## IP0

### Juergen Moser Lecture: The Many Facets of Chaos

Chaos reveals itself differently in different situations. Understanding its many aspects or facets will help in creating innovative models. My talk will illustrate how different facets of chaos lead us in different directions in my recent works on: HIV population dynamics; determining the current state of the atmosphere (for weather prediction); genome assembly (determining the sequence of ACGT's for a species); partial control of chaos .

James A. Yorke
University of Maryland
Departments of Math and Physics and IPST
yorke@umd.edu

## IP1

### Will the Climate Change Mathematics?

Computational models of the Earth system lie at the heart of modern climate science. Concerns about their predictions have been illegitimately used to undercut the case that the climate is changing and this has put dynamical systems in an awkward position. It is important that we extricate ourselves from this situation as climate science, whose true objective is to build an understanding of how the climate works, badly needs our expertise. I will discuss ways that we, as a community, can contribute by highlighting some of the major outstanding questions that drive climate science, and I will outline their mathematical dimensions. I will put a particular focus on the issue of simultaneously handling the information coming from data and models. I will argue that this balancing act will impact the way in whch we formulate problems in dynamical systems.

Christopher Jones
University of North Carolina at Chapel Hill, USA &
University of Warwick, United Kingdom
ckrtj@amath.unc.edu

## IP2

### From Newton's Cradle to New Materials

The bouncing beads of Newton's cradle fascinate children and executives alike, but their symmetric dance hides complex nonlinear dynamic behavior. Lift a bead on one side off a chain of a few suspended beads, let it swing back: one bead bounces off on the other side. Do the same with a long chain of beads: several beads bounce off on the other side. This represents an example of nonlinear wave dynamics, which can be exploited for a variety of engineering applications. By assembling grains in crystals or layers in composites such that they support nonlinear waves, we are developing new materials and devices with unique properties. We have constructed acoustic lenses that allow sound to travel as compact bullets that can be used in medical applications, have developed new materials for absorbing explosive blasts, and are exploring new ways to test aircraft wings and bone implants nondestructively with the help of nonlinear waves.

Chiara Daraio
Aeronautics and Applied Physics
California Institute of Technology
daraio@caltech.edu

## IP3

### How Can We Model the Regulation of Stress Hormones?

Daily and monthly rhythms of hormones are well recognised. Less well known are the more rapid ultradian changes which are a characteristic of most biologically active hormone systems. We have looked at the regulation of the stress hormones glucocorticoids secreted by the adrenal glands. It has always been assumed that the episodic release of these hormones was a result of some form of pulse generator in the brain. A dispassionate look at this system however, revealed that there was a feedforward:feedback relationship between the pituitary gland and the adrenal gland providing scope for a peripheral oscillating hormonal system. The background to this system and the biological testing of our mathematical predictions will be described.

Stafford Lightman
University of Bristol, United Kingdom
Stafford.Lightman@bristol.ac.uk

## IP4

### Climate Sensitivity, Feedback and Bifurcation: From Snowball Earths to the Runaway Greenhouse

The concept of climate sensitivity lays at the heart of assessment of the magnitude of the imprint of human activities on the Earth's climate. Most commonly, the "climate" is represented by a simple projection such as a global mean temperature, and we wish to know how this changes in response to changes in a single control parameter – usually atmospheric CO2 concentration. This problem is an instance of a broad class of related problems in parameter dependence of dynamical systems. I will discuss the shortcomings of the traditional linear approach to this problem, particularly in light of the spurious "runaway" states produced when feedback becomes large. The extension to include nonlinear effects relates in a straightforward way to bifurcation theory. I will discuss explicit examples arising from ice-albedo, water vapor, and cloud feedbacks. Finally, drawing on the logistic map as an example, I will discuss the problem of defining climate sensitivity for problems exhibiting structural instability.

Raymond T. Pierrehumbert
The University of Chicago
Dept. of the Geophysical Sciences
rtp1@geosci.uchicago.edu

## IP5

### Robust and Generic Dynamics: A Phenomenon/mechanism Correspondence

If we consider that the mathematical formulation of natural phenomena always involves simplifications of the physical laws, real significance of a model may be accorded only to those properties that are robust under perturbations. In loose terms, robustness means that some main features of a dynamical system are shared by all nearby systems. In the talk, we will explain the structures related to the presence of robust phenomena and the universal mechanisms that lead to lack of robustness. Providing a conceptual framework, the goal is also to show how to provide a generic correspondence phenomenon/mechanism for all dynamical systems.

Enrique Pujals

Instituto Nacional de Matemática Pura e Aplicada, Brazil
enrique@impa.br

### IP6

### Models and Control of Collective Spatio-Temporal Phenomena in Power Grids

We are asking modern power grids to serve under conditions it was not originally designed for. We also expect the grids to be smart, in how they function, how they withstand contingencies, respond to fluctuations in generation and load, and how the grids are controlled. To meet these ever increasing expectations requires extending power grid models beyond the scope of traditional power engineering. In this talk aimed at applied mathematicians and physicists I first review basics of power flows, and then outline a number of new problems in modeling, optimization and control theory for smart grids. In particular, I describe new approaches to control of voltage and reactive flow in distribution networks, algorithms to study distance to failure, and statistical analysis of cascading blackouts in transmission networks.

Michael Chertkov
Los Alamos National Laboratory
chertkov@lanl.gov

### IP7

### Pattern Formation and Partial Differential Equations

The research I present is motivated by specific, but ubiquitous pattern in models from physics: Domain and wall patterns the magnetization forms in ferromagnets, the coarsening of the phase distribution in demixing of polymer blends, the roughening of a crystal surface under deposition. Dynamically speaking, the type of models ranges from variational formulations, over (driven) gradient flows to non-gradient systems. The challenge for a rigorous analysis lies in the fact that we are interested in generic behavior of solutions, as expressed by (experimentally and numerically observed)scaling laws, that hold in the limit of large system sizes. We argue that methods from the theory of partial differential equations can be used to provide at least one-sided, optimal bounds on these scaling laws.

Felix Otto
Max Planck Institute for Mathematics in the Sciences
Leipzig, Germany
Felix.Otto@mis.mpg.de

### IP8

### Mathematical Models for Tissue Engineering Applications

The broad goal of tissue engineers is to grow functional tissues and organs in the laboratory to replace those which have become defective through age, trauma, and disease and which can be used in drug screening applications. To achieve this goal, tissue engineers aim to control accurately the biomechanical and biochemical environment of the growing tissue construct, in order to engineer tissues with the desired composition, biomechanical and biochemical properties (in the sense that they mimic the in vivo tissue). The growth of biological tissue is a complex process, resulting from the interaction of numerous processes on disparate spatio-temporal scales. Advances in the understanding of tissue growth processes promise to improve the viability and suitability of the resulting tissue constructs. In this talk, I highlight some of our recent mathematical modelling work that aims to provide insights into tissue engineering applications.

Sarah Waters
University of Oxford
waters@maths.ox.ac.uk

### IP9

### Moving Pattern Formation from the Real World to the Lab, and the Reverse

This talk will describe three pattern formation experiments where natural systems were imported directly into the laboratory. The overall shape and subsequent rippling instability of icicles is a complex free-boundary growth problem. It has been linked theoretically to similar phenomena in stalactites. We grew laboratory icicles determined the motion of their ripples. Washboard road is the result of the instability of a flat granular surface under the action of rolling wheels. The rippling of the road sets in above a threshold speed and leads to waves which travel down the road. We studied these waves both in the laboratory and using 2D molecular dynamics simulation. Columnar joints are uncanny formations of ordered cracks in certain lava flows. We studied these both in a lab analog system and in the field. Each of these three cases nicely illustrates the pleasures and pitfalls of such "naturalistic" pattern formation experiments. Collaborators: Antony Szu-Han Chen, Nicolas Taberlet, Jim McElwaine, Lucas Goehring and L. Mahadevan

Stephen Morris
University of Toronto, Canada
smorris@physics.utoronto.ca

### CP1

### Internal Lever Arm Model for Myosin II

Myosin II is a special type of enzyme, called motor protein, capable of transforming chemical energy into mechanical work. Among the many different approaches of the different disciplines, one of the most commonly used is the enzyme kinetic approach, that uses a set of (arbitrary) discrete states, with different transition rate constants between them. Here, we present a purely mechanical model giving a more realistic continuous pathway between the local equilibrium states of the molecule.

Andras Bibo
Department of Structural Mechanics,
Budapest University of Tecnology and Economics
biboan@gmail.com

### CP1

### Modeling DNA Overstretching at the Basepair Level

Many stretching experiments on single DNA molecules indicate that DNA initially overwinds when stretched, then it unwinds and, at large forces, it undergoes a phase-transition indicated by a plateau on the force-displacement diagrams. We utilize a discrete, basepair level model to investigate the response of short DNA molecules to stretching, taking into account the sequence dependent physical properties of DNA alongside with the coupling between the step parameters. By constructing bifurcation diagrams of equilibrium configurations and studying the dependence on basepair combinations we show that the discrete model predicts overwinding followed by unwinding as a result of coupling between modes of deformation, and that the overstretching transition observed in our study is a result of shear instability.

Attila G. Kocsis
Department of Structural Mechanics
Budapest University of Technology and Economics
attila.g.kocsis@gmail.com

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

### CP1

### Geometric Mechanics of Molecules with Non-Local Interactions

We derive equations of motion for the molecules exhibiting both local (elastic) and non-local (e.g. electrostatic or Lennard-Jones) interactions using a modified exact geometric rods theory. We explicitly compute the equations when the charges positioned off the elastic backbone. We show that helices are exact stationary solutions of the resulting integro-differential equations, and that their linear stability can be analyzed exactly. Classification of helical states and their stability for realistic polymers is also provided.

Vakhtang Putkaradze
Colorado State University
putkarad@math.colostate.edu

### CP2

### Bifurcations in Models of Evolution of Polymorphism

Biological processes that lead to polymorphism can be described using models of competing populations. The introduction of new competitors occurs on a timescale that is long compared to the timescale of the population models. To the extent that the dynamics on these timescales decouple, evolutionary models that describe polymorphic branching can be interpreted as discrete dynamical systems whose state space is the set of omega-limits of the underlying population models. This talk develops this idea, and effect of bifurcations in the population models on evolutionary outcomes.

Ernest Barany
New Mexico State University
Dept of Mathematical Sciences
ebarany@nmsu.edu

### CP2

### Cell Population Dynamics: Bifurcation Theory Reveals Emergent Behaviour.

Quorum sensing, a biochemical mechanism enabling communication between unicellular microbes, allows emergence of coordinated multicellular behaviour like synchronisation and change of state. An agent based model describing cellular metabolic states, based on Danino et. al (2010) experiments is derived and analysed. Numerical continuation uncovers possible emergent modes of coordination across varying size populations in varying volume environment. Mean field bifurcation analysis and large scale simulations in BSim, a novel 3D simulation framework, validate theoretical results.

Petros Mina
Department of Engineering Mathematics
University of Bristol
petros.mina@bristol.ac.uk

Mario Di Bernardo
University of Bristol
Dept of Engineering Mathematic
m.dibernardo@bristol.ac.uk

Krasimira Tsaneva-Atanasova
Department of Engineering Mathematics
University of Bristol
K.Tsaneva-Atanasova@bristol.ac.uk

Nigel Savery
University of Bristol
Biochemistry
n.j.savery@bristol.ac.uk

### CP2

### Dynamics of Infection Spreading in Adaptive Networks with Communities

When an epidemic spreads in a population, individuals may adaptively change the structure of their social contact network to reduce infection risk. Here we study the spread of epidemics on an adaptive network with community structure. We model the effect of heterogeneous communities on infection levels and epidemic extinction. We show how an epidemic can alter the community structure. We also study stochastic reintroduction of infection to a community where the disease has died out.

Ilker Tunc
The College of William and Mary
Applied Science Department
itunc@email.wm.edu

Leah Shaw
The College of William & Mary
lbshaw@wm.edu

### CP3

### Synchronization of Degrade-and-fire Oscillations in Synthetic Gene Networks

In this talk, I will describe our recent experimental and theoretical work on the synchronization of synthetic gene networks exhibiting oscillatory gene expression within bacterial cells. Recently, we constructed a synthetic two-gene oscillator based on delayed auto-repression, and observed robust and tunable "degrade-and-fire" oscillations in individual bacteria. Using a variant of the same design in which the feedback is mediated by a small molecule AHL, we were able to observe synchronized gene expression oscillations in a colony of bacteria within a microfluidic chamber. In large systems, the collective oscillations formed propagating spatiotemporal waves typical for reaction-diffusion systems. I will introduce a theoretical model of the collective oscillations based on diffusively-coupled delay-differential equations which allowed us to explain the observed phenomenology.

Lev S. Tsimring

University of California, San Diego
ltsimring@ucsd.edu

Tal Danino, Octavio Montragon-Palomino
UCSD
tdanino@ucsd.edu, omondrag@ucsd.edu

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

### CP3

### Cell Cycle Synchronization vs. Clustering

Motivated by experiments and theoretical work on respiratory oscillations in yeast cultures, we study ordinary differential equations models of cell-cycle systems with cell-cycle dependent feedback. We assume very general forms of the feedback and study the dynamics, particularly the clustering behaviour of such systems.

Erik M. Boczko
Department of Biomedical Informatics
Vanderbilt University Medical School
erik.m.boczko@vanderbilt.edu

Bastien Fernandez
Centre de Physique Theorique
bastien@cpt.univ-mrs.fr

Todd Young
Ohio University
Department of Mathematics
youngt@ohio.edu

Richard Buckalew
University of Ohio
rb301008@ohio.edu

### CP4

### Dynamics in Modular Networks at the Mesoscale Level

Modularity is one of the most important features that real networks exhibit since it greatly determines their functionality. Although it is being analyzed from different viewpoints, it is not yet well understood the dynamical behavior of modular networks at the mesoscale level. In this talk we propose a technique to identify this behavior, presenting a theoretical justification of it and illustrating its validity by means of several applications.

Juan A. Almendral, Inmaculada Leyva
University of Rey Juan Carlos
Madrid, Spain
juan.almendral@urjc.es, inmaculada.leyva@urjc.es

Daqing Li
Department of physics
Bar Ilan University
li.daqing.biu@gmail.com

Irene Sendina-Nadal
University of Rey Juan Carlos, Madrid, Spain
irene.sendina@urjc.es

Javier M. Buldu
Rey Juan Carlos University
javier.buldu@urjc.es

Shlomo Havlin
Bar-Ilan University
havlin@ophir.ph.biu.ac.il

Stefano Boccaletti
CNR
stefano.boccaletti@fi.isc.cnr.it

### CP4

### Clustering of Networks with Mesoscaled Structure Through Multilevel Networks

The concept of multilevel network has been introduced in order to embody some topological properties of heterogeneous-type complex systems which are not completely captured by the classical models. In this talk we will focus on different approaches of clustering and the analytical relationships between them. As main feature it will be shown some analytical bounds among the clustering of each slice, the clastering of the projection network and the clustering of the whole multilevel network.

Regino Criado, Julio Flores, Alejandro García del Amo, Jesús Gómez-Gardeñes
Universidad Rey Juan Carlos
regino.criado@urjc.es, julio.flores@urjc.es,
alejandro.garciadelamo@urjc.es,
jesus.gomez.gardenes@urjc.es

Miguel Romance
Departamento de Matematica Aplicada
Universidad Rey Juan Carlos
miguel.romance@urjc.es

### CP4

### Communicability, Centrality and Communities in Complex Networks

The concept of communicability in complex networks is presented. A general mathematical framework for defining communicability functions is then introduced, which gives rise to the use of matrix functions in networks. We present a measure based on the exponential adjacency matrix of the network and extend this idea to the resolvent, pseudo-inverse of the Laplacian, Psi matrix functions and some new matrix functions. The method is then illustrated for the definition of centrality measures as well as for the detection of communities in networks. For the last topic a set of methods and algorithms are briefly presented and analysed.

