connected to every other rotor. We study the HMF on complex networks of interactions amongst the rotors. We find that although the network structure impacts the onset of rotor synchronization and the path to synchrony, the maximum possible synchrony is fairly independent of network structure.

Yogesh Virkar
Department of Computer Science
University of Colorado, Boulder
yogesh.virkar@colorado.edu

Juan G. Restrepo
Department of Applied Mathematics
University of Colorado at Boulder
Juanga@Colorado.EDU

James D. Meiss
University of Colorado
Dept of Applied Mathematics
jdm@colorado.edu

CP16

Transient Spatiotemporal Chaos in a Network of Coupled Morris-Lecar Neurons

Spatiotemporal chaos collapses to either a rest state or a propagating pulse solution in a ring network of diffusively coupled, excitable Morris-Lecar neurons. The addition of weak excitatory synapses can increase the Lyapunov exponent, expedite the collapse, and promote the collapse to the rest state rather than the pulse state. A pulse solution may no longer be asymptotic for certain network topologies and (weak) synapses.

Renate A. Wackerbauer
University of Alaska Fairbanks
Department of Physics
rawackerbauer@alaska.edu

Jacopo Lafranceschina
University of Alaska Fairbanks
jlafranceschina@alaska.edu

CP16

Consequence of Symmetry Breaking in Two Coupled Kuramoto Networks

We explore symmetry breaking in a two-population Kuramoto network, using the ansatz of Ott and Antonsen [Chaos 18, 037113 (2008)]. We find that the system is a generalized formulation for a single population of symmetrically-coupled, bimodally-distributed oscillators. We explore this systems equilibria and invariant sets and characterize the bifurcations of both the incoherent and partially-coherent states. We then identify and break several symmetries present in this system, to see how the dynamics change.

Scott T. Watson
George Mason University
swatso10@gmu.edu

Ernest Barreto
George Mason University
Krasnow Institute
ebarreto@gmu.edu

Bernard Cotton
George Mason University
paso@gmu.edu

Paul So
George Mason University
The Krasnow Institute
paso@gmu.edu

CP16

Control of Stochastic and Induced Switching in Biophysical Complex Networks

While the response of biological systems to noise has been studied extensively, there has been limited understanding of how to exploit these fluctuations to induce a desired cell state. Here we present a method based on the Friedlin-Wentzell action to predict and control noise-induced switching between different attracting states in genetic regulatory networks. We utilize this methodology to identify new candidate strategies for cancer therapy in a coupled ODE model of the cell death pathway.

Daniel Wells
Northwestern University
Department of Engineering Sciences and Applied Mathematics
wellsd@u.northwestern.edu

William Kath
Department of Applied Mathematics, Northwestern University
Department of Neurobiology, Northwestern University
kath@northwestern.edu

Adilson E. Motter
Northwestern University
motter@northwestern.edu

CP16

Studies of Stable Manifolds of a Spatially Extended Lattice Kuramoto Model

We study the steady state solution of the 1D and 2D spatially extended Kuramoto model with nearest-neighbor coupling for a range of system sizes. Past the critical coupling σ_c, different possible steady states can appear including phase coherence (synchronization), and phase locking (traveling wave states). We characterize the terminal behavior of a space of initial conditions for a variety of boundary conditions: periodic, zero-flux and free.

Andrea J. Welsh, Flavio Fenton
Georgia Institute of Technology
awelsh8@gatech.edu, flavio.fenton@physics.gatech.edu

CP17

Efficient Kernel Algorithm for the Dynamic Mode Decomposition of Observed Data

The dynamic mode decomposition (DMD) is a recently proposed algorithm for decomposing time series data observed from nonlinear dynamical systems. We extend the DMD by using a statistical technique called the kernel method. Our extended DMD can compute the mode decomposition significantly faster and more accurately than other methods. In addition, we theoretically discuss the sufficient condition for the modes to be reconstructed from observed time series. We illustrate the validity and usefulness of our method by numerical examples.

Wataru Kurebayashi, Sho Shirasaka
Tokyo Institute of Technology
kure@fa2.so-net.ne.jp, shirasaka.s.aa@m.titech.ac.jp

Hiroya Nakao
Graduate School of Information Science and Engineering, Tokyo Institute of Technology
nakao@mei.titech.ac.jp

CP17

Perturbing the Cat Map: Mixed Elliptic and Hyperbolic Dynamics

Arnolds cat map is a prototypical dynamical system with uniformly hyperbolic dynamics. We study a family of maps homotopic to the cat map that has a saddle and a parabolic fixed point. Lerman conjectured that this map has a mixed phase space. We present some evidence in support. The elliptic orbits are confined to a channel bounded by manifolds of the fixed points. The complement appears to have positive measure with positive Lyapunov exponents.

James D. Meiss
University of Colorado
Dept of Applied Mathematics
jdm@colorado.edu

Lev Lerman
Lobachevsky State University of Nizhny Novgorod
lermanl@mm.unn.ru

CP17

Invariant Manifolds and Space Mission Design in the Restricted Four-Body Problem

Invariant manifolds play a crucial role in designing low-energy trajectories of a spacecraft. We consider the four-body problem of Sun, Earth, Moon and a spacecraft by regarding the system as a coupled system of distinct RC3BPs with perturbations, namely, the systems of Sun-Earth-S/C+ (Moon perturb) and Earth-Moon-S/C+ (Sun perturb). We clarify tube-like invariant manifolds of each perturbed system and design a transfer trajectory from Earth to Moon by patching trajectories associated with the invariant manifolds.

Kaori Onozaki
Waseda university
green-11street@ruri.waseda.jp

Hiroaki Yoshimura
Waseday University
yoshimura@waseda.jp

CP17

Mixing on a Hemisphere

Motivated by mixing in 3D rotated granular flows, we study the nonlinear dynamics of piecewise isometries (PWI) on a hemispherical shell for different rotation protocols. Mappings of singularities, termed the exceptional set, E, cover the hemisphere's surface in a variety of complex patterns and explain the ultimate degree of mixing but not the rate of mixing. To understand the mixing rate, we explore a Lyapunov exponent inspired method based on the partitioning property of PWI.

Paul Park
Northwestern University
paul-park@northwestern.edu

Paul Umbanhowar, Julio Ottino
Northwestern University
Evanston, IL 60208-3109
umbanhowar@northwestern.edu,
jm-ottino@northwestern.edu

Richard M. Lueptow
Northwestern University
Department of Mechanical Engineering
r-lueptow@northwestern.edu

CP17

Classification of Critical Sets and Images for Quadratic Maps of the Plane

Real quadratic maps of the plane form a 12-parameter family and exhibit a huge range of complicated dynamics. To consider the whole class of maps together, we consider only critical sets (J_0) and their images (J_1). J_0 is a possibly degenerate conic section. Possibilities for J_1 are surprisingly restricted. We study this classification with a hierarchical structure - first via a normal form for homogeneous quadratic maps, and then for linear perturbations of these homogeneous maps.

Bruce B. Peckham
Dept. of Mathematics and Statistics
University of Minnesota Duluth
bpeckham@d.umn.edu

Chia-Hsing Nien
Department of Financial and Computational Mathematics
Providence University Taichung City 43301 Taiwan
chnien@gm.pu.edu.tw

Richard McGehee
University of Minnesota
mcgehee@umn.edu

Bernd Krauskopf, Hinke M. Osinga
University of Auckland
Department of Mathematics
b.krauskopf@auckland.ac.nz, H.M.Osinga@auckland.ac.nz

CP17

The Existence of Horseshoe Dynamics in Three Dimensional Lotka-Volterra Systems

We prove the existence of horseshoe dynamics in three dimensional Lotka-Volterra systems. The proof uses a Shilnikov-type structure adapted to the geometry of the these systems.

Rizgar Salih, Colin Christopher
Plymouth University
rizgar.salih@postgrad.plymouth.ac.uk,
c.christopher@plymouth.ac.uk

CP18

Inferring Causal Structures in Complex Systems Via Causation Entropy

Perhaps the most fundamental question in science in complex systems is to infer causes from influences between many coupled elements. Empirically inferring causal structure in complex systems by means of statistical and information theoretic techniques applied to time series data is a highly challenging and sensitive problem. We report here on our latest results of casual coupling inferences within the framework of the Optimal Causation Entropy (oCSE) approach, together with example applications.

Carlo Cafaro, Warren Lord, Jie Sun, Erik Bollt
Clarkson University
ccafaro@clarkson.edu, lordwm@clarkson.edu,

sunj@clarkson.edu, bolltem@clarkson.edu

CP18

Robustness of Nonlinear Models

We propose an algorithm to test the robustness to parameter variation of complex nonlinear models. In order to find the minimal parameter perturbation that can destroy a nominal solution, the algorithm uses numerical continuation techniques to move towards the closest bifurcation point to the nominal parameter values, then solves a constrained optimization problem to identify the closest point of the bifurcation manifold to the nominal parameters.

Fabio Della Rossa
Dipartimento di Elettronica, Informazione e Bioingegneria
Politecnico di Milano
fabio.dellarossa@polimi.it

Alessandro Colombo
Politecnico di Milano
alessandro.colombo@polimi.it

Fabio Dercole, Carlo Piccardi
Dipartimento di Elettronica, Informazione e Bioingegneria
Politecnico di Milano
fabio.dercole@polimi.it, carlo.piccardi@polimi.it

CP18

A New Filter for State Estimation in Neural Mass Models

The presentation will introduce a new filter for state estimation of neural mass models. The ability to estimate and track states in large-scale neural models is critical for developing robust therapies via model-based feedback control using electrical stimulation. Model-based control is particularly important for diseases such as epilepsy, where pathologies are highly patient-specific. The new filter is similar to the unscented Kalman filter, where a Gaussian approximation is used. However, the mean and covariance of the state estimates are propagated analytically. The analytic results lead to an increase in estimation accuracy and a decrease in computational demands. The development of the new methods presented in this presentation will facilitate the development of large-scale patient-specific computational model of neurological diseases and open the door to the possibility of novel therapies.

Dean R. Freestone
University of Melbourne, Australia
& The Bionics Institute, Melbourne, Australia
deanfreestone@gmail.com

Philippa Karoly, Dragan Nesic, Mark Cook
The University of Melbourne
p.karoly@student.unimelb.edu.au,
dnesic@unimelb.edu.au, markcook@unimelb.edu.au

David Grayden
University of Melbourne, Australia
& The Bionics Institute, Melbourne, Australia
grayden@unimelb.edu.au

CP18

Hysteresis Effects in Pedestrian Flows

We model a crowd of pedestrians as point particles mutually interacting through 'social' forces and forces from constraining walls and obstacles. In counterstreaming constricted flows, blocking evolves through a Hopf bifurcation into oscillatory flows. In flows around an obstacle, we find that a simple local correlation term in the social force gives rise to hysteresis, with obstacle position as the parameter. We have performed experiments to compare with the dynamical model.

Poul G. Hjorth
Technical Univ of Denmark
Department of Mathematics
pghj@dtu.dk

Jens Starke
Technical University of Denmark
Department of Mathematics
j.starke@mat.dtu.dk

CP18

Dynamics of Correlated Novelties

One new thing often leads to another. Kauffman and others have hypothesized that this correlation between novelties is important for understanding anything that evolves: life, technology, language, etc. Ill discuss a simple model that predicts the dynamical fingerprints of correlated novelties (they take the form of certain statistical signatures) and then test the predictions against enormous data sets of human activity (listening to songs, writing words in books, making up tags, and editing Wikipedia pages).

Steven H. Strogatz
Cornell
shs7@cornell.edu

CP18

Systems with Hidden Slow Fast Dynamics

Examples of biochemical systems with complicated non-obvious slow fast structures will be presented. In suitable scalings or blow-ups hidden slow manifolds organizing the dynamics can be found and utilized in the analysis of the dynamics.

Peter Szmolyan
Institute for Analysis and Scientific Computing
Vienna University of Technology
peter.szmolyan@tuwien.ac.at

CP19

A Dynamical and Algebraic Study of a Family of Lienard Equations Transformable to Riccati Equations

In this talk we present some algebraic and dynamical results corresponding to the five parameter differential equation

$$yy' = (\alpha x^{2k} + \beta x^{m-k-1})y + \gamma x^{2m-2k-1} \quad y' = \frac{dy}{dx},$$

being $a, b, c \in \mathbb{C}$, $m, k \in \mathbb{Z}$ and

$$\alpha = a(2m+k)x^{m+k-1} \quad \beta = b(2m-k)x^{m-k-1}, \quad \gamma = -(amx^{4k}+cx^{2k}+bm).$$

This equation is a foliation of a five parameter Lienard equation, which is transformed into a Riccati equation. These transformations are used to do an algebraic analysis about the obtaining of explicit solutions (in differential

Galois sense) of the Lienard equation, as well the obtaining of some elements from Darboux theory of integrability: invariant algebraic curves, first integrals, cofactors, etc.. of the Lienard vector field. Finally, a qualitative analysis is presented (type of critical points, Lyapunov functions, etc..)

Primitivo B. Acosta-Humanez, Jorge Rodriguez-Contreras, Alberto Reyes-Linero
Universidad del Atlantico
primi@intelectual.co, jorge.jrodri@gmail.com, areyesmat@gmail.com

CP19

New Asymptotics of Homoclinic Orbits Near Bogdanov-Takens Bifurcation Point

We derive explicit asymptotics for the homoclinic orbits near a generic Bogdanov-Takens (BT) point, with the aim to continue the branch of homoclinic solutions that is rooted in the BT point in parameter and state space. We present accurate second-order homoclinic predictor of the homoclinic bifurcation curve using a generalization of the Poincaré-Lindstedt (P-L) method. We show that the P-L method leads to the same homoclinicity conditions as the classical Melnikov technique, the branching method and the regular perturbation method (R-P). The R-P method shows a “parasitic turn” near the saddle point. The new asymptotics based on P-L do not have this turn, making it more suitable for numerical implementation. We show how to use these asymptotics to calculate the initial homoclinic cycle to continue homoclinic orbits in two free parameters. The new homoclinic predictors are implemented in the Matlab continuation package MatCont to initialize the continuation of homoclinic orbits from a BT point. Several examples in the case of multidimensional state spaces are included.

Bashir M. Al-Hdaibat
Dept. of Applied Math., Computer Science and Statistics
Gent University, Belgium
Bashir.AlHdaibat@UGent.be

Willy Govaerts
Ghent University
willy.govaerts@ugent.be

Yuri Kuznetsov
Department of Applied Mathematics,
University of Twente, The Netherlands
i.a.kouznetsov@utwente.nl

Hil Meijer
Twente University, NL
h.g.e.meijer@utwente.nl

CP19

Periodic Orbit Theory of Continuous Media

Nonlinear PDEs of a wide range, from Navier-Stokes equations for viscous fluids to the Yang-Mills equations for gauge fields, can exhibit chaos. One can use high dimensional exact coherent solutions of these systems to predict physical observables by utilizing trace sums over relative periodic orbits. These trace formulas are exact for classical systems, but, as we shall demonstrate on several applications, their convergence can be highly nontrivial.

Nazmi Burak Budanur
School of Physics and Center for Nonlinear Science
budanur3@gatech.edu

Predrag Cvitanovic
Center for Nonlinear Science
Georgia Institute of Technology
predrag.cvitanovic@physics.gatech.edu

CP19

Metric Invariance Entropy and Conditionally Invariant Measures

Invariance entropy is a measure for the data rate needed to make a subset of the state space of a control systems invariant. Here a notion of metric invariance entropy is constructed with respect to a conditionally invariant measure for control systems in discrete time. It is shown that the metric invariance entropy is an invariant under conjugations and that the topological invariance entropy (also called feedback entropy) provides an upper bound.

Fritz Colonius
University of Augsburg
fritz.colonius@math.uni-augsburg.de

CP19

A Fast Explicit Method for Computing Invariant Solutions of High-Dimensional Dynamical Systems with Continuous Symmetries

Given a dynamical system with a continuous symmetry, we construct a perturbed system whose trajectories converge to the invariant solutions of the original dynamical system. The perturbation term is a measure of the curvature of the trajectories and is readily computable from the equations of motion. The computational cost is therefore reduced considerably compared to algorithms based on Newton's iterations or variational methods.

Mohammad Farazmand
Mathematics, ETH Zurich
farazmand@physics.gatech.edu

Predrag Cvitanovic
Center for Nonlinear Science
Georgia Institute of Technology
predrag.cvitanovic@physics.gatech.edu

CP19

Dimensionality Reduction of Collective Motion by Principal Manifolds

Current nonlinear dimensionality reduction methods as applied to collective motion of agents may exhibit unfaithful embedding, due to limitations of control over the mapping between original and embedding spaces. We propose an alternative approach by minimizing the orthogonal error while topologically summarizing the high-dimensional data. We construct embedding coordinates in terms of geodesic distances along smoothed principal curves, such that, the mapping between original and embedding spaces is defined in terms of local coordinates.

Kelum D. Gajamannage
Clarkson University
dineshhk@clarkson.edu

Sachit Butail

Indraprastha Institute of Information Technology Delhi
sbutail@iiitd.ac.in

Maurizio Porfiri
Dept. of Mechanical, Aerospace and Manufacturing Engineering
Polytechnic University
mporfiri@nyu.edu

Erik Bollt
Clarkson University
bolltem@clarkson.edu

CP20

On the Numerical Integration of One Nonlinear Parabolic Equation

In the present paper author considers initial-boundary problem to following nonlinear parabolic equation:

$$\frac{\partial U}{\partial t} = \frac{\partial}{\partial x}\left(k\left(\frac{\partial U}{\partial x}\right)\frac{\partial U}{\partial x}\right)+f\left(x,t,U\right),\ (x,t)\in(0,\,1)\times(0,\,T],\ T>0.$$

For the mentioned problem author constructs the corresponding difference scheme and in certain conditions proves the convergence of its solution to the solution of the source problem with the convergence rate $O\left(\tau+h^2\right)$. For the same difference scheme in the same conditions the existence and uniqueness of its solution is proved.

Mikheil Tutberidze
Ilia State University
Associated Professor
mikheil.tutberidze@iliauni.edu.ge

CP20

A Continuous Model for the Pathfinding Problem with Self-Recovery Property

We propose a model which is capable of finding a path connecting two specified vertices which are connected by unidirectional edges. The system has a self-recovery property, i.e., the system can find a path when one of the connections in the existing path is suddenly terminated.

Kei-Ichi Ueda
Faculty of Science, University of Toyama
kueda@sci.u-toyama.ac.jp

Masaaki Yadome
WPI-AIMR, Tohoku University
yadome@wpi-aimr.tohoku.ac.jp

Yasumasa Nishiura
RIES, Hokkaido University
Japan
nishiura@wpi-aimr.tohoku.ac.jp

CP20

Patterns on Curved Backgrounds: the Influence of Local Curvature on Pattern Formation

We indicate how the concepts and approaches developed in the context of the (linear) theory of patterns on flat backgrounds (such as $\mathbb{R}^2$) can be extended to more general surfaces with nonvanishing curvature. The influence of local curvature on the appearance and dynamics of patterns is demonstrated by a number of example surfaces, where it is clear that surface curvature can have nontrival and surprising effects.

Frits Veerman
Mathematical Institute
University of Oxford
veerman@maths.ox.ac.uk

Philip K. Maini
Centre for Mathematical Biology
University of Oxford
maini@maths.ox.ac.uk

CP20

Nonlinear Behaviors As Well As Bifurcation Mechanism in Switched Dynamical Systems

Dynamical model of a typical centrifugal flywheel governor system with periodic switches between two forms of external torque has been established. Two types of bifurcation can be observed in the autonomous subsystem, where the Hopf bifurcation may lead to the occurrence of periodic oscillation, while the fold bifurcation may result in the disappearance of the equilibrium points. The dynamics often behaves in periodic oscillations with the same frequency as the periodic switch. Generalized Hopf bifurcation may lead to the alternation of the behaviors between periodic movements and quasi-periodic oscillations.

Yu V. Wang
York College, The City University of New York
vwang@york.cuny.edu

CP20

Gpu-Based Computational Studies of the Interaction Between Reentry Waves and Gap Junctional Uncoupling in Cardiac Tissues

The obstruction of coronary flow can cause cardiac arrhythmias including ventricular tachycardia and ventricular fibrillation. Gap junctional uncoupling associates with this process but to date the detailed underlying mechanism remains unclear. Our project investigates the dynamic relationship between gap junctional uncoupling and cardiac arrhythmia using GPU computing. This study promises to deepen our understanding of this phenomenon and could enable us to control cardiac arrhythmia by manipulating the gap junctional coupling.

Zhihui Zhang
Florida State University
zz11c@my.fsu.edu

CP21

β_1-Adrenergic Regulation of Action Potential and Calcium Dynamics in a Model of Mouse Ventricular Myocytes

A detailed experimentally-based compartmentalized model of the β_1-adrenergic signaling system in mouse ventricular myocytes is developed. Model simulations reproduced experimental data on phosphorylation dynamics of major ionic currents and calcium binding proteins, voltage-clamp data on ionic currents, modulation of the cardiac mouse action potential and calcium transients by the β_1-adrenergic signaling system. Action mechanisms of phosphodiesterase and protein kinase A inhibitors on the mouse action potential and calcium dynamics at the cellular level are discussed.

Vladimir E. Bondarenko
Department of Mathematics and Statistics
Georgia State University
vbondarenko@gsu.edu

CP21

A Mathematical Model for Frog Population Dynamics with Batrachochydrium Dendrobatidis (Bd) Infection

Chytridiomycosis is a disease that poses a serious threat to frog populations worldwide. Several studies confirmed that inoculation of *Janthinobacterium lividum* (*Jl*) can inhibit the disease. In this talk, I present a mathematical model of a frog juvenile-adult population infected with chytridiomycosis caused by the fungal pathogen *Batrachochydrium dendrobatidis* (*Bd*) to investigate on how the inoculation of anti-*Bd* bacterial species *Jl* could reduce *Bd* infection on frogs.

Baoling Ma
University of Louisiana - Lafayette
bxm4254@louisiana.edu

CP21

A Model of Heart Rate Dynamics for Changes in Exercise Intensity

A nonlinear dynamical systems model for heart rate is investigated for changes in exercise intensity. The model equilibria are used to determine the instantaneous heart rate of an individual during acute bouts of exercise that vary in intensity (power output) and cadence. Theoretical predictions show good agreement with laboratory cycling tests that were performed on several healthy adults.

Michael J. Mazzoleni
Duke University
michael.mazzoleni@duke.edu

Claudio Battaglini
University of North Carolina at Chapel Hill
claudio@email.unc.edu

Brian Mann
Duke University
brian.mann@duke.edu

CP21

The Evolutionary Dynamics of Gamete Recognition Genes

Fertilization of gametes in broadcast spawners such as sea urchins and abalone is modeled as a random walk process with successful fertilization depending on variables such as binding efficiency, sperm and egg concentration, and physical characteristics of gametes. We develop a dynamical system modeling the evolution of binding genes and illustrate the conditions under which less efficient binding is favored. The stability of different binding strategies exhibits a complex series of bifurcations with increasing sperm concentration.

David Mcavity, Mottet Geneva
The Evergreen State College
mcavityd@evergreen.edu, gjmottet@gmail.com

CP21

Spike Time Dependent Plasticity in a Spiking Neural Network

To determine which inputs for a neuron are important and which information a neuron should listen to is an important problem during brain development and during learning. Spike-Timing Dependent Plasticity (STDP) is a physiological adaptation mechanism of synaptic regulation which make a neuron to determine which neighboring neurons are worth by potentiating those inputs and depressing the other. We work on obtaining a good mathematical understanding of Spike-Timing Dependent Plasticity (STDP). This involves understanding why STDP works so well and the significance of factors like STDP type, learning window and scaling under increasing network size. The mathematical model we construct, by using phase oscillators is a good example of discrete adaptive asynchronous network. This is a joint work with Mike Field from Rice University.

Anushaya Mohapatra
Oregon State University
iitmmanu@gmail.com

Mike Field
Rice University Houston
mikefield@gmail.com

Chris Bick
Rice University
bick@rice.edu

CP22

Computational Topology Techniques for Characterizing Time Series Data

Full and accurate reconstruction of dynamics from time-series data—e.g., via delay-coordinate embedding—is a real challenge, but useful information can be gleaned from incomplete embeddings. We apply computational topology to a sequence of lower-dimensional embeddings of the data. Even though the full topology cannot be computed from these incomplete reconstructions, we conjecture that there are some results that can be computed from a *sequence* of such reconstructions, and that these are useful in time-series analysis.

Elizabeth Bradley
University of Colorado
Department of Computer Science
Elizabeth.Bradley@Colorado.EDU

James D. Meiss
University of Colorado
Dept of Applied Mathematics
jdm@colorado.edu

Joshua T. Garland
University of Colorado at Boulder
Department of Applied Mathematics
joshua.garland@colorado.edu

Nicole Sanderson
University of Colorado
Department of Mathematics

nicole.sanderson@colorado.edu

CP22

Plankton Models with Time Delay

We consider a three compartment (nutrient-phytoplankton-zooplankton) model with nutrient recycling. When there is no time delay the model has a conservation law and may be reduced to an equivalent two dimensional model. We consider how the conservation law is affected by the presence of a state dependent time delay in the model. We study the stability and bifurcations of equilibria when the total nutrient in the system is used as the bifurcation parameter.

Sue Ann Campbell
University of Waterloo
Dept of Applied Mathematics
sacampbell@uwaterloo.ca

Matt Kloosterman
Dept of Applied Mathematics
University of Waterloo
mkloosterman@uwaterloo.ca

Francis Poulin
Department of Applied Mathematics
University of Waterloo
fpoulin@uwaterloo.ca

CP22

Noise, Chaos and Entropy Generation in a Time-Delayed Dynamical System

Dynamical chaos and single photon detection are two physical sources of randomness employed to generate fast, cryptographically secure random numbers. We present an experimental system with both types of randomness: an electro-optic feedback loop incorporating a single-photon detector. We describe how the dynamics change from shot noise to deterministic chaos as the photon rate increases, and how the entropy rate can reflect either chaos or shot noise depending on sampling rate and resolution.

Aaron M. Hagerstrom, Rajarshi Roy
University of Maryland
aaron.hagerstrom@gmail.com, rroy@umd.edu

Thomas E. Murphy
University of Maryland, College Park
Dept. of Electrical and Computer Engineering
tem@umd.edu

CP22

Stochastic Delay in Gene Regulation: Exact Stability Analysis

Gene regulatory networks consist of interacting genes and proteins and they control the response of cells to environmental stimuli. The biochemical reactions involved in gene expression take finite time which lead to time delays that vary stochastically due to the inherent intracellular noise. In this talk we analyze the dynamics of systems with stochastic delays and derive exact stability conditions of equilibria based on the second moment dynamics.

Mehdi Sadeghpour, Gabor Orosz
University of Michigan, Ann Arbor
Department of Mechanical Engineering
mehsad@umich.edu, orosz@umich.edu

CP23

Noise and Determinism of Stimulated Brillouin Scattering Dynamics in Optical Fiber

Stimulated Brillouin scattering (SBS) is a noise-initiated nonlinear optical phenomenon that occurs in optical fiber. We present numerical modeling and experimental observations of SBS in single-mode optical fiber. We employ several statistical methods to quantify and examine the roles of determinism and stochasticity of SBS using time-delay embedding, false near neighbors and Hurst exponents. Experimental and theoretical results display a transition in the nature of statistical fluctuation properties from lower to higher input powers.

Diana A. Arroyo-Almanza
Institute of Physical Science and Technology,
University of Maryland
dianita3a@gmail.com

Rafael Setra, Zetian Ni
University of Maryland
rafawaffle@gmail.com, nzt2011@126.com

Thomas E. Murphy
University of Maryland, College Park
Dept. of Electrical and Computer Engineering
tem@umd.edu

Rajarshi Roy
University of Maryland
rroy@umd.edu

CP23

Vector Rogue Waves and Dark-Bright Boomeronic Solitons in Autonomous and Non-Autonomous Settings

In this talk, I will discuss the dynamics of vector rogue waves and dark-bright solitons in two-component nonlinear Schrödinger (NLS) equations with variable coefficients. Using a suitable transformation for the wave functions, the two-component NLS system is converted into the well-known integrable Manakov system. Then, the vector rogue and dark-bright boomeron-like soliton solutions of the latter are converted back into ones of the original non-autonomous model. Using direct numerical simulations, I will present the formation and existence of such soliton solutions in the non-autonomous case.

Efstathios Charalampidis
Department of Mathematics and Statistics
University of Massachusetts, Amherst
charalamp@math.umass.edu

R. BABU Mareeswaran, T. Kanna
Post Graduate and Research Department of Physics
Bishop Heber College, India
babu_nld@rediffmail.com, kanna_phy@bhc.edu.in

Panayotis Kevrekidis
University of Massachusetts
kevrekid@math.umass.edu

Dimitri Frantzeskakis

University of Athens
dfrantz@phys.uoa.gr

CP23

Control of Extreme Events in the Bubbling Onset of Wave Turbulence in the Forced and Damped Non-Linear Schrödinger Equation

The existence of high amplitude intermittent fluctuation in many non-linear dynamical systems constitutes a problem of great relevance in different fields of science. In this work we show the existence of an intermittent transition from temporal chaos to turbulence in a spatially extended dynamical system, namely the forced and damped one-dimensional non-linear Schrödinger equation. For some values of the forcing parameter the system dynamics intermittently switches between ordered states and turbulent states, which may be seen as extreme events in some contexts. In a Fourier phase-space the intermittency takes place due to the loss of transversal stability of unstable periodic orbits embedded in a low-dimensional chaotic attractor. We mapped these transversely unstable regions and locally perturbed the system in order to significantly reduce the occurrence of extreme events of turbulence.

Paulo Galuzio
Department of Physics
Federal University of Parana
ppg06@fisica.ufpr.br

Ricardo L. Viana
Departmento de Fisica
Federal University of Parana
viana@fisica.ufpr.br

Sergio R. Lopes
Department of Physics
Federal University of Parana
lopes@fisica.ufpr.br

CP23

Reducibility of One-dimensional Quasi-periodic Schrödinger Equations

Consider the time-dependent linear Schrödinger equation

$$i\dot{q}_n = \epsilon(q_{n+1}+q_{n-1})+V(x+n\omega)q_n+\delta\sum_{m\in Z} a_{mn}(\theta+\xi t)q_m, \quad n\in Z,$$

where V is a nonconstant real-analytic function on T, ω satisfies a certain Diophantine condition and $a_{mn}(\theta)$ is real-analytic on T^b, $b \in Z_+$, decaying with $|m|$ and $|n|$. We prove that, if ϵ and δ are sufficiently small, then for a.e. $x \in T$ and "most" frequency vectors $\xi \in T^b$, it can be reduced to an autonomous equation. Moreover, for this non-autonomous system, "dynamical localization" is maintained in a quasi-periodic time-dependent way.

Jiansheng Geng
Nanjing University
jgeng@nju.edu.cn

CP23

Numerical Continuation of Invariant Solutions of the Complex Ginzburg-Landau Equation

We compute solutions of the complex Ginzburg-Landau equation (CGLE) invariant under the action of the 3-dimensional Lie group of symmetries $A(x,t) \to e^{i\theta}A(x+\sigma, t+\tau)$. From an initial set of such solutions we obtain a sequence of new sets of invariant solutions via numerical continuation along paths in the parameter space of the CGLE. Solutions are obtained by solving an underdetermined system of nonlinear algebraic equations resulting from use of a spectral-Galerkin discretization in both space and time of the CGLE and the use of a path following method. The set of initial solutions led to distinct, new invariant solutions of the CGLE in the final parameter region. All the solutions are unstable, and have multiple modes and frequencies active, respectively, in their spatial and temporal spectra. Symmetry gaining/breaking behavior associated with the spatial reflection symmetry $A(x,t) \to A(-x,t)$ was common in the parameter regions traversed.

Vanessa Lopez
IBM Watson Research Center
lopezva@us.ibm.com

CP23

Nonlinear Oscillations and Bifurcations in Silicon Photonic Resonators

Silicon microdisk resonators are micron-scale optical devices in which optical, thermal, electron/hole, and mechanical effects interact to produce a wide range of dynamical phenomena. In the strongly nonlinear regime, we demonstrate the presence of Hopf and homoclinic bifurcations leading to the onset and destruction of self-sustained oscillations. We further show that the six-dimensional system of equations governing microdisk behavior can be reduced to a nearly-one-dimensional relaxation-oscillator system, and qualitative dynamics are well represented by a toy model.

Alexander Slawik, Daniel Abrams
Northwestern University
alexanderslawik2015@u.northwestern.edu,
dmabrams@northwestern.edu

CP24

Finding the Stokes Wave: From Low Steepness to Almost Limiting Wave

A Stokes wave is a fully nonlinear wave that travels over the surface of deep water. We solve Euler equations with free surface in the framework of conformal variables via Newton Conjugate Gradient method and find Stokes waves in regimes dominated by nonlinearity. By investigating Stokes waves with increasing steepness we observe peculiar oscillations occur as we approach Stokes limiting wave. Finally by analysing Pade approximation of Stokes waves we infer that analytic structure associated with those waves has branch cut nature.

Sergey Dyachenko
University of Arizona
sdyachen@math.arizona.edu

CP24

Blow-Ups in Nonlinear Pdes, Composite Grid-Particle Methods, and Stochastic Particle Systems

I will discuss a numerical method best suited for solving evolution PDEs exhibiting singular and multiscale behavior (shocks or blow-ups). This method employs representation of solution simultaneously as a field (discretized on a grid or via finite elements) and a particle system. The field and the particles exchange mass according to criteria based

on the types of singularities that are formed in a given system. Examples with Keller-Segel equations of bacterial chemotaxis, Fisher-Kolmogorov, Burgers, and a few other equations will be presented.

Ibrahim Fatkullin
University of Arizona
Department of Mathematics
ibrahim@math.arizona.edu

CP24

Singularities of the Stokes' Wave: Numerical Simulation

Two-dimensional potential flow of the ideal incompressible fluid with free surface and infinite depth can be described by a conformal map of the fluid domain into the complex lower half-plane. Stokes wave is the fully nonlinear gravity wave propagating with constant velocity.

Alexander O. Korotkevich
Dept. of Mathematics & Statistics, University of New Mexico
L.D. Landau Institute for Theoretical Physics RAS
alexkor@math.unm.edu

CP24

Branch Cut Singularity of Stokes Wave

Stokes wave is the fully nonlinear gravity wave propagating with the constant velocity. We consider Stokes wave in the conformal variables which maps the domain occupied by fluid into the lower complex half-plane. Then Stokes wave can be described through the position and the type of complex singularities in the upper complex half-plane.

Pavel M. Lushnikov
Department of Mathematics and Statistics
University of New Mexico
plushnik@math.unm.edu

CP24

Coupled Parametrically Forced Oscillators and Modulated Cross-Waves

Recent experiments and theory for subharmonic cross-waves in horizontally vibrated containers found slowly modulated (quasiperiodic) solutions that cycle between balanced and one-sided excitation. We analyze a generalized model of coupled parametrically forced oscillators with arbitrary relative phase to understand how these solutions arise, depending on coupling and forcing, and relate this to an exchange symmetry permitted by specific forcing phases. A complex bifurcation scenario involving secondary modes and homoclinic bifurcations emerges in many cases.

Jeff Porter, Pablo Salgado Sanchez, Ignacio Tinao, Ana Laveron-Simavilla
Universidad Politecnica de Madrid
jeff.porter@upm.es, pablo.salgado.sanchez@alumnos.upm.es, itinao@eusoc.upm.es, ana.laveron@upm.es

CP25

Jetting-BubblingTransition in Microflows

Gas-liquid flows in microchannels are found to be primarily of two types - jetting and bubbling. The dynamics of gas-liquid micro flows is captured using viscous potential flow (VPF) theory. A linear stability analysis is carried out and the jetting to bubbling transition is predicted using the Briggs criterion of absolute-convective instability transition. We study the effect of the wide parameter space (Reynolds number, Weber number, density ratio, viscosity ratio and confinement) on this transition.

Dipin S. Pillai
Ph.D. Scholar
Indian Institute of Technology Madras, India
dipinsp@gmail.com

S. Pushpavanam
Professor
Indian Institute of Technology Madras, India
spush@iitm.ac.in

CP25

Finding Model Parameters Without Prior Knowledge of Solve-Able Regions: A Solar Thermochemistry Case-Study

Reduction of cobalt oxide nanoparticles is the first step in a solar thermochemical process to sustainably produce hydrogen from water with concentrated sunlight. Using non-isothermal reaction data from the process as a case-study, we demonstrate a two-stage particle-swarm optimization method to find kinetic parameters in the shrinking core model without a valid initial guess or bounding under multiple, simultaneous rate-limiting conditions. The technique developed is broadly applicable to identifying parameters in data-fitting numerically intractable models.

Karl Schmitt
University of Maryland, College Park
Dept. of Mathematics, AMSC
karl.schmitt@valpo.edu

Luke Venstrom
Valparaiso University
Dept. of Mechanical Engineering
luke.venstrom@valpo.edu

William D. Arloff
Valparaiso University
william.arloff@valpo.edu

Leandro Jaime
Valparaiso University
Dept. of Mechanical Engineering
leandro.jaime@valpo.edu

CP25

Experiments on a Pinball-Like Oscillator

The response of a harmonically-excited mechanical system in which a severe nonlinearity occurs due to an impact is presented. The system receives a discrete input of energy at the impact condition: it is kicked. This is reminiscent of the unpredictability of the classic pinball machine. Close correlation is obtained between a mechanical experiment and numerical simulation, including unusual bifurcation sequences and co-existing responses.

Lawrie N. Virgin
Department of Civil and Environmental Engineering
Duke University

l.virgin@duke.edu

CP25

Exploring the Hyperbolicity of Chaotic Rayleigh-Bénard Convection

Covariant Lyapunov vectors allows us to quantify the direction of the stable and unstable manifolds of the tangent space for the high-dimensional chaotic dynamics of Rayleigh-Bénard convection. The principal angle between these manifolds can be used to determine the hyperbolicity of the dynamics. We use numerical simulations to compute the covariant Lyapunov vectors of Rayleigh-Bénard convection to probe fundamental features of the dynamics of an experimentally accessible and high-dimensional system.

Mu Xu, Mark Paul
Department of Mechanical Engineering
Virginia Tech
xumu8621@vt.edu, mrp@vt.edu

CP25

Snakes on An Invariant Plane: Coupled Translational-Rotational Dynamics of Flying Snakes

Flying snakes of the genus *Chrysopelea* use body flattening and three-dimensional body undulations in a dynamic yet controlled glide through air. Given this complexity, salient body dynamics relevant to glide stability are unknown. We investigate a tandem airfoil model with snake-like features to better understand aerodynamic effects of undulation and translational-rotational mechanical coupling on motion and stability during a glide. We elucidate some dynamical phenomena that occur including bifurcations, limit cycles, and a gliding manifold.

Isaac Yeaton, Hodjat Pendar, Jake Socha
Virginia Tech
iyeaton@vt.edu, hpendar@vt.edu, jjsocha@vt.edu

Shane D. Ross
Virginia Tech
Engineering Science and Mechanics
sdross@vt.edu

CP26

Constant Rebalanced Portfolio Strategy Is Rational in a Multi-Group Asset Trading Model

We evaluate the performance of various trading strategies within the context of the multi-group asset flow differential equations model. We consider scenarios in which strategies vary continuously and slowly, and derive mathematical justification for constant rebalanced portfolio (CRP) strategies. The CRP strategy minimizes investment risks as investor wealth is maintained when the price moves from and then returns to its original value; non-CRP strategies may be exploited by others resulting in a loss of wealth.

Mark DeSantis
Mathematics
Univ of Pittsburgh
desantis@chapman.edu

David Swigon
Department of Mathematics
University of Pittsburgh
swigon@pitt.edu

CP26

How Monetary Policy Can Cause Forecasting Uncertainty

Federal Reserve Chairwoman Yellen seems to be guided by a rule that keeps interest rates low (high), when the economy is operating below (above) its trend. Instead of stabilizing the economy, the unintended consequence of the Yellen Rule is greater uncertainty, due to nonlinear feedback. The resulting forecast errors can be modeled by applying a Sprott nonlinear dynamical system of simple chaos, perturbed by random noise and shocked by excess demand for real money.

James M. Haley
Point Park Universtiy
kapucensko51@comcast.net

CP26

Non-Smooth Dynamics and Bifurcations in a Model of Electricity Market

This paper proposes a model for the supply and demand of electricity in a domestic market based on system dynamics. Additionally, the model shows piecewise-smooth differential equations. Mathematical analysis and simulation explain some counter-intuitive dynamics which also were detected in practice. Then, a general model is proposed, which is closer to real electricity markets. Discontinuities have a large effect on the qualitative analysis. A first result to be noted is the use of asynchronous maps for understanding what happens when parameters are varied, leading to non-smooth bifurcations. To our knowledge. there are still no reports in the literature about its use in socio-economic market systems. The other noteworthy result in this research is the effect that the *ROI* (Investment returns) has on the system dynamics since it leads to different surfaces whose slope change according to the parameters.

Gerard Olivar Tost
Department of Mathematics and Statistics
Universidad Nacional de Colombia - Manizales
golivart@unal.edu.co

Johnny Valencia Calvo
Ph.D Candidate in Systems Engineering and Computer Sciences
School of Mines - Universidad Nacional de Colombia
jovalenciacal@unal.edu.co

CP27

Towards Understanding Mechanisms of Pain Transmission: a Systems Theoretic Approach

Pain is a universal experience. Motivated by a lack of understanding of pain mechanisms, we develop a reduced low-dimensional model of the dorsal horn circuit—the first central relay of sensory inputs to the brain. We determine how a cellular switch of firing patterns in dorsal horn transmission cells—tonic, plateau, endogenous bursting—contributes to a functional switch of information transfer—faithful transmission, enhancement, or blocking of nociceptive information.

Pierre Sacré
University of Liège

pierre.sacre@alumni.ulg.ac.be

Sridevi Sarma
Johns Hopkins University
sree@jhu.edu

CP27

Optogenetic Stimulation of a Meso-Scale Human Cortical Model

Mesoscale models of cortical activity provide a means to study neural dynamics at the level of neuron populations, and offer a safe and economical way to test the effects and efficacy of stimulation techniques on the dynamics of the cortex. Here, we use a physiologically relevant mesoscale model of the cortex, consisting of a set of stochastic, highly non-linear partial differential equations, to study the hypersynchronous activity of neuron populations during epileptic seizures. We use optogenetic stimulation to control seizures in a hyperexcited cortex, and to induce seizures in a normally functioning cortex. The high spatial and temporal resolution this method offers makes a strong case for the use of optogenetics in treating epileptic seizures. We use bifurcation analysis to investigate the effect of optogenetic stimulation in the meso scale model, and its efficacy in suppressing the non-linear dynamics of seizures.

Prashanth Selvaraj
University of California, Berkeley
pselvaraj@me.berkeley.edu

Andrew J. Szeri
University of California at Berkeley
Department of Mechanical Engineering
aszeri@me.berkeley.edu

James W. Sleigh
University of Auckland
Waikato Clinical School
sleighj@waikatodhb.govt.nz

Heidi E. Kirsch
UC San Francisco
heidi.kirsch@ucsf.edu

CP27

Assessing the Strength of Directed Influences Among Neural Signals

Inferring Granger-causal interactions between processes promises deeper insights into mechanisms underlying network phenomena, e.g. in the neurosciences where the level of connectivity in neural networks is of particular interest. Renormalized partial directed coherence can be used to investigate Granger causality in such multivariate systems. A major challenge in estimating respective coherences is a reliable parameter estimation of vector autoregressive processes. We discuss improvements of the estimation procedure that are particularly relevant in the neurosciences.

Linda Sommerlade
Freiburg Center for Data Analysis and Modeling
University of Freiburg
l.sommerlade@abdn.ac.uk

Marco Thiel
University of Aberdeen
Scotland
m.thiel@abdn.ac.uk

Claude Wischik
TauRx Therapeutics Ltd
cmw@taurx.com

Bjoern Schelter
Institute for Complex Systems and Mathematical Biology
b.schelter@abdn.ac.uk

CP27

Analysis of Cholera Epidemics with Bacterial Growth and Spatial Movement

In this work, we propose novel epidemic models for cholera dynamics by incorporating a general formulation of bacteria growth and spatial variation. In the first part, a generalized ODE model is presented and it is found that bacterial growth contributes to the increase of the basic reproduction number. With the derived basic reproduction number, we analyze the local and global dynamics of the model. Particularly, we give a rigorous proof on the endemic global stability by employing the geometric approach. In the second part, we extend the ODE model to a PDE model with the inclusion of diffusion to capture the movement of human hosts and bacteria in a heterogeneous environment. The disease threshold of this PDE model is studied again by using the basic reproduction number. The results on the threshold dynamics of the ODE and PDE models are compared, and verified through numerical simulation.

Xueying Wang
Washington State University
xueying@math.wsu.edu

CP27

Benefits of Noise in Synaptic Vesicle Release

Noise is not only a source of disturbance but can also be beneficial for neuronal information processing. The release of neurotransmitter vesicles in synapses is an unreliable process, especially in the central nervous system. Here we study the effect of the probabilistic nature of this process and show that how stochasticity in vesicle docking and release can be beneficial for synaptic transmission.

Calvin Zhang, Charles S. Peskin
Courant Institute of Mathematical Sciences
New York University
calvinz@cims.nyu.edu, peskin@cims.nyu.edu

CP27

Growth Dynamics for Pomacea Maculata

Pomacea maculata is a relatively new invasive species to the Gulf Coast region and potentially threatens local agriculture (rice) and ecosystems (aquatic vegetation). The population dynamics of *Pomacea maculata* have largely been un-quantified. We directly measured the growth rates of individually marked snails grown in a common tank to quantify their growth patterns. However, due to large intra- and inter- individual variability and sample size, we were not able to get statistically rigorous estimates (i.e., tight confidence intervals) on overall growth dynamics. However, we were able to use a model comparison statistic to determine that there are distinct growth stages. Further, these data

strongly suggest that male and female growth dynamics, size distributions, and overall weights, are notably different with females being generally larger. We performed simulation studies based on observed variability, and are using these models to design additional lab experiments and field studies.

Lihong Zhao
University of Louisiana at Lafayette, Mathematics Department
lzhao@louisiana.edu

Karyn L. Sutton
University of Louisiana
Lafayette
sutton@louisiana.edu

Jacoby Carter
USGS National Wetlands Research Center
carterj@usgs.gov

CP28

Optimal Control of Building's Hvac System with on-Site Energy Storage and Generation System

Commercial and residential buildings consume more than 40% of the total energy in most countries, and HVAC (Heating Ventilation and Air Conditioning) systems typically consume more than 50% of the building energy consumption. A recent study indicates that optimal control of HVAC system can achieve energy savings of up to 45%. Therefore, optimized control of HVAC system can potentially reduce significant amount of energy consumption of buildings. In this work, we describe a model predicted control (MPC) framework that optimally computes the control profiles of the HVAC system considering the dynamic demand response signal, on-site storage of electricity, on-site generation of electricity, greenhouse gas emission as well as occupants comfort. The approach would determine how to power the HVAC system from the optimal combination of grid electricity, on-site stored electricity and on-site generated electricity.

Raya Horesh
IBM T.J. Watson Research Center
rhoresh@us.ibm.com

Young M. Lee
IBM T.J. Watson Reseach Center
ymlee@us.ibm.com

Leo Liberti
IBM
LIX, Ecole Polytechnique, Palaiseau, France
leoliberti@gmail.com

Young Tae Chae
Hyundai Engineering & Construction Co., Ltd
Research and Development Division , Seoul, Republic of Korea
y.t.chae@gmail.com

Rui Zhang
IBM T.J. Watson Reseach Center
zhangrui@us.ibm.com

CP28

Optimal Treatment Strategies for HIV-TB Co-Infected Individuals

Initiating anti-HIV treatment during ongoing TB treatment for HIV-TB co-infected individuals has advantages and disadvantages. Here, we develop a dynamical system (system of ODEs) that helps identify an ideal treatment strategy for HIV-TB co-infected individuals. Using our model, we formulate and analyze an optimal control problem in order to determine a HIV-TB treatment protocol that provides a minimum cumulative burden from this co-infection.

Abhishek Mallela
University of Missouri-Kansas City
abhishek.mallela@gmail.com

Suzanne M. Lenhart
University of Tennessee
Department of Mathematics
lenhart@math.utk.edu

Naveen K. Vaidya
Dept of Maths & Stats, University of Missouri - Kansas City
Kansas City, Missouri, USA
vaidyan@umkc.edu

CP28

Towards a Structural Theory of Controllability of Binary Networks

Almost all complex networks satisfy structural controllability theory except for some special networks which form a set of Lesbesgue measure zero. A important class of networks is ***binary networks***, that is networks for which all of the existing connections have the same associated weight. However, these networks often do not satisfy structural controllability theory. We focus on this class of networks and propose some graphical tools that can be used to characterize the structural controllability of binary networks.

Afroza Shirin
Graduate Stedents
Department of Mechanical Engineering, University of New Mexi
ashirin@unm.edu

CP29

Stripe to Spot Transition in a Plant Root Hair Initiation Model

A generalised Schnakenberg system with source and loss terms and a spatially dependent coefficient of the nonlinear term is studied in 2D. The system captures active and inactive forms of the kinetics of a small G-protein ROP, which are catalysed by a gradient of the plant hormone auxin. Localised stripe-like solutions of active ROP occur for high enough total auxin concentration and lie on a complex bifurcation diagram of single and multi-pulse solutions. Transverse stability computations show that these 1D solutions typically undergo a transverse instability into spots. The spots so formed typically drift and undergo secondary instabilities such as spot replication. A 2D numerical continuation analysis is performed that shows the various stable hybrid spot-like states can coexist. Upon describing the dispersion relation of a certain non-local eigenvalue problem, the parameter values studied lead to

an analytical explanation of the initial instability.

Victor F. Brena-Medina
University of Bristol
victorb@matmor.unam.mx

Daniele Avitabile
School of Mathematical Sciences
University of Nottingham
Daniele.Avitabile@nottingham.ac.uk

Alan R. Champneys
University of Bristol
a.r.champneys@bristol.ac.uk

Michael Ward
Department of Mathematics
University of British Columbia
ward@math.ubc.ca

CP29

Symmetry Groups and Dynamics of Time-Fractional Diffusion Equation

In science and engineering the processes in which both spatial and temporal variations occur are often known as diffusion. Mostly diffusion process is anomalous due to the heterogeneous nature of medium therefore it can be best described in terms of fractional derivatives. We propose a new approach to construct the symmetry groups of fractional diffusion equation and using these groups we provide some interesting physical interpretation to understand the dynamics of anomalous diffusion.

Muhammad D. Khan
Institute of Business Management
danish.khan@iobm.edu.pk

CP29

Onset of Singularities in the Pattern of Fluctuational Paths of a Nonequilibrium System

A generic feature of systems away from thermal equilibrium is the occurrence of singularities in the patterns of most probable trajectories followed in rare fluctuations to remote states in phase space. We study how the singularities emerge as the system is driven away from thermal equilibrium by an increasingly strong perturbation. We find where there is a threshold in the perturbation strength and the scaling of the singularity location if there is no threshold.

Oleg B. Kogan
Cornell University
obk5@cornell.edu

Mark I. Dykman
Department of Physics and Astronomy
Michigan State University
dykman@pa.msu.edu

CP29

Polynomial Mixing Rates of Particle Systems

In this talk I will present our results on polynomial mixing rates of some particle systems that are derived from the study of microscopic heat conduction. We rigorously prove that an energy dependent Kac-type model admits polynomial mixing rates $\sim t^{-2}$. In the end, I will show that similar slow (polynomial) mixing rates appear in many other microscopic heat conduction models.

Yao Li
Courant Institute of Mathematical Sciences,
New York University
yaoli@cims.nyu.edu

MS1

Nonlinearity Saturation as a Singular Perturbation of the Nonlinear Schrödinger Equation

Saturation of a Kerr-type nonlinearity in the generalized nonlinear Schrödinger equation (NLS) can be regarded as a singular perturbation which regularizes the well known blow-up phenomenon in the cubic NLS. An asymptotic expansion is proposed which takes into account multiple scale behavior both in the longitudinal and transverse directions. We find that interaction of a solitary wave and an adjacent wave field is governed by behavior of eigenfunctions of the linearized fast-scale operator. In one dimension, the solitary wave acts solely to reflect impinging waves and accelerates by an elastic transfer of momentum. In two dimensions, the solitary wave can be made transparent to the ambient field for a certian value of wave power. This is joint work with Jordan Allen-Flowers.

Karl Glasner
The University of Arizona
Department of Mathematics
kglasner@math.arizona.edu

MS1

Dark-Bright, Dark-Dark, Vortex-Bright and Other Multi-Component NLS Beasts: Theory and Recent Applications

Motivated by recent work in nonlinear optics, as well as in Bose-Einstein condensate mixtures, we will explore a series of nonlinear states that arise in such systems. We will start from a single dark-bright solitary wave, and then expand our considerations to multiple such waves, their spectral properties, nonlinear interactions and experimental observations. A twist will be to consider the dark solitons as effective potentials that will trap the bright ones, an approach that will also prove useful in characterizing the bifurcations and instabilities of the system. Beating, so-called dark-dark soliton variants of such states will be touched upon. Generalizations of all these notions in higher dimensions and, so-called, vortex-bright solitons will also be offered.

Panayotis Kevrekidis
University of Massachusetts
kevrekid@math.umass.edu

MS1

Bifurcation and Competitive Evolution of Network Morphologies in the Strong Functionalized Cahn-Hilliard Equation

The Functionalized Cahn Hilliard (FCH) is a higher-order free energy for blends of amphiphillic polymers and solvent which balances solvation energy of ionic groups against elastic energy of the underlying polymer backbone. Its gradient flows describe the formation of solvent network structures which are essential to ionic conduction in polymer membranes. The FCH possesses stable, coexisting

network morphologies and we characterize their geometric evolution, bifurcation and competition through a center-stable manifold reduction which encompasses a broad class of coexisting network morphologies. The stability of the different networks is characterized by the meandering and pearling modes associated to the linearized system. For the H^{-1} gradient flow of the FCH energy, using functional analysis and asymptotic methods, we drive a sharp-interface geometric motion which couples the flow of co-dimension 1 and 2 network morphologies, through the far-field chemical potential. In particular, we derive expressions for the pearling and meander eigenvalues for a class of far-from-self-intersection co-dimension 1 and 2 networks, and show that the linearization is uniformly elliptic off of the associated center stable space.

Noa Kraitzman
Michigan State University
kraitzm1@msu.edu

MS1

Nonlinear Stability of Source Defects

Defects are interfaces that mediate between two wave trains. Of particular interest in applications are sources for which the group velocities of the wave trains to either side of the defect point away from the interface. While sources are ubiquitous in experiments, their stability analysis presents many challenges. In this talk, I will discuss nonlinear-stability results for sources that rely on pointwise estimates.

Bjorn Sandstede
Division of Applied Mathematics
Brown University
bjorn_sandstede@brown.edu

MS2

Dynamics of Autonomous Boolean Networks

Autonomous Boolean networks are known to display complex dynamics, originating from the absence of an external clock, internal time delays and the non-ideal behaviour of the logic gates. We study experimentally such networks on a field-programmable gate array (FPGA). In particular, we show that networks consisting of only a few logic elements can produce long transients. We demonstrate how these transients can be used to successfully perform reservoir computing, a new machine learning paradigm.

Otti D'Huys, Nicholas D. Haynes
Department of Physics, Duke University
otti.dhuys@phy.duke.edu, nickdavidhaynes@gmail.com

Miguel C. Soriano
IFISC (UIB-CSIC)
Campus Universitat de les Illes Balears, Palma de Mallorca
miguel@ifisc.uib-csic.es

Ingo Fischer
Campus Universitat de les Illes Balears
IFISC (UIB-CSIC)
ingo@ifisc.uib-csic.es

Daniel J. Gauthier
Department of Physics, Duke University
gauthier@phy.duke.edu

MS2

Gene Network Models Including mRNA and Protein Dynamics

Qualitative models of gene regulatory networks have generally considered transcription factors to regulate directly the expression of other transcription factors, without any intermediate variables. In fact, gene expression always involves transcription, which produces mRNA molecules, followed by translation, which produces protein molecules, which can then act as transcription factors for other genes. Suppressing these multiple steps implicitly assumes that the qualitative behaviour does not depend on them. Here we explore a class of expanded models that explicitly includes both transcription and translation, keeping track of both mRNA and protein concentrations. We mainly deal with regulation functions that are steep sigmoids or step functions, as is often done in protein-only models. Our results thus show that including mRNA as a variable may change the behavior of solutions.

Roderick Edwards
University of Victoria
Canada
edwards@uvic.ca

MS2

Database for Switching Networks As a Tool for Study of Gene Networks

Continuous time Boolean networks, or switching networks, represent an attractive platform for qualitative studies of gene regulation, since the dynamics at fixed parameters is relatively easily to compute. However, it is quite difficult to analytically understand how changes of parameters affect dynamics. Database for Dynamics is an excellent tool for studying these models, as it rigorously approximates global dynamics over a parameter space. The results obtained by this method provably capture the dynamics a predetermined spatial scale. We combine these two approaches to present a method to study switching networks over a parameter spaces. We apply our method to experimental data for cell cycle dynamics.

Tomas Gedeon
Montana State University
Dept of Mathematical Sciences
gedeon@math.montana.edu

MS2

Evolution of Gene Networks

Genetic activity is partially regulated by a complicated network of proteins called transcription factors. An outstanding scientific puzzle is to understand how this genetic network can evolve. I discuss evolution of dynamics in simplified models of genetic networks. By changing the logical structure randomly, it is possible to evolve the networks in an effort to identify networks that display rare dynamics - e.g. networks with long stable cycles or with a high level of topological entropy. In the context of the models, it is possible to estimate optimal mutation rates. The theoretical models pose the problem of how evolution can robustly take place in organisms.

Leon Glass
McGill University

Department of Physiology
glass@cnd.mcgill.ca

MS3

Controlling Long-Term Spatial Distributions of Autonomous Vehicles in Stochastic Flow Environments

We present a control strategy for aquatic vessels that leverages the environmental dynamics and noise to efficiently navigate in a stochastic fluidic environment using the theory of large fluctuations. We show that a vehicle's likelihood of transition between regions in the flow can be manipulated by the proposed control strategy, resulting in efficient navigation from one region to another. We then experimentally verify the strategy in a fluid environment using autonomous vehicles.

Christoffer R. Heckman
U.S. Naval Research Laboratory
crheckman@gmail.com

Ani Hsieh
Drexel University
mhsieh1@drexel.edu

Ira B. Schwartz
Naval Research Laboratory
Nonlinear Dynamical Systems Section
ira.schwartz@nrl.navy.mil

MS3

Tracking of Geophysical Flows by Robot Teams: An Experimental Approach

This talk presents our group's recent efforts in using teams of robots to track geophysical fluid features like Lagrangian Coherent Structures. The talk will focus on our development of the multi-robot Coherent Structure Testbed a novel multi-robot experimental testbed capable of creating ocean-life flows in a laboratory setting. I will show experimental results of various single vehicle and multi-robot control strategies for tracking different fluidic features in a flow field and navigating in stochastic flows.

Ani Hsieh, Dhanushka Kularatne, Dennis Larkin
Drexel University
mhsieh1@drexel.edu, dnk32@drexel.edu,
den2158@gmail.com

Eric Forgoston
Montclair State University
Department of Mathematical Sciences
eric.forgoston@montclair.edu

Philip Yecko
Cooper Union
yecko@cooper.edu

MS3

Conditional Statistics with Lagrangian Coherent Structures

Coherent structures are ubiquitous in the environment. In order to analyze mixing and transport processes, conditional statistics are typically generated and scaling laws are identified. Classically, these are based on flow domain partitions from Eulerian quantities. However, recent studies show that Eulerian quantities are not invariant subject to arbitrary frame translation and rotation. We show in this talk scalar dispersion and residence time statistics based on Lagrangian partitions, where new scaling law behaviors are identified.

Wenbo Tang, Phillip Walker
Arizona State University
wenbo.tang@asu.edu, phillip.walker@asu.edu

MS3

Controlled Lagrangian Prediction Using An Ensemble of Flow Models

The technique of controlled Lagrangian prediction (CLP) is developed to employ an ensemble of flow modes to provide odometry-like localization information for underwater vehicles. CLP can then be fused with other underwater localization technology to enable simultaneous localization and map-making (SLAM). Map-making functionality will be performed to update each flow model with the latest sensor information and to decide the best flow model to use that gives the minimum localization error at any given time.

Fumin Zhang
School of Electrical and Computer Engineering
Georgia Institute of Technology
fumin@gatech.edu

MS4

Constrained Motion of Point Vortices Interacting Dynamically with Rigid Bodies in Ideal Flow

The equations of motion for the dynamic interaction of rigid bodies and point vortices in ideal flow were only recently derived, in 2002 by Shashikanth et al and in 2003 by Borisov et al. We compare these equations with those obtained by a suitable application of Diracs method of constraints to the N-vortex problem. In 2008, Vankerschaver et al derived the unconstrained equations through symplectic reduction, but several assumptions were made in the analysis. We investigate the possibility of relaxing some of these assumptions.

Michael Fairchild, Scott Kelly
UNC Charlotte
mjfairch@uncc.edu, scott.kelly@uncc.edu

MS4

The Poincare-Hopf Theorem in Nonholonomic Mechanics

This talk discusses using the Poincare-Hopf theorem and the technique of Hamiltonization as a means to study the integrability nonholonomic mechanical systems (briefly, mechanical systems subject to non-integrable velocity constraints). We will focus primarily on a generalized Klebsh-Tisserand case of the Suslov problem, and use the aforementioned approach to determine the topology of the (two-dimensional) invariant manifolds, and in particular their genus. The results will be contrasted with those expected of Hamiltonian systems.

Oscar Fernandez
Wellesley College
ofernand@wellesley.edu

Anthony M. Bloch

University of Michigan
Department of Mathematics
abloch@umich.edu

Dmitry Zenkov
North Carolina State University
Department of Mathematics
dvzenkov@ncsu.edu

MS4

Discretization of Hamiltonian Incompressible Fluids

The geometry of incompressible, inviscid fluids can be described by Arnold's classic formulation in terms of geodesics on the Lie group of volume-preserving diffeomorphisms. In recent years this formulation has been discretized for computational purposes, creating a geometricnumerical method that obeys a discretized version of Kelvin's circulation theorem. This talk will present an extension of this discretization into the corresponding Hamiltonian view of incompressible inviscid fluids, thereby giving a method based on the vorticity equation. Along the way we will discuss the general principles of this style of discretization, which involves approximating the Lie group of volume-preserving diffeomorphisms by a finite-dimensional Lie-group and then localizing the resulting equations by means of a non-holonomic constraint.

Gemma Mason
CMS dept.
Caltech
gem@caltech.edu

Christian Lessig
Technishe Universitat Berlin
christian.lessig@tu-berlin.de

Mathieu Desbrun
Dept. of Computing & Mathematical Sciences
CALTECH
mathieu@cms.caltech.edu

MS4

The Lie-Dirac Reduction for Nonholonomic Systems on Semidirect Products

We consider Dirac systems with symmetry for nonholonomic mechanical systems on Lie groups with broken symmetry. We show reduction of Lagrange-Dirac systems and Dirac-Hamilton systems in the context of Lie-Dirac reduction with advected parameters. Then, we develop implicit Euler-Poincare-Suslov and Lie-Poisson-Suslov equations with advected parameters with some illustrative examples such as the Chaplygins ball and the second order Rivlin-Ericksen fluids. We also discuss the Dirac reduction on semidirect products by stages on the Hamiltonian side.