Ernesto Estrada
University of Strathclyde
ernesto.estrada@strath.ac.uk

### CP5

### Vortex Generation by An Oscillatory Magnetic Obstacle

We consider the flow induced by oscillating magnets in a quiescent electrically conducting fluid. The motion of the magnets produces a periodic flow pattern that involves the interaction of vortices created at different times of the cycle. As a result, hyperbolic and elliptic points are created and conveyed within the flow. We propose a simple normal

form model for the flow, and show that it reproduces the bifurcations of flow patterns found numerically.

Morten Brøns
Technical University Denmark
brons@mat.dtu.dk

### CP5
### Optimal Harmonic Response in a Confined Bödewadt Boundary Layer Flow

The Bödewadt boundary layer flow on the stationary bottom end wall of a finite rotating cylinder is very sensitive to perturbations and noise. A comprehensive exploration of response to variations in the amplitude and frequency of harmonic forcing reveils sharply delineated linear- and nonlinear-response regimes, with a sharp transition between them at moderate amplitudes. Axisymmetric waves always decay to the steady basic state when the harmonic modulation is suppressed, and the experimentally observed persistent circular waves are not self-sustained.

Juan M. Lopez
Arizona State University
Department of Mathematics
lopez@math.asu.edu

Younghae Do
Kyungpook National University
yhdo@knu.ac.kr

Francisco Marques
Univ. Polit
'ecnica de Catalunya
Applied Physics
marques@fa.upc.edu

### CP5
### Vortex Sheet Model for a Turbulent Mixing Layer

A vortex sheet model is used to study the evolution of a vortex sheet in an Euler fluid. The equation of motion of the sheet is derived explicitly in closed form. The vortex sheet rolls up into a smooth double branched spiral instead of a chaotic cloud of point vortices. The problem of spontaneous appearance of singularity in an evolving vortex sheet is partially suppressed by slight desingularization of the sheet along arc length.

Ujjayan Paul, Roddam Narasimha
Jawaharlal Nehru Centre for Advanced Scientific Research
ujjayan@jncasr.ac.in, roddam@jncasr.ac.in

### CP6
### Stability of Periodic-Wave Solutions in the Parametrically Driven Damped Nonlinear Schroedinger Equation

This equation has two cn- and two dn-wave solutions. Of these, two solutions are proven to be unstable for all values of the driving and damping parameters, against perturbations periodic with the period of the wave. The third wave is unstable (to antiperiodic perturbations) when the forcing is weak and/or the period of the wave is large, but becomes stable in the opposite limit. The stability properties of the fourth periodic solution depend on the forcing and the period in a complex way.

Igor Barashenkov, Maxim Molchan
University of Cape Town
Igor.Barashenkov@gmail.com, m.moltschan@gmail.com

### CP6
### Nonlinear Asymptotic Stability for a Generalized Gierer-Meinhardt Model

This paper shows the nonlinear asymptotic stability in the semi-strong interaction regime of $N$-pulses in a singularly perturbed, weakly damped, reaction-diffusion system. We prove results for a general nonlinearity that includes more specific systems such as the Gierer-Meinhardt model. We use renormalization group techniques to prove nonlinear asymptotic stability. We achieve this by showing the eigenvalue problem dichotomizes into a stable region near zero and a smaller center region. We additionally show contractive semigroup estimates.

Thomas Bellsky
Michigan State University
Department of Mathematics
bellskyt@msu.edu

Keith Promislow
Michigan State University
kpromisl@math.msu.edu

### CP6
### Asymptotic Analysis of a Specific Type of Multi-Bump Blowup Solutions of the Ginzburg-Landau Equation

Via a geometric construction, two types of multi-bump blowup solutions of the Ginzburg-Landau equation were shown to exist previously. At $\xi = 0$, one type of the solutions is exponentially small, the other type is algebraically small. Here, we use asymptotic methods to study the solutions which are algebraically small at $\xi = 0$. The key ingredient of the analysis is that the maximum of the solutions, the bump, must be placed at an essentially different location than for the other type of solutions.

Vivi Rottschafer
Leiden University
Dept of Mathematics
vivi@math.leidenuniv.nl

### CP7
### Some Effects of the Gamma Distribution on the Dynamics of a Scalar Delay Differential Equation

We consider a scalar two-delay differential equation, consisting of one discrete and one gamma-distributed delay. We characterise the stability of the trivial solution as well as the functional dependence of the stability regions of the Hopf bifurcation of this solution upon the parameter $m \in \mathbf{Z}^+$, the gamma distribution index.

Israel Ncube
Memorial University of Newfoundland
incube@swgc.mun.ca

Sue Ann Campbell
University of Waterloo
Dept of Applied Mathematics

sacampbell@uwaterloo.ca

### CP7

### Periodic Orbits in Differential Equations with State-Dependent Delay

Delay-differential equations with a state-dependent delay are inherently nonlinear such that phenomena such as periodic orbits are possible and even likely. I show that periodic orbits are given as roots of a system of smooth algebraic equations. One immediate consequence of this is that the techniques developed for the analysis of the Hopf bifurcation work as expected also in systems with state-dependent delays.

Jan Sieber
University of Portsmouth
Dept. of Mathematics
jan.sieber@port.ac.uk

### CP7

### Cavitation in Tissue under High-Intensity Focused Ultrasound

Micro-bubbles occurring in tissue during heating of tumours by high-intensity focused ultrasound can enhance or inhibit treatment. Thus understanding of the oscillations is essential. The bubbles are modelled as a system of coupled damped driven nonlinear oscillators, whose stability is investigated analytically and numerically. Tissue compressibility leads to a system of state dependent neutral delay differential equations. It found that delays stabilise the system, inhibiting many of the mechanisms which result in unpredictable oscillations.

David Sinden, Eleanor Stride, Nader Saffari
Department of Mechanical Engineering
University College London
d.sinden@ucl.ac.uk, e.stride@ucl.ac.uk, n.saffari@ucl.ac.uk

### CP8

### Computing N-Heteroclinic EtoP Orbits Near Non-Reversible Homoclinic Snaking

Non-reversible homoclinic snaking of a codimension-one homoclinic orbit to an equilibrium is a phenomenon that is known to occur near certain heteroclinic cycles that connect an equilibrium and a periodic orbit (EtoP cycle). It can be shown numerically that there are other connecting orbits in its neighbourhood: N-heteroclinic EtoP connections, which take additional excursions along the original EtoP cycle. We present a method to find and continue them in parameters.

Thorsten Riess
Universitaet Konstanz
thorsten.riess@uni-konstanz.de

### CP8

### On the Numerical Integration of One Nonlinear Parabolic Equation

The author constructs the finite difference scheme to initial-boundary problem to the following nonlinear parabolic equation

$$\frac{\partial U}{\partial t} = \alpha\left(x,\, t,\, U,\, \frac{\partial^2 U}{\partial x^2}\right) + \beta\left(x,\, t\right)\left(\frac{\partial U}{\partial x}\right)^2.$$

For the mentioned scheme the theorems of existence and uniqueness of solution and theorem of its convergence to the solution of source problem are proved.

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

### CP9

### Information Propagation Models and Social Networks

With the rise of social networking platforms such as Facebook and Twitter, it has become easier than ever for rumors to propagate through social networks. Various theoretical frameworks exist to describe the dynamics of information propagation for such systems, but results for these frameworks typically do not agree. This talk will identify the implicit assumptions of some of these frameworks, including a non-autonomous model which takes into account the decaying relevance of the information, with an emphasis on Twitter.

Michael Busch
University of California, Santa Barbara
mbusch@engineering.ucsb.edu

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

### CP9

### Why Ignoring Your Darwinian Fitness May be Adaptive: Evolutionary Dynamics of Movement Strategies in the Presence of Realistic Constraints

Ecological modelers generally assume that organisms tend to move to maximize their fitness. However, it remains unclear what movement mechanisms might actually produce higher fitness. We study a single-species, two-patch habitat selection model (two coupled ordinary differential equations) and compute analytically an optimal conditional movement strategy. We apply tools of adaptive dynamics to show numerically that this strategy is evolutionarily and convergence stable. We demonstrate that higher fitness can be achieved by ignoring fitness-dependent cues.

Theodore E. Galanthay, Samuel Flaxman
University of Colorado
theodore.galanthay@colorado.edu,
samuel.flaxman@colorado.edu

### CP9

### Modelling the Dynamics of Decision-Making on Networks

A dynamical model using an ensemble of coupled active elements with coupling via a network has been studied numerically. The topology of the network and dynamical behavior attributed individual elements can make a big difference to the spread of information on the network. Results will be presented, showing the evolution of interacting individuals on various networks. The results can be interpreted in the context of the decision-making behavior of a market of consumers, for example the diffusion of energy technologies in a social network.

Nick McCullen
School of Mathematics
University of Leeds
N.J.McCullen@leeds.ac.uk

Mikhail Ivanchenko
University of Leeds, UK
Now at University of Nizhny Novgorod, Russia
ivanchen@maths.leeds.ac.uk

Vladimir Shalfeev
Department of Radiophysics,
Nizhny Novgorod University
shalfeev@rf.unn.ru

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

Tim Foxon
School of Earth and Environment,
University of Leeds
t.j.foxon@leeds.ac.uk

William Gale
School of Process, Environmental and Materials Engineering,
University of Leeds
w.f.gale@leeds.ac.uk

### CP10

### Existence and Stability of Symmetric Periodic Sbc Orbits in the Planar Pairwise Symmetric Four-Body Problem

We prove the analytic existence of a symmetric periodic simultaneous binary collision (SBC) orbit in a regularized planar pairwise symmetric equal mass four-body problem. We numerically continue this orbit to unequal masses 1, $m$, 1, $m$ with $0 < m < 1$, and numerically investigate the stability of these orbits. This shows that stability seems to occur when $0.538 \leq m \leq 1$ and instability seems to occur when $0 < m < 0.537$.

Lennard F. Bakker
Brigham Young University
bakker@math.byu.edu

Tiancheng Ouyang
Brigham Young University
Provo, UT 84602
ouyang@math.byu.edu

Duokui Yan
Chern Institute of Mathematics
Nankai University, China
duokuiyan@gmail.com

Skyler Simmons
Brigham Young University
xinkaisen@yahoo.com

### CP10

### Improving Hurricane Forecasts Using Unmanned Aircraft: Motion Coordination in a Strong Flowfield

This talk describes progress on collaborative research that combines mathematical tools from aerospace engineering, data assimilation, and atmospheric science in an effort to improve the accuracy of hurricane forecasts using a fleet of unmanned aircraft. Hurricane-force winds are a major obstacle to multi-aircraft path planning. Existing results for motion coordination often fail to converge in winds that exceed the vehicle speed. This talk introduces preliminary results on feasible trajectories and motion coordination in strong winds.

Levi DeVries, Angela Maki
University of Maryland
Department of Aerospace Engineering
lddevrie@gmail.com, angelamaki618@gmail.com

Doug Koch, Sharan Majumdar
University of Miami
Rosenstiel School of Marine and Atmospheric Science
dkoch@rsmas.miami.edu, majumdar@rsmas.miami.edu

Derek A. Paley
University of Maryland
Department of Aerospace Engineering
dpaley@umd.edu

### CP10

### From Systematic Search to Systematic Proof

IIn dynamical systems, periodic orbits represent a group of important objects to describe the nature of the system. Some authors have developed powerful algorithms to perform a systematic search of p.o. However, those are only numerical approximations. Here we present a Computer Assisted Proof method to produce rigorous results, using interval arithmetic for operations. As result we present rigorous "skeletons' of p.o. for different systems.

Marcos Rodriguez
University of Zaragoza
Universidad de Zaragoza
marcos@unizar.es

Roberto Barrio
University of Zaragoza, SPAIN
rbarrio@unizar.es

### CP12

### Analyzing the Bifurcations of Ergodic Tori Using a Second Poincaré Section

We consider the local bifurcations that can happen to a quasiperiodic orbit in a 3-dimensional map: (a) a torus doubling resulting in two disjoint loops, (b) a torus doubling resulting in a single closed curve with two loops, (c) the appearance of a third frequency, and (d) the birth of a stable torus and an unstable torus. We analyze these bifurcations in terms of the stability of the point at which the closed invariant curve intersects a "second Poincaré section'. We show that these bifurcations can be classified depending on where the eigenvalues of this fixed point cross the unit circle.

Soumitro Banerjee

Indian Institute of Science education & Research,
Kolkata, India
soumitro.banerjee@gmail.com

Damian Giaouris
School of Electrical, Electronic and Computer
Engineering
Newcastle University, UK
damian.giaouris@newcastle.ac.uk

### CP12
### Modelling and Dynamics of Lasers Coupled by a Passive Resonator

The modelling of spatially extended coupled lasers requires an accurate description of the nonlinear interaction of the individual lasers. Here, we decompose the spatiotemporal optical fields into spatial eigenmodes of the entire coupled system. The resulting composite cavity model is $S^1$-symmetric and we describe different methods to reduce this symmetry, without introducing algebraic singularities. This greatly facilitates the use of numerical continuation to study the locking/unlocking transitions of the coupled laser system.

Hartmut Erzgraber, Sebastian M. Wieczorek
University of Exeter
Mathematics Research Institute
h.erzgraber@exeter.ac.uk, s.m.wieczorek@exeter.ac.uk

### CP12
### Multiple Time Scale Dynamics in the Gyorgyi and Field Models of the Belousov-Zhabotinsky Reaction

The Györgyi and Field model $D_{III}$ of the BZ reaction reproduces empirically observed behavior at experimental parameters. Using the methods from multiple time scale dynamics, we show that a delayed/dynamic Hopf bifurcation is responsible for generating the behavior in the models that is observed experimentally. We show that the global return mechanism of the model is associated with trajectories following a family of stable limit cycles of the layer equation.

Christopher J. Scheper
Center for Applied Mathematics
Cornell University
cjs73@cornell.edu

John Guckenheimer
Cornell University
jmg16@cornell.edu

### CP13
### Dynamics of the Data Assimilation Linked Ecosystem Carbon Model (dalec)

The Data Assimilation Linked Ecosystem Carbon model (DALEC) is a relatively simple but effective process based vegetation model, aiming to recreate the carbon cycle of forests. A mathematical analysis of DALEC provides an understanding of the dynamics of the model. We are able to pinpoint value ranges of certain parameters in the model, pertinent to survival of the forest. We also examined the effect of increasing $CO_2$ in the atmosphere and rising temperatures.

Anna M. Chuter
University of Surrey, Guildford, United Kingdom
a.chuter@surrey.ac.uk

### CP13
### The Dynamic Radiation Environment Assimilation Model Project (dream)

DREAM uses Kalman filter like techniques to assimilate space environment measurements with a physics-based model of the radiation belts. Although more general now, DREAM was designed for measurements from instruments on GPS and geosynchronous satellites. Like efforts in ocean and atmospheric science, DREAM uses sparse measurements to estimate the state of a system governed by partial differential equations. From our state estimates, we can calculate the energetic electron environment for other orbits.

Humberto C. Godinez
Los Alamos National Laboratory
Applied Mathematics and Plasma Physics
hgodinez@lanl.gov

Andrew M. Fraser
Los Alamos National Laboratory
andy@fraserphysics.com

### CP13
### Quantifying Uncertainty in Climate Change Science Through Empirical Information Theory

Quantifying the uncertainty for the present climate and the predictions of climate change in the suite of imperfect Atmosphere Ocean Science computer models is a central issue in climate change science. We develop a systematic approach to quantify model errors in the climate models through empirical information theory. Examples with direct relevance to climate change science including the prototype behavior of greenhouse tracer gases are considered.