Hiroaki Yoshimura
Waseday University
yoshimura@waseda.jp

François Gay-Balmaz
Ecole Normale Superieure de Paris
francois.gay-balmaz@lmd.ens.fr

MS5

Combined Effects of Connectivity and Inhibition in a Model of Breathing Rhythmogenesis

The pre-Btzinger complex is an area in the brainstem which generates the breathing rhythm, an essential function for life. We model this area with realistic bursting neurons coupled in a large sparse network. We study how synchronous activity of the population changes due to (1) the number of connections each cell receives (2) the fraction of cells which are inhibitory, and (3) the strength of excitatory and inhibitory synapses. The model is compared to experimental data. We also ask, how do multiple phases of activity arise? Can they arise spontaneously in unstructured networks, or do they require more structured networks like block models?

Kameron D. Harris
Applied Mathematics
University of Washington
kamdh@uw.edu

Tatiana Dashevskiy
Center for Integrative Brain Research
Seattle Children's Research Institute
tatiana.malashchenko@seattlechildrens.org

Eric Shea-Brown
Department of Applied Mathematics
University of Washington
etsb@amath.washington.edu

Jan-Marino Ramirez
Center for Integrative Brain Research
University of Washington
nino.ramirez@seattlechildrens.org

MS5

A Complex Networks Approach to Malaria's Genetic Recombination Dynamics

Malaria parasites evade immune systems by sequentially expressing diverse proteins on the surface of infected red blood cells. These camouflage proteins come from rapid genetic recombination that shuffles the genes that encode the proteins. Because this shuffling precludes the use of traditional sequence analysis techniques, we take a new approach by mapping sequences to a network in which each vertex represents a single sequence and constraints on recombination reveal themselves in the networks community structure. We validate this approach on synthetic sequences. Application of this technique to a large set of sequences from both human- and ape-infecting malaria parasites reveals that the observed genetic states of six distinct malaria species have arisen due to recombining and evolving a common set of initial sequence content, dating back prior to the speciation of humans and chimpanzees from their most recent common ancestors.

Daniel B. Larremore, Caroline Buckee
Center for Communicable Disease Dynamics
Harvard School of Public Health
larremor@hsph.harvard.edu, cbuckee@hsph.harvard.edu

Aaron Clauset
University of Colorado at Boulder

Computer Science
aaron.clauset@colorado.edu

MS5

Not-So-Random Graphs Through Wide Motifs

This work focuses on two powerful analytical methods that can model stochastic processes on (and/or of) complex networks: one recasts the problem as a set of ordinary differential equations, and the other amounts to a branching process. Both methods are based on the idea of breaking the network into smaller pieces—hereafter called "motifs"—that may be re-assembled according to specific rules. However, these techniques are limited to random graphs containing no cycles, except for the cycles explicitly represented within the motifs used in their assembly. This is a major problem for real-world phenomenons (such as cascading failures due to flows reorganization) that fundamentally depend on the presence of cycles much longer than what these motifs-based methods allow. In this work, I will present recent developments concerning "wide motifs", which generalize both the concepts of "motifs" and "tree decomposition". By opposition to traditional motifs, cycles may be broken into pieces to span multiple wide motifs, thus allowing for cycles of arbitrarily long lengths that may share intricate overlaps. This perspective can be used for a broad spectrum of networks, spanning from deterministic structures to random graphs, thus blurring the line between these extremes. The approach broadens the class of problems that can be approached analytically and introduces new challenges in the detection and characterization of network structures. Conceptual similarities with "belief propagation" algorithms and the "tensor network" representation of entangled quantum states should allow for these different fields to cross-fertilize.

Pierre-Andre Noel
Department of Mechanical Engineering
University of California, Davis
noel.pierre.andre@gmail.com

MS5

Causal Network Inference by Optimal Causation Entropy

The abundance of time series data, which is in sharp contrast to limited knowledge of the underlying network dynamic processes that produce such observations, calls for a general and efficient method of causal network inference. We develop mathematical theory of Causation Entropy (CSE), a model-free information-theoretic statistic designed for causality inference. We prove that for a given node in the network, the collection of its direct causal neighbors forms the minimal set of nodes maximizing Causation Entropy, a result we refer to as the Optimal Causation Entropy (oCSE) Principle, for which we develop efficient algorithms. Analytical and numerical results for Gaussian processes on large random networks highlight that inference by oCSE outperforms previous leading methods including Conditional Granger Causality and Transfer Entropy. Interestingly, our numerical results also indicate that the number of samples required for accurate inference depends strongly on network characteristics such as the density of links and information diffusion rate and not on the number of nodes.

Jie Sun, Erik Bollt
Clarkson University
sunj@clarkson.edu, bolltem@clarkson.edu

Dane Taylor
Statistical and Applied Mathematical Sciences Institute
Dept of Mathematics, University of North Carolina, Chapel Hi
taylordr@live.unc.edu

MS6

Model-Based Glucose Forecasting for Type 2 Diabetics

Type 2 diabetes affects 9 million Americans. While treatment is complex, two important components include quantifying the features of glucose dynamics and forecasting the effect of nutrition on glucose levels. Both topics are addressed in this talk. First, electronic health record data are used to identify features of glucose dynamics that correlate with mortality via a regression. Second, a dual unscented Kalman filter and two mechanistic models are used to forecast glucose using real data.

David J. Albers
Colombia University
Biomedical Informatics
dja2119@cumc.columbia.edu.

MS6

Predicting Recovery of Consciousness in Patients with Brain Injury

Oscillatory electrical activity is associated with information processing in the brain. Patients with severe brain injuries often exhibit disorders of consciousness along with disturbed oscillatory activity. This project was designed to determine whether continuous measures of brain oscillations can be used to predict recovery of consciousness on the time-scale of days. Sparse partial least squares and high-dimensional classification algorithms are used to determine latent variables used for prediction in a novel subset of patients.

Hans-Peter Frey
Department of Neurology, Columbia University
hf2289@cumc.columbia.edu

MS6

Assimilating Sleep - Putting the Model to the Data

Over the past four years we investigated tools for data assimilation and forecasting from models of the sleep-wake regulatory system. Ill report on the challenges we now face as we collect data from brainstem cell groups in freely behaving animals and attempting to apply these tools.

Bruce J. Gluckman
Penn State University
brucegluckman@psu.edu

MS6

Time Series Modeling and Analysis Using Electronic Health Record Data

Electronic health record data contain valuable information about biology and health care, but the data hold a number of challenges, including the fact that measurements are sparse and irregular. Furthermore, health care is a highly complex process that makes drawing causal conclusions very difficult. We discuss alternate time parameterizations that may lead to a more stationary time series, and we discuss the use of Granger causality to tease out causes and confounders.

George Hripcsak
Department of Bioinfomatics, Columbia University
hripcsak@columbia.edu

MS7

Reconstruction of Structural Connectivity in Neuronal Networks Using Compressive Sensing of Network Dynamics

Taking into account the prominence of sparsity in neuronal connectivity, we develop a framework for efficiently reconstructing neuronal connections in a sparsely-connected, feed-forward network model with nonlinear dynamics. Driving the network with a small ensemble of random stimuli, we derive a set of underdetermined linear systems relating the network connectivity to neuronal firing rates. Via compressive sensing, we accurately recover sparse network connectivity and also realistic network inputs distinct from the training set of stimuli.

Victor Barranca
New York University
barranca@nyu.edu

Douglas Zhou
Shanghai Jiao Tong University
zdz@sjtu.edu.cn

David Cai
Courant Institute for Mathematical Sciences, NYU
Shanghai Jiao-Tong University
cai@cims.nyu.edu

MS7

Theoretical Modeling of Neuronal Dendritic Integration

We address the question of how a neuron integrates excitatory (E) and inhibitory (I) inputs from different dendritic sites. For an idealized neuron with an unbranched dendrite, a conductance-based cable model is derived and its asymptotic solutions are constructed. The solutions reveal the underlying mechanisms of a dendritic integration rule discovered in a recent experiment. We then extend our analysis to the multi-branch case and confirm our analysis through numerical simulation of a realistic neuron.

Songting Li, Douglas Zhou
Shanghai Jiao Tong University
songting@cims.nyu.edu, zdz@sjtu.edu.cn

David Cai
New York University
Courant institute
cai@cims.nyu.edu

MS7

Functional Connectomics from Data: Constructing Probabilistic Graphical Models for Neuronal Networks

The nervous system of the nematode Caenorhabditis elegans (C. elegans) is comprised of 302 neurons for which electro-physical connectivity map (i.e. connectome) is fully resolved. Although the static connectome is available, inference of dominant neural pathways that control sensorimotor responses is challenging since neurons are dynamical objects and interactions within the network are also dynamic. In our study, we construct a Probabilistic Graphical Model (PGM) for the C. elegans connectome that represents the 'effective connectivity' between the neurons (correlations) and takes into account the dynamics. The structure of the PGM is learned using Bayesian methods capable of learning the structure of an undirected graphical model from a collection of time series. The collections are obtained by a systematic excitation of neurons in a recently developed computational dynamical model for the C. elegans that simulates single neural responses and interactions between the neurons (synaptic and gap). Bayesian inference methods applied to the constructed PGM allow us to extract neural pathways in the connectome of C. elegans responsible for experimentally well characterized movements of the worm such as forward and backward locomotion. In addition, we show that the framework allows for inference of pathways that correspond to movements that were not fully characterized in experiments and to perform 'reverse-engineering' studies in which a typical setup on the motor neurons layer is imposed and dominant pathways that propagate to the sensory layer through the interneurons layer are being identified.

Eli Shlizeman
University of Washington
shlizee@uw.edu

MS7

Topology Reconstruction of Neuronal Networks

Current experimental techniques usually cannot probe the global interconnection pattern of a network. Thus, reconstructing or reverse- engineering the network topology of coupled nodes based upon observed data has become a very active research area. Most existing reconstruction methods are based on networks of oscillators with generally smooth dynamics. However, for nonlinear and non-smooth stochastic dynamical systems, e.g., neuronal networks, the reconstruction of the full topology remains a challenge. Here, we present a noninterventional reconstruction method, which is based on Granger causality theory, for the widely used conductance-based, integrate-and-fire type neuronal networks. For this nonlinear system, we have established a direct theoretical connection between Granger causal connectivity and structural connectivity.

Douglas Zhou
Shanghai Jiao Tong University
zdz@sjtu.edu.cn

Yanyang Xiao, Yaoyu Zhang, Zhiqin Xu
Department of Mathematics and Institute of Natural Sciences
Shanghai Jiao Tong University
xyy82148@gmail.com, yaoyuzhang@foxmail.com, xuzhiqin@sjtu.edu.cn

David Cai
Courant Institute for Mathematical Sciences, NYU
Shanghai Jiao-Tong University
cai@cims.nyu.edu

MS8

Investigation of Boussinesq non-linear Interactions

Using Intermediate Models

Nonlinear coupling among wave modes and vortical modes is dissected in order to probe the question: Can we distinguish the wave-vortical interactions largely responsible for formation versus evolution of coherent, balanced structures? It is well known that the quasi-geostrophic (QG) equations can be derived from the Boussinesq system in a non-perturbative way by ignoring wave interactions and considering vortical modes only. One qualitative difference between those two models is the lack of skewness in the QG dynamics. In this talk, non-perturbative intermediate models that include more and more classes of non-linear interactions will be used to identify their role in different qualitative properties of the Boussinesq system. Numerical results will be shown to describe the effect of each class in the transfer of energy between vortical modes and waves, transfer of energy (or the lack of it) between scales, formation of vortices and skewness.

Gerardo Hernandez-Duenas
National University of Mexico, Juriquilla
Institute of Mathematics
hernandez@im.unam.mx

Leslie Smith
Mathematics and Engineering Physics
University of Wisconsin, Madison
lsmith@math.wisc.edu

Samuel Stechmann
University of Wisconsin - Madison
stechmann@wisc.edu

MS8

Internal Wave Generation by Convection

When a convectively unstable region is adjacent to a stably stratified region, the convection can produce internal waves within the stable region. This is thought to occur in stars, gaseous planets, the Earths atmosphere, oceans and lakes, and possibly even the Earths core. We describe a model for estimating the wave generation by convection based on Lighthills theory, and compare the model to high-resolution simulations using the Dedalus code.

Daniel Lecoanet
UC Berkeley
Astronomy Department
dlecoanet@berkeley.edu

Keaton Burns
MIT Kavli Institute for Astrophysics and Space Research
keaton.burns@gmail.com

Geoffrey M. Vasil
Theoretical Astrophysics Center
Astronomy Department, University of California, Berkeley
geoffrey.m.vasil@gmail.com

Eliot Quataert
UC-Berkeley
eliot@berkeley.edu

Benjamin Brown
LASP and Dept. Astrophysical & Planetary Sciences
University of Colorado, Boulder
bpbrown@gmail.com

Jeffrey Oishi
Department of Physics
Farmingdale State College
jsoishi@gmail.com

MS8

Interaction of Inertial Oscillations with a Geostrophic Flow

The interaction between large horizontal scale pure inertial oscillations and small horizontal scale geostrophic field is investigated in this work. As a result of the interaction rapid vertically propagating near inertial waves and trapped or non-propagating inertial oscillations form. The trapped oscillations inherit smaller spatial scales from the geostrophic field and remains in the upper ocean. The near inertial waves propagate into the deep ocean within days, thus allowing the inertial signal to be felt in the deep ocean. The study hence offers an alternate explanation for the age old problem of vertical propagation of near inertial waves and formation of small scale inertial oscillations in an idealized set up. The interaction is however non-energetic, which is consistent with previous works.

Jim Thomas
New York University
Courant Institute
jthomas@cims.nyu.edu

Shafer Smith
Center for Atmosphere Ocean Science
Courant Institute
shafer@cims.nyu.edu

Oliver Buhler
Courant Institute of Mathematical Sciences
New York University
obuhler@cims.nyu.edu

MS8

Interactions Between Near-Inertial Waves and Turbulence in the Ocean

Wind forcing of the ocean generates a spectrum of inertia-gravity waves that is sharply peaked near the local inertial (or Coriolis) frequency. The corresponding near-inertial waves (NIWs) are highly energetic and play a significant role in the slow, large-scale dynamics of the ocean. To analyse this role, we develop a new model of the nondissipative interactions between NIWs and mean flow using a variational implementation of the generalised-Lagrangian-mean formalism. The new model couples the Young & Ben Jelloul model of NIWs with a quasi-geostrophic model in which the relation between potential vorticity and streamfunction is modified by a quadratic wave term. The model reveals that NIWs act as an energy sink for the mean flow: NIWs forced at large scales experience a horizontal scale cascade through refraction and advection; as a result, their potential energy increases at the expense of the mean energy. The implications for ocean energetics are discussed.

Jacques Vanneste
School of Mathematics
University of Edinburgh

J.Vanneste@ed.ac.uk

MS9

Local Inference of Gene Regulatory Networks from Time Series Data

Temporal dynamics of gene expression levels may be partially explained by interactions between certain proteins, called transcription factors, which act to either promote or repress RNA-synthesis (transcription) of specific genes. Discovering the regulatory relationships in these transcription networks is a difficult goal of systems biology, but one which promises to greatly enhance experimental design. In this talk, we describe a statistical approach to infer the structure of gene regulatory networks from time series data.

Francis C. Motta, Kevin McGoff, Anastasia Deckard, Xin Guo Guo, Tina Kelliher, Adam Leman, Steve Haase, John Harer
Duke University
motta@math.duke.edu, mcgoff@math.duke.edu, anastasia.deckard@duke.edu, xg20@stat.duke.edu, cmk35@duke.edu, adam.leman@duke.edu, shaase@duke.edu, john.harer@duke.edu

MS9

Patterns in Discrete Ecological Dynamical Systems Revealed Through Persistent Homology

Persistent homology captures information about a system regarding longevity of topological features, such as level sets of a function. This provides a novel perspective when applied to discrete time dynamical systems. In particular, interesting patterns arise when applied to the logistic map; a common population model. This pattern will be discussed and extended to other systems, including continuous systems.

Rachel Neville
Colorado State University
neville@math.colostate.edu

MS9

Network Spread and Control of Invasive Species and Infectious Diseases

We introduce a method for coupling vector-based transportation networks (e.g. agents traveling by vehicle) onto a spatially continuous model of a biological epidemic. Analysis for plant invasions yields a unique, stable, steady-state solution with an optimal control for the infected vectors, with network topology affecting the efficacy of the control. Numerical results are shown for the cheatgras invasion of Rocky Mountain National Park based on the presence model of Strickland *et al.* 2014.

Christopher Strickland
SAMSI Statistical and Mathematical Sciences Institute
wcstrick@live.unc.edu

Patrick Shipman
Department of Mathematics
Colorado State University
shipman@math.colostate.edu

MS9

Topological Data Analysis for and with Contagions on Networks

The study of contagions on networks is central to the understanding of collective social processes and epidemiology. When a network is constrained by an underlying manifold such as Earth's surface (as in most social and transportation networks), it is unclear how much spreading processes on the network reflect such underlying structure, especially when long-range edges are also present. We address the question of when contagions spread predominantly via the spatial propagation of wavefronts (e.g., as observed for the Black Death) rather than via the appearance of spatially-distant clusters of contagion (as observed for modern epidemics). To provide a concrete scenario, we study the Watts threshold model (WTM) of social contagions on what we call noisy geometric networks, which are spatially-embedded networks that consist of both short-range and long-range edges. Our approach involves using multiple realizations of contagion dynamics to map the network nodes as a point cloud, for which we analyze the geometry, topology, and dimensionality. We apply such maps, which we call WTM maps, to both empirical and synthetic noisy geometric networks. For the example of a noisy ring lattice, our approach yields excellent agreement with a bifurcation analysis of the contagion dynamics. Importantly, we find for certain dynamical regimes that we can identify the network's underlying manifold in the point cloud, highlighting the utility of our method as a tool for inferring low-dimensional (e.g., manifold) structure in networks. Our work thereby finds a deep connection between the fields of dynamical systems and nonlinear dimension reduction.

Dane Taylor
Statistical and Applied Mathematical Sciences Institute
Dept of Mathematics, University of North Carolina, Chapel Hi
taylordr@live.unc.edu

Florian Klimm
Master of Science (Physics)
Humboldt-Universität, Berlin
klimm@physik.hu-berlin.de

Heather Harrington
University of Oxford
harrington@maths.ox.ac.uk

Miroslav Kramar
Rutgers University
Department of mathematics
miroslav@math.rutgers.edu

Konstantin Mischaikow
Department of Mathematics
Rutgers, The State University of New Jersey
mischaik@math.rutgers.edu

Mason A. Porter
University of Oxford
Oxford Centre for Industrial and Applied Mathematics
porterm@maths.ox.ac.uk

Peter J. Mucha
University of North Carolina Chapel Hill

mucha@unc.edu

MS10

Stability Analysis of PDEs with Two Spatial Dimensions Using Lyapunov Methods and SOS

In this talk we consider stability of parabolic linear partial differential equations with polynomial coefficients and two spatial variables. We use Sum-of-Squares, polynomial optimization, and the Positivstellensatz to numerically search for quadratic inhomogeneous Lyapunov functions. Negativity of the derivative is enforced using a new type of slack variable called a "spacing function". The technique was tested numerically on a two-dimensional biological PDE model of population growth model and compared to the analytic solution.

Evgeny Meyer, Matthew Peet
Arizona State University
evgenymeyer@gmail.com, mpeet@asu.edu

MS10

Differential Equations with Variable Delay and Their Connection to Partial Differential Equations

Time delay systems can be described by delay differential equations or by a partial differential equation (PDE) with non-local boundary conditions. The domain of the PDE is equal to the state space interval of the delay system. For variable delays a moving boundary appears in the PDE representation. Conditions for a transformation from variable delay (domain) to constant delay (domain) are studied, leading to a fundamental dichotomy of variable delay systems with qualitatively different properties.

Gunter Radons
Chemnitz University of Technology
radons@physik.tu-chemnitz.de

Andreas Otto
Institute of Physics
Chemnitz University of technology
andreas.otto@physik.tu-chemnitz.de

David Mueller
Chemnitz University of Technology
david.mueller@physik.tu-chemnitz.de

MS10

Delayed Boundary Conditions in Control of Continua

The mechanical model of a basic problem of electroacoustics is considered. The governing PDE is the 1D wave equation with delayed boundary conditions. The system can be transformed into a delay differential equation of neutral type with two delays. The zero-measure regions are constructed analytically in the parameter plane of the gain parameter and the ratio of the delays where the system is exponentially stable. The physical relevance of this peculiar stability chart is highlighted.

Gabor Stepan
Department of Applied Mechanics
Budapest University of Technology and Economics
stepan@mm.bme.hu

Li Zhang
Nanjing University of Aeronautics and Astronautics
zhangli@nuaa.edu.cn

MS10

What Is Wrong with Non-Smooth Mechanics and How Memory Effects Can Fix It?

Non-smooth mechanics has many intricacies. It can provide some surprising predictions or even fail to predict the dynamics past certain singularities. Such singularities where the equations break down include various forms of the Painleve paradox and the two-fold singularity of frictional systems. This talk looks at the reasons why these singularities occur and addresses the issue by adding more physics to the mechanical model. It turns out that finite wave-speed within the mechanical system is sufficient for unique predictions, which can be taken into account with a single correction term dependent only on the wave speed and geometry.

Robert Szalai
University of Bristol
r.szalai@bristol.ac.uk

MS11

Phase Transitions in Models for Social Dynamics

Flocking models abound in the recent mathematical and scientific literature. These models can be applied to organisms which exhibit collective behavior; such models are often applied to insects, fish, birds, and even to humans. I will introduce several flocking models, both deterministic and stochastic, at the microscopic scale. I will then discuss their kinetic and hydrodynamic limits and show that phase transitions can occur on all three scales.

Alethea Barbaro
Case Western Reserve University
alethea.barbaro@case.edu

MS11

A Center Manifold and Complex Phases for a Large Number of Interacting Particles

We investigate a system of ordinary differential equations (ODEs) describing interacting particles, with applications to schools of fish. This model has many advantages over discrete systems of interacting particles and seems to capture the interactions of animals better than the classical discrete Czirok-Vicsek (or boids) model. The main difference is that in our system the animal is allowed to adjust its velocity as well as direction to that of its neighbors. This is the behavior observed in nature and it makes our system more suitable to applications to real animals. The system of ODEs can also be analyzed using methods from dynamical systems and it turns out to have a two-parameter (velocity and direction) asymptotic solution as t becomes large. It also possesses a very rich set of stationary solutions that all are unstable.
In this talk we discuss the center manifold of the migrating state (attractor) and applications to simulations of anchovies off the coast of Peru and Chile. The effects of El Nino will also discussed.

Bjorn Birnir
University of California
Department of Mathematics
birnir@math.ucsb.edu

Luis Bonilla
Universidad Carlos III de Madrid
G. Millan Institute of Fluid Dynamics, Nanoscience & IndMath
bonilla@ing.uc3m.es

Jorge Cornejo-Donoso
UCSB
Bren School
jcornejo@lifesci.ucsb.edu

MS11

Modeling Earthquake Cycles on Faults Separating Variable Materials

We have developed a computational method for studying how the earthquake cycle is affected by heterogeneities in the material surrounding a fault. Finite difference operators satisfying a summation-by-parts rule are applied to the 2D elastodynamic wave equation and weak enforcement of boundary conditions are enforced through the simultaneous-approximation-method. This combined approach leads to a provably stable and high-order accurate method. Non-planar fault geometries, variable materials and inelastic response are incorporated. As a first step we consider the bimaterial problem on planar, vertical strike slip fault. We find that rupture propagates in the preferred direction and we are currently studying the long term behavior of the earthquake cycle and under what conditions rupture in the non-preferred direction (periodically observed on natural faults) is possible.

Brittany Erickson
Portland State University
berickson@pdx.edu

MS11

Mathematical Challenges in Ground State Formation of Isotropic and Anisotropic Interaction

In this talk we will present a mathematical framework for studying ground state formation in a general class of kinematic models which are often used to understand the physical, biological and social world. I will first discuss the case of when particles communicate isotropically and, time permitting, will present new developments in the mathematical theory of anisotropic pattern formation.

David T. Uminsky
University of San Francisco
Department of Mathematics
duminsky@usfca.edu

MS12

Synchronization over Networks Inspired by Echolocating Bats

While number of organisms have made use of active sensory systems, bats are particularly effective at echolocation, wherein they emit ultrasonic waves and sense echoes to navigate their environment. One of the greatest challenges of echolocating in a group is jamming, which occurs when echoes from an individuals calls become difficult to distinguish from those of its peers. Nevertheless, bats are observed to avoid the negative effects of jamming in behavioral experiments. Drawing inspiration from this phenomenon, we incorporate the effect of jamming into a classical model of synchronization among coupled dynamic systems by superposing a disturbance topology on the communication network. Within this framework, we develop conditions for stochastic synchronization and the rate of convergence to synchronized states.

Subhradeep Roy, Nicole Abaid
Virginia Polytechnic Institute and State University
sdroy@vt.edu, nabaid@vt.edu

MS12

Versatile Vibrations: Partially Synchronized States in Mechanical Systems from Microns to Kilometers

In this talk I'll describe the dynamics of coupled oscillators in three systems: optomechanical microdisk resonators, mechanical metronomes, and pedestrians on suspension bridges. Though drastically different in origin and in scale, the equations of motion share many similarities. I will present analytical and numerical techniques for solving those equations and discuss some unsolved problems and open questions regarding networks of coupled oscillators.

Daniel Abrams
Northwestern University
dmabrams@northwestern.edu

MS12

Wind-Induced Synchrony Causes the Instability of a Bridge: When Millennium Meets Tacoma

We aim at better understanding the cause of dangerous vibrations and bridges collapsing as a result of wind-induced oscillations at a frequency different from the natural frequencies of a bridge, including the collapse of the Tacoma Narrows Bridge and a long-wave resonance vibration of the Volga Bridge. We propose a synchronization-based mechanism that can explain the shift of the resonant frequency due to wind-induced synchronization of suspension cables/load-bearing elements of a bridge. We also draw parallels between wind-excitation and crowd synchrony and present a bifurcational, analytically tractable model, inspired by the Millennium Bridge case.

Igor Belykh
Department of Mathematics and Statistics
Georgia State University
ibelykh@gsu.edu

Russell Jeter
Georgia State University
russell.jeter@outlook.com

Vladimir Belykh
Lobachevsky State University of Nizhny Novgorod, Russia
belykh@unn.ac.ru

MS12

Network Graph Can Promote Faster Consensus Reach Despite Large Inter-Agent Delays

This presentation stems from the authors work on the interplay between delays, graphs, and dynamical systems. Here, we consider a class of widely-studied linear consensus problem with inter-agent communication delays. For this class of systems, it is known that consensus is guaranteed only if the inter-agent delay is less than a certain margin, known as the delay margin. We investigate how delays and the arising graph formed by agent connectivity can influence

the speed of reach of agents to consensus. Since the solution to this problem is analytically intractable, simulation studies with randomization are systematically performed to investigate it. The three non-trivial findings are as follows: (i) for large inter-agent delays less than the delay margin, there exist some particular graphs that promote considerably faster reach of agents to consensus, (ii) for a given graph, consensus in the presence of larger delays can be reached faster if inter-agent couplings are weaker but not stronger, (iii) for small size networks, there seems to be a way to decide which inter-agent links to remove in order for the agents to reach consensus faster. These preliminary results call for further research in the pursuit of revealing the most immune graphs that also promote large decay rate in system states of various dynamical systems, against the detrimental effects of delays.

Min Hyong Koh
Northeastern University
koh.m@husky.neu.edu

Rifat Sipahi
Department of Mechanical and Industrial Engineering
Northeastern University
rifat@coe.neu.edu

MS13

Stochastic Boundary Conditions for Molecular Dynamics: From Crystal to Melt

Motivated by the need for closure relations in continuum-atomistic simulations, we develop non-periodic molecular dynamic boundary conditions with consistent dynamics to traditional NPT algorithms. A hypothesized stochastic model is employed at the boundary and parameters are fit on the fly via statistical sampling of the interior. Such a method allows us to examine non-traditional computational domains that allow us to focus on interfaces while accounting for local curvatures.

Gregory J. Herschlag
Department of Mathematics
Duke University
gjh@math.duke.edu

Sorin Mitran
University of North Carolina Chapel Hill
mitran@unc.edu

MS13

Tipping and Warning Signs for Patterns and Propagation Failure in SPDEs

In this talk, I shall report on recent results regarding early-warning signs for pattern formation in stochastic partial differential equations. In particular, it will be shown that classical scaling laws from stochastic ordinary differential equations can be carried over to the SPDE case. This is illustrated in the context of the Swift-Hohenberg equation, analytically and numerically. Furthermore, I shall discuss numerical results for warning signs for the stochastic Fisher-KPP equation in the case of noisy invasion front traveling waves near positive absorption probability events leading to propagation failure. Several interesting potential future directions for dynamical systems analysis of SPDEs will also be sketched.

Christian Kuehn
Vienna University of Technology
ck274@cornell.edu

Karna V. Gowda
Northwestern University
karna.gowda@u.northwestern.edu

MS13

Fluctuating Hydrodynamics of Microparticles in Viscoelastic Fluids

Abstract not available.

Scott McKinley
University of Florida
scott.mckinley@ufl.edu

MS13

Low-Damping Transition Times in a Ferromagnetic Model System

Abstract not available.

Katherine Newhall
Courant Institute of Mathematical Science
New York University
knewhall@unc.edu

MS14

Topological Detection of Structure in Neural Activity Recordings

In biology, observations are often related to variables of interest through unknown monotonic nonlinearities. Detecting structure in the presence of such nonlinearities can be challenging, as eigenvalue-based methods are often misleading. However, algebro-topological tools can provide measurements robust to such transformations, allowing the detection of the presence or absence of intrinsic structure. To demonstrate, we detect the geometric structure arising from hippocampal place cells directly from neural recordings.

Chad Giusti
Warren Center for Network and Data Sciences
University of Pennsylvania
cgiusti@seas.upenn.edu

Carina Curto, Vladimir Itskov
Pennsylvania State University
cpc16@psu.edu, vladimir.itskov@psu.edu

MS14

An Algebro-Topological Perspective on Hierarchical Modularity of Networks

(Joint work with R. Levi and S. Raynor) Recent research by, among others, Bassett and her collaborators, has shown that brain networks exhibit hierarchical modularity, which varies with time during learning. In this talk I will describe work on applying methods from algebraic topology in an attempt to characterize and classify those hierarchically modular graphs that arise as brain networks.

Kathryn Hess
École Polytechnique Federale De Lausanne

kathryn.hess@epfl.ch

MS14

The Topology of Fragile X Syndrome

Fragile X syndrome (FXS) is the most common known inherited cause of developmental disability and the most common single-gene risk factor for autism. In this talk I will give a brief description of the algorithm used by Mapper/Iris to produce a Reeb-like graph representation from a dataset, and then describe how its application to MRI data has led to the potential identification of higher and lower functioning subgroups within a population of children with FXS.

David Romano
Stanford School of Medicine
dromano@stanford.edu

MS14

The Neural Ring: Using Algebraic Geometry to Analyze Neural Codes

Neurons represent external stimuli via neural codes, and the brain infers properties of a stimulus space using only the intrinsic structure of the neural code. We define the neural ring, an algebraic object that encodes the combinatorial data of a neural code. Neural rings can be expressed in a 'canonical form' that translates to a minimal description of code's structure. This provides information about structure in the stimulus space, and how changing the code affects these properties.

Nora Youngs
Department of Mathematics
Harvey Mudd College
nyoungs@hmc.edu

MS15

Modeling Excitable Dynamics of Cardiac Cells

In the past decades many mathematical models of different complexity have been devised describing the excitable dynamics of cardiomyocytes and cardiac tissue. To assess these models their ability to predict experimental cardiac dynamics has to be probed. The model evaluation can be performed in a data assimilation frame work where the model is driven by measured data and after some transient time the input is switched off and the output of the free running model is compared to the true evolution of the experimental system. To assess the fidelity of selected models we employ different state and parameter estimation algorithms, and apply them to experimental data.

Sebastian Berg
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
sebastian.berg@ds.mpg.de

T.K. Shajahan, Jan Schumann-Bischoff
Max Planck Institute for Dynamics and Self-Organization
shajahan@ds.mpg.de, jan.schumann-bischoff@ds.mpg.de

Ulrich Parlitz, Stefan Luther
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
ulrich.parlitz@ds.mpg.de, stefan.luther@ds.mpg.de

MS15

Reconstructing Dynamics of Unmodeled Variables

Assimilation of data with models of physical processes is a crucial component of modern scientific analysis. In recent years, nonlinear versions of Kalman filtering have been developed, in addition to methods that estimate model parameters in parallel with the system state. We propose a substantial extension of these tools to deal with the specific case of unmodeled variables, when training data from the variable is available. The method uses a stack of several, nonidentical copies of a physical model to jointly reconstruct the variable in question. We demonstrate the ability of this technique to accurately recover an unmodeled experimental quantity, such as an ion concentration, from a single voltage trace after the training period is completed. The method is applied to reconstruct the potassium concentration in a neural culture from multielectrode array voltage measurements.

Franz Hamilton
George Mason University
fhamilto@masonlive.gmu.edu

Timothy Sauer
Department of Mathematical Sciences
George Mason University
tsauer@gmu.edu

MS15

Intramural Forecasting of Cardiac Dynamics Using Data Assimilation

As a first step in reconstructing the three-dimensional propagation and breakup of electrical waves, a data-assimilation system is coupled to a simple model of cardiac electrical dynamics. Data assimilation is a technique common in numerical weather prediction for combining observations with a numerical model to derive an improved estimate of the state of a dynamical system. Here an ensemble Kalman filter is used on synthetic data for both 1D and 3D models.

Matthew J. Hoffman
Rochester Institute of Technology
mjhsma@rit.edu

Elizabeth M. Cherry
Rochester Institute of Technology
School of Mathematical Sciences
excsma@rit.edu

MS15

Tracking Neuronal Dynamics During Seizures and Alzheimer's Disease

Observability of a dynamical system requires an understanding of its statethe collective values of its variables. However, existing techniques are too limited to measure all but a small fraction of the physical variables and parameters of neuronal networks. We constructed models of the biophysical properties of neuronal membrane, synaptic, and microenvironment dynamics, and incorporated them into a model-based framework from modern control theory. We demonstrated the meaningful estimation of the dynamics of small neuronal networks using as few as a single measured variable. Specifically, we assimilated noisy membrane potential measurements from individual hippocampal neurons to reconstruct the dynamics of networks of these cells, their extracellular microenvironment, and the activities of different neuronal types during seizures. We used reconstruction to account for unmeasured parts of the neuronal system, relating micro-domain metabolic processes to cellular excitability, and validate the reconstruction of cellular dynamical interactions against actual measurements. Recently, we applied the method to intracellular Ca2+ dynamics using cytoplasmic Ca2+ as an observable to reconstruct and identify the differences between mitochondrial bioenergetics in control and Alzheimers disease states.

Ghanim Ullah
University of South Florida
gullah@usf.edu

MS16

Feasibility of Micro-Grid Adoptions in Spatially-Embedded Urban Networks

We present a data-driven citywide simulation scheme that combines heterogeneous demand with a complex systems approach. We present micro grid simulations via DC power flow dynamics combined with real (photovoltaic) PV generation and demand profiles of individual buildings in a city, modeled after high temporal-resolution smart-grid data. We explore the efficiency of spatial networks at three different scales from individual buildings to micro-grid neighborhoods to an entire city.

Marta Gonzalez
Civil and Environmental Engineering
MIT
martag@mit.edu

MS16

Cascading Failures and Stochastic Methods for Mitigation in Spatially-Embedded Random Networks

We have demonstrated that cascading failures are non-self-averaging in spatial graphs, hence predictability is poor and conventional mitigation strategies are largely ineffective. In particular, we have shown that protecting all nodes (or edges) by the same additional capacity (tolerance) can actually lead to larger global failures, i.e., "paying more can result in less", in terms of robustness. Here, we explore stochastic methods for optimal distribution of resources (capacities) subject to a fixed total cost.

Gyorgy Korniss
Department of Physics, RPI
korniss@rpi.edu

MS16

Spatial Distribution of Population and Scaling in Human Travel

An interesting scaling law connecting the travel time and distance was recently observed in human traveling modes and information spreading. Further we go, faster we do that. Seemingly the spatial distribution of population and the presence of hubs are responsible for this very general phenomenon. Investigating the connection between population density distribution and the mean traveling speed brings new clues to understand this puzzling phenomenon and optimize human travel and information flow.

Zoltan Neda
Babes-Bolyai University
Department of Physics
zneda@phys.ubbcluj.ro

Geza Toth
Hungarian Central Statistical Office
geza.toth@ksh.hu

Andras Kovacs
Edutus College
Department of International Business
kovacs.andras@edutus.hu

Istvan Papp, Levente Varga
Babes-Bolyai University
Department of Physics
steve.prst@gmail.com, vlewir@gmail.com

MS16

The Brain in Space

Based on experimental evidence here we argue that computing in the brain is based on deeply physical principles in which form follows function: although there is a complex network of computing elements, this network is not an abstract graph, but a physical network embedded both in space and time and these physical properties are just as much part of information processing in the brain as the signals themselves that are being transmitted through the network.

Zoltan Toroczkai
University of Notre-Dame
toro@nd.edu

Maria Ercsey-Ravasz
Faculty of Physics
Babes-Bolyai University, Romania
ercsey.ravasz@phys.ubbcluj.ro

Kenneth Knoblauch, Henry Kennedy
Stem cell and Brain Research Institute, INSERM U846
Bron, France
ken.knoblauch@inserm.fr, henry.kennedy@inserm.fr

MS17

On the Role of Stochastic Delays in Gene Regulatory Networks

In gene regulatory networks delays emerge from sequential assembly and accumulation of macromolecules. Furthermore, the stochastic nature of biochemical processes leads to stochastic variations in the delay. This may lead to counter intuitive dynamics where increasing uncertainty can increase the robustness of the system. In this talk we present novel methods that allow us to evaluate the exact stability of equilibria in systems with stochastic delays. We demonstrate these tools on an auto-regulatory network.

Marcella Gomez, Matthew Bennett
Rice University
mg47@rice.edu, matthew.bennett@rice.edu

Richard Murray

Control and Dynamical Systems
California Institute of Technology
murrayrm@cds.caltech.edu

MS17

New Mechanisms for Patterns, Transitions, and Coherence Resonance for Systems with Delayed Feedback

Controlling patterns via delayed feedback is an efficient means of pattern resilience. Computations demonstrate complex dynamics for PDE's with Pyragas control. We give a new analysis for stochastic PDE's with delay, capturing novel spatio-temporal pattern mechanisms in the Swift-Hohenberg equation (SHE) with Pyragas control, not observed for the standard SHE. We show that traveling waves appear via coherence resonance-type phenomena and compare these to other multimode patterns generated by delays.

Rachel Kuske
University of British Columbia
rachel@math.ubc.ca

Chia Lee
UBC Mathematics
lchiaying.lee@gmail.com

Vivi Rottschaefer
Mathematical Institute
Leiden University
vivi@math.leidenuniv.nl

MS17

Dynamics with Stochastically Delayed Feedback: Designing Connected Vehicle Systems

In this talk we present novel mathematical tools that allow one to evaluate the dynamics of systems where stochacticity appears in the feedback delay. In particular we analyze the mean and second moment dynamics in order to evaluate absolute and convective instabilities in networked system. We apply these methods to networks of vehicles that exchange information via vehicle-to-vehicle (V2V) communication. In such systems stochastic delays appear due to intermittencies and packet loss.

Gabor Orosz, Wubing Qin
University of Michigan, Ann Arbor
Department of Mechanical Engineering
orosz@umich.edu, wubing@umich.edu

MS17

Synchronization of Degrade-and-Fire Oscillations Via a Common Activator

In this talk, we examine an experimentally motivated stochastic model for coupled degrade-and-fire gene oscillators, where a core delayed negative feedback establishes oscillations within each cell, and a shared delayed positive feedback couples all cells. We use analytic and numerical techniques to investigate conditions for one cluster and multi-cluster synchrony. A nonzero delay in the shared positive feedback, as expected for experimental systems, is found to be important for synchrony to occur.

William H. Mather
Virginia Tech Physics
wmather@vt.edu

Jeff Hasty
Department of Bioengineering
University of California, San Diego
hasty@ucsd.edu

Lev S. Tsimring
University of California, San Diego
ltsimring@ucsd.edu

MS18

Homoclinic Snaking Near a Codimension-two Turing-Hopf Bifurcation Point

Spatiotemporal Turing-Hopf pinning solutions near a codimension two Turing-Hopf point are studied. Both the Turing and Hopf bifurcations are supercritical and stable. The pinning solutions exhibit coexistence of stationary stripes of near critical wavelength and time periodic oscillations near the characteristic Hopf frequency. The solution branches are organized in a series of saddle-node bifurcations similar to snaking structures of stationary pinning solutions. Time dependent depinning dynamics outside the saddle-nodes are illustrated. Wavelength variation within the snaking region is discussed, and reasons for the variation are given in the context of amplitude equations. The pinning region is compared favorably to the Maxwell line found numerically by time evolving the amplitude equations

Justin C. Tzou
Dalhousie University
tzou.justin@gmail.com

Yiping Ma
Department of Applied Mathematics
University of Colorado, Boulder
yiping.m@gmail.com

Alvin Bayliss
Northwestern University
a-bayliss@northwestern.edu

Bernard J Matkowsky
Department of Engineering Sciences and Applied Mathematics
Northwestern University
b-matkowsky@northwestern.edu

Vladimir A. Volpert
Northwestern University
v-volpert@northwestern.edu

MS18

Localised Solutions in a Non-Conservative Cell Polarization Model

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.

Nicolas Verschueren Van Rees, Alan Champneys
University of Bristol
nv13699@bristol.ac.uk, enarc@bristol.ac.uk

MS18

Slow Dynamics of Localized Spot Patterns for Reaction-Diffusion Systems on the Sphere

In the singularly perturbed limit corresponding to large a diffusivity ratio between two components in a reaction-diffusion (RD) system, many such systems admit quasi-equilibrium spot patterns, where the solution concentrates at a discrete set of points in the domain. In this context, we derive and study the differential algebraic equation (DAE) that characterizes the slow dynamics for such spot patterns for the Brusselator model on the surface of a sphere. Localized spot patterns can undergo a fast time instability and we derive the conditions for this phenomena, which depend on the spatial configuration of the spots and the parameters in the system. In the absence of these instabilities, our numerical solutions of the DAE system for $N = 2$ to $N = 8$ spots suggest a large basin of attraction to a small set of possible steady-state configurations. We discuss the connections between our results and the study of point vortices on the sphere, as well as the problem of determining a set of elliptic Fekete points, which correspond to globally minimizing the discrete logarithmic energy for N points on the sphere.

Philippe H. Trinh
Program in Applied and Computational Mathematics
Princeton University
ptrinh@princeton.edu

Michael Ward
Department of Mathematics
University of British Columbia
ward@math.ubc.ca

MS18

The Origin of Finite Pulse Trains: Homoclinic Snaking in Excitable Media

Many physical, chemical and biological systems exhibit traveling waves as a result of either an oscillatory instability or excitability. The latter may admit a large multiplicity of stable and spatially localized wavetrains consisting of different numbers of traveling pulses. The existence of these states is related here to the presence of homoclinic snaking in the vicinity of a subcritical, finite wavenumber Hopf bifurcation. The pulses are organized in a slanted snaking structure resulting from the presence of a heteroclinic cycle between small and large amplitude traveling waves. Connections of this type require a multivalued dispersion relation. This dispersion relation is computed numerically and used to interpret the profile of the pulse group. The different spatially localized pulse trains can be accessed by appropriately customised initial stimuli thereby blurring the traditional distinction between oscillatory and excitable systems.

Arik Yochelis
Jacob Blaustein Institutes for Desert Research, Sede Boqer
Ben-Gurion University of the Negev
yochelis@bgu.ac.il

Edgar Knobloch
University of California at Berkeley
Dept of Physics
knobloch@berkeley.edu

MS19

A Geometric Approach to Stationary Defect Solutions

In this talk we consider the impact of a very simple and small spatial heterogeneity on the existence of localized patterns in a system of PDEs in one spatial dimension. The existence problem reduces to the problem of finding a heteroclinic orbit in an ODE in ‘time’ x, for which the vector field for x ¿ 0 differs slightly from that for x ¡ 0, under the assumption that there is such an orbit in the unperturbed problem. We show that both the dimension of the problem as well as the nature of the linearized system near the endpoints of the heteroclinic orbit has a remarkably rich impact on the existence these defect solutions.

Arjen Doelman
Mathematisch Instituut
doelman@math.leidenuniv.nl

Peter van Heijster
Mathematical Sciences School
Queensland University of Technology
petrus.vanheijster@qut.edu.au

Feng Xie
Mathematisch Instituut, Leiden University
Dept. of Appl. Math., Donghua University
fxie@dhu.edu.cn

MS19

Reformulating Spectral Problems with the Krein Matrix

Successful resolution of spectral problems in Hamiltonian systems require that we locate not only the eigenvalues, but we also determine the Krein signature of those which are purely imaginary. The well-known Evans function determines the location and multiplicity of the eigenvalues, but in its classical form it does not allow a determination of the signature. On the other hand, the Krein matrix, and the accompanying Krein eigenvalues, allow us to not only find the eigenvalues, but the graphs can be used to determine the signature. We will briefly consider the construction of the matrix, and discuss its role in applications.

Todd Kapitula
Calvin College
Dept of Math & Statistics
tkapitula@gmail.com

MS19

Stability in Spatially Localized Patterns

Motivated by numerical stability results on spatially localized patterns in spatially extended systems, we show how the stability of patterns that are formed of nonlocalized fronts can be understood from the spectra of the underlying fronts. We use extended Evans functions to understand the spectral properties of these patterns on the original unbounded domain and on large but bounded domains and compare our results to previous findings on resonance poles and edge bifurcations.

Elizabeth J. Makrides
Brown University
Division of Applied Mathematics
elizabeth_makrides@brown.edu

Bjorn Sandstede
Division of Applied Mathematics
Brown University
bjorn_sandstede@brown.edu

MS19

Existence of Pearled Patterns in the Planar Functionalized Cahn-Hilliard Equation

The functionalized Cahn-Hilliard (FCH) equation supports planar and circular bilayer interfaces as equilibria which may lose their stability through the pearling bifurcation: a periodic, high-frequency, in-plane modulation of the bilayer thickness. In two spatial dimensions we employ spatial dynamics, a center manifold reduction, normal form analysis and a fixed-point-theorem argument to show that the reduced system admits a degenerate 1:1 resonant normal form, from which we deduce that the onset of the pearling bifurcation coincides with the creation of a two-parameter family of pearled equilibria which are periodic in the in-plane direction and exponentially localized in the transverse direction.

Qiliang Wu
Michigan State University
qwu@msu.edu

MS20

Homeostasis As a Network Invariant

The simplest mathematical definition of *homeostasis* is as follows. Suppose a system $\dot{X} = F(X)$ has a stable equilibrium X^0 and the system depends on an input parameter I. Homeostasis occurs when one of the variables of $X^0(I)$ — say the j^{th} — is approximately constant over a broad range of I. We translate finding homeostasis to finding singular points $\frac{\partial X_j^0}{\partial I}(I_0) = 0$. We discuss the question: When are homeostasis singularities invariants of the system when viewed as a network?

Martin Golubitsky
Ohio State University
Mathematical Biosciences Institute
mg@mbi.osu.edu

Ian Stewart
University of Warwick
ianstewart.joat@virgin.net

MS20

Optimized Networks Have Cusp-like Dependence on Structural Parameters

Using synchronization stability as a prototypical example, we demonstrate a general phenomenon observed in complex networks of coupled dynamical units: the optimization of collective dynamics leads to cusp-like dependence on network-structural parameters, such as the number of nodes/links and the magnitude of structural perturbations. We show that this phenomenon is observed in a wide range of systems, including Turing instability in activator-inhibitor systems and the dynamics of generators in power grids.

Takashi Nishikawa, Adilson E. Motter
Northwestern University
t-nishikawa@northwestern.edu, motter@northwestern.edu

MS20

Symmetries, Cluster Synchronization, and Isolated Desynchronization in Complex Networks

Many networks are observed to produce patterns of synchronized clusters, but their prediction in general is difficult. We use computational group theory to find network symmetry and cluster synchronization. The number of symmetries can be astronomically large. We show this experimentally using an electro-optic network. We observe a surprising phenomenon (isolated desynchronization) in which some clusters lose synchrony while leaving others connected to them synchronized. This is explained by a subgroup decomposition of the group.

Louis M. Pecora
Naval Research Lab
louis.pecora@nrl.navy.mil

Francesco Sorrentino
University of New Mexico
Department of Mechanical Engineering
fsorrent@unm.edu

Aaron M. Hagerstrom
University of Maryland
aaron.hagerstrom@gmail.com

Rajarshi Roy
University of Maryland, College Park, MD, USA
lasynch@gmail.com

Thomas E. Murphy
University of Maryland, College Park
Dept. of Electrical and Computer Engineering
tem@umd.edu

MS20

Symmetry Breaking and Synchronization Patterns in Networks of Coupled Oscillators

In a recent paper [1] we considered the dynamics of a collection of oscillators coupled to form a network and we showed that the analysis of the network symmetries can be used to predict the emergence of cluster synchronization patterns. In particular, we focused on a specific solution corresponding to the partition of the network nodes in clusters, characterized by the 'maximal symmetry'. In general, given a network, there are other cluster synchronous solutions that may emerge, which correspond to symmetry breakings of the maximal symmetry solution. While in [1], we presented a method to characterize this one solution and its stability, we will try to extend this approach to the 'lower symmetry' solutions. In particular, we will outline a procedure to exhaustively study the existence and stability of all these solutions. [1] L. M. Pecora, F. Sorrentino, A. M. Hagerstrom, T. E. Murphy, R. Roy, "Cluster Synchronization and Isolated Desynchronization in Complex Networks with Symmetries", Nature Communications, 5,

4079 (2014)

Francesco Sorrentino
University of New Mexico
Department of Mechanical Engineering
fsorrent@unm.edu

Aaron M. Hagerstrom
University of Maryland
aaron.hagerstrom@gmail.com

Louis M. Pecora
Naval Research Lab
louis.pecora@nrl.navy.mil

Thomas E. Murphy
University of Maryland, College Park
Dept. of Electrical and Computer Engineering
tem@umd.edu

Rajarshi Roy
University of Maryland, College Park, MD, USA
lasynch@gmail.com

MS21

A Multi Agent Control Strategy for Sampling Uncertain Spatio-Temporally Varying Flow Fields

Uncertainties are a key factor when measuring geophysical flows to determine optimal positions for mobile sensors. To include uncertainties with a physical model of the environment, a model-based observer framework is used, which integrates measurements from sensors and propagates the estimated field by computational fluid dynamics. Spatiotemporal flow, concentration and uncertainty layers of this observer are combined with importance and collision avoidance maps to generate optimal paths for a team of underactuated autonomous sampling vehicles.

Axel Hackbarth
Hamburg University of Technology
axel.hackbarth@tuhh.de

Edwin Kreuzer
Institute of Mechanics and Ocean Engineering
Hamburg University of Technology
kreuzer@tuhh.de

MS21

Bayesian Nonlinear Assimilation for Eulerian Fields and Lagrangian Trajectories

We consider the Bayesian nonlinear assimilation of Eulerian and Lagrangian flow data, exploiting nonlinear governing equations and mutual information structures inherent to coastal ocean dynamical systems and optimally inferring the corresponding multiscale fields and transports. Our Bayesian nonlinear smoothing combines reduced-order Dynamically-Orthogonal equations with Gaussian Mixture Models, extending linearized backward pass updates to a Bayesian nonlinear setting. This mutual information transfer, both forward and backward in time, is linked to Lagrangian concepts, coherent structures and optimal sampling. Examples are provided with a focus on transports in fluid flows. This is joint work with Tapovan Lolla, Patrick Haley, Jing Lin, Deepak Subramani and our MSEAS group at MIT.

Pierre Lermusiaux
MIT
pierrel@mit.edu

MS21

Optimal Control in Lagrangian Data Assimilation

Inferring the state of an ocean flow is an integral part of environmental monitoring. Autonomous vehicles with a limited capacity for locomotion are increasingly being used for data assimilation of various quantities of interest in the ocean, including the underlying time-independent velocity field. We assess the efficacy of optimal control techniques to guide Lagrangian data assimilation in 2-dimensional flows, focusing on assimilation of the velocity field itself.

Damon Mcdougall
Institute for Computational Engineering Sciences
The University of Texas at Austin
damon@ices.utexas.edu

Richard O. Moore
New Jersey Institute of Technology
rmoore@njit.edu

MS21

A Hybrid Particle-Ensemble Kalman Filter for High Dimensional Lagrangian Data Assimilation

We apply the recently proposed hybrid particle-ensemble Kalman filter to assimilate Lagrangian data into a nonlinear, high dimensional quasi-geostrophic ocean model. Effectively the hybrid filter applies a particle filter to the highly nonlinear, low-dimensional Lagrangian instrument variables while applying an ensemble Kalman type update to the high-dimensional Eulerian flow field. We will present some initial results and discuss both challenges and opportunities that this strategy provides.

Elaine Spiller
Marquette University
elaine.spiller@marquette.edu

Laura Slivinski
Woods Hole Oceanographic Institution
lslivinski@whoi.edu

Amit Apte
TIFR Centre for Applicable Mathematics
Bangalore, India
apte@math.tifrbng.res.in

MS22

The Geometry of the Toda Lattice Map

In this talk we consider some of the geometry behind the Flaschka coordinates for the Toda lattice equations. We show in particular that the Flaschka mapping is a momentum map and indicate how it can be generalized to study related systems such as rigid body flows on lower triangular matrices. This is joint work with Francois Gay-Balmaz and Tudor Ratiu.

Anthony M. Bloch
University of Michigan
Department of Mathematics

abloch@umich.edu

MS22

Geodesic Finite Elements on Symmetric Spaces and Their Applications to Multisymplectic Variational Integrators

To obtain multisymplectic discretizations of Hamiltonian PDEs with symmetries, we introduce group-equivariant geodesic finite-element spaces that take values in symmetric spaces. This is achieved by endowing symmetric spaces, and in particular, the space of positive-definite matrices, Lorentzian matrices, and symplectic matrices, with a Riemannian metric structure that is induced by a metric on the general linear group. This allows us to apply the Riemannian center of mass construction to obtain manifold-valued shape functions.

Phillip Grohs
ETH Zurich
Seminar for Applied Mathematics
pgrohs@sam.math.ethz.ch

Melvin Leok
University of California, San Diego
Department of Mathematics
mleok@math.ucsd.edu

Joe Salamon
University of California, San Diego
Department of Physics
jsalamon@physics.ucsd.edu

John Moody
University of California, San Diego
Department of Mathematics
jbmoody@ucsd.edu

MS22

Dynamics and Optimal Control of Flexible Solar Updraft Towers

The use of solar chimneys for energy production has been suggested more than 100 years ago but was hampered in large part due to the high cost of erecting tall towers. Recently, alternative technique of flexible towers built of inflatable toroidal bladders was suggested. We develop a geometric theory of motion and control of such towers, and report on the results of experiments demonstrating the remarkable stability of the tower in real-life conditions.

Vakhtang Putkaradze
University of Alberta
putkarad@ualberta.ca

MS22

Hamel's Formalism for Infinite-Dimensional Mechanical Systems

Hamel's formalism is a form of Lagrangian mechanics that generalizes both Euler-Lagrange and Euler-Poincare equations. This is accomplished by unlinking the configuration and velocity measurements. The use of this formalism often leads to a simpler representation of dynamics. This talk will introduce Hamel's formalism for infinite-dimensional mechanical systems and demonstrate its utility in constrained dynamics.

Dmitry Zenkov
North Carolina State University
Department of Mathematics
dvzenkov@ncsu.edu

MS23

Self-Oscillations Via Two-Relay Controller: Design, Analysis, and Applications

Limit cycles induced by relay feedback systems and its application to underactuated mechanical systems will be addressed. Particularly, a two-relay controller (TRC) is proposed for generation of Self-Oscillations (SO) in dynamic systems. The design procedures are proposed using three methodologies: the one based on DF, on Poincaré maps, and on Locus of Perturbed Relay System method. The results are illustrated by experiments on SO generation in a wheel pendulum, Furuta pendulum, and a 3-DOF helicopter.

Luis T. Aguilar
CITEDI-IPM
laguilar@citedi.mx

Igor Boiko
The Petroleum Institute
iboiko@pi.ac.ae

Leonid Fridman, Rafael Iriarte
Universidad Nacional Autonoma de Mexico
lfridman@unam.mx, ririarte@unam.mx

MS23

Periodic Solutions in Dynamical Systems with Relay: Existence, Stability, Bifurcations

We consider a system of ordinary differential equations with hysteresis of a relay type. In particular, such a system describes diffusion equations with hysteretic control on the boundary. We analyze existence, stability, and bifurcations of periodic solutions. Furthermore, we show that additional time-delay terms can favorably change the stability of periodic solutions. The first part of our talk is based on a joint work with Sergey Tikhomirov and the second part with Eyal Ron.

Pavel Gurevich
Free University Berlin
gurevich@math.fu-berlin.de

MS23

Population Dynamics with the Preisach Operator

We consider population dynamics models where species (individuals) can switch between two modes of behavior in response to exogenous stimuli. The switching rule of each individual is modeled by a two-threshold non-ideal relay; the averaged state of the individuals feeds back into the system. We consider the SIR and predator-prey type models extended by these switching dynamics and discuss continuous sets of equilibria, robust homoclinic trajectories and other dynamics.

Dmitry Rachinskiy
Department of Mathematical Sciences
University of Texas at Dallas

dxr124030@utdallas.edu

MS23

Reaction-Diffusion Equations with Discontinuous Relay Nonlinearity

We consider reaction-diffusion equations involving a relay discontinuity in the source term, which is defined at each spatial point. In particular, such problems describe chemical reactions and biological processes in which diffusive and nondiffusive substances interact according to hysteresis law. We show that behaviour of such systems essentially depends on the initial data. For the so-called transverse initial data we show that solutions of the problem can be described by a certain free boundary problem. In the case of non-transverse initial data values of the relay form a spatially periodic or spatially quasyperiodic pattern that originates at a point and propagates outwards.

Sergey Tikhomirov
Max Planck Institute for Mathematics in the Science
Chebyshev Laboratory, Saint-Petersburg State University
sergey.tikhomirov@mis.mpg.de

Pavel Gurevich
Free University Berlin
gurevich@math.fu-berlin.de

MS24

Influence of Finite Larmor Radius on Critical Parameters for Invariant Curves Break Up in Area Preserving Maps Models of ExB Chaotic Transport

We consider 2-dimensional area preserving maps describing chaotic transport in magnetized plasmas with zonal flows perturbed by electrostatic drift waves. We include finite Larmor radius effects by gyro-averaging the corresponding Hamiltonians of the nontwist maps. Dynamical systems methods based on recurrence time statistics are used to quantify the dependence on the Larmor radius of the threshold for the destruction of shearless transport barriers.

Julio Fonseca
University of Sao Paulo
jfonseca@if.usp.br

Diego Del-Castillo-Negrete
Oak Ridge National Laboratory
delcastillod@ornl.gov

Iber L. Caldas
Instituto de Fsica, Universidade de So Paulo
ibere@if.usp.br

MS24

Breakup of Tori in Multiharmonic Nontwist Standard Maps

Invariant circles play a prominent role in the dynamics of area-preserving maps. Unfortunately, much of the theory developed to study these circles in twist maps does not apply to nontwist systems. In this talk we will employ a quasi-Newton, Fourier-based method to compute the conjugacies of the circles. We will then demonstrate how the near-critical conjugacies provide insight into the mechanics of the breakup of the circles and the topology of the invariant sets afterwards.

Adam M. Fox
Department of Mathematics
Western New England University
adam.fox@wne.edu

James D. Meiss
University of Colorado
Dept of Applied Mathematics
jdm@colorado.edu

MS24

Nontwist Worm Map

In this work we propose a nontwist discrete map to investigate how the confinement of chaotic regions affects the topology of phase space. We choose to modify the Hamiltonian that generates the standard nontwist map, in order to create two linear barriers on the y-axis. As the perturbation is increased, we observe an onset of avoided regions not visited by chaotic orbits initiated inside the range formed by the introduced barriers. On the other hand, unstable manifolds from two hyperbolic fixed points, located outside the chosen region, can pass through these barriers, filling the avoided regions generated by the confinement proposed. The effect that allows the diffusion of chaotic orbits in only certain directions is known as the ratchet effect, which has been extensively studied in dissipative and Hamiltonian systems, due to its relevance in biology and nanotechnology. The possible observation of the ratchet effect in our map motivates our analyses.

Caroline G. L. Martins
Institute for Fusion Studies
carolinegameiro@gmail.com

P. J. Morrison
Department of Physics and Institute of Fusion Studies
The University of Texas at Austin
morrison@physics.utexas.edu

J. D. Szezech
Universidade Estadual de Ponta Grossa
jdanilo@gmail.com

I. L. Caldas
Universidade de So Paulo
Instituto de Fsica
ibere@if.usp.br

MS24

Breakup of Shearless Tori and Reconnection in the Piecewise-Linear Standard Nontwist Map

A piecewise-linear version of the area-preserving standard nontwist map is considered as a simple model of a piecewise-smooth map which also violates the twist condition. Using symmetry lines and involutions, I compute periodic orbits to analyze periodic orbit collisions and separatrix reconnection. The transition to chaos due to the destruction of the shearless curve with rotation number equal to the inverse golden mean is studied using Greene s residue criterion.

Alexander Wurm
Department of Physical & Biological Sciences
Western New England University

awurm@wne.edu

MS25

The Role of Voltage-Dependent Electrical Coupling in the Control of Oscillations

We focus on the role of voltage-dependent electrical coupling in determining existence, stability and qualitative properties of solutions in the crab gastric mill rhythm. The network consists of a mutually inhibitory pair of neurons that receive electrical input from a particular projection neuron together with the synaptic input from a pacemaker neuron. Using singular perturbation techniques and phase-plane space analysis, we derive and analyze a low-dimensional map that encodes the effects of these distinct inputs.

Christina Mouser
William Patterson University
mouserc@wpunj.edu

Farzan Nadim
New Jersey Institute of Technology
& Rutgers University
farzan@njit.edu

Amitabha Bose
New Jersey Inst of Technology
Department of Mathematical Sciences
bose@njit.edu

MS25

The Essential Role of Phase Delayed Inhibition in Decoding Synchronized Oscillations

The widespread presence of synchronized neuronal oscillations in the brain suggests the existence of a mechanism that can decode such activity. Candidate mechanisms include: high-spike threshold detection (HTD) and phase-delayed inhibition (PDI). Despite being more complex, PDI has been observed in multiple systems, suggesting an inherent advantage over the alternative. We show that PDI is capable of detecting synchrony far more robustly than HTD, making the motif essential in any system with noisy encoders.

Badal Joshi
California State University, San Marcos
bjoshi@csusm.edu

Mainak Patel
College of William and Mary
mjpatel@wm.edu

MS25

Neural Mechanisms of Limb Coordination in Crustacean Swimming

Long-tailed crustaceans swim by rhythmically moving limbs called swimmerets. Over the entire biological range of animal size and paddling frequency, movements of adjacent swimmerets maintain an approximate quarter-period phase difference with the more posterior limbs leading the cycle. Recently we have demonstrated that this frequency-invariant stroke pattern is the most effective and mechanically efficient paddling rhythm across the full range of biologically relevant Reynolds numbers in crustacean swimming. Here, we argue that the organization of the neural circuit underlying swimmeret coordination provides a robust mechanism for generating this stroke pattern.

Tim Lewis
University of California, Davis
tjlewis@ucdavis.edu

MS25

Understanding and Distinguishing Multiple Time Scale Oscillations

CPGs may exhibit behavior, including bursting, involving multiple distinct time scales. Our goal is to understand bursting dynamics in multiple-time-scale systems, motivated by a model of respiratory CPG neuron. We apply geometric singular perturbation theory to explain the mechanisms underlying some interesting forms of bursting dynamics involving multiple forms of activity within each cycle. We consider how many time scales are involved, obtaining some non-intuitive results, and identify solution properties that truly require three time scales.

Yangyang Wang
University of Pittsburgh
yaw23@pitt.edu

Jonathan E. Rubin
University of Pittsburgh
Department of Mathematics
rubin@math.pitt.edu

MS26

How Small a Thought: Design of Mixing and Separation Processes with Dynamical Systems

We use dynamical systems to design manufacturing processes. Two examples are: (1) The Rotated Arc Mixer, an embodiment of the KAM theorem, increases manufacturing productivity 25% and decreases mixing energy 95%. (2) The dynamical system for inertial particles in a laminar flow has both attracting and repelling regions, the interplay of which localizes particles when the Reynolds number exceeds a critical value with applications in solid-liquid separations. The predicted instability boundary agrees well with data.

Guy Metcalfe
CSIRO Materials Science & Engineering
Melbourne, Australia
guy.metcalfe@csiro.au

MS26

3D Chaotic Advection in Langmuir Cells

We investigate Lagrangian transport processes in a row of horizontally aligned, vertically sheared, alternating cylindrical vortices: a simple model of ocean Langmuir circulations. We map out the chaotic regions and barriers that result when the system is subject to three-dimensional steady and unsteady disturbances. Chaotic advection occurs in resonant layers within each Langmuir cell, and exchange between the cells via three-dimensional turnstile lobes also occurs.

Larry Pratt
Woods Hole Oceanographic Inst.
lpratt@whoi.edu

Irina Rypina
Woods Hole Oceanographic Institution
irypina@whoi.edu

MS26

Chaotic Mixing and Transport Barriers

We present experiments on chaotic transport in two- and three-dimensional flows. The 2D flows are oscillating vortex chains with a wind that produces Lévy flights and superdiffusive transport. We consider two 3D flows: (a) a nested vortex chain flow, which gives rise to chaotic mixing even if the flow is time-independent; and (b) a vortex chain with Ekman pumping for which all transport barriers can be destroyed even for arbitrarily small time-dependent perturbations.

Thomas H. Solomon
Department of Physics & Astronomy
Bucknell University
tsolomon@bucknell.edu

MS26

Experimental Investigation of Fundamental Lagrangian Transport Phenomena

Principal goal is experimental validation of the predicted response of a prototypical 3D unsteady flow with spheroidal (as opposed to toroidal) invariant surfaces to weak perturbations. Investigated are fundamental features as symmetries and periodic lines in the unperturbed state and the formation of tubular structures upon weak perturbation. The latter promote global transport and, ultimately, 3D chaos. Moreover, the experiments validate the essential independence of this response upon the particular nature of the perturbation.

Michel Speetjens
Laboratory for Energy Technology, Dept. Mech. Eng.
Eindhoven University of Technology
m.f.m.speetjens@tue.nl

MS27

Dynamics of Asynchronous Networks

Systems that have the structure of a network of interconnected nodes are abundant in nature and technology. Many mathematical models of such networks are given as ordinary differential equations defined by smooth vector fields. These traditional or “synchronous’ network models, however, fail to incorporate features seen in real world; for example, individual components of a network cannot stop and restart in finite time. Asynchronous networks are an attempt to set up a mathematical framework to study systems that exhibit stopping of nodes and their bifurcations. We compare our framework to traditional approaches of differential equations with discontinuous vector fields and show equivalence under certain assumptions. We also explore deadlocks as specific dynamical states in which all nodes stop and never restart. These states cannot occur in a synchronous setup but are a natural feature of asynchronous settings.

Christian Bick
Max Planck Institute for Dynamics and Self-Organization:
bick@nld.ds.mpg.de

Michael Field
Imperial College London
Rice University
michael.j.field@rice.edu

Anushaya Mohapatra
Oregon State University
mohapata@math.oregonstate.edu

MS27

Pulse Bifurcations in Stochastic Neural Fields

We study the effects of additive noise on traveling waves in spatially extended neural fields. Neural fields equations have an integral term, characterizing synaptic interactions between neurons at different spatial locations of the network. Traveling pulse solutions emerge when considering the effects of local negative feedback, generating a drift instability. Near this criticality, we derive a stochastic amplitude equation describing the pulse dynamics when the noise and the deterministic instability are of comparable magnitude.

Zachary Kilpatrick
University of Houston
zpkilpat@math.uh.edu

Gregory Faye
École des hautes études en sciences sociales
gfaye@ehess.fr

MS27

Classifying Bifurcations in Coupled Cell Networks

Stewart and Golubitsky observed that robust synchrony in coupled cell networks is determined by quotient networks. This result was recently generalized by DeVille and Lerman, who noted that any so-called ‘graph fibration’ induces a conjugacy between the dynamics of a network and its quotients. Starting from the simple observation that any ‘self-fibration’ hence induces a symmetry, we present a theory of center manifold reduction that is specifically suited for coupled cell networks.

Eddie Nijholt, Bob Rink, Jan Sanders
VU University Amsterdam
eddie.nijholt@gmail.com, b.w.rink@vu.nl,
jan.sanders.a@gmail.com

MS27

Dynamics of Heterogeneous Networks: Reductions and Coherent Behaviour

Recent experiments show that networks exhibit multiple levels of coherent dynamics depending on the connectivity level of the network. Striking examples are found in the brain. Indeed, synchronisation between highly connected neurons coordinate and shape development in hippocampal networks. We provide a probabilistic approach for random networks with chaotic dynamics. We develop a reduction technique to describe the dynamics of the highly connected network layers in terms of the network's microscopic details.

Tiago Pereira
Department of Mathematics
Imperial College, London, UK
tiago.pereira@imperial.ac.uk

Matteo Tanzi, Sebastian van Strien
Imperial College London
matteotanzi@hotmail.it, s.van-strien@imperial.ac.uk

MS28

Oscillatory Dynamics of the Candelator

We describe the dynamics of the popular “candle see-saw” experiment in which a candle lit at both ends undergoes vertical oscillations as liquid wax drips from either end. We compare existing theory for small oscillations ($\theta < 30^\circ$) and numerical simulations for large oscillations to experimental data.

Greg A. Byrne, Mary Elizabeth Lee, Flavio Fenton
Georgia Institute of Technology
gregory.byrne@physics.gatech.edu, mlee413@gatech.edu, flavio.fenton@physics.gatech.edu

MS28

Period Doubling in the Saline Oscillator

We provide today a simple, nonlinear system that captures many aspects of cardiac dynamics. The saline oscillator is a two chambered plastic box with one orifice connecting the two chambers. There is a jet of fluid flowing through the orifice. Along with this jet is a local voltage that parallels the flow of the jet. The voltage from the saline oscillator highly resembles an action potential and can produce period one and period two cycles.

Diandian Diana Chen
Georgia Institute of Technology
School of Physics
dchen87@gatech.edu

Flavio Fenton
Georgia Institute of Technology
flavio.fenton@physics.gatech.edu

MS28

Synchronization Patterns in Simple Networks of Optoelectronic Oscillators

Simple motifs are important constituents of complex networks; insight into the patterns of synchrony for different connection topologies is relevant to understanding how they perform different dynamical functions. Global synchrony, the formation of clusters and desynchronized behavior are all aspects of operation that are observed in the experiments we describe on coupled optoelectronic oscillators. We explore the dependence of these patterns of synchrony and their stability in relationship to the symmetries of the network motifs.

Briana Mork
University of Maryland
briemork@gmail.com

Kate Coppess
University of Michigan
Ann Arbor, MI USA
kcoppess@umich.edu

Caitlin R. S. Williams
University of Maryland
Dept. of Physics
willcrs@umd.edu

Aaron M. Hagerstrom, Joseph Hart
University of Maryland
aaron.hagerstrom@gmail.com, jhart12@umd.edu

Thomas E. Murphy
University of Maryland, College Park
Dept. of Electrical and Computer Engineering
tem@umd.edu

Rajarshi Roy
University of Maryland
rroy@umd.edu

MS28

Noise-Induced Transitions in Bistable Tunnel Diode Circuits

We measure first-passage time distributions of electrical current switching in a bistable tunnel diode circuit driven with adjustable noise intensity. Near a saddle-node bifurcation, the logarithm of mean switching time scales *linearly* with distance to the bifurcation point and inversely with noise intensity. This suggests a noise-induced switching process that is mediated by nucleation to a distinct state of current flow, with nucleation occurring either at the edge or interior of the diode.

Stephen Teitsworth, Yuriy Bomze, Steven Jones, Ryan McGeehan
Duke University
teitso@phy.duke.edu, bomze456@phy.duke.edu, scijones@umich.edu, ryan.mcgeehan@duke.edu

MS29

Population Models Applied to Model the Pregnancy to Labor Transition

In human pregnancy the steroid hormone progesterone acts via two receptors designated PR-A and PR-B. At term PR-A interferes with PR-B’s anti-inflammatory function to initiate labor. We present a model of PR-B’s interactions with inflammation and use the dimensionless model to predict the onset of labor in two human transcriptome datasets. Solving the dimensionless model allows us to plot the trajectory of a womans pregnancy in time and study the dynamics of the PR-A/PR-B interaction.

Douglas Brubaker
CWRU School of Medicine
Center for Proteomics and Bioinformatics
dkb50@case.edu

Alethea Barbaro
Case Western Reserve University
alethea.barbaro@case.edu

Mark Chance
Case Western Reserve University
Center for Proteomics and Bioinformatics
mrc16@case.edu

Sam Mesiano
Case Western Reserve University Dept. of Reproductive Biolog

sam.mesiano@case.edu

MS29

Stochastic Fluctuations in Suspensions of Swimming Microorganisms

Mean field theories have had a good deal of success in explaining many features regarding the remarkable dynamics of suspensions of swimming microorganisms, including the onset of patterned motion in certain parameter regimes. We describe an extension of these mean field theories to include stochastic fluctuations in the density of the swimming microorganisms, and some computational issues in simulating the resulting stochastic partial differential equations.

Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
kramep@rpi.edu

Yuzhou Qian
Rensselaer Polytechnic Institute
qianyuzhou1@gmail.com

Patrick Underhill
Rensselaer Polytechnic Institute
Department of Chemical and Biological Engineering
underhill@rpi.edu

MS29

A Model for Riot Dynamics: Shocks, Diffusion and Thresholds

In this talk I will introduce variants of a system of differential equations that model social outbursts, such as riots. The systems involves coupling of an explicit variable representing the intensity of rioting activity and an underlying (implicit) field of social tension. Our models include the effects of exogenous and endogenous factors as well as various propagation mechanisms. I will discuss various properties of this system, including the existence of traveling wave solutions whose speed experiences a transition based on a critical threshold for the social tension.

Nancy Rodriguez-Bunn
University of North Carolina at Chapel Hill
Department of Mathematics
nrod@email.unc.edu

Henri Berestycki, Jean-Pierre Nadal
CMAS-EHESS
hb@ehess.fr, jpnadal@ehess.fr

MS29

Crowd Modeling: How Can People Respond to Fear

We present a model for crowd dynamics where the motion of individuals is assumed to depend on their level of excitement (or fear) and thus the mechanism by which the emotion spreads play an important role. We start with an agent based Cucker-Smale-like model for which we derive the continuity equation from the mean field limit and analyze their asymptotic behavior. Then we explore numerically how variations, in both the effects of the emotion and its mechanism of propagation, affects the dynamics of the crowd.

Jesus Rosado Linares
Universidad de Buenos Aires - CONICET
Departamento de Matematica
jrosado@dm.uba.ar

Alethea Barbaro
Case Western Reserve University
alethea.barbaro@case.edu

Andrea L. Bertozzi
UCLA Department of Mathematics
bertozzi@math.ucla.edu

MS30

A Self-Organising Distributed Strategy for Optimal Synchronisation of Networked Mechanical Systems

We consider the problem of adapting a weighted graph in a distributed fashion to maximise a desired cost function, as for instance the algebraic connectivity of the graph subject to constraints such as maximum weighted degree at each node and non-negativity of edge weights. The proposed method adapts edge weights in continuous time and is robust to topological changes in the network. We apply the strategy to solve the problem of optimising synchronisation in a network of coupled mechanical systems.

Louis Kempton, Guido Hermann
University of Bristol, UK
l.kempton@bristol.ac.uk, g.hermann@bristol.ac.uk

Mario Di Bernardo
University of Bristol
Dept of Engineering Mathematic
m.dibernardo@bristol.ac.uk

MS30

Synchronization in Dynamical Networks of Noisy Nonlinear Oscillators, Or Collective Behavior of Zebrafish

Zebrafish is a popular laboratory animal species for the investigation of several functional and dysfunctional biological processes. Their burst-and-coast swimming style is well described through a stochastic mean reverting jump diffusion model. Here, we analyze zebrafish schooling by modeling their social interactions through a noisy vectorial network model, in which each fish is assimilated to a network node whose neighbors are randomly and uniformly selected from the group. Through numerical simulations and closed-form results, we assess the role of the network size, number of neighbors, and noise features on the stochastic synchronization.

Violet Mwaffo, Ross Anderson
Dept. of Mechanical and Aerospace Engineering
New York University Polytechnic School of Engineering
vmwaffo@nyu.edu, ross.anderson@nyu.edu

Maurizio Porfiri
Dept. of Mechanical, Aerospace and Manufacturing
Engineering
Polytechnic University

mporfiri@nyu.edu

MS30

Synchronization of a Nonlinear Beam Coupled with Deformable Substrates

The nonlinear dynamics of a distributed mechanical system comprised of a beam mechanically coupled with a deformable substrate is considered. A mathematical model of the coupled system is constructed with the inclusion of beam's geometric nonlinearities and the combined effect of strain and strain rate in the material response of the substrate. Synchronization between the beam and the substrate is formally investigated through the evolution of the governing system on nonlinear partial differential equations. It is shown how locomotion of the beam can be achieved by synchronization with motions of the substrate, and how material and geometric properties of the substrate can be inferred by synchronization with imposed motions of the beam.

Davide Spinello
University of Ottawa
davide.spinello@uottawa.ca

MS30

Synchronization Control of Electrochemical Oscillator Assemblies by External Inputs

We consider the manipulation of a collection of heterogeneous nonlinear oscillators, which have unobservable state and receive a common input, to form dynamical synchronization structures. Examining the conditions for entrainment of an oscillator to a periodic input yields insight into a non-traditional control methodology. Phase coordinate transformation, ergodic averaging, and novel waveform design algorithms are used to produce inputs that establish structures in the systems' oscillation phases. The complexity of realizable designs is limited by the nonlinearity and heterogeneity of oscillators in the ensemble. The technique is applied successfully in experiments involving assemblies of electrochemical oscillators.

Anatoly Zlotnik
Washington University in St. Louis
azlotnik@lanl.gov

Istvan Z. Kiss
Department of Chemistry
Saint Louis University
izkiss@slu.edu

Raphael Nagao
Saint Louis University
raphnagao@gmail.com

Jr-Shin Li
Washington University in St. Louis
jsli@ese.wustl.edu

MS31

Extreme Events on Small-World Networks of Excitable Units

We investigate small-world networks of excitable units that exhibit different types of collective dynamics, which include extreme events. The transitions between the different types of dynamics are irregular and self-generated. We discuss the mechanisms behind these transitions as well as the impact of the coupling topology on the observed phenomena.

Gerrit Ansmann, Klaus Lehnertz
Department of Epileptology
University of Bonn, Germany
gansmann@uni-bonn.de, klaus.lehnertz@ukb.uni-bonn.de

Ulrike Feudel
University of Oldenburg
ICBM, Theoretical Physics/Complex Systems
ulrike.feudel@uni-oldenburg.de

MS31

Extreme Events in Nature: Harmful Algal Blooms

Harmful algal blooms (HABs) are rare events in the ocean characterized by a sudden large abundance of toxic phytolankton species. We study the mechanism behind the emergence of HABs by modeling the population dynamics as an excitable system involving the competition between different activators, toxic and non-toxic species, as well the preference of the inhibitor, the grazing zooplankton, for certain activators. We show how toxin production, hydrodynamics and variable nutrient input influence the trigger mechanism.

Ulrike Feudel
University of Oldenburg
ICBM, Theoretical Physics/Complex Systems
ulrike.feudel@uni-oldenburg.de

Subhendu Chakraborty
DTU Aqua, Denmark
subc@aqua.dtu.dk

Cornelius Steinbrink
University Oldenburg, Germany
cornelius.steinbrink@uni-oldenburg.de

Rajat Karnatak
Theoretical Physics/Complex Systems, ICBM
University Oldenburg
rajat.karnatak@uni-oldenburg.de

Helmut Hillebrand
University Oldenburg, Germany
ICBM, Planktology
helmut.hillebrand@uni-oldenburg.de

MS31

Forecasting and Controlling Dragon-King Events in Coupled Dynamical Systems

It is often believed that extreme events in dynamical system follow a scale-free, power-law probability distribution and hence these events are unpredictable. We study extreme events in coupled chaotic oscillators and find that the largest events deviate from the power law distribution (so-called dragon-kings). We show that it is possible to forecast in real time an impending dragon-king and that they can be suppressed by applying tiny perturbations to the system.

Daniel J. Gauthier
Duke University
gauthier@phy.duke.edu

Hugo Cavalcante
Departamento de Informatica
Universidade Federal da Paraiba
hugo.cavalcante@gmail.com

Marcos Oria
Grupo de Fisica Atomica e Lasers-DF
Universidade Federal da Paraiba
oria@otica.ufpb.br

Didier Sornette
Department of Management, Technology and Economics
ETH Zurich
dsornette@ethz.ch

Ed Ott
University of Maryland
eo4@umail.umd.edu

MS31

Extreme Events in Stochastic Multistable Systems

Pulses with extremely large amplitude appear in a system with coexisting attractors subject to stochastic processes. We demonstrate the emergence of such pulses in fiber and semiconductor lasers close to saddle-node bifurcations, and show how their probability depends on noise and laser parameters.

Alexander N. Pisarchik
Centro de Investigaciones en Optica
apisarch@cio.mx

Ricardo Sevilla-Escoboza, Guillermo Huerta-Cuellar, Rider Jaimes-Reátegui
Centro Universitario de los Lagos
Universidad de Guadalajara
sevillaescoboza@gmail.com, g.huerta@lagos.udg.mx, rjaimes@culagos.udg.mx

MS32

Convergent Heat Conduction in One-Dimensional Lattices with Dissociation

The paper considers highly debated problem of convergence of heat conductivity in one-dimensional chains. We conjecture that the convergence may be promoted due to possibility of the chain to dissociate. To clarify this point, we study the simplest model of this sort – a chain of linearly elastic rods with finite size. Formation of gaps between the rods is the only possible mechanism for scattering of the elastic waves. Heat conduction in this system turns out to be convergent. Moreover, an asymptotic behavior of the heat conduction coefficient for the case of large densities and relatively low temperatures obeys simple Arrhenius-type law.

Oleg Gendelman
Technion Israel Institute of Technology
ovgend@tx.technion.ac.il

Alexander Savin
Institute of Chemical Physics, Moscow, Russia
asavin00@gmail.com

MS32

Bistable Nonlinear Energy Sink Coupled System for Energy Absorption and Harvesting

The nonlinear dynamics of a two-degree-of-freedom system consisting of a linear oscillator (LO) coupled to a bistable light attachment (NES) is investigated. The parameters of the bistable NES are optimized in order to make it functioning as a linear TMD for low-amplitude, in-well, oscillations. The energy transfer mechanisms between the LO and the NES are discussed in order to assess the potential of this configuration for absorption and harvesting purposes.

Francesco Romeo
University of Rome - La Sapienza
francesco.romeo@uniroma1.it

Giuseppe Habib
University of Liege
giuseppe.habib@ulg.ac.be

MS32

Stochastic Closure Schemes for Bi-stable Energy Harvesters Excited by Colored Noise

The goal of this work is the development of a closure methodology that can overcome the limitations of traditional statistical linearization/Gaussian closure schemes and can approximate the steady state statistical structure of bistable systems. Our approach is based on the minimization of a cost functional that expresses i) second-order moment information for the dynamics and ii) pdf representation constraints for bi-stable systems. Our results compare favorably with direct Monte-Carlo simulations.

Themistoklis Sapsis
Massachusetts Institute of Techonology
sapsis@mit.edu

Han Kyul Joo
MIT
hkjoo@mit.edu

MS32

Acceleration of Charged Particles in the Presence of Fluctuations

We consider resonances-driven acceleration and energy transport of charged particles in the earth magnetotail in the presence of high-frequency fluctuations of the background magnetic field. We show that fluctuations significantly affect both capture into resonance, by forcing particles to escape from the surfatron resonance and thus altering the resulting energy spectrum of particles; and scattering by resonance, by changing the structure of beamlets, which are regular islands in chaotic sea.

Africa Ruiz Mora, Dmitri Vainchtein
Dept. of Mechanical Engineering
Temple University, USA
tuf41522@temple.edu, dmitri@temple.edu

MS33

Models of Large Deviations and Rare Events for Optical Pulses

In optical systems, amplified spontaneous emission noise leads to errors if noise-induced fluctuations are large. We discuss methods for modeling large deviations in such systems. In particular, we show how the problem of finding large deviations can be formulated as a constrained optimization problem that combines the pulse evolution equation and, in some cases, a detector model. The results of the combined optimization are then used to guide importance-sampled Monte-Carlo simulations to compute error probabilities.

William Kath
Department of Applied Mathematics, Northwestern University
Department of Neurobiology, Northwestern University
kath@northwestern.edu

MS33

Influence of Periodic Modulation in Extreme Optical Pulses

Semiconductor lasers with optical injection display a rich variety of behaviours, including extreme pulses, which have been identified as rogue waves (RWs). We have shown that RWs can be completely suppressed via direct current modulation, with appropriated modulation amplitude and frequency. Here we show that, when RWs are not suppressed, their probability depends on the modulation phase. There are "safe' windows where no RWs occur. The most extreme RWs occur at the window boundary.

Cristina Masoller
Universitat Politècnica de Catalunya (UPC
Departament de Fsica i Enginyeria Nuclear (DFEN)
cristina.masoller@gmail.com

MS33

Rare Events in Stochastic Dynamical Systems with Delay: From Random Switching to Extinctions

We consider delayed multi-attractor noise-induced switching, and extinction in populations systems with delay near bifurcation points. For weak noise, the rates of inter-attractor switching and extinction are exponentially small. Finding these rates is formulated as a set of acausal variational problems, which in turn give the most probable paths followed in switching or extinction. Explicit general theoretical results obtained show the analytical results agree well with the numerical simulations for both switching and extinction rates.

Ira B. Schwartz
Naval Research Laboratory
Nonlinear Dynamical Systems Section
ira.schwartz@nrl.navy.mil

Thomas W. Carr
Southern Methodist University
Department of Mathematics
tcarr@smu.edu

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

Mark Dykman
Michigan State University
dykman at pa.msu.edu.

MS33

Rare Event Extinction on Stochastic Networks

We consider stochastic extinction of an epidemic on a network. We use a pair-based proxy model for nodes and links for a susceptible-infected-susceptible (SIS) epidemic on a random network. Extending the theory of large deviations to random networks, we predict extinction times and find the most probable path to extinction. Predictions are shown to agree well with Monte Carlo simulations of the network.

Leah Shaw
College of William and Mary
lbshaw@wm.edu

Brandon S. Lindley
Naval Research Laboratory
blindley@nlsleah.nrl.navy.mil

Ira B. Schwartz
Naval Research Laboratory
Nonlinear Dynamical Systems Section
ira.schwartz@nrl.navy.mil

MS34

A Mathematical Model of Cancer Stem Cell Lineage Population Dynamics with Mutation Accumulation and Telomere Length Hierarchies

Cancer develops when cells acquire a sequence of mutations, which determines a hierarchy among the cells, based on how many more mutations they need to accumulate in order to become cancerous. Telomere loss and differentiation define another cell hierarchy, on top of which is the stem cell. This mutation-generation model combines the mutation-accumulation hierarchy with the differentiation hierarchy of the cells, allowing us to take a step further in examining cancer acquisition and growth.

Georgi Kapitanov
Department of Mathematics
Purdue University
georgi-kapitanov@uiowa.edu

MS34

How Much and How Often? Mathematical Models of Cancer Vaccine Delivery

Cancer immunotherapy was heralded as the Breakthrough of the Year 2013 by Science magazine due to innovations in strategies to harness the immune system to fight cancer. Yet many questions remain unanswered: What is the correct mixture of therapies to give, in what order should they be given, and according to what schedule? In this talk I will present mathematical models that can be used to suggest answers to these questions.

Ami Radunskaya
Pomona College
Mathematics Department
aer04747@pomona.edu

MS34

A Cell Population Model Structured by Cell Age

Incorporating Cell-cell Adhesion

An analysis is given of a continuum model of a proliferating cell population, which incorporates cell movement in space and cell progression through the cell cycle. The model consists of a nonlinear partial differential equation for the cell density in the spatial position and the cell age coordinates. The equation contains a diffusion term corresponding to random cell movement, a nonlocal dispersion term corresponding to cell-cell adhesion, a cell age dependent boundary condition corresponding to cell division, and a nonlinear logistic term corresponding to constrained population growth. Basic properties of the solutions are proved, including existence, uniqueness, positivity, and long-term behavior dependent on parametric input. The model is illustrated by simulations applicable to in vitro wound closure experiments, which are widely used for experimental testing of cancer therapies.

Glenn Webb
Department of Mathematics
Vanderbilt University
glenn.f.webb@vanderbilt.edu

MS34

Mathematical Models of the Treatment of Chronic Lymphocytic Leukemia with Ibrutinib and the Development of Drug Resistance

Chronic lymphocytic leukemia (CLL) is the most common leukemia in the western world. A recently developed targeted kinase inhibitor, ibrutinib, has shown very promising results in clinical trials and has now been approved for the treatment of the disease. I will discuss mathematical models that have been used to analyze the dynamics of CLL cells during drug therapy, and show how this model can be used to estimate parameters and obtain important insights into the mechanisms of action of the drug. Further, I will discuss mathematical models that seek to predict the duration for which ibrutinib can maintain control of the disease, and when drug resistance causes relapse of the disease.

Dominik Wodarz
Dept. of Ecology and Evolutionary Bio
University of California, Irvine
dwodarz@uci.edu

MS35

Inertia Effects in the Dynamics of Spherical and Non-Spherical Objects at Low Reynolds Number

Particles moving in a fluid at low but finite Reynolds numbers experience hydrodynamic forces that may be significantly affected by fluid inertia. As a result the particle dynamics (both translational and rotational) may be strongly altered. This presentation aims at presenting theoretical tools, essentially based on matched asymptotic expansions, which allow to take these effects into account in certain situations.

Fabien Candelier
Aix-Marseille University
France
fabien.candelier@univ-amu.fr

MS35

Influence of the History Force on Inertial Particle Advection: Gravitational Effects and Horizontal Diffusion

We study the advection dynamics of inertial particles in order to understand the sedimentation of marine snow. In this work we analyze the effect of the Basset force, an integral over the particle's history, on the advection of slowly moving, dense or nearly neutral particles in the presence of gravity. We highlight the parameters and select case studies where memory changes the vertical and horizontal transport.

Ksenia Guseva
University of Oldenburg, Theoretical Physics/Complex Systems
Oldenburg, Germany
ksenia.guseva@uni-oldenburg.de

Ulrike Feudel
University of Oldenburg
ICBM, Theoretical Physics/Complex Systems
ulrike.feudel@uni-oldenburg.de

Tamas Tel
Eötvös Loránd University, Budapest, Hungary
Institute for Theoretical Physics
tel@general.elte.hu

MS35

Effect of Fluid and Particle Inertia on the Dynamics and Scaling of Ellipsoidal Particles in Shear Flow

Simulations of the rotational behaviour of ellipsoidal particles in linear shear flow are made by the Lattice Boltzmann Method. As fluid and/or particle inertia is increased, a number of rotational states are observed and the bifurcation sequence is detected and analysed. The behaviour of triaxial particles will be presented in some detail. It is observed that the drift to chaotic rotation observed in creeping flow seems to be less significant with fluid inertia present.

Tomas Rosen
KTH Mechanics
Royal Institute of Technology
rosen@mech.kth.se

Yusuke Kotsubo
Tokyo University
yusuke@fel.t.u-tokyo.ac.jp

Cyrus Aidun
G.W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
cyrus.aidun@me.gatech.edu

Fredrik Lundell
KTH Stockholm
Sweden
fredrik@mech.kth.se

MS35

The Effect of Particle and Fluid Inertia on the Dynamics of Particles in Flows

The dynamics of a very small particle suspended in a fluid flow is simple: the centre-of-mass is advected by the fluid velocity, and the orientational dynamics is determined by the sequence of fluid-velocity gradients that the particle experiences. For larger particles inertial effects may become important. Particle inertia is relatively straightforward to treat and there has recently been substantial progress in understanding its effect upon the dynamics of particles in flows. The effect of fluid inertia, by contrast, is more difficult to describe. In this talk I will review what is known about the effect of fluid inertia upon the translational and orientational motion of particles in flows.

Bernhard Mehlig
Gothenburg Univ
Gothenburg, Sweden
Bernhard.Mehlig@physics.gu.se

MS36

How Nonsmooth Are the Earth Sciences?

Geological folding of sedimentary rock layers is often thought of as being a smooth process, leading to regular sinusoidal folds. In fact, a look at actual rocks will show you that they often fold in a different non-smooth manner, with sharp corners. Such folding patterns include kink bands and (zig-zag) chevron folds. Non-smooth features are often linked to the presence of (possibly precious) minerals deep underground. In this talk I will develop a theory for such non-smooth behaviour which accounts for the friction and compression between rock layers. This theory gives a consistent description of the non-smooth folding patterns in terms of novel homoclinic bifurcations.

Chris Budd
Dept. of Mathematical Sciences
University of Bath, UK
mascjb@bath.ac.uk

Tim J. Dodwell
Bath Institute of Complex System
tjd20@bath.ac.uk

MS36

Analysis of an Arctic Sea Ice Model in a Nonsmooth Limit

We analyze an energy balance model for the Arctic, which takes the form of a low-dimensional, periodically forced dynamical system that captures key feedbacks, in the limit of discontinuous ice-albedo feedback. This mathematical simplification enables detailed analysis and provides intuition for the role that the discontinuity boundary in phase space plays in the bifurcation structure of the model. We explore how this analysis provides an alternative perspective on previous numerical studies of this model.

Kaitlin Hill
Engineering Sciences and Applied Mathematics
Northwestern University
k-hill@u.northwestern.edu

Mary Silber
Northwestern University
Dept. of Engineering Sciences and Applied Mathematics
m-silber@northwestern.edu

MS36

Mathematical Quantifications of Resilience

Roughly speaking, resilience refers to the capacity of a system to absorb disturbance and still retain its structure and function. This ecologically and socially relevant definition of resilience is used in ecology, medicine, and climate science, and by policy makers in community, government and conservation efforts. Despite this fast growing interest in resilience across the sciences and social sciences, there is little work done to describe resilience in quantifiable mathematical terms. The Resilience Focus Group of the Mathematics and Climate Research Network is working on quantifiable definitions of resilience. A continuous dynamical system is used to model the undisturbed ecological or biological system, but what kind of perturbations best model disturbance to the system? How is resilience different from Lyaponov stability of the system? What metrics could we use to understand this difference?

Alanna Hoyer-Leitzel
Mathematics Department
Bowdoin College
ahoyerle@bowdoin.edu

MS36

The Search for Glacial Cycles: A Quasiperiodically Forced Nonsmooth System in a Conceptual Climate Model

The glacial-interglacial cycle provides mesmerizing dynamical system and modeling topics. We present a novel energy balance model with glacial mass balance adjustment. The model is a non-smooth dynamical system with nonautonomous orbital forcing, exhibiting a similar sawtooth result typical of glacial and interglacial cycles. Some future dynamical challenges will be outlined.

Esther Widiasih
Mathematics and Science Subdivision
University of Hawai'i West O'ahu
widiasih@hawaii.edu

James Walsh
Oberlin College
jawalsh@oberlin.edu

Richard McGehee, Jonathan Hahn
University of Minnesota
mcgehee@math.umn.edu, hahnx240@umn.edu

MS37

Probabilistic Approach to Deployment Strategy in Lagrangian Data Assimilation

A sequence of position observations by Lagrangian instruments, such as drifters and floats, contains time-integrated information of local flow velocity along the trajectories. Direct assimilation of these Lagrangian observations is effective in estimating time-evolving, underlying flow. Along a trajectory, each observation has a limited region of influence where dynamic correlation to the observation location is significant. Because trajectories are governed by the Lagrangian geometry of the underlying flow, design of the deployment strategy should take into account the detection of the Lagrangian geometry. However, even when the underlying flow is perfectly known, detection of the Lagrangian geometry is challenging. In this talk, we present a probabilistic approach to Lagrangian data assimilation that incorporates the detection of the Lagrangian geometry while estimating the underlying flow and design the

deployment strategy accordingly.

Kayo Ide
Dept. of Atmospheric and Oceanic Sciences
University of Maryland, College Park
ide@umd.edu

MS37

A Quantitative Measure of Observability for Data Assimilations

For complicated systems found in numerical weather prediction, we introduce a characterization of observability to quantify the quality of information provided by sensors and prior knowledge. Optimal sensor positions can be found by maximizing the observability. To evaluate the performance of this method we consider the assimilation sensitivity of the optimized sensors as well as the performance in Monte Carlo experiments against test cases. Lastly we discuss the application of the method to mobile sensors.

Wei Kang
Naval Postgraduate School
Department of Applied Mathematics
wkang@nps.edu

Sarah King, Liang Xu
Naval Research Laboratory
sarah.king.ctr@nrlmry.navy.mil,
liang.xu@nrlmry.navy.mil

MS37

Multivehicle Motion Planning in the Presence of Ocean Eddies

We present a path-planning paradigm for a team of autonomous sampling platforms in the presence of coherent ocean eddies. Vehicle paths near eddies are planned by utilizing Hamiltonian dynamics with added dissipation to generate control vector fields for vehicle guidance. The path-planning framework is based on the concept of an active singularity whose strength is a tunable control input. The active singularities are associated with individual vehicles and the Hamiltonian structure of their dynamics enables a principled method for motion planning.

Frank D. Lagor
University of Maryland
Department of Aerospace Engineering
flagor@umd.edu

Derek A. Paley
University of Maryland
Dept. Aerospace Engineering and Inst. for Systems Research
dpaley@umd.edu

MS37

Bayesian Nonlinear Smoothing and Mutual Information for Adaptive Sampling

New schemes are presented for optimal Bayesian nonlinear state estimation and adaptive sampling of nonlinear fluid and ocean dynamical systems, both forward and backward in time. The Bayesian nonlinear smoothing combines reduced-order Dynamically-Orthogonal (DO) equations with Gaussian Mixture Models (GMMs), extending linearized backward pass updates to a Bayesian nonlinear setting. Bayesian nonlinear adaptive sampling schemes are then derived to predict the observations to be collected that maximize the mutual information about variables of interest. Examples are provided for fluid and ocean flows. This is joint work with our MSEAS group at MIT.

Tapovan Lolla, Pierre Lermusiaux
MIT
ltapovan@mit.edu, pierrel@mit.edu

MS38

A 3D Model of Cell Signal Transduction

We consider a 3D model of cell signal transduction in which the enzymes promoting the various stages in the signal are in fixed positions within the cell. We use the method of matched asymptotic expansions to reduce the partial differential equation modeling the signal transduction process to a system of ordinary differential equations. We consider various bifurcations and the addition of delay to the system.

David Iron
Dalhousie University, Canada
iron@mathstat.dal.ca

MS38

Organization of Metabolic Reactions for Improved Efficiency: Carbon Fixation and Bioengineering Applications

Recent advances in the experimental understanding of cellular organization motivate the need for novel spatial modeling of reactions in cells. Cells organize biochemical reactions to optimize growth, prevent toxic side-reactions, and direct metabolic flux. We review recent experimental work, traditional methods for modeling metabolic networks, and open problems. We present an example model of how the organization of carbon fixation reactions in photosynthetic bacteria improves reaction efficiency reducing the energy needed for growth of cells.

Niall M. Mangan
Massachusetts Institute of Technology
mangan@mit.edu

MS38

An Spatial Model of Anti-Cancer Drug Resistance: the Role of the Micro-Environment

Although resistance to chemotherapeutic agents seems to be bound to appear, it is difficult to determine whether it arises prior to, or as a result of, cancer therapy. We developed a hybrid discrete-continuous mathematical model to explore anti-cancer drug resistance development. We describe cells through a particle-spring approach responding to changing levels of oxygen and drug concentrations, using partial differential equations. We consider two kinds of resistance (namely pre-existing and acquired) and explore the role of microenvironmental niches of drug and oxygen in tumor cell survival and tumor expansion.

Kerri-Ann Norton
Johns Hopkins University
Department of Biomedical Engineering
knorton4@jhmi.edu

Kasia Rejniak
H. Lee Moffitt Cancer Center & Research Institute

Integrated Mathematical Oncology
kasia.rejniak@moffitt.org

Jana Gevertz
The College of New Jersey
gevertz@tcnj.edu

Judith Pérez-Velázquez
Helmholtz Zentrum München
Institute of Computational Biology
perez-velazquez@helmholtz-muenchen.de

Zahra Aminzare
Rutgers university
zahra.aminzare@gmail.com

Alexandria Volkening
Brown University
alexandria_volkening@brown.edu

MS38

Synthetic Genetic Circuits for Spatial Patterning

One promise of synthetic biology is the creation of genetic circuitry that enables the execution of logical programming in living cells. Our lab has previously engineered intracellular and multicellular oscillators that give robust dynamic behavior and observed them at the single cell and colony level using time-lapse microscopy. We have recently turned to the task of creating a circuit giving robust spatial oscillations of gene expression in a population – stripes. The key to robust oscillations in temporal genetic oscillators was positive feedback coupled to delayed negative feedback. In the spatial case, time delay corresponds to spatial offset, suggesting that stripe formation will require local positive feedback coupled to long-range negative feedback. This is essentially the model of pattern formation first described by Turing and expanded on by Gierer and Meinhardt. These models as originally formulated require two signals diffusing at very different rates, but similar patterning mechanisms can function even if the two signals diffuse at the same rate. Signals that do not crosstalk are required for these patterning mechanisms, but orthogonal signals for synthetic genetic circuits have proved elusive. Recently we have developed a system that permits two signals to be used in the same cell and her we describe efforts to construct self-organizing genetic circuits using this new tool.

Paul Steiner
University California San Diego
San Diego, CA USA
paul.jamesen@gmail.com

MS39

Reduced Models for Granular and Ecological Dynamics

The potency of reduced dynamical models is illustrated with two examples: First, by a sequence of reductions from infinite-dimensional to discrete dynamical models of granular flows. The effectiveness of these models for predicting granular dynamics is demonstrated, as are some innovative integrability results they have inspired. Secondly, effective reduced discrete dynamical models for ecological dynamics are described and analyzed, and some associated serendipitous insights on the identification and analysis of strange attractors are outlined.

Denis Blackmore
New Jersey Institute of Technology
Newark, NJ 07102, USA
deblac@m.njit.edu

Anthony Rosato
New Jersey Institute of Technology
Newark, NJ 07102, USA
anthony.rosato@njit.edu

Hao Wu
New Jersey Institute of Technology
Newark, NJ 07102 USA
wh45@njit.edu

MS39

Collective Coordinates as Model Reduction for Nonlinear Wave Interactions

The linear superposition of two traveling wave solutions of a PDE offers a quantitative description of nonlinear wave interactions, provided certain parameters, usually termed "collective coordinates", of the shapes (e.g., the trajectories of the centers) are considered unknown a priori. For PDEs with Hamiltonian structure, substituting such an ansatz into the Lagrangian leads to a reduced-order dynamical model (a "coarse-grain" description) in the form of (a few) coupled nonlinear ODEs. To demonstrate the versatility of this variational technique, the sine–Gordon wave and the $K^*(l,p)$ evolution equations are considered.

Ivan C. Christov
Los Alamos National Laboratory
christov@alum.mit.edu

MS39

On the Calogero Type Integrable Discretization of Nonlinear Dynamical Systems

The Calogero type matrix discretization scheme is applied to constructing Lax type integrable discretizations of nonlinear dynamical systems. The Lie-algebraic integrability properties of co-adjoint flows on the related Markov type Lie algebras are discussed.

Anatolij Prykarpatski
AGH University of Science and Technology
30-059 Krakow, Poland
pryk.anat@ua.fm

MS39

A Scheme for Modeling and Analyzing the Dynamics of Logical Circuits

It is shown how logical circuits can be modeled by discrete dynamical systems. While continuous dynamical systems provide quite accurate mechanistic models, they tend to be computationally expensive to simulate. In contrast, simulating a discrete dynamical system is relatively inexpensive. A model for the RS flip-flop circuit is constructed using chaotic NOR gates. Next, a systematic - algorithmic - first principles approach is developed and shown to be useful in obtaining models of more complicated logical circuits.

Aminur Rahman

New Jersey Institute of Technology
ar276@njit.edu

MS40

Predator-Swarm Interactions

We propose a minimal model of predator-swarm interactions which captures many of the essential dynamics observed in nature. Different outcomes are observed depending on the predator strength. For a weak predator, the swarm is able to escape the predator completely. As the strength is increased, the predator is able to catch up with the swarm as a whole, but the individual prey is able to escape by confusing the predator: the prey forms a ring with the predator at the centre. For higher predator strength, complex chasing dynamics are observed which can become chaotic, and eventually leading to successful prey capture. Our model is simple enough to be amenable to a full mathematical analysis, which is used to predict the shape of the swarm as well as the resulting predatorprey dynamics as a function of model parameters. The complex shape of the swarm in our model during the chasing dynamics is similar to the shape of a flock of sheep avoiding a shepherd.

Theodore Kolokolnikov
Dalhousie University
tkolokol@mathstat.dal.ca

MS40

Non-Standard Travelling Waves in Traffic and Pedestrian Flow Models

Non-standard waves for particle models of car traffic and pedestrian flow are presented and analyzed both analytically and numerically. The car traffic model is an extended optimal velocity model with velocity dependent driver strategies which shows traveling multi-pulse traffic jams and modulated waves. The pedestrian model is based on a social force model with asymmetric couplings (pedestrians in front have bigger influence on the pedestrian behaviour) and shows transitions to multi-lane waves and peristaltic motion.

Paul Carter
Division of Applied Mathematics
Brown University
paul_carter@brown.edu

Peter Leth Christiansen
Department of Applied Mathematics and Computer Science
Technical University of Denmark
plch@dtu.dk

Yuri Gaididei
Bogolyubov Institute for Theoretical Physics
Kiev
yurgaid@gmail.com

Carlos Gorria
Department of Applied Mathematics and Statistics
University of the Basque Country
carlos.gorria@ehu.es

Christian Marschler
Technical University of Denmark
Department of Mathematics and Computer Science
chrms@dtu.dk

Bjorn Sandstede
Division of Applied Mathematics
Brown University
bjorn_sandstede@brown.edu

Mads Peter Soerensen
Department of Mathematics
Technical University of Denmark
M.P.Soerensen@mat.dtu.dk

Jens Starke
Technical University of Denmark
Department of Mathematics
j.starke@mat.dtu.dk

MS40

Topological Data Analysis of Biological Aggregation Models

We apply tools from topological data analysis to two mathematical models inspired by biological aggregations such as bird flocks, fish schools, and insect swarms. Our data consists of numerical simulation output from the models of Vicsek, *et al.* and D'Orsogna, *et al.*. These models are dynamical systems describing the movement of agents who interact via alignment, attraction, and/or repulsion. Each simulation time frame is a point cloud in position-velocity space. We analyze the topological structure of these point clouds, interpreting the persistent homology by calculating the first few Betti numbers. These Betti numbers count connected components, topological circles, and trapped volumes present in the data. To interpret our results, we introduce a visualization that displays Betti numbers over simulation time and topological persistence scale. We compare our topological results to order parameters typically used to quantify the global behavior of aggregations, such as polarization and angular momentum. The topological calculations reveal events and structure not captured by the order parameters.

Chad M. Topaz
Macalester College
ctopaz@macalester.edu

Lori Ziegelmeier, Tom Halverson
Dept. of Mathematics, Statistics, and Computer Science
Macalester College
lziegel1@macalester.edu, halverson@macalester.edu

MS40

Modeling Stripe Formation in Zebrafish

Zebrafish is a small fish with distinctive black and yellow stripes that form due to the interaction of different pigment cells. We present a comprehensive agent-based model for stripe formation in zebrafish that describes the full spectrum of biological data: development from a larval pre-pattern, ablation experiments, and mutations. We find that fish growth shortens the necessary scale for long-range interactions and that iridophores, a third type of pigment cell, maintain stripe boundary integrity.

Alexandria Volkening
Brown University
alexandria_volkening@brown.edu

Bjorn Sandstede
Division of Applied Mathematics

Brown University
bjorn_sandstede@brown.edu

MS41

Stability of Power Grid: Dynamical Systems Perspective

Power grids can be conveniently represented as dynamical systems. Their normal operations depend on two kinds of stability: steady state and transient stability. An overview of the techniques for estimation of both types of stability will be given. An approach for improving the stability based on using electrical vehicles plugged to the grid will be presented. Influence of the delays on the stabilization will be also shown.

Andrej Gajduk
Macedonian Academy of Sciences and Arts, Skopje, Macedonia
agajduk@manu.edu.mk

Mirko Todorovski
Ss Cyril and Methodius University, Faculty of electrical eng
mirko@feit.ukim.edu.mk

Lasko Basnarkov
Macedonian Academy of Sciences and Arts
lasko.basnarkov@gmail.com

Ljupco Kocarev
University of California, San Diego
Institute for Nonlinear Science
lkocarev@ucsd.edu

MS41

Analysis of Systems in Buildings Using Koopman Operator Methods

Commercial buildings consume 20% of U.S. energy half of which is due to Heating, Ventilation, & Air Conditioning. Due to the multiple time-scales and spatial configurations of HVAC sub-systems, energy efficiency is difficult to achieve. By projecting building time-series data onto eigenmodes of the Koopman operator, interactions between sub-systems become identifiable leading to improved building performance. Technique is illustrated on model simulated predictions and actual sensor data.

Michael Georgescu
University of California, Santa Barbara
mvgeorge@engineering.ucsb.edu

MS41

Time Series Prediction for Renewable Energy Resources

The prediction of renewable energy outputs is almost equivalent to weather forecasting, although the time resolutions often required are different between these two: the prediction of renewable energy often needs the finer resolution that can go down to the orders of seconds and minutes. The prediction of renewable energy outputs of such a finer resolution can be realized by employing time series prediction with empirical observations rather than refining outputs of global circulation models.

Yoshito Hirata
Institute of Industrial Science
The University of Tokyo
yoshito@sat.t.u-tokyo.ac.jp

Kazuyuki Aihara
JST/University of Tokyo, Japan
Dept of Mathematical Sciences
aihara@sat.t.u-tokyo.ac.jp

Hideyuki Suzuki
University of Tokyo
hideyuki@mist.i.u-tokyo.ac.jp

MS41

Hierarchical Subsystem Clustering for Distributed Control of Networked Systems

We examine hierarchical subsystem clustering for networked systems in the framework of hierarchical distributed control proposed by the authors. More specifically, for various existing clustering methods such as the K-means method, we numerically examine stability as well as control performance of the whole control system with resultant subsystem clusters. This study is expected to be a first step towards development of hierarchical distributed control theory with systematic determination of subsystem clustering.

Tomonori Sadamoto, Takayuki Ishizaki, Jun-ichi Imura
Tokyo Institute of Technology
sadamoto@cyb.mei.titech.ac.jp, ishizaki@mei.titech.ac.jp, imura@mei.titech.ac.jp

MS42

On the Relationship Between Koopman Mode Decomposition and Dynamic Mode Decomposition

We present an explicit relationship between Koopman Mode Decomposition (KMD) of dynamical systems and companion-matrix version of Dynamic Mode Decomposition (DMD). We use this relationship to explain some of the differences in the variants of DMD algorithm. We also discuss some applications of DMD as a tool to extract Koopman modes from experimental and computational data.

Hassan Arbabi
UC Santa Barbara
arbabi@umail.ucsb.edu

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

MS42

Extracting Spatial-Temporal Coherent Patterns in Large-Scale Neural Recordings Using Dynamic Mode Decomposition

There is a broad need in the neuroscience community to understand and visualize large-scale recordings of neural activity, big data acquired by tens or hundreds of electrodes simultaneously recording dynamic brain activity over minutes to hours. Such dynamic datasets are characterized by coherent patterns across both space and time, yet existing computational methods are typically restricted to analysis either in space or in time separately. Here we report the adaptation of dynamic mode decomposition (DMD), an algorithm originally developed for the study of fluid physics, to large-scale neuronal recordings. We validated the DMD approach on sub-dural electrode array recordings from human subjects performing a known motor activation task. Next, we leveraged DMD in combination with machine learning to develop a novel method to extract sleep spindle networks from the same subjects. We suggest that DMD is generally applicable as a powerful method in the analysis and understanding of large-scale recordings of neural activity.

Bing W. Brunton
University of Washington
bbrunton@uw.edu

MS42

Dynamic Mode Decomposition with Control with a Special Focus on Epidemiological Applications

Here, we present a new method called Dynamic Mode Decomposition with control (DMDc) which, similar to Dynamic Mode Decomposition (DMD), finds low-order models from high-dimensional, complex systems, but now incorporates the effect of external control. In contrast to DMD, DMDc is capable of producing an accurate input-output model recovering the dynamics and modes without being corrupted by external forcing. We focus on a set of epidemiological applications which have both dynamics and interventions (control).

Joshua L. Proctor
Intellectual Ventures
JoshLProctor@gmail.com

MS42

A Rigorous Definition and Theory of Dynamic Mode Decomposition

Dynamic mode decomposition (DMD) is often described algorithmically, rather than through a set of defining mathematical properties, as other decompositions are. In this talk, we present a formal definition of DMD that agrees with the familiar algorithmic descriptions. This establishes a foundation from which new theory and algorithms can be developed. For instance, it allows for non-sequential datasets and elucidates the connections between DMD, Koopman operator theory, the eigensystem realization algorithm, and linear inverse modeling.

Jonathan H. Tu
UC Berkeley
jhtu@berkeley.edu

Clarence Rowley
Princeton University
Department of Mechanical and Aerospace Engineering
cwrowley@princeton.edu

MS43

Methods for Implementing Exactly Solvable Chaos in Electronic Circuits

Exactly solvable chaos may lend many advantages to applications in radar, communications, computing and security. In order for these technologies to benefit from the use of exactly solvable chaos, these governing equations must be first implemented using various electronic circuit design techniques. This work outlines various methodologies for realizing exactly solvable chaos using mixed-signal electronic circuits, while considering many crucial component design limitations such as frequency response, bandwidth, noise, linearity and parasitics.

Aubrey N. Beal, Robert Dean
Auburn University
anb0011@auburn.edu, deanron@auburn.edu

MS43

A Pseudo-Matched Filter for Solvable Chaos

In the work of Corron *et al.* [Chaos **20**, 023123 (2010)], a matched filter is derived for the chaotic waveforms produced by a piecewise-linear dynamical system. Motivated by these results, we systematically investigate the matched filters properties in order to design a pseudo-matched filter, which captures important features of the matched filter and is realized using first order filters. Using numerical simulations and statistical analyses, we compare the performances of the matched and pseudo-matched filters.

Seth D. Cohen
Ducommun Miltec
Huntsville, AL
seth.cohen@amrdec.army.mil

MS43

Communication Waveforms and Exactly Solvable Chaos

We show that, under practical constraints, an optimal communication waveform is chaotic. That is, we assume a simple matched filter and derive the corresponding basis function that maximizes the receiver signal-to-noise performance. We then consider a communication waveform using this basis function, and surprisingly we find a waveform return map that is conjugate to a chaotic shift map. We also show a relationship of the optimal waveform to an exactly solvable hybrid chaotic oscillator that has been previously reported.

Ned J. Corron
U.S. Army RDECOM
ned.corron@us.army.mil

Jonathan N. Blakely
US Army RDECOM
Jonathan.Blakely@us.army.mil

MS43

Exactly Solvable Chaos in An Electromechanical Oscillator

A novel electromechanical chaotic oscillator is described that admits an exact analytic solution. The oscillator is a hybrid dynamical system with governing equations that include a linear second order ordinary differential equation with negative damping and a discrete switching condition that controls the oscillatory fixed point. The system produces provably chaotic oscillations with a topological structure similar to either the Lorenz butterfly or Rössler's folded-band oscillator depending on the configuration. Exact solutions are written as a linear convolution of a fixed basis pulse and a sequence of discrete symbols. We find close agreement between the exact analytical solutions and the physical oscillations. Waveform return maps for both configurations show equivalence to either a shift map or tent map, proving the chaotic nature of the oscillations.

Lucas Illing
Reed College
illing@reed.edu

MS44

A Measurable Perspective on Finite Time Coherence

The concept of coherent structures in a flow refers to notions of subsets of the flow which preserve some measurable quantity, despite the generally nonlinear flow: something simple embedded in the complexity. Our own perspective of shape coherent sets is defined in terms of flow that is locally as rigid body motions, and uncovered by investigating boundary curvature evolution. Key for unifying to other concepts of coherence is choice of measure interpreted across domains .

Erik Bollt
Clarkson University
bolltem@clarkson.edu

Tian Ma
Department of Mathematics and Computer Science
Clarkson University
mat@clarkson.edu

MS44

Rigorous Numerical Approximation of Invariant Measures – History and Recent Progress

Interest in rigorous schemes to approximate invariant measures in ergodic theory dates back at least to Ulam's celebrated 1960 conjecture about their approximation via finite-dimensional Markov chains. We review this history from the modern perspective of spectral perturbation. Recently, with R. Murray, convex optimization techniques have been proposed; we compare and contrast these with Ulam's scheme. Finally, we place all of these approaches into a unified setting of regularized least-squares optimization for solution of the (ill-posed) Perron-Frobenius fixed point problem.

Chris Bose
Mathematics and Statistics
University of Victoria, Canada
cbose@uvic.ca

MS44

Non-Autonomous Dynamical Systems, Multiplicative Ergodic Theorems and Applications

Non-autonomous dynamical systems yield very flexible models for the study of time-dependent systems, with driving mechanisms ranging from deterministic forcing to stationary noise. Multiplicative ergodic theorems (METs) encompass fundamental information for the study of transport phenomena in such systems, including Lyapunov exponents, invariant measures and coherent structures. In this talk, we will discuss recent developments on METs, motivated by questions coming from oceanic and atmospheric dynamics.

Cecilia Gonzalez Tokman
School of Mathematics and Statistics
University of New South Wales
ceciliagt@unsw.edu.au

Gary Froyland
UNSW Australia
g.froyland@unsw.edu.au

Anthony Quas
University of Victoria
aquas@uvic.ca

MS44

On Triangularization of Matrix Cocycles in the Multiplicative Ergodic Theorem

The Multiplicative Ergodic Theorem shows that a real matrix cocycle is block diagonalizable over the real numbers, given mild hypotheses; that is, the cocycle is cohomologous to one in which the matrices are supported on blocks corresponding to the Lyapunov exponents. We shall talk about block *triangularizing* cocycles, and investigate when this may occur; namely, not all cocycles may be triangularized, even over the complex numbers.

Joseph Horan
Department of Mathematics and Statistics
University of Victoria
jahoran@uvic.ca

MS45

Vibration Energy Harvesting Based on Nonlinear Targeted Energy Transfer

We investigate the use of targeted energy transfer via essential (nonlinearizable) stiffness nonlinearity to promote efficient energy harvesting. The system of interest consists of two oscillators, a linear primary and strongly nonlinear secondary, coupled electromechanically. The primary is a grounded linear oscillator; the secondary, the harvester, is a lightweight oscillating mass attached to the primary mass through a permanent magnet, inductance coil, and untensioned steel wire positioned normal to the direction of the oscillation, which provides the purely cubic essential nonlinearity. Impulsive excitation of the primary at a sufficiently high level results in transient resonance capture with the secondary, resulting in a large-amplitude high-frequency component in the harvester response. Energy generated is harvested in a circuit via the magnet and coil. Performance is demonstrated through both simulation and experiment.

Kevin Remick
Department of Mechanical Science and Engineering
University of Illinois - Urbana- Champaign
remick2@illinois.edu

D Dane Quinn
University of Akron
Dept of Mechanical Engineering
quinn@uakron.edu

D. Michael McFarland
University of Illinois
dmmcf@illinois.edu

Lawrence Bergman
University of Illinois - Urbana - Champaign
lbergman@illinois.edu

Alexander Vakakis
University of Illinois

avakakis@illinois.edu

MS45

Nonlinear Energy Harvesting in Granular Media

In this talk, we explore the possibility of using granular crystals for the purpose of vibration energy harvesting. In particular, we focus on time-periodic structures of such systems and how the interplay of spatial heterogeneity, discreteness and nonlinearity can lead to desirable localization properties. We approach the problem with computational, analytical and experimental tools.

Christopher Chong
ETH Zurich
cchong@ethz.ch

MS45

2D Energy Channeling in the Locally Resonant Acoustic Metamaterials

Dynamics of locally resonant, acoustic meta-materials is a subject of intense study of the past few years. As of today there is a lack of a substantial theoretical understanding of the dynamics of locally resonant, 1D, 2D non-linear lattices. In the present talk I'll present the recent results of the theoretical study of controlled, unidirectional energy transport, wave redirection and nonlinear energy channeling in the locally resonant, 2D metamaterials, incorporating internal rotators.

Yuli Starosvetsky
Technion, Israel Institute of Technology
staryuli@tx.technion.ac.il

Kirill Vorotnikov
Faculty of Mechanical Engineering
Technion - Israel Institute of Technology
kvv@technion.ac.il

MS45

Non-Linearizable Wave Equation: Nonlinear Sonic Vacuum

We consider low-energy oscillations of a finite spring-mass chain in the plane, with geometric nonlinearity generating a smooth nonlinear sonic vacuum with zero speed of sound, and strongly non-local nonlinear terms despite only next-neighbor physical interactions between particles. The nonlinear normal modes of this system are identical to those of a simple linear spring-mass chain. Asymptotic analysis reveals a rich structure of resonance manifolds, mixed standing/traveling waves, and strong nonlinear energy exchanges between modes.

Leonid Manevich
Semenov Institute of Chemical Physics
Russian Academy of Sciences
manevitchleonid3@gmail.com

Alexander Vakakis
University of Illinois
avakakis@illinois.edu

MS46

The Effect of Extrinsic Noise on Gene Regulation

Stochastic gene expression is influenced both by intrinsic noise (IN) arising from intracellular variability and extrinsic noise (EN) arising from intercellular variability. While IN is well understood, a rigorous understanding of how EN influences the function of genetic networks is still lacking. Here we study the IN/EN interplay in simple network motifs, focusing of how EN characteristics affect the overall statistics. Our analytical predictions are compared with Monte-Carlo simulations efficiently accounting for fluctuating reaction rates.

Michael Assaf
Racah Institute of Physics
Hebrew University of Jerusalem
michael.assaf@mail.huji.ac.il

MS46

Fundamental Limits to the Precision of Multicellular Sensing

Single cells sense their environment with remarkable precision. At the same time, cells communicate. How are sensing and communication related? I will describe a system in which epithelial cells, by communicating, can detect shallower chemical gradients than single cells can alone. A minimal stochastic model provides fundamental limits on the precision of communication-aided sensing, which we validate in the experimental system. Our results demonstrate that known sensory limits are altered when communication is accounted for.

Andrew Mugler
Department of Physics and Astronomy
Purdue University
amugler@purdue.edu

Matthew Brennan
Johns Hopkins University
matthew.d.brennan@yale.edu

Andre Levchenko
Yale University
andre.levchenko@yale.edu

Ilya Nemenman
Emory University
ilya.nemenman@emory.edu

MS46

Inferring Predictive Signal-Activated Gene Regulation Models from Noisy Single-Cell Data

Spatial, temporal and stochastic fluctuations can cause genetically identical cells to exhibit wildly different behaviors. At first glance, fluctuations seem to compromise cellular responses, complicate modeling, and disrupt predictive understanding and control. Under closer examination, cellular fluctuations actually become exceptionally useful. I will discuss how integrating single-cell experiments with precise spatiotemporal stochastic analyses can reveal new insight, enable quantitatively predictive models, and improve the controllability of heterogeneous gene regulation

in bacteria, yeast and mammalian systems.

Brian Munsky
College of Engineering
Colorado State University
munsky@engr.colostate.edu

MS46

Coarse-Graining Biochemical Networks

We consider a generic stochastic model either for ion transport through a single channel with arbitrary internal structure or arbitrary enzyme kinetics. We show that measurements of statistics of transition times through specific states of such a system contain only restricted information about parameters of the model. This observation allows one to identify the most relevant variables that can be quickly estimated if statistical measurements are performed on a biochemical process at a single molecule level. For example, we show that the Poisson indicator in enzyme kinetics depends only on three parameters in addition to the parameters of the Michaelis-Menten curve that characterizes average enzyme turnover rate in a very broad class of enzyme models. Nevertheless, measurement of Poisson indicator or Fano factor for such renewal processes can discriminate reactions with multiple intermediate steps as well as provide valuable information about the internal kinetic rates.

Nikolai Sinitsyn
Theoretical division
Los Alamos National Laboratory
sinitsyn@lanl.gov

MS47

Computation of the Koopman Eigenfunctions Is a Systematic Method for Global Stability Analysis

The Koopman operator framework provides a novel approach to global stability analysis of dynamical systems, which can be seen as an extension of classic stablility analysis of linear systems. We show that the existence of specific eigenfunctions of the operator is a necessary and sufficient condition for global stability of the attractor. Moreover, the computation of the eigenfunctions in a polynomial basis yields systematic methods for stability analysis and estimation of the basin of attraction.