Boris Gershgorin
Courant Institute
borisg@cims.nyu.edu

Andrew Majda
Courant Institute NYU
jonjon@cims.nyu.edu

### CP14
### Optimal Phase Response Curve for Synchronization of Limit-Cycle Oscillators.

Synchronization phenomena of non-interacting limit-cycle oscillators induced by common noisy signals are analyzed. Poisson impulses and Gaussian white noise are two important cases of the input signals that facilitate such noise-induced synchronization. We obtain the optimal phase response curve of the oscillator for each case, which minimizes the Lyapunov exponent of small phase perturbations. We introduce a class of noisy signal that can be interpolated between the Gaussian and Poisson cases and examine the transition.

Shigefumi Hata

Nonliner Dynamics Group, Department of Physics,
Graduate School of Sciences, Kyoto University
hata@ton.scphys.kyoto-u.ac.jp

Hiroya Nakao
Department of Physics
Kyoto University
nakao@ton.scphys.kyoto-u.ac.jp

### CP14

### Scalable Parallel Physical Random Number Generator Based on a Superluminescent LED

We describe an optoelectronic system for simultaneously generating parallel, independent streams of random bits using spectrally separated noise signals obtained from a single optical source. Using a pair of non-overlapping spectral filters and a fiber-coupled superluminescent light-emitting diode (SLED), we produced two independent 10 Gb/s random bit streams, for a cumulative generation rate of 20 Gb/s. The system relies principally on chip-based optoelectronic components that could be integrated in a compact, economical package.

Xiaowen Li
Institute for Research in Electronics And Applied Physics
University of Maryland
xwli@bnu.edu.cn, xwli@umd.edu

Adam B. Cohen
Institute for Research in Electronics And Applied Physics,
Department of Physics
abcohen@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

### CP14

### Dynamics and Bifurcations of Stochastic Mean-Field Equations

The brain is composed of an extremely large number of neurons with nonlinear dynamics and interactions, and subject to noise. Following the works of McKean, Sznitman, and Tanaka, we rigorously derive a novel Mean-Field equation for the dynamics of infinitely many interacting neurons. In contrast with standard approaches, it is an infinite-dimensional implicit equation on the probability distribution of the solution. We analyze the existence, uniqueness, stability and bifurcations of the solutions of these new equations for standard neuronal models and compare the obtained dynamics to more customary approaches.

Jonathan D. Touboul
Department of Mathematical Physics
The Rockafeller University
jonathan.touboul@inria.fr

### CP15

### On the Origin and Nature of Finite-Amplitude Instabilities in Physical Systems

Finite-amplitude instabilities are ubiquitous, but their theory and precise definitions require clarification. In this work, we discuss the interrelation of various notions connected with finite-amplitude instabilities and offer a precise context for these phenomena. Then we establish a connection between nonnormality of linear operators, energy conservation by nonlinear operators and the existence of finite-amplitude instabilities in finite- and infinite-dimensional dynamical systems, both in the conservative and dissipative cases. This is a joint work with Prof. Jerrold Marsden.

Rouslan Krechetnikov
Department of Mechanical Engineering
University of California at Santa Barbara
rkrechet@engineering.ucsb.edu

### CP15

### Low-Dimensional Models and Anomaly Detection for TCP-like Networks Using the Koopman Operator

Given a family of observables on a TCP-like network, a low-dimensional model is extracted from data by projecting onto the associated eigenmodes of the Koopman operator. It is not guaranteed that these eigenmodes are orthogonal which requires an oblique projection onto this basis, in contrast to a POD-Galerkin approach. The evolution of the model is compared with data and used for anomaly detection.

Ryan Mohr, Igor Mezic
University of California, Santa Barbara
mohrrm@engr.ucsb.edu, mezic@engineering.ucsb.edu

### CP15

### Analytical Time and Frequency Cause-and-Effect Analyses Using Volterra Series

In this lecture, generalized analytical first and second Volterra kernels in time and frequency domains are presented for a nonlinear second order system as a paradigm for many dynamic systems. Step and periodic inputs are also employed to quantify and qualify the nonlinear response characteristics from the system's fundamental components. The proposed analytical solution shows the ability of Volterra-based model to predict and understand the nonlinear system behavior beyond that attainable by linear-based models.

Ashraf Omran, Brett Newman
Old Dominion University
Mechanical and Aerospace Engineering
aomra001@odu.edu, newman@aero.odu.edu

### CP17

### An Arbitrary Stokes Flow in and Around a Liquid Sphere

Stokes flows past liquid spherical boundaries are discussed. In particular, a method of solution to discuss the problem of an arbitrary unsteady Stokes flow past a liquid sphere is presented by employing a recent solution of unsteady Stokes equations. The surface equation of the deformed sphere is determined up to the first order approximation. This method can be extended to study singularity driven

flows inside a liquid sphere.

Sripadmavati Bhavaraju
Department of Mathematics & Statistics,
University of Hyderabad, Hyderabad - 500046, India
bspadmavathi@hotmail.com

**CP17**

**Stirring and Mixing in a Stokes' Flow: Topological Chaos, Almost Invariant Sets, and Lobe Dynamics**

Stretching rate is a well-known measure of chaos that is characteristic of a well-stirred fluid system. However, high stretching rate is not always accompanied by optimal mixing. We consider time-dependent Stokes' flow in a lid-driven cavity as an example system for studying the relationship between stretching and the homogenization of a passive scalar concentration. We explain this relationship using the topology of almost invariant set motions and lobe dynamics.

Mohsen Gheisarieha, Mark Stremler
Virginia Tech
gheisari@vt.edu, stremler@vt.edu

**CP17**

**Low Dimensional Models for Optimal Streaks in the Blasius Boundary Layer**

This talk is concerned with the low dimensional structure of optimal streaks in the Blasius boundary layer. Optimal streaks are well known to exhibit an approximate self-similarity, which consists of the streamwise velocity remains almost independent of both the spanwise wavenumber and the streamwise coordinate. However, the reason of this self-similar behaviour is still unexplained, and this is necessary to identify the low dimensional nature of optimal streaks. After revisiting the structure of the streaks near the leading edge singularity, two additional approximately self-similar relations are identified, which allows the approximate self-similarity description to be completed. Based on these, two low dimensional models are derived with one and two degrees of freedom, respectively. The simpler model provides a description of optimal streaks that is independent of the streamwise stage where optimal streaks are defined, while the two-equations model includes the effect of streamwise position. Both models are consistent and provide good approximations.

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

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

**CP18**

**Effect of Delay in a Lotka-Volterra Type Predator-Prey Model with a Transmissible Disease in the Predator Species**

We consider a system of delay differential equations modeling the predator-prey eco-epidemic dynamics with a transmissible disease in the predator population. The time lag in the delay terms represent the predator gestation period. Threshold values for a few parameters determining the feasibility and stability conditions of some equilibria are discovered and similarly a threshold is identified for the disease to die out. Hopf bifurcations are investigated in the presence of zero and non-zero time lag.

Sabiar Rahaman
Department of Mathematics, SSHS, India
sabiar.rahaman@yahoo.com

Sabuddin Sarwardi
Department of Mathematics, Aliah University, India
sarwardi.ioer@gmail.com

Mainul Haque
University of Nottingham, UK (Malaysia Campus)
pmxmh1@nottingham.ac.uk

**CP18**

**Complexity in a Prey-Predator Delayed Model with Modified Leslie-Gower and Holling-Type II Schemes**

The complex dynamics is explored in a delayed prey predator model with modified Leslie-Gower scheme and Holling type-II functional response. The existence of periodic solutions via Hopf-bifurcation with respect to delay parameters are established. The complex dynamical behavior of the system outside the domain of stability is evident from the exhaustive numerical simulation. The Properties of Hopf bifurcation are also determined using normal form theory and center manifold argument.

Anuraj Singh, Sunita Gakkhar
Department of Mathematics
IIT Roorkee
anurajiitr@gmail.com, sungkfma@iitr.ernet.in

**CP19**

**Hebbian Learning in Hopfield Networks Leads to Reaction-Diffusion Equations on Geometrical Shapes.**

We show that a Hopfield network, coupled to a learning equation (Hebbian with decay), stimulated by a periodic input can be averaged and derived from an energy, which implies convergence of the network connectivity. Then, we interpret the dynamics with fixed weights as an equivalent reaction-diffusion equation on a high dimensional geometrical support prescribed by the inputs. Restricting this geometrical support dimension leads to classical patchy cortical maps observed in the visual cortex, for instance.

Mathieu N. Galtier
INRIA Sophia, NeuroMathComp team
mathieu.galtier@inria.fr

Olivier Faugeras
INRIA Sophia-Antipolis
olivier.faugeras@inria.fr

Paul C. Bressloff
University of Utah and University of Oxford, UK
Department of Mathematics
bressloff@math.utah.edu

**CP19**

**Illusory Persistent States in a Model of Visual Mo-**

**tion Perception**

We explore the solution structure in a model of motion estimation in which the cortical activity is described by coupled integro-differential equations. A fixed-velocity visual stimulus produces coexisting stable solutions, or persistent states, that represent different percepts. Bifurcations of these solutions are related to changes in the way that the visual stimulus can be interpreted. Numerical and analytical tools are applied in order to classify the bifurcation structure in terms of key parameters.

James Rankin, Olivier Faugeras, milien Tlapale, Romain Veltz, Pierre Kornprobst
INRIA Sophia-Antipolis
James.Rankin@inria.fr, olivier.faugeras@inria.fr, emilien.tlapale@inria.fr, romain.veltz@inria.fr, pierre.kornprobst@inria.fr

### CP19
### Patterns of Excitation Waves in Cerebral Cortex

We describe propagating wave patterns in rodent cortex observed by voltage-sensitive dye imaging. Plane/target waves and rotating spiral waves occur frequently during delta dominant state (slow wave sleep) and theta dominated state (rodent REM sleep). Cortex in vivo is forced to oscillate with multiple rhythms generated in thalamus and other structures. Spirals as an emergent organizer of spatiotemporal patterns, can interact with thalamocortically generated rhythms in the cortex, resulting in simplified patterns organized by the rotating wave.

Jian-Young Wu
Georgetown University
Physiology and Biophysics
wuj@georgetown.edu

### CP20
### Phase Oscillator Networks with Star-Like Coupling: Bifurcation Analysis

Although our interest to this subject is inspired by attention modeling, phase oscillator networks may be helpful in neurobiology, physics, etc. A network with a central oscillator (CO) and N peripheral oscillators (POs) is studied. Detailed bifurcation analysis (N=2 and N=3) identifies parametric regions corresponding to different dynamical modes. Conditions for multistable regime of in-phase and antiphase synchronization between the CO and groups of POs are described. Other possible regimes include quasiperiodicity, chimera-like states and chaos.

Oleksandr Burylko
Institute of Mathematics
Ukranian academy of Sciences
burylko@yahoo.co.uk

Yakov Kazanovich
Institute of Mathematical Problems in Biology
Russian Academy of Sciences
kazanovichyakov@gmail.com

Roman M. Borisyuk
School of Computing and Mathematics
University of Plymouth, UK
rborisyuk@plymouth.ac.uk

### CP20
### Dynamical Properties of the Repressilator Model

We study dynamical properties of an artificial regulatory oscillator called repressilator. Oscillations arise from the existence of an absorbing torus-like region in the phase space of the model. This geometric structure requires monotonic repression at all promoters and the absence of any regulatory connections apart from a cyclic repression loop. If the cyclic repression is strong, a pair of diffusively coupled repressilators displays fast synchronization similar to that in relaxation oscillators.

Alexey Kuznetsov
Indiana University-Purdue University Indianapolis
alexey@math.iupui.edu

### CP20
### Sensitivity Analysis of Phase Response Curves

The Phase Response Curve (PRC) has proven a useful tool for the reduction of complex oscillator models to one-dimensional phase models. We introduce the sensitivity analysis of this important mathematical object and its numerical implementation. As an application, we study simple biochemical models of circadian oscillators and discuss how sensitivity analysis helps drawing connections between the state-space model of the oscillator and its phase response curve.

Pierre Sacré
Université de Liege
pierre.sacre@ulg.ac.be

Rodolphe Sepulchre
University of Liege
Belgium
R.Sepulchre@ulg.ac.be

### CP21
### Structural Properties and Models for Multilevel Networks

Many real-life complex systems, such as social or communication networks, can be modeled by using networks with a mesoscaled structure, but until very recently there were no sharp mathematical models to analyze these phenomena. In this talk we will present the metric and structural properties of multilevel networks which are one of the latest models that fit meso-scaled structures and we also give some randomized growing models to produce such objects.

Miguel Romance
Departamento de Matematica Aplicada
Universidad Rey Juan Carlos
miguel.romance@urjc.es

Regino Criado, Julio Flores, Alejandro Garcia del Amo
Universidad Rey Juan Carlos
regino.criado@urjc.es, julio.flores@urjc.es, alejandro.garciadelamo@urjc.es

Jesus Gomez-Gardenes
Universidad de Zaragoza
gardenes@gmail.com

**CP21**

**Unveiling Multi-functional Proteins by Means of the Synchronization Properties of the PPI Network**

By considering the network of the physical interactions between proteins of the yeast together with a manual and single functional classification scheme, we introduce a method able to reveal important information on protein function, at both micro- and macro-scale. In particular, the inspection of the properties of oscillatory dynamics on top of the protein interaction network leads to the identification of misclassification problems in protein function assignments, as well as to unveil correct identification of protein functions. We also demonstrate that our approach can give a network representation of the meta-organization of biological processes by unraveling the interactions between different functional classes.

Irene Sendina-Nadal
University of Rey Juan Carlos, Madrid, Spain
irene.sendina@urjc.es

Yanay Ofran
Bar Ilan University
yanay@ofranlab.org

Juan A. Almendral
University of Rey Juan Carlos
Madrid, Spain
juan.almendral@urjc.es

Javier Buldu
Universidad Rey Juan Carlos
javier.buldu@urjc.es

Inmaculada Leyva
University of Rey Juan Carlos
Madrid, Spain
inmaculada.leyva@urjc.es

Daqing Li
Department of physics
Bar Ilan University
li.daqing.biu@gmail.com

Shlomo Havlin
Bar-Ilan University
havlin@ophir.ph.biu.ac.il

Stefano Boccaletti
CNR-Istituto dei Sistemi Complessi
stefano.boccaletti@isc.cnr.it

**CP21**

**Complex Networks Mesoscopically Characterized by IPO: Courtship Grammar Beyond Chance**

Complex noiseless dynamical systems can be represented in a compressed manner by unstable periodic orbits. This method is extended to describe the similarity of noisy systems. As an application, we consider Drosophila′s precopulatory courtship, for which we reveal the existence of a complex grammar. More specifically, we extract the grammar (or: the automaton) class it belongs to, which points at a power similar to that of human communication.

Ruedi Stoop
Institute of Neuroinformatics ETHZ/UNIZH
Switzerland
ruedi@ini.phys.ethz.ch

**CP22**

**The Iterated Traveler's Dilemma: Seeking Stability in An Unstable Action Space**

The ITD is a two-person, non-zero-sum game that contrasts (i) a unique Nash equilibrium that corresponds to very low payoffs, with (ii) a unique yet highly unstable action pair that maximizes social welfare. By pitting several strategies against one another in a round-robin style tournament, we hope to gain some understanding of the asymptotic behavior of strategy pairs and how competitors can settle into highly lucrative yet unstable points, despite what classical game theory suggests.

Philip Dasler
Department of Computer Science
University of Houston
philip.dasler@gmail.com

Predrag Tosic
University of Houston
ptosic@central.uh.edu

**CP22**

**Prediction of Computer Dynamics**

Building on recent work that establishes that computer systems can be effectively analyzed using a dynamical systems approach, we use time-series methods to forecast processor and memory usage patterns. Even a short-term prediction of these quantities can be effective in tailoring system resources 'on the fly' to the dynamics of a computing application.

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

Elizabeth Bradley
University of Colorado
Department of Computer Science
lizb@cs.colorado.edu

**CP22**

**Statistics of Branched Flow Structure in Optical Media**

Freak waves arise in areas of significant interest such as ocean dynamics and two-dimensional electron gas systems. We find that these exotic waves can occur in optical media with random disorders in the refractive index, and the associated high-intensity distribution follows a power-law. We develop an analytic theory to explain the power-law behavior. The occurrence of freak waves may have implications to metamaterial-based device operations.