Alexandre Mauroy, Igor Mezic
University of California, Santa Barbara
a.mauroy@ulg.ac.be, mezic@engineering.ucsb.edu

MS47

Koopman Mode Expansion in Theory and Practice

We discuss current theory and practice of applications of Koopman operator methods in dynamical systems and its relationship with computational methods. The approach has recently been extended to associate geometrical objects such as isochrons and isostables with level sets of Koopman eigenfunctions. We will also discuss the relationship between numerical methods such as Dynamic Mode Decomposition and Koopman Mode Decomposition, and extensions of theory to stability of nonlinear systems and control.

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

MS47

Generalized Laplace Analysis and Spaces of Observables for the Koopman Operator

We extend Koopman spectral analysis to spectral operators of scalar type having non-unimodular spectrum and give conditions on the spectrum so that spectral projections can be computed using Laplace averages. This naturally extends the theory existing for dynamical systems restricted to an attractor, where spectral projections are computed using Fourier averages, to dissipative systems. For dynamical systems with dissipation, we construct a natural space of observables for which the associated Koopman operator is spectral.

Ryan Mohr
University of California, Santa Barbara
mohrrm@engr.ucsb.edu

MS47

What Can the Koopman Operator Do for Dynamical Systems?

We report on "Operator Theoretic Aspects of Ergodic Theory" as developed in the new monograph with the same name (Springer 2015, coauthored by Tanja Eisner, Balint Farkas, Markus Haase and R.N.) and their applications to nonlinear dynamical systems.

Rainer Nagel
University of Tubingen
rana@fa.uni-tuebingen.de

MS48

An Observational Basis for Sudden Stratospheric Warmings As Bifurcations in Planetary Wave Amplitude

Sudden stratospheric warmings (SSWs) are midwinter events in which the polar cap temperature and circulation undergo large and abrupt changes. Currently two competing theories contend to explain the explosive stratospheric wave amplitude growth that triggers a SSW: anomalously large planetary wave forcing, or nonlinear resonance. In this work we utilize 35 years of atmospheric data to show that SSWs are most likely triggered by a wave amplitude bifurcation due to nonlinear resonance.

John R. Albers
CIRES, University of Colorado
NOAA/ESRL Phys. Sci. Division
john.albers@noaa.gov

MS48

Tropical-Extratropical Wave Interactions in the Atmosphere

The coupling between moist convective processes and large-scale circulation is at the core of tropical-extratropical atmospheric interactions. Observational evidence of this type of phenomena will be presented and a reduced model will be proposed to understand the physical processes underlying this type of multi-scale interactions. In particular, the model will be used to interpret the relative roles of tropical versus extratropical wave sources of moist convection modulations at low latitudes.

Juliana Dias
NOAA Earth System Research Laboratory
juliana.dias@noaa.gov

MS48

The Use of Green Functions of the Shallow Water Model for Understanding Climate Anomalies

Climate anomalies are frequently connected the intensity and positioning of anomalous tropical heat sources. Green Functions of simplified atmospheric models constitute a simple tool for identifying the origin of major climate anomalies. Examples will be shown for the 2014 climate anomalies such as the North American extreme cold period, the flooding in western Europe and the warm conditions in eastern Europe, and the extreme drought in Southeastern South America that caused severe water shortage.

Pedro Leite da Silva Dias
Laboratorio Nacional de Computacao Cientifica, Brazil
IAG, University of Sao Paulo, Brazil
pldsdias@lncc.br

MS48

The Role of Noise in Bifurcations in Fluids and the Atmosphere

Triggering the strongest disturbances to the wintertime stratospheric polar vortex sudden stratospheric warming (SSWs) is to first order governed by the strength of forcing due to planetary-scale atmospheric waves and the vortexs waveguide. Using a model of SSWs, stochastic Kida vortex equations, we show that the basin of attraction is not only more complex than previously believed, but can be significantly altered by additive noise. Resulting soft bifurcation caused by the random basin is the possible mechanism leading to a SSW.

Yuzuru Sato
RIES, Hokkaido University
ysato@math.sci.hokudai.ac.jp

David J. Albers
Colombia University
Biomedical Informatics
dja2119@cumc.columbia.edu.

MS49

Dangerous Border Collision Bifurcation in Piecewise Smooth Maps

A dangerous bifurcation has been defined as a situation where a stable period-1 orbit occurs before and after the bifurcation, and yet the basin of attraction shrinks to zero size at the bifurcation point. It is known that this phenomenon can occur is non-smooth systems. In this paper we generalize the definition to one in which any attracting orbit may exist before and after the bifurcation, and their basins of attraction shrink to zero size at the bifurcation point, resulting in divergence of orbits starting from all initial conditions. Using the normal form of a 2D piecewise smooth map, we develop the conditions and show the parameter space regions where this phenomenon occurs.

Soumitro Banerjee
Indian Institute of Science education & Research,
Kolkata, India
soumitro.banerjee@gmail.com

Arindam Saha
IISER Kolkata, India
arindamsaha1507@gmail.com

Viktor Avrutin
IPVS
University of Stuttgart
viktor.avrutin@ipvs.uni-stuttgart.de

Laura Gardini
University of Urbino
Department of Economics, Society and Politics
laura.gardini@uniurb.it

MS49

Generalized Hopf Bifurcation in a Nonsmooth Climte Model

Low dimensional ocean circulation box models have been used by many scientists to model large scale behavior in ocean dynamics. The convection box model we will discuss in this talk exhibits oscillitory behavior, and so was influential to the field at its time of publication. The model depends on abrupt transitions between two different mixing states, and has a natural nonsmooth limit. In this talk we discuss the Hopf bifurcation in the smooth model, and its continuation to the nonsmooth limit. We will also discuss general forms for this type of nonsmooth Hopf bifurcation.

Julie Leifeld
University of Minnesota
leif0020@umn.edu

MS49

Canard Phenomena in Nonsmooth Systems

This presentation will present new results on canard phenomena in planar nonsmooth systems. Canard explosion in piecewise-smooth, continuous, planar systems will be discussed, including the super-explosion phenomenon. Additionally, the talk will touch on canard trajectories in discontinuous systems. It will be shown that it is possible for a discontinuous system to undergo a canard explosion, where part of the stable canard cycle is a Filippov sliding solution.

Andrew Roberts
Department of Mathematics
The University of North Carolina at Chapel Hill
andrew.roberts@cornell.edu

MS50

Intrinsic Mechanisms for Pattern Generation in Three-Node Networks

Bursting patterns can be qualified and modeled using low-dimensional models. We show that, depending on intrinsic mechanisms of release, escape, and post-inhibitory rebound, reciprocally inhibitory Fitzhugh-Nagumo type networks can produce a range of phase-locked states such as anti-phase bursting, propagating waves, and peristaltic patterns with recurrently phase-varying lags. Phase-lag return maps identify phase states with rhythm switching and attractor robustness revealed using external inhibition.

Our qualification promotes the use of simplified modeling for CPG circuitries.

Jarod Collens
Georgia State University
Neuroscience Institute and Mathematics Department
jcollens1@student.gsu.edu

Aaron Kelley
GSU
aarnkelley@gmail.com

Deniz Alacam
Georgia State University
Mathematics Department
dalacam1@student.gsu.edu

Tingli Xing
Georgia State University
USA
txing1@student.gsu.edu

Drake Knapper
Georgia State University
dknapper1@student.gsu.edu

Justus T. Schwabedal
Neuroscience Institute
Georgia State University
jschwabedal@gmail.com

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

MS50

From Andronov-Hopf to Z_3 Heteroclinic Bifurcations in Cpgs

We study the formation of some rhythmic states in various 3-cell network motifs of a multifunctional central pattern generator (CPG) via several computational tools. The study is complemented with a detailed analysis of a single leech heart neuron, including bifurcations, spike-counting techniques and Lyapunov exponents, that gives a "roadmap" for the basic neuron. We locate a complete route of Andronov-Hopf and heteroclynic cycle connections in the 3-cell leech heart neurons and we illustrate the use of advanced GPU computing technologies and suitable numerical algorithms.

Marcos Rodriguez
Centro Universitario de la Defensa
marcos@unizar.es

Roberto Barrio, Sergio Serrano
University of Zaragoza, SPAIN
rbarrio@unizar.es, sserrano@unizar.es

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

MS50

Key Bifurcations of Bursting Polyrhythms in 3-Cell Central Pattern Generators

We identify and describe the key qualitative rhythmic states in various 3-cell network motifs of a multifunctional central pattern generator (CPG). Such CPGs are neural microcircuits of cells whose synergetic interactions produce multiple states with distinct phase-locked patterns of bursting activity. To study biologically plausible CPG models, we develop a suite of computational tools that reduce the problem of stability and existence of rhythmic patterns in networks to the bifurcation analysis of fixed points and invariant curves of a Poincare return maps for phase lags between cells. We explore different functional possibilities for motifs involving symmetry breaking and heterogeneity. This is achieved by varying coupling properties of the synapses between the cells and studying the qualitative changes in the structure of the corresponding return maps. Our findings provide a systematic basis for understanding plausible biophysical mechanisms for the regulation of rhythmic patterns generated by various CPGs in the context of motor control such as gait-switching in locomotion. Our analysis does not require knowledge of the equations modeling the system and provides a powerful qualitative approach to studying detailed models of rhythmic behavior. Thus, our approach is applicable to a wide range of biological phenomena beyond motor control.

Jeremy Wojcik
Applied Technology Associates, USA
jwojcik1@gsu.edu

Robert Clewley
Georgia State University
Department of Mathematics and Statistics, and
Neuroscience
rclewley@gsu.edu

Justus T. Schwabedal
Neuroscience Institute
Georgia State University
jschwabedal@gmail.com

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

MS51

Impact of Single-Neuron Dynamics on Transfer of Correlations from Common Input

One source of spike train correlations in the nervous system is common input, a consequence of the ubiquity of coding by populations. The details of how input correlations map onto output spike correlations is surprisingly complex, depending on single-neuron dynamics in subtle ways. Much progress has been made in untangling this relationship in Type I and Type II excitable neurons, in both simplified phase oscillator and conductance-based models. In this talk, we apply these techniques to novel patterns of excitability that arise in the presence of calcium currents.

Andrea K. Barreiro
Department of Mathematics
Southern Methodist University

abarreiro@smu.edu

MS51
Integrate-and-Fire Model of Insect Olfaction

When a locust detects an odor, the stimulus triggers a series of synchronous oscillations of the neurons in the antennal lobe, followed by slow dynamical modulation of the firing rates. I model this behavior using an Integrate-and-Fire neuronal network with excitatory and inhibitory neurons, each with a fast and slow inhibitory conductance response. I derived a coarse-grained model for each (excitatory and inhibitory) neuronal population, which allows for more detailed analysis of the olfaction mechanisms.

Pamela B. Fuller
Rensselaer Polytechnic Institute
Fullep@rpi.edu

Gregor Kovacic
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
kovacg@rpi.edu

David Cai
Courant Institute for Mathematical Sciences, NYU
Shanghai Jiao-Tong University
cai@cims.nyu.edu

MS51
A Network of Excitatory and Inhibitory Neurons with Gap Junctions

Brain networks are known to give rise to global oscillations that are linked to synchronized neuronal activity. How these oscillations arise is not yet completely understood. Researchers believe that electric coupling through sites called gap junctions may facilitate their emergence, and determine some of their properties. Following data from experimental papers, we construct a detailed model with synaptic and electric coupling for excitatory and inhibitory neurons using a modified version of the Hodgkin Huxley equations.

Jennifer Kile
Rensselaer Polytechnic Institute
kilej@rpi.edu

Gregor Kovacic
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
kovacg@rpi.edu

David Cai
Courant Institute for Mathematical Sciences, NYU
Shanghai Jiao-Tong University
cai@cims.nyu.edu

MS51
Phase Delayed Inhibition and the Representation of Whisker Deflection Velocity in the Rodent Barrel Cortex

The primary sensory feature represented within the rodent barrel cortex is the velocity with which a whisker has been deflected. Whisker deflection velocity is encoded within the thalamus via population synchrony (higher deflection velocities entail greater thalamic synchrony). Thalamic (TC) cells project to regular spiking (RS) cells within the barrel cortex, as well as to inhibitory cortical fast-spiking (FS) neurons, which in turn project to RS cells. Thus, TC spikes result in EPSPs followed, with a small time lag, by IPSPs within an RS cell; i.e., the RS cell decodes TC population synchrony by employing a phase-delayed inhibition synchrony detection scheme. In this work, we construct a biophysical model of a basic 'building block' of barrel cortex (the feedforward circuit consisting of TC cells, FS cells, and a single RS cell) and we examine the role of the purely feedforward circuit, and of the phase-delayed inhibition network architecture, in explaining the experimental data.

Mainak Patel
College of William and Mary
mjpatel@wm.edu

Runjing Liu
Duke University
runjing.liu@duke.edu

Badal Joshi
California State University, San Marcos
bjoshi@csusm.edu

MS52
Extending the Zero Derivative Principle

The Zero Derivative Principle determines an approximate invariant manifold in a singular perturbation systems of ODEs by repeated differentiation of the slow components of the vector field. We show that even if the slow components are not identified correctly, an approximate invariant manifold still results from the algorithm, a most useful feature for systems with no explicit time scale separation. We show results for the Templator, a simple model for a self-replicating biological system.

Morten Brons
Technical University Denmark
mobr@dtu.dk

Eric Benot
Universite de la Rochelle
ebenoit@univ-lr.fr

Mathieu Desroches, Maciej Krupa
INRIA Paris-Rocquencourt
mathieu.desroches@inria.fr, maciej.krupa@inria.fr

MS52
Idealized Models for Vortex Shedding and Fluid-Body Interactions

The dynamics of free solid bodies in fluids can be influenced significantly by vortex shedding. Although this phenomenon depends fundamentally on fluid viscosity, reduced-order models for vortex shedding can be realized in some cases by imposing velocity constraints on systems involving inviscid fluids. Models obtained in this way can be framed naturally in the context of geometric mechanics and can simplify problems of analysis and control design pertaining to the locomotion of biologically inspired aquatic robots.

Scott D. Kelly
Mechanical Engineering and Engineering Science
University of North Carolina at Charlotte

scott@kellyfish.net

MS52

Visualization of Reduced Granular Dynamics

Reduced dynamical models often lend themselves to straightforward plots of the correspond dynamics. Yet, the intricate geometry and topology of the resulting phase portrait can prove challenging to convey in a picture. In this talk, some recent and ongoing work on the visualization of low-dimensional dynamical systems will be discussed. In particular, results obtained for a reduced model of granular dynamics will be considered. Joint work with D. Blackmore and A. Rosato.

Xavier M. Tricoche
Purdue University
West Lafayette, IN 4707-4348
xmt@purdue.edu

MS52

A Novel Semidiscete Scheme for a Reduced Continuum Flow Model

We focus on numerical methods for solving the BSR equations - a reduced dynamical model for granular and other flows. Using a reliable numerical scheme for the BSR model, we study the dynamics of a vertically tapped column of particles. A novel semi-discrete numerical scheme has been derived to demonstrate the value of BSR models for predicting the evolution of granular and other flows. Simulation results are compared with experiments and DEM results.

Hao Wu
New Jersey Institute of Technology
Newark, NJ 07102 USA
wh45@njit.edu

Denis Blackmore
New Jersey Institute of Technology
Newark, NJ 07102, USA
deblac@m.njit.edu

MS53

Initiation of Rain and Inertial Particles

Abstract not available.

Markus Abel
University of Potsdam
markus.abel@physik.uni-potsdam.de

MS53

Aggregate Growth in Optimizing Steel Production

Abstract not available.

Nikolas Rimbert
Université de Lorraine
nicolas.rimbert@univ-lorraine.fr

MS53

Ostwald Ripening and Nanoparticle Growth

Abstract not available.

Martin Rohloff
MPI Dynamics and Self-Organization Goettingen
martin.rohloff@ds.mpg.de

MS53

Episodic Precipitaton

Abstract not available.

Jürgen Vollmer
Max Planck Institute for Dynamics and Self-Organization
juergen.vollmer@ds.mpg.de

MS54

Model Free Tuning of Wind Farms for Maximizing Power Production

In this minisymposium, we introduce our recent result on the model-free approach for maximizing power production of wind farms. In particular, by exploiting the special structure of the wind farm about turbines location and wind direction, we show our multi-resolution SPSA based method that can achieve fast model-free controller tuning. Simulation results illustrate that the proposed method yields the maximum total power production with faster convergence compared with other existing model-free methods.

Mohd Ashraf Ahmad
Department of Systems Science,
Graduate School of Informatics, Kyoto University
mashraf@ump.edu.my

Shun-Ichi Azuma
Kyoto University
sazuma@i.kyoto-u.ac.jp

Toshiharu Sugie
Department of Systems Science
Kyoto University
sugie@i.kyoto-u.ac.jp

MS54

Basin Stability for Evaluating Large Perturbations in Power Grids

The human brain, power grids etc. are all characterized by multistability. We claim that the traditional linearization-based approach to stability is often too local to adequately assess how stable a state is. Instead, we quantify it in terms of basin stability, a new measure related to the volume of the basin of attraction which is non-local and easily applicable, even to high-dimensional systems and apply it to the Northern European power system.

Juergen Kurths
Humboldt Univ,Germany, Potsdam Institute for Climate Impact
Research, Germany, and Aberdeen University, UK

juergen.kurths@pik-potsdam.de

MS54

Predicting Critical Links in Complex Supply Networks

Link failures repeatedly induce large-scale outages in power grids and other complex supply networks. Yet, which links are particularly sensitive to inducing such outages is still not fully understood. Here we propose two criteria to predict critical links on the basis of the topology of the undamaged network and its load distribution *prior to* link failure. These criteria outperform critical link prediction based on pure loads or flows more than six-fold.

Marc Timme
Network Dynamics, Max Planck Inst. f. Dyn. & Self-Org.
Goettingen, Germany
timme@nld.ds.mpg.de

Dirk Witthaut
Systemforschung und Technologische Entwicklung
(IEK-STE)
Forschungszentrum Julich
d.witthaut@fz-juelich.de

Martin Rohden
Jacobs University Bremen
martin@nld.ds.mpg.de

Xiaozhu Zhang, Sarah Hallerberg
Network Dynamics, Max Planck Inst. Dynamics and
Self-Org.
xzhang@nld.ds.mpg.de, shallerberg@nld.ds.mpg.de

MS55

Compressive Sensing and Dynamic Mode Decomposition

This work explores compression and compressive sensing strategies for computing the dynamic mode decomposition (DMD) from heavily subsampled or output-projected data. We demonstrate this architecture on three model systems. First, we construct a spatial signal from a sparse vector of Fourier coefficients driven by a linear dynamical system. Next, we consider the double gyre flow field, which is a model for chaotic mixing in the ocean. Finally, we explore the 2D cylinder at Re=100.

Steven Brunton
University of Washington
sbrunton@uw.edu

MS55

Improving the Accuracy of Dynamic Mode Decomposition in the Presence of Noise

The usefulness of dynamic mode decomposition (DMD) relies on its ability to extract accurate dynamic features from imperfect, noisy data. By deriving the statistical properties of the DMD algorithm, we demonstrate that sensor noise biases the results of DMD in a predictable manner. We introduce a number of modifications to the DMD algorithm that give improved robustness to noisy data, which are validated on a range of synthetic, numerical and experimental data sets.

Scott Dawson, Maziar S. Hemati
Princeton University
stdawson@princeton.edu, mhemati@princeton.edu

Matthew O. Williams
Program in Applied and Computational Mathematics
Princeton University
mow2@Princeton.edu

Clarence Rowley
Princeton University
Department of Mechanical and Aerospace Engineering
cwrowley@princeton.edu

MS55

Parallel Qr Algorithm for Data-Driven Decompositions, in Particular Dynamic Mode Decomposition

Many fluid flows of engineering applications, although very complex in appearance, can be approximated by lower-order models governed by a few modes, able to capture the dominant behavior (dynamics) of the system. Recently, different techniques have been developed, designed to extract the most dominant coherent structures from the flow. Some of the more general techniques are based on data-driven decompositions, most of which rely on performing a singular value decomposition (SVD) on a formulated snapshot matrix. As the number of degrees of freedom of a simulation increases, the resulting data-matrix becomes longer, otherwise referred to as a tall-and-skinny (TS) matrix. Ultimately, the SVD of a TS data-matrix can no longer be handled on a single processor. To overcome this limitation, the present study employs the parallel TSQR algorithm of Demmel *et al.* (2012), which is further used as a basis of the underlying parallel SVD. This algorithm is shown to scale well on machines with a large number of processors and, therefore, allows the decomposition of very large data-sets.

Taraneh Sayadi, Peter Schmid
Imperial College London
sayadi@illinois.edu, peter.schmid@imperial.ac.uk

MS55

Using Dynamic Mode Decomposition to Extract Linear Global Modes from Nonlinear Fluid Flow Solvers

We present a dynamic mode decomposition (DMD) based technique to capture the dominant linear global modes and eigenvalues using snapshots from a nonlinear flow solver. This approach relies on tracking the growth of perturbation from the base state with a nonlinear solver. The guidelines for the DMD-based analysis to predict stability properties of the flow are discussed. Validations are performed against the global stability analysis based on the linearized flow solver and full eigenvalue problem.

Kunihiko Taira
Florida State University
ktaira@fsu.edu

Aditya Nair
Florida State University
Mechanical Engineering
agn13@my.fsu.edu

Shervin Bagheri
KTH Mechanics

Linné Flow Centre
shervin.bagheri@mech.kth.se

MS56

Morse Homology on Spaces of Braids

A Morse Homological theory is constructed on spaces of braids, allowing us to consider simultaneously distinct periodic solutions of gradient-like scalar ODEs of the form

$$u_s = u_{tt} - u + V(t, u, u_t)$$

with possibly different periods simultaneously. This gives information on existence of certain solutions but also makes it possible to do computation on Floer Homology by linking the (very) infinite dimensional Floer Homology and the finite dimensional Conley Index of a discretised dynamical system.

Patrick Hafkenscheid
VU University Amsterdam
p.hafkenscheid@vu.nl

Robert Vandervorst
VU Amsterdam
Department of Mathematics
vdvorst@few.vu.nl

Marcio Gameiro
University of Sao Paulo
gameiro@icmc.usp.br

MS56

Computing Conley-Morse Databases

Abstract not available.

Shaun Harker
Department of Mathematics
Rutgers University
sharker@math.rutgers.edu

MS56

Rigorous Computing in Strongly Indefinite Problems

Floer homology was originally developed in the late 80s by A. Floer to solve the Arnold Conjecture which states that the number of periodic solutions of a periodic Hamiltonian system is bounded from below by the topological invariants of the manifold on which the Hamiltonian system is defined. In this setting the periodic orbits are the solutions of the Euler-Lagrange equations, i.e. critical points of a strongly indefinite action functional. Being an infinite dimensional version of Morse theory, Floer homology is defined in terms of (1) the critical points; (2) their relative indices; and (3) the connecting orbits between critical points with relative index one. While Floer homology is a powerful and celebrated theory, there remains an outstanding issue: how computable is it? Recent years have witnessed the development of exciting rigorous computational methods to make Conley-Morse homology computable and applicable to a broad class of dynamical systems. Now the question is: can we do the same with Floer-Morse homology? In this talk, we introduce some preliminary results about rigorous computing in Floer homology, i.e. we present a rigorous computational technique to compute critical points of strongly indefinite functional as well as their relative indices.

Jean-Philippe Lessard
Université Laval
jean-philippe.lessard@mat.ulaval.ca

Jan Bouwe Van Den Berg
VU University Amsterdam
janbouwe.vanden.berg@vu.nl

MS56

Reconstructing Functions from Dense Samples

Abstract not available.

Vidit Nanda
Department of Mathematics
University of Pennsylvania
vnanda@sas.upenn.edu

MS57

Global Invariant Manifolds Unravelling Shilnikov Chaos

We analyse the role of two-dimensional global invariant manifolds in the transition through a chaotic Shilnikov homoclinic bifurcation in a 3D model for an optically injected laser. We compute the respective two-dimensional global manifolds, and their intersection curves with a suitable sphere, as families of orbit segments with a two-point boundary-value-problem setup. This allows us to determine how the arrangement of global manifolds changes through the bifurcation and how this influences the topological organisation of phase space. In this way, we find that the stable manifold of the associated saddle-focus is an accessible set of the stable manifold of a chaotic saddle (the Shilnikov chaotic set) that contains countably many periodic orbits of saddle type. In intersection with a suitably chosen sphere we find that this stable manifold is an indecomposable continuum consisting of infinitely many closed curves that are locally a Cantor bundle of arcs.

Pablo Aguirre
Universidad Técnica Federico Santa Mara
Departamento de Matemática
pablo.aguirre@usm.cl

Bernd Krauskopf, Hinke M. Osinga
University of Auckland
Department of Mathematics
b.krauskopf@auckland.ac.nz, H.M.Osinga@auckland.ac.nz

MS57

The Lorenz System Near the Loss of the Foliation Condition

We consider the onset of hooks in the Poincaré return map of the famous Lorenz system, when the one-dimensional Lorenz map ceases to accurately represent the dynamics. We employ a two-point boundary value problem set-up to calculate a point of tangency of the two-dimensional unstable manifold $W^u(\Gamma)$ of a periodic orbit Γ with the stable foliation. This allows us to continue this boundary curve in any of the system parameters.

Jennifer L. Creaser
University of Auckland
j.creaser@auckland.ac.nz

Bernd Krauskopf, Hinke M. Osinga
University of Auckland
Department of Mathematics
b.krauskopf@auckland.ac.nz, H.M.Osinga@auckland.ac.nz

MS57

Analytic Proof of Lorenz Attractors in Flows and Maps

In this talk I will give an overview of the recent results regarding the theoretical proof of the birth of strange Lorenz attractors in various models. This includes the criteria of the birth of Lorenz attractors from global bifurcations of flows (double homoclinic loop), which were also applied to prove analytically (without a computer assistance) that such an attractor is present in the Lorenz model (the 14th Smale's problem). This result allows to obtain conditions of the birth of Lorenz attractors in local bifurcations of flows as well as local and global bifurcations of diffeomorphisms.

Ivan Ovsyannikov
University of Bremen, Germany
Ivan.I.Ovsyannikov@gmail.com

MS57

The Many Facets of Chaos

There are many ways that a person can encounter chaos, such as through a time series from a lab experiment, a basin of attraction with fractal boundaries, a map with a crossing of stable and unstable manifolds, a fractal attractor, or in a system for which uncertainty doubles after some time period. These encounters appear so diverse, but the chaos is the same in all of the underlying systems; it is just observed in different ways. We describe these different types of chaos. We will give two conjectures about the types of dynamical behavior that is observable if one randomly picks out a dynamical system without searching for a specific property. In particular, we conjecture that from picking a system at random, one observes (1) only three types of basic invariant sets: periodic orbits, quasiperiodic orbits, and chaotic sets; and (2) that all the definitions of chaos are in agreement.

Evelyn Sander
George Mason University
esander@gmu.edu

MS58

The Quantification of the Nonergodic Property Via Snapshot Attractors: An Application to a Conceptual Climate Model

The natural measure of a snapshot attractor can be approximated only with the use of an ensemble of trajectories. We quantitatively describe the limitations for extracting estimates on the relevant probabilities from the time evolution of a single trajectory. For instance, temporal averages over finite time intervals taken along a single trajectory are found to typically differ from the corresponding ensemble averages. This can be regarded as a measure of the nonergodic property. In addition, we introduce further, probabilistic measures for nonergodicity. We show that even in stationary systems ergodic behavior sets in for asymtotically long times, no characteristic time exists for the convergence. Ergodicity is typically broken down even for asymtotically long times in nonautonomous systems with a permanent shift of their parameters. We illustrate via a conceptual climate model that this nonergodic snapshot framework might be useful in Earth System dynamics.

Gabor Drotos
Eotvos University
gabor.drotos@gmail.com

Tamas Bodai
Meteorologisches Institut
Universität Hamburg
tamas.bodai@uni-hamburg.de

Tamas Tel
Eötvös Loránd University, Budapest, Hungary
Institute for Theoretical Physics
tel@general.elte.hu

MS58

Random Attractors and How They Help Understand Climate Change and Variability

Until recently, there were two basic approaches to apprehend the complexity of climate change: deterministically nonlinear and stochastically linear, or the Lorenz and the Hasselmann approach. The theory of random dynamical systems provides a framework for unifying these two approaches. We apply this theory to study the random attractors of nonlinear, stochastically perturbed climate models, and define climate sensitivity via Wasserstein distances between such attractors. Numerical results are presented for a highly simplified ENSO model.

Michael Ghil
Ecole Normale Supérieure, Paris, and
University of California, Los Angeles
ghil@lmd.ens.fr

MS58

Snapshot Attractors and the Transition to Extensive Chaos in Large Systems of Mean-Field Coupled Oscillators

We consider systems of many (N) mean-field coupled oscillators with two types of dynamics: low dimensional attractors (in which the oscillator states all clump into just a few values), and extensively chaotic states (in which the attractor dimension scales linearly with N). We use the concept of snapshot attractors to analyze extensively chaotic states focusing on the associated fractal dimension. We also study dynamical transitions from low dimensional attractors to extensive chaos and vice verse.

Edward Ott
University of Maryland
Inst. for Research in Electronics and Applied Physics
edott@umd.edu

Wai Lim Ku
Univ. of Maryland
wlku@umd.edu

Michelle Girvan
University of Maryland
girvan@umd.edu

MS58

SRB Measures for Time-Dependent and Random

Attractors

For autonomous systems of ODEs with chaotic attractors, large-time orbit distributions are described by SRB measures. This theory carries over very well to random dynamical systems, for which the picture is in fact simpler due to the averaging effects of random noise. Some of the ideas extend even to time-dependent attractors without any notion of stationary. I will review known ideas and report on new results.

Lai-Sang Young
Courant Institute of Mathematical Sciences
New York Univ.
lsy@cims.nyu.edu

MS59

Chimeras in Networks of Identically Coupled Mechanical Oscillators

Synchronization has been vastly observed in nature as well as in man-made systems. Synchronous states are possible when two or more oscillators are interacting with each other. In particular, arrays of identical oscillators can exhibit a fascinating spatiotemporal pattern, termed chimera state, in which synchronous domains coexist with incoherent ones. Previous studies have addressed this phenomenon theoretically and experimentally. However, the spontaneous emergence of chimeras in translationally invariant networks remains an experimental challenge. Here, we use a one-dimensional network of identically coupled identical mechanical oscillators, to implement an experimental demonstration yielding this unique phenomenon. Our findings, supported by a mathematical model, bring new insights into the search for chimeras in nature.

Rosangela Follmann
Polytechnic School of University of Sao Paulo
rosangelafollmann@gmail.com

Daniel Abrams, Adilson E. Motter
Northwestern University
dmabrams@northwestern.edu, motter@northwestern.edu

MS59

Synchronization Properties Related to Neighborhood Similarity in a Complex Network of Non-Identical Oscillators

We explore in this article complex networks of non-identical interacting oscillators. More specif- ically, the impact of Similar or Dissimilar neighborhoods over the emergence of synchronization is studied. These scenarios are defined based on a vertex weighted graph measure, the Total Dissonance, which comprises the sum of the dissonances between all neighbor oscillators in the network. Our numerical simulations show that the more homogeneous is a network, the higher tend to be both the coupling strength required to phase-lock and the associated final phase configuration spread over the circle. On the other hand, the initial spread of partial synchronization occurs faster for Similar neighborhoods in comparison to Dissimilar ones.

Elbert E. Macau
INPE - Brazilian National Institute for Space Research
LAC - Laboratory for Computing and Applied Mathematics
elbert.macau@inpe.br

Celso Bernardo Freitas
Instituto Nacional de Pesquisas Espaciais - INPE
Sao Jose dos Campos, SP, Brasil
cbnfreitas@gmail.com

Ricardo L. Viana
Departmento de Fisica
Federal University of Parana
viana@fisica.ufpr.br

MS59

Chimera States in Networks with Symmetry-Breaking Coupling

In a network of Stuart-Landau oscillators with nonlocal topology and symmetry-breaking coupling we establish novel partially coherent inhomogeneous spatial patterns, which combine the features of chimera states (coexisting incongruous coherent and incoherent domains) and oscillation death (oscillation suppression), which we call chimera death. Moreover, we find chimera states with respect to amplitude dynamics rather than the phase (amplitude chimeras). Additionally, we show that two distinct scenarios from oscillatory behavior to a stationary state regime are possible: a transition from an amplitude chimera to chimera death via in-phase synchronized oscillations, and a direct abrupt transition for larger coupling strength. We believe our results are of particular importance for the life sciences. For instance, these peculiar hybrid states may account for the observation of partial synchrony in neural activity, like unihemispheric sleep etc. A. Zakharova, M. Kapeller, E. Schöll, Chimera Death: Symmetry Breaking in Dynamical Networks, Phys. Rev. Lett. 112, 154101 (2014)

Anna Zakharova
Institute of Theoretical Physics
Berlin, Germany
anna.zakharova@tu-berlin.de

Marie Kapeller
Berlin Institute of Technology
Berlin, Gernamy
marie.kapeller@physik.hu-berlin.de

Eckehard Schöll
Technische Universität Berlin
Institut für Theoretische Physik
schoell@physik.tu-berlin.de

MS59

Dynamics of Clustering in Networks with Repulsive Interaction

In dynamics of simple coupled systems attracting interaction usually leads to synchronization. In contrast, repulsive interaction is able to split the ensemble into clusters, to create multistability and, as we will show, in certain cases even generate continuous families of oscillatory states.

Michael A. Zaks
Department of Stochastic Processes, Institute of Physics
Humboldt University of Berlin
mzaks@uni-potsdam.de

MS60

Dynamic Mode Decomposition for Multi-

Resolution Analysis

The dynamic mode decomposition (DMD) is an ideal method for decomposing complex systems into spatio-temporal modes with prescribed temporal signatures. The frequency and duration of the data collection process can be adapted, much as in wavelet theory, to sift out information at different temporal scales. Indeed, an iterative refinement of progressively shorter snapshot sampling windows and recursive extraction of DMD modes from slow-to increasingly-fast time scales allows for a multi-resolution DMD analysis that allows for improved analytics. Moreover, it also allows for improved analytic predictions of the short-time future state of the system which is of critical importance for control protocols.

J. Nathan Kutz
University of Washington
Dept of Applied Mathematics
kutz@uw.edu

MS60

Approximating the Koopman Operator Using Extended Dynamic Mode Decomposition

It has recently been observed that eigenvalues and modes of the Koopman operator may be approximated using a data-driven algorithm called Dynamic Mode Decomposition (DMD). We first provide a new definition of DMD that is equivalent to the original, but is more amenable to analysis. We then describe an Extended DMD method which approximates the Koopman operator directly, using a user-specified set of basis functions, and allows one to compute Koopman eigenvalues, modes, and eigenfunctions.

Clarence Rowley
Princeton University
Department of Mechanical and Aerospace Engineering
cwrowley@princeton.edu

Matthew O. Williams
Program in Applied and Computational Mathematics
Princeton University
mow2@Princeton.edu

MS60

Koopman Operator Techniques in Power Grid Analysis

Spectral properties of the so-called Koopman operator provide an alternative framework for dynamical systems analysis. This enables a new technique of nonlinear modal decomposition, which is referred to as the Koopman Mode Decomposition (KMD). In this presentation, we will outline our recent efforts on applications of KMD to analysis of power grid dynamic performances such as stability analysis and network partitioning. This will lead to a data-driven framework of analysis and operation of the future power grid that can handle high penetration of renewable energy resources.

Yoshihiko Susuki
Kyoto University / JST-CREST
susuki.yoshihiko.5c@kyoto-u.ac.jp

MS60

Machine Learning and the Koopman Operator: Algorithms and Applications

We present two extensions of Extended Dynamic Mode Decomposition (EDMD), which is a data-driven method that approximates the eigenvalues, eigenfunctions, and modes of the Koopman operator. The first is algorithmic: we show that EDMD can be rewritten as a kernel method, which enables Koopman-based computation in large systems to be performed. The second is an application: the Koopman eigenfunctions are used as a set of intrinsic coordinates that enable data-fusion/state-reconstruction tasks to be accomplished.

Matthew O. Williams
Program in Applied and Computational Mathematics
Princeton University
mow2@Princeton.edu

MS61

What Is the Right Functional for Variational Data Assimilation?

Variational data assimilation refers to matching model trajectories with observations. This is usually accomplished by minimising a quadratic error functional which, in discrete time with gaussian perturbations, can be interpreted as the likelihood of a trajectory. Different ways to solve this problem though can lead to different solutions in the limit of $\Delta t \to 0$. This corresponds to the fact that in continuous time, there are several contenders for the likelihood of a trajectory.

Jochen Bröcker
University of Reading, UK
School of Mathematical and Physical Sciences
j.broecker@reading.ac.uk

MS61

Time Delay Methods for Variational Data Assimilation

We investigate an extension to variational data assimilation by modifying the minimized cost function. A penalty to the cost function is added if the state vector at a given time is inconsistent with the measurements at a later time. The idea is to inform the choice of unmeasured state variables by looking at how they affect the observed dynamics over a window of time, rather than comparing the optimum path only at adjacent times.

Uriel I. Morone
UCSD
umorone@ucsd.edu

MS61

Filtering Unstable Quadratic Dissipative Systems

The long-time behavior of filters for partially observed quadratic dissipative dynamical systems is considered. It is proven that for both discrete-time and continuous-time observations the 3DVAR filter can recover the signal within a neighborhood defined by the size of the observational noise, as long as a sufficiently large proportion of the state vector is observed; an explicit form for a sufficient constant observation operator is given. Three models of interest fit into this class – Lorenz '63, Lorenz '96, and 2D Navier-Stokes on a torus. Furthermore, in the case of Lorenz '96, non-constant adaptive observation operators are studied numerically, with data incorporated by use of both the

3DVAR and the extended Kalman filter. It is shown that for carefully chosen adaptive observations, the proportion of state coordinates necessary to accurately track the signal is significantly smaller than the proportion proved to be sufficient for constant observation operator. Indeed it is shown that the necessary number of observations may even be significantly smaller than the total number of positive Lyapunov exponents of the underlying system.

Kody Law
SRI UQ Center, CEMSE, KAUST
kodylaw@gmail.com

Abhishek Shukla
Warwick
a.shukla@warwick.ac.uk

Daniel Sanz-Alonso
University of Warwick
d.sanz-alonso@warwick.ac.uk

Andrew Stuart
Mathematics Institute,
University of Warwick
a.m.stuart@warwick.ac.uk

MS61

Observability of Chaotic Lorenz-96 Systems

In 1996 E. Lorenz proposed a ring of one-dimensional ODEs for describing some meteorological quantity at equidistant locations along a latitude circle. Since then this systems became a frequently used hyperchaotic model for exploring new concepts in dynamical systems theory. In our contribution we shall use it as a prototypical example for illustrating, testing, and comparing methods for observability analysis, and state and parameter estimation.

Jan Schumann-Bischoff
Max Planck Institute for Dynamics and Self-Organization
jan.schumann-bischoff@ds.mpg.de

Stefan Luther, Ulrich Parlitz
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
stefan.luther@ds.mpg.de, ulrich.parlitz@ds.mpg.de

MS62

Control of Complex Diffusion in Networks of NEMS

Recent advances in NEMS enable us to explore nonlinear phenomena on networks in unprecedented ways. We apply methods from control of complex diffusion to the oscillators' complex envelopes as coupled via a linear diffusion term. We focus on network synchronization and our ability to guide the system to synchronized states by controlling a small number of oscillators' natural linear frequencies. Additionally, we investigate control of other limit cycles in small systems with simple network structure.

Jeff Emenheiser
UC Davis
Physics Department
jemenheiser@ucdavis.edu

Mehran Mesbahi
University of Washington
mesbahi@uw.edu

Raissa D'Souza
UC Davis
raissa@cse.ucdavis.edu

MS62

Intrinsic Computation in NEMS

The ways in which nanoscale systems generate, store, and process information and dissipate energy yield insights into their behavior, potential technological functions, and fundamental physics of computation. Nanoelectromechanical systems (NEMS) are nonlinear and subject to thermal fluctuations, making them an ideal experimental platform to probe the trade-offs between intrinsic computation and energy use. I will present results quantifying intrinsic computation in the dynamics of the theoretical counterpart of many NEMS devices, the noisy Duffing oscillator.

Russell Hawkins
UC Davis
Complexity Sciences Center
rrhawkins@ucdavis.edu

MS62

Phase Synchronization Between Nanoelectromechanical Oscillators

Synchronization, the mutual entrainment of limit cycle oscillators, is a ubiquitous phenomenon both in the physical and biological sciences. There exist many observation studies of this phenomenon; however, controlled experiments in this field are scant. In this talk, I will describe an experiment in synchronization based on NanoElectroMechanical (NEMS) oscillators. In addition to the ability to measure the amplitude and phase dynamics of individual nodes, the experiment demonstrates a large degree of control over the parameters of the system. Both the coherent and stochastic dynamics will be discussed.

Matt Matheny
California Institute of Technology
matheny@caltech.edu

MS63

Ensemble Inflation by Shadowing Techniques

The artificial inflation of ensembles is a technique common to ensemble data assimilation whereby the ensemble variance is increased in order to prevent deviation of the ensemble from the truth. Various techniques for inflating ensembles exist in the literature. This talk will discuss ensemble shadowing and our implementation of shadowing techniques as a method of ensemble inflation. We will also present results from a low order chaotic system that support using shadowing inflation.

Thomas Bellsky
Arizona State University
thomas.bellsky@maine.edu

Lewis Mitchell
University of Adelaide

lewis.mitchell@adelaide.edu.au

MS63

Ionospheric Weather Forecasting Using the Letkf Scheme

We assimilate satellite observations to forecast ionospheric electron density using the Local Ensemble Transform Kalman Filter(LETKF). This assimilation scheme generates forecasts from an ensemble of initial conditions and forms its analysis by computing a unique linear combination of the forecast ensembles at each grid point using nearby observations. The ionosphere model used is the TIEGCM. Assessments of the LETKF include validation against independent data sources as well as skill in estimating ionospheric drivers, forecast ensemble uncertainty, and spatially sharp electron density gradients.

Juan Durazo
Arizona State University
Juan.Durazo@asu.edu

MS63

Predicting Flow Reversals in a Cfd Simulated Thermosyphon Using Data Assimilation

A thermal convection loop is a circular chamber filled with water, heated on the bottom half and cooled on the top half. With sufficiently large forcing of heat, the direction of fluid flow in the loop oscillates chaotically, forming an analog to the Earths weather. As is the case for state-of-the-art weather models, we only observe the statistics over a small region of state space, making prediction difficult. To overcome this challenge, data as- similation methods, and specifically ensemble methods, use the computational model itself to estimate the uncertainty of the model to optimally combine these observations into an initial condition for predicting the future state. First, we build and verify four distinct DA methods. Then, a computational fluid dynamics simulation of the loop and a reduced order model are both used by these DA methods to predict flow reversals. The results contribute to a testbed for algorithm development.

Andrew Reagan
University of Vermont
andrew.reagan@uvm.edu

MS63

An Application of Lagrangian Data Assimilation to Katama Bay, Ma

Lagrangian data assimilation (LaDA) methods directly use observations of passive drifters in a flow in order to estimate the underlying currents. We apply the ensemble Kalman filter in this context to a model of Katama Bay in Martha's Vineyard, using real drifter observations. We compare the augmented-vector method of LaDA to so-called pseudo-Lagrangian methods. Finally, we judge the method's performance using Eulerian data of the bay from the same time.

Laura Slivinski
Woods Hole Oceanographic Institution
lslivinski@whoi.edu

Larry Pratt
Woods Hole Oceanographic Inst.
lpratt@whoi.edu

Irina Rypina
Woods Hole Oceanographic Institution
irypina@whoi.edu

MS64

A Mechanism of Spiral Wave Unpinning and Its Implications for the Treatment of Cardiac Arrhythmias with Periodic Far-Field Pacing

Spiral waves pinned to inexcitable regions of tissue pose a particular challenge in the effort to control cardiac arrhythmias without a strong defibrillating electrical shock. We investigate one particular unpinning mechanism due to far-field pulses in a two-dimensional model of excitable media and determine its potential benefits over alternative low-energy strategies such as anti-tachycardia pacing. Furthermore, we explore how a simple map-based model can predict success rates for more realistic scenarios involving periodic stimuli.

Philip Bittihn
Biodynamics Lab
University of California, Sandiego
pbittihn@ucsd.edu

Anna Behrend
Max Planck Institute for Dynamics and Self-Organization
Göttingen, Germany
anna.behrend@ds.mpg.de

Stefan Luther
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
stefan.luther@ds.mpg.de

MS64

The Effects of Cardiac Fibroblasts on Wave Propagation in Ventricular Tissue: Insights from Numerical Studies of Mathematical Models

We study spiral-wave turbulence in partial-differential-equation models for human cardiac tissue, with both myocytes and fibroblasts. We obtain results for cells, with one myocyte coupled to several fibroblasts, and for tissue. We study (a) regularly and (b) randomly arranged fibroblasts, systematize their role in modifying the cardiac action potential and the propagation of activation waves, and investigate a low-amplitude control scheme for the suppression of spiral-wave turbulence.

Alok R. Nayak
Indian Institute of Science, Bangalore, India
alokiisc05@gmail.com

Rahul Pandit
Indian Institute of Science, Bangalore
rahul@physics.iisc.ernet.in

MS64

How to Control Spiral Waves Using Weak Signals: A Few Suggestions

In this talk I will describe a few recently developed methods to control dynamics of spiral waves and spatiotemporal chaos in excitable media. Control is achieved by the application of small amplitude external signals in a fashion designed to exploit nonlinear properties of excitable systems. Payoffs for the experimental realisation of such robust methods to control spiral dynamics is enormous and could have several practical applications, potentially including a device for safe cardiac defibrillation.

S Sridhar
Ghent University, Belgium
dharmails@gmail.com

MS64

Controlling Spiral Wave Dynamics in Cardiac Monolayers Using Far Field Pulses

Waves in two-dimensional excitable media forms patterns such as target waves and spiral waves. Spiral waves tend to attach to the heterogeneities in the medium and form very stable structures. We study controlling such waves using far field electric pulses in two-dimensional layers of cultured cardiac cells. We will discuss resetting and terminating spiral waves using periodic far field pulses.

Shajahan Thamara Kunnathu
Max Planck Institute for Dynamics and Self Organization
shajahan@ds.mpg.de

Sebastian Berg
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
sebastian.berg@ds.mpg.de

Valentin Krinsky
Max Planck Institute for Dynamics and Self-Organization
valentin.krinsky@ds.mpg.de

Stefan Luther
Max Planck Institute for Dynamics and Self-Organization
Research Group Biomedical Physics
stefan.luther@ds.mpg.de

MS65

Anatomy Induced Drift of Reentrant Waves in Human Atrium

In biophysically and anatomically realistic model of human atrium, we demonstrate functional effects of atrial anatomical structures on reentrant waves spontaneous drift. Spiral waves drift from thicker to thinner regions, along ridge-like structures of pectinate muscules (PM) and cristae terminalis, anchor to PM-atrial wall junctions or to some locations with no obvious anatomical features. The insight can be used to improve low-voltage defibrillation protocols, and predict atrial arrhythmia evolution given a patient specific atrial anatomy.

Irina Biktasheva
University of Liverpool
ivb@liv.ac.uk

Vadim N. Biktashev
College of Engineering, Mathematics and Physical Sciences
University of Exeter
V.N.Biktashev@exeter.ac.uk

Sanjay R. Kharche
University of Exeter
s.r.kharche@exeter.ac.uk

Gunnar Seemann
Karlsruhe Institute of Technology
Germany
gunnar.seemann@kit.edu

Henggui Zhang
University of Manchester
UK
henggui.zhang@manchester.ac.uk

MS65

Stabilized Wave Segments in An Excitable Medium with a Phase Wave at the Wave Back

We determine analytically the propagation velocity and the shape of stationary propagating wave segments in excitable media supporting excitation waves with trigger fronts and phase backs. Relationship between the medium excitability and the wave segment parameters is described using the free boundary approach. This leads to two universal limits, restricting the region of existence of stabilized wave segments. Comparison of the analytical results with numerical simulations of the Kessler-Levine model demonstrates their good quantitative agreement.

Eberhard Bodenschatz
Max Planck Institute for Dynamics & Self-Organization
eberhard.bodenschatz@ds.mpg.de

Vladimir Zykov
Max Planck Institute for Dynamics and Self-Organization
vladimir.zykov@ds.mpg.de

MS65

Use of Delay-Differential Equations in Cardiac Models

Period-2 behavior of cardiac electrical responses, referred to as alternans, often leads to more complicated arrhythmias. To date, alternans has been generated mathematically from the loss of stability of the period-1 solution in coupled nonlinear ODE/PDE systems. We build on the fact that delays arise naturally in non-instantaneous cellular processes and present an alternative approach using delay-differential equations (DDEs), which are known to promote complex dynamics. We analyze the dynamical behaviors of our DDE system and discuss the implications of our findings.

Elizabeth M. Cherry, Ryan Thompson
Rochester Institute of Technology
School of Mathematical Sciences
excsma@rit.edu, rpt1914@rit.edu

MS65

Spiral Wave Activity in a Mixture of Resting and Oscillating Cardiomyocytes: Limitations on Biopacemaker Development

Self-organization of interconnected elements is important for development of biopacemakers. Monolayers of pluripotent cell-derived cardiomyocytes exhibit spontaneous activation and consist of a heterogeneous network of cells. A simple stochastic model of cell distributions combined with a Fitzhugh-Nagumo type model highlights the importance of spatial granularity of spontaneous cells on biopacemaker activity. Interestingly, spiral wave activity and the desired simultaneous activation of the biopacemaker are found in opposite spectrum of oscillating cell spatial patterns.

Philippe Comtois
Institute of Biomedical Engineering,
Universite de Montreal
philippe.comtois@umontreal.ca

MS66

Traveling Waves in a Laminar Neural Field Model of Visual Cortex

One of the challenges in the mathematical and computational modeling of primary visual cortex (V1) is developing recurrent networks models that keep track of neural activity with respect to both retinotopic and feature-based degrees of freedom such as orientation selectivity. This is further complicated by the fact that different cortical layers have different response properties. In this talk we present a laminar neural field model consisting of a superficial layer of orientation-selective cells interacting vertically with a deep layer of non-orientation selective cells. We use the model to analyze the propagation of orientation selectivity across cortex.

Samuel R. Carroll
University of Utah
carroll@math.utah.edu

Paul C. Bressloff
University of Utah
Department of Mathematics
bressloff@math.utah.edu

MS66

A Computational Model of the Influence of Depolarization Block on Initiation of Seizure-like Activity

Seizure-like activity can be triggered in a network of excitatory and inhibitory neurons when excessive excitation is not suppressed by matching inhibition. Recent experimental studies report that inhibitory neurons, receiving strong excitatory drive, were functionally impaired due to depolarization block prior to propagation of ictal discharges. In this talk, we will discuss different types of dynamics emerging from a network of excitatory and inhibitory neurons when inhibitory neurons are prone to depolarization block. We find that the network may reach the pathological state via saddle-node bifurcation or homoclinic bifurcation. Oscillatory activity present in the network allows us to produce tonic to clonic phase transition observed in epileptic brain slices and human patients. We also discuss the effects of network motifs on promoting pathological dynamics. The convergent motifs from excitatory neurons onto inhibitory neurons, which may be observed in mossy fiber sprouting, facilitates depolarization block in inhibitory neurons so that the network can enter the pathological state more easily. The mean field equation accounting for the network structure allows us to make predictions about the effects of different type of network motifs. The predictions from the mean field model are verified by simulating a network of conductance-based neurons.

Duane Nykamp
School of Mathematics
University of Minnesota
nykamp@math.umn.edu

MS66

Finite Size Effects in Networks of Theta Neurons

The dynamics of a large but finite number of coupled spiking neurons is not well understood. We analyze finite size effects in a network of synaptically coupled theta neurons. We show how the system can be characterized by a functional integral from which finite size effects are calculated perturbatively. We consider how finite size effects affect the stability of the asynchronous state of a uniformly coupled network. We then discuss the implications for bump attractors.

Siwei Qiu
NIDDK/LBM
NIH
siwei.qiu@nih.gov

Carson C. Chow
National Institutes of Health
carsonc@mail.nih.gov

MS66

Optimal Decision-Making in a Changing Environment

We derive a continuous stochastic differential equation describing the optimal accumulation of evidence in a changing environment. Our results apply to two choice decision making wherein the underlying truth switches stochastically. Sequential analysis is used to determine the prior probabilities of finding the truth in one of two states. Passing to the continuum limit and non-dimensionalizing, we find the evidence accumulation process depends on a single parameter, information received per mean switch time.

Alan Veliz-Cuba
University of Houston
Rice University
alanavc@math.uh.edu

Zachary Kilpatrick
University of Houston
zpkilpat@math.uh.edu

Kreimir Josic
Department of Mathematics, University of Houston
josic@math.uh.edu

MS67

Costs and Benefits of Mutational Robustness in Rna Viruses

The accumulation of mutations in RNA viruses is thought to facilitate rapid adaptation to changes in the environment. However, most mutations have deleterious effects, especially for viruses. Thus, tolerance to mutations should determine the nature and extent of genetic diversity in the population. I will present a combination of population genetics theory, computer simulation, and experimental evolution to examine the advantages and disadvantages of tolerance to mutations, also known as mutational robustness.

Simone Bianco
IBM Research

sbianco@us.ibm.com

MS67

Evolutionary Dynamics of Mutator Phenotypes in Changing Environments

Stochastic switching is an example of phenotypic bet-hedging, where offspring can express a phenotype different from that of their parents. Even though phenotypic switching is well documented in viruses, yeast, and bacteria, there has been little exploration of the evolution of these mutator phenotypes under spatially and temporally fluctuating selection pressures. In this talk, I will use a population genetic model to explore the interaction of temporal and spatial variation in determining the evolutionary dynamics of phenotypic switching. Although the formulation of the model is in terms of non-genetic switching, the same framework can be used to study the evolution of genetic mutation rates under volatility in selection. This study offers new insights into how the interplay of spatial and temporal environmental variability can influence the evolution of phenotypic switching rates, mutation rates, or other sources of phenotypic variation.

Oana Carja
University of Pennsylvania
ocarja@sas.upenn.edu

MS67

The Acceleration of Evolutionary Spread by Long-Range Dispersal

The spreading of evolutionary novelties across populations is the central element of adaptation. Unless population are well-mixed (like bacteria in a shaken test tube), the spreading dynamics not only depends on fitness differences but also on the dispersal be- havior of the species. Spreading at a constant speed is gener- ally predicted when dispersal is sufficiently short-ranged, specifically when the dispersal kernel falls-off exponentially or faster. However, the case of long-range dispersal is unresolved: While it is clear that even rare long-range jumps can lead to a drastic speedup as air-trafficmediated epidemics show it has been difficult to quantify the ensuing stochastic dynamical pro- cess. Yet, such knowledge is indispensable for a predictive understanding of many spreading processes in natural populations. I present a simple iterative scaling approximation supported by simulations that accurately predicts evo- lutionary spread which is determined by a tradeoff between frequency and potential effectiveness of long-distance jumps. In contrast to the exponential laws predicted by deterministic mean- field approximations, we show that the asymptotic spatial growth is either according to a power-law or a stretched exponential, depending on the tails of the dispersal kernel. More importantly, we provide a full time-dependent description of the convergence to the asymptotic behavior which can be anomalously slow and is relevant even for long times. I will discuss to what extend our results might be used to improve the inference of the evolutionary spread based on genealogical trees, which is however a largely open problem.

Oskar Hallatschek
Department of Physics
UC Berkeley
ohallats@berkeley.edu

MS67

Thermodynamics and Statistical Mechanics of Viral Evolution

We analyze a simplified model of viral infection and evolution using the grand canonical ensemble and formalisms from statistical mechanics and thermodynamics to calculate the behavior of a macroscopic number of viruses, and to derive thermodynamic variables for the system. We model the infection process as a series of energy barriers determined by the genetic states of the virus and host as a function of immune response and system temperature. We find a phase transition between a positive temperature regime of normal replication and a negative temperature disordered phase of the virus. These phases define different regimes in which different genetic strategies are favored. Perhaps most importantly, it demonstrates that the system has a real thermodynamic temperature. For normal replication, this temperature is linearly related to effective temperature. For all temperatures and immunities studied, we find a universal curve relating the order parameter to viral evolvability. Real viruses have finite length RNA segments that encode for proteins which determine their fitness; hence the methods put forth here could be refined to apply to real biological systems; perhaps providing insight into immune escape, the emergence of novel pathogens and other results of viral evolution.

Barbara Jones, James Kaufman
IBM Research
bajones@us.ibm.com, jhkauf@us.ibm.com

Justin Lessler
Johns Hopkins Bloomberg School of Public Health
jlessler@jhsph.edu

MS68

Characterizing the Structure of Multilayer Networks

The development of Complex Network's Theory is providing radical new ways of understanding many different processes from physical, social, engineering, information and biological sciences. Several notions, such as networks of networks, multidimensional networks, multilevel networks, multiplex networks, interacting networks, interdependent networks, and many others have been introduced, and even different mathematical approaches, based on tensor representation have been proposed. In this talk we will discuss a general framework for multilayer networks that includes the great majority of the different approaches addressed so far in the literature and review some of attempts to extend the notions, measures and models from single layer to multilayer networks.

Regino Criado
Universidad Rey Juan Carlos
regino.criado@urjc.es

Miguel Romance
Departamento de Matematica Aplicada
Universidad Rey Juan Carlos
miguel.romance@urjc.es

MS68

Synchronization and the problem of Targeting in

Multilayer Networks

We concentrate on the case involving a two-layer master-slave network to steer a desired collective behavior, 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.

Ricardo Gutierrez
Department of Chemical Physics
The Weizmann Institute of Science
rcd.gutierrez@gmail.com

Irene Sendina Nadal
Universidad Rey Juan Carlos
irene.sendina@urjc.es

Massimiliano Zanin
Technical University of Madrid
massimiliano.zanin@ctb.upm.es

David Papo
Universidad Politécnica de Madrid, Spain
papodav@gmail.com

Stefano Boccaletti
CNR-Istituto dei Sistemi Complessi
stefano.boccaletti@isc.cnr.it

MS68

Game and Diffusion Dynamics in Multilayer Networks

Besides the structure of interactions within networks, also the interactions between networks are of the outmost importance. We therefore study the outcome of the evolutionary games on multilayer networks that are connected by means of a utility function, which determines how payoffs on networks jointly influence the success of players in each individual network.. To reach this aim, we consider the symmetric, asymmetric utility function and find the symmetric breaking phenomenon and the spontaneous emergence of multilayer network reciprocity. Along this line, the role of partially correlation is investigated and the optimal condition for cooperation is found. Finally, we consider the co-evolution mechanisms of evolutionary games on multilayer networks and find that the optimal cooperation can be attributed to individual self-organization trait.

Zhen Wang
Baptist University of Hong Kong
zhenwang0@gmail.com

MS68

Synchronization in Time Varying Networks: the Non Commutative Case

We provide a rigorous solution to the problem of constructing a structural evolution for a network of identical coupled dynamical units switching between topologies without structural constraints. Our method guarantees that the coupling matrices eigenvectors change smoothly in time. This allows to extend the Master Stability Function formalism, and to use it to assess the stability of a synchronized state when the network topology evolution is fully general, and not necessarily restricted to commuting structures.

Charo I. del Genio
University of Warwick
c.i.del-genio@warwick.ac.uk

MS69

The Response of Statistical Averages to Small Stochastic Forcing

We present a response theory for statistical averages of deterministic dynamical systems perturbed by a small stochastic forcing. We derive the response formula explicitly in terms long-time averages of the tangent map of the unperturbed system, and show that the response is the second-order effect with respect to the magnitude of perturbation. We also demonstrate that for a finite response time the response is consistent with the prediction of the classical response theory for stochastic systems with smooth invariant distribution density perturbed by a small stochastic forcing.

Rafail Abramov
Department of Mathematics, Statistics and Computer Science
University of Illinois at Chicago
abramov@math.uic.edu

MS69

Is Our Sensing Compressed?

Considering many natural stimuli are sparse, can a sensory system evolve to take advantage of sparsity? We show significant downstream reductions in the numbers of neurons transmitting stimuli in early sensory pathways might be a consequence of sparsity. Our work points to a potential mechanism for transmitting stimuli related to compressed-sensing (CS) data acquisition. Through simulation, we examine the characteristics of networks that optimally encode sparsity and the role of receptive fields in stimulus sampling.

Gregor Kovacic
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
kovacg@rpi.edu

MS69

A Multiscale Method for Optical Responses of Nano Structures

We introduce a new framework for the multiphysical modeling and multiscale compu- tation of nano-optical responses. The semi-classical theory treats the evolution of the electromagnetic field and the motion of the charged particles self-consistently by coupling Maxwell equations with Quantum Mechanics. To overcome the numerical challenge of solving high dimensional many body Schrödinger equations involved, we adopt the Time Dependent Current Density Functional Theory (TD-CDFT). In the regime of linear responses, this leads to a linear system of equations determining the electromagnetic field as well as current and electron densities simultaneously. A self-consistent multiscale method is proposed to deal with the well separated space scales. Numerical examples are presented to illustrate the resonant condition.

Di Liu

Michigan State University
Department of Mathematics
richardl@math.msu.edu

MS69

Parareal Methods for Highly Oscillatory Dynamical Systems

We introduce a multiscale parareal method that efficiently numerically integrates highly oscillatory ordinary differential equations. The algorithm computes a low-cost approximation of all slow variables in the system. Then, fast phase-like variables are ob- tained using the parareal iterative methodology and an alignment algorithm. The method may be used either to enhance the accuracy and range of applicability of the multiscale method in approximating only the slow variables, or to resolve all the state variables. The numerical scheme does not require that the system is split into slow and fast coordinates. Moreover, the dynamics may involve hidden slow variables, for example, due to resonances. Convergence of the parareal iterations is proved and demonstrated in numerical examples.

Richard Tsai
Department of Mathematics
University of Texas, Houston
ytsai@math.utexas.edu

MS70

Invariant Manifolds of Multi Interior Spike States for the Cahn-Hilliard Equation

We construct invariant manifolds of interior multi-spike states for the nonlinear Cahn-Hilliard equation and then investigate the dynamics on it. An equation for the motion of the spikes is derived. It turns out that the dynamics of interior spikes has a global character and each spike interacts with all the others and with the boundary. Moreover, we show that the speed of the interior spikes is super slow, which indicates the long time existence of dynamical multi-spike solutions in both positive and negative time. This result is obtained through the application of a companion abstract result concerning the existence of truly invariant manifolds with boundary when one has only approximately invariant manifolds.

Peter W. Bates
Michigan State University
Department of Mathematics
bates@math.msu.edu

MS70

Oscillatory Pulses in FitzHugh-Nagumo

It is well known that the FitzHugh-Nagumo system exhibits stable, spatially monotone traveling pulses. Also, there is numerical evidence for the existence of spatially oscillatory pulses, which would allow for the construction of multi-pulses. Here we show the existence of oscillatory pulses rigorously, using geometric blow-up techniques and singular perturbation theory.

Paul A. Carter
Department of Mathematics
Brown University
pacarter@math.brown.edu

Bjorn Sandstede
Division of Applied Mathematics
Brown University
bjorn_sandstede@brown.edu

MS70

Slow-Fast Factorization of the Evans Function Via the Riccati Transformation in the Semi-Strong Regime

The complexity of singularly perturbed linear stability problems can be reduced by factorizing the Evans function in accordance with the scale separation. The factorization has always been established by geometric arguments, customized for the specific equations and solutions under consideration. We present an alternative method, that formalizes and generalizes the factorization procedure. This analytic method is based on the Riccati transformation. We employ our techniques to study the spectral stability of semi-localized periodic pulse patterns.