Xuan Ni, Wenxu Wang
Electrical Engineering
Arizona State University
xuan.ni@asu.edu, wwang64@asu.edu

Ying-Cheng Lai
Arizona State University
Department of Electrical Engineering

Ying-Cheng.Lai@asu.edu

**CP23**

**A Dynamical Model of the Innate Immune Response in the Lungs**

The immune system of the lungs has many unique features not captured by mathematical models of the general immune system. We propose a set of differential equations that accurately model many of these known features of pulmonary innate immunity and analyze these equations. We show that their solutions have basic dynamical properties which agree with experimental results in the pulmonary immune system.

Richard Buckalew
University of Ohio
rb301008@ohio.edu

Todd Young
Ohio University
Department of Mathematics
youngt@ohio.edu

Erik M. Boczko
Department of Biomedical Informatics
Vanderbilt University Medical School
erik.m.boczko@vanderbilt.edu

**CP23**

**Development of a Model of Human Cardiovascular System and Heart Rate Variability**

We have developed a model of cardiovascular system that includes baroreflex (a sophisticated multi-feedback nonlinear dynamical system), the pulsating heart, and mechanical effect of respiration. The model is parameterized by matching the time dependence and frequency spectrum of heart period produced by the model with experimental data under regular and paced breathing conditions. The parameterization and analysis of the model have been performed by using our software GoSUM (Global Optimization, Sensitivity and Uncertainty in Models).

Vladimir Fonoberov
Chief Scientist
AIMdyn, Inc
vfonoberov@aimdyn.com

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

Marsha Bates
Rutgers University
mebates@rutgers.edu

**CP23**

**Gradient Flow Model for Osmotic Cell Swelling**

A basic model for cell swelling by osmosis is constructed, resulting in a free boundary problem. For radially symmetric initial conditions, this model can be formulated as a gradient flow on a metric by choosing a suitable pair of functional and metric. This particular choice does not require the osmotic force to be included in the formulation explicitly. It appears that this result can be generalized to non-symmetric initial conditions.

Martijn Zaal
VU University Amsterdam
mzl400@few.vu.nl

**CP25**

**A Neutral Theory of Speciation Matching Empirical Diversity**

The number of living species on Earth has been estimated to be between 10 and 100 million. Understanding the processes that have generated such remarkable diversity is one of the greatest challenges in evolutionary biology. We proposed recently a new *topopatric* mechanism of speciation in which a population, with genetically identical individuals homogeneously distributed in space, spontaneously breaks up into species when subjected to mutations and to two mating restrictions: individuals can select a mate only from within a maximum spatial distance S from itself and if the genetic distance from the selected partner is less than a maximum value G. Species develop depending on the mutation rate and on the parameters S and G. The number of species fluctuate in time, reflecting a dynamical balance between extinctions and speciation events. The resulting species-area relationships and abundance distributions are consistent with observations in nature. Finally we consider variations in the topology of the environment, simulating nearly one-dimension geometries (rivers) and rings.

Marcus A. Aguiar
Universidade Estadual de Campinas
aguiar@ifi.unicamp.br

Yaneer Bar-Yam
New England Complex Systems Institute
Cambridge, MA, 02142
yaneer@necsi.edu

Michel Baranger
MIT
Cambridge, MA, 02139
baranger@mailaps.org

Les Kaufman
Boston University
Boston, MA, 02215
lesk@bu.edu

Elizabeth Baptestini
IFGW - UNICAMP
Campinas, SP, Brazil, 13083-970
betinha@ifi.unicamp.br

Ayana Martins
IB - USP
Sao Paulo, SP, Brazil, 05508-090
ayanamartins@gmail.com

**CP25**

**Mesoscale Analysis of Porous Soil Networks**

Porous structure of soils using complex network models based on heterogeneous preferential attachment scheme is presented. Pores are considered as nodes and the links between them are determined by an affinity function that depends on their intrinsic properties. To simulate the soil textures, an application to different real soils is presented.

Analysing these networks at mesoscale level, community structure that depends on the pore size distributions and their spatial location has been found

Rosa M. Benito, Juan Pablo Cardenas, Antonio Santiago, Ana Tarquis, Juan Carlos Losada
Universidad Politecnica de Madrid
rosamaria.benito@upm.es,
jpcardenas.agronomos@upm.es, antonio.santiago@upm.es, anamaria.tarquis@upm.es, juancarlos.losada@upm.es

Florentino Borondo
Universidad Autonoma de Madrid
f.borondo@uam.es

### CP25

**Analysis of the Pattern Formation in Various Models of Hormone Transport**

Abstract not available at time of publication.

Delphine Draelants
Dept. Mathematics and Computer Science
Universiteit Antwerpen, Belgium
delphine.draelants@student.ua.ac.be

### CP26

**Fluctuation Analysis Via Synthetic Diffusion**

Detrended Fluctuation Analysis (DFA) probes signal fluctuations for long range correlations, evidenced by power-law scaling. We show: DFA is intimately related to R/S Analysis, cannot "detrend", exhibits significant bias for short time windows, and the least-squares fitting used to estimate scaling is inefficient and detrimentally affected by the biased region. We demonstrate that standard diffusion measurement is an unbiased equivalent of the heuristic DFA and R/S methods and develop an more efficient weighted least squares scheme.

Robert Bryce
R&D Canada Centre for Operational Research and Analysis
101 Colonel By Drive, Ottawa ON, K1A 0K2, Canada
Robert.Bryce@drdc-rddc.gc.ca

### CP26

**Nonlinearities in Stocks As a Consequence of Socio-Political Events: Classification of Events Triggering Nonlinearity in Stock Exchange**

We propose that socio-political and economical events can be classified using Hinich-Portmanteau-Bicorrelation test with Windowing technique. We use BSE-100 index and KSE-100 index returns data for analysis and it is concluded that magnitude of an event should be considered a measure of impact on stock markets. The present study also reveals market mentality towards a specific event, thus how long a specific trend lasts is an important viewpoint for investors and scientists in the field.

Syed Nasir Danial, Rosheena Siddiqi
Bahria University (Karachi Campus)
snasir.danial@gmail.com, siddiqi.rosheena@gmail.com

### CP26

**Chaotic Fluctuations in Stocks in a Market : Approximating with the Duffing-Oscillator Model**

Speculations combined with supply demand inelasticities may render the commodity system unstable in the face of disturbances. Changes in stocks of agricultural commodities are affected by production responses to price changes and speculations. Such nonlinear interactions incorporating delays in a market may explain the commodity oscillations. We approximate the nature of market conditions and examine the chaos in the time series of yearly fluctuations in stocks of two commodities-rice and wheat with the Duffing-oscillator model. Statistical tests and correlation dimension calculation confirm that the time series is noise free for rice but contaminated for wheat. The time signals obtained by Fourier-periodogram analysis are approximated with the deterministic and stochastic Duffing-oscillator models and the parameters are estimated using an analytical approach (based on harmonic analysis) and a statistical parameter estimation based approach, respectively. In both cases the parameters reflect the market conditions operating for the commodities during the period. We obtain phase portraits and lyapunov exponents of the model for the estimated parameters which show that the behavior is non-chaotic for different driving frequencies in case of rice whereas it may be chaotic for wheat. However the stochastic model reveals the noise in the estimation and confirms that the estimation is much more reliable for rice than wheat. While several methods verify noise-induced transitions to chaos, present work attempts to show that noise renders the estimation unreliable. Exogenous random shocks or simply measurement errors may distort the system dynamics/stability making it appear chaotic. Since chaos is generated endogenously, our results may indicate that interactions between market forces lead to regular behavior in commodity stocks in the absence of random influences. The latter has policy implications and remains a moot issue.

Varsha S. Kulkarni
Indiana University Bloomington
vskulkar@indiana.edu

Raghav Gaiha
University of Delhi
rdg@bol.net.in

### CP27

**Bifurcation and Stability Properties for Asymptotically Asymmetric Slowly Non-Dissipative Equations**

In this talk I will present recent work on bifurcation, stability, and nodal properties for scalar parabolic PDEs of the form $u_t = u_{xx} + b^+u^+ - b^-u^- + g(u)$. I will discuss how the structure of the 3-dimensional bifurcation diagrams and the interconnectedness of the nodal and stability properties of the stationary solutions are key to the extension of global attractor theory to reaction-diffusion equations with jumping nonlinearities.

Nitsan Ben-Gal
Department of Computer Science & Applied Mathematics
The Weizmann Institute of Science
Nitsan.Ben-Gal@weizmann.ac.il

Kristen Moore
University of Michigan
ksmoore@umich.edu

Juliette Hell

Freie Universität Berlin
Institut für Mathematik
jhell@zedat.fu-berlin.de

### CP27

### Existence and Regularity Result for Functional Integrodifferential Equations with Finite Delay Via Fractional Operators: An Application to Bacterial Growth And Multilication .

This work is concerned with the strict solution for partial functional integrodifferential equations with finite delay in a Banach space. The results are obtained by using the resolvent operators and Banch type fixed point theorem, in the context of fractional operators.

Hechmi Hattab
ENIT-LAMSIN - Tunis TUNISIA
hechmi.hattab@lamsin.rnu.tn

### CP27

### Some Applications of Differential Galois Theory in Dynamical Systems

Differential Galois theory is an extension of the classical one to differential equations and it treats the problem on integrability of differential equations by quadratures. In this talk, using the differential Galois theory, we discuss bifurcations of homoclinic orbits and Sturm-Liouville type eigenvalue problems on the infinite interval. Roughly speaking, we give the following results.
Theorem 1. The differential Galois groups for variational equations around homoclinic orbits are triangularizable under some nondegenerate conditions if their saddle-node or pitchfork bifurcations occurs.
Theorem 2. The differential Galois groups for Sturm-Liouville type eigenvalue problems are triangularizable under some nondegenerate conditions if they have a solution. It is a well-known fact in the differential Galois theory that differential equations are integrable by quadratures if their differential Galois groups are triangularizable. Finally, we apply the theory to two examples: bifurcations of pulses in coupled real Ginzburg-Landau equations and spectral stability of a traveling front in the Allen-Cahn equation. Numerical results are also given. This is a joint work with David Blázquez-Sanz of Sergio Arboleda University in Bogota, Colombia.

Kazuyuki Yagasaki
Niigata University
Department of Information Engineering
yagasaki@ie.niigata-u.ac.jp

### CP28

### Lagrangian Coherent Structures in Aerobiological Transport

An emerging application of Lagrangian coherent structures (LCSs) is to aerobiology, specifically the study of biological transport through the atmosphere, where one predicts the motion of fluid-borne microbes whose population structure may be linked with LCSs. We report recent interdisciplinary work in this area, which involves a collaboration of biologists and dynamicists. We also address the issue of accurate prediction of LCSs based on meteorological forecasts, which guides our atmospheric sampling efforts.

Amir E. Bozorgmagham
Virginian tech
aebm@vt.edu

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

David Schmale
Virginia Tech
dschmale@vt.edu

Phanindra Tallapragada
University of North Carolina
tssap@vt.edu

### CP28

### Fast Computations of Lagrangian Coherent Structures in 2 and 3 Dimensions

Lagrangian coherent structures (LCS) offer an appealing tool for analysis of transport and mixing in fluid flows with general time dependence. Much recent work has focused on efficient computations of LCS to reduce the necessary computational time. We present recent work focusing on ridge- and surface-tracking algorithms for fast computations of LCS with applications to several biological and geophysical flows.

Douglas M. Lipinski
University of Colorado at Boulder
lipinskd@colorado.edu

Kamran Mohseni
University of Florida, Gainesville, FL
mohseni@ufl.edu

### CP28

### Invariant Manifolds in Chaotic Advection-Reaction-Diffusion Systems

Invariant manifolds are well known organizing structures in chaotic advection. We consider reaction-diffusion dynamics within a fluid simultaneously undergoing chaotic advection. Prior work demonstrates that such systems generate "burning fronts" with rich structure, including mode locking. We construct invariant manifolds that incorporate the additional reaction-diffusion dynamics. They provide a clear criterion for mode locking and an explanation of the front patterns. We also present results on direct experimental measurements of such manifolds.

John R. Mahoney
University of California, Merced
jmahoney3@ucmerced.edu

Kevin A. Mitchell
Univ of California, Merced
School of Natural Sciences
kmitchell@ucmerced.edu

Tom Solomon
Dept. of Physics and Astronomy
Bucknell University, Lewisburg, PA, USA
tom.solomon@bucknell.edu

### CP29

### Multistability Analysis Via a Lyapunov-Based Ap-

**proach**

This talk focuses on multistability theory for discontinuous dynamical systems having multiple isolated and a continuum of equilibria. Multistability is the property whereby the solutions of a dynamical system alternate between two or more mutually exclusive Lyapunov stable and convergent equilibrium states over time. In this talk, we extend the definition and theory of multistability to discontinuous autonomous dynamical systems. In particular, nontangency Lyapunov-based tests for multistability for discontinuous systems with Filippov and Carathéodory solutions are established. The results are then applied to excitatory-inhibitory biological neuronal networks to explain the underlying mechanism of action for anesthesia and consciousness from a multistable dynamical system perspective.

Qing Hui
Department of Mechanical Engineering
Texas Tech University
qing.hui@ttu.edu

## CP29

### Discontinuity Geometry - An Alternative Way to Analyse Impacting Systems

Periodically-forced impact oscillators may undergo both standard (smooth) bifurcations and grazing bifurcations and it is well-known that under parameter variation there is sometimes a saddle-node bifurcation present in the neighbourhood of a grazing bifurcation and sometimes it is absent. Here we will use discontinuity-geometry to analyse the saddle-node and grazing bifurcation relationship and explain why a saddle-node bifurcation can sometimes be found in the vicinity of a grazing bifurcation and why it sometimes is absent.

Neil Humphries, Petri Piiroinen
School of Mathematics, Statistics and Applied Mathematics
National University of Ireland, Galway
n.humphries1@nuigalway.ie, petri.piiroinen@nuigalway.ie

## CP29

### Non-Smooth Bifurcations in a Sustainable Development Model

Sustainable development in a community plays an important role in environmental and social sciences. Modelling such systems includes coupling of population, ecosystemic, economic and social variables. In our 4-dimensional model we found Hopf, saddle-node bifurcations and chaotic motion. When two such communities are linked in a commerce-exchange scenario, where commerce conditions depend on the state variables, the whole system becomes non-smooth. We found non-smooth bifurcations when the commerce conditions, which depend on parameters, are varied.

Gerard Olivar
Department of Electrical and Electronics Engineering
Universidad Nacional de Colombia, sede Manizales
golivart@unal.edu.co

Jorge Amador
CeiBA Complexity
Universidad Nacional de Colombia, sede Manizales
jaamadorm@unal.edu.co

David Angulo
Department of Electrical and Electronics Engineering
Universidad Nacional de Colombia, sede Manizales
dangulog@unal.edu.co

Hector Granada
Universidad Nacional de Colombia, sede Manizales
hagranadad@unal.edu.co

## CP30

### A Systems-Biology Investigation of Heat-Shock Protein Regulated Gene Networks: Mathematical Models, Predictions and Laboratory Experiments

A mathematical model is proposed of the Heat-shock proteins (which is initiated in all living organisms whenever proteins are damaged by metal stress) regulatory network. We perform a detailed mathematical analysis (including stability, bifurcation and asymptotic studies) and investigate the influence of single and mixed stress (divalent plus trivalent) responses; particularly mixtures of two similar divalent metal ions produce additive effects, whereas mixtures of two dissimilar metals show interfering effects. Laboratory experiments confirm these predictions.