Björn De Rijk
Leiden University
brijk@math.leidenuniv.nl

Arjen Doelman
Mathematisch Instituut
doelman@math.leidenuniv.nl

Jens Rademacher
University of Bremen
jdmr@uni-bremen.de

MS70

Travelling Waves for Fully Discretized Bistable Reaction-Diffusion Problems

We study various temporal and spatial discretization methods for bistable reaction-diffusion problems. The main focus is on the functional differential operators that arise after linearizing around travelling waves in the spatially discrete problem and studying how the subsequent discretization of time affects the spectral properties of these operators. This represents a highly singular perturbation that we attempt to understand via a weak-limit method based on the pioneering work of Bates, Chen and Chmaj (2003). Once this perturbation is understood, one can study the existence and (non)-uniqueness of waves in the fully discretized reaction-diffusion system.

Hermen Jan Hupkes
University of Leiden
Mathematical Institute
hhupkes@math.leidenuniv.nl

MS71

Nonlocal Aggregation Models: A Primer of Swarm Equilibria

Biological aggregations (swarms) exhibit morphologies governed by social interactions and responses to environment. Starting from a particle model we derive a nonlocal PDE describing evolving population density. We study equilibria and their stability via the calculus of variations which yields analytical solutions. These solutions include features such as spatial localization with compact support, mass concentrations, and discontinuous density jumps that are also observed numerically. We apply our methods to a model of locust swarms.

Andrew J. Bernoff
Harvey Mudd College
Department of Mathematics
ajb@hmc.edu

Chad M. Topaz
Macalester College
ctopaz@macalester.edu

MS71

Fire Ants Build, Morph, and Repair to Survive Floods

Fire ants are model organisms for studying active self-healing materials. By linking their legs together, they build highly interconnected networks that can quickly rearrange themselves in response to applied stress. In this talk, we present experiments and modeling that elucidate their construction. Spherical rafts of ants morph into pancakes within minutes; towers are constructed to provide an equal compressive load on each ant. We also use plate-on-plate rheology to show ants modify their elastic and viscous moduli by rearrangement of their bodies. Particular consideration is given to showing how structural shape and material properties arise from movement and interactions between ants.

David Hu
Georgia Institute of Technology
hu@me.gatech.edu

MS71

Quantifying Collective Cell Migration During Cancer Progression

During cancer progression, tumor cells migrate throughout the body, forming clinically dangerous secondary tumors. This metastatic process begins when cells leave the primary tumor, either as individual cells or collectively migrating groups. Using quantitative image analysis techniques, we are able to extract motion information from time-lapse images of epithelial sheets with varying malignancy. Adapting metrics originally used to study fluid flows we characterize the dynamics of these cell lines and compare to collective dynamics models.

Rachel Lee
Department of Physics
University of Maryland College Park
rmlee@umd.edu

Haicen Yue
University of California San Diego
yuehaicen0228@gmail.com

Wouter-Jan Rappel
Department of Physics
University of California, San Diego
rappel@physics.ucsd.edu

Wolfgang Losert
Department of Physics
University of Maryland, College Park
wlosert@glue.umd.edu

MS71

Aggregate Behaviors of Heterogeneous, Delay-Coupled Agents

Emerging collective motions of swarms of interacting agents are a subject of great interest with a wide range of applications. We show, using mean-field analysis, how collective motion patterns and segregation of populations of agents with different dynamic properties emerge naturally in a model based on self-propulsion and attractive pairwise interactions between delay-coupled agents. We show persistence of behaviors with non-global coupling and reduced swarm populations, and verify these results through simulation and experiments.

Klementyna Szwaykowska
Plasma Physics Divsion
Naval Research Laboratory
klementyna.szwaykowska.ctr@nrl.navy.mil

Christoffer R. Heckman
U.S. Naval Research Laboratory
crheckman@gmail.com

Luis Mier-y-Teran
Johns Hopkins Bloomberg School of Public Health
lmier-y@jhsph.edu

Ira B. Schwartz
Naval Research Laboratory
Nonlinear Dynamical Systems Section
ira.schwartz@nrl.navy.mil

MS72

Clustering, Malleability and Synchronization of Hodgkin-Huxley-Type Neurons

In this work we consider a "network of network" of bursting neurons described by the Huber-Braun model. Each network is coupled internally in a small word scheme while each network is coupled to all other networks using the connectivity matrix of the cat cerebral cortex. Three dynamical behavior are analyzed: network clustering generation, characterized by the coherence of a group of network; malleability of the entire network face small changes in the intra coupling (internal to a network) and inter coupling (between networks) parameters; and the synchronization of the entire network. In particular we pay attention in the complex interplay between inter and intra coupling that makes the network to be very adaptive to small variations on the coupling parameters.

Sergio R. Lopes, Thiago de L. Prado
Department of Physics
Federal University of Parana
lopes@fisica.ufpr.br, thiagolprado@gmail.com

Ricardo L. Viana
Departmento de Fisica
Federal University of Parana
viana@fisica.ufpr.br

José C. P. Coninck
Department of Mathematics
Federal Technological University of Parana
coninck@gmail.com

Juergen Kurths
Humboldt Univ,Germany, Potsdam Institute for Climate Impact
Research, Germany, and Aberdeen University, UK
juergen.kurths@pik-potsdam.de

MS72

Nontrivial Collective Dynamics in Networks of Pulse Coupled Oscillators

A wealth of complex phenomena arise in coupled phase oscillators – typically associated to various forms of synchronization – but the collective (macroscopic) dynamics itself is usually regular (either consisting in a fixed point or in a limit cycle for the macroscopic variables). This is somehow surprising, as the collective dynamics follows from the evolution of functional, i.e. infinite dimensional, equations. We discuss a few examples, where the collective motion is chaotic and possibly even high-dimensional. Disorder in the form of diversity among the oscillator frequencies (such as in the standard Kuramoto model) appears to be a basic ingredient, accompanied by the selection of suitable phase response curves. The possible extension to phase-oscillators setups will be also discussed.

Antonio Politi
Institute for Complex Systems and Mathematical Biology,
University of Aberdeen, UK
a.politi@abdn.ac.uk

Ekkehard Ullner
ICSMB, Department of Physics
University of Aberdeen, UK
e.ullner@abdn.ac.uk

MS72

Synchronization in a Cortical Multilayered Computational Model: A Simulation Study

We performed a simulation study on the emergence of synchronous states in a cortical network model. The model consists of excitatory and inhibitory neurons arranged in four layers representing local cortical circuit. Neurons are described by Izhikevich model with parameters that reproduce firing behavior of different excitatory and inhibitory neuronal types. We studied versions of the model without synaptic plasticity and with synaptic plasticity modeled by an asymmetric spike-timing-dependent plasticity (STDP) rule. The version without synaptic plasticity displayed asynchronous irregular spontaneous activity while the version with STDP displayed synchronous activity with properties dependent on the neuronal types comprising the network.

Antonio C. Roque, Renan O. Shimoura, Rodrigo F. O. Pena
Department of Physics, FFCLRP
University of Sao Paulo, Ribeirao Preto, SP, Brazil
antonior@ffclrp.usp.br, renanshimoura@gmail.com, rfdop@uol.com.br

MS72

Effects of Reciprocal Inhibitory Coupling in Synchronous Neurons

The influences of chemical and electrical synapses are investigated here using Hodgkin-Huxley model neurons. We study the dynamics displayed by a pair of neurons coupled by either (*i*) only chemical inhibition or by (*ii*) electrical coupling first and then chemical inhibition. In both scenarios the neuron with the lower firing rate stops spiking for strong enough inhibition, while the faster neuron remains active. However, in scenario (*ii*) the originally slower neuron stops spiking earlier, suggesting that synchronization introduces an element of instability into the two-neuron network.

Epaminondas Rosa
Illinois State University
Department of Physics
erosa@ilstu.edu

MS73

Crossover Collisions of Scroll Waves

The interaction of a pair of scroll waves is studied in a chemical system by optical tomography. When the two locally counter-rotating filaments approach each other closer than radius of the spiral core, they may collide. These crossover collisions lead to a rupture and a subsequent reconnection of the filaments. Each reconnected filament consisted of parts that originated from both of the original filaments. The conditions for rupture and reconnection of filaments will be discussed.

Dennis Kupitz
Institut of Experimental Physics
dennis.kupitz@gmx.de

Marcus Hauser
Institute of Experimental Physics
Otto-von-Guericke-University, Magdeburg, Germany
marcus.hauser@ovgu.de

MS73

Role of Small Sized Heterogeneities in the Onset and Perpetuation of Arrhythmias

We investigate, in silico, the dynamics of rotors in 2D and in an anatomical model of human ventricles. We study the effect of small size ionic heterogeneities, similar to those measured experimentally. We show that they can anchor and also attract rotors rotating at a substantial distance from the heterogeneity. It depends on the extent of the heterogeneities and can be as large as 5-6 cm. We discuss possible mechanism of the observed phenomena.

Alexander Panfilov
Department of Physics and Astronomy, Gent University
Alexander.Panfilov@UGent.be

Arne Defauw, Nele Vandersickel
Department of Physics and Astronomy Ghent University,Belgium
arne.defauw@ugent.be, nele.vandersickel@ugent.be

Peter Dawyndt
Department of Applied Mathematics, Computer Science and
Statistics, Ghent University, Ghent
peter.dawyndt@ugent.be

MS73

Effects of Substrate Geometry on Spiral Wave Chi-

rality

We introduced inexcitable obstacles into 1-cm-diameter cardiac monolayers, leading to the initiation of clockwise-rotating, counterclockwise-rotating, and pairs of spiral waves. Simulations demonstrated that the location of the obstacle and the side pacemaker frequency controlled spiral wave chirality. Instabilities observed in action potential duration restitution curves computed at different spatial locations predicted sites of propagation failure, and, thus, spiral wave chirality.

Thomas D. Quail
McGill University
thomas.quail@mail.mcgill.ca

Alvin Shrier, Leon Glass
McGill University
Department of Physiology
alvin.shrier@mcgill.ca, glass@cnd.mcgill.ca

MS73

Scroll Waves in Viscous Systems with Stokes Flow: Writing Filaments and Other New Tricks

Excitable and oscillatory reaction-diffusion systems can self-organize vortex states that rotate around one-dimensional phase singularities. We have studied the dynamics of these scroll waves and filaments in the Belousov-Zhabotinsky reaction with a particular emphasis on the interaction of filaments with internal heterogeneities and the system boundaries. For a highly viscous system, scroll waves can be pinned to moving glass rods and repositioned at will. If the glass rod extends only along a fraction of the filament, the free filament gets stretched out along the rod trajectory and the trailing end moves with a speed that depends on the local curvature. We also performed experiments on scroll wave drift along step-shaped height changes. Our experimental results are complemented by simulations of which some explicitly consider the Stokes flow generated by the slowly moving heterogeneities.

Oliver Steinbock
Department of Chemistry and Biochemistry
Florida State University
steinbck@chem.fsu.edu

MS74

Dynamics of Networks with Partially Symmetric Connectivity Matrices

According to the long-standing Hebbian hypothesis, external stimuli are stored in long-term memory thanks to modifications of synaptic connectivity in neural circuits that are activated by such stimuli. However, the details of synaptic 'learning rules', as well as the impact of synaptic plasticity on network dynamics, are still unclear. In this talk, I will describe two complementary directions whose goal is to improve our understanding of these questions. The first consists in investigating the effects of realistic 'learning rules' that have been used to fit in vitro data on network dynamics. The second consists in inferring synaptic 'learning rules' from the changes in neuronal activity upon repeated presentations of initially novel stimuli.

Nicolas Brunel
Departments of Statistics and Neurobiology
The University of Chicago
nbrunel@galton.uchicago.edu

MS74
Oscillations in Neuronal Networks

Neurons in the visual cortex exhibit heterogeneity in feature selectivity and the tendency to generate action potentials synchronously with other nearby neurons. Visual responses from cat visual cortex during gamma oscillations reveal a postive correlation between strength of oscillations, propensity towards synchronization, and sharpness of orientation tuning. We present a model that can account for the correlations between these three properties and could apply more generally to any brain region with analogous neuron types.

Stefanos Folias
Department of Mathematical Sciences
University of Alaska Anchorage
sfolias@uaa.alaska.edu

MS74
On a Kinetic Fitzhugh-Nagumo Equation

We consider the dynamics of the electric activity of a neuron within a large network, described at a mesoscopic scale incorporating intrinsic stochastic dynamics and disordered interactions. We are concerned with showing (i) existence and linear stability of steady states, as well as (ii) nonlinear exponential stability in the weak connectivity regime. We illustrate these results analyzing the electrically coupled Fitzhugh-Nagumo kinetic equation.

Cristobal Quininao
Laboratoire Jacques-Louis Lions
cristobal.quininao@college-de-france.fr

MS74
Assembling Collective Activity in Neural Circuits

Experimental breakthroughs are yielding an unprecedented view of the brain's connectivity and of its coherent dynamics. But how does the former lead to the latter? We use graphical and point process methods to reveal the contribution of successively more-complex network features to coherent spiking.

Eric Shea-Brown
Department of Applied Mathematics
University of Washington
etsb@amath.washington.edu

MS75

Entropy, Dissipation and Information Processing in Models of Complex Systems

Recent advances in the study of (biological) complex systems have shown an intimate connection between dissipation and computation. Information theory provides a universal framework to formalize these notions. In this talk, I review complex systems as information-processing devices, which compute patterns at the expense of information written to hidden degrees of freedom. As an example, I review how such a picture yields a direct connection between the notions of dissipation used in the major modelling paradigms of complex systems: Markovian stochastic dynamics (stochastic thermodynamics, Monte-Carlo simulations) and thermostatted equations of motion (molecular dynamics simulations).

Bernhard Altaner
Max-Planck Insitute for Dynamics and Self-Organization
bernhard.altaner@ds.mpg.de

MS75

Degrees of Information Processing in Chaotic Dynamical Systems

It is well known that chaotic dynamical systems generate information. This is typically captured by the Kolmogorov-Sinai entropy, the supremum of Shannon entropy rates over all possible partitions of the system. We have recently shown that this is a rather crude measure, and can in fact be dissected in to two pieces: a part that is remembered by being correlated with future behavior, and a part which is forgotten and plays no role in the temporal evolution of the system. Here, we show that although the entropy rate is invariant for both Markov and generating partitions of the system, its decomposition is not. We compare these values for the tent map, and comment on what this means for study of such chaotic systems as information generators or processors.

Ryan G. James
University of California, Davis
rgjames@ucdavis.edu

MS75

Time-Dependent Chaotic Attractors Shape Information Content in Neural Networks

Large networks of sparsely coupled, excitatory and inhibitory cells occur throughout the brain. They are responsible for ongoing and complex computations, the exact mechanisms of which are poorly understood. Groups of connected neurons form very high-dimensional Dynamical Systems that are often responding to rich, temporally fluctuating signals from various afferents. For many models of these networks, a striking feature is that their dynamics are chaotic and thus, are sensitive to small perturbations. How does this chaos manifest in the neural code? Understanding how the dynamics of large driven networks shape their capacity to encode and process information presents a sizeable challenge. Inspired by this question, I will discuss the use of Random Dynamical Systems Theory as a framework to study information processing in high-dimensional, non-autonomous systems. Using a neural network model, I will present recent results linking random strange attractors to noise entropy and input discrimination of dynamical observables.

Guillaume Lajoie
Department of Applied Mathematics
University of Washington
glajoie@amath.washington.edu

MS75

Deconstructing Maxwells Demon

The thermodynamic role of information processing has become an active topic of research because of its relevance to a wide range of problems, from bacterial sensing and feedback control of microscopic systems to single-photon cooling of atoms. This is most dramatically captured in the gedanken experiment of Maxwells demon, where a neat-fingered intelligent being can violate the second law of thermodynamics by extracting work from a single heat source. With an exactly solvable model, we discuss a possible working mechanism of the demon. We draw a nonequilibrium phase diagram and show that, depending on the location on the diagram, the model can act either as an engine, converting into work the extracted heat from the single heat source, or as a Landauer eraser, erasing information and consuming external work in the process.

Dibyendu Mandal
University of California, Berkeley
dibyendu.mandal@berkeley.edu

MS76

Microfluidic Networks of Belousov-Zhabotinsky Drops

Several microfluidic based experimental systems of networks of non-linear chemical oscillators are presented. 2D planar arrays of oscillators with nearest neighbor coupling involving both inhibitory and excitatory species are developed. We explore phenomena such as synchronization, oscillator death and assess the number of attractors, as well as their basin of attraction, as a function of the topology of the network and the heterogeneity of the oscillators and their coupling strength.

Seth Fraden
Brandeis University
Department of Physics
fraden@brandeis.edu

MS76

Synchronization and Network Topology of Electrochemical Micro-Oscillators in On-Chip Integrated Flow Cells

We present that oscillatory reactions taking place on electrode arrays in single or branched flow channels inherently form a network, whose characteristics can be tuned with the position of the electrodes. The network structure is decoded from experimental measurements and the structure is interpreted with a theory. The unusual, spatially dependent network topology induces a unique dynamical response in the form of a spatial gradient in the extent of synchronization with large set of electrodes.

Istvan Z. Kiss, Yanxin Jia, Yifan Liu, Jasmine Coleman
Department of Chemistry
Saint Louis University
izkiss@slu.edu, yjia4@slu.edu, liuyifan@slu.edu, jcolem13@slu.edu

MS76

Synchronization in Networks of Coupled Chemical Oscillators

We have studied heterogeneous populations of chemical oscillators to characterize different types of synchronization behavior. The formation of phase clusters in stirred suspensions of Belousov-Zhabotinsky oscillators is described, where the (global) coupling occurs through the medium. We then describe the formation of phase clusters and chimera states in populations of photosensitive oscillators. The nonlocal coupling occurs via illumination intensity that is dependent on the state of each oscillator. The behavior of oscillators in ring configurations as a function of the number of oscillators is described, including traveling cluster states. References: A. F. Taylor et al., Angewandte Chemie Int. Ed. 50, 10161 (2011); M. R. Tinsley et al.,

Nature Physics 8, 662 (2012); S. Nkomo et al., Phys. Rev. Lett. 110, 244102 (2013).

Kenneth Showalter
West Virginia University
Department of Chemistry
kshowalt@wvu.edu

MS76

Long Transients to Synchronization in Random Networks of Electrochemical Oscillators

In sparse, connected, random networks of attractively coupled oscillators one can expect a range of dynamical equilibria, such as complete synchronization, phase synchronization, partial synchronization or incoherence [Toenjes et al., Chaos 20, 033108 (2010)]. Here we report on experiments studying the transitions to and from a regime of phase synchronized electrochemical oscillators forming complex wave patterns on a small ring network with a few random non-local connections.

Ralf Toenjes
Potsdam University
Dept. of Physics and Astronomy
ralf.toenjes@uni-potsdam.de

Michael Sebek
Saint Louis University
Department of Chemistry
msebek@slu.edu

Istvan Z. Kiss
Department of Chemistry
Saint Louis University
izkiss@slu.edu

MS77

Travelling Waves and Canards in a Model of Wound Healing Angiogenesis

We discuss the existence of travelling waves in a singularly perturbed model of wound healing angiogenesis. We use geometric singular perturbation theory, supplemented with canard theory due to a fold in the critical manifold where normal hyperbolicity is lost. Along this fold, canard points may exist that allow solution trajectories to pass through the fold. These so-called canard solutions are crucial to establishing the existence of travelling waves, in particular, that contain shocks.

Kristen Harley
Queensland University of Technology
ke.harley@student.qut.edu.au

Peter van Heijster
Mathematical Sciences School
Queensland University of Technology
petrus.vanheijster@qut.edu.au

Robert Marangell
The University of Sydney
robert.marangell@sydney.edu.au

Graeme Pettet
Queensland University of Technology
School of Mathematical Sciences
g.pettet@qut.edu.au

Martin Wechselberger
University of Sydney
martin.wechselberger@sydney.edu.au

MS77

Singularities in Front Bifurcations with Scale Separation

A paradigm for the occurrence of fronts are phase separation phenomena and Allen-Cahn type equations provide the simplest model class. The coupling to further equations with scale-separation leads to a surprisingly rich class of singularly perturbed problems that is amenable to analysis. Over the past decades several methods have been developped to obtain rigorous existence and stability results also for more complicated patterns than single fronts. In this talk we showcase an analysis of a three-component model with two linear equations coupled to an Allen-Cahn equation with scale separation. We show the front dynamics is organized by a butterfly catastrophe that leads to accelerating and direction reversing slow fronts. In addition, a more general result concerning the imbedding of arbitrary singularities in such front bifurcations is shown. This is joint work with Martina Chirilus-Bruckner, Peter van Heijster and Arjen Doelman.

Jens Rademacher
University of Bremen
jdmr@uni-bremen.de

MS77

Pinning and Unpinning in Nonlocal Equations

We investigate pinning regions and unpinning asymptotics in nonlocal equations. We show that phenomena are related to but different from pinning in discrete and inhomogeneous media. We establish unpinning asymptotics using geometric singular perturbation theory in several examples. We also present numerical evidence for the dependence of unpinning asymptotics on regularity of the nonlocal convolution kernel.

Taylor Anderson
Mount Holyoke
ander23t@mtholyoke.edu

Gregory Faye
École des hautes études en sciences sociales
gfaye@ehess.fr

Arnd Scheel
University of Minnesota
School of Mathematics
scheel@math.umn.edu

David Stauffer
Cornell University
dstauffer11@gmail.com

MS77

Canard Supersonique

Looking at the gas dynamics of stars under the assumption of spherical symmetry, I will show that transonic events in such systems are canard phenomena – peculiar solution structures identified in geometric singular perturbation problems. Consequently, stellar winds are carried by

supersonic ducks, and canard theory provides a mathematical framework for this astrophysical phenomenon. So, whenever you have the chance to watch an *aurora*, remember the superheros behind that scene – transonic canards!

Martin Wechselberger
University of Sydney
wm@maths.usyd.edu.au

MS78

Control of Moreau's Sweeping Process: Some Results and Open Problems

While the existence theory is a very active area of research since the '70s, the understanding of the dynamics and of the control of the sweeping process is an entirely new subject. The talk will focus on some models and open problems, together with recent results, obtained in collaboration with other authors (including Nguyen D. Hoang, B. Mordukhovich, R. Henrion), on necessary conditions for various cases of optimal control for the sweeping process. In particular, the case where the moving set depends on control parameters will be considered and the obtained necessary conditions will be illustrated through examples. If time permits also a minimum time problem will be addressed.

Giovanni Colombo
University Padova
colombo@math.unipd.it

MS78

On the Response of Sweeping Processes to Perturbation

If x_0 is an equilibrium of an autonomous differential equation $\dot{x} = f(x)$ and $\det \|f'(x_0)\| \neq 0$, then x_0 persists under autonomous perturbations and x_0 transforms into a T-periodic solution under non-autonomous T-periodic perturbations. In this paper we discover an analogues structural stability for Moreau sweeping processes of the form $-\dot{u} \in N_B(u) + f_0(u)$, $u \in R^2$, i. e. we consider the simplest case where the derivate is taken with respect to the Lebesgue measure and where the convex set B of the reduced system is an immovable unit ball of R^2. We show that an equilibrium $\|u_0\| = 1$ persists under periodic perturbations, if the projection $\overline{f} : \partial B \to R^2$ of f_0 on the tangent to the boundary ∂B is nonsingular at u_0. Supported by RFBR grants 14-01-00867, 14-01-92004, 13-01-00347.

Mikhail Kamenski
Department of Mathematics, Voronezh State University
Universitetskaja pl. 1, Voronezh, 394006, Russia
mikhailkamenski@mail.ru

Oleg Makarenkov
University of Texas at Dallas
makarenkov@utdallas.edu

MS78

Dynamics of Sweeping Processes with Jumps in the Driving Term

For discontinuous driving terms, sweeping processes were originally formulated first for step multifunctions and then extended to BV moving convex sets. Another natural procedure consists in extending the classical continuous process from absolutely continuous to BV driving terms through a continuity method [V. Recupero, *A continuity method for sweeping processes*, J. Differential Equations, 2011]. We show that this method leads to a new of notion of sweeping process and we compare the two different dynamics.

Vincenzo Recupero
Department of Mathematics
Politecnico di Torino, Italy
vincenzo.recupero@polito.it

MS78

Estimation and Control Problems in Systems with Moreau's Sweeping Process

This talk will address control-theoretic design problems for dynamical systems modeled as variants of Moreau's sweeping process. As a first case, we consider physical systems which comprise a time-varying Lipschitz vector field and the set-valued mapping resulting from a first-oder convex sweeping process. A well-posedness result on existence and uniqueness of solutions for such systems is presented. The result is used for designing controllers, and state estimators in the context of output regulation problem. An extension of these techniques is used to derive Lyapunov stability conditions and design state estimators for systems involving sweeping processes with proximally regular set-valued mappings. We next consider second order sweeping processes which are useful in modeling mechanical systems with unilateral constraints. The problem of velocity estimation is considered using only the position measurements, which becomes nontrivial due to discontinuities in the velocity caused by the impacts. A state estimator is proposed which has the form of a measure differential inclusion. It is shown that there exists a unique solution to the proposed differential inclusion and that solution converges to the actual velocity of the system.

Aneel Tanwani
Department of Mathematics
University of Kaiserslautern, Germany
tanwani@mathematik.uni-kl.de

MS79

The Dynamics of Vortices and Masses over Surfaces of Revolution

One of the today's challenges is the formulation of the N-body and N-vortex dynamics on Riemann surfaces. In this talk we show how the two problems are strongly related one another from the point of view of the intrinsic geometry of the surface where thedynamics takes place. Given a surface M of metric g and the distribution of matter S on M, we deduce the dynamics of the masses and some of its properties.

Stefanella Boatto
Dep. de Matematica Aplicada, IM
Universidade Federal de Rio de Janeiro
boatto.stefanella@gmail.com

Gladston Duarte
Pós-Graduao do Instituto de Matemática
Universidade Federal de Rio de Janeiro
gladston.df@gmail.com

David G. Dritschel
Department of Applied Mathematics

University of St Andrews
dgd@mcs.st-and.ac.uk

Teresa J. Stuchi
Instituto de Fisica
Universidade Federal de Rio de Janeiro
tstuchi@if.ufrj.br

Carles Simo
Departamento de Matematica i Analisi
Universitat de Barcelona
carles@maia.ub.es

Rodrigo Schaefer
Departament de Matemàtica Aplicada I Anàlisi
ETSEIB-UPC
schaefer@upc.br

MS79

Eulerian Geometric Integration of Fluids for Computer Graphics

We present two geometric numerical methods for fluid simulation in computer animation. One is built to enforce Kelvin's theorem in a semi-Lagragian manner, while the other is derived from first principles using a finite dimensional approximation of the group of volume-preserving diffeomorphisms. The two resulting time integrators are shown to exhibit much improved numerical behavior. Time permitting, we will also discuss extensions to magnetohydrodynamics and geophysical flows.

Mathieu Desbrun
Dept. of Computing & Mathematical Sciences
CALTECH
mathieu@cms.caltech.edu

Dmitry Pavlov
Department of Mathematics
Imperial College
d.pavlov@imperial.ac.uk

Evan S. Gawlik
Stanford University
egawlik@stanford.edu

Yiying Tong
Computer Science and Engineering
Michigan State University
ytong@msu.edu

Gemma Mason
CMS dept.
Caltech
gem@caltech.edu

Eva Kanso
University of Southern California
kanso@usc.edu

MS79

Poincare-Birkhoff Normal Forms for Hamiltonian Relative Equilibria

Consider a cotangent bundle Hamiltonian system with a free, proper and compact Lie symmetry. We present an iterative algorithm suitable for the application of the Poincare-Birkhoff normal forms method near a relative equilibrium on a fixed momentum level set.

Cristina Stoica
Department of Mathematics
Wilfrid Laurier University
cstoica@wlu.ca

MS79

Studies on Dynamics of Vortices on a Flat Torus

In this talk I will present a complete description of the dynamics of two vortices on flat tori. The dynamics is determined by a Hamiltonian equation for the evolution of the center of vorticity with a Hamiltonian function defined in terms of Jacobi theta functions. We describe the bifurcation curves obtained under variations of the module parameter of the torus. The analysis of the stability for some special solutions are in progress.

Humberto H. de Barros Viglioni
Departamento de Matematica
Universidade Federal de Sergipe
ufs@viglioni.mat.br

MS80

Spiral Pinballs

Spiral waves in excitable media possess both wave-like and particle-like properties. When resonantly forced, spiral cores drift like particles along straight trajectories. These trajectories may reflect from medium boundaries or from obstacles within the medium. Interestingly, such reflections are almost always non-specular (that is, they have english), and this results in interesting ricochet paths within the medium. Paths may be further complicated if the medium itself undergoes motion.

Jacob Langham
Mathematics Institute
University of Warwick
J.Langham@warwick.ac.uk

Dwight Barkley
University of Warwick
Mathematics Institute
D.Barkley@warwick.ac.uk

MS80

Drift of Scroll Waves in Thin Layers Caused by Thickness Features

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.

Irina Biktasheva
University of Liverpool
ivb@liv.ac.uk

Hans Dierckx
Department of Physics and Astronomy

Ghent University
hans.dierckx@ugent.be

Vadim N. Biktashev
College of Engineering, Mathematics and Physical Sciences
University of Exeter
V.N.Biktashev@exeter.ac.uk

MS80

Tidal Forces Act on Cardiac Filaments

During cardiac arrhythmias, scroll waves of electrical activation rotate around a filament curve. By treating the anisotropy of cardiac tissue as a curved space, I derive the laws of motion for filaments in anisotropic reaction-diffusion systems. In addition to the familiar filament twist and curvature terms, intrinsic curvature (Riemann curvature terms) also act as tidal forces on the filament.

Hans Dierckx
Department of Physics and Astronomy
Ghent University
hans.dierckx@ugent.be

MS80

Computation of Unstable Solutions of Cardiac Models on Static and Evolving Domains

Although typical cardiac models respect global Euclidean symmetries, these symmetries are generally broken by chaotic solutions. A generalized amplitude-phase representation allows "decomposition' of such chaotic multi-spiral solutions into tiles, each of which contains a single spiral described by an unstable periodic or relative periodic solution that respects translational and rotational symmetries locally. We present a method for computing such solutions on irregular domains with stationary or moving boundaries and discuss their properties.

Christopher Marcotte
Georgia Institute of Technology
christopher.marcotte@gmail.com

Roman Grigoriev
Georgia Institute of Technology
Center for Nonlinear Science & School of Physics
roman.grigoriev@physics.gatech.edu

MS81

First-Passage Times of Random Walks in Confined Geometries

Abstract not available.

Olivier Benichou
Universite Pierre et Marie Curie
benichou@lptl.jussieu.fr

MS81

Asymptotic Analysis of Narrow Escape Problems in Non-Spherical 3D Domains

Narrow escape problems for non-spherical 3D domains with $N \geq 1$ boundary traps are considered. We compute an asymptotic expression for the average mean first passage time (AMFPT) for three-dimensional domains bounded by a level surface of an orthogonal coordinate system. A two-term asymptotic expansion for the AMFPT is derived for an arbitrary N; it is compared with COMSOL numerical solutions. Steps are taken towards the derivation of higher-order asymptotics and a position-dependent MFPT formula.

Alexei F. Cheviakov
Department of Mathematics and Statistics
University of Saskatchewan
cheviakov@math.usask.ca

Daniel Gomez
University of British Columbia
dag857@mail.usask.ca

MS81

First Passage Times in Biological Self-Assembly

Nucleation and self-assembly in biology usually involve a fixed number of constituents aggregating into clusters of a finite maximal size. Motivated by this scenario, we derive the corresponding backward Kolmogorov equation for the cluster probability distribution and study the distribution of times it takes for a single maximal cluster to be completed, starting from any initial particle configuration. Surprisingly, we find, both analytically and numerically, that faster detachment can lead to a shorter mean time to first completion of a maximum-sized cluster. This result is due to the redistribution of trajectory weights upon increasing the detachment rate so that paths that take a shorter time to complete a cluster become more likely.

Maria D'Orsogna
CSUN
dorsogna@csun.edu

Tom Chou
UCLA
Departments of Biomathematics and Mathematics
tomchou@ucla.edu

MS81

Signal Focusing Through Active Transport

The precision of cellular signaling and novel diagnostic devices is limited by the counting noise imposed by the thermal diffusion of molecules. Many macromolecules and organelles bind to molecular motors and are actively transported. We will show that a random albeit directed delivery of molecules to within a typical diffusion distance to the receptor reduces the noise correlation time, thereby improving sensing precision. The conditions for improved sensing are compatible with observations in living cells.

Aljaz Godec
Universität Potsdam
agodec@uni-potsdam.de

Ralf Metzler
Inst for Physics & Astronomy
University of Potsdam
rmetzler@uni-potsdam.de

MS82

Control of Multiscale Dynamical Systems

New applications in materials, medicine, and computers

are being discovered where the control of events at the molecular and nanoscopic scales is critical to product quality, although the primary manipulation of these events during processing occurs at macroscopic length scales. These systems motivate the creation of tools for the control of multiscale systems that have length scales ranging from the atomistic to the macroscopic. This talk describes a systematic approach that consists of stochastic parameter sensitivity analysis, Bayesian parameter estimation applied to ab initio computational chemistry calculations and experimental data, model-based experimental design, hypothesis mechanism selection, and multistep optimization. The application of control theory to the analysis and design of multiscale simulation codes is also discussed.

Richard D. Braatz
Massachusetts Institute of Technology
Department of Chemical Engineering
braatz@mit.edu

MS82

Some Results on the Backward Stability of Singular Perturbation Approximations of Linear and Nonlinear Stochastic Control Systems

An important aspect of model reduction of large-scale control systems is the estimation of the approximation error as a function of the control input. A different question is whether feedback controls computed from a reduced model are a reasonable approximation of the optimal control for the original model, the computation of which is often infeasible. In this talk we present recent results on the backward stability of singular perturbation approximations of a certain class of stochastic control systems and discuss various applications.

Carsten Hartmann
Freie Universität Berlin (Free University of Berlin)
chartman@mi.fu-berlin.de

MS82

Variational Integrators for Multiscale Dynamics

In this talk variational integrators are developed for the structure-preserving integration of systems with dynamics on multiple time scales. The construction is based on a derivation in closed form via a discrete variational principle on a time grid consisting of macro and micro time nodes. The structure preserving properties as well as the convergence behavior of the multirate integrator are analyzed and its performance is demonstrated by numerical examples.

Sina Ober-Bloebaum
Universität Paderborn (University of Paderborn)
sinaob@math.uni-paderborn.de

Sigrid Leyendecker
University of Erlangen-Nuremberg
sigrid.leyendecker@ltd.uni-erlangen.de

MS82

Control of Oscillators, Temporal Homogenization, and Energy Harvest by Super-Parametric Resonance

We show how to control an oscillator by periodically perturbing its stiffness, such that its amplitude follows an arbitrary positive smooth function. This also motivates the design of circuits that harvest energies contained in infinitesimal oscillations of ambient electromagnetic fields. To overcome a key obstacle, which is to compensate the dissipative effects due to finite resistances, we propose a theory that quantifies how small/fast periodic perturbations affect multidimensional systems. This results in the discovery of a mechanism that reduces the resistance threshold needed for energy extraction, based on coupling a large number of RLC circuits.

Molei Tao
Courant Institute, NYU
mtao@gatech.edu

MS83

Nonlinear Waves in Microsphere-Based Metamaterials

Locally-resonant metamaterials and granular media are both highly dispersive and known to drastically affect acoustic wave propagation. In this work, we consider the nonlinear dynamics of a system at the intersection of these two types of media: a locally-resonant metamaterial composed of microscale spheres adhesively coupled to an elastic substrate, where the spheres act as nonlinear local resonators. Dynamical simulations of a discrete element model representing the metamaterial are compared with photoacoustic experimental measurements.

Nicholas Boechler
University of Washington
Department of Mechanical Engineering
boechler@uw.edu

MS83

Multiscale Analysis of Strongly Localized Waves

Abstract not available.

Guillaume James
Laboratoire Jean Kuntzmann, Université de Grenoble and CNRS
INRIA Grenoble
guillaume.james@imag.fr

MS83

Standing Waves on Tadpole Graphs

We develop a detailed rigorous analysis of edge bifurcations of standing waves in the nonlinear Schrodinger (NLS) equation on a tadpole graph (a ring attached to a semi-infinite line subject to the Kirchhoff boundary conditions at the junction). It is shown in the recent work of C. Cacciapuoti, D. Finco, and D. Noja by using explicit Jacobi elliptic functions that the cubic NLS equation on a tadpole graph admits a rich structure of standing waves. Among these, there are different branches of localized states bifurcating from the edge of essential spectrum of an associated Schrodinger operator. In this work, joint with D. Noja (Milan), we show by using the Lyapunov-Schmidt reduction that the bifurcation phenomenon is general for other power nonlinearities and moreover, the local properties of bifurcating standing waves can be characterized in full details. We distinguish a primary branch of never vanishing standing waves bifurcating from the trivial solution and an infinite sequence of higher branches with oscillating behavior in the ring. The higher branches are not small at threshold and bifurcate from the branches of degenerate standing waves with vanishing tail outside the ring. Each higher nontrivial branch breaks the symmetry of the degenerate branch. Moreover, we analyze stability of bifurcating standing waves. Namely, we show that the primary branch is composed by orbitally stable standing waves, while the nontrivial higher branches are linearly unstable near the bifurcation point. The stability character of the degenerate branches remains inconclusive at the analytical level, whereas heuristic arguments and numerical approximations support the conjecture of their linear instability at least near the bifurcation point.

Dmitry Pelinovsky
McMaster University
Department of Mathematics
dmpeli@math.mcmaster.ca

MS83

Granular Acoustic Switches and Logic Elements

We present analytical, numerical, and experimental demonstration of an acoustic switch, analogous to its electric/optical counterpart, based on a 1D chain of granular crystals. This system controls the propagation of primary output stress waves by applying secondary control waves, exploiting the nonlinear dynamic effects of the granular chain. We also realize OR and AND acoustic logic gates using multiple control signals.

Jinkyu Yang, Feng Li
University of Washington
jkyang@gmail.com, lif@ciomp.ac.cn

Paul Anzel
California Institute of Technology
panzel@caltech.edu

Panayotis Kevrekidis
University of Massachusetts
kevrekid@math.umass.edu

Chiara Daraio
ETH Zürich, Switzerland and California Institute of Tech
daraio@ethz.ch

MS84

Modulating Synaptic Plasticity Within In Vitro Hippocampal Networks

Synaptic plasticity, in the form of long-term potentiation (LTP) and long-term depression (LTD), is thought to underlie learning and memory. Both must be highly regulated for proper memory storage to take place. We chemically induce LTP and LTD within networks of hippocampal neurons and quantify the changes in action potential firing within the purview of network dynamics.

Rhonda Dzakpasu
Georgetown University
Department of Physics
rd259@georgetown.edu

MS84

Traveling Patterns in Lateral Inhibition Neural Networks

We investigate the necessary condition- asymmetry in the coupling function, for traveling pulses to exist in a neural network coupled with lateral inhibition. We then compute the traveling pulses using a system of equivalent delayed differential equations derived from the neural field model. We further study the dynamical dependency of traveling pulses on the gain and coupling parameters, and demonstrate how to determine the stability of given traveling pulses.

Yixin Guo
Drexel University
Department of Mathematics
yixin@math.drexel.edu

Aijun Zhang
Department of Mathematics
Drexel University
zhangai@tigermail.auburn.edu

MS84

Homogenization Theory for Neural Field Models

This talk is divided into two parts. In the first part we review the derivation of the homogenized one - population Amari equation by means of two - scale convergence technique in the case of periodic microvariation in the connectivity function. In the second part we discuss the existence and stability of single and multibump solutions of the homogenized model.

John Wyller
Department of Mathematical Sciences and Technology
Norwegian University of Life Sciences
john.wyller@nmbu.no

MS84

Asymmetric Stationary Bumps in Neural Field Models

For 1D neural field models, we show that the symmetry of the connectivity function causes a degeneracy, permitting the existence of asymmetric bump solutions. When the governing nonlinear integral equation is transformed into a higher-order ODE, the degeneracy leads to a conserved quantity. With this, we construct a horseshoe map and obtain infinitely many asymmetric/symmetric bump solutions. We then discuss the persistence of these solutions under perturbations of the connectivity function and the nonlinear gain.

Dennis Yang
Department of Mathematics
Drexel University
gyang@math.drexel.edu

MS85

Contact Network Models for Immunizing Infections

Many infectious agents spread via close contact between infected and susceptible individuals. The nature and structure of interactions among individuals is thus of fundamental importance to the spread of infectious disease. Heterogeneities among host interactions can be modeled with contact networks, and analyzed using tools of percolation theory. Thus far, the field of contact network epidemiology has largely been focused on the impact of network structure on the progression of disease epidemics. In this talk, we introduce network models which incorporate feedback of the disease spread on network structure, and explore how this feedback limits the potential for future outbreaks. This has implications for seasonal diseases such as influenza, and supports the need for more adaptive public health policies in response to disease dynamics.

Shweta Bansal
Penn State University
shweta@sbansal.com

MS85

Mathematical Models of the Spatial and Evolutionary Dynamics of Influenza A

The research areas of population biology and dynamical systems already have a fruitful shared history. Within this, disease modelling has been particularly lively for both its rich dynamics and its practical importance. In this talk, we will have a brief tour of some of the types of models that are in use for both the spatial and evolutionary aspects of the spread of influenza at the population level, and some of the future mathematical challenges.

Julia R. Gog
Department of Applied Mathematics and Theoretical Physics
University of Cambridge
jrg20@cam.ac.uk

MS85

A Multi-Scale Model of Multiple Exposures to a Pathogen

Dose size and incubation period length are related for many infectious diseases. We explore a dose-dependent latent period of infection (a component of incubation period) following multiple exposures to a pathogen, and study its effect on disease transmission in a population. The immuno-epidemiological model is developed using a threshold-type delay, which is transformed in a biologically natural way, to a system of differential equations with state-dependent delay. Bistability results, which has implications in infection control.

Jane Heffernan
Centre for Disease Modelling, Mathematics & Statistics
York University
jmheffer@yorku.ca

Redouane Qesmi
York University
rqesm@mathstat.yorku.ca

Jianhong Wu
Department of Mathematics and Statistics
York University
wujh@mathstat.yorku.ca

MS85

Evaluation of Combined Strategies for Controlling Dengue Fever

Dengue is the most significant mosquito-borne viral infection of humans, causing 50-100 million infections annually. The main line of attack against dengue has been traditional mosquito control measures, such as insecticides. The coming years will see the broadening of our anti-dengue arsenal to include genetically-modified mosquitoes, biocontrol methods—such as Wolbachia—and vaccines. In this talk, I will discuss mathematical modeling that is being used to help design dengue control efforts using one, or a combination, of these methods.

Alun Lloyd
North Carolina State University
alun_lloyd@ncsu.edu

MS86

Experimental Studies of Burning Invariant Manifolds as Barriers to Reaction Fronts

We study Belousov-Zhabotinsky reaction fronts in the following flows: (a) a single vortex flow; (b) a chain of oscillating vortices; and (c) extended vortex array or spatially disordered flows. In these flows, front propagation is impeded and sometimes pinned by burning invariant manifolds (BIMs) which act as one-way barriers. Experimental measurements of barriers are compared with BIMs that are predicted numerically. We consider the limits of validity of the BIM approach to more complicated flows.

Savannah Gowen
Mount Holyoke College
50 College Street, South Hadley, MA 01075
gowen22s@mtholyoke.edu

Tom Solomon
Bucknell University
tsolomon@bucknell.edu

MS86

Front Pinning in Single Vortex Flows

We study fronts propagating in 2D fluid flows and show that there exist stable invariant front configurations for fairly generic flows. Here we examine the simple flow which combines a single vortex with an overall wind. Existence of the stable front is related to the underlying fluid bifurcation. This elementary structure has application in chemical reactor beds and laminar combustion in well-mixed fluids.

John R. Mahoney
University of California, Merced
jmahoney3@ucmerced.edu

Kevin A. Mitchell
University of California, Merced
Physics
kmitchell@ucmerced.edu

MS86

Propagation of An Autocatalytic Reaction Front in Heterogeneous Porous Media

We investigate experimentally and numerically the coupling of the propagation of an auto-catalytic reaction and the flow in porous media. We will investigate the different propagation modes depending on the flow direction, its amplitude and the disorder of the medium. More particularly, we will demonstrate that heterogeneity of the medium induces a rich variety of front dynamic and morphology.

Laurent Talon
Univ. Paris-Sud
Orsay, F-91405, France

talon@fast.u-psud.fr

Dominique Salin
lab. FAST, UMPC
salin@fast.u-psud.fr

MS86

Front Propagation in Cellular Flows for Fast Reaction and Small Diffusivity

We investigate the influence of cellular flows on the propagation of Fisher-Kolmogorov-Petrovsky-Piskunov chemical fronts in the limit of small molecular diffusivity and fast reaction i.e., large Péclet (Pe) and Damköhler (Da) numbers. We develop an asymptotic theory that describes the front speed in terms of a periodic path – an instanton – that minimizes a certain functional and yields closed-form results for $(\log Pe)^{-1} \ll Da \ll Pe$ and $Da \gg Pe$. Our theoretical predictions are compared with (i) numerical solutions of an eigenvalue problem and (ii) simulations of the advection–diffusion–reaction equation.

Alexandra Tzella, Jacques Vanneste
School of Mathematics
University of Edinburgh
a.tzella@bham.ac.uk, J.Vanneste@ed.ac.uk

MS87

Geometric Optics and Piecewise Linear Systems

Light through a chessboard material with two different refractive indices (for black and white squares) is refracted and reflected in complicated ways. I will describe the derivation of a return map for a geometric ray obeying Snell's Law and use this to derive properties of the rays.

Paul Glendinning
University of Manchester
p.a.glendinning@manchester.ac.uk

MS87

Analysis of Traveling Pulses and Fronts in a Nonsmooth Neural Mass Model

We study the activity of coupled populations of excitatory and inhibitory neurons in a neural firing rate model that includes 1D nonlocal, spatial coupling. To facilitate analysis of spatio-temporal patterns, we approximate the (typically smooth) nonlinear firing rate function with the Heaviside step function. We study the corresponding nonsmooth differential system in traveling wave coordinates, with a particular interest in how the system transitions from traveling front to pulse as the time-constant of inhibition increases.

Jeremy D. Harris
Department of Mathematics
University of Pittsburgh
jdh71@pitt.edu

MS87

Are Plankton Discontinuous, Smooth Or Slow-Fast (and Furious)?

In this talk, we first discuss a piecewise-smooth dynamical system constructed for one predator feeding on two different types of prey and inspired by plankton observations. The piecewise-smooth model has a discontinuity between the two vector fields. Thus, we then construct and discuss different smooth reformulations of the model and compare model predictions with data on freshwater plankton.

Sofia Piltz
University of Oxford
sofia.piltz@linacre.ox.ac.uk

MS87

Infinitely Many Coexisting Attractors in the Border-Collision Normal Form

The nature of piecewise-linear maps (such as the tent map) facilitates exact calculations, yet such maps can display extremely complicated dynamics (including chaos). This talk looks at two mechanisms by which two-dimensional piecewise-linear continuous maps can exhibit infinitely many stable, or asymptotically stable, periodic solutions at special points of parameter space. Scaling laws indicate the rate at which the number of coexisting attractors decreases with the distance from these points.

David J. Simpson
Institute of Fundamental Sciences
Massey University
d.j.w.simpson@massey.ac.nz

MS88

Swarming of Self-propelled Particles in Fluids

Self propulsion, a distinction between active swarmers and passive interacting particles, often invokes speed regulation strategies that can be essential for a swarm to develop and maintain a certain flocking formation. However, speed regulation depends on the ability of a swarmer to sense its own speed relative to its perceived surroundings. Here we study a swarming system in low-Reynolds number flows, examining the effects of hampered speed regulation by the disturbance flow on flock formations.

Yaoli Chuang
California State University, Northridge
yaoli.chuang@csun.edu

Maria D'Orsogna
CSUN
dorsogna@csun.edu

MS88

Origin and Structure of Dynamic Social Networks Based on Cooperative Actions

Societies are built on social interactions. A novel theoretical framework to model dynamic social networks focusses on individual actions instead of interactions between individuals and thereby eliminates the traditional dichotomy between the strategy of individuals and the structure of the population. As a consequence, altruists, egoists and fair types are naturally determined by the local social structures, while globally egalitarian networks or stratified structures arise. Cooperative actions drive the emergence and shape the structure of social networks.

Christoph Hauert, Lucas Wardil
The University of British Columbia

christoph.hauert@math.ubc.ca, wardil@math.ubc.ca

MS88

Hotspots in a Non-Local Crime Model

We extend the Short et al. burglary hotspot model to allow for a larger class of criminal movement. Specifically, we allow criminals to travel according to a Lévy flight rather than Brownian motion. This leads to a non-local system of differential equations. The stability of the homogeneous state is studied both numerically and through a Turing-type analysis. The hotspot profiles are then constructed to leading order in a singular regime.

Scott Mccalla
Montana State University
scott.mccalla@montana.edu

Jonah Breslau
Pomona College
jonah.breslau@gmail.com

Sorathan Chaturapruek
Harvey Mudd College
tum_chaturapruek@hmc.edu

Theodore Kolokolnikov
Dalhousie University
tkolokol@mathstat.dal.ca

Daniel Yazdi
University of California, Los Angeles
danielyazdi@ucla.edu

MS88

Co-Dimension One Self Assembly

Self assembly refers to emergent behavior that occurs in systems with a large number of interacting molecules or nanoparticles. These systems produce ordered, supramolecular structures solely due to the interactions between their constituent molecules or particles. My talk will focus on mathematical models for physical processes, such as the assembly of inorganic polyoxometalate (POM) macroions into hollow spherical structures or the assembly of surfactant molecules into micelles and vesicles, where the supramolecular structure has co-dimension one characteristics. I will discuss both the mathematical theory that characterizes when such structures can arise, as well as applications of these insights to physical models of these assemblies.

James von Brecht
California State University, Long Beach
james.vonbrecht@csulb.edu

Scott Mccalla
Montana State University
scott.mccalla@montana.edu

David T. Uminsky
University of San Francisco
Department of Mathematics
duminsky@usfca.edu

MS89

Network Reliability As a Tool for Using Dynamics to Probe Network Structure

We apply the Moore-Shannon network reliability polynomial to infectious disease epidemiology on large social networks. Special cases of the polynomial represent the probability of cascading failures or epidemic outbreaks in complex networks. Although its exact evaluation is NP-hard, efficient, scalable Monte-Carlo estimation is practical. A physical interpretation supports analytical understanding of how local structures interact with dynamics to produce global function.

Stephen Eubank
Virigina Bioinformatics Institute, VA Tech
seubank@vbi.vt.edu

Yasamin Khorramzadeh
Physics Dept.
Virginia Tech
yasi@vbi.vt.edu

Mina Youssef
Virginia Bioinformatics Institute
Virginia Tech
myoussef@vbi.vt.edu

Shahir Mowlaei, Madhurima Nath
Physics Dept.
Virginia Tech
shahir@vt.edu, nmaddy@vbi.vt.edu

MS89

Dynamical Macro-Prudential Stress Testing Using Network Theory

We present a dynamic model to reveal the systemic structure of a banking system, to analyze its sensitivity to external shocks and to evaluate the presence of contagious underlying features of the system. As a case study, we make use of the Venezuelan banking system in the period of 1998–2013. The introduced model was able to capture, in a dynamic way, changes in the structure of the system and the sensitivity of banks portfolio to external shocks. Results suggest the fruitfulness of this kind of approach to policy makers and supervision agencies to address macro-prudential dynamical stress testing and regulation.

Dror Y. Kenett
Boston University, Physics Department
drorkenett@gmail.com

MS89

Role of Netwok Topology in Collective Opinion Formation

To investigate the role of network structures on the phenomena of collective opinion formation, we investigate several modifications to the voter model on co-evolving networks. For example we modify the rewiring step by a path-length-based preference for rewiring that reinforces local clustering and show that reinforcement of clustering in a voter model can have significant ramifications. Furthermore, we will be employing this voter model dynamics to analyze the structures of various empirical social network data sets.

Nishant Malik
Department of Mathematics
University of North Carolina at Chapel Hill, NC, USA

nmalik@email.unc.edu

MS89

Linear Dynamics on Brain Networks: A Tool for Understanding Cognition

Human cognitive function is a complex phenomenon that occurs via intricate neuronal dynamics evolving over a sculpted anatomical network architecture housed within the skull. Yet, fundamental structural drivers of these functions remain poorly understood. Drawing inspiration from network control theory, here we utilize a simple linear model of brain dynamics on experimentally measured anatomical networks to predict the role of brain areas (network nodes) in moving the brain into (i) easily reachable states, (ii) difficult-to-reach states, and (iii) states that require interactions between network communities, which traditionally map to cognitive systems including audition, vision, and motor systems. Our predictions map well to known functions of brain areas, suggesting that structural network architecture forms a fundamental constraint on observed cognitive processes underlying human thought. More broadly, our study illustrates the utility of dynamic models on networks to uncover critical drivers of system function.

Danielle Bassett
School of Engineering and Applied Science
University of Pennsylvania
dsb@seas.upenn.edu

Fabio Pasqualetti
Department of Mechanical Engineering
University of California, Riverside, CA
fabiopas@engr.ucr.edu

MS90

The Dynamics of Alopecia Areata

Alopecia areata is an autoimmune disease causing distinct patterns of hair loss. Little is known regarding the causes or treatment of the disease. We develop an ODE model for alopecia areata dynamics which incorporates one of the current hypotheses that explains a range of experimental observations and suggests several avenues for treatment. Sensitivity analysis is used to determine which inputs have the greatest influence helping focus the study on avenues with the highest potential impact.

Atanaska Dobreva
Florida State University
adobreva@math.fsu.edu

Ralf Paus
University of Manchester
University of Münster
ralf.paus@uksh.de

Nicholas Cogan
Florida State University
cogan@math.fsu.edu

MS90

Epistemic Uncertainty Quantification Using Fuzzy Set Theory

Epistemic uncertainty due to lack of knowledge is inevitable in modeling and simulation. The existing stochastic tools do not readily apply to epistemic uncertainty quantification since probability distributions may not be available. In this paper, we propose a general three-step procedure based on fuzzy set theory to deal with epistemic uncertainty and extend it for mixed epistemic and aleatory uncertainty quantification. The convergence rate of obtained numerical solutions is analyzed and demonstrated with examples.

YanYan He
Scientific Computing and Imaging Center
University of Utah
yhe@sci.utah.edu

Dongbin Xiu
University of Utah
dongbin.xu@utah.edu

MS90

Using Sensitivity Analysis to Understand *S. aureus* Infections

The immune system is a complex network of interactions that challenges the technology and skills of biologists and mathematicians who study it. We present results from global sensitivity analysis techniques (PRCC and Sobol') for two different models, one ODE and one PDE, and discuss the usefulness of these results for: model reduction, understanding immune system interactions, focusing data assimilation techniques on parameters of interest, and motivating biological experiments in the context of *S. aureus* infections.

Angela M. Jarrett
Florida State University
Department of Mathematics
ajarrett@math.fsu.edu

Nick Cogan, M Yousuff Hussaini
Florida State University
cogan@math.fsu.edu, myh@csit.fsu.edu

MS90

Computational Aspects of Stochastic Collocation with Multi-Fidelity Models

We shall discuss a numerical approach for the stochastic collocation method with multifidelity simulation models. The method combines the computational efficiency of low-fidelity models with the high accuracy of high-fidelity models. We shall illustrate the advantages of the method via a set of more comprehensive benchmark examples including several two-dimensional stochastic PDEs with high-dimensional random parameters. Finally, We suggest that tri-fidelity simulations with a low-fidelity, a medium-fidelity, and a high-fidelity model would be sufficient for most practical problems.

Xueyu Zhu
Scientific Computing and Imaging Center
University of Utah
xzhu@sci.utah.edu

Dongbin Xiu
University of Utah

dongbin.xiu@utah.edu

MS91

Moreau Sweeping Processes on Banach Spaces

The sweeping process or Moreau's process in a Hilbert space H (introduced and studied by J.J. Moreau in J.D.E. in 1977) is an interesting problem in both Analysis and Mechanics

$$-\dot{y}(t) \in N(C(t); y(t)) \text{ a.e. in } [0,T], y(0) = y_0 \in C(0)$$

where $C(t)$ is a closed convex moving set depending on the time $t \in [0,T]$ and $y : [0,T] \to H$ is a BV mapping. There are a plethora of variants in this problem in Hilbert spaces.

In this talk I will present my last recent results on the existence of solutions for several extensions to Banach spaces of Moreau sweeping processes and its variants. The main problems that will be presented are: For a given reflexive smooth Banach space X,

$(P1)$ Find $y : [0,T] \to X^*$ such that

$$\begin{cases} -\frac{d}{dt}(y(t)) \in N(C(t); J^*(y(t))) + F(t; J^*(y(t))) \text{ a.e. in } [0,T] \text{ and} \\ J^*(y(t)) \in C(t), \forall t \in [0,T], \text{ and } J^*(y(0)) \in C(0). \end{cases}$$

$(P2)$ Find $y : [0,T] \to X^*$ such that

$$\begin{cases} -y(t) \in N(C(t); J^*(\frac{d}{dt}(y(t)))) + F(t; J^*(y(t))) \text{ a.e. in } [0,T] \text{ and} \\ J^*(\frac{d}{dt}(y(t))) \in C(t), \text{ a.e. on } [0,T], \text{ and } J^*(y(0)) \in C(0), J^*(\frac{d}{dt}y(0)) \in C(0). \end{cases}$$

$(P3)$ Find $y : [0,T] \to X^*$ such that

$$\begin{cases} -\frac{d}{dt}(y(t)) \in N(C(t, J^*(y(t))); J^*(y(t))) \text{ a.e. in } [0,T] \text{ and} \\ J^*(y(t)) \in C(t, J^*(y(t))), \forall t \in [0,T], \text{ and } J^*(y(0)) \in C(0, J^*(y(0))). \end{cases}$$

Here J^* is the normalized duality mapping in X^* defined from X^* to X by

$$J^*(x^*) = \{j^*(x^*) \in X : \langle x^*, j^*(x^*)\rangle = \|j^*(x^*)\|\|x^*\| = \|x^*\|^2 = \|j^*(x^*)\|^2\}.$$

Messaoud Bounkhel
Department of Mathematics
King Saud University, Saudi Arabia
bounkhel@ksu.edu.sa

MS91

Periodic Solutions of Moreau Sweeping Processes and Applications

The concept of equilibrium has been introduced by O. Makarenkov in recent studies of the following autonomus Moreau sweeping process:

$$-u'(t) \in N_B(u(t)) + f(u(t)).$$

In the case of periodically perturbed f there exists a solution in the neighbourhood of the equilibrium. By using contraction mapping theory it is possible to prove stability of closed orbit for a prototypic sweeping process in a Hilbert space.

Ivan Gudoshnikov
Department of Mathematical Sciences
University of Texas at Dallas
ixg140430@utdallas.edu

MS91

Evolution Equations Governed by Sweeping Processes and Applications in Heat Equations with Controlled Obstacles

In this talk, we provide results on existence, stability and optimality conditions for the following class of evolution equations

$$-\dot{x}(t) \in \partial\Phi(x(t)) + N(x(t); C(t, u(t))) \quad \text{a.e. } t \in [0,T]; \quad x(0) = x_0.$$

We then apply these results for heat equations with controlled obstacles. This talk bases on joint work with Juan Peypouquet and Luis M. Briceño-Arias.

Hoang Nguyen
Department of Mathematics
University of Technical Federical Santa Maria, Chile
hoang1311@gmail.com

MS91

Sweeping Process and Congestion Models for Crowd Motion

We propose a mathematical model of crowd motion in emergency evacuation. This microscopic model takes into account the local interactions between pedestrians. The underlying evolution problem takes the form of a first order differential inclusion.and its well-posedness can be proved with the help of recent results concerning sweeping process by uniformly prox-regular sets. Furthermore, we propose a numerical scheme (adapted from Moreau's catching-up algorithm) and prove its convergence.

Juliette Venel
Lab de Mathematiques et leurs Applications de Valenciennes
Universite Lille-Nord de France
juliette.venel@univ-valenciennes.fr

MS92

Braid Dynamics, Self-organized Criticality, and Solar Coronal Heating

Magnetic field lines in the atmosphere of the sun are anchored at the surface, and exist in a highly conducting environment. Hence their topological structure can only change gradually via surface motions, or violently via flaring events. We present models for the evolution of the braid structure to a self-organized state. The discrete nature of the flux distribution at the surface enhances the resulting energy dissipation.

Mitchell Berger
Department of Mathematics
University of Exeter
M.Berger@exeter.ac.uk

MS92

Characterizing Complexity of Aperiodic Braids of Trajectories

A braid of trajectories is an algebraic model of the sequence of interchanges of particles advected by a flow. Insights based on braid-theoretic arguments typically require periodicity of analyzed trajectories. This talk explores what can be deduced from generic, non-periodic trajectories sampled from a flow. We define an aperiodic quantifier of braid complexity and present its dependence on flow parameters, on number of trajectories analyzed, and discuss connections to topological entropy.

Marko Budisic
University of Wisconsin-Madison
Department of Mathematics
marko@math.wisc.edu

Jean-Luc Thiffeault
Dept. of Mathematics
University of Wisconsin - Madison
jeanluc@math.wisc.edu

MS92

Topological Shocks in Burgers Turbulence

We shall discuss statistical properties of global solutions to the random forced Burgers equation. The problem is closely related to analysis of minimizers for random time-dependent Lagrangian systems. We show that for such systems on compact manifolds there exists a unique global minimizer. We also discuss dynamical properties of shocks and show that their global structure is quite rigid and reflects the topology of the configuration manifold

Kostantin Khanin
Department of Mathematics
University of Toronto
khanin@math.toronto.edu

MS92

Topology of Vortex Trajectories in Wake-Like Flows

Complex vortex patterns can emerge downstream of bluff bodies as the result of fluid-structure interaction. As in many fluid systems, the vortex cores define regions that remain coherent for relatively long times. Using a reduced-order model of the dynamics, the topological complexity of the flow is examined through braiding of the vortex trajectories. This wake-like model provides an example of how topological chaos may occur naturally through the dynamics of coherent structures.

Mark A. Stremler
Biomedical Engineering and Mechanics
Virginia Tech
stremler@vt.edu

MS93

On the Generation of Spiral and Scroll Waves by Periodic Stimulation of Excitable Media in the Presence of Obstacles of Minimum Size

In this work we consider the periodic stimulation of two and three dimensional excitable media in the presence of obstacles. We focus our attention in the understanding of the minimum size obstacles that allow generation of spiral and scroll waves, and describe different mechanisms that lead to the formation of such waves. The present studies might be helpful in understanding and controlling the appearance of spiral and scroll waves in the medium.