Mainul Haque
University of Nottingham, UK (Malaysia Campus)
pmxmh1@nottingham.ac.uk

John King
University of Nottingham
john.king@nottingham.ac.uk

David dePomarai
School of Biology
University of Nottingham, UK
david.depomerai@nottingham.ac.uk

## CP30

### Analysis and Design of a Versatile Synthetic Network for Inducible Gene Expression in Mammalian Systems

We present a mathematical model for a novel synthetic gene regulatory network. The aim of this circuit is to act as a bistable switch for *in vivo* delivery of short hairpin RNA (shRNA) which can induce RNA interference (RNAi) of a target mRNA. We will show how the circuit can be controlled to induce sustained expression of a shRNA, using the transient input of two different inducer molecules.

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

## CP30

### The Nonlinear Dynamics of Transcription Regulation in Mammalian Timekeeping

Mammalian time-keeping plays a crucial role in coordinating many physiological functions (including but not limited to) sleep, cell cycle, metabolism, and calcium regulation. This master clock is hypothesized to be governed by the Supra-Chiasmatic Nuclei (SCN). Each cell in the SCN is an autonomous oscillator driven by a negative feedback loop involving core clock proteins; inter-cellular coupling mecha-

nisms enables synchronization within this network of cells. Without this synchronization, the SCN cannot properly function. In this talk, we discuss two recent results of nonlinear regulation mechanisms in mammalian time-keeping. We start by exploring a simple model of transcription that results in chaotic behavior in a single cellular oscillator. We then focus attention on a detailed model of SCN cells, with each cell coupled to form a SCN network; we find that varying the level of the BMAL core clock protein acts as a tuning parameter, which determines whether stable oscillations in SCN network will occur. Most surprisingly, these results have been verified by experiments. This talk is the based on joint work with Danny Forger.

Richard Yamada
University of Michigan
yryamada@umich.edu

**CP32**

**Investigating Global Brain States Using Empirical Mode Decomposition Based Weighting Function Analysis and Permutation Based Entropic Measures**

Permutation entropy, a symbolic dynamic measure of fluctuations, is combined with EMD and weighting function analysis to investigate nonlinear and non-stationary dynamical systems. This approach has potentially widespread applicability in the nonlinear sciences, but emphasis here is upon digital recordings of EEG and MEG in human, task free, resting and sleep states. The analyses presented provides new insights into temporal changes in global brain state reflected in the quantitative dynamics of the brain's electromagnetic fields.

John L. Aven
San Diego State University
Department of Mathematics
chaotic_aven@yahoo.com

Arnold Mandell
Cielo Institute
arnoldjosephmandell@gmail.com

Tom Holroyd, Richard Coppola
NIH-NIMH
Core MEG Laboratory
tomh@kurage.nimh.nih.gov, coppolar@mail.nih.gov

**CP32**

**A General Theory of Percolation Thresholds for Networks**

Percolation on networks has applications ranging from epidemic and information spreading to system robustness. Extending previous results restricted to directed or Markovian networks, we introduce a general theory for predicting the percolation threshold based on an analysis of the network adjacency matrix. In addition to its applicability for networks with non-Markovian statistics, our method is easily implemented when the adjacency matrix is known. We illustrate our theory with various examples.

Dane Taylor
Dept. Applied Math
University of Colorado
dane.taylor@colorado.edu

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

**CP32**

**Noise Bridges Dynamical Correlation and Topology in Coupled Oscillator Networks**

We study the relationship between dynamical properties and interaction patterns in complex oscillator networks in the presence of noise. A striking finding is that noise leads to a general, one-to-one correspondence between the dynamical correlation and the connections among oscillators for a variety of node dynamics and network structures. The universal finding enables an accurate prediction of the full network topology based solely on measuring the dynamical correlation. The power of the method for network inference is demonstrated by the high success rate in identifying links for distinct dynamics on both model and real-life networks. The method can have potential applications in various fields due to its generality, high accuracy, and efficiency.

Wenxu Wang
Electrical Engineering
Arizona State University
wwang64@asu.edu

Ying-Cheng Lai
Arizona State University
Department of Electrical Engineering
Ying-Cheng.Lai@asu.edu

Jie Ren, Baowen Li
Department of Physics and Centre for Computational Science
and and Engineering, National University of Singapore
renjie@nus.edu.sg, phylibw@nus.edu.sg

**CP33**

**New Computational Methods for Open Dynamics**

We will present a new class of constrained optimisation based methods for approximating dynamically interesting objects in open systems, including conditionally invariant measures, locally invariant sets and exponential escape rates. We have successfully applied similar methods to the computation of invariant measures for closed systems (Bose and Murray, SIAM J Opt, 2007), but open systems present significant additional difficulties due to non-convexity of the underlying optimisation problems. The talk will introduce approach, describe the theoretical challenges and give a couple of examples.

Rua Murray
Department of Mathematics and Statistics
University of Canterbury, NZ
rua.murray@canterbury.ac.nz

Christopher Bose
Dept Mathematics & Statistics
University of Victoria
cbose@math.uvic.ca

**CP33**

**Recent Advances in Mostly Conjugacy**

Two dynamical systems are considered to be the the same, if there exists a conjugacy between them. This is seldom observed in real world modeling. The past works of Bollt and Skufca, have developed a systematic methodology to compare systems which are not quite conjugate, coining the phrase "mostly conjugacy". We now extend "mostly conjugacy" to stochastically perturbed dynamical systems. We also describe a recent direction, where a Monge Kantarovich approach is adopted.

Rana D. Parshad
clarkson university
rparshad@clarkson.edu

Erik Bollt
Clarkson University
bolltem@clarkson.edu

joe skufca
clarkson univrsity
jskufca@clarkson.edu

Jiongxuan Zheng
Clarkson University
jizheng@clarkson.edu

## CP33

### A Conjecture of Lorenz: Transitive Plus Noninvertible Implies Sensitive

In a 1989 paper, "Computational chaos - a prelude to computational instability," E. Lorenz conjectured that a map with an attractor on which two distinct points mapped to the same image point must be chaotic. He provided a "nonrigorous argument" which did not turn out to lead to a proof. We have precisely formulated and proved his conjecture, imprecisely stated as: a noninvertible map having an invariant set with a dense orbit must exhibit sensitivity to initial conditions. Lorenz was studying how "poorly" Euler's method approximates solutions to a differential equation as the time step is increased. Numerical simulations suggested that a certain two-dimensional map exhibited a noninvertible attractor. Since the conjecture is true, this provides strong evidence of chaos. More generally, this conjecture aids the understanding of a noninvertible route to chaos via the breakup of an invariant circle. It is also related to a noninvertible route to chaos involving the breakup of an invariant circle. We provide a relatively simple proof of this conjecture. The proof requires the addition of a small step to existing results in the literature dating back to Auslander and Yorke [1980], Silverman [1992] and Glassner and Weiss [1993].

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

Garrett Taft
Indiana University - Purdue University Indianapolis
g.t.taft@gmail.com

## CP34

### Feedback Control of Traveling and Standing Waves in the O(2) Equivariant Hopf Bifurcation Problem

The Hopf bifurcation with O(2) symmetry arises naturally in pattern-formation problems posed on one-dimensional spatially periodic domains, and leads to both standing and traveling wave solution branches. We exploit the symmetries of these solutions to design non-invasive feedback controls that can select and stabilize the targeted solution branch, in the event that it bifurcates unstably. If the targeted branch bifurcates subcritically, the feedback involves a time-delay of Pyragas type.

Genevieve Brown
Northwestern University
Genevieve-brown@northwestern.edu

Claire M. Postlethwaite
University of Auckland
c.postlethwaite@math.auckland.ac.nz

Mary C. Silber
Northwestern University
Dept. of Engineering Sciences and Applied Mathematics
m-silber@northwestern.edu

## CP34

### Stabilizing Traveling Waves in the One-Dimensional CGLE Using Spatio-Temporal Feedback Control

We investigate spatio-temporal feedback control of traveling plane wave solutions of the complex Ginzburg-Landau equation in the Benjamin-Feir unstable regime. The feedback, similar to Pyragas control, exploits the symmetry of traveling waves in a natural way. An appropriately chosen time-delayed feedback term, compensated with a spatial shift, stabilizes most of the family of traveling waves. In other instances, a second feedback term that involves only spatial shifts is required. Stability results are confirmed using DDE-BIFTOOL.

Tiffany M. Psemeneki
Northwestern University
tpsem@northwestern.edu

Mary C. Silber
Northwestern University
Dept. of Engineering Sciences and Applied Mathematics
m-silber@northwestern.edu

## CP34

### Partial Control of Chaotic Transients and Escape Times

When we attempt to control a linear system in which some noise has been added, typically we need a control higher or equal to the amount of noise added. When we have a region in phase space where there is a chaotic saddle, all initial conditions will escape from it after a transient with the exception of a set of points of zero Lebesgue measure. The action of an external noise makes all trajectories escape even faster. Attempting to avoid those escapes by applying a control smaller than noise seems to be an impossible task. Here we show, however, that this goal is indeed possible, based on a geometrical property found typically in this situation: the existence of a horseshoe. The horseshoe implies that there exists what we call safe sets, which assures that there is a general strategy that allows one to keep trajectories inside that region with a control smaller than noise. We call this type of control partial control of chaos [Samuel Zambrano, Miguel A. F. Sanjun, and James A. Yorke. Partial Control of Chaotic Systems. Phys. Rev. E 77, 055201(R) (2008), Samuel Zambrano and Miguel A. F. Sanjun. Exploring Partial Control of Chaotic Systems.

Phys. Rev. E 79, 026217 (2009)] that allows one to keep the trajectories of a dynamical system close to the saddle even in presence of a noise stronger than the applied control. In this talk recent progress and new results on this control strategy related to escapes times [Juan Sabuco, Samuel Zambrano, and Miguel A. F. Sanjun. Partial control of chaotic transients and escape times. New Journal of Physics 12, 113038 (2010)] are presented. This is joint work with James A Yorke (USA), Samuel Zambrano and Juan Sabuco (Spain).

Miguel Sanjuan
Department of Physics
Universidad Rey Juan Carlos, Madrid (Spain)
miguel.sanjuan@urjc.es

### CP35

### Pinning of Rotating Waves in Systems with Imperfect So(2) Symmetry

Experiments in small aspect-ratio Taylor-Couette flows have reported the presence of a band in parameter space where rotating waves become steady non-axisymmetric solutions (pinning) via infinite-period bifurcations that previous numerical simulations were unable to reproduce. Here we present numerical simulations that include a small tilt of one of the endwalls, simulating the effects of imperfections that break the $SO(2)$ axisymmetry of the problem, and indeed are able to reproduce the experimentally observed pinning of the rotating waves. A detailed analysis of the corresponding normal form shows that the problem is more complex than expected.

Francisco Marques
Universitat Politecnica de Catalunya
Department of Applied Physics
marques@fa.upc.es

Alvaro Meseguer
Department of Applied Physics
Universitat Politecnica de Catalunya
alvar@fa.upc.edu

Juan M. Lopez
Arizona State University
lopez@math.asu.edu

RAFAEL Pacheco
ASU
rpacheco@math.asu.edu

### CP35

### Interaction of Faraday Waves and Cross-Waves

We examine the connection between Faraday waves, which arise in vertically vibrated systems, and "cross-waves", which are found in horizontally forced systems, by combining vertical and horizontal forcing. Ongoing experiments utilizing two perpendicularly oriented shakers will be described, including the effect on pattern formation of varying the two forcing frequencies, amplitudes, and phases. These results will be compared with theoretical predictions based on an appropriate set of model equations.

Jeff Porter, Ignacio Tinao, Ana Laveron-Simavilla
Universidad Politecnica de Madrid
jeff.porter@upm.es, itinao@eusoc.upm.es, ana.laveron@upm.es

### CP35

### Nonlinear Three-Wave Interactions and Spatio-Temporal Chaos

Three-wave interactions play a key role in pattern formation problems where there are quadratic nonlinearities, such as the Faraday wave experiment. We consider three-wave interactions between two circles of wavevectors, where two modes on either circle can drive one on the other, and show how mutual reinforcement can lead to complex patterns such as quasipatterns and spatio-temporal chaos. We explore the dynamics in a model PDE and in the weakly nonlinear Navier-Stokes equations.

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

Anne Skeldon
University of Surrey
Guildford, UK
a.skeldon@surrey.ac.uk

### CP36

### Manipulating the Excitatory/inhibitory Balance Alters ¡i¿in Vitro¡/i¿ Dynamical Patterns in Neuronal Networks

How are conserved activity patterns altered when the balance between excitation and inhibition is perturbed? Proper balance is essential for normal brain function, including cognitive processing and the representation of sensory information. When the balance is compromised, neurological disorders may result. We use a simple reduced network of cultured hippocampal and striatal neurons to investigate how manipulating this balance affects synchronized bursting activity, the most prominent temporal signature of cultured neural networks.

Rhonda Dzakpasu
Georgetown University
Department of Physics
dzakpasu@physics.georgetown.edu

Xin Chen
Georgetown University
chenxinenator@gmail.com

Mark Niedringhaus
Georgetown University Medical Center
mniedrin@gmail.com

### CP36

### Multi-bump Standing Pulses in a Firing Rate Model

We study standing pulses in a firing rate model with a general class of synaptic couplings and firing rate functions. We present an intrinsic relationship between the underlying integral equation and a class of ODEs. Then by tracking invariant manifolds' passage near a hyperbolic fixed point of the ODE, we establish the existence of N-bump homoclinic orbits that correspond to multi-bump standing pulse solutions of the integral equation. We also analyze the coexistence and bifurcations of the multi-bump standing pulse solutions.

Yixin Guo

Drexel University
Department of Mathematics
yixin@math.drexel.edu

Dennis Guang Yang
Department of Mathematics, Cornell University
gyang@math.drexel.edu

**CP36**

**Effect of Nodal Scale on the Analysis of Whole-Brain Anatomical Networks**

A number of experimental groups have employed MRI and biomagnetic imaging to model brain connectivity in living humans as anatomical networks. However, different studies have used very different numbers of nodes when constructing their network models, and a wide variation in network properties (e.g., small-worldness, path length, and clustering coefficients) has been observed. We present numerical results discussing whether these variations in network properties with node number are associated with the intrinsic anatomical features of brain networks, or instead emerge from more general attributes of networks (not specifically associated with brain anatomy).

Adam S. Landsberg
Claremont McKenna College, Pitzer College, Scripps College
alandsberg@jsd.claremont.edu

Eric Friedman
ORIE
Cornell University
ejf27@cornell.edu

**CP37**

**Spatial Filter and Backward Time Approach of Probabilistic Method to Advection Diffusion Equation**

Advection diffusion equations can be studied using a probabilistic approach to analyze transport of densities. The motion of diffusive particles is given by the Langevin equation $d\vec{X} = \vec{V}dt + \sqrt{2D}\, d\vec{W}$. The solution of the advection equation can be written as an expectation of a functional which is typically evaluated using a monte carlo method. We introduce a new method using backward time integration and spatial averaging. We apply this method to the study of the transport of densities by a perturbed cellular, divergence-free velocity field and small diffusion.

Sophie Loire
University of California Santa Barbara
sloire@engr.ucsb.edu

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

**CP37**

**Amplitude Equations for the Stochastic Ginzburg-Landau Equation**

In this talk, we consider stochastic Ginzburg-Landau or Allen-Cahn equation with degenerate additive noise. Using the natural separation of time-scales near a change of stability, we derive rigorously amplitude equations and their higher order corrections. We show that degenerate additive noise has the potential to stabilize the dynamics of the dominant modes.

Wael W. Mohammed
Phd student
wael.mohammed@math.uni-augsburg.de

Dirk Blömker
Universitat Augsburg
Germany
dirk.bloemker@math.uni-augsburg.de

**CP37**

**A Stochastic Boundary Forcing Model for Simulating Wave Turbulence Systems**

The beta-Fermi-Pasta-Ulam (FPU) model can serve as an example of a discretized wave turbulence system with four-wave nonlinear interactions. We present a stochastic boundary forcing technique for the numerical simulation of a subdomain of a periodic beta-FPU chain, with a view toward modeling the correct time evolution of the energy spectrum more accurately than conventional periodic boundary conditions would.

Warren Towne, Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
townew@rpi.edu, kramep@rpi.edu

Yuri V. Lvov
Rensselaer Polytechnic Institute
lvovy@rpi.edu

**CP38**

**Transient Chaos in a Damped, Undriven System: The Magnetic Pendulum**

Through the example of the magnetic pendulum, we look at the properties of transient behaviour in dissipative, undriven systems. First, we look at the fractality of the basin boundaries of the attractors, in this case, the magnets above which the pendulum stops. We find that fractality depends on the resolution used for the computation, which means that the properties of the boundary are not scale independent. For example, the plot of the time it takes the pendulum to stop vs. the initial conditions shows irregular clusters of sudden jumps. To characterise the behaviour we use finite-scale, time-dependent versions of the usual chaos parameters, like Lyapunov exponents, entropies, dimensions and escape rates. For the escape rate, in particular, we find that it depends exponentially on time. We compare the results with chaotic scattering in Hamiltonian systems, where chaos quantities and fractality are well-defined.

György Károlyi
Budapest University of Technology and Economics
karolyi@tas.me.bme.hu

Tamas Tel
Institute for Theoretical Physics
Etovos University, Hungary
tel@general.elte.hu

Adilson E. Motter
Northwestern University
motter@northwestern.edu

Marton Gruiz
Institute for Theoretical Physics
Eotvos University
gruizmarton@t-online.hu

### CP38

### Phase Control of Escapes and Basin Boundary Metamorphoses

Basin boundary metamorphoses are characteristic in some kinds of chaotic dynamical systems. They take place when one parameter of the system is varied and it passes thorough certain critical value. Previous works shown that this phenomenon involves certain particular unstable orbits in the basin boundary which are accessible from inside one of the basins. In this talk, we show that parametric harmonic perturbations can produce basin boundary metamorphosis in chaotic dynamical systems. The main findings of our research are oriented in both, the study of the fractal dimension of the basin boundaries and in the study of the variation of the area of the basin once we change the value of one suitable parameter [Seoane *et al.* Europhys. Lett. 90, 30002 (2010)]. The physical context of this work is related with the phenomenon of particles escaping from a potential well, which is illustrated by using as prototype model the Helmholtz oscillator [Seoane *et al.* Phys. Rev. E 78, 016205 (2008)]. Finally, Melnikov analysis of the reported phenomenon has also been carried out. This is joint work with S. Zambrano, Inés P. Mariño, and Miguel A. F. Sanjuán. (Spain).

Jesus M. Seoane
Nonlinear Dynamics and Chaos Group.
Universidad Rey Juan Carlos
jesus.seoane@urjc.es

### CP38

### Permutation Complexity of Spatiotemporal Dynamics

In recent years permutation complexity tools has been shown to be a powerful tool for time series analysis. This family of tools makes use of any quantity or functional based on the order relations (permutations) appearing between consecutive elements of a sequence. In this talk we show how these tools can also be applied for the analysis of complex spatiotemporal dynamics. The aim of this analysis is both to characterize that complexity and to discriminate between different types of complex spatiotemporal dynamics. We introduce our ideas making use of Cellular Automata, and we show that our ideas can be used for the analysis of spatiotemporal data from Coupled Map Lattices (CMLs) and of Magneto Encephalograms (MEGs).

Samuel Zambrano
Nonlinear Dynamics and Chaos Group.
Universidad Rey Juan Carlos
samuel.zambrano@urjc.es

José M. Amigó
Universidad Miguel Hernandez
Centro de Investigacion Operativa
jm.amigo@umh.es

Miguel Sanjuán
Universidad Rey Juan Carlos
Departamento de Ciencias de la Naturaleza y Fsica Aplicada
miguel.sanjuan@urjc.es

### CP39

### Border Collision Bifurcations, Organizing Centers, and Continuity Breaking

We investigate bifurcation structures in piecewise-smooth maps and demonstrate under which conditions an intersection of two border collision bifurcation curves in a 2D parameter plane represents an organizing center where an infinite number of periodic orbits emerge. Depending on the local properties of the map on both sides of the boundary, we determine the bifurcation structure formed by these orbits. This problem turns out to be associated with the continuity breaking in a fixed point.

Viktor Avrutin
IPVS
University of Stuttgart
viktor.avrutin@ipvs.uni-stuttgart.de

Laura Gardini
University of Urbino
Department of Economics and Quantitative Methods
laura.gardini@uniurb.it

Albert Granados
IPVS, University of Stuttgart
albert.granados@ipvs.uni-stuttgart.de

Michael Schanz
University of Stuttgart, Germany
michael.schanz@ipvs.uni-stuttgart.de

Iryna Sushko
National Academy of Sciences of Ukraine, Kiev, Ukraine
ira_sushko@hotmail.com

### CP39

### The Moving Average Transformation

We show that the moving average filter can be used as a tool for smoothing non-differentiable flows. Viewing the action of the filter as a change of variables these systems are transformed to ODEs with continuous RHSs which enjoy a (slightly subtle) topological equivalence. This gives us a novel way to understand the complicated topology of a discontinuous flows state space. It also provides a theoretical justification for applying standard analysis to smoothed data when analysing time-series from a non-smooth system.

James L. Hook
University of Manchester
james.hook@postgrad.manchester.ac.uk

### CP39

### Analysis of the Dynamics Near a Degenerate Grazing Point for Rigid Impact Oscillators

In this work we study dynamics of one-dimensional oscillators with rigid fixed impacts. We introduce degenerate grazing points with some order of degeneracy as the points where an orbit touches (grazes) tangent a rigid barrier with zero velocity and zero derivatives of the velocity up to some order. Dynamics of the oscillator near the grazing point is investigated up to some extend.

Gheorghe Tigan, Jeroen Lamb, Oleg Makarenkov
Imperial College London
g.tigan@imperial.ac.uk, jsw.lamb@imperial.ac.uk,

o.makarenkov@imperial.ac.uk

**CP42**

**Dynamically Reorganizing Neural Networks for Stimulus Decorrelation**

The neuronal network that performs the initial processing of odor information in the brain exhibits persistent rewiring even in adult animals. We investigate how such a reorganization allows this network to adapt to decorrelate representations of similar stimuli. Using a simple model in which the survival of the neurons depends on their activity, we investigate the influence of experimentally motivated nonlinear neuronal dynamics on the performance of the network.

Siu Fai Chow
Northwestern University
siuchow2008@u.northwestern.edu

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

**CP42**

**Synchronizing Distant Nodes: A Universal Classification of Time-Delayed Networks**

Stability of synchronization in delay-coupled networks of identical units generally depends in a complicated way on the coupling topology. We show that for large coupling delays synchronizability relates in a simple way to the spectral properties of the network topology. This allows a universal classification of networks with respect to their synchronization properties and solves the problem of complete synchronization in networks with strongly delayed coupling.

Valentin Flunkert
TU Berlin
flunkert@itp.physik.tu-berlin.de

Serhiy Yanchuk
Humboldt University Berlin
yanchik@math.hu-berlin.de

Thomas Dahms
TU Berlin
dahms@physik.tu-berlin.de

Eckehard Schöll
Technische Universität Berlin
Institut für Theoretische Physik
schoell@physik.tu-berlin.de

**CP42**

**Robustness of the Master Stability Function Approach to Network Synhronization**

We consider a typical experimental scenario for a set of dynamical systems that are coupled through a network to achieve synchronization. We analyze a wide range of possible deviations (mismatches) from nominal conditions that may affect simultaneously the individual units' dynamics, the individual units' output functions, and the coupling gains between the systems. We reduce the stability of the synchronous solution in a master stability function form and show that in the case of stability, the mismatches act as forcing terms that maintain the network in a state of approximate synchronization.

Francesco Sorrentino
Universita degli Studi di Napoli Parthenope
francesco.sorrentino@uniparthenope.it

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

**CP43**

**Non-Gaussian Noise and its Effects on Scaling Laws Near Bifurcation Points**

We study noise-induced switching of a system close to bifurcation parameter values where the number of stable states changes. For non-Gaussian noise, the switching exponent, which gives the logarithm of the switching rate, displays a non-power-law dependence on the distance to the bifurcation point. This dependence is found for Poisson noise. Even weak additional Gaussian noise dominates switching sufficiently close to the bifurcation point, leading to a crossover in the behavior of the switching exponent.

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

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

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

**CP43**

**Stochastic Extinction in the Presence of Delayed Feedback**

Extinction processes are stochastic events that occur in many applications of finite populations such as reaction kinetics, population dynamics, and bio-chemical reactions. We consider the problem of stochastic extinction as a rare event occurring in systems with delayed feedback. We derive a general formulation of the probability of extinction, and show analytically and numerically, how delay modulates the exponent of the mean time to extinction in systems with both Gaussian and non-Gaussian noise.

Thomas W. Carr
Southern Methodist University
Department of Mathematics
tcarr@smu.edu

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

Lora Billings

Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

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

**CP43**

**Set-based Corral Control in Stochastic Dynamical Systems**

We consider the problem of stochastic prediction and control in a time-dependent stochastic environment, such as the ocean, where escape from an almost invariant region occurs due to random fluctuations. We determine high-probability control-actuation sets using geometric and probabilistic methods. These methods allow us to design regions of control that provide an increase in loitering time while minimizing the amount of control actuation. Our methods provide an exponential increase in loitering times with only small changes in actuation force. The result is that the control actuation makes almost invariant sets more invariant.

Eric Forgoston, Lora Billings, Philip Yecko
Montclair State University
Dept. of Mathematical Sciences
eric.forgoston@montclair.edu,
billingsl@mail.montclair.edu, yeckop@mail.montclair.edu

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

**CP44**

**Workspace Estimation of Cooperating Robots after Joint Failure**

Remotely operating vehicles must have built-in robustness to failure. We compute the post-failure workspace of two three-link serial robots, where the failure of one robots joint is overcome by another arm grasping the broken link. We present an homotopy continuation algorithm for finding the optimal placement of such synergistic robot arms and the optimal grasp point on the final link of the broken robot. Finally, Monte-Carlo methods are used to estimate the post-failure workspace.

Daniel A. Brake, Vakhtang Putkaradze
Colorado State University
brake@math.colostate.edu, putkarad@math.colostate.edu

Daniel J. Bates
Colorado State University
Department of Mathematics
bates@math.colostate.edu

Anthony Maciejewski
Colorado State University
Electrical and Computer Engineering
aam@colostate.edu

**CP44**

**Equations with Advanced Arguments in a Segway Model**

A study about a very simple Segway model is presented that uses only one accelerometer to balance itself. The output of the controller incorporates both the angular position and the angular acceleration of the Segway's body. Different models of proportional-differential controllers are considered. Analogue controllers with feedback delay result in equations with advanced arguments (infinitely unstable system), while digital controllers provide stable balancing. The structure was manufactured and its stable motion is verified experimentally.

Tamas Insperger
Budapest University of Technology and Economics
Department of Applied Mechanics
inspi@mm.bme.hu

Richard Wohlfart
Budapest University of Technology and Economics
wohl@mm.bme.hu

Janos Turi
University of Texas at Dallas
turi@utdallas.edu

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

**CP44**

**Identification of Nonlinear Characteristics Based on Bistability in Delayed Model of Cutting**

Nonlinear effects in cutting processes described by delay-differential equations result in parameters where chatter occurs together with stable stationary cutting. A measurement is proposed to identify the width of this bi-stable zone as function of chip thickness. The constant width of this unsafe zone corresponds to the classical power law, while a global maximum of the width of this zone may refer to the existence of inflexion and/or asymptote in the cutting force characteristics.

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

Zoltan Dombovari
Department of Applied Mechanics
Budapest University of Technology and Economics
dombo@mm.bme.hu

Jokin Munoa
Ideko Research Alliance IK4
Danobat Group
jmunoa@ideko.es

**CP45**

**A Multicomponent Model for Heterogeneous Biofilms**

Biofilms are common pathogenic bacterial communities typically existing in damp environments. A biofilm forms when bacteria adhere to surfaces in a moist environment by excreting a slimy, glue-like substance called the extracellu-

lar polymeric substance (EPS). Sites for biofilm formation include all kinds of surfaces: natural materials above and below ground, metals, plastics, medical implant materials, even plant and body tissues. Wherever you find a combination of moisture, bacteria, nutrients and a surface, you are likely to find biofilms. Biofilms are a common cause of chronic infection, and the costs associated with the treatment and prevention of biofilm related infections amounts to billions of dollars annually. We develop a tri-component model for biofilm and solvent mixtures, in which the extracellular polymeric substance (EPS) network, bacteria and effective solvent consisting of the solvent, nutrient, drugs etc. are modeled explicitly. The tri-component mixture is assumed incompressible as a whole while inter-component mixing, dissipation, and conversion are allowed. A linear stability analysis is conducted on constant equilibria revealing up to two unstable modes dependent upon the regime of the model parameters. Computational simulations in one and two spatial dimensions are carried out to investigate the nonlinear dynamics of the EPS network, bacteria distribution, drug and nutrient distribution in a channel with and without shear.

Brandon S. Lindley, Qi Wang
University of South Carolina
blindley@nlsleah.nrl.navy.mil, wangq@mailbox.sc.edu

Tianyu Zhang
Mathematics
Montana State University
zhang@math.montana.edu

### CP45

### Stretch-Dependent Proliferation in a One-Dimensional Elastic Continuum Model of Cell Layer Migration

A recently developed mathematical model of cell layer migration based on an assumption of elastic deformation of the cell layer leads to a generalized Stefan problem. The model is extended to incorporate stretch-dependent proliferation, and the resulting PDE system is analyzed for self-similar solutions. The efficiency and accuracy of adaptive finite difference and MOL schemes for numerical solution are compared. We find a large class of assumptions about the dependence of proliferation on stretch that lead to traveling wave solutions.

Tracy L. Stepien
University of Pittsburgh
tls52@pitt.edu

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

### CP45

### Continuum Model of Collective Cell Migration in Wound Healing and Colony Expansion

We derive a two-dimensional continuum mechanical model of cell layer migration that is based on a novel assumption of elastic deformation of the layer and incorporates the force of lamellipodia, the adhesion of cells to the substrate, and the adhesion of cells to each other as well as cell proliferation and apoptosis. The evolution equations, which give rise to a Stefan type problem, are solved numerically using a level set method. The model successfully reproduces data from experiments on the contraction of an enterocyte cell layer during wound healing and the expansion of a colony of MDCK cells.

David Swigon, Julia Arciero
Department of Mathematics
University of Pittsburgh
swigon@pitt.edu, jarciero@pitt.edu

Qi Mi
Department of Sports Medicine and Nutrition
University of Pittsburgh
pittmiqi@gmail.com

### CP45

### Modeling Compressive Nonlinearity of Mammalian Hearing

We introduce a cochlea model with outer hair cell somatic motility as the active process. The model includes longitudinal coupling through the outer hair and the basilar membrane mechanics. We show that introducing inhomogeneity in the feedback strength causes a radical increase of the response above the characteristic frequency. Moreover, combined with strong feedback inhomogeneity induces instability and oscillations that are associated with spontaneous otoacoustic emissions.

Robert Szalai, Alan R. Champneys
University of Bristol
r.szalai@bristol.ac.uk, a.r.champneys@bristol.ac.uk

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

### CP46

### Models of Unidirectional Propagation in Heterogeneous Excitable Media

In this talk nonlinear (ordinary and partial) differential equation models of unidirectional propagation of the action potential in excitable media will be presented. In each case, the parameters are heterogeneous and unidirectional propagation arises from homogeneous initial data. Linear models with similar behavior are analyzed to find the critical parameter regions over which unidirectional propagation may occur. The model behavior is related to reentrant arrhythmias in cardiac tissue.