Daniel Olmos
Department of Mathematics
Universidad de Sonora
daniel.olmosliceaga@gmail.com

Humberto Ocejo
Universidad de Sonora
hocejo@gmail.com

MS93

Interaction of Electric Field Stimuli with Scroll Waves in Three Dimensions

An applied electric field interacts differently with an action potential scroll wave depending on its orientation with the scroll wave's filament. In particular, defibrillation characteristics of the electric field are often more favorable when oriented parallel to the filament, particularly in the case of a thin medium. Theory and computer simulations will be presented illustrating the dynamics of the scroll-wave-electric-field interaction and its dependence on wall thickness and field orientation.

Niels Otani
Rochester Institute of Technology
nfosma@rit.edu

Valentin Krinski
INLN,CNRS, France
valentin.krinski@inln.cnrs.fr

MS93

Describing Scroll Wave Ring Interactions Via Interacting Potentials

We study the dynamics of scroll rings using a simplified model of cardiac action potential (the Karma model) that produces scroll waves with circular core at high excitability (positive tension regime). We calculate the trajectories of symmetric scroll rings as a function of core radius and distance to a bottom boundary and derive a potential function that can then be used to characterize and predict the dynamics without the need for integrating the whole system.

Flavio M. Fenton
Georgia Institute of Technology
flavio.fenton@physics.gatech.edu

Jairo Rodriguez
Universidad de Sonora
jjairo86@gmail.com

Daniel Olmos
Department of Mathematics
Universidad de Sonora
daniel.olmosliceaga@gmail.com

MS93

Unusually Simple Way to Create Spiral Wave in An Excitable Medium

Our analytical and numerical results indicate that a sufficiently strong jump in the diffusion coefficient can result in a unidirectional propagation block in a nonuniform excitable medium. This phenomenon can be used to create spiral wave in a two-dimensional medium with a specific size and geometry of the inhomogeneity. Following this way the spiral wave can be created simply after a single excitation stimulus while others known methods need at

least two stimuli.

Vladimir Zykov, Alexei Krekhov
Max Planck Institute for Dynamics and Self-Organization
vladimir.zykov@ds.mpg.de, alexei.krekhov@ds.mpg.de

Eberhard Bodenschatz
Max Planck Institute for Dynamics & Self-Organization
eberhard.bodenschatz@ds.mpg.de

MS94

Narrow Escape to Traps with Absorbing and Reflecting Portions

We study the Narrow Escape Problem to a small trap with a mixed configuration of absorbing and reflecting sections. In the limit of small trap radius, we derive a high order expansion for the mean survival time which incorporates the asymmetry of the trap through an orientation term. The orientation of the trap is found to significantly influence capture time, particularly in the scenario where the trap is undergoing prescribed motion.

Alan E. Lindsay
Applied Computational Mathematics and Statistics
University of Notre Dame
a.lindsay@nd.edu

MS94

Sampling First-Passage Events When Drift Is Included in the First-Passage Kinetic Monte Carlo Method

We have developed a method for simulating stochastic reaction-drift-diffusion systems, where the drift arises from potential fields. The method combines elements of the First-Passage Kinetic Monte Carlo (FPKMC) method for reaction-diffusion systems and the Wang-Peskin-Elston lattice discretization of drift-diffusion. The original FPKMC uses analytic solutions of the diffusion equation and therefore cannot include nonlinear drift. In our method (Dynamic Lattice FPKMC), each molecule undergoes a continuous-time random walk on its own adaptive lattice.

Ava Mauro
Applied and Computational Math and Stats
University of Notre Dame
ava.j.mauro.10@nd.edu

Samuel A. Isaacson
Boston University
Department of Mathematics and Statistics
isaacson@math.bu.edu

MS94

Uniform Asymptotic Approximation of Diffusion to a Small Target

The problem of the time required for a diffusing molecule within a large bounded domain to first locate a small target is prevalent in biological modeling. I consider this problem for a small spherical target. Uniform in time asymptotic expansions in the target radius of the solution to the corresponding diffusion equation is developed. The approach is based on combining short-time expansions using pseudo-potential approximations with long-time expansions based on first eigenvalue and eigenfunction approximations. These expansions allow the calculation of corresponding expansions of the first passage time density for the diffusing molecule to find the target.

Jay Newby
Mathematical Biosciences Institute
The Ohio State University
newby.23@mbi.osu.edu

MS94

Drunken Robber, Tipsy Cop: First Passage Times, Mobile Traps, and Hopf Bifurcations

For a random walk on a confined one-dimensional domain, we consider mean first passage times in the following two scenarios: a randomly moving trap and an oscillating trap. In both cases, we find that a stationary trap actually performs better than a very slowly moving trap; however, a trap moving sufficiently fast performs better than a stationary trap. Also, we will show the connection between MFPT and Hopf-bifurcation in Gray-Scott model.

Justin C. Tzou
Dalhousie University
tzou.justin@gmail.com

Shuangquan Xie
Mathematics and Statistics
Dalhousie University
xies@mathstat.dal.ca

Theodore Kolokolnikov
Dalhousie University
tkolokol@mathstat.dal.ca

MS95

A Dynamical Switching of Reactive and Nonreactive Modes at High Energies

In Hamiltonian systems, the reaction coordinate, the degree of freedom along which reaction proceeds, has been considered to be unchanged independent of the total energy of the system. I will present our recent finding that, for more than two degrees of freedom Hamiltonian systems, the identity of reaction coordinate can change, in general, as a function of the total energy of the system through the breakdown of normally hyperbolic invariant manifold located around the saddle.

Tamiki Komatsuzaki
Hokkaido University
tamiki@es.hokudai.ac.jp

Mikito Toda
Nara Women's University
toda@ki-rin.nara-wu.ac.jp

Hiroshi Teramoto
Hokkaido University
teramoto@es.hokudai.ac.jp

MS95

Control of a Model of DNA Opening Dynamics via Resonance with a Terahertz Field

We study the internal resonance, energy transfer, and control of DNA opening dynamics via parametric resonance. The model is a chain of pendula in Morse potential that takes into account helicity, inhomogeneity, and environ-

mental effects. While the model is robust to noise, we demonstrate the possibility of triggering its opening dynamics by targeting certain internal modes with specific terahertz fields. This may suggests that DNA natural dynamics can be significantly affected by terahertz radiation exposures.

Wang-Sang Koon
California Institute of Technology
koon@cds.caltech.edu

MS95

Obtaining Coarse-Grained Models from Multiscale Data

In many applications it is desirable to infer stochastic coarse-grained models from observational data of a multiscale process. Estimators such as the maximum likelihood estimator can, however, be strongly biased in this setting. In this talk we discuss a novel inference methodology that does not suffer from this drawback. Moreover, we exemplify through a real-world data set how these data-driven coarse-graining techniques can be used to study the statistical properties of a given temporal process.

Sebastian Krumscheid
École Polytechnique Fédérale de Lausanne (EPFL)
sebastian.krumscheid@epfl.ch

Greg Pavliotis
Imperial College London
g.pavliotis@imperial.ac.uk

Serafim Kalliadasis
Department of Chemical Engineering
Imperial College London
s.kalliadasis@imperial.ac.uk

MS95

Mode-Specific Effects in Structural Transitions of Atomic Clusters with Multiple Channels

We present the dynamical origin of mode-specific effects in structural transitions of atomic clusters with multiple channels. We employ the hyperspherical coordinates to identify reactive modes and driving modes for the respective channels of structural transitions. It is shown that the branching ratios among different channels depend significantly on the modes that are initially activated. Such mode-specific branching ratios are explained in terms of the dynamical coupling and energy transfer between reactive modes and driving modes.

Tomohiro Yanao
Waseda University
yanao@waseda.jp

MS96

Discrete Breathers in Vibro-Impact Lattice Models

Vibro-impact models offer a unique opportunity for obtaining exact analytic solutions for discrete breathers in one-dimensional and two-dimensional systems (with trivial possibility of generalization for 3D case). The solutions are obtained both for Hamiltonian models and for their forced/damped counterparts. Moreover, a formalism based on saltation matrices allows efficient analysis of global stability patterns for such breather solutions.

Itay Grinberg
Faculty of Mechanical Engineering
Technion - Israel Institute of Technology
grinbergitay@gmail.com

Oleg Gendelman
Technion Israel Institute of Technology
ovgend@tx.technion.ac.il

MS96

Stable Two-Dimensional Solitons in Free Space: Gross-Pitaevskii Equations with the Spin-Orbit Coupling

Abstract not available.

Boris Malomed
Department of Physical Electronics, Faculty of Engr.
Tel Aviv University, 69978 ISRAEL
malomed@eng.tau.ac.il

MS96

Nonlinear Dynamics of Non-Stretched Membrane

We present the analytical study of resonance non-stationary dynamics in the discrete initially non-stretched membrane. The model consists of the weightless string with n attached masses which are supported in turn by n orthogonal weightless strings. It is shown that the intense energy exchange(nonlinear beats) in such discrete membrane can be realized between different parts of the system (effective particles). Its analytical description is obtained in terms of limiting phase trajectories (LPT) with using the non-smooth transformations. The LPT bounds the domain of ordered motion in the phase space of the system. Increase of the excitation energy leads to two dynamical transitions caused by instability of one of nonlinear normal modes and LPT, respectively. As a result of the second transition the non-stationary energy localization arises. The obtained analytical solutions are confirmed by numerical simulations.

Leonid Manevich
Semenov Institute of Chemical Physics
Russian Academy of Sciences
manevitchleonid3@gmail.com

MS96

Mixed Solitary Shear Waves in a Granular Network

We study primary pulse transmission in two-dimensional granular networks and predict a new type of mixed nonlinear solitary pulses shear waves, and pulse equi-partition between the chains of the network. An analytical model is asymptotically studied, based on the one-dimensional nonlinear mapping technique of Starosvetsky. To confirm the theoretical predictions we experimentally tested a series of two-dimensional granular networks, and validated the occurrence of strong energy exchanges and equi-partition for sufficiently large number of beads.

Yijing Zhang
University of Illinois at Urbana-Champaign
yzhng123@illinois.edu

Md. Arif Hasan
Mechanical Science and Engineering
University of Illinois
mhasan5@illinois.edu

Yuli Starosvetsky
Technion, Israel Institute of Technology
staryuli@tx.technion.ac.il

D. Michael McFarland, Alexander Vakakis
University of Illinois
dmmcf@illinois.edu, avakakis@illinois.edu

MS97

Cyclic Drug Delivery Devices and Monotone Dynamical Systems

In the case of a gel membrane geometry, we show existence of oscillatory solutions corresponding to the system oscillating between the collapsed and the swollen phases, as the ionic concentration reaches a critical threshold. We apply the theory to the design of a cyclic drug delivery device activated by a chemical reaction that releases the positively charged ions that trigger the volume transition.

Maria-Carme Calderer
Deparment of Mathematics
University of Minnesota, USA
calde014@umn.edu

MS97

Evaluation of the Diffusion Coefficient of Nanoparticles Using Mathematical Simulation

We developed a novel, non-expensive nanoparticle (NP) drug-carrying system produced by self-assembly. A major objective was to evaluate the NP diffusion properties. To characterize their drug-release properties drug-loaded particles were placed in the donor of a double-compartment diffusion cell and the drug concentration in the receiver was sampled periodically. In this study we show a mechanistic model and mathematical simulation that, coupled with the experimental results, was used to evaluate the nanoparticle diffusion coefficient.

Giora Enden
Department of Biomedical Engineering, Ben-Gurion University
Israel
genden@bgu.ac.il

Amnon Sintov
Department of Biomedical Engineering, Ben-Gurion University
asintov@bgu.ac.il

MS97

Viscoelastic Effects in Drug Delivery

Classical models of Hookean solid and Newtonian liquid may be insufficient for description of biological fluids and materials used in controlled drug delivery. Instead, different viscoelastic models may be appropriate. We present a number of examples where viscoelasticity effects are significant. Among them are: (i) non-Fickian drug release from a swelling polymer particle; (ii) dynamics of a pore in a lipid membrane; (iii) drug delivery through a mucus layer in pulmonary airways. The support of the US-Israel Binational Science Foundation (grant No. 2008122) is acknowledged.

Alexander Nepomnyashchy
Department of Mathematics
Technion
nepom@techunix.technion.ac.il

Vladimir A. Volpert
Northwestern University
v-volpert@northwestern.edu

Yulia Kanevsky
Technion - Israel Institute of Technology
yuliyakanevsky@gmail.com

MS97

Fluid Flow and Drug Delivery in a Brain Tumor

We consider the problem of steady/unsteady fluid flow and drug delivery in a growing brain tumor. Objective is to understand the physiology of fluid flow and examine the effect of concurrent application of two anti-cancer drugs in a brain tumor. Therapeutic Index, which is a measure of efficiency of drug delivery in the tumor, is determined for different values of the parameters and discussed in the absence or presence of drugs' interactions.

Ranadhir Roy
University of Texas-Pan American
rroy@utpa.edu

Daniel Riahi
University of Texas - Pan American
driahi@utpa.edu

MS98

HIV Viral Rebound Times Following Suspension of Art: Stochastic Model Predictions

Suspension of antiretroviral treatment (ART) for HIV typically leads to rapid viral load rebound to pre-treatment levels. However, reports suggest that early ART initiation may delay viral rebound, for months, years, or permanently (post-treatment control, PTC), after ART suspension. We present a model of post-treatment HIV dynamics. From a branching process formulation we derive viral rebound time probability densities and the probability of PTC. Using these, we discuss viral rebound times and conditions for PTC.

Jessica M. Conway
Pennsylvania State University
jmconway@psu.edu

MS98

Modeling HCV Infection: Viral Dynamics and Genotypic Diversity

Hepatitis C virus (HCV) is present in the host with multiple variants generated by its error prone RNA-dependent RNA polymerase. We developed a series of models of viral dynamics for non-overlapping generations, based on difference equations, that allows us to follow the diversification of HCV virus early on during infection. We compared the analytical solutions of these models with a more detailed agent-based model of the HCV lifecycle. We found that the simplified model describes infection well, as long as

saturation effects are not present. We then compared the predictions of these models with data from acute infection in 9 plasma donors, with frequent sampling early in infection.

Ruy M. Ribeiro
Theoretical Biology and Biophysics
Los Alamos National Laboratory
ruy@lanl.gov

MS98

Modeling Equine Infectious Anemia Virus Infection: Virus Dynamics, Immune Control, and Escape

Equine Infectious Anemia Virus is a retrovirus that establishes persistent infection in horses. Mathematical models of within-host infection dynamics including immune responses will be presented. Analysis of the models yields thresholds that would be necessary for immune responses to successfully control infection. Furthermore, model results predict the conditions under which multiple competing strains coexist or a subdominant viral strain escapes antibody neutralization and dominates the infection. Numerical simulations are presented to illustrate the results.

Elissa Schwartz
Washington State University
ejs@wsu.edu

MS98

Modeling HIV Infection Dynamics under Conditions of Drugs of Abuse

Drugs of abuse are associated with higher viral loads and lower host-immune responses in HIV-infected drug abusers. To explore effects of drugs of abuse on HIV infection, I will present dynamical system models that agree well with experimental data from simian immunodeficiency virus infections of morphine-addicted macaques. Using our models, we evaluate morphine-induced alterations in target cell susceptibility and HIV-specific immune response that result in higher viral replications and accelerated disease progressions.

Naveen K. Vaidya
Dept of Maths & Stats, University of Missouri - Kansas City
Kansas City, Missouri, USA
vaidyan@umkc.edu

MS99

The Domain Dependence of Chemotaxis in a Two-Dimensional Turbulent Flow

Coherent structures are ubiquitous in environmental and geophysical flows. Recent advances in the identification of finite-time transport barriers have enabled the extraction of organizing templates for passive scalars in the limit of infinitesimal diffusion. In this presentation, we try to relate Lagrangian mixing and its corresponding measures to reaction processes in turbulent flows. Using a specific example of chemotaxis process in turbulence, we demonstrate that elliptic regions of the flow trigger higher uptake advantage for motile species of microorganisms. We analyze how the flow field and the relevant flow topology lead to such a relation.

Kimberley Jones
School of Mathematical & Statistical Sciences
Arizona State University, Tempe, AZ, 85287
kmjones8@asu.edu

Wenbo Tang
Arizona State University
wenbo.tang@asu.edu

MS99

Flow and Grow: Experimental Studies of Time-Dependent Reaction-Diffusion-Advection Systems

When a reaction-diffusion-advection system becomes non-autonomous, a new dimensionless parameter emerges: γ, the ratio of growth to flow timescales. For $\gamma \sim 1$, the interaction between growth and flow can produce complex resonance phenomena. My team and I have developed an experimental apparatus capable of simultaneous measurements of velocity fields and front locations in RDA. I will present studies varying $\gamma = 1$ and discuss implications for phytoplankton growth in Earth's oceans, where $\gamma = 0.8$.

Douglas H. Kelley
University of Rochester
218 Hopeman Engineering Building Rochester, NY 14627-0132
d.h.kelley@rochester.edu

MS99

Lagrangian Coherent Structures for Reaction Fronts in Unsteady Flows

Recent theoretical and experimental investigations have highlighted the role of invariant manifolds, termed *burning invariant manifolds* (BIMs), as one-way barriers to reaction fronts propagating through time-independent or time-periodic flows. This talk extends the concept of BIMs to unsteady flows, thereby constructing coherent structures that organize and constrain the propagation of reaction fronts through general flows. Following Farazmand, Blazevski, and Haller [Physica D 278279, 44 (2014)], we characterize coherent structures as curves of minimal Lagrangian shear.

Kevin A. Mitchell
University of California, Merced
Physics
kmitchell@ucmerced.edu

John R. Mahoney
University of California, Merced
jmahoney3@ucmerced.edu

MS99

Transport in Chaotic Fluid Convection

Many interesting problems can be formulated as a diffusing concentration field that is also advected by a complex fluid flow in a large spatially-extended domain. We explore the case where this field is also reacting, as in chemical and combustion problems, or motile, as in bioconvection. Using large-scale parallel numerical simulations we quantify the dynamics of a propagating front in a chaotic flow field and the complex patterns of bioconvection for conditions accessible to experiment.

Mark Paul
Department of Mechanical Engineering
Virginia Tech
mrp@vt.edu

MS100

Some Nonsmooth Problems Inspired by Conceptual Climate Models

In this talk, I'll outline the development of a global energy balance model that includes ice-albedo feedback and greenhouse gas effects. I'll explore how the choice of temperature-dependent albedo affects transitions between stable steady states and periodic orbits of the system by applying modern techniques from nonsmooth dynamical systems.

Anna M. Barry
Institute for Mathematics and its Applications
University of Minnesota
annab@math.ubc.ca

MS100

Continuation of Chatter in a Mechanical Valve

This presentation considers the analysis of periodic chatter in a mechanical pressure-relief valve, with emphasis on global interactions associated with a Shilnikov bifurcation. It reviews work in non-smooth systems by Piiroinen and Nordmark for the numerical parameter continuation of periodic orbits with infinitely many switches in finite time, using forward integration and nonlinear root solvers, and describes an alternative formulation expressed in terms of coupled boundary-value problems, implemented in the COCO framework.

Harry Dankowicz
University of Illinois at Urbana-Champaign
Department of Mechanical Science and Engineering
danko@illinois.edu

Erika Fotsch
University of Illinois at Urbana-Champaign
fotsch1@illinois.edu

Alan R. Champneys
University of Bristol
a.r.champneys@bristol.ac.uk

MS100

Lost in Transition: Nonlinearities in the Dynamics of Switching

When a system transitions abruptly from one behaviour to another, empirical models often describe well what happens just after and just before the transition, but not *during*. Worse, attempts to model the switch itself may involve complex higher dimensional and smaller scale processes. We can access the *hidden dynamics* of the transition, though, using simple dynamical principles. To do so fully requires a nonlinear theory of transitions in piecewise smooth dynamical systems.

Mike R. Jeffrey
University of Bristol
mike.jeffrey@bristol.ac.uk

MS100

Grazing Bifurcations in Engineering and Medical Systems

Abstract not available.

Marian Wiercigroch
University of Aberdeen
King's College
m.wiercigroch@eng.abdn.ac.uk

MS101

Nonlinear Dynamics of Variational Data Assimilation

Using the path integral formulation of statistical data assimilation, we show how to find the consistent global minimum path, show its dependence on the number of measurements at each observation time, and demonstrate that in certain parameter regimes, the corrections to the variational approximation is small and computable.

Henry D. Abarbanel
Physics Depratment
Univ of California, San Diego
habarbanel@ucsd.edu

Kadakia Nirag
UCSD
nkadakia@physics.ucsd.edu

Jingxin Ye
Department of Physics
University of California at San Diego
j9ye@ucsd.edu

Uriel I. Morone, Daniel Rey
UCSD
umorone@ucsd.edu, nadrey@ucsd.edu

MS101

Attractor Comparisons Based on Density

In this work a chaotic attractor is described as a density distribution in phase space. Describing the attractor as a density allows attractors to be compared using a small number of coefficients. Fits of these comparison coefficients as a function of some parameter change in the attractor can be used to predict how the attractor will change as a parameter changes. These density comparisons are used here to detect nonlinearity in a simple electronic circuit or to track parameter changes in a circuit based on the Rossler system. Comparisons between attractors could be useful for tracking changes in an experiment when the underlying equations are too complicated for vector field modeling.

Thomas L. Carroll
Naval Reseach Laboratory
thomas.carroll@nrl.navy.mil

MS101

Manifold Learning Approach for Modelling Collective Chaos in High-Dimensional Dynamical Sys-

tems

It has been known that a certain dynamical system exhibits lower-dimensional motion at a macroscopic level whereas it also keeps high-dimensional chaos at a microscopic level, called collective chaos. In this study, we propose an approach based on manifold learning in order to extract variables constructing nonlinear coordinate to the attractor of collective chaos. We apply the proposed approach to models including sparse networks of chaotic maps and leaky integrate-and-fire neurons.

Hiromichi Suetani
Department of Physics and Astronomy
Kagoshima University
hsue@me.com

MS101

Precision Variational Approximations in Statistical Data Assimilation

Data assimilation (DA) comprises transferring information from observations of a complex system to physically-based system models with state variables $\mathbf{x}(t)$. Typically, the observations are noisy, the model has errors, and the initial state of the model is uncertain, so the DA is statistical. One can thus ask questions about expected values of functions $\langle G(X) \rangle$ on the model path $X = \{\mathbf{x}(t_0), \ldots, \mathbf{x}(t_m)\}$ as it moves through an observation window $\{t_0, \ldots, t_m\}$. The probability distribution on the path $P(X) = \exp[-A_0(X)]$ determines these expected values. Variational methods seeking extrema of the 'action' $A_0(X)$ are widespread for estimating $\langle G(X) \rangle$ in many fields of science. In a path integral formulation of statistical DA, we consider variational approximations in a standard realization of the action where measurement and model errors are Gaussian. We (i) discuss an annealing method for locating the path X^0 giving a consistent global minimum of the action $A_0(X^0)$, (ii) consider the explicit role of the number of measurements at each measurement time in determining $A_0(X^0)$, and (iii) identify a parameter regime for the scale of model errors which allows X^0 to give a precise estimate of $\langle G(X^0) \rangle$ with computable, small higher order corrections.

Jingxin Ye
Department of Physics
University of California at San Diego
j9ye@ucsd.edu

MS102

Shadow Networks: Discovering Hidden Nodes with Models of Information Flow

Complex, dynamic networks underlie many systems, and understanding these networks is the concern of a great span of important scientific and engineering problems. Quantitative description is crucial for this understanding yet, due to a range of measurement problems, many real network datasets are incomplete. Here we explore how accidentally missing or deliberately hidden nodes may be detected in networks by the effect of their absence on predictions of the speed with which information flows through the network. We use Symbolic Regression (SR) to learn models relating information flow to network topology. These models show localized, systematic, and non- random discrepancies when applied to test networks with intentionally masked nodes, demonstrating the ability to detect the presence of missing nodes and where in the network those nodes are likely to reside.

James Bagrow
Department of Mathematics & Statistics
University of Vermont
jbagrow@uvm.edu

MS102

A Network Measure for the Analysis and Visualization of Large-Scale Graphs

Given an undirected graph, we describe a two-dimensional integer-valued measure, the Q-matrix, based on the connected component size distribution of its degree-limited subgraphs. This generalization of the degree distribution yields a small sparse matrix representing the number of weakly connected components of a particular size during a prescribed percolation process. When viewed as a two-dimensional histogram, this landscape yields a canonic visual representation, i.e. an identification portrait, revealing important network properties.

Roldan Pozo
National Institute of Standards and Technology, USA
pozo@cam.nist.gov

MS102

Revealing Collectivity in Evolving Networks: A Random Matrix Theory Approach

Networks are the result of the tangled interconnections among their nodes. As the network evolves, group of nodes often undergo similar evolution patterns, giving rise to collective behavior. Here, we aim to uncover and quantify the degree of collectivity in the evolution of a complex network. In particular, we use Random Matrix Theory to identify significant correlations between the temporal topological properties (e.g. degree, centrality) of nodes. We apply our method to both functional networks, obtained from stocks and climate correlation data, and structural networks, obtained from Internet AS-level connectivity data.

Saray Shai
Department of Mathematics
University of North Carolina at Chapel Hill
sshai@live.unc.edu

MS103

On the Computation of Attractors for Delay Differential Equations

In this talk we will introduce a numerical method which allows to approximate (low dimensional) invariant sets for infinite dimensional dynamical systems. We will particularly focus on the computation of attractors for delay differential equations. The numerical approach is inherently set oriented - that is, the invariant sets are computed by a sequence of nested, increasingly refined approximations -, and does not rely on long term simulations of the underlying system.

Michael Dellnitz
University of Paderborn, Germany

dellnitz@math.upb.de

MS103

Computing Coherent Sets in Turbulent Systems

In time dependent dynamics, it is often possible to divide phase space into sets which are seperated by transport barriers. Finding these sets helps to understand the global dynamical behavior of systems arising in, e.g. atmospheric flows, plasma physics and biological models. In this talk we present a new approach for the computation of coherent sets by incorporating time-continuous diffusion into the model. This leads to an advection-diffusion equation (the Fokker-Planck equation) whise solution we approximate using spectral collocation. The approach does not need any particle trajectories and is therefore suited for systems where these are hard to obtain, e.g. turbulent systems.

Andreas Denner
Center for Mathematics
Technische Universitaet Muenchen
andreas.denner@ma.tum.de

Oliver Junge
Center for Mathematics
Technische Universitaet Muenchen, Germany
oj@tum.de

MS103

The Geometry of Lagrangian Coherent Structures

We propose a novel, geometric method to identify subsets of phase space that retain small boundary size relative to volume as they are evolved by a nonlinear dynamical system. We describe a computational method to identify coherent sets based on eigenfunctions of a new dynamic Laplacian operator. Finally, we demonstrate that the dynamic Laplacian operator can be realised as a zero-diffusion limit of the classical probabilistic method for finding coherent sets, which is based on small diffusion.

Gary Froyland
UNSW Australia
g.froyland@unsw.edu.au

MS103

Coherent Families: Spectral Theory for Transfer Operators in Continuous Time

The decomposition of the state space of a dynamical system into metastable or almost-invariant sets is important for understanding macroscopic behavior. This concept is well understood for autonomous dynamical systems, and has recently been generalized to non-autonomous systems via the notion of coherent sets. We elaborate here on the theory of coherent sets in continuous time for periodically-driven flows and describe a numerical method to find periodic families of coherent sets without trajectory integration.

Peter Koltai
Free University Berlin
peter.koltai@fu-berlin.de

Gary Froyland
UNSW Australia
g.froyland@unsw.edu.au

MS104

Finite-Time Lagrangian Transport Through Surfaces in Volume-Preserving Flows

We present a Lagrangian approach to the quantification of transport of conserved quantities through a given hypersurface in general time-dependent, n-dimensional volume-preserving flows. This is of significant importance for (i) the calculation of coherent transport by Lagrangian material sets such as coherent vortices in geophysical fluid flows, and (ii) semi-Lagrangian approaches to numerically solving scalar advection equations.

Daniel Karrasch
ETH Zurich, Switzerland
karrasch@imes.mavt.ethz.ch

MS104

A Direct Method for Computing Failure Boundaries of Non-autonomous Systems

We present an efficient method, based on continuation of a two-point boundary value problem, to investigate the parameter dependence of system behaviour for models that are subject to an external forcing. As an example we consider a model of a post-tensioned self-centring frame that experiences an earthquake. The failure boundary is the boundary of the region in the space of possible earthquakes for which the frame displacement remains within a given range.

Hinke M. Osinga
University of Auckland
Department of Mathematics
H.M.Osinga@auckland.ac.nz

MS104

Interactions Between Noise and Rate-Induced Tipping

A non-autonomous system passes a tipping point when gradual changes in input levels cause the output to change suddenly. I investigate a new way to help detect tipping before it occurs. For rate-induced tipping, analysing how much the system deviates from the quasi-steady state equilibrium gives an early-warning indicator. I show that early-warning indicators are present as soon as the most likely path for escape deviates from the quasi-steady state.

Paul Ritchie
University of Exeter
Mathematics research Institute
pdlr201@exeter.ac.uk

MS104

Rate-Induced Bifurcations in Slow-Fast Systems

Rate-induced bifurcations describe the failure to track a moving stable state in systems with drifting parameters. Unlike classical bifurcations, they occur only above some critical drift rate. We investigate rate-induced bifurcations in slow-fast systems, using the theory of folded singularities and canards, to uncover thresholds with intricate band structures, separating initial states that track the moving stable state from those that destabilise. These novel

thresholds explain non-obvious tipping point and excitability phenomena that often puzzle scientists.

Sebastian M. Wieczorek
University of Exeter
Mathematics Research Institute
sebastian.wieczorek@ucc.ie

MS105

First Passage Time Problems for Stochastic Hybrid Systems

We review recent work on the analysis of first-passage time problems in stochastic hybrid systems. A stochastic hybrid system involves the coupling between a piecewise deterministic dynamical system and a time-homogeneous Markov chain on some discrete space. Examples include voltage-gated ion channels, intermittent transport by molecular motors, and stochastic neural networks. We construct a path-integral representation of solutions to the underlying master equation, and use this to derive a large deviation principle for escape problems. We show that the resulting Hamiltonian is given by the principle eigenvalue of a linear operator that depends on the transition rates of the Markov chain and the nonlinear functions of the piecewise deterministic system.

Paul C. Bressloff
University of Utah
Department of Mathematics
bressloff@math.utah.edu

MS105

Exploration and Trapping of Mortal Random Walkers

The calculation of first passage times has a long history, more recently extended to "anomalous" walks (subdiffusive or superdiffusive) in addition to those that lead to ordinary diffusion. However, the possible death of a walker before reaching its target has only recently been considered. Evanescence obviously profoundly affects quantities such as the survival probability of a target. I will talk about the effects of evanescence on first passage properties.

Katja Lindenberg
Department of Chemistry and Biochemistry
University of California San Diego, USA
klindenberg@ucsd.edu

Santos B. Yuste, Enrique Abad
Universidad de Extremadura
santos@unex.es, eabad@unex es

MS105

Trajectory-to-Trajectory Fluctuations in the First-Passage Phenomena in Bounded Domains

We propose a novel method to quantify the trajectory-to-trajectory fluctuations of the first passage of a Brownian motion (BM) to targets on the boundary of compact domains, based on the distribution of the uniformity index, measuring the similarity of the first passage times of two independent BMs starting at the same location. This analysis permits us to draw several general conclusions about the importance of the trajectory-to-trajectory fluctuations on the first-passage behavior.

Gleb Oshanin
Laboratoire de physique théorique de la matière condensée
gleb.oshanin@gmail.com

MS105

Application of First-Passage Ideas to the Statistics of Lead Changes in Basketball

We investigate occurrences of lead changes in NBA basketball games. For evenly-matched teams, so that the score difference can be modeled as unbiased diffusion, the probability P(t) that a lead change occurs at time t in a game of length T is exactly soluble and surprisingly has maxima at t=0 and t=T. We generalize to teams of unequal strengths and also provide a criterion for when a lead of a given size is safe.

Sidney Redner
Boston University
Physics Department
redner@santafe.edu

Aaron Clauset
University of Colorado at Boulder
Computer Science
aaron.clauset@colorado.edu

Marina Kogan
University of Colorado
Computer Science
marina.kogan@cs.colorado.edu

MS106

Bifurcation Analysis of a Model for the El Niño Southern Oscillation

We consider a phenomenological model for the El Niño Southern Oscillation system in the form of a delay-differential-equation. We conduct a bifurcation analysis of the model in the two parameters of seasonal forcing strength and oceanic wave delay time, dividing the parameter plane into regions of different solution types. Our analysis highlights parameter sensitivity, explains and expands on previously published results and uncovers surprisingly complicated behaviour concerning the interplay between seasonal forcing and delay-induced dynamics.

Andrew Keane
Department of Mathematics
The University of Auckland
a.keane@auckland.ac.nz

Bernd Krauskopf
University of Auckland
Department of Mathematics
b.krauskopf@auckland.ac.nz

Claire Postlethwaite
University of Auckland
c.postlethwaite@auckland.ac.nz

MS106

Interplay of Adaptive Topology and Time Delay in the Control of Cluster Synchronization

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 how to construct networks such that they exhibit not only a given cluster state but also with a given frequency. 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.

Judith Lehnert
Institut für Theoretische Physik
Technische Universität Berlin
lehnert@itp.tu-berlin.de

Alexander Fradkov
Department of Theoretical Cybernetics
Saint-Petersburg State University
fradkov@mail.ru

Eckehard Schöll, Philipp Hövel
Institut für Theoretische Physik
Technische Universität Berlin
schoell@physik.tu-berlin.de, phoevel@physik.tu-berlin.de

Anton Selivanov
Department of Theoretical Cybernetics
Saint-Petersburg State University
antonselivanov@gmail.com

MS106

Connection Between Extended Time-Delayed Feedback and Nonlinear Fixed-Point Problems

Time-delayed feedback control is an elegant method to find periodic orbits in an experiment without a-priori knowledge of their shape. However, the method has various topological restrictions, limiting the cases where it can be used. This presentation will use a singular perturbation argument to show that for the extended time-delayed control (as introduced by Socolar) the classical odd-number limitation still holds in the limit of slow updating of the reference signal.

Jan Sieber
University of Exeter
j.sieber@exeter.ac.uk

MS106

Pattern Formation in Systems with Multiple Delayed Feedbacks

Dynamical systems with complex delayed interactions arise commonly when propagation times are significant, yielding complicated oscillatory instabilities. We consider systems with multiple, hierarchically long time delays, and using a suitable space-time representation we uncover features otherwise hidden in their temporal dynamics. The behavior in the case of two delays is shown to 'encode' two-dimensional spiral defects and defects turbulence. A multiple scale analysis sets the equivalence to a complex Ginzburg-Landau equation. We also demonstrate this phenomenon for a semiconductor laser with two delayed optical feedbacks.

Serhiy Yanchuk
Humboldt University of Berlin
yanchuk@math.hu-berlin.de

MS107

Voltage Stability in Power Networks and Microgrids

The AC power flow equations in a complex network display a rich phenomenology, but despite more than four decades of investigation the solution space remains poorly understood. Here we present a sharp and intuitive parametric condition for the existence of a stable power flow solution. Our condition immediately leads to non-conservative loading margins, grid stability indices, and an accurate series expansion of the stable solution. We illustrate our results with monitoring and control applications.

Florian Dorfler
Mechanical Engineering
University of California at Santa Barbara
dorfler@ethz.ch

John Simpson-Porco
University of California
johnwsimpsonporco@engineering.ucsb.edu

Francesco Bullo
Mechanical & Environmental Engineering
University of California at Santa Barbara
bullo@engineering.ucsb.edu

MS107

Finding Useful Statistical Indicators of Instability in Stochastically Forced Power Systems

Via a case study of a multi-machine power system, we identify those (relatively few) system variables whose measured autocorrelation and variance provide reliable warning of instability sufficiently before a collapse occurs. Our search for such useful early warning signs (EWS) is enabled by a semi-analytical calculation based on the Lyapunov equation and is confirmed by simulations. We also study how these statistics are impacted by measurement noise and discuss methods to reduce that impact. Several numerical experiments confirm the validity of the identified EWSs and also reveal potential limitations.

Goodarz Ghanavati, Paul Hines
University of Vermont
goodarz.ghanavati@gmail.com, paul.hines@uvm.edu

Taras Lakoba
University of Vermont
Department of Mathematics and Statistics
tlakoba@uvm.edu

MS107

A Parametric Investigation of Rotor Angle Stability Using Direct Methods

An estimate of the critical clearing time (CCT) for a fault is formulated using the direct methods for power system transient stability. By perturbing the energy functions used in the direct methods we present an analytic stability metric that can be used as a lower bound for the CCT. This new

metric is used to support a parametric enquiry into the stability of a small but non-trivial power system.

Lewis G. Roberts
University of Bristol (UK)
lewis.roberts@bristol.ac.uk

Alan R. Champneys
University of Bristol
a.r.champneys@bristol.ac.uk

Mario Di Bernardo
University of Bristol
Dept of Engineering Mathematic
m.dibernardo@bristol.ac.uk

Keith Bell
University of Strathclyde
Glasgow, Scotland
keith.bell@strath.ac.uk

MS107

Synchronization Stability of Lossy and Uncertain Power Grids

Direct energy methods have been extensively developed for the transient stability analysis and contingency screening of power grids. However, there are no analytical energy functions proposed for power grids with losses. The difficulty originates from the nonlinear and asymmetric couplings among generators, which make the natural energy function nondecreasing. This paper extends the recently introduced Lyapunov Functions Family method to certify the synchronization stability for lossy multimachine power grids. We present techniques to explicitly construct Lyapunov functions and propose algorithms for Lyapunov function adaptation to specific initial states, both by solving a number of linear matrix inequalities (LMIs). The Lyapunov Functions Family approach is also applicable to uncertain power grids where the stable equilibrium is unknown due to possible uncertainties in the mechanical torques. We formulate this new control problem and introduce techniques to certify the robust stability of a given initial state with respect to a set of equilibria.

Konstantin Turitsyn
Massachusetts Institute of Technology
turitsyn@mit.edu

Thanh Long Vu
MIT
longvu@mit.edu

MS108

Bifurcations of Generalised Julia Sets Near the Complex Quadratic Family

We consider a nonanalytic perturbation of the complex quadratic family that is associated to wild Lorenz-like chaos. The perturbation opens up the critical value to a disk and saddle points and their stable and unstable sets appear. These sets interact with the generalised Julia set, leading to the (dis)appearance of chaotic attractors and to generalised Julia sets in the form of Cantor bouquets, Cantor tangles and Cantor cheeses.

Stefanie Hittmeyer, Bernd Krauskopf, Hinke M. Osinga
University of Auckland
Department of Mathematics
stefanie.hittmeyer@auckland.ac.nz,
b.krauskopf@auckland.ac.nz, H.M.Osinga@auckland.ac.nz

MS108

A Global Bifurcation of Mixed-mode Oscillations

This talk describes the existence of an elusive Shilnikov bifurcation in the Koper model. This result closes a chapter in one of the early and influential investigations of complex and chaotic mixed-mode oscillations. The bifurcation is located using a mixture of investigations of invariant manifold intersections and continuation methods. We also study structural stability and global returns, leading us to formulate a modified geometric model for a Shilnikov bifurcation in the slow-fast regime.

Ian M. Lizarraga
Cornell Center for Applied Mathematics
iml32@cornell.edu

John Guckenheimer
Cornell University
jmg16@cornell.edu

MS108

Parameterization Method for Local Stable/unstable Manifolds of Periodic Orbits

I will discuss a numerical method for computing stable/unstable manifolds of periodic orbits for differential equations that leads to high order Fourier-Taylor expansions for the invariant manifolds. The inputs are Fourier series approximations of the periodic orbit and its Floquet normal form which are computed using iterative algorithms and Galerkin projections. The Fourier approximation of the Floquet normal form is then used in order to efficiently compute the parameterization of the local invariant manifold.

Jason Mireles James
Rutgers University
jmireles@math.rutgers.edu

MS108

Practical Stability Versus Diffusion in the Spatial Restricted Three-body Problem

We examine the role of the four-dimensional centre manifold $W^c_{L_3}$ of the equilibrium L_3 of the Spatial Restricted Three-Body Problem, and its stable and unstable invariant manifolds, in two dynamical processes for a small mass parameter. The first one consists of the Arnold diffusion mechanism associated to the existence of transition chains of heteroclinic connections. The second process consists of long-term confinement of trajectories in a practical stability domain in a large vicinity of $L_{4,5}$.

Maisa O. Terra
ITA - Technological Institute of Aeronautics
Mathematics Department
maisa@ita.br

Carles Simó
University of Barcelona
carles@maia.ub.es

Priscilla de Sousa-Silva
Instituto Tecnológico de Aeronáutica, Brazil

priandss@ita.br

MS109

Perspectives on Theories of Diabetogenesis and Glucose Management

The personalization of treatment is a key difficulty in the clinical management of type 2 diabetes today. Although it is widely agreed that glucose control is central to antidiabetic therapy, there is little consensus on how to achieve it. We believe that the concurrent measurement of redox status, such as through glutathione in particular, can be used to assess the progress of therapy as well as provide quantitative targets for glucose control. In my talk I will describe reasons in support of this argument, and a minimal model for achieving it. I will also present a theory of diabetogenesis that implicates oxidative stress as a central causal factor, and our attempts at modeling it.

Pranay Goel
Indian Institute for Science Education and Research
pranay.goel@gmail.com

Saroj Ghaskadbi
Dept. of Zoology
Savitribai Phule Pune University
ssg@unipune.ernet.in

MS109

Therapeutic Mechanisms of High Frequency DBS in Parkinsons Disease: Neural Restoration Through Loop-Based Reinforcement

High frequency deep brain stimulation (HFS) is clinically recognized to treat parkinsonian movement disorders but its mechanisms remain elusive. Current hypotheses suggest that the therapeutic merit of HFS stems from increasing the regularity of the firing patterns in the basal ganglia (BG). Although this is consistent with experiments in humans and animal models of Parkinsonism, it is unclear how the pattern regularization would originate from HFS. To address this question, we built a computational model of the cortico-BG-thalamo-cortical loop in normal and parkinsonian conditions. We simulated the effects of subthalamic deep brain stimulation both proximally to the stimulation site and distally through orthodromic and antidromic mechanisms for several stimulation frequencies (20-180Hz) and, correspondingly, we studied the evolution of the firing patterns in the loop. The model closely reproduced experimental evidence for each structure in the loop and showed that neither the proximal effects nor the distal effects individually account for the observed pattern changes, while the combined impact of these effects increases with the stimulation frequency and becomes significant for HFS. Perturbations evoked proximally and distally propagate along the loop, rendezvous in the striatum, and, for HFS, positively overlap (reinforcement), thus causing larger post-stimulus activation and more regular patterns in striatum. Reinforcement is maximal for the clinically-relevant 130Hz stimulation and restores a more normal activity in the nuclei downstream. These results suggest that reinforcement may be pivotal to achieve pattern regularization and restore the neural activity in the nuclei downstream, and may stem from frequency-selective resonant properties of the loop.

Sridevi Sarma
Johns Hopkins University
sree@jhu.edu

Sabato Santaniello
University of Colorado
sabato@engr.uconn.edu

MS109

Unification of Neuronal Spikes, Seizures, and Spreading Depression

The pathological phenomena of seizures and spreading depression have long been considered separate physiological events in the brain. By incorporating conservation of particles and charge, and accounting for the energy required to restore ionic gradients, we extend the classic HodgkinHuxley formalism to uncover a unification of neuronal membrane dynamics. By examining the dynamics as a function of potassium and oxygen, we now account for a wide range of neuronal activities, from spikes to seizures, spreading depression (whether high potassium or hypoxia induced), mixed seizure and spreading depression states, and the terminal anoxic wave of death. Such a unified framework demonstrates that all of these dynamics lie along a continuum of the repertoire of the neuron membrane. Our results demonstrate that unified frameworks for neuronal dynamics are feasible, can be achieved using existing biological structures and universal physical conservation principles, and may be of substantial importance in enabling our understanding of brain activity and in the control of pathological states.

Steven J. Schiff
Penn State University
Center for Neural Engineering
sschiff@psu.edu

Yina Wei
Univ California Riverside
weiyina039@gmail.com

Ghanim Ullah
University of South Florida
gullah@usf.edu

MS109

Termination of Cardiac Alternans Using Isostable Response Curves

Phase reduction has been tremendously useful for understanding the dynamics of nonlinear oscillators, but has been difficult to extend to systems with stable fixed points, such as excitable systems. Using the notion of isostables, we present a general method for isostable reduction of excitable systems. This reduction is applied to both single- and multi-cell systems of cardiac activity in order to formulate an energy optimal control strategy to terminate cardiac alternans, a precursor to cardiac arrest.

Dan D. Wilson
Mechanical Engineering
University of California, Santa Barbara
dan.d.wilson8@gmail.com

Jeff Moehlis
Dept. of Mechanical Engineering
University of California – Santa Barbara
moehlis@engineering.ucsb.edu

MS110

Triggers of Rogue Waves in Deep Water Envelope

Equations

Rogue ocean waves have caused considerable damage to ships and coastal structures. We analyze the role of spatial localization in triggering rogue waves in the modified nonlinear Schrodinger equation. Specifically, we develop a reduced order model that allows us to determine the characteristics of wave packets likely to focus and grow in amplitude. We use this analysis to develop a computationally efficient scheme for predicting rogue waves by identifying these potentially dangerous wave packets.

Will Cousins
MIT
wcousins@mit.edu

Themistoklis Sapsis
Massachusetts Institute of Techonology
sapsis@mit.edu

MS110

Boundary Conditions and the Linking of Computational Domains in Patch Dynamics Schemes

Abstract not available.

I. G. Kevrekidis
Princeton University
yannis@princeton.edu

MS110

Resilient Algorithms for Reconstructing and Simulating Gappy Flow Fields in CFD

It is anticipated that in future generations of massively parallel computer systems a significant portion of processors may suffer from hardware or software faults rendering large-scale computations useless. In this work we address this problem from the algorithmic side, proposing resilient algorithms that can recover from such faults irrespective of their fault origin. In particular, we set the foundations of a new class of algorithms that will combine numerical approximations with machine learning methods.

Seungjoon Lee
Division of Applied Mathematics, Brown University
seungjoon_lee@brown.edu

Ioannis Kevrekedis
Princeton University
yannis@princeton.edu

George E. Karniadakis
Brown University
Division of Applied Mathematics
george_karniadakis@brown.edu

MS110

Better Buffers for Patches in Macroscale Simulation of Systems with Microscale Randomness

The 'equation-free' methodology couples many small patches of microscale computations across space to empower computational simulation over macroscale spatial domains of interest. We derive generally optimum coupling of patches and core averaging when the microscale is inherently 'rough' as in molecular or agent simulations. As a canonical problem in this universality class we analyse the case of inhomogeneous diffusion on a lattice. The minimal error on the macroscale is generally obtained by coupling patches with patch cores half as large as the patch, thus creating coupling active over the other half of the patch. The results indicate that patch dynamics is useful for computational simulation of a wide range of systems with fine scale roughness.

Anthony J. Roberts
University of Adelaide
anthony.roberts@adelaide.edu.au

MS111

Controlling Hyperbolic Trajectories and Invariant Manifolds in Flows

Hyperbolic trajectories are important in governing fluid motion, since their attached stable and unstable manifolds form crucial flow separators. We derive the control velocity ensuring that a hyperbolic trajectory follows specified nonautonomous motion in $\mathbb{R}^n$. We control both the Lorenz system, and a 3D droplet model, respectively obtaining a specified long-term attractor, and intra-droplet mixing. Ongoing work on determining control velocities for obtaining prescribed nonautonomous (un)stable manifold motion is also presented.

Sanjeeva Balasuriya
University of Adelaide
School of Mathematical Sciences
sanjeevabalasuriya@yahoo.com

Kathrin Padberg-Gehle
Institute of Scientific Computing
TU Dresden
kathrin.padberg@tu-dresden.de

MS111

Closed-Loop Control of Complex and Turbulent Flows Using Machine Learning Control: a Reverse Engineering Approach

We propose a model-free methodology to find closed-loop control laws for complex and turbulent flows using genetic programming. Avoiding the necessity to derive a model, the sensor-to-control law is derived by creating and evolving expression-trees according to a cost function. We show the efficiency of the method by the control of strongly nonlinear systems, and its practicality by exhibiting the results obtained on four turbulent experimental flows.

Thomas Duriez
Buenos Aires University
Laboratory of Fluid Dynamics
thomas.duriez@gmail.com

Vladimir Parezanovic, Kai Von Krbek, Jean-Paul Bonnet, Laurent Cordier
Institute PPRIME, CNRS
vladimir.parezanovic@univ-poitiers.fr,
kai.von.krbek@krbek.de,
jean.paul.bonnet@univ-poitiers.fr,
laurent.cordier@univ-poitiers.fr

Bernd R. Noack
Institut PPRIME, CNRS
bernd.noack@univ-poitiers.fr

Marc Segond, Markus W Abel

Ambrosys GmbH
marc.segond@ambrosys.de, markus.abel@ambrosys.de

Nicolas Gautier, Jean-Luc Aider
PMMH Laboratory, UMR 7636 CNRS, ESPCI
nclgautier.espci@gmail.com, jean-luc.aider@espci.fr

Cedric Raibaudo, Christophe Cuvier, Michel Stanislas
Laboratoire de Mécanique de Lille, UMR CNRS 8107
École Centrale de Lille
cedric.raibaudo@gmail.com, christophe.cuvier@gmail.com, michel.stanislas@ec-lille.fr

Antoine Debien, Nicolas Mazellier, Azeddine Kourta
Labratoire PRISME, Université d'Orléans, Orléans, France
antoine.debien@univ-orleans.fr, nicolas.mazellier@univ-orleans.fr, azeddine.kourta@univ-orleans.fr

Steven Brunton
University of Washington
sbrunton@uw.edu

MS111

Mesohyperbolicity, Mix-Norm and the Hunt for Mh370

The disappearance of MH370 has exposed the disconcerting lack of efficient methods for searching objects moving in a complex and dynamic environment. Lagrangian kinematics of mesoscale features are visible in mesohyperbolicity maps which can be used to predict the time evolution of any initial distribution and incorporated in the design of a search strategy. A modified version of DSMC search algorithm determines multiple search agents trajectories using ergodicity ideas and the Mix-Norm as a metric.

Sophie Loire
University of California Santa Barbara
sloire@engr.ucsb.edu

Hassan Arbabi
UC Santa Barbara
arbabi@umail.ucsb.edu

Stefan Ivic
Rijeka University
stefan.ivic@gmail.com

Patrick Clary
UCSB
pclary@umail.ucsb.edu

Bojan Crnkovic, Nelida Crnjaric-Zic
Rijeka University
bojan.crnkovic@gmail.com, nelida@riteh.hr

Igor Mezic
UCSB
mezic@engr.ucsb.edu

MS111

Control of Thin-Layer Flows with Patterned Surfaces

When a shallow layer of inviscid fluid flows over a smoothly-patterned substrate, the fluid particle trajectories are, to leading order in the layer thickness, geodesics on the two-dimensional curved space of the substrate. We use 3D-printed substrates to show that the pattern made by a jet striking a bumpy surface is described by the geodesic equation. Because the geodesic equation is fourth order, the geodesics are chaotic even for simple substrates. This could offer a new method of improving mixing by varying the shape of the substrate.

Jean-Luc Thiffeault
Dept. of Mathematics
University of Wisconsin - Madison
jeanluc@math.wisc.edu

Jay Johnson
University of Texas at Austin
jjohnson281@gmail.com

MS112

Experimental Observation of Rhythm Control of Human Gait Using Moving Floor

Human and animals maintain stability of gait and posture by tuning their motion rhythms. In order to approach this rhythm control mechanisms, human motion with floor disturbance is measured and rhythm characteristic of human is discussed. Response to high frequency floor disturbance during walking is observed for calculating the phase response curve, and response to rotational floor is measured for considering the posture control.

Tetsuro Funato
Mechanical Engineering
Japanese University of Electro-Communications
tfunato@ieee.org

Shinya Aoi, Nozomi Tomita, Tsuchiya Kazuo
Kyoto University
shinya_aoi@kuaero.kyoto-u.ac.jp, tomita@math.kyoto-u.ac.jp, tsuchiya@kuaero.kyoto-u.ac.jp

MS112

What Can Coupled, Nonlinear Oscillators Say About Noisy, Perturbed Cockroaches

Cockroaches are remarkably stable runners, exhibiting rapid recovery from external perturbations. To uncover the mechanisms responsible for this, we recorded leg kinematics of freely running animals in both undisturbed and perturbed trials. Perturbations were applied to single legs via magnetic impulses and the resulting transient effects on all legs and recovery times to normal pre-perturbation kinematics were studied. We estimated coupling architectures and strengths by fitting data to a six leg-unit phase oscillator model. Using maximum likelihood techniques, we found that a network with nearest-neighbor interleg coupling best fitted the data, and that, while coupling strengths vary among preparations, overall inputs entering each leg are approximately balanced and consistent. Simulations of models encountering perturbations suggest that the coupling schemes estimated from our experiments allow animals relatively fast and uniform recoveries from perturbations. This is joint work with E. Couzin-Fuchs, T. Kiemel, O. Gal and A. Ayali.

Philip Holmes
Princeton University
Program in Applied and Computaional Mathematics &

MAE Dept
pholmes@math.princeton.edu

MS112

Formation Mechanism for Basin of Attraction of Bipedal Working Models

In this presentation, I will talk about the stability of simple bipedal walking models. Especially, I focus on the geometric structure of basin of attraction. By some numerical computations for the basin of attraction, interesting and complex geometric structures, for example, the region is thin and fractal-like, but the formation mechanism is not known. I will explain the mechanism with the saddle property and hybridness of bipedal walking models.

Obayashi Ippei
Department of Matheamtics
Kyoto University
obayashi@math.kyoto-u.ac.jp

MS112

Lateral Balance of Human Walking and Human Structure Interaction

Although synchronisation of pedestrian frequencies to lateral ground vibrations has been observed in the past, the mechanism leading to this behaviour is still not well understood. To this end experimental data from pedestrians freely-walking on a laterally oscillating treadmill are analysed revealing adaptive stepping patterns. At the same time simple spring-mass models of this motion are derived and analysed. The applicability of Kuramoto synchronisation model to capture this behaviour is examined.

John Macdonald
Civil Engineering Department
University of Bristol
john.macdonald@bristol.ac.uk

Jeremy Burn
University of Bristol
j.f.burn@bristol.ac.uk¿

Matteusz Bocian
University of Exeter
University of Bristol
mateusz.bocian@bristol.ac.uk

Alan R. Champneys
University of Bristol
a.r.champneys@bristol.ac.uk

MS113

The Evolution of Complexity in Arctic Melt Ponds: a Statistical Physics Perspective

Recent analysis of Arctic melt pond images reveals that the pond shape transitions from simple to complex around a critical area of 100 square meters. To explain this onset of complexity, a two-dimensional Ising model for pond evolution is proposed that incorporates ice-albedo feedback and the underlying thermodynamics. A second-order phase transition from isolated to clustered ponds is found, with the pond complexity in the clustered phase consistent with the observations.

Yiping Ma
Department of Applied Mathematics
University of Colorado, Boulder
yiping.m@gmail.com

MS113

Statistical Physics Models for Critical Phenomena in Permafrost Lakes

There is an interesting problem, where geometrical changes of the patterns and its stochastic behavior can lead to the critical phenomena in a climate system. As a result of tundra permafrost thawing, permafrost lakes have extended, and methane from ground has entered the atmosphere. We have suggested a nonlinear model for phase transitions in permafrost lakes (based on Ginzburg-Landau theory from statistical physics). We have applied this model to study abrupt permafrost methane emission.

Ivan Sudakov
University of Utah
Mathematics Department
sudakov@math.utah.edu

MS113

Growth and Fluctuations of Suncups on Alpine Snowpacks: Comparison of Field Observations with a Nonlinear Pde Model

A mathematical model for suncups on alpine snow exposed to solar radiation is compared with field observations. The model consists of a fourth order nonlinear partial differential equation similar to the KPZ equation. The patterns fluctuate chaotically in time, and the fluctuations can be described in terms of diffusion of individual suncups. The rate at which the suncups diffuse contains information about the effect of the suncups on the albedo of the snow.

Tom Tiedje
Faculty of Engineering
University of Victoria
ttiedje@uvic.ca

Kevin A. Mitchell
Simon Fraser University
Department of Mathematics
kevmitch@math.sfu.ca

MS113

How Climate Model Complexity Impacts the Stability of the Sea Ice Cover

Two types of idealized climate models find instabilities during the retreat of sea ice under global warming: (i) annual-mean latitudinally-varying diffusive energy balance models and (ii) seasonally-varying single-column models. Comprehensive global climate models, however, typically find no instabilities. To bridge this gap, we develop an idealized model that includes both latitudinal and seasonal variations. Our results suggest that the ice cover is significantly more stable than found in previous idealized models.

Till Wagner
Scripps Institution of Oceanography
University of California San Diego
tjwagner@ucsd.edu

Ian Eisenman

Scripps Institution of Oceanography
eisenman@ucsd.edu

MS114

Possible Mechanisms for Generation of Beta Oscillations in Parkinsons Disease

In Parkinson's disease abnormal oscillations in neural activity in beta frequency range (13-30Hz) have been observed in the basal ganglia, and their power correlates with the severity of symptoms. We consider a simple model of cortico-basal-ganglia circuit. We show that there exist different regions of its parameters for which the model can match the dataset of Tachibana et al. describing neural activity in Parkinson's disease. These different regions correspond to different mechanisms of oscillations' generation.

Alexander Pavlides
University of Oxford
alex.pavlides@ndcn.ox.ac.uk

John Hogan
Bristol Centre for Applied Nonlinear Mathematics
Department of Engineering Mathematics, University of Bristol
s.j.hogan@bristol.ac.uk

Rafal Bogacz
Associate Professor
Oxford University, UK
rafal.bogacz@ndcn.ox.ac.uk

MS114

Identifying and Tracking Transitions in Neural Spiking Dynamics in the Subthalamic Nucleus of Parkinsons Patients

Accurate statistical modeling of spiking dynamics in neurological disease is important for understanding how the disease develops, progresses, and manifests clinical symptoms. In particular, abnormal oscillatory firing patterns of neurons in the subthalamic nucleus (STN) of patients with Parkinson's disease (PD) have been postulated to play a role in the pathogenesis of motor deficits. We present a point process analysis framework that allows us to identify and characterize the rhythmic dynamics in STN spike trains, test for statistically significant changes to those dynamics, and track the temporal evolution of such changes. The approach incorporates generalized linear modeling theory for point processes with state space modeling to estimate, instant by instant, changes in the influence of past spiking history on the current spiking probability. We demonstrate the method on both simulated and actual data recorded from human STN.

Uri Eden
Associate Professor Department of Mathematics and Statistics
Boston University
tzvi@bu.edu

MS114

Oscillations and Action Selection in a Multi-Channel Model of the Basal Ganglia

We present a population-level model of basal ganglia action selection based on segregated oscillatory channels, star-like connectivity and partial synchronisation. Although a pair of STN and GP populations (a "micro-channel") cannot oscillate without self-excitation, in pairs they show rhythmic activity at a range of intrinsic frequencies, chosen during training. Adjusting the intrinsic frequency of a central channel selects groups of micro-channels via partial synchronisation. We describe the analysis and possible biological interpretation of our model.

Roman M. Borisyuk
School of Computing and Mathematics, Plymouth University
PL4 8AA, UK
rborisyuk@plymouth.ac.uk

Robert Merrison-Hort
Plymouth University
robert.merrison@plymouth.ac.uk

MS114

Cortical Impact on the Dynamics of Subthalamo-pallidal Networks

Parkinsonian hypokinetic motor symptoms are associated with the beta-band synchronized oscillations throughout basal ganglia-thalamo-cortical circuits. This study explores the oscillatory interactions between cortical and basal ganglia networks in Parkinson's disease in the model of the basal ganglia. The patterns of responses of beta-band bursting in the model suggest that the experimentally observed beta-band synchronization in Parkinson's disease may be promoted by the simultaneous action of both cortical and subthalamo-pallidal network mechanisms.

Leonid Rubchinsky
Department of Mathematical Sciences
Indiana University Purdue University Indianapolis
leo@math.iupui.edu

Sungwoo Ahn
Indiana University Purdue University Indianapolis
ahnmath@gmail.com

Elizabeth Zauber
Indiana University School of Medicine
szauber@iupui.edu

Robert Worth
Department of Neurosurgery
Indiana University School of Medicine
rworth@iupui.edu

MS115

Topology Predicts Dynamics; Dynamics Constrain Topology

Networks are often the structure on which high dimensional dynamical systems operate. Inferring network topology from dynamics and constructing networks to exhibit target dynamics are complimentary strategies to understand their interplay. Recent efforts can infer the structure of a network from manipulations and observations of network dynamics. A computational study of a detailed model of a neuronal network suggests that networks with similar dynamics exist in connected sets in the space of all possible networks.

Srinivas Gorur-Shandilya
Interdepartmental Neuroscience Program
Yale University, US

srinivas.gs@yale.edu

MS115

Data-Driven Network Inference: Achievements, Problems, Possible Research Directions

Complex networks are powerful representations of spatially extended systems and can advance our understanding of their dynamics. A large number of analysis techniques is available that aim at inferring the underlying network structure from data. Despite great successes in various fields, there still exist a number of problems for which there are currently no satisfactory solutions. This talk will discuss these problems as well as possible research directions to help find better solutions.

Klaus Lehnertz
Department of Epileptology
University of Bonn, Germany
klaus.lehnertz@ukb.uni-bonn.de

MS115

Network Structure from Responses of Time-invariants

Inferring how complex systems are interconnected solely from dynamical experiments [1] constitutes a fundamental inverse problem with practical relevance across the natural and technical sciences. So far, most inference approaches either require a high degree of knowledge about the units and the coupling modes or rely on the system being in simple states such as close to fixed points. Moreover, most approaches require the knowledge of the temporal order of the units' states or their relations. Here we present a complementary approach that instead employs invariant measures (i.e. distributions of points sampled in state space) in response to small driving forces. Given sufficiently long time series, inference is successful for very distinct systems, from networks of chaotic oscillators to genetic regulatory circuits underlying the circadian clock. These results expand our ability to infer structural connectivity of networks given temporally unordered observations, possibly stemming from different experiments with uncontrolled initial conditions. [1] J. Phys. A: Math. Theor. 47:343001 (2014).

Mor Nitzan
Hebrew University of Jerusalem
Israel
mor.nitzan@mail.huji.ac.il

Jose Casadiego
Max Planck Institut for Dynamics and Self-Organization
joscas@nld.ds.mpg.de

Marc Timme
Network Dynamics, Max Planck Inst. f. Dyn. & Self-Org.
Goettingen, Germany
timme@nld.ds.mpg.de

MS115

Data Based Modelling: Inferring the Direct Directed Network Structure from Data

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.

Björn Schelter
Institute for Complex Systems and Mathematical Biology
University of Aberdeen, UK
b.schelter@abdn.ac.uk

Marco Thiel
Department of Physics - King's College
University of Aberdeen, UK
m.thiel@abdn.ac.uk

MS116

Averaging and Kam Theory in Torus Canards

We consider rotated slow-fast systems of van der Pol type. Depending on the rotation speed, the resulting 3D system has 2 fast or 2 slow variables. There exists also an intermediate region with three timescales. In the region of two fast variables we prove the existence of an invariant torus and in the intermediate regime we use KAM theory to show the existence of chaotic dynamics.