John G. Alford
Tulane University
jalford@shsu.edu

### CP46

### Bifurcation and Chaotic Dynamics in a Cardiac Model with Memory

In predictions of arrhythmia, restitution is considered as the most important predictor for electrical stability, although cardiac memory is also important. We report a novel prediction model consisting of two separate curves, which was used to simulate memory effect in addition to restitution. Results showed period-doubling bifurcations, conduction block; and importantly, higher order periodicity and chaos similar to ventricular fibrillation, following a seeming return to stability, a feature not predicted by other models.

Linyuan Jing
Center for Biomedical Engineering
University of Kentucky
lji222@uky.edu

Abhijit Patwardhan
Center for Biomdeical Engineering
University of Kentucky
abhijit@uky.edu

### CP46

### Spatiotemporal Dynamics of Calcium-Driven Alternans in Cardiac Tissue

We study a system of continuum coupled maps that models the spatiotemporal dynamics of calcium-driven alternans in cardiac tissue. As calcium instability is increased, we find a first transition from no alternans to smooth traveling waves, followed by a second novel bifurcation from smooth traveling waves to stationary patterns with discontinuous phase reversals. The transition is characterized by phase reversals that occur in a thin boundary layer whose thickness vanishes at the transition point.

Per Sebastian Skardal
University of Colorado at Boulder
skardal@colorado.edu

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

Alain Karma
Northeastern University
Center for Interdisciplinary Research in Complex Systems
alainkarma@gmail.com

### CP47

### Breaking the Symmetry of the Bimodal Kuramoto System

In recent work, the complete bifurcation diagram for the bimodal Kuramoto system was reported. This system is a collection of phase oscillators with a bimodal frequency distribution, connected via global mean-field coupling. We cast this system as a pair of interacting populations in order to make clear a number of symmetries inherent in the original system, and investigate the attractors and bifurcations that arise as these symmetries are broken.

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

Bernard C. Cotton
George Mason University
ebarreto@gmu.edu

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

### CP47

### A Transport Equation for Pulse-Coupled Phase Oscillators and a Lyapunov Function for Its Global Analysis

We consider the continuous limit of an infinite number of pulse-coupled phase oscillators. Under monotonicity assumptions on the phase response curve of the oscillators, we introduce a Lyapunov function that provides a global stabilty analysis of the asynchronous (uniform flux) solution. The proposed Lyapunov function has a natural interpretation of total variation distance between densities. The result is applied to various models, including the continuous limit of LIF oscillators (Peskin model).

Alexandre Mauroy
University of Liège / Montefiore Institute (B28)
Departement of Electrical Engeneering and Computer Science
Alexandre.Mauroy@ulg.ac.be

Rodolphe Sepulchre
University of Liege
Belgium
R.Sepulchre@ulg.ac.be

### CP47

### What Does Thermodynamic Limit Tell Us About Chimera States?

Chimera states are recently discovered spatio-temporal patterns with a surprising dynamical behavior, where a spatially homogeneous system of identical oscillators with identical coupling topologies self-organizes into a spatially intermittent pattern of regions with different synchronous behavior, e.g., with coherent and incoherent motion. The macroscopic dynamics of the chimera state can be explained to a large extent by considering the corresponding thermodynamic limit equation. However, the bifurcation analysis of this equation requires a delicate interpretation as soon as we go back to a finite size system of coupled oscillators.

Oleh Omel'chenko
Weierstrass Institute
omelchen@wias-berlin.de

Matthias Wolfrum
Weierstrass Institute for Applied Analysis and Stochastics
wolfrum@wias-berlin.de

### CP48

### Multiple Phase Locked States in Half-Center Oscillators

We study half-center networks, formed by two endogenously bursting neurons, with fast non-delayed inhibitory connections. We find that fast reciprocal inhibition, known to facilitate anti-phase bursting, can also produce multiple co-existent phase locked states, including stable in-phase bursting. We demonstrate that this phenomenon is general by analyzing different models of fast synapses and bursting cells: leech heart inter-neurons, Sherman pancreatic beta cells and Purkinje neurons. We discuss implications for locomotion and memory storage.

Sajiya Jalil, Igor Belykh
Department of Mathematics and Statistics
Georgia State University

sja_jalil@yahoo.com, ibelykh@gsu.edu

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

**CP48**

**Crawling Without CPG: A Neuromechanical Model**

Locomotion of soft bodied animals is usually achieved by the propagation of contraction/extension waves along the body. The generation of these rhythmic movements has been classically attributed to pattern generation in the nervous systems, but new experimental results seems to contradict this hypothesis. Here we discuss an alternative mechanism where the mechanical properties of the body and the substrate are coupled with simple neuronal dynamics to achieve coordination. Analytical and numerical results are presented, along with a qualitative comparison with data.

Paolo Paoletti, L. Mahadevan
School of Engineering and Applied Sciences
Harvard University
paoletti@seas.harvard.edu, lm@seas.harvard.edu

**CP48**

**A Mechanism of Abrupt Transitions Between Firing Frequency Regimes in Entorhinal stellate Cells**

In this work we investigate the biophysical and dynamic mechanism responsible for the abrupt (threshold-like) transition between theta (4 - 10 Hz) and hyperexcitable ( 60 Hz) firing frequencies in stellate cells (SCs) as the result of an increase in the level of recurrent excitation. Abrupt transitions are not observed in isolated cells as the result of increases in the levels of tonic drive. Differently from other mechanisms of hyper-excitability, there is no bistability involved.

Horacio G. Rotstein
New Jersey Institute of Technology
horacio@oak.njit.edu

Tilman Kispersky
Brandeis University
tilman@brandeis.edu

John White
department of Bioengineering
The University of Utha
john.white@utah.edu

**CP48**

**Astrocyte Mediated Modifications in Functional Neuronal Network Strucutre**

We used a novel clustering algorithm to detect changes in neuronal dynamics elicited by modifications in astrocytic density in cultured neuronal networks. The networks in the high glial group show an increase in global synchronization as the cultures age, while those in the low glial group remain locally synchronized. We additionally quantify the overall synchronization levels present in the cultures and show that the total level of synchronization in the high glial group is stronger than in the low glial group. These results indicate an interdependence between the glial and neuronal networks present in dissociated cultures.

Sarah Feldt
University of Michigan
sarahfel@umich.edu

Jane Wang, Elizabeth Shtrahman
Applied Physics
University of Michgan
janexw@umich.edu, lshtrah@umich.edu

Eva Olariu
Neuroscience Program
University of Michigan
eolariu@umich.edu

Michal Zochowski
Biophysics
University of Michigan
michalz@umich.edu

**CP49**

**Synchronization of Spatiotemporal Chaos in Rayleigh-Bénard Convection**

Synchronization of spatiotemporal chaos in Rayleigh-Bénard convection is studied numerically by imposing the time-dependent boundary conditions from a principal domain onto an initially quiescent target domain. The two convection layers are considered synchronized when they exhibit the same chaotic dynamics. We are interested in identifying a synchronization length scale to quantify the size of chaotic element and in its relationship with the chaotic length scale determined from computations of the fractal dimension.

Alireza Karimi
Department of Engineering Science & Mechanics
Virginia Tech
karimi@vt.edu

Mark Paul
Department of Mechanical Engineering
Virginia Tech
mrp@vt.edu

**CP49**

**Designing a Computing System Based on a Chaotic Dynamical System by Use of Numerical Analysis**

The complex dynamics of chaotic systems can perform computation. Previously the exact dynamical equations of the chaotic system were used to design a computing system. We demonstrate a chaos computing system can also be designed by having only a time series from the underlying chaotic system. We numerically extract unstable periodic orbits and their eigenvalues from the time series, and then determine the functionality of underlying dynamical system and its robustness in doing computation.

Behnam Kia
School of Electrical, Computer and Energy Engineering, ASU
School of Biological and Health Systems Engineering, ASU
bkia1@asu.edu

Mark Spano, William Ditto
School of Biological and Health Systems Engineering
Arizona State University
mark.spano@mac.com, william.ditto@asu.edu

### CP49
### Chaotic Properties in Violin Sounds

Violin sounds show complicated twisted orbits which look like strange attractors. We found that violin sounds have determinism beyond pseudo-periodicity with positive Lyapunov exponents. Poincaré sections of violin sounds show complicated state transitions. Our results show that violin sounds are likely to be of deterministic chaos.

Masanori Shiro
University of Tokyo
mm@shiros.net

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

### CP49
### Length Scale of Interaction in Spatiotemporal Chaos

Extensive systems have no long scale correlations and behave as a sum of their parts. Various techniques are introduced to determine a characteristic length scale of interaction beyond which spatiotemporal chaos is extensive in reaction-diffusion networks. Information about network size, boundary condition or abnormalities in network topology gets scrambled in spatiotemporal chaos, and the attenuation of information provides such characteristic length scales.

Renate A. Wackerbauer, Dan Stahlke
University of Alaska Fairbanks
Department of Physics
ffraw1@uaf.edu, dan@gina.alaska.edu

### CP50
### Chaotic Ionization of Bidirectionally Kicked Rydberg Atoms

A highly excited quasi one-dimensional Rydberg atom exposed to periodic alternating external electric field pulses exhibits chaotic behavior. The ionization of this system is governed by a homoclinic tangle attached to a fixed point at infinity. We present and explain the results from two experiments designed to probe the structure of the phase space turnstile. The first experiment focuses on observing a step-function-like behavior of the ionization fraction as a function of the strength and period of the applied electric field pulses. The second experiment observes the periodic dips in survival probability as a function of the position of the starting electron ensemble in phase space. Both experiments highlight the important role phase space turnstiles play in interpreting the ionization process.

Korana Burke
UC Merced
kburke@ucmerced.edu

Kevin A. Mitchell
Univ of California, Merced
School of Natural Sciences
kmitchell@ucmerced.edu

Barry Dunning, Brendan Wyker, Shuzhen Ye
Rice University
fbd@rice.edu, bwyker@rice.edu, sy9@rice.edu

### CP50
### Quantum Scars in Graphene Billiards

The quasiparticle of graphene behaves like chiral, massless Dirac Fermions in the low energy range, thus the concentrations of wave functions about classical unstable periodic orbits provides a probe for relativistic quantum scars. A number of issues, e.g., geometric symmetry of the billiard, small perturbations, effect of magnetic field, etc., will be discussed. Relation with conductance fluctuation and local magnetic moment generation for corresponding open graphene quantum dots will also be discussed.

Liang Huang
Department of Electrical Engineering
Arizona State University, Tempe, Arizona 85287, USA
liang.huang@asu.edu

Ying-Cheng Lai
Arizona State University
Department of Electrical Engineering
Ying-Cheng.Lai@asu.edu

Celso Grebogi
King's College
University of Aberdeen
grebogi@abdn.ac.uk

David Ferry
Arizona State University
ferry@asu.edu

### CP50
### A New Experimental Probe for Investigating the Dynamics of Relativistic Electrons in Storage Rings

In a storage ring, relativistic electron bunches follow a closed orbit, during typically several hours. When the bunch charge exceeds a threshold, spatio-temporal instabilities occur, leading to rapidly evolving patterns. However these patterns are usually not accessible to observations. Here we use an alternate method, consisting to study the bunch dynamics when it experiences perturbations from laser pulses. The results are compared to numerical simulations and analytic approximations of the underlying Fokker-Planck-Vlasov model.

Christophe Szwaj
Universite de Lille (France)
Laboratoire PHLAM
christophe.szwaj@univ-lille1.fr

**CP50**

**Quantum Chaotic Scattering in Graphene Systems**

We investigate the transport fluctuations in both nonrelativistic quantum dots and graphene quantum dots with both hyperbolic and nonhyperbolic chaotic scattering dynamics in the classical limit. We find that nonhyperbolic dots generate sharper resonances than those in the hyperbolic case. Strikingly, for the graphene dots, the resonances tend to be much sharper. This means that transmission or conductance fluctuations are characteristically greatly enhanced in relativistic as compared to non-relativistic quantum systems.

Rui Yang, Liang Huang
School of Electrical, Computer, and Energy Engineering
Arizona State University, Tempe, AZ 85287, USA
ryang8@asu.edu, liangasu@gmail.com

Ying-Cheng Lai
Arizona State University
Department of Electrical Engineering
Ying-Cheng.Lai@asu.edu

Celso Grebogi
King's College
University of Aberdeen
grebogi@abdn.ac.uk

**CP51**

**Dissipative 3D Vortices, Their Filaments' Tension and Response Functions**

We consider a parametric region in the FitzHugh-Nagumo model where stable alternative scroll wave solutions with different periods exist. We use asymptotics based on response functions to predict filament tension of the scrolls. We find that alternative scrolls can have filament tensions of opposite signs. We confirm these predictions by direct simulations, and also show conversion of alternative vortices into each other by uniform shocks, interaction with boundaries, and curvature of scroll filaments.

Irina Biktasheva
University of Liverpool
ivb@liv.ac.uk

Dwight Barkley
University of Warwick
Mathematics Institute
d.barkley@warwick.ac.uk

Vadim N. Biktashev
University of Liverpool, UK
vnb@liverpool.ac.uk

ANDREW J. Foulkes
University of Manchester, UK
andrew.foulkes@manchester.ac.uk

**CP51**

**Collective Movement of Animals and the Emergence of Territorial Patterns**

We formulate the problem of animal territoriality as a form of collective movement of wandering animals that continuously deposit scent marks and avoid the locations recently marked by other conspecifics. We show that the dynamics of each territory, i.e. the area delimited by the locations where the scent marks of neighbours are present, becomes a 2D exclusion process, and that only two parameters, population density and the active scent time, control how territorial patterns emerge.

Luca Giuggioli
University of Bristol
Bristol Centre for Complexity Sciences
Luca.Giuggioli@bristol.ac.uk

Jonathan Potts, Stephen Harris
University of Bristol
jonathan.potts.08@bristol.ac.uk, s.harris16@talktalk.net

**CP51**

**A New Type of Relaxation Oscillations in a Model for Enzyme Reactions**

We present a geometric analysis of a new type of relaxation oscillations in a model of an enzyme reactions cascade. The model developed by A. Goldbeter describes the mitosis part of the cell division cycle in eukaryotes. We rewrite the model as a three dimensional singularly perturbed system and use a combination of topological and geometric methods (Conley index theory and the blow-up method) to prove the existence of a periodic orbit in the model.

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

Peter Szmolyan
Institut for Applied Mathematics and Numerical Analysis
Vienna University of Technology
szmolyan@tuwien.ac.at

**CP51**

**Stability Analysis of Pulsative Solutions of Legiato-Lefever Equation**

We study the stability and bifurcation of steady states for a certain kind of a damped driven nonlinear Schrodinger equation with cubic nonlinearity and detuning term in one space dimension, mathematically in a rigorous sense. It is known by numerical simulation that the system shows lots of coexisting spatially localized structures as a result of subcritical bifurcation. Since the equation does not have variational structure, unlike the conservative case, we cannot apply a variational method capturing the ground state. Hence, we analyze the equation from a viewpoint of bifurcation theory. In the case of a finite interval, we prove the fold bifurcation of nontrivial stationary solutions around the codimension two bifurcation point of the trivial equilibrium by exact computation of fifthorder expansion on a center manifold reduction. In addition, we analyze the steady-state mode interaction and prove the bifurcation of mixed-mode solutions, which will be a germ of localized structures on finite interval. Finally, we study the corresponding problem on the entire real line by use of spatial dynamics. We obtain a small dissipative soliton bifurcated adequately from the trivial equilibrium. In additon, we will toal about some results in two space dimensional domain. References [1] L. A. Lugiato and R. Lefever, Spatial Dissipative Structures in Passive Optical Systems, Phys. Rev. Lett., 58 (1987), 22092211. [2] T. Miyaji, I. Ohnishi and Y. Tsutsumi, Bifurcation analysis to the Lugiato-Lefever

equation in one space dimension, Physica D, 239 (2010), 20662083. [3] M. Golubitsky, I. Stewart and D. G. Schaeffer, Singularities and Groups in Bifurcation Theory II, Applied Mathematical Sciences, 69, Springer- Verlag, New York (1988).