Albert Granados
SISYPHE, INRIA
alberto.granados_corsellas@inria.fr

MS116

Averaging and Generic Torus Canards

Recently, torus canards have been identified in a range of neuronal burster models, and the majority of these slow/fast systems have a single slow variable. The transition from spiking to bursting occurs via a torus canard explosion, resulting in the existence of non-generic torus canards within a small parameter range. We analyse a coupled neuron model with two slow variables, and using averaging, identify folded saddle and node singularities. These structures and their bifurcations result in generic torus canards, leading to rich dynamics over a wide parameter range.

Kerry-Lyn Roberts
University of Sydney
K.Roberts@maths.usyd.edu.au

MS116

Torus Canard Breakdown

We discuss the conditions giving rise to torus and period-doubling bifurcation pathways from tonic spiking to bursting in slow-fast systems typical in life science applications. We employ Poincare return maps to disclose fine details of the torus breakdown resulting in the rapid onset of spontaneous bursting in a Hodgkin-Huxley type model of a hair cell. Hair cells are peripheral receptors serving on the first stage in transduction of mechanical stimuli to electrical signals in the senses of hearing and balance of vertebrates. These sensors rely on nonlinear active processes to achieve astounding sensitivity, selectivity and dynamical range.

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

Alexander Neiman
Ohio University
neiman@phy.ohiou.edu

MS116
The Interaction Between Classical Canards and Torus Canards

Canards are separatrices of slow/fast systems that lie at the intersection of attracting and repelling invariant slow manifolds. Closely associated with folded equilibria, canards have been studied extensively in $\mathbb{R}^3$. Less well-understood are torus canards, which lie at the intersection of attracting and repelling families of limit cycles. In this work, we explore the relationship between folded node/saddle canards and torus canards in various model systems.

Theodore Vo
University of Sydney
theovo@bu.edu

MS117
The Kuramoto Model of Coupled Oscillators with a Bi-Harmonic Coupling Function" Maxim Komarov

We study synchronization in a Kuramoto model of globally coupled phase oscillators with a bi-harmonic coupling function, in the thermodynamic limit of large populations. We develop a method for an analytic solution of self-consistent equations describing uniformly rotating complex order parameters, both for single-branch (one possible state of locked oscillators) and multi-branch (two possible values of locked phases) entrainment. We show that synchronous states coexist with the neutrally linearly stable asynchronous regime. The latter has a finite life time for finite ensembles, this time grows with the ensemble size as a power law.

Maxim Komarov
Department of Physics and Astronomy
Potsdam University
maxim.a.komarov@gmail.com

MS117
On the Mechanical Origin of Chimera States

Previously, we have demonstrated the emergence of chimera states in an experiment with mechanical oscillators (Martens, E. A., *et al.* PNAS (2013)) and introduced a mathemtical model based on mechanical principles. Here, I analyze this model and establish a link to abstract mathematical models in which chimera were originally discovered. With the analysis, I explain the stability diagram, discuss a new state and provide the first physical interpretation of how chimeras may arise in real world situations.

Erik A. Martens
Max Planck Institute for Dynamics & Self-Organization
erik.martens@ds.mpg.de

MS117
Chimera States in Globally Coupled Oscillators

Chimera states in coupled oscillator systems, where despite of full symmetry, part of the oscillators are synchronized while other are desynchronized, have attracted large interest recently, also because of several experimental realizations. Probably, the most nontrivial situation is that of a globally coupled populations, where one and the same force acts on all oscillators in the ensemble. We give two examples of chimera formation in such a setup, and describe the underlying mechanisms of sel-induced bistability between synchrony and asynchrony.

Arkady Pikovsky
Department of Physics
University of Potsdam, Germany
pikovsky@uni-potsdam.de

Michael Rosenblum
Potsdam University
Department of Physics and Astronomy
mros@uni-potsdam.de

Azamat Yeldesbay
Department of Physics and Astronomy
University of Potsdam, Germany
azayeld@gmail.com

MS117
Mean Field Theory of Assortative Networks of Phase Oscillators

In this talk I present a technique to study synchronization in large networks of coupled oscillators, combining a mean field approximation with the ansatz of Ott and Antonsen. The formulation is illustrated on a network Kuramoto problem with degree assortativity and correlation between the node degrees and the natural oscillation frequencies. We find that degree assortativity can induce transitions from a steady macroscopic state to a temporally oscillating macroscopic state through Hopf and SNIPER bifurcations.

Juan G. Restrepo
Department of Applied Mathematics
University of Colorado at Boulder
Juanga@Colorado.EDU

Edward Ott
University of Maryland
Inst. for Research in Electronics and Applied Physics
edott@umd.edu

MS118
Singular Bogdanov-Takens Bifurcations in the Plane

We present perturbations from planar vector fields having a line of zeros and representing a singular limit of Bogdanov-Takens (BT) bifurcations. We introduce the notion of slow-fast BT-bifurcation and we provide an overview of a complete study of the bifurcation diagram and the related phase portraits, based on geometric singular perturbation theory, including blow-up.

Peter De Maesschalck
Hasselt University
peter.demaesschalck@uhasselt.be

MS118
Canard Orbits in Planar Slow-Fast Piecewise-Linear Systems

The basis of most neuron models is to assume that a neuron behaves as an electrical circuit, which are faithfully modeled by piecewise linear (PWL) systems. Also, neuron models are characterized by different time scales. In this work, we analyze the existence of canard orbits in a family of planar PWL slow-fast systems. The purpose is to use the results to provide models of neurons equally efficient to the smooth models, offering better mathematical tractability.

Soledad Fernandez-Garcia
Inria Paris-Rocquencourt
France
soledad.fernandez-garcia@inria.fr

Mathieu Desroches, Martin Krupa
INRIA Paris-Rocquencourt
mathieu.desroches@inria.fr, maciej.p.krupa@gmail.com

Antonio E. Teruel
University of the Balearic Islands
Palma, Spain
antonioe.teruel@uib.es

MS118

Theoretical Analysis of Homoclinic Canards

Abstract not available.

Jean-Pierre Francoise
University Pierre & Marie Curie - Paris 6
France
Jean-Pierre.Francoise@upmc.fr

MS118

Folded Nodes, Canards and Mixed Mode Oscilations in 3D Piecewise-Linear Systems

New advances in 3D piecewise-linear slow-fast systems (PWL) are presented. In particular, a complete comparison with the smooth case near folded singularities is shown: singular phase portraits, singular weak and strong canards and control of the number of maximal canards are obtained in a way that is entirely compatible with the smooth case. Furthermore, by using previous analysis we present a minimal model displaying periodic canard induced mixed mode oscillations near a PWL folded-node.

Antonio E. Teruel
University of the Balearic Islands
Palma, Spain
antonioe.teruel@uib.es

Mathieu Desroches
INRIA Paris-Rocquencourt
mathieu.desroches@inria.fr

Enrique Ponce
Departamento de Matemática Aplicada
EEscuela Técnica Superior de Ingeniera, Seville, Spain
eponcem@us.es

Rafel Prohens
University of the Balearic Island, Palma Spain
rafel.prohens@uib.es

Antoni Guillamon
Politecnic University of Catalunya
antoni.guillamon@upc.edu

Emilio Freire
Departamento Matematica Aplicada II
Universidad de Sevilla, Spain
efrem@us.es

MS119

Symbolic Dynamical Unfolding of Spike-Adding Bifurcations in Chaotic Neuron Models

We show the systematic changes in the topological structure of chaotic attractors occurring as spike-adding and homoclinic bifurcations are encountered in the slow-fast dynamics of neuron models (detailed in the Hindmarsh-Rose model), where we show that the UPOs appearing after each spike-adding bifurcation are associated with specific symbolic sequences opened when the small parameter of the system decreases. This allows us to understand how these bifurcations modify the internal structure of the chaotic attractors.

Roberto Barrio
University of Zaragoza, SPAIN
rbarrio@unizar.es

Marc Lefranc
PhLAM/Université Lille I,
France
marc.lefranc@univ-lille1.fr

M. Angeles Martinez
University of Zaragoza
SPAIN
gelimc@unizar.es

Sergio Serrano
University of Zaragoza, SPAIN
sserrano@unizar.es

MS119

Stokes Phenomenon in a Singularly Perturbed Differential Equation

It is well known that bifurcation problems can often be studied with the help of singular perturbation theory. In these problems invariant manifolds and solutions can be found in the form of formal series. The series typically diverge and relations with analytical solutions is described by the Stokes phenomenon. In this talk we discuss the recent developments of the theory and illustrate it with examples.

Vassili Gelfreich
University of Warwick, UK
v.gelfreich@warwick.ac.uk

MS119

Canard Orbits and Mixed-Mode Oscillations in a Chemical Reaction Model

To study how mixed-mode oscillations are organised in Koper's three-dimensional chemical reaction model, we compute the two-dimensional attracting and repelling slow manifolds and their intersection curves, known as canard orbits. We also show how a tangency between the repelling slow manifold and the two-dimensional unstable manifold of a saddle-focus equilibrium shapes the dynamics locally

and globally.

Bernd Krauskopf, Jose Mujica, Hinke M. Osinga
University of Auckland
Department of Mathematics
b.krauskopf@auckland.ac.nz, j.mujica@auckland.ac.nz, H.M.Osinga@auckland.ac.nz

MS119

Homoclinic Orbits With Many Loops Near a $0^2 i\omega$ Resonant Fixed Point Of Hamiltonian Systems

In this talk we study the existence of homoclinic connections near the equilibrium point of a family of Hamiltonian systems in the neighborhood of a $0^2 i\omega$ resonance. For reversible non Hamiltonian vector fields, the splitting of the homoclinic orbits lead to exponentially small terms which prevent the existence of homoclinic connections with one loop to periodic orbits of size smaller than an exponentially small critical size. The same phenomenon occurs here but we get round this difficulty thanks to geometric arguments specific to Hamiltonian systems and by studying homoclinic orbits with many loops.

Tiphaine Jézéquel
LMPT, Université de Tours
tiphaine.jezequel@lmpt.univ-tours.fr

Patrick Bernard
CEREMADE, Université Paris - Dauphine
patrick.bernard@ens.fr

ric Lombardi
Institut de Mathématiques de Toulouse
Université Paul Sabatier, Tolouse, France
lombardi@math.univ-toulouse.fr

MS120

Slow Manifolds for a Nonlocal Spde

This work is concerned with invariant manifolds for a slow-fast nonlocal stochastic evolutionary system quantified with a scale paramenter. Under suitable conditions, it is proved that an invariant manifold exists. Furthermore, it is shown that if the scale paramenter tends to zero, the invariant manifold tends to a slow manifold which captures long time dynamics.

Lu Bai
Huazhong University of Science and Technology
bailu0322@163.com

MS120

Slow Manifolds and Interface Motion for Stochastic PDEs

We consider examples of spatially one-dimensional stochastic partial differential equations like the Cahn-Hilliard equation perturbed by additive noise, and study the dynamics of interfaces for the stochastic model. The dynamic of the stochastic infinite dimensional system is given by the motion along a finite dimensional deterministic slow manifold M parametrized by the interface positions. Main results include stochastic stability for M, and a derivation of an effective equation for the interface positions. Joint work with Dimitra Antonopoulou and Georgia Karali.

Dirk Blömker
Universitat Augsburg
Germany
dirk.bloemker@math.uni-augsburg.de

MS120

On the Complete Dynamical Behavior for Three Dimensional Stochastic Competitive Lotka-VolterraSystems

Abstract not available.

Jifa Jiang
Shanghai Normal University
jiangjf@shnu.edu.cn

MS120

Self-similarity in Stochastic PDEs

This talk present some methods to study the self-similarity of some SPDEs under certain assumptions. Attraction of the self-similar solution is shown by applying random invariant manifold theory (in almost sure sense) and a diffusion approximation (in distribution) in the case of additive noise and stochastic advection respectively.

Wei Wang
Nanjing University
wangweinju@aliyun.com

MS121

Exploring Experimental Paths for Reliable Mathematical Models of Friction

Structural vibration controlled by interfacial friction is widespread, ranging from earthquakes and violin strings, to vehicle brake squeal and friction dampers in gas turbines. To predict, control or prevent these systems' behaviours, a constitutive description of frictional interactions is inevitably required. We shall explore the validity of friction models from the nonlinear dynamics of a driven forced single degree of freedom oscillator in view of recent experimental data gathered from the Cambridge pin-on-disc experiment.

Thibaut Putelat
University of Bristol
t.putelat@bristol.ac.uk

MS121

Testing of a Spacecraft Structure with Non-Smooth Nonlinearities

The dynamics of the SmallSat, a real-life spacecraft possessing a complex isolation device with multiple nonsmooth nonlinearities, is investigated. Experiments show that nonlinearities induce modal interactions between modes with non-commensurate linear frequencies. A model of the structure with a simplified description of the nonlinear connections is first built using techniques available in industry. Numerical continuation is then exploited to compute nonlinear normal modes and uncover the interaction phenomena which can jeopardize the structural integrity.

Ludovic Renson
Université de Liège
l.renson@ulg.ac.be

J.P. Noel, G. Kerschen

University of Liege
jp.noel@ulg.ac.be, g.kerschen@ulg.ac.be

MS121

Painlevé Paradox: Lessons That We Do Not Learn from Simple Examples

Painlevé's paradox (non-uniqueness and non-existence in the dynamics of rigid multi-body system with friction) is usually studied via single-contact examples, which exhibit a limited variety of interesting dynamics. In this talk, I show new phenomena based on the analysis of systems with two unilateral, sliding contacts. These include seemingly regular systems, which fail to follow a unique and existing solution; and systems, in which the lack of solutions is not resolved by 'tangential impacts'.

Peter L. Varkonyi
Budapest University of Technology and Economics
vpeter@mit.bme.hu

MS121

Nonlinear Dynamics and Bifurcations of Rotor-Stator Contact in Rotating Machines

A modified Jeffcott rotor model is studied that includes the effects of coupled lateral-torsional deformations and rotor-stator contact with friction. Numerically, bifurcations are found that cause instability or lift-off of either forward or backward whirl. The results are compared for three different nonsmooth friction laws and are favorably compared with analytical predictions. Implications of the results for the dynamics of drill-strings and turbomachinery are discussed.

Nicholas Vlajic
Quantum Measurement Division: Force and Mass Group
National Institute of Standards and Technology
nick.vlajic@gmail.com

Alan R. Champneys
University of Bristol
a.r.champneys@bristol.ac.uk

Michael Friswell, Kiran Vijayan
Swansea University
m.i.friswell@swansea.ac.uk, kiran.vijayan@gmail.com

MS122

Nonlinear Waves in a Lugiato-Lefever Model

The Lugiato-Lefever equation is a cubic nonlinear Schrödinger equation with damping, detuning and driving force arising as a model in nonlinear optics. Steady waves of this equation are found as solutions of a four-dimensional reversible dynamical system in which the evolutionary variable is the space variable. Relying upon tools from bifurcation theory and normal forms theory, we show the existence of various types of steady solutions, including spatially localized and periodic solutions. Finally, we discuss some stability properties of periodic solutions.

Mariana Haragus
Universite de Franche-Comte
mharagus@univ-fcomte.fr

MS122

Stability of Traveling Waves in a Model for a Thin Liquid Film Flow

We consider a model for the flow of a thin liquid film down an inclined plane in the presence of a surfactant, which is known to possess various families of traveling waves. We use a combination of analytical and numerical means to show that the spectra of these waves are within the closed left-half complex plane.

Vahagn Manukian
Miami University Hamilton
manukive@muohio.edu

MS122

Oscillons Near Hopf Bifurcations of Planar Reaction Diffusion Equations

Oscillons are planar, spatially localized, temporally oscillating, radially symmetric structures often arising near forced Hopf bifurcations.Using spatial dynamics, we show that the dynamics on the center manifold of a periodically forced reaction diffusion equation (fRD) near a Hopf bifurcation can be captured by the forced complex GinzburgLandau equation (fCGL). Thus, oscillon solutions to the fRD can be thought of as a foliation over localized solutions to the fCGL.

Kelly Mcquighan
Boston University
kmcquigh@bu.edu

Bjorn Sandstede
Division of Applied Mathematics
Brown University
bjorn_sandstede@brown.edu

MS122

The Entry-exit Function and Geometric Singular Perturbation Theory

For small $\epsilon > 0$, the system $\dot{x} = \epsilon$, $\dot{z} = h(x,z)z$, with $h(x,0) < 0$ for $x < 0$ and $h(x,0) > 0$ for $x > 0$, admits solutions that approach the x-axis while $x < 0$ and are repelled from it when $x > 0$. The limiting attraction and repulsion points are given by the well-known entry-exit function. For $h(x,z)z$ replaced by $h(x,z)z^2$, we explain this phenomenon using geometric singular perturbation theory. The linear case can be reduced to the quadratic case, which is related to periodic traveling waves in a diffusive predator-prey model.

Peter De Maesschalck
Hasselt University
peter.demaesschalck@uhasselt.be

Stephen Schecter
North Carolina State University
Department of Mathematics
schecter@ncsu.edu

MS123

Pattern-formation in Semiarid Vegetation: Using

Bifurcation Theory for Model Comparison

In semi-arid ecosystems, water is considered a limiting resource for vegetation growth. This principle gives rise to a variety of PDE models describing vegetation-water interactions that predict the formation of self-organized spatial patterns in vegetation communities as a response to resource scarcity. We use bifurcation theory to identify robust structures that persist across different models of this phenomenon. From this perspective, we find system behaviors that are robust to uncertainty in model choice, and we identify models that are not sensitive to small structural perturbations.

Sarah Iams
Northwestern University
Evanston, IL
smi6@cornell.edu

MS123

Models of Patchy Invasion: A Mathematical Toy Or a New Paradigm?

A theory based on diffusion-reaction equations predicts the invasive species spread as a traveling population front separating the invaded and non-invaded regions. However, it appears to be at odds with some recent observations. In some cases, the spread takes place through formation of a distinct patchy spatial structure without any continuous boundary. I will revisit the traditional diffusion-reaction framework and show that the patchy spread is its inherent property in case the invasive species is affected by predation or pathogens. The patchy spread described by a diffusion-reaction model appears to be a scenario of alien species invasion "at the edge of extinction". I will also show that patchy spread is not an exclusive property of the diffusion-reaction systems but can be observed as well in different types of model.

Sergei Petrovskii
Department of Mathematics
University of Leicester
sp237@leicester.ac.uk

MS123

The Effect of Slow Spatial Processes in a Phytoplankton-Nutrient Model

We consider a system of reaction-diffusion equations describing the interaction of phytoplankton in the deep ocean with its nutrient. Recently, we have studied bifurcations and stability of two types of patterns exhibited by this PDE system. The result is two-fold. On the one hand, our analysis captures field observations, thereby validating the model we used. On the other hand, our analysis is of mathematical interest. In a formal derivation, using asymptotic methods, we extend a classic version of center manifold reduction to a regime where the, usually necessary, spectral gap condition is violated. With this tool, we capture parameter regimes in which each of the patterns is stable and flourishes.

Lotte Sewalt
Leiden University
lotte@math.leidenuniv.nl

Arjen Doelman
Mathematisch Instituut
doelman@math.leidenuniv.nl

Antonios Zagaris
Universiteit Twente
a.zagaris@utwente.nl

MS123

Stripe Pattern Selection by Advective RD Systems: Resilience of Banded Vegetation on Slopes

We study a Gray-Scott type system of PDEs that models vegetation in (semi-)arid regions. Observations of stripe patterns along slope contours are widespread. We focus on stripe break up into rectangles/hexagons. It is shown that an increase in slope/advection leads to an increase of resilience/stability of vegetation stripes. The analytical results generalize to classes of systems.

Eric Siero
Leiden University, Mathematical Institute
esiero@math.leidenuniv.nl

Arjen Doelman
Mathematisch Instituut
doelman@math.leidenuniv.nl

Jens Rademacher
University of Bremen
jdmr@uni-bremen.de

MS124

Input-Ouptut Analysis in Channel Flows and Implications for Flow Control

The Navier-Stokes equations for channel flows are a prototype model for turbulent boundary layer flow control, specifically for the problem of skin-friction drag reduction. To carry out model-based control designs, control-oriented dynamical models of the processes to be controlled are needed. Such models need to contain the phenomena that are to be controlled and stabilized. We present an input-output analysis of channel flows, and control-oriented linearized models that contain much of the phenomenology of bypass transition.

Bassam A. Bamieh
UC Santa Barbara
bamieh@engineering.ucsb.edu

MS124

Nematic Liquid Crystal Flow in a Microfluid: Topological Transitions

Motivated by recent experimental work by Sengupta and co-workers on flow of a nematic liquid crystal (NLC) within a microfluidic, we consider flow of NLC within a channel, with homeotropic (perpendicular) anchoring on the director field at the walls. We find that this setup admits two exact steady solutions, with distinct director topology; and that based on energetic arguments, as the flow rate is increased, there is a transition from one solution to the other.

Linda Cummings
Department of Mathematical Sciences
New Jersey Institute of Technology
linda.j.cummings@njit.edu

Thomas Anderson
Caltech

tga3@njit.edu

Lou Kondic
Department of Mathematical Sciences, NJIT
University Heights, Newark, NJ 07102
kondic@njit.edu

MS124

Correlating Dynamical Structures with Forcing in 2D Flow

Lagrangian Coherent Structures (LCSs) have been widely studied in recent years, and have been shown to be a useful characterization of complex fluid flows. However, current methods to detect LCSs require knowledge of future information, and it is not known how to generate LCSs on demand. As a step toward moving past simple observation, I will discuss the correlations between forcing in an experimental quasi-2D flow and the resulting LCSs.

Nicholas T. Ouellette
Yale University
Department of Mechanical Engineering and Materials Science
nicholas.ouellette@yale.edu

MS124

Multi-Objective Optimal Control of Transport and Mixing in Fluids

Aspects of controlling transport and mixing in fluid flows have received considerable scientific interest in the last few years. Here we describe a multi-objective optimal control framework for the optimization of advective processes with respect to certain transport or mixing properties. We demonstrate it with a number of example systems, which may serve as simple models of microfluidic devices.

Kathrin Padberg-Gehle
Institute of Scientific Computing
TU Dresden
kathrin.padberg@tu-dresden.de

Sina Ober-Blöbaum
University of Paderborn
sinaob@uni-paderborn.de

MS126

Effects of Implementing Contraction to Calcium-Voltage Models

In this study we present a systematical methodology to incorporate a contraction model (Negroni_Lascano_1996) into fourteen well known single cell electrophysiology (EP) models. To evaluate how well these coupled electromechanical (EM) models behave, we study them under postextrasystolic pacing (PESP) protocol. We first compare the dynamics between the new EM models and the original EP models then we compare the contractile strength of the new EM models with the experiment (Yue et al 1985).

Yanyan Ji, Flavio M. Fenton
Georgia Institute of Technology
yji47@gatech.edu, flavio.fenton@physics.gatech.edu

Richard Gray
U.S. Food and Drug Administration
richard.gray@fda.hhs.gov

MS126

Synchronization of Calcium Sparks and Waves

In this presentation, we show how membrane potential affects Ca sparks and waves, especially during delayed afterdepolarizations (DADs). We use a physiologically detailed mathematical model to investigate individual factors which affect Ca spark generation and wave propagation. We found that depolarization promotes Ca wave propagation and hyperpolarization prevents it. We will discuss the details of the underlying mechanisms in the talk.

Daisuke Sato
UC davis
dsato@ucdavis.edu

MS126

Nucleation and Dynamics of Spontaneous Ca Waves in Cardiac Cells

Spontaneous Calcium release (SCR) occurs when ion channel fluctuations lead to the nucleation of calcium waves in cardiac cells. This phenomenon is important since it has been linked to various cardiac arrhythmias. However, to date it is not understood what determines the timing and location of the spontaneous events within cells. Here we have developed a simplified model of SCR and analyzed a determinstic mean field limit sheds light on the essential features of this phenomenon. We find that SCR is typically nucleated at preferred sites of the cell which can determined by studying the structure of eigenvectors of a class of Euclidean random matrices. Using this approach we estimate the timing of SCR in terms of physiological parameters such as the spatial arangement of calcium release units, and the local ion channel kinetics.

Yohannes Shiferaw
California State University
Northridge
yshiferaw@csun.edu

MS126

Complex Dynamic Patterns of Voltage and Calcium in Mammalian Hearts

Cardiac dynamics is govern with bidirectional coupling between transmembrane-voltage (Vm) and free intracellular calcium (Cai). Altering this coupling it is known to be the important precursor of different forms of cardiac arrhythmia and cardiac alternans as triggers for cardiac reentry. We present our experimental method for simultaneous measurements of Vm and Cai with a single sensor, and obtained experimental results of alternans and ventricular fibrillation development in different mammalian hearts (pig, rabbit, cat).

Ilija Uzelac, Flavio M. Fenton
Georgia Institute of Technology
ilija.uzelac@physics.gatech.edu,
flavio.fenton@physics.gatech.edu

MS127

Dynamic Information Routing in Complex Net-

works

Abstract not available.

Christoph Kirst
Center for Studies in Physics and Biology
Rockefeller University, US
Christoph.Kirst@Rockefeller.edu

MS127

Unraveling Network Topology from Derivative-Variable Correlations

A method of network reconstruction from the dynamical time series is introduced, relying on the concept of derivative-variable correlation. Using a tunable observable as a parameter, the reconstruction of any network with known interaction functions is formulated via simple matrix equation. We suggest a procedure aimed at optimizing the reconstruction from the time series of length comparable to the characteristic dynamical time scale. Our method also provides a reliable precision estimate. We illustrate the method's implementation via elementary dynamical models, and demonstrate its robustness to both model and observation errors.

Zoran Levnajic
Laboratory of Data Technologies
Faculty of Information Studies, Novo Mesto, Slovenia
zoran.levnajic@fis.unm.si

MS127

Reconstructing Network Connectivity by Triplet Analysis

We discuss recovery of the directional connectivity of a small oscillator network via the phase dynamics reconstruction from multivariate data. Instead of the pairwise analysis, we analyse triplets of nodes and reveal an effective phase connectivity which is close but generally not equivalent to a structural one. By comparing the coupling functions reconstructed from all possible triplets, we achieve a good separation between existing and non-existing connections, and thus reliably reproduce the network structure.

Michael Rosenblum
Potsdam University
Department of Physics and Astronomy
mros@uni-potsdam.de

MS127

From Neural Dynamics to Network Properties and Cognitive Function

It remains unclear to what extend structural and functional network measurements are complementary, or rather provide orthogonal information about network state. We developed framework to capture neuronal correlations over short timescales and use them to quantify large-scale functional connectivity shifts indicative of slower structural network changes. We applied it to simulated as well as experimental data. We observed state dependent, network-wide structural modifications and significant changes in network stability, which is linked to behavior.

Daniel Maruyama
Department of Physics
University of Michigan
dmaruyam@umich.edu

Nicollette Ognjanovski
Department of Molecular, Cellular and Developmental Biology
University of Michigan
nnognjan@gmail.com

Sara Aton
2Department of Molecular, Cellular and Developmental Biology
University of Michigan
saton@umich.edu

Michal Zochowski
Department of Physics and Biophysics Program
University of Michigan
michalz@umich.edu

MS128

Rigorous Numerics for Symbolic Dynamics and Topological Entropy Bounds

Outer approximations of continuous, discrete-time systems, or maps, incorporate bounded error and allow for the rigorous extraction of dynamics via Conley Index theory and other tools. Recent advances, including joint work with W. Kalies, M. D. LaMar, R. Trevino and R. Frongillo, have extended the class of maps to which these methods may be applied and improved the types of results that one may obtain, specifically in terms of semi-conjugate symbolic dynamics and associated lower bounds on topological entropy. I will describe some of this recent work and show sample results.

Sarah Day
The College of William and Mary
sday@math.wm.edu

Rafael Frongillo
The University of California at Berkeley
raf@cs.berkeley.edu

MS128

Orbital Stability Investigations for Travelling Waves in a Nonlinearly Supported Beam

We consider the fourth-order problem

$$\varphi_{tt} + \varphi_{xxxx} + f(\varphi) = 0, \quad (x,t) \in \mathbf{R} \times \mathbf{R}^+,$$

with a nonlinearity f vanishing at 0. Solitary waves $\varphi = u(x+ct)$ satisfy the ODE

$$u'''' + c^2 u'' + f(u) = 0 \quad \text{on } \mathbf{R},$$

and for the case $f(u) = e^u - 1$, the existence of at least 36 travelling waves was proved in [Breuer, Horák, McKenna, Plum, Journal of Differential Equations 224 (2006)] by computer assisted means. We investigate the orbital stability of these solutions via computation of their Morse indicies, which heavily relies on spectral bounds for the linearized operator, and using results from [Grillakis, Shatah, Strauss, Journal of Functional Analysis 74 (1987) and 94 (1990)]. We make use of both analytical and computer-assisted techniques.

Michael Plum
Karlsruhe University (KIT)

Germany
michael.plum@kit.edu

MS128

The Parametrization Method in Infinite Dimensions

Understanding the dynamics near the equilibrium solutions of a PDE is a first step towards a global dynamical scaffold. Their (un)stable manifolds are a powerful tool in this analysis. We apply the Parameterization Method of Cabre, Fontich and de la Llave in order to study finite dimensional unstable manifolds in infinite dimensional phase space. We present both numerical implementations for some dissipative PDEs and a-posteriori theorems which provide rigorous error bounds for the numerical approximations.

Christian P. Reinhardt
Department of Mathematics, VU University Amsterdam
c.p.reinhardt@vu.nl

Jason Mireles-James
Departement of Mathematics
Florida Atlantic University
jmirelesjames@fau.edu

MS128

Rigorous Numerics for Some Pattern Formation Problems

This talk is about applications of recently developed techniques from rigorous computational dynamics to pattern formation phenomena. We discuss the differences and similarities in the analytic setup of three examples, namely radially symmetric spots in the Swift-Hohenberg model, transitions between hexagonal spots and stripe patterns, and phase separation in diblock copolymers. These examples, which entail both ODEs and PDEs, also showcase the interplay between rigorous numerical methods and asymptotic techniques.

Jan Bouwe Van Den Berg
VU University Amsterdam
Department of Mathematics
janbouwe@few.vu.nl

MS129

Neural Field Models Which Include Gap Junctions

Neural field models are normally derived under the assumption that connections between neurons are synaptic rather than via gap junctions. I will show how to derive a neural field model from a network of "theta neurons" with both synaptic and gap junction connectivity. The derivation is exact in the limit of an infinite number of neurons.

Carlo R. Laing
Massey University
Auckland
c.r.laing@massey.ac.nz

MS129

From Ensembles of Pulse-Coupled Oscillators to Firing-Rate Models

Ensembles of pulse-coupled oscillators are often encountered in biological and technological systems. We report on two recent findings: 1) The solution of the prototypical model proposed by Winfree in 1967. Using the Ott-Antonsen ansatz, the effect of pulse width on the onset of macroscopic synchronization is clarified. 2) For ensembles of quadratic integrate-and-fire neurons, a "Lorentzian ansatz" permits us to obtain exact low-dimensional firing-rate equations; in contrast to the current heuristic models used in neuroscience.

Diego Pazó
Instituto de Fisica de Cantabria (IFCA)
Santander, Spain
pazo@ifca.unican.es

Ernest Montbrio
Universitat Pompeu Fabra
Barcelona, Spain
ernest.montbrio@upf.edu

Alex Roxin
Centre de Recerca Matematica
Bellaterra (Barcelona), Spain
aroxin@crm.cat

MS129

Suppressing Complex Collective Behavior in a Network of Theta Neurons by Synaptic Diversity

A large heterogeneous network of globally coupled theta neurons can demonstrate a range of collective behavior from simple equilibrium states to a collective rhythmic state. Other complexity such as multistability, quasi-periodicity, and macroscopic chaos can also occur. In the current work, we introduce heterogeneity in the neurons coupling strength and we find that synaptic diversity increases the robustness of equilibrium states and suppresses the emergence of the collective rhythmic state and other complex network behavior.

Lucas Lin
Thomas Jefferson High School for Science and Technology
lucas.lin177@gmail.com

Ernest Barreto
George Mason University
Krasnow Institute
ebarreto@gmu.edu

Paul So
George Mason University
The Krasnow Institute
paso@gmu.edu

MS130

Mixed-Mode Bursting Oscillations (MMBOs): Slow Passage Through a Spike-adding Canard Explosion

Mixed-Mode Bursting Oscillations (MMBOs) are solutions of slow-fast dynamical systems that exhibit both small amplitude oscillations (SAOs) and bursts consisting of one or multiple large-amplitude oscillations (LAOs). The name MMBO is given in analogy to Mixed-Mode Oscillations (MMOs), which consist of alternating SAOs and LAOs, without the LAOs being organized into burst events. I will show how MMBOs are created naturally in systems that have a spike-adding bifurcation, or spike-adding mechanism, and in which the dynamics of one (or more) of the slow variables causes the system to pass slowly through that bifurcation due to the presence of a folded node. The analysis is carried out for a prototypical fourth-order system of this type, which consists of the third-order Hindmarsh-Rose burster, known to have the spike-adding mechanism, and in which one of the key bifurcation parameters also varies slowly.

Mathieu Desroches
INRIA Paris-Rocquencourt
mathieu.desroches@inria.fr

Tasso J. Kaper
Boston University
Department of Mathematics
tasso@math.bu.edu

Martin Krupa
INRIA Paris-Rocquencourt
maciej.p.krupa@gmail.com

MS130

An Organizing Center for Spatiotemporal Bursting

As the fundamental model of two timescales spatiotemporal excitability, FitzHugh-Nagumo model has the interpretation of a normal form reduction organized by the hysteresis singularity. We mimick the analog geometric construction in the universal unfolding of the winged cusp and obtain a three timescales model for spatiotemporal excitability. Bursts and traveling bursts are shown to be the prototypical behaviors of the proposed model, in full analogy with the spikes and traveling pulses of FitzHugh-Nagumo model.

Alessio Franci
Cambridge University
England
af529@cam.ac.uk

Guillaume Drion
Brandeis University
Brandeis, MA
gdrion@brandeis.edu

Rodolphe Sepulchre
University of Cambridge
Cambridge, UK
r.sepulchre@eng.cam.ac.uk

MS130

Three Timescale Phenomena in Coupled Morris-Lecar Equations

Theory for the analysis of systems with two timescales is well established, but some dynamical phenomena are not captured by two timescale models and less is understood about how to efficiently study systems with three or more timescales. Motivated by applications in neural dynamics, we study a pair of Morris-Lecar systems coupled so that there are three timescales in the full system. We identify complex oscillations that appear to be intrinsically three timescale phenomena, and use geometric singular perturbation theory to explain the mechanisms underlying these solutions.

Pingyu Nan
University of Auckland
pnan011@aucklanduni.ac.nz

Yangyang Wang
University of Pittsburgh
yaw23@pitt.edu

Vivien Kirk
University of Auckland
v.kirk@auckland.ac.nz

Jonathan E. Rubin
University of Pittsburgh
Department of Mathematics
rubin@math.pitt.edu

MS130

Averaging, Folded Singularities and Torus Canards in a Coupled Neuron Model

We consider transitions between various bursting and tonic spiking regimes in a coupled neuron model. Analysis of an averaged reduced system reveals the critical roles of folded singularities and the associated bifurcation scenarios, including a novel FSN III bifurcation; some of these bifurcations correspond to torus bifurcations, yielding torus canards, in the full system. We also show that the complete set of bifurcations is captured in a canonical system that can be treated analytically.

Kerry-Lyn Roberts
University of Sydney
K.Roberts@maths.usyd.edu.au

Jonathan E. Rubin
University of Pittsburgh
Department of Mathematics
rubin@math.pitt.edu

Martin Wechselberger
University of Sydney
wm@maths.usyd.edu.au

MS131

Unitary Representations of Diffeomorphisms: Halfway Between Koopmanism and Transfer Operator Theory

Koopmanism is derived from a representation of diffeomorphisms on the space of real valued functions. Dual to this pictures is the Frobenius-Perron operator where a diffeomorphism is represented as a linear operator on densities. In this talk we will present a unitary representation of the diffeomorphism group on the Hilbert space of half-densities. The resulting representation induces numerical advection schemes which will be useful in a variety of scenarios. In particular, we may create spectral methods which preserve the ring structure of functions, conserve total mass, deform vector fields, and more. Such structure preservation is important as one considers problems in higher dimensions and requests qualitative accuracy in exchange for numerical precision.

Henry O. Jacobs
Imperial College London
Mathematics
hoj201@gmail.com

MS131

Optimal Control Design and Value Function Esti-

mation for Nonlinear Dynamical Systems

This presentation considers the infinite-time discounted optimal control problem for continuous time input-affine polynomial dynamical systems subject to polynomial state and box input constraints. We propose a sequence of sum-of-squares (SOS) approximations of this problem obtained by first lifting the original problem into the space of measures with continuous densities and then restricting these densities to polynomials. These approximations are tightenings, rather than relaxations, of the original problem and provide a sequence of rational controllers with value functions associated to these controllers converging (under some technical assumptions) to the value function of the original problem.

Milan Korda
Ecole Polytechnique Federale de Lausanne
milan.korda@epfl.ch

MS131

Transfer Operator Methods for Stability Analysis and Control

Linear transfer Perron-Frobenius operator-based methods are developed for global stability analysis and control design of deterministic and stochastic nonlinear systems. The transfer operator-based Lyapunov measure is introduced as a new tool to verify weaker set-theoretic notion of almost everywhere stability. Just as an invariant measure is a counterpart of the attractor (recurrence), this measure is demonstrated as a stochastic counterpart of stability (transience). The Lyapunov measure is shown to be dual to the Lyapunov function. In addition to the theoretical results, we also present a computational method for the approximation of the Lyapunov measure and almost everywhere stabilizing feedback controller. These computational methods are based on set-oriented numerical approaches. The linear nature of the framework provides linear programming-based computational methods for finite dimensional approximation of the Lyapunov measure and stabilizing controller.

Umesh Vaidya
Iowa State University
ugvaidya@iastate.edu

MS131

Numerical Advection of Probability Densities for High Dimensional Systems

Understanding the effect of propagating uncertainty in initial condition through dynamical systems is critical while engineering verifiably safe systems. Given its importance, many numerical methods have been proposed to advect probability densities over an initial condition set by carefully manipulating nonnegative valued functions and densities. This management of nonegative objects unfortunately restricts the applicability of these numerical methods to low dimensional dynamical systems. In this talk, I describe a method to address this shortcoming by developing a linear advection equation over half densities, which can be thought of as the square root of classical nonnegative densities. This construction allows us to prove a rate of convergence for various numerical methods and allows us to successfully advect smooth probability densities through high dimensional systems.

Ram Vasudevan
University of California Berkeley
Massachusetts Institute of Technology
ramv@umich.edu

MS132

Stochastic Center Manifolds Without Gap Conditions

The existence of invariant manifolds requires that the spectrum of linear part of a deterministic system or stochastic system contains large gaps. However, for some dynamical systems, the condition of spectral gap condition is not satisfied. In this case, it is still unknown whether there exists invariant manifolds. This paper concerns the center manifolds of the stochastic systems without the spectral gap condition.

Xiaopeng Chen
Peking University
chenxiao002214336@outlook.com

MS132

How to Quantify Non-Gaussian Stochastic Dynamics?

Dynamical systems arising in engineering and science are often subject to random fluctuations, which may be Gaussian or non-Gaussian described by Brownian motion or a-stable Levy motion, respectively. Non-Gaussianity of the noise manifests as nonlocality at a macroscopic level. Stochastic dynamical systems with a-stable Levy motions have attracted a lot of attention recently. The non-Gaussianity index a is a significant indicator for various dynamical behaviors. The speaker will present a few aspects of non-Gaussian stochastic dynamical systems, highlighting some delicate and profound impact of noise on dynamics. Then, he will focus on understanding stochastic dynamics by examining certain deterministic quantities.

Jinqiao Duan
Institute for Pure and Applied Mathematics
UCLA
duan@iit.edu

MS132

Random Dynamical Systems for Non-Densely Defined Evolution Equations

We consider abstract random evolution equations given by

$$x'(t) = Ax(t) + F(\theta_t\omega, x(t)), x(0) = x_0 \in \overline{D(A)}. \quad (1)$$

Here, we suppose that A is a non-densely defined linear operator. Therefore, the C_0-semigroup approach no longer applies. Such situations can occur for instance due to nonlinear boundary conditions. By using integrated semigroup theory, we can show under suitable assumptions, the existence of a random dynamical system for the above equation and discuss its asymptotic behavior. Finally, we analyze a class of non-densely defined stochastic differential equations driven by a Banach-space valued Brownian motion. Our aim is to construct an Ornstein-Uhlenbeck process, which allows us to reduce the stochastic problem into a pathwise one.

Alexandra Neamtu
Friedrich-Schiller-University Jena

alexandra.neamtu@uni-jena.de

MS133

Lessons Learnt from the Two-Ball Bounce Problem

I revisit a popular classroom demonstration where a light rigid body and a larger heavier ball are vertically aligned and dropped together. Experimental results obtained using a high-speed camera are compared to a discrete model using Newtonian restitution, showing poor agreement as the separation distance becomes small. An alternative model based on membrane theory is developed and compared favourably to experimental data in the limits of very small separation distance and mass ratio.

Yani Berdeni
University of Bristol
yani.berdeni@bristol.ac.uk

MS133

Predicting Conditions for Self-sustained Vibration in Drillstrings

High amplitude vibration in drillstrings is often the result of a self-sustained regime of vibration such as torsional stick-slip oscillation; forward whirl; or backward whirl. The nonlinear interactions underlying these regimes come from bit-rock interaction and side-wall contact. We present a novel approach for modelling these regimes: assuming local nonlinearity, we derive conditions necessary to sustain a given regime once it has already initiated. Results are numerically validated and give insight into each phenomenon.

Tore Butlin
University of Cambridge
tb267@cam.ac.uk

MS133

Contact and Friction Within Geometrically Exact Shell Theory - Modeling Microslip and Dissipation in Structural Systems

We consider the representation of the dissipation due to frictional interfaces within large-scale structural systems. In this work contact and friction are incorporated within geometrically exact shell theory, providing insight into the relationship between the observed dissipation and the loading characteristics on the shell. Finally, the use of such formulations as a basis for reduced-order modeling and extensions to the larger problem of structural damping are highlighted.

D Dane Quinn
University of Akron
Dept of Mechanical Engineering
quinn@uakron.edu

MS133

A New Semi-Analytical Algorithm for Two-Dimensional Coulomb Frictional System

A closed form solution for the trajectory of a planer particle loaded by constant external force with Coulomb friction has been proposed. Together with analytical patches close to slip/stick transitions, this solution has been employed to build a new semi-analytical algorithm for two-dimensional frictional system subjected to time-varying external loads under the assumption that the external loads can be treated as constant if the time step is sufficient small.

Xiaosun Wang
Wuhan University
China
wxs@whu.edu.cn

Jim Barber
University of Michigan
jbarber@umich.edu

MS134

Stability of Combustion Fronts in Hydraulically Resistant Porous Media

We study front solutions of a system that models combustion in porous media. The spectral stability of the fronts is studied on the linear and nonlinear level. For the spectral stability analysis we use a combination of energy estimates and numerical Evans function computations.

Anna Ghazaryan
Miami University
ghazarar@miamioh.edu

MS134

Invasion Fronts in Systems of Reaction Diffusion Equations

We study invasion speeds in a system of coupled Fisher-KPP equations. For certain parameter regimes we prove that the speed selected by compactly supported initial data is faster for the coupled system than for the uncoupled one. The proof relies on the construction of sub and super solutions.

Matt Holzer
Department of Mathematics
George Mason University
mholzer@gmu.edu

MS134

An Overview of Evans Function Computation

We give an overview of Evans function and the numerical techniques used to compute it. We provide a mini-tutorial on STABLAB, a MATLAB-based toolbox for Evans function computation, and show how to avoid some of the common pitfalls that arise in Evans function computation. There are also a number of best practices that we highlight, noting that there are many variations on methods and formulations. Different situations call for different approaches.

Jeffrey Humpherys
Brigham Young University
jeffh@math.byu.edu

MS134

Orbital Stability of Waves Traveling Along Vortex Filaments

By the term vortex filament, we mean a mass of whirling fluid or air (e.g. a whirlpool or whirlwind) concentrated along a slender tube. The most spectacular and well-known example of a vortex filament is a tornado. A waterspout

and dust devil are other examples. In more technical applications, vortex filaments are seen and used in contexts such as superfluids and superconductivity. One system of equations used to describe the dynamics of vortex filaments is the Vortex Filament Equation (VFE). The VFE is a system giving the time evolution of the curve around which the vorticity is concentrated. In this talk, we develop a framework for studying the stability solutions of the VFE, based on the correspondence between the VFE and the NLS provided by the Hasimoto map. We use this framework to establish the orbital stability of certain classes of solutions including solitons and closed solutions taking the form of torus knots.

Stéphane Lafortune
College of Charleston
lafortunes@cofc.edu

PP1

The Breakup of Invariant Tori in 4-D Maps Using the Slater's Criterion

In the late of 40s, N. B. Slater proved that an irrational translation over an unity circle can take at most three different return counts to a connected interval ($\delta < 1$). In addition, these three recurrence times are expressible by the continued fraction expansion of the irrational number used to the translation. This remarkable result has an immediate connection with invariant tori, whose rotation number in the bi-dimensional phase space is also irrational and can be related to a motion over the circle. Thus, the evaluation of three recurrence times has been used to predict breakup of such invariant tori in several 2-D dynamical systems. Here we introduce the Slater's theorem in the context of higher dimension Hamiltonian systems to estimate the breakup of invariant tori in a 4-Dimensional symplectic map.

Celso Abud
University of Sao Paulo
cabud@if.usp.br

Ibere L. Caldas
Institute of Physics
University of Sao Paulo
ibere@if.usp.br

PP1

Theta Model for Quartic Integrate-and-Fire Neuron Model

The theta model is convenient to investigate the population dynamics of coupled noisy neurons due to the periodic boundary conditions of the corresponding Fokker-Planck equation. However, quantitative relationships between the theta model and conductance-based neuron models has not been thoroughly explored. We propose a version of the theta model derived from a quartic integrate-and-fire model, which has quantitatively equivalent dynamics to biophysically realistic Wang-Buzsaki model. We also analyze the population dynamics of this new model.

Akihiko Akao, Yutaro Ogawa
Graduate School of Frontier Sciences
The University of Tokyo
akao@neuron.t.u-tokyo.ac.jp,
ogawa@neuron.t.u-tokyo.ac.jp

Bard Ermentrout
University of Pittsburgh
Department of Mathematics
bard@pitt.edu

Yasuhiko Jimbo
Graduate School of Engineering
The University of Tokyo
jimbo@neuron.t.u-tokyo.ac.jp

Kiyoshi Kotani
Research Center for Advanced Science and Technology
The University of Tokyo
kotani@neuron.t.u-tokyo.ac.jp

PP1

A Solution of Linear Programming Problems with Interval Coefficients

In this talk, we consider a linear programming problem where the coefficients are interval. For these problems, we cannot apply the technique of the classical linear programming directly. We focus on a satisfactory solution approach based on the inequality relations that was introduced by Alolyan and to solve the interval linear programming problem. In order to solve such a problem, we present an algorithm that find the solution of such a problem and show the efficiency of the algorithm and present a numerical example.

Ibraheem Alolyan
King Saud University
ialolyan@ksu.edu.sa

PP1

Developing a Model Approximation Method and Parameter Estimates for a Solar Thermochemistry Application

We will show the model and software development process used in creating a robust parameter optimizer for a solar reactor. The basic reaction model is numerically difficult to solve, so several proprietary elements of code were developed to interface with standard optimization routines. Integrating complex toolboxes and non-standard code led to several insights into good development practices which will be highlighted.

William D. Arloff
Valparaiso University
william.arloff@valpo.edu

Karl Schmitt
Valparaiso University
Department of Mathematics
karl.schmitt@valpo.edu

Luke Venstrom, Leandro Jaime
Valparaiso University
Dept. of Mechanical Engineering
luke.venstrom@valpo.edu, leandro.jaime@valpo.edu

PP1

Hamiltonian Hopf Bifurcations in Schrdinger Trimers

The cubic nonlinear Schrdinger equation is fundamentally important in the physics of waves, arising in optical fibers, waveguides, Bose-Einstein condensates, and water waves.

We investigate the phase space of the three-mode discrete NLS in the weakly nonlinear regime. We enumerate the families of standing waves and use normal forms to describe several families of relative periodic orbits whose topologies change due to Hamiltonian Hopf bifurcations and others.

Casayndra H. Basarab
New Jersey Institute of Technology
chb4@njit.edu

Roy Goodman
NJIT
NJIT
goodman@njit.edu

PP1

Computing the Optimal Path in Stochastic Dynamical Systems

In stochastic systems, we are often interested in quantifying the optimal path that maximizes the probability of switching between metastable states. However, in high-dimensional systems, the optimal path is often extremely difficult to approximate. We consider a variety of problems from population biology and demonstrate a constructive methodology to quantify the optimal path using a combination of finite-time Lyaponuv exponents, statistical selection criteria, and a Newton-based iterative minimizing scheme.

Martha Bauver
Montclair State University
bauverm1@mail.montclair.edu

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

Eric Forgoston
Montclair State University
Department of Mathematical Sciences
eric.forgoston@montclair.edu

PP1

Effects of Quasi-Steady-State Reduction on Biophysical Models with Oscillations

Many mathematical models of biological systems possess multiple time scales. A common first step in the analysis of such models is the elimination of one or more of the fastest variables via quasi-steady-state reduction (QSSR). However, this process sometimes leads to changes in the dynamics by introducing or removing bifurcations. We discuss the persistence of Hopf bifurcations under QSSR and show examples of qualitative changes to oscillatory dynamics that can be induced by QSSR.

Sebastian D. Boie, Vivien Kirk
University of Auckland
s.boie@auckland.ac.nz, v.kirk@auckland.ac.nz

James Sneyd
University of Auckland
Department of Mathematics
sneyd@math.auckland.ac.nz

PP1

Analyzing Cycling Dynamics in Stochastic Systems

We consider a Langevin model where external noise causes random switching between metastable states. A chain of these states, such as those found in a multi-well potential, enables cycling dynamics. Switching times are found using a variational approach. Additionally, a probabilistic argument is used to understand the cycling dynamics. Analytical results agree well with numerical simulations for a range of well depths and noise intensities.

Pralhad Burli
Montclair State University
burlip1@mail.montclair.edu

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

Eric Forgoston
Montclair State University
Department of Mathematical Sciences
eric.forgoston@montclair.edu

PP1

Limit Cycles in a Simplified Basal Ganglia Model

Muscle rigidity associated with Parkinson's disease is thought to be correlated with the loss of dopamine and the emergence of beta oscillations in the basal ganglia. As dopamine-producing neurons die off, synaptic connection strengths change leading to a favoring of the Indirect Pathway. Though a model of the entire basal ganglia process is quite complicated, we show that a simplified version can exhibit both steady-state and limit cycle behavior by changes in connection strength alone.

Michael Caiola
Rensselear Polytechnic Institute
caiolm@rpi.edu

Mark Holmes
Rensselaer Polytechnic Institute
holmes@rpi.edu

PP1

Mathematical Modelling of Spatial Sorting and Evolution in a Host-Parasite System

We examine the spatial self-structuring of traits in both a cane toad population and lungworm parasite population, which evolves with the cane toad population. In particular, the traits we focus on are dispersal ability for the cane toad population and both prepatent period and larval size for the lungworm parasite population. Along with the spatial self-structuring of these traits, our results confirm observations made in empirical studies; particularly, that there is a noticeable lag between the host and parasite population, that older populations regress to lower dispersal speeds and that "spatial sorting" of dispersal ability can still occur with a disadvantage in reproductivity and/or survival in more motile individuals. Moreover, we find that such a disadvantage in reproductivity and/or survival is unlikely to be large if spatial sorting is to have a noticeable effect on the rate of range expansion, as it has been observed to have over the last 60 years in northern Australia.

Matthew H. Chan
University of Sydney
M.Chan@maths.usyd.edu.au

Gregory Brown, Richard Shine
School of Biological Sciences, University of Sydney
gregory.brown@sydney.edu.au, rick.shine@sydney.edu.au

Peter S. Kim
University of Sydney
School of Mathematics and Statistics
pkim@maths.usyd.edu.au

PP1

Using Tangles to Quantify Topological Mixing of Fluids

Topological entropy (TE), a measure of topological mixing, can be studied by the braiding of ghost rods. We study the system of Grover et al. [Chaos 22,043135 (2012)] using a heteroclinic tangle. In this approach, we explain TE through intersecting stable and unstable manifolds using homotopic lobe dynamics (HLD). The HLD method uses ghost rods placed on heteroclinic orbits, which allows us to compute TE in excess of that given by simple periodic braiding.

Qianting Chen
University of California, Merced
qchen2@ucmerced.edu

Sulimon Sattari
University of California, Merced
School of Natural Sciences
ssattari2@ucmerced.edu

Kevin A. Mitchell
University of California, Merced
Physics
kmitchell@ucmerced.edu

PP1

New Computational Tools for Non-Smooth Dynamical Systems

We will present development of new computational tools capable to comprehensively analyse the non-smooth dynamical systems. They will allow for high accuracy and speed brute force numerical simulation of dynamical systems having various types of discontinuities. On the same platform a powerful and convenient path-following module is being developed allowing for modelling and analysis of non-smooth systems efficiently. As an example, we will present the modelling and analysis of soft impact oscillators. The ultimate aim of the project is to take the state-of-art of computational tools available for non-smooth systems a step further.

Antonio S. Chong
Centre of Applied Dynamic Research, CADR
University of Aberdeen, Scotland, United Kingdom
a.chong@abdn.ac.uk

Marian Wiercigroch
Centre for Applied Dynamics Research, School of Engineering,
University of Aberdeen, AB24 3UE, Aberdeen, Scotland, UK.
m.wiercigroch@abdn.ac.uk

PP1

Modeling the Lymphocytic Choriomeningitis Virus: Insights into Understanding Its Epidemiology in the Wild

The lymphocytic choriomenigitis virus (LCMV) is a rodent-spread virus commonly recognized as causing neurological disease that exhibits asymptomatic pathology. We looked to construct an epidemiological model of a mouse population to better understand how this virus can remain endemic. We used an SIRC model that incorporated gender dynamics as to capture the primary aspects of the disease, and establish some initial findings under which the carriers remained stable.

Christy Contreras
Arizona State University
ccontr11@asu.edu

PP1

Causal Relationships Between Time Series: Generalizing Takens' Theorem to a Dynamical Network

We consider a set of scalar time series measured from a dynamical system evolving on an invariant manifold M. Takens' Theorem says that the state space reconstruction (SSR) for a time series is generically diffeomorphic to M. A non-generic SSR does not faithfully represent M. We prove that it generically represents the dynamics of a feedback system within the larger dynamical system. Time series SSRs are compared to recover potential causal relationships between feedback systems.

Bree Cummins
Department of Mathematics
Tulane University
breecummins@gmail.com

Tomas Gedeon
Montana State University
Dept of Mathematical Sciences
gedeon@math.montana.edu

Kelly Spendlove
Rutgers University
kelly.spendlove@gmail.com

PP1

Regular Acceleration from Low Initial Energies in a Magnetized Relativistic System

We consider a relativistic particle interacting with a uniform magnetic field and a stationary electrostatic wave. According to the parameters of the wave, triangular islands appear in the low energy region of phase space. In this scenario, a particle with initial energy close to its rest energy is accelerated and achieves a considerable final energy. We obtain analytically the parameter region for which the particle can be regularly accelerated from very low initial energies.

Meirielen C. De Sousa
Instituto de Fsica, Universidade de So Paulo, Brazil

meirielenso@gmail.com

Iber L. Caldas
Instituto de Fsica, Universidade de So Paulo
ibere@if.usp.br

Fernanda Steffens
Deutsches Elektronen-Synchrotron, Germany
fsteffens@uol.com.br

Renato Pakter, Felipe Rizzato
Instituto de Fsica, Universidade Federal Rio Grande do Sul
pakter@if.ufrgs.br, rizzato@if.ufrgs.br

PP1

Estimating the L^∞-Norm of Linear Solutions of Cahn-Hilliard

Using a simple toy model we approach the problem of L^∞-bounds on linear solutions of the strong subspace of Cahn-Hilliard solutions and relate it to its pattern development.

Philipp Düren
Universität Augsburg
philipp.dueren@math.uni-augsburg.de

PP1

Spike Adding in Transient Dynamics

Many mathematical models of neuron activity exhibit complex oscillations in response to stimulus from an applied current or from other neurons. We consider the effect of a single short stimulus on a neuron that is otherwise quiescent, focussing on the transient response induced by the stimulus. We use numerical continuation methods and exploit the presence of different time scales in the model to explain how the oscillatory pattern in the transient response depends on parameters.

Saeed Farjami
The University of Auckland
s.farjami@auckland.ac.nz

Hinke M. Osinga
University of Auckland
Department of Mathematics
H.M.Osinga@auckland.ac.nz

Vivien Kirk
University of Auckland
v.kirk@auckland.ac.nz

PP1

Front-Dynamics and Pattern Selection in the Wake of Triggered Instabilities

Pattern-forming fronts are often controlled by some external stimulus which progresses at fixed speed, rendering the medium unstable. Such "triggers" control dynamics in two generic ways corresponding to pushed and pulled fronts. The former is governed by oscillatory nonlinear interactions, leading to hysteresis and multi-stability. The latter is governed by absolute spectra and interacts monotonically. We use heteroclinic bifurcation and functional analytic techniques to study prototypical examples in the complex Ginzburg Landau and Cahn-Hilliard equations.

Ryan Goh, Arnd Scheel
University of Minnesota
gohxx037@math.umn.edu, scheel@umn.edu

PP1

Pattern Sequences as Early-warning Signs of Critical Transition in Models of Dryland Vegetation

Regular spatial patterns (resembling tiger stripes and leopard spots) occur in the vegetation of many dryland ecosystems, and are hypothesized to be a self-organized response to water scarcity. Numerous partial differential equation models of vegetation-water interactions based on this hypothesis have been proposed to investigate how patterned ecosystems may respond to increased water scarcity. As a precipitation parameter decreases in value, a sequence of patterns, gaps $\rightarrow$ labyrinths $\rightarrow$ spots, is observed in simulations of many of these models. Observations of this kind have led this sequence to be suggested as an early-warning sign of dryland vegetation collapse. In a previous bifurcation theoretic analysis, we analytically studied transitions between two pattern-forming instabilities to assess the generic robustness of the "gaps $\rightarrow$ labyrinths $\rightarrow$ spots' sequence. We found that alternative sequences of patterns are possible in this generic setting, and we conjectured that a calculable quantity signals the appearance of the standard pattern transition sequence in the models. Here, we test this conjecture in two widely studied vegetation models through weakly nonlinear analyses and numerical simulations. We find that our conjecture holds in these models for the space of parameter values considered. In addition, we find that a sequence involving only spot patterns occurs as a common alternative to the standard sequence.

Karna V. Gowda, Yuxin Chen
Northwestern University
karna.gowda@u.northwestern.edu,
yuxinchen2018@u.northwestern.edu

Sarah Iams
Northwestern University
Evanston, IL
smi6@cornell.edu

Mary Silber
Northwestern University
Dept. of Engineering Sciences and Applied Mathematics
m-silber@northwestern.edu

PP1

Rigorous Computation of Radially Symmetric Stationary Solutions of Pdes

We present a rigorous numerical method for proving the existence of radially symmetric solutions of stationary PDEs on the entire space. By combining numerical methods with functional analytic estimates, we show the existence of a solution by showing the existence of a fixed point of an equivalent fixed-point problem $T(x) = x$. We shall apply this method to a previously unsolved Ginzburg-Landau type equation.

Chris M. Groothedde
VU University Amsterdam

c.m.groothedde@vu.nl

PP1

Dynamics of Register Transitions in Human Vocal Fold Modeling

There are several theories as to the mechanism of register transitions in the human voice. The suddenness of the change under smooth variations of aerodynamic and biomechanical parameters suggests a bifurcation-like phenomenon with hysteresis. Often, the mechanics of the human vocal folds are modeled by a simple system of coupled oscillators. We show in theory and simulations what dynamical phenomena in these systems could generate such transitions.

Jesse Haas
GIPSA-Lab, Institut Polytechnique de Grenoble
jesse.haas@gipsa-lab.grenoble-inp.fr

PP1

A Mathematical Model of Saliva Secretion and Calcium Dynamics

Oscillations in free intracellular calcium (Ca^{2+}) concentration carry signals that control cellular processes such as neuronal firing and secretion. Experimental data show that oscillations of Ca^{2+} in certain salivary duct cells are coupled to oscillations in inositol trisphosphate (IP_3). I will describe a recently constructed model of Ca^{2+} dynamics in salivary duct cells that captures important dynamical features of the data and shows how the dynamics of IP_3 affects certain features of the calcium oscillations.

Jung Min Han, James Sneyd, Vivien Kirk
University of Auckland
jhan158@aucklanduni.ac.nz, v.kirk@auckland.ac.nz, sneyd@math.auckland.ac.nz

PP1

Mixed-Mode Oscillations and Twin Canards

We consider mixed-mode oscillations (MMOs), featuring a mix of small and large amplitudes, in dynamical systems with one fast and two slow variables. These oscillations are organised by canard orbits, which are intersection curves between attracting and repelling two-dimensional slow manifolds. We show how paired or twin canards with the same number of small oscillations arise in fold bifurcations of slow manifolds, and what this implies for the observed MMOs.

Ragheb Hasan
University of Auckland
cris.hasan@auckland.ac.nz

Hinke M. Osinga, Bernd Krauskopf
University of Auckland
Department of Mathematics
H.M.Osinga@auckland.ac.nz, b.krauskopf@auckland.ac.nz

PP1

A Dynamical Analysis of Steam Supply Network Based on Invariant Manifold

In this presentation, we analyze dynamics of heat supply in a simple steam supply system. The system consists of two steam boilers and a steam pipe which enables heat transfer between the two boilers. An invariant manifold representing steady operating condition of the system is located, and its existence and persistence are investigated. This clarifies the stability aspect of the steam supply system.

Hikaru Hoshino
Department of Electrical Engineering, Kyoto University
hoshino@dove.kuee.kyoto-u.ac.jp

Yoshihiko Susuki
Kyoto University / JST-CREST
susuki.yoshihiko.5c@kyoto-u.ac.jp

PP1

Defects in Spatially Extended Systems

We look at the effects of defects on pattern formation as a perturbation problem. We present a few examples of spatially extended pattern forming systems, and explain why regular perturbation theory fails due to critical continuous spectrum. We show how Kondratiev spaces can help alleviate this difficulty: the linearization at periodic patterns becomes a Fredholm operator, albeit with negative index. Together with far-field matching procedures, we obtain deformed stripe patterns or pacemakers using implicit function type continuation.

Gabriela Jaramillo
University of Minnesota
jara0025@math.umn.edu

Arnd Scheel
University of Minnesota
School of Mathematics
scheel@math.umn.edu

PP1

Delayed Feedback Model of Axonal Length Sensing

It has been proposed that an axon is able to gauge its own length based on the frequency of the oscillations of a molecular motor-based retrograde chemical signal. The frequency is inversely related to the length of the axon. We model the chemical oscillations using a system of delay differential equations and reproduce this relationship. We then investigate the behavior of these chemical signals as we model motor dynamics using stochastic partial differential equations.

Bhargav R. Karamched
University of Utah
Salt Lake City, UT
karamche@math.utah.edu

Paul C. Bressloff
University of Utah
Department of Mathematics
bressloff@math.utah.edu

PP1

Nonlinear Dynamical Systems in Finance

Dynamical system is very popular and important issue in todays World. It is important to understand systems in geology, mathematics, microbiology, biology, computer science, economics, engineering, finance, algorithmic trading, meteorology, philosophy, physics, politics, population dynamics, psychology, meteorology, robotics etc. Then with having clear understanding about system we can make better predictions. In poster, definition and usage areas of nonlinear dynamical system and chaos will be covered. Main aim is understanding the dynamical system in finance.

Deniz K. Kiliç
SIAM student membership,student at Middle East Technical Uni
versity,Institute of Applied Mathematics(member of SIAM)
deniz.kenan.kilic@gmail.com

PP1

Polyrhythmic Synchronization in Modular Networks

CPGs comprised of coupled interneuron circuits underlie wide ranges of natural rhythmic behaviors. Phase lag return maps describing polyrhythmic behavior in three-node reciprocally-inhibitory Fitzhugh-Nagumo type networks characterize regimes of robustness and stability similar to natural patterns. Further, we examine complex rhythm generation in modular network settings coupling two such networks. Transition from small local-networks to so-called network-of-networks permits within-circuit multiphase coordinated pattern storage that may underlie learning and memory of more complex motor rhythm patterns.

Jarod Collens
Georgia State University
Neuroscience Institute and Mathematics Department
jcollens1@student.gsu.edu

Justus T. Schwabedal
Neuroscience Institute
Georgia State University
jschwabedal@gmail.com

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

Drake Knapper
Georgia State University
dknapper1@student.gsu.edu

PP1

Discriminating Chaotic and Stochastic Dynamics Through the Permutation Spectrum Test

In this poster a new test for detecting determinism from time series data will be presented. The test involves looking for reoccurring patterns in time series data. The test will be described and the results of the test applied to several model systems and real-world data sets will be presented. The presentation will conclude with a discussion of future avenues of research related to the test.

Christopher W. Kulp
Dept. of Physics and Astronomy
kulp@lycoming.edu

Luciano Zunino
Centro de Investigaciones pticas (CONICET La Plata-CIC)
lucianoz@ciop.unlp.edu.ar ¡lucianoz@ciop.unlp.edu.

PP1

Coupling Methods As a Tool for Sensitivity Analysis of Stochastic Differential Equations

Under appropriate assumptions of Ergodicity, the expected value of observables for dynamical systems can be approximated by time averages. The introduction of stochastic forcing in the form of additive white noise can result in greatly increased varience of the observable estimates, making sensitivity analysis a delicate task. In this setting, coupling methods can be employed as a tool for varience reduction. The methods and their applications to Stochastic Differential Equations will be discussed.

Andrew Leach
University of Arizona
ableach@email.arizona.edu

PP1

Transient Dynamics in Ensemble of Inhibitory Coupled Rulkov Maps

We study numerically three Rulkov maps with mutual inertia inhibitory couplings. We study numerically different dynamical regimes that can be obtained in this ensemble by governing coupling parameters, in particular, sequential activity regime and multistable regime, and bifurcation transition from one regime to another.

Tatiana A. Levanova, Grigory Osipov
Lobachevsky State University of Nizhny Novgorod
levanova.tatiana@gmail.com, grosipov@gmail.com

PP1

Complex Collective Behavior in a Network of Theta Neurons is Suppressed by Synaptic Diversity

In the wake of a study that examined the collective dynamics of a large network of uniformly coupled Type 1 neurons, we explored how the patterns of macroscopic behavior change with respect to alterations in different neuron parameters of a model that includes realistic biological diversity through connection variability. Our analysis demonstrated that heterogeneity in coupling strength increases the robustness of equilibrium states and increasing synaptic diversity suppresses the emergence of the collective rhythmic state.

Lucas Lin
Thomas Jefferson High School for Science and Technology
lucas.lin177@gmail.com

Paul So
George Mason University
The Krasnow Institute
paso@gmu.edu

Ernest Barreto
George Mason University
Krasnow Institute
ebarreto@gmu.edu

PP1

Shape Coherence and Finite-Time Curvature Evo-

lution in Time-Dependent Dynamical Systems

We present finite-time curvature (FTC) as a local propensity of curvature elements to change. The FTC simplifies the recent study of shape coherence in nonautonomous dynamical systems. Trough (low) FTC curves indicate shape coherent sets. Finding slowly evolving boundary curvature describes slowly changing shapes in otherwise complex nonlinear flows, where stretching and folding may dominate. FTC troughs are often nearby the popular Finite-Time Lyapunov Exponent (FTLE) ridges, but often the FTC indicates entirely different regions.

Tian Ma
Department of Mathematics and Computer Science
Clarkson University
mat@clarkson.edu

Erik Bollt
Clarkson University
bolltem@clarkson.edu

PP1

Snaking on Networks: From Local Solutions to Turing Patterns

The emergence of patterns of activity on complex networks with reaction-diffusion dynamics on the nodes is studied. The transition is investigated between the single-node solutions, studied previously [Wolfrum, Physica D (2012)], and the fully developed global activation states (so called Turing states). Numerical continuation reveals snaking bifurcations connecting different solutions, similar to those found in reaction diffusion systems on regular lattice network topologies, shedding light on the origin of the multistable "Turing' patterns reported previously [Nakao & Mikhailov, Nature 2010].

Nick McCullen
Architecture and Civil Engineering
University of Bath
N.J.McCullen@bath.ac.uk

Matthias Wolfrum
Weierstrass Institute for Applied Analysis and Stochastics
wolfrum@wias-berlin.de

Thomas Wagenknecht
University of Leeds
deceased

PP1

Fractal Boundaries in the Parameters Space of Deterministic Dynamical Systems

Nonlinear dynamical systems may exhibit sensitivity to small perturbations in their control parameters. Such sensitivity is source of uncertainties on the predictability of tunning parameters that lead these systems to either a chaotic or a periodic behavior. In this work, by quantifying such uncertainties in different classes of nonlinear systems, we obtain the exterior dimension of parameters sets that lead the system to chaotic or to periodic behavior. we show that this dimension is fractal, explaining the sensitivity observed in tunning the parameter to those two behaviors. Moreover, we show that this dimension is roughly the same for the classes of investigated systems.

Everton S. Medeiros
Physics Institute - University of So Paulo
eucaotico@gmail.com

Iber L. Caldas
Instituto de Fsica, Universidade de So Paulo
ibere@if.usp.br

Murilo Baptista
University of Aberdeen
murilo.baptista@abdn.ac.uk

PP1

A Biophysical Model for the Role of Network Topology in Regulating a Two-Phase Breathing Rhythm

Respiration occurs in a two-phase pattern, with alternating inspiration and expiration. This arises from alternating activity among groups of neurons in the pre-Btzinger and Btzinger areas in the brainstem. However, much about the network mechanisms that produce this activity remains unknown. Using a biophysical computational model to explore different topological structures and their ability to generate a two-phase rhythm, we show how modular vs. random structure of the inhibitory connections affect global dynamics.

Joshua Mendoza
Department of Applied Mathematics, University of Washington
Lewis Hall #202, Box 353925, Seattle, WA 98195-3925
USA
joshmend@uw.edu

Kameron Decker Harris
Department of Applied Mathematics, University of Washington
kamdh@uw.edu

Eric Shea-Brown
University of Washington
Department of Applied Mathematics
etsb@uw.edu

Jan Ramirez
Center for Integrative Brain Research, Seattle Childrens
nino.ramirez@seattlechildrens.org

Tatiana Dashevskiy
Center for Integrative Brain Research
Seattle Children's Research Institute
tatiana.malashchenko@seattlechildrens.org

PP1

Modeling Effects of Drugs of Abuse on Hiv-Specific Antibody Responses

Drugs of abuse enhance HIV replication and diminish host immune responses. Here, we present a dynamical system model that helps quantify the effects of drugs of abuse on altering HIV-specific antibody responses. Our model is consistent with the experimental data from simian immunodeficiency virus infection of morphine-addicted macaques. Using our model, we show how altered antibody responses due to drugs of abuse affect steady state viral load and CD4 count in HIV-infected drug abusers.

Jones M. Mutua

University of Missouri - Kansas City (UMKC)
jmm7w6@mail.umkc.edu

Anil Kumar
University of Missouri - Kansas City
kumaran@umkc.edu

Naveen K. Vaidya
Dept of Maths & Stats, University of Missouri - Kansas City
Kansas City, Missouri, USA
vaidyan@umkc.edu

PP1

Time-Delayed Model of Immune Response in Plants

When studying the dynamics of plant infections, it is essential to correctly account for detailed mechanisms of plant immune response. We have developed and analysed a new mathematical model of plant immune response that takes post-transcriptional gene silencing into account. We have performed analytical and numerical bifurcation analysis to investigate how stability of the steady states depends on time delays, and also to illustrate different dynamical regimes that can be exhibited by the model.

Giannis Neofytou, Konstantin Blyuss
University of Sussex
G.Neofytou@sussex.ac.uk, k.blyuss@sussex.ac.uk

PP1

Analysis and Control of Pre-Extinction Dynamics in Stochastic Populations

We consider a stochastic population model where the intrinsic noise causes random switching between metastable states before the population goes extinct. Switching and extinction times are found using a master equation approach and a WKB approximation. In addition, a probabilistic argument is used to understand the pre-extinction cycling dynamics. We also implement a control method to decrease the mean time to extinction. Analytical results agree well with numerical Monte Carlo simulations.

Garrett Nieddu
Montclair State University
nieddug1@mail.montclair.edu

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

Eric Forgoston
Montclair State University
Department of Mathematical Sciences
eric.forgoston@montclair.edu

PP1

An Explicit Formula for R_0 of Tick-Borne Relapsing Fever

Tick Borne Relapsing Fever (TBRF) is a disease spread among mammals by soft bodied ticks in the Western United States which is characterized by (possibly multiple) relapsing states of fever and muscle aches. There is a natural question regarding how the number of relapse states affects the spread. In this poster we will use analytical methods to derive an expression for TBRF's fundamental reproductive number R_0 as a function of the number of relapses.

Cody Palmer
University of Montana
cody.palmer@umontana.edu

PP1

Title Not Available

Our work builds on Kurebayashi et al. (2013), where they derive a general phase equation for an autonomous system with a slowly varying parameter. We reproduce their result using the Fredholm alternative, and extend it to weakly coupled oscillators by deriving an equation for the interaction function with a slowly varying parameter. We test our theory with a lambda-omega system and a Traub+adaptation model using stochastic, periodic, and quasi-periodic slow parameters.

Youngmin Park
University of Pittsburgh
yop6@pitt.edu

PP1

Stochastic Motion of Bumps in Planar Neural Fields

We analyze the effects of spatiotemporal noise on stationary pulse solutions (bumps) in neural field equations on planar domains. Fluctuations in neural activity are modeled as a Langevin equation. Noise causes bumps to wander diffusively. We derive effective equations describing the bump dynamics as Brownian motion in two-dimensions. We also consider weak external inputs that can pin the bump so that it obeys an Ornstein-Uhlenbeck process with coefficients determined by input shape.

Daniel Poll
University of Houston
Department of Mathematics
dbpoll@math.uh.edu

Zachary Kilpatrick
University of Houston
zpkilpat@math.uh.edu

PP1

Automatically Proving Periodic Solutions to Polynomial ODEs

Rigorously proving the existence of a solution to ODEs in a neighborhood of a given numerical approximation is of primary importance in order to determine the accuracy of the numerical approximation. One approach is to use a functional analytic setting that is well suited to continuation techniques. We discuss an implementation for periodic solutions to general systems of polynomial ODEs. We present several examples that serve as test problems for the automated algorithm.

Elena Queirolo
Vrije Universiteit Amsterdam

e.queirolo@vu.nl

PP1

Repulsive Inhibition Promotes Synchrony in Excitatory Networks of Bursting Neurons

We show that the addition of pairwise repulsive inhibition to excitatory networks of bursting neurons induces synchrony, in contrast to one's expectations. Through stability analysis, we reveal the mechanism underlying this purely synergetic phenomenon and demonstrate that it originates from the transition between bursting of different types, caused by excitatory-inhibitory synaptic coupling. We also reveal a synergetic interplay of repulsive inhibition and electrical coupling in synchronization of bursting networks.

Reimbay Reimbayev, Igor Belykh
Department of Mathematics and Statistics
Georgia State University
reimbayev2@student.gsu.edu, ibelykh@gsu.edu

PP1

Quasipatterns in Two and Three Dimensions

Quasipatterns (patterns with no translation symmetry but with rotation symmetry on average) can occur in a variety of systems, including Faraday waves, nonlinear optics, polymer micelles and coupled reaction-diffusion systems. This poster will explore how having two interacting wavelengths in the physical system can stabilise quasipatterns in two and three dimensions, or can lead to spatio-temporal chaos.

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

PP1

Computing Chaotic Transport Properties in a Mixed Phase Space with Periodic Orbits

Chaotic transport can be quantified using periodic orbits, but difficulties arise in a mixed Hamiltonian phase space. Homotopic Lobe Dynamics uses topological forcing by intersections of stable and unstable manifolds of anchor orbits to find periodic orbits in such a space. We compute decay rates for the Hénon map in a variety of parameter regimes. In a hyperbolic plateau, periodic orbit continuation is used to accurately compute the decay rate for the entire interval.

Sulimon Sattari
University of California, Merced
School of Natural Sciences
ssattari2@ucmerced.edu

Kevin A. Mitchell
University of California, Merced
Physics
kmitchell@ucmerced.edu

PP1

Rigorous Computations for BVPs with Chebyshev-series

The main goal of my research is to bridge the gap between non-rigorous numerical simulation of dynamical systems and mathematically sound results. Recently, a rigorous numerical procedure based on Chebyshev-series (a non-periodic analog of Fourier series) was developed to solve ODEs and BVPs. My research is concerned with extending this method by incorporating domain decomposition. Applications include rigorous computations of connecting and periodic orbits in the Lorenz-system.

Ray Sheombarsing
VU University Amsterdam
R.S.S.Sheombarsing@vu.nl

PP1

Central Configurations of Symmetrically Restricted Five-Body Problem

We study the central configuration of a highly symmetric five-body problem where four of the masses are placed at the vertices of the isosceles trapezoid and the fifth body can take various positions on the axis of symmetry. We identify regions in the phase space where it is possible to choose positive masses which will make the configuration central. We propose a global regularization scheme which removes singularities associated with single-binary collisions. Finally we numerically show existence of quasi-periodic orbits in the central configuration regions.

Anoop Sivasankaran
Khalifa University of Science Technology and Research
Department of Applied Mathematics and Science
anooppgd@gmail.com

Muhammad Shoaib
University of Hail, Department of Mathematics
Saudi Arabia
safridi@gmail.com

Abdulrehman Kashif
University of Hail, Department of Mathematics
kashmology@gmail.com

PP1

Finite Time Diagnostics and Transport Barriers in Non Twist Systems

Internal transport barriers that appear in Hamiltonian dynamical systems have been proposed as an explanation for the cessation or reduction of transport in physical systems at describe fluids and plasmas. These barriers may have various physical or dynamical origins, yet they can and have been used to control experiments and sometimes to improve desired confinement of trajectories. We use the so-called standard nontwist map, a paradigmatic example of non twist systems, to analyze the parameter dependence of the transport through a broken barrier. On varying a proper control parameter, we identify the onset of structures with high stickiness that give rise to an effective barriers. We use the finite-time rotation number to identify transport barriers that separate different regions of stickiness. The identified barriers are comparable to those obtained by using finite-time Lyapunov exponents.

Jose D. Szezech Jr
University State of Ponta Grossa
jdanilo@gmail.com

Ibere L. Caldas
Institute of Physics

University of Sao Paulo
ibere@if.usp.br

Sergio R. Lopes
Department of Physics
Federal University of Parana
lopes@fisica.ufpr.br

Ricardo L. Viana
Departmento de Fisica
Federal University of Parana
viana@fisica.ufpr.br

Philip Morrison
Physics Department
University of Texas at Austin
morrison@physics.utexas.edu

PP1

Robust Pulse Generators in An Excitable Medium

We study a spontaneous pulse-generating mechanism in an excitable medium with jump-type heterogeneity. We investigate the conditions for the onset of robust-type pulse generators, and then we show the global bifurcation structure of heterogeneity-induced patterns, including the homoclinic orbits that are homoclinic to a special type of heterogeneity-induced ordered pattern. These numerical approaches assist us in identifying a candidate for the organizing center as a codimension-two gluing bifurcation.

Takashi Teramoto
Asahikawa Medical University
teraponn@mac.com

PP1

Dynamical Building Blocks in Turbulent Two-Dimensional Channel Flow

Although the classical sweep-ejection cycles cannot be self-sustaining itself, two-dimensional channel flows keep them regenerating for a quite long time. The relation between localized coherent structures and their collective dynamics is investigated numerically focusing on a turbulent-laminar interface. The existence of interfaces reduces the complexity of the collective dynamics arising around them. We use the damping filter technique to simulate a laminar-turbulent interface in a periodic box.

Toshiki Teramura
Department of Physics and Astronomy,
Graduate School of Science, Kyoto University, Japan
teramura@kyoryu.scphys.kyoto-u.ac.jp

Sadayoshi Toh
Graduate School of Science, Kyoto University, Japan
toh@kyoryu.scphys.kyoto-u.ac.jp

PP1

Phase Models and Oscillators with Time Delayed All-to-All Coupling

We consider a system modeling a network of globally delayed coupled identical oscillators. Assuming weak coupling, we reduce the system to a phase model where the delay acts as a phase shift. We show how the delay affects the stability of different symmetric cluster states, and applied the results to a network of six globally coupled Morris-Lecar oscillators with synaptic coupling. Furthermore, we compare the phase model results to bifurcation studies of the full model.

Zhen Wang
University of Waterloo
z377wang@uwaterloo.ca

PP1

Efficient Design of Navigable Networks

Navigation is a dynamic process where individual agents try to reach targets given limited knowledge. In a network of agents, we term a successive gradient-like navigation path to the target as a greedy path, and show that (interestingly) it violates many known properties of usual network paths such as symmetry and transitivity even for undirected networks. Despite these complications, we are able to design an efficient scheme that allows every network to be navigable.

B.M. Shandeepa D. Wickramasinghe
Clarkson University, 8 Clarkson avenue, Potsdam,Ny
wickrabs@clarkson.edu

Jie Sun
Clarkson University
sunj@clarkson.edu

PP1

Instability of Certain Equilibrium Solutions of the Euler Fluid Equations

We look at the stability of the family of stationary solutions $\cos(mx + ny)$ of the Euler Equations on a toroidal domain. We use a Poisson structure preserving truncation described by Zeitlin [1991] to turn the problem into a finite-mode system, and a splitting into subsystems described by Li [2000]. We show that for many m and n these stationary solutions are unstable.

Joachim Worthington
University of Sydney, Australia
joachimworthington@gmail.com

Holger R. Dullin
University of Sydney
School of Mathematics and Statistics
hdullin@usyd.edu.au

Robby Marangell
University of Sydney
r.marangell@maths.usyd.edu.au

PP1

A Symbolic Method in Chua's Circuit

A symbolic method is introduced in a three-dimensional Chua's circuit with a smooth cubic nonlinearity. The new method is able to reveal thousands of homoclinic bifurcation curves in a bi-parametric plane with a small amount of computational cost. Co-dimension two points, t-points and close homoclinc curves are detected as well. Based on the bi-parametric plots of the Chua's circuit, chaotic structure

of the Chua's circuit is studied.

Tingli Xing
Georgia State University
USA
txing1@student.gsu.edu

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

PP1

Interactions of Solitary Modes in Models of Bacterial Chemotaxis

We study the interaction of two colliding bacterial populations in a one-dimensional nutrient gradient. The outcome of such collisions varies. For example, upon collision, two populations of *E. coli* will either mix together to become one indistinguishable population or deflect off and move away from one another. We use a Keller-Segel model of bacterial chemotaxis to determine mechanisms by which each observed outcome may occur and make experimental predictions about the behavior following a collision.

Glenn S. Young
University of Pittsburgh
Department of Mathematics
gsy2@pitt.edu

Hanna Salman
University of Pittsburgh
Department of Physics and Astronomy
hsalman@pitt.edu

Bard Ermentrout
University of Pittsburgh
Department of Mathematics
bard@pitt.edu

Jonathan Rubin
University of Pittsburgh
Pittsburgh, PA
jonrubin@pitt.edu

PP1

The Spread of Activity with Refractory Periods over Directed Networks

We study propagation of activity in a discrete time dynamical system on several directed network topologies. At each time step, active nodes send the signal onward through their outgoing connections, and fall into a refractory period. In particular, we investigate the number and length of attractors (node sequences that can sustain activity indefinitely) and transients on networks of varying topologies including random, small-world, scale-free.

Daniel R. Zavitz
University of Utah
Department of Mathematics
zavitz@math.utah.edu

Alla Borisyuk
University of Utah
Dept of Mathematics
borisyuk@math.utah.edu

PP2

Intermittent Synchronization/desynchronization in Population Dynamics

Synchronous dynamics of spatially distinct oscillating populations is a well-known phenomenon in ecology. Mathematical modeling of this phenomenon has been largely focused on the synchronization conditions and the properties of synchronized dynamics. Yet the synchrony in the real populations is not necessary strong and therefore exhibit intervals of uncorrelated, desynchronized dynamics. We explore the properties of these time-intervals and discuss potential advantages and disadvantages of short numerous desynchronization intervals vs. few long desynchronization intervals.

Sungwoo Ahn
Indiana University Purdue University Indianapolis
sungwoo.ahn@asu.edu

Leonid Rubchinsky
Department of Mathematical Sciences
Indiana University Purdue University Indianapolis
leo@math.iupui.edu

PP2

Parabolic Bursting in Inhibitory Neural Circuits

We study the rhythmogenesis of network bursting emerging in inhibitory motifs comprised of tonic spiking interneurons described by an adopted Plant model.Such motifs are the building blocks in larger neural networks, including the central pattern generator controlling swim locomotion of sea slug Melibe leonine.

Deniz Alacam
Georgia State University
Mathematics Department
dalacam1@student.gsu.edu

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

PP2

An Accurate Computation of the Tangent Map for Computation of Lagrangian Coherent Structures

The tangent map (flow map gradient) is often used in dynamical systems for computation of Lagrangian coherent structures. In more sophisticated methods it is important to recover the complete spectrum of this operator, as well as the eigenvectors. Traditional methods to compute the tangent map using finite differencing often fail in accurately computing these quantities. Due to nonlinear effects of the flow, perturbations of trajectories mapped forward by the tangent map may grow excessively and they collapse on the dominant eigenvector of the map. We describe alternative techniques to overcome these issues. Both continuous or discrete singular value decompositions with efficient implementations are used to automatically carry out computation of finite time Lyapunov exponents and directions. Results on sum of Lyapunov exponents for divergent free flow, as well as sensitivity to integration time are compared

in contrast to previous methods.

Siavash Ameli, Shawn Shadden
University of California, Berkeley
sameli@berkeley.edu, shadden@berkeley.edu

PP2

Nonlinear Dynamics in Coupled Semiconductor Laser Network Implementations

Coupled semiconductor lasers subject to optical injection and/or feedback are known to exhibit complex dynamics in their emitted output. Current implementations usually employ only a few lasers in order to map the regimes of the exhibited dynamics. In the present work, a large-scale network of coupled semiconductor lasers is built experimentally, including up to 24 laser devices. Rich dynamics are recorded, depending on the conditions of coupling strength and time delays among the laser nodes.

Apostolos Argyris, Michail Bourmpos, Alexandros Fragkos, Dimitris Syvridis
Department of Informatics and Telecommunications
National & Kapodistrian University Of Athens
argiris@di.uoa.gr, mmpour@di.uoa.gr, alx_f@di.uoa.gr, dsyvridi@di.uoa.gr

PP2

Symplectic Maps with Reversed Current in a Tokamaks

Plasmas are confined in tokamaks by magnetic field lines. We derive a bidimensional conservative map which describes these lines considering a non-monotonic profile of safety factor with reversed current density, first in equilibrium [C. Martins et al., Analytical solutions for Tokamak equilibria with reversed toroidal current, PoP 18(2011)], and then we will apply a perturbation (ergodic magnetic limiter). We will investigate island chains, chaos and particle transport.

Bruno Bartoloni
University of Sao Paulo
Institute of Physics
bartolonis@yahoo.com.br

Ibere L. Caldas
Institute of Physics
University of Sao Paulo
ibere@if.usp.br

PP2

Analysis of Spatiotemporal Dynamical Systems from Multi-Attribute Satellite Images

We deduce and then analyze oceanic fluid systems by remote sensing from satellite images. Time varying vector fields are computed from the nonautonomous system by temporal intensity changes of observed product movements. To emphasize prior assumed physics, an objective function and consequent calculus of variations follows. As an important initial task, we show how to remove sensor-data biased of stripes from images by developing a new approach in terms of a nonisotropic total variation denoising.

Ranil Basnayake, Erik Bollt
Clarkson University
basnayrk@clarkson.edu, bolltem@clarkson.edu

Nicholas Tufillaro
Oregon State University
nbt.osu@gmail.com

Jie Sun
Clarkson University
sunj@clarkson.edu

PP2

Phase Response Analysis of the Circadian Clock in Neurospora Crassa

Circadian rhythm is crucial in maintaining an organism's daily routine. We present a model which accurately simulates the molecular components governing the circadian clock of the model organism, *Neurospora crassa*. Environmental cues such as light perturb the phase of the circadian oscillator, a phenomenon generally measured with a phase response curve (PRC). Our model advocates that Neurospora's phase response to light is primarily regulated by the degradation of the clock protein White Collar-1 (WC-1).

Jacob Bellman
University of Cincinnati
bellmajb@mail.uc.edu

PP2

Time Series Based Prediction of Extreme Events in High-Dimensional Excitable Systems

We investigate extreme events in a high-dimensional deterministic system: a network of FitzHugh-Nagumo units. We present a data-driven approach to predict extreme events which is only based on the time series of some observables and on the coupling topology of the network. By iterative predictions, we are able to forecast the onset of an extreme event as well as the propagation and extinction of excitation, i.e. the full life-cycle of an extreme event.

Stephan Bialonski
Max-Planck-Institute for the Physics of Complex Systems
bialonsk@pks.mpg.de

Gerrit Ansmann
Department of Epileptology
University of Bonn, Germany
gansmann@uni-bonn.de

Holger Kantz
Max-Planck-Institute for the Physics of Complex Systems
kantz@pks.mpg.de

PP2

Slow-fast Analysis of Earthquake Faulting

We consider a rate and state dependent friction law to study earthquake fault dynamics. We show that the system has an embedded slow-fast structure. Using techniques from geometric singular perturbation theory and centre manifold theory we perform an analytical investigation of the problem.

Elena Bossolini
Ph.D. student
DTU Compute, Institute for Mathematics and Computer Science
ebos@dtu.dk

Kristian Uldall Kristiansen, Morten Brøns
Technical University of Denmark
Department of Applied Mathematics and Computer Science
krkri@dtu.dk, mobr@dtu.dk

PP2

Quasicycles in the Stochastic Hybrid Morris-Lecar Neural Model

Intrinsic noise from the stochastic nature of voltage-gated ion channels affects a neuron's ability to produce subthreshold oscillations and respond to weak periodic stimuli. While it is known that stochastic models can produce oscillations in regimes where the deterministic model has only a stable fixed point, little work has explored these connections to channel noise. Using a stochastic hybrid Morris-Lecar model, we use various approximation schemes to derive a stochastic differential equation, then derive the power spectrum and quantify how oscillations are affected by channel noise.

Heather A. Brooks
University of Utah
heather@math.utah.edu

Paul C. Bressloff
University of Utah
Department of Mathematics
bressloff@math.utah.edu

PP2

Computation of Normally Hyperbolic Invariant Manifolds

In this poster we explain a method for the computation of normally hyperbolic invariant manifolds (NHIM) in discrete dynamical systems. The method is based in finding a parameterization for the manifold formulating a functional equation. We solve the invariance equation using a Newton-like method taking advantage of the dynamics and the geometry of the invariant manifold and its invariant bundles. Particularly, we present two different kind of methods to compute normally hyperbolic invariant tori, NHIT. The first method is based on a KAM-like theorem in a-posteriori format for the existence of quasi-periodic invariant tori, which provides us an efficient algorithm for computing NHIT, by adjusting parameters of the family. The second method allows us to compute a NHIT and its internal dynamics, which is a-priori unknown. We implement both methods to continue the invariant tori with respect to parameters, and to explore different mechanisms of breakdown.

Marta Canadell
Universitat de Barcelona
marta.canadell.cano@gmail.com

Alex Haro
Dept. of Mat. Apl. i Analisi
Univ. de Barcelona
alex@maia.ub.es

PP2

Equivalent Probability Density Moments Determine Equivalent Epidemics in An Sirs Model with Temporary Immunity

In an SIRS compartment model for a disease we consider the effect of different probability distributions for remaining immune. We show that to first approximation the first three moments of the corresponding probability densities are sufficient to well describe oscillatory solutions corresponding to recurrent epidemics. We consider six different distributions and show that by tuning their parameters such that they have equivalent moments that they all exhibit equivalent dynamical behavior.

Thomas W. Carr
Southern Methodist University
Department of Mathematics
tcarr@smu.edu

PP2

A Novel Speech-Based Diagnostic Test for Parkinsons Disease Integrating Machine Learning with Web and Mobile Application Development for Cloud Deployment

Parkinson's disease remains one of the most poorly diagnosed neurological conditions despite the critical need of early diagnosis for effective management and treatment. This work presents a new method of diagnosing Parkinson's disease and accompanying scalable web and mobile applications towards the goal of employing this diagnostic test to the cloud. This method provides a more simple, inexpensive, and rapid approach than traditional diagnosis strategies by requiring the patient to only speak into a microphone attached to their computer or mobile device before providing a diagnosis within seconds. This work employs speech processing algorithms, an artificial neural network for machine learning, and an application framework with a user-friendly interface that packages the speech test and diagnosis results for easy access by patients and physicians. The diagnosis test developed was tested with actual patient data and was shown to be highly accurate.

Pooja Chandrashekar
Thomas Jefferson High School for Science and Technology
2015pchandr2@tjhsst.edu

PP2

An Agent-Based Model for mRNA Localization in Frog Oocytes

During early development of Xenopus laevis oocytes, mRNA moves from the nucleus to the periphery. We use an agent-based model to study the movement of mRNA by molecular motor transport and diffusion. Our results suggest that an anchoring mechanism is required to achieve the observed localization of mRNA: simulations indicate that anchoring of a particular motor-mRNA complex may be sufficient for relocation and that binding between different molecular motors may contribute to transport.

Veronica M. Ciocanel
Brown University
Brown University
veronica_ciocanel@brown.edu

Bjorn Sandstede
Division of Applied Mathematics
Brown University

bjorn_sandstede@brown.edu

PP2

Effects of Stochastic Gap-Junctional Coupling in Cardiac Cells and Tissue

Action potentials propagate in cardiac tissue in part through gap junctions. Gap-junction gating dynamics are functions of both gap-junctional voltage and time and also are stochastic in nature. We derive a system of stochastic differential equations to model these gating dynamics within the context of the Luo-Rudy-1 description of ionic currents. We perform simulations on a 1D cable and show the effects of stochastic gating on action potential propagation. Results on conduction block, action potential propagation speed and gap junctional resistance will be presented.

William Consagra
Rochester Institute of Technology
School of Mathematical Sciences
wxc5756@rit.edu

PP2

Maximizing Plant Fitness Under Herbivore Attack

When attacked by insect herbivores, plants emit volatile chemicals. These chemicals are known to induce local defenses, prime neighboring plants for defense, and attract predators and parasitoids to combat the herbivores, but these chemical defenses are coupled with fitness costs. We examine the interactions between the model plant, goldenrod, and one of its insect herbivores, Trirhabda virgata, in order to draw conclusions about what defense strategies will maximize a goldenrods fitness.

Karen M. Cumings, Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
cumink@rpi.edu, kramep@rpi.edu

Bradford C. Lister
Rensselaer Polytechnic Institute
Department of Biological Sciences
listeb@rpi.edu

PP2

The Derivation of Mass Action Laws: Issues and Questions

There are well-trodden paths that enable one to pass from stochastic individual-based models to deterministic population-level models. I will point out a few issues that arise along the way: these make the journey slightly more involved and interesting than one might expect.

Jonathan Dawes
University of Bath
J.H.P.Dawes@bath.ac.uk

Max O. Souza
Departamento de Matemática Aplicada
Universidade Federal Fluminense
msouza@mat.uff.br

PP2

Heterogeneity and Oscillations in Small Predator-Prey Swarms

Real-world predator-prey interactions often involve a predator chasing a flock of prey. We examined a dynamical systems model of predator-prey interactions, governed by isometric interaction kernels incorporating classical swarming for the prey. Since many parameter values lead to the predator splitting the swarm into smaller, unevenly-sized groups, we investigate the effects of heterogeneity among predator-prey interactions in small swarms. We show that a variety of behaviors, including oscillations, are possible in the small swarm case.

Jeff Dunworth
University of Pittsburgh
jbd20@pitt.edu

Bard Ermentrout
University of Pittsburgh
Department of Mathematics
bard@pitt.edu

PP2

Bacterial Disinfection with the Presence of Persisters

Many important diseases like Tuberculosis are caused by biofilms.Among the bacteria within a biofilm, persisters are a subpopulation which are tolerant to antibiotics and knowing more about them is very critical and helpful. In this poster we will look at the behavior of the bacteria with three phases: Susceptible, Stationary and Persisters, and we will show that considering the third phase gives us more accurate results comparing to the previous studies with just Susceptible and Persisters and this new model matches the experimental results better.

Sepideh Ebadi
Florida State University
s.ebaadi@gmail.com

PP2

Chaotic Mixing in a Curved Channel with Slip Surfaces

In this work, we show that laminar flow in a planar curved channel can generate chaotic trajectories, if the top and bottom walls are alternately patterned with slip surfaces. Existing micro-mixers based on flow through curved sections, have either complex 3D geometries, or are effective only at relatively high Reynolds numbers [Stremler, Phil. Trans. A., 362, 10191036]. Using slip surfaces, we overcome both these limitations, while simultaneously reducing viscous drag on the fluid.

Piyush Garg
Department of Chemical Engineering
Indian Institute of Technology Roorkee
piyush10astro@gmail.com

Jason R. Picardo, Subramaniam Pushpavanam
Department of Chemical Engineering
Indian Institute of Technology Madras

picardo21@gmail.com, spush@iitm.ac.in

PP2

Feasibility of Binding Heteroclinic Networks

Many neuronal systems exhibit multi-sensory dynamics. Multisensory integration is a process by which information from different sensory systems is combined to influence perception, decisions, and overt behavior. In this context, the different sensory systems, such as sight, sound, smell, taste and so on, are called sensory modalities. In each modality, there are cognitive modes which are large collections of neurons firing at the same time in synchrony in a functional network. In order to explain the sequential mental processes in the brain, we study a heteroclinic binding model where active brain modes form different modalities which are processed in parallel. Under certain assumptions, the existence of the so-called multimodality heteroclinic network was established. we prove that for each collection of successive heteroclinic orbits inside the network, there is an open set of initial points such that the trajectory going through each of them follows the prescribed collection of successive heteroclinic orbits and stays in a small neighborhood of it. We also show that the symbolic complexity function of the system restricted to this neighborhood is a polynomial of degree $L-1$ where L is the number of modalities.

Xue Gong
Ohio University
xg345709@ohio.edu

Valentin Afraimovich
Universidad Autónoma de San Luis Potos
S.L.P., México
valentin.afraimovich@gmail.com

PP2

Dynamic Square Patterns in 2D Neural Fields

We present analysis and simulation of periodic solutions near $D_4 x T^2$ symmetric Hopf bifurcations in two different neural field models. The first model consists of a scalar integral equation that incorporates finite transmission speed through spatiotemporal delays. The second model incorporates finite transmission speed using a telegraph equation (ie. a hyperbolic PDE), but also includes local ion channel dynamics and 2 interacting populations of neurons.

Kevin R. Green, Lennaert van Veen
UOIT
kevin.green@uoit.ca, lennaert.vanveen@uoit.ca

PP2

Controllability of Brain Networks

Cognitive function is driven by dynamic interactions between large-scale neural networks, enabling behavior. We use control theory to offer a mechanistic explanation for how the brain moves among cognitive states. Our results suggest that densely connected areas facilitate the movement of the brain to easily-reachable states. Weakly connected areas facilitate the movement of the brain to difficult-to-reach states. Areas located on the boundary between network communities facilitate the integration or segregation of diverse cognitive systems.

Shi Gu
Complex Systems Group
University of Pennsylvania
gus@sas.upenn.edu

Fabio Pasqualetti
Department of Mechanical Engineering
University of California, Riverside, CA
fabiopas@engr.ucr.edu

Matthew Ceislak, Scott Grafton
Department of Psychological and Brain Sciences
University of California, Santa Barbara, CA
mattcieslak@gmail.com, scott.grafton@psych.ucsb.edu

Danielle S. Bassett
Department of Electrical & Systems Engineering,
University of Pennsylvania, Philadelphia, PA
dsb@seas.upenn.edu

PP2

Compressive Sensing with Exactly Solvable Chaos

Recent advances in sampling theory allow the reconstruction of signals sampled at sub-Nyquist rates. Compressive sensing operates under the premise that signal acquisition and data compression can be carried out simultaneously. Building on recent work in chaotic communications, a compressive negative Beta encoder/decoder is presented that represents data in an irrational radix. Using an exact chaotic oscillator and pulsed linear filter, a complete A/D and D/A architecture based on chaotic dynamics can be built in hardware.

Sidni Hale, Anthony DiPofi, Bradley Kimbrell
Radix Phi
sidni@radixphi.com, anthony@radixphi.com, bradley@radixphi.com

PP2

Identifying the Role of Store-Operated Calcium Channels in Astrocytes Via An Open-Cell Model

Astrocytes are the most common glial cells in the brain, communicating via calcium transients, and possibly modulating neuronal signals. However, these calcium dynamics differ between in vivo and in vitro. We suggest a new open-cell mathematical model that allows us to vary parameters such as cell volume and flux through calcium channels not easily accessible by experimentalists. Our results support the idea that store-operated calcium channels play a key role, and suggest realistic, follow-up experiments.

Gregory A. Handy
University of Utah Mathematics Department
handy@math.utah.edu

Alla Borisyuk
University of Utah
Dept of Mathematics
borisyuk@math.utah.edu

Marsa Taheri
University of Utah
Department of Bioengineering
marsa.taheri@utah.edu

John White
department of Bioengineering

The University of Utha
john.white@utah.edu

PP2

Behavioral Dynamics and STD Transmission

Many mathematical models of infectious disease transmission represent contact patterns using fixed rate parameters. However, individual contact and protective behaviors are likely to respond elastically to disease outbreaks. We use the replicator-mutator equations from evolutionary game theory to couple the dynamics of protective sexual behavior to a simple SIS compartmental model. Our combined model demonstrates a shift in effective contact reduction behavior over the course of the outbreak, driven by the behavioral-disease interaction dynamics.

Michael A. Hayashi
University of Michigan School of Public Health
mhayash@umich.edu

Marisa Eisenberg
University of Michigan
marisae@umich.edu

PP2

Master Stability Functions for the Fixed Point Solution of Synchronized Identical Systems with Linear Delay-Coupling and a Single Constant Delay

This poster presents master stability functions for the fixed point solution of any network of synchronized identical systems with linear delay-coupling and a single constant delay. The connection between these master stability functions and amplitude death islands is also provided using numerical simulations of small oscillator networks with identical chaotic node dynamics.

Stanley R. Huddy, Jie Sun
Clarkson University
huddysr@clarkson.edu, sunj@clarkson.edu

PP2

Rigorous Numerics for Analytic Solutions of Differential Equations: The Radii Polynomial Approach

The radii polynomial method has been used for validating numerical approximations to C^k periodic solutions of differential equations. This paper discusses the extension (via weighted Fourier sequence spaces) of the method to solutions in the analytic category, which often leads to better bounds and the possibility of continuation of the solution as a manifold in parameter space. It then details two examples in which our numerics have led us to computer-assisted proof of solutions.

Allan R. Hungria
University of Delaware
allanh@udel.edu

Jean-Philippe Lessard
Université Laval
jean-philippe.lessard@mat.ulaval.ca

Jason Mireles-James
Departement of Mathematics
Florida Atlantic University
jmirelesjames@fau.edu

PP2

Windows of Opportunity: Synchronization in On-Off Stochastic Networks

We study dynamical networks whose topology and intrinsic parameters stochastically change, on a time scale that ranges from fast to slow. When switching is fast, the stochastic network synchronizes as long as synchronization in the averaged network, becomes stable. We prove global stability of synchronization in the fast switching limit. Beyond fast switching, we reveal unexpected windows of intermediate switching frequencies in which synchronization becomes stable despite the instability of the averaged/fast-switching network.

Russell Jeter
Georgia State University
russell.jeter@outlook.com

Igor Belykh
Department of Mathematics and Statistics
Georgia State University
ibelykh@gsu.edu

PP2

Two-Theta Neuron: Phase Models for Bursting Networks

We continue our reduction approach to study bursting outcomes of central pattern generators using coupled two-theta phase models. We examine configurations of 3-cell CPGs with inhibitory, excitatory and electrical synapses, and model and compare with corresponding real-world exemplary networks. Occurrence, robustness and transformations of CPG outcomes are studied using 2D return maps, stable fixed points and invariant circles correspond to bursting patterns with fixed and varying phase lags.

Aaron Kelley
GSU
aarnkelley@gmail.com

PP2

A mathematical model for adaptive crawling locomotion

Crawling with locomotory wave is a fundamental method of biological locomotion in invertebrate including limbless and legged animals. We conducted observations of crawling locomotion in largely different conditions. In particular, it was found that centipedes can variously change their leg-density waves which represent spatio-temporal coordination pattern of ground friction. Here, we present a simple mechano-mathematical model for crawler so that it provides observed mode transition depending on the external / internal conditions.

Shigeru Kuroda
Research Institute for Electronic Science,
Hokkaido university
shigeru.kuroda@es.hokudai.ac.jp

Toshiyuki Nakagaki
Rearch Institute for Electronical Science
Hokkaido University

nakagaki@es.hokudai.ac.jp

PP2

Canard-Mediated Dynamics in a Phantom Burster

We present canard-mediated dynamics arising in a phantom burster, formed by a multiple timescale model composed of FitzHugh-Nagumo systems, which represents an alternating pulse and surge pattern in a neuro-secretory context. So far, global and local features of the model have been studied in the context of slow-fast dynamics and mixed-mode oscillations where folded singularities and associated canard trajectories have a particular importance. Here, we study the effect of the folded singularities in slow-fast transitions.

Elif Köksal Ersöz, Mathieu Desroches, Maciej Krupa, Frédérique Cleément
INRIA Paris-Rocquencourt
elif.koksal@inria.fr, mathieu.desroches@inria.fr, maciej.krupa@inria.fr, frederique.clement@inria.fr

PP2

Effective Dispersion Relation of the Nonlinear Schrödinger Equation

The linear part of the Nonlinear Schrödinger Equation (NLS) ($iq_t = q_{xx}$) has dispersion relation $\omega = k^2$. We don't necessarily expect solutions to the NLS to behave nicely or have any kind of effective dispersion relation, since we expect nonlinear waves to be strongly coupled and not sinusoidal in time. However, I have seen that solutions to the NLS are actually weakly coupled and are often nearly sinusoidal in time with a dominant frequency. In fact, when I look at long-time average of either a solution with many solitons or with many unstable modes, the power spectral density does indicate a quadratic dispersion relation that has been shifted by a constant proportional to the amplitude of the initial condition: $\omega = k^2 - 2A$ where $A = \frac{\|\hat{q}(k,0)\|^2}{2\pi}$. I will show a number of plots confirming this.

Katelyn J. Leisman, Gregor KovaČiČ
Rensselaer Polytechnic Institute
plaisk@rpi.edu, kovacg@rpi.edu

David Cai
New York University
Courant institute
cai@cims.nyu.edu

PP2

Mathematical Model of Bidirectional Vesicle Transport and Sporadic Capture in Axons

We model the transport of vesicles along an axon using an advection-diffusion equation which includes vesicle degradation and sporadic capture by presynaptic targets. Our model shows that the steady state concentration of vesicles distributed along the axon does not decay exponentially in space for some parameter values. We also study how heterogeneity in the distribution of targets can enhance cargo delivery by performing a multi-scale homogenization in space.

Ethan Levien
University of Utah
levien@math.utah,edu

Paul C. Bressloff
University of Utah
Department of Mathematics
bressloff@math.utah.edu

PP2

Modelocking in Chaotic Advection-Reaction-Diffusion Systems

Systems undergoing chaotic advection-reaction-diffusion dynamics have rich topological structures that define the front propagation. Here we use burning invariant manifolds (BIMs) to provide a theoretical framework that explains modelocking as observed experimentally and in numerical simulations. The existence of a relative periodic orbit and the shape of the BIM determine the type of modelocking. Using this technique we find higher order modelocking types and discuss the switching of modelocking types observed in experiments.

Rory A. Locke
UC-Merced
rlocke@ucmerced.edu

John R. Mahoney
University of California, Merced
jmahoney3@ucmerced.edu

Kevin A. Mitchell
University of California, Merced
Physics
kmitchell@ucmerced.edu

PP2

Effect of Multi-Species Mass Emergence on Biodiversity

Mass emergences are a regular occurrence in rivers and streams. Many aquatic insects depend on safety in numbers to escape the water and reproduce. This strategy not only allows individual species to enhance reproductive success by reducing predation rates, but also creates opportunities for scarcer species that synchronize their emergence with more prevalent species. We construct a heuristic model to study inherent protections afforded by biodiversity and consider implications for repopulation efforts in pollution-impacted systems.

James E. McClure
Advanced Research Computing
Virginia Tech
mcclurej@vt.edu

Nicole Abaid
Virginia Polytechnic Institute and State University
nabaid@vt.edu

PP2

A B Cell Receptor Signaling Model and Dynamic Origins of Cell Response

The kinase Syk is imperative for the intricate signaling events that occur in B cells, events which lead to cellular responses when antigens bind to B cell receptors (BCRs). We have constructed a deterministic model for BCR signaling centered around Syk. After tuning feedbacks between key kinases and phosphatases, we demonstrated qualitative agreement between the model and dose response data from

literature. We investigate the role of positive and negative feedbacks in determining cell response.

Reginald Mcgee
Purdue University
mcgee3@purdue.edu

PP2

Stability of Morphodynamic Equilibria in Tidal Basins

Interesting bed patterns are observed in the tidal basins of, for example, the Wadden Sea along the Dutch, German and Danish coast. To get a better understanding of these phenomena, a morphodynamic model has been constructed. The goal is to find the morphodynamic equilibria and their stability, and to investigate their sensitivity to parameter variations. Therefore, the equations have been scaled and asymptotically analysed. Using finite element method and continuation techniques, the equilibrium of the bed has been determined.

Corine J. Meerman
Leiden University
Mathematical Institute
cmeerman@math.leidenuniv.nl

Vivi Rottschäfer
Department of Mathematics
Leiden University
vivi@math.leidenuniv.nl

Henk Schuttelaars
Delft Institute of Applied Mathematics
Delft University of Technology
h.m.schuttelaars@tudelft.nl

PP2

Frequency-Dependent Left-Right Coordination in Locomotor Pattern Generation

Coordination between left and right activities in the spinal cord during locomotion is controlled by commissural interneurons (CINs). Several types have been genetically identified including both excitatory (VOV) and inhibitory (V0D). Genetic elimination of these CINs caused switching from a normal left-right alternation to a left-right synchronized pattern. Ablation of V0D neurons resulted in a lack of left-right alternation at low locomotor frequencies, whereas selective ablation of V0V CINs switched the motor output to a left-right synchronized pattern at high frequencies. We developed a model of neural circuits consisting of four pacemaker neurons, left and right flexors and extensors, interacting via V0D and V0V commissural pathways. The model reproduced all experimentally identified regimes in the corresponding frequency ranges. We qualitatively analyzed the behavior of this network in the above regimes and transitions between them.

Yaroslav Molkov
Indiana University - Purdue University Indianapolis
yaroslav.molkov@gmail.com

Bartholomew Bacak, Ilya A. Rybak
Drexel University College of Medicine
bjb87@drexel.edu, rybak@drexel.edu

PP2

Capacity for Learning the Shape of Arena in the Single-Celled Swimmer, Viewed from Slow Dynamics of Membrane Potential.

We have studied for some years the learning capacity for time and space in unicellular organisms. Here we present that protozoan ciliates, Paramecium and Tetrahymena, show the swimming trajectory adaptive to the shape (e.g. capillary and droplet) of swimming arena in which they experienced just before. As the swimming activity is regulated by membrane potential in the ciliates, a possible mechanism is considered according to the equations of Hodgkin-Huxley type with the additional slower variable.

Toshiyuki Nakagaki
Rearch Institute for Electronical Science
Hokkaido University
nakagaki@es.hokudai.ac.jp

Itsuki Kunita
Hokkaido University
kunita@es.hokudai.ac.jp

Tatsuya Yamaguchi
Kyushu University
tatsuya yayamayamaguchiguchi@gmail.com

Masakazu Akiyama
Hokkaido University
akiyama@es.hokudai.ac.jp

Atsushi Tero
Kyushu University
tero.atsushi@gmail.com

Shigeru Kuroda
Research Institute for Electronic Science,
Hokkaido university
shigeru.kuroda@es.hokudai.ac.jp

Kaito Ooki
Hokkaido University
ooki@mail.sci.hokudai.ac.jp

PP2

Co-Dimension Two Bifurcations in Piecewise-Smooth Continuous Dynamical Systems

The mean-field equations for a network of type I neurons is a piecewise-smooth continuous (PWSC) system of ordinary differential equations. This system displays two prominent co-dimension two non-smooth bifurcations involving collisions of a saddle-node equilibrium with a switching manifold, and a Hopf equilibrium with a switching manifold. These bifurcations are analytically resolved for the mean-field system in full detail. The genericity of these bifurcations for an arbitrary PWSC system is also discussed.

Wilten Nicola
University of Waterloo
wnicola@uwaterloo.ca

Sue Ann Campbell
University of Waterloo

Dept of Applied Mathematics
sacampbell@uwaterloo.ca

PP2

Analysis of Malaria Transmission Dynamics with Saturated Incidence

Mathematical model for malaria transmission in a two-interacting population with saturated incidence was formulated and robustly analysed. The model was shown to exhibit a subcritical bifurcation whenever a unique threshold, R_0, increases through unity. However, under specific conditions, globally asymptotically stable malaria-free and endemic equilibria were established at $R_0 < 1$ and $R_0 > 1$ respectively. Further, sensitivity analysis and simulations were performed to examine the effects of some parameters on the model.

Samson Olaniyi
Department of Pure and Applied Mathematics
Ladoke Akintola University of Technology, Ogbomoso
solaniyi@lautech.edu.ng

PP2

Temporally Periodic Neural Responses from Spatially Periodic Stimuli

Certain static spatial visual patterns induce temporally varying neural responses, such as in pattern-sensitive epilepsy and some visual illusions. These temporal responses are often strong only in a very narrow spatial frequency band and nonexistent at other spatial frequencies. We present a spatially distributed neural field model that captures this resonant behavior in simulations, and demonstrate analytically this strong sensitivity to the spatial wavelength with a perturbation calculation near the instability.

Jason E. Pina
University of Pittsburgh Department of Mathematics
jep113@pitt.edu

Bard Ermentrout
University of Pittsburgh
Department of Mathematics
bard@pitt.edu

PP2

Using a Stochastic Field Theory to Understand Collective Behavior of Swimming Microorganisms

Large groups of active particles can show collective behavior and enhanced fluctuations, but mean field theories to understand them ignore fluctuations. We have extended these field theories to include stochastic fluxes and have quantified the dynamics in terms of enhanced diffusion and mixing and number fluctuations. We have also compared with results with the mean field theory and discrete particle-based simulations.

Yuzhou Qian
Rensselaer Polytechnic Institute
qianyuzhou1@gmail.com

Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
kramep@rpi.edu

Patrick Underhill
Rensselaer Polytechnic Institute
underp3@rpi.edu

PP2

Consensus and Synchronization over Biologically-Inspired Networks: From Collaboration to Antagonism

The vast majority of work on consensus and synchronization of coupled dynamical systems considers their interactions to be collaborative. In our present work, we study two different networks representing more realistic scenarios; one consists of dynamic leaders in a collaborative network and another consists of agonistic and antagonistic interactions. We establish closed form results for the rate of convergence to consensus for both the cases and conditions for stochastic synchronization in the second case.

Subhradeep Roy, Nicole Abaid
Virginia Polytechnic Institute and State University
sdroy@vt.edu, nabaid@vt.edu

PP2

Oscillatory Shear Flow Influence on the Two Point Vortex Dynamics

Bounded and unbounded quasi-periodic dynamics of two point vortices of unequal strengths embedded in an oscillatory shear flow with rotation is addressed with an emphasis on their impact on passive tracer transport. All the sets of the vortex signs are shown to induce qualitatively divergent transport patterns. Regions enduring effective stretching, and consequently prone to intense mixing are identified by means of finite-time Lyapunov exponents.

Evgeny Ryzhov
V.I. Ilichev Pacific Oceanological Institute
ryzhovea@poi.dvo.ru

Konstantin Koshel
V.I. Ilichev Pacific Oceanological Institute
Far Eastern Federal University
kvkoshel@poi.dvo.ru

PP2

Waveaction Spectra for Fully Nonlinear MMT Model

We investigate a version of the Majda-McLaughlin-Tabak model of dispersive wave turbulence where the linear term in the time derivative is removed. We are interested in the long-time average of the distribution of waveaction throughout the system as a function of wavenumber. We consider driven-damped and undriven, undamped cases of the model. Our theoretical predictions, which include self-similarity arguments and statistical mechanical methods, are found to agree with time dynamics simulations.

Michael Schwarz
Rensselaer Polytechnic Institute
mschwarz137@gmail.com

Gregor Kovacic
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
kovacg@rpi.edu

Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
kramep@rpi.edu

David Cai
Courant Institute for Mathematical Sciences, NYU
Shanghai Jiao-Tong University
cai@cims.nyu.edu

PP2

Wild Dynamics in Nonlinear Integrate-and-Fire Neurons: Mixed-Mode Bursting, Spike Adding and Chaos.

Nonlinear integrate-and-fire neuron models are hybrid dynamical systems combining continuous differential equations and discrete resets, where spikes are defined by the divergence of the membrane potential to infinity. The nature of the spike pattern has been related to the orbits of a discrete map, the adaptation map, which was studied in a number of situations where it was regular. We analyze here cases of discontinuous adaptation map and show that extremely wild behaviors can appear.

Justyna H. Signerska
INRIA MYCENAE Laboratory, Paris;
Mathematical Neuroscience Lab, CIRB Collège de France
justyna-hanna.signerska@college-de-france.fr

Jonathan D. Touboul
The Mathematical Neuroscience Laboratory
College de France & INRIA Paris
jonathan.touboul@college-de-france.fr

Alexandre Vidal
University of Evry-Val-d'Essonne
Department of Mathematics - Analysis and Probability Lab
alexandre.vidal@univ-evry.fr

PP2

Return Times and Correlation Decay in Linked Twist Maps

Linked twist maps form an archetypal class of non-uniformly hyperbolic system, of particular relevance to fluid mixing. Previous results demonstrate that they have a polynomial decay of correlations. Of practical interest is the time at which the system begins to experience this algebraic tail in the decay, after the faster, chaotic, exponential mixing has taken place.

Rob Sturman
University of Leeds
rsturman@maths.leeds.ac.uk

PP2

Osteocyte Network Formation

We construct a model of a dynamic network that consists of osteocytes, a type of cell within bone. On the bone-tissue interface, osteoblasts secrete the osteoid bone matrix and multi-nucleated osteoclasts resorb it. These osteoblasts can also differentiate into osteocytes. In pathological bone, the highly regulated bone remodelling signalling pathway is disrupted. By understanding these dynamics, we hope to gain insights into how to predict structural differences between healthy and cancerous tissue.

Jake P. Taylor-King
Mathematical Institute, The University of Oxford.
jake.taylor-king@sjc.ox.ac.uk

Mason A. Porter
University of Oxford
Oxford Centre for Industrial and Applied Mathematics
porterm@maths.ox.ac.uk

Jon Chapman
Mathematical Institute
The University of Oxford
chapman@maths.ox.ac.uk

David Basanta
Integrated Mathematical Oncology
Moffitt Cancer Center
david@cancerevo.org

PP2

On a FitzHugh-Nagumo Kinetic Model for Neural Networks

This paper undertakes the analysis of the existence and uniqueness of solutions for a mean-field FitzHugh-Nagumo equation arising in the modeling of the macroscopic activity of the brain. In particular, we prove existence of solution and non trivial stationary solution to evolution equation without restriction on the connectivity coefficient $\varepsilon > 0$ and, using a semigroup factorisation method in Banach spaces, uniqueness of the stationary solution and its exponential NL stability in the small connectivity regime.

Cristobal Quininao
Laboratoire Jacques-Louis Lions
cristobal.quininao@college-de-france.fr

Jonathan D. Touboul
The Mathematical Neuroscience Laboratory
College de France & INRIA Paris
jonathan.touboul@college-de-france.fr

Stéphane Mischler
Université Paris-Dauphine
mischler@ceremade.dauphine.fr

PP2

Examining Partial Cascades in Clustered Networks with High Intervertex Path Lengths

There has been significant study of cascades on networks with various properties. There is a well-known branching process approach developed by James Gleeson that is useful for sparse locally treelike networks, particularly those with low mean intervertex path lengths. We examine methods to apply to networks with longer intervertex path lengths, which may contribute to a partial cascade not seen with Gleeson's method.

Yosef M. Treitman
Rensselaer Polytechnic Institute
treitmaniac@gmail.com

Peter R. Kramer
Rensselaer Polytechnic Institute

Department of Mathematical Sciences
kramep@rpi.edu

PP2

Almost Complete Separation of a Fluid Component from a Mixture Using the Burgers Networks of Micro-separators

Two ways of networking micro-separators to separate hydrogen, for example, from a mixture almost completely are proposed. Each separator has two outlets for slightly higher and lower concentrations whose difference is modeled by a quadratic map of the average concentration at its inlet. In the continuum the networks are governed by the Burgers equation or its variant with nonlinear no-flux boundary conditions. The initial boundary value problem is exactly solvable. A family of equilibria attract globally. The target component is shown to be extracted from one side of a stationary shock. Micro-devices for testing the idea are also proposed.

Shinya Watanabe
Mathematics & Informatics
Ibaraki University
shinya@mx.ibaraki.ac.jp

Sohei Matsumoto
Research Center for Ubiquitous MEMS and Micro Engineering,
National Inst. of Advanced Industrial Science & Technology
sohei.matsumoto@aist.go.jp

Tomohiro Higurashi, Yuya Yoshikawa, Naoki Ono
Department of Engineering Science and Mechanics
Shibaura Institute of Technology
md14071@shibaura-it.ac.jp, ab11112@shibaura-it.ac.jp, naokiono@shibaura-it.ac.jp

PP2

New Data Anysis Approach for Complex Signals with Low Signal to Noise Ratio's

We propose a toolbox for signals comparisons with low SNR. We combine techniques from dynamical systems and information theory to quantify and extract information in the data sets. Data sets with SNR's of 0.3 to 0.002 were analyzed. Useful information was found and quantized with tight bounds on the estimate. We also compare to Gaussian noise and show our toolbox can be used to separate signals with low SNR from white noise.

Jeremy Wojcik
Georgia State University
Dept. Mathematics and Statistics
wojcik.jeremy@gmail.com

PP2

Data Assimilation for Traffic State and Parameter Estimation

Our goal is to apply data assimilation techniques to microscopic and macroscopic traffic models to estimate traffic states and parameters. We found ways in which sensor data as well as GPS data of moving cars can be assimilated in a unified freeway. We implemented this approach using both ensemble Kalman and particle filter and evaluated their efficacy using microscopic and macroscopic models. We applied our results to real traffic data from Minnesota Transportation Department.

Chao Xia
Brown University
chao_xia@brown.edu

Bjorn Sandstede, Paul Carter
Division of Applied Mathematics
Brown University
bjorn_sandstede@brown.edu, paul_carter@brown.edu

Laura Slivinski
Woods Hole Oceanographic Institution
lslivinski@whoi.edu

PP2

Stochastic Active-Transport Model of Cell Polarization

We present a stochastic model of active vesicular transport and its role in cell po- larization, which takes into account positive feedback between membrane-bound signaling molecules and cytoskeletal filaments. In particular, we consider the cytoplasmic transport of vesicles on a two-dimensional cytoskeletal network, in which a vesicle containing signaling molecules can randomly switch between a diffusing state and a state of directed motion along a filament. We show that the geometry of the cytoskeletal filaments plays a crucial role in determining whether the cell is capable of spontaneous cell polarization or only polarizes in response to an external chemical gradient.The former occurs if filaments are nucleated at sites on the cell membrane (cortical actin), whereas the latter applies if the filaments nucleate from organizing sites within the cytoplasm (microtubule asters).

Bin Xu
University of Utah, salt lake city,Utah
xu@math.utah.edu

Paul C. Bressloff
University of Utah
Department of Mathematics
bressloff@math.utah.edu

PP2

Statistical Properties of Finite Systems of Point-Particles Interacting Through Binary Collisions

In a finite system of point-particles interacting through binary collisions, particles number of collisions and time of last collision are functions of the initial distributions of the positions and velocities of all particles. We investigate a one-dimensional system of N particles interacting through either elastic or inelastic collisions. In particular, given random initial particle positions and velocities, we establish formulae for the distributions of the number of collisions and final collision times.

Alexander L. Young
University of Arizona
Program in Applied Mathematics
young@math.arizona.edu

Joceline Lega
University of Arizona, USA
lega@math.arizona.edu

Sunder Sethuraman
University of Arizona
Department of Mathematics
sethuram@math.arizona.edu

PP2

Heteroclinic Separators of Magnetic Fields in Electrically Conducting Fluids

We partly solve the problem of existence of separators of a magnetic field in plasma. We single out in plasma a 3-body with a boundary in which the movement of plasma is of special kind which we call an (a-d)-motion. The statement of the problem and the suggested method for its solution lead to some theoretical problems from Dynamical Systems Theory. The work was supported by RFBR, Grants 12-01-00672-a and 13-01-12452-ofi-m.

Evgeny Zhuzhoma
National Research University Higher School of Economics
zhuzhoma@mail.ru

Vyatcheslav Grines, Timur Medvedev
Lobachevsky State University of Nizhni Novgorod
vgrines@yandex.ru, mtv@unn.ru

Olga Pochinka
National Research University Higher School of Economics
olga-pochinka@yandex.ru