Tomoyuki Miyaji
Research Institute for Mathematical Sciences,
Kyoto university
tmiyaji@kurims.kyoto-u.ac.jp

Isamu Ohnishi
Hiroshima University
isamu_o@math.sci.hiroshima-u.ac.jp

Yoshio Tsutsumi
Department of Mathematics, Graduate School of Science
Kyoto University
tsutsumi@math.kyoto-u.ac.jp

### CP52

### Control of An Anaerobic Digester Through Normal Form of Fold Bifurcation

Nonlinear dynamics and bifurcations are ubiquitous in engineering systems. Computing the corresponding normal form of a bifurcation close to an operation point, and taking this model as the nominal plant, we design a nonlinear control which takes advantage of the precise bifurcation scenario. This general method is applied to a 4-dimensional anaerobic digester with adaptive control, which shows saddle-node and transcritical bifurcations. Our method has low control effort and error and faster convergence rate.

Gerard Olivar, Fabiola Angulo
Department of Electrical and Electronics Engineering
Universidad Nacional de Colombia, sede Manizales
golivart@unal.edu.co, fangulog@unal.edu.co

Alejandro Rincon
Universidad Nacional de Colombia, sede Manizales
arincons@unal.edu.co

### CP52

### Microwave Chaotic Oscillators Using Time-Delayed Feedback

We describe a nonlinear microwave circuit that uses time-delayed feedback to a voltage-controlled microwave oscillator. We present experimental measurements of the bifurcation diagram, showing dynamical behaviors ranging from periodic to chaotic, depending on the feedback strength. When two such systems were bidirectionally coupled, we observed envelope and phase synchronization between them. The phase synchronization was investigated by applying the Hilbert transform to the measured microwave signals generated by the two synchronized systems.

Hien Dao
Chemical Physics Program
University of Maryland- College park
hiendao@umd,edu

John Rodgers
Institute for Research in Electronics and Applied Physics
University of Maryland- College Park
rodgers@umd.edu

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

### CP52

### Swarm Clustering Arising from Consensus Algorithms

The rendezvous problem is to provide a distributed algorithm that causes a large number of agents to meet at the same location, perhaps under severe communication constraints. If there is a fixed, connected communication network, an averaging algorithm solves the problem; however, if the network changes in time, the averaging algorithm will produce localized clusters of agents. We provided an efficient computational framework to determine the location and relative sizes of clusters in an arbitrary two-dimensional environment with a random initial distribution of agents.

Bruce Rogers
Duke University
bruce@math.duke.edu

### CP52

### Effect of Micro Structure Anisotropy on Dynamically Self Assembled Two Dimensional Structures

We study dynamical self assembly (SA) process in two dimensional space from a topological perspective. Each micro-structure is modeled as an n-fold symmetric disk with distinct sites of attachment. Every pair of active site interacts with a short range potential. We introduce the concept of local minimal structures to study all possible local SA configurations. Our simulations suggest that the edge count generated between a specific pair of active sites is a good observable to quantify topological dominance of one assembly rule over another. We offer a dynamical and thermodynamical insight into the reasons for this.

Gunjan Thakur
Department of Mechanical Engineering
University of California at Santa Barbara
gunjan@engineering.ucsb.edu

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

### CP53

### Stability Analysis for Periodic Waves of a Fourth Order Beam Equation

We consider the periodic waves of a fourth order Beam Equation. We use constrained minimization technique to show the existence of such solutions. We study the spectrum of the linearized operator both analytically and numerically. Based on the linearly unstable modes found in the numerics, we propose a method to show nonlinear instability.

Milena Stanislavova
University of Kansas, Lawrence
Department of Mathematics
stanis@math.ku.edu

Aslihan Demirkaya

University of Kansas, Lawrence
ademirkaya@math.ku.edu

**CP53**

**Bifurcation of Hyperbolic Planforms in a Relation with a Model of Texture Perception**

Motivated by a model for the perception of textures by the visual cortex in primates introduced by Chossat and Faugeras (Hyperbolic planforms in relation to visual edges and textures perception, Plos. Comp. Bio. 2009) and then theoretically studied in Faye-Chossat etal (Some theoretical results for a class of neural mass equation, ArXiv 2010, submitted to the Journal of Mathematical Neuroscience), we analyse the bifurcation of periodic patterns for integro-differential equations describing the state of a system defined on the space of structure tensors, when these equations are further invariant with respect to the isometries of this space. We show that the problem reduces to a bifurcation problem in the hyperbolic plane $D$ (Poincaré disc). We apply the machinery of equivariant bifurcation theory (see Chosst-Faye etal, Bifurcation of hyperbolic planforms, Journal of Nonlinear Science 2010) in order to classify all possible H-planforms satisfying the hypotheses of the Equivariant Branching Lemma. We study separately the 4 dimensional cases as no simple reduction can be made.

Grégory Faye
INRIA Sophia Antipolis France
gregory.faye@sophia.inria.fr

Pascal Chossat
INRIA, Sophia Antipolis, CNRS, ENS Paris, France
CNRS and University of Nice Sophia-Antipolis
chossat@unice.fr

Olivier Faugeras
INRIA Sophia Antipolis France
olivier.faugeras@inria.fr

**CP53**

**Anomalous Thermalization of Nonlinear Wave Systems**

We investigate both theoretically and experimentally the hamiltonian nonlinear propagation of partially-coherent optical waves which is ruled by NLS-type equations. Using wave-turbulence theory, we show that the existence of degenerate resonance conditions leads to an irreversible evolution of the wave systems towards specific equilibrium states of a fundamental different nature than the usual thermodynamic equilibrium distribution; in particular, this new thermodynamic equilibrium does not respect the expected energy equipartition among the modes.

Pierre Suret
Universite de Lille 1
Pierre.Suret@univ-lille1.fr

Claire Michel, H.R. Jauslin, A. Picozzi
Université de Bourgogne
Claire.Michel@u-bourgogne.fr, Hans.Jauslin
@u-bourgogne.fr, Antonio.Picozzi@u-bourgogne.fr

Stephane Randoux
Université de Lille 1
Stephane.Randoux@univ-lille1.fr

**CP54**

**Modelling and Parameters Indentification of Permanent Synchronous Motors**

This paper deals with a dynamic estimator for fully automated parameters indentification of permanent magnet three-phase synchronous motors. High performance application of permanent magnet synchronous motors (PMSM) is increasing. PMSM models with accurate parameters are significant not only for precise control system designs but also in traction applications. Acquisition of these parameters during motor operations is a challenging task due to the inherent nonlinearity of motor dynamics. This paper proposes parameters estimator technique for PMSMs. A dynamic estimator is shown. The estimator uses the measurements of input voltage, current and mechanical angular velocity of the motor, the estimated winding inductance, and resistance to identify the amplitude of the linkage flux. The presented technique is generally applicable and could be used also for the estimation of mechanical load and for other types of electrical motors, as well as for other dynamic systems with nonlinear model structure. Through simulations of a synchronous motor used in automotive applications, this paper verifies the effectiveness of the proposed method in identification of PMSM model parameters and discusses the limits of the found theoretical and the simulation results.

Paolo Mercorelli
University of Applied Sciences Wolfsburg
p.mercorelli@ostfalia.de

**CP54**

**Dynamical Systems in Circuit Designers Eyes**

Recent developments in communication and computer circuits make the dynamical system theory more than ever important to EE designers. At the same time the languages of these two worlds (design and DS theory) remain mutually incomprehensible. This paper aims at diminishing the gap by describing some fairly simple but important circuits from both points of view, in particular it presents successes and limits of state space analysis and presents some open design problems.

Michal Odyniec
NST
USA
m.odyniec@ieee.org

**CP54**

**Satisfiability of Elastic Demand in the Smart Grid**

We study a stochastic model of electricity production and consumption where appliances are adaptive and adjust their consumption to the available production, by delaying their demand and possibly using batteries. The model incorporates production volatility due to renewables, ramp-up time, uncertainty about actual demand versus planned production, delayed and evaporated demand due to adaptation to insufficient supply. We study whether threshold policies stabilize the system. The proofs use Markov chain theory on general state space.

Dan-Cristian Tomozei
Technicolor
dan-cristian.tomozei@epfl.ch

Jean-Yves Le Boudec

EPFL-I&C
jean-yves.leboudec@epfl.ch

**CP54**
**Chaos Control in a Transmission Line Model**

In a transmission line oscillator a linear wave travels along a piece of cable,the transmission line, and interacts with terminating electrical components. Diodes are integrated into almost all electronic devices as a means of protecting the logic circuits from destructive outside signals and high-voltage discharges. In the simple network model that we will present, we show nonlinear and chaotic effects associated with diodes that if transmitted into the primary circuitry will disrupt or possibly damage the device .

Ioana A. Triandaf
Naval Research Laboratory
Plasma Physics Division
triandaf@russel.nrl.navy.mil

**CP55**
**Forecasting Bifurcations for Sensing Applications**

Characterizing bifurcations after they occur is currently possible by a variety of techniques. However, forecasting bifurcations (i.e. predicting them before they occur) is a significant challenge and an important need in several fields, including sensing. A few existing approaches detect bifurcations before they occur by exploiting the critical slowing down phenomenon. However, the perturbations needed in those approaches are limited to very small levels and that represents a significant drawback. Large levels of perturbation have not been used mainly because of a lack of an adequate formulation robust to experimental noise. This presentation provides such a needed formulation, and discusses an approach to predict bifurcations more accurately, especially when the dynamics is far from the bifurcation. Both numerical and experimental results are presented to demonstrate the proposed technique and show its advantages over other prediction methods.

Bogdan I. Epureanu
Department of Mechanical Engineering
University of MIchigan - Ann Arbor
epureanu@umich.edu

**CP55**
**Unfolding the Catastrophe of the Elastic Web of Links**

An axially compressed rod with infinite bending and axial stiffness and finite shear stiffness has one critical point on its trivial equilibrium path. The elastic web of links with $N$ columns can be used as a discrete model of this rod. It has an $(N-1)$-tuple cusp catastrophe at its bifurcation point along the trivial equilibrium path. We will show the discrete model, and how varying shear stiffness or a small bending stiffness disturbs the bifurcation diagram of the discrete system (i.e. the $(N-1)$-tuple cusp catastrophe unfolds to lower order cusp catastrophes).

Róbert K. Németh
Budapest University of Technology and Economics
Department of Structural Mechanics
nemeth.robert@gmx.net

Attila G. Kocsis
Department of Structural Mechanics
Budapest University of Technology and Economics
attila.g.kocsis@gmail.com

**CP55**
**Heteroclinic Breakdown Beyond All Orders in Generic Analytic Unfoldings of the Hopf-Zero Singularity**

A classical problem in the study of the Hopf-zero bifurcation, is to obtain Shilinkov bifurcations in its unfoldings. The first step is to prove that the heteroclinic orbit between the two saddle-focus type equilibrium points, which exists in the normal form up to any order, breaks down. This breakdown makes possible the existence of homoclinic orbits to the equilibrium points. In this talk, we show that this splitting is a "beyond all orders" phenomenon, in the sense that it is exponentially small with respect to the perturbative parameter. Moreover, we provide a formula which measures the distance between the corresponding stable and unstable one dimensional manifolds. We show that, for generic unfoldings, this formula does not agree with the one provided by the classical Melnikov approach. Moreover, the condition which guarantees the splitting of the heteroclinic connection depends of the full jet of the unfolding and can not be checked using classical perturbation theory.

Tere M. Seara
Univ. Politecnica de Catalunya
Tere.M-Seara@upc.edu

Immaculada Baldoma, Oriol Castejon
Universitat Politecnica de Catalunya
immaculada.baldoma@upc.edu, oriol.castejon@upc.edu

**CP55**
**Dynamic Stability of Rigid Objects with Frictional Supports**

Various engineering structures and quasi-static robots are modelled by rigid bodies with frictional contacts. Little is known about the stability of such objects against dynamic perturbations, due to their nonlinear, and discontinuous responses. We present novel sufficient local stability conditions for planar objects on slopes, demonstrate some intriguing properties of the exact stability condition, discuss the role of impact rules, and propose a simple and robust algorithm to stabilize three-dimensional objects on arbitrary terrains.

Peter L. Varkonyi
Budapest University of Technology and Economics
vpeter@mit.bme.hu

David Gontier
Ecole Normale Superieure, Paris
davidgontier@gmail.com

Joel W. Burdick
California Institute of Technology
Department of Mechanical Engineering
jwb@robotics.caltech.edu

**MS1**
**Langmuir Circulation, Mixing, and Instabilities in**

**the Ocean Surface Boundary Layer**

The wind- and surface-wave-driven oceanic boundary layer (BL) is the sight of intense, episodic mixing events mediated by fluid dynamical instability processes. On the scale of the O(100) meter deep BL, a primary mechanism for vertical transport and mixing is Langmuir circulation (LC). Over scales ranging from 1-10 kilometers (the "submesoscales"), upper ocean dynamics are dominated by internal waves and lateral density fronts, which themselves are susceptible to other instability processes (e.g. symmetric instabilities). Here, a combination of linear stability theory, numerical simulations, and multiscale asymptotic analysis is used to investigate the oft-neglected impact of LC on submesoscale mixing and transport phenomena.

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

Ke Li
University of Wisconsin
likekeustc@hotmail.com

Zhexuan Zhang, Ziemowit Malecha
University of New Hampshire
zhexuan.zhang@unh.edu, ziemowitzima@gmail.com

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

**MS1**

**Optimal Stirring for Passive Scalar Mixing**

We address the challenge of optimal incompressible stirring to mix an initially inhomogeneous distribution of passive tracers. As a measure for mixing we adopt the $H^{-1}$ norm of the scalar fluctuation field. This 'mix-norm' is equivalent to (the square root of) the variance of a low-pass filtered image of the tracer concentration field, and is a useful gauge even in the absence of molecular diffusion. We show that the mix-norm's vanishing as time progresses is evidence of the stirring flow's mixing property in the sense of ergodic theory. For the case of a periodic spatial domain with a prescribed instantaneous energy or power budget for the stirring, we determine the flow field that instantaneously maximizes the decay of the mix-norm, i.e., the instantaneous optimal stirring — when such a flow exists. When no such 'steepest descent' stirring exists, we determine the flow that maximizes that rate of increase of the rate of decrease of the norm. This local-in-time stirring strategy is implemented computationally on a benchmark problem and compared to an optimal control approach utilizing a restricted set of flows.

Charles R. Doering
University of Michigan
Mathematics, Physics and Complex Systems
doering@umich.edu

Zhi Lin
University of Minnesota
Institute for Mathematics
& Its Applications
zlin@umn.edu

Jean-Luc Thiffeault
Dept. of Mathematics
University of Wisconsin - Madison
jeanluc@math.wisc.edu

**MS1**

**Internal Trapping of Bodies, Plumes and Jets in a Stratified Fluid: A Theoretical and Experimental Study**

The motion of bodies and fluids moving through a stratified background fluid arises naturally in the context of carbon (marine snow) settling in the ocean, as well as less naturally in the context of the recent gulf oil spill. The details of the settling rates may play a role in assessing the role of the ocean in the earth's carbon cycle. In this lecture, we look at phenomena associated with falling spheres in stratified fluids, and in particular focus upon the critical parameters setting when transient sphere levitation is possible. We present detailed theory for single bodies at both inviscid and viscous extremes, and overview closure models for handling the jet and plume cases. this work is joint with Roberto Camassa

Richard McLaughlin
UNC Chapel Hill
rmm@amath.unc.edu

**MS1**

**Topological Detection of Lagrangian Coherent Structures**

In many applications, particularly in geophysics, we often have fluid trajectory data from floats, but little or no information about the underlying velocity field. The standard techniques for finding transport barriers, based for example on finite-time Lyapunov exponents, are then inapplicable. However, if there are invariant regions in the flow this will be reflected by a 'bunching up' of trajectories. We show that this can be detected by tools from topology.

Jean-Luc Thiffeault
Dept. of Mathematics
University of Wisconsin - Madison
jeanluc@math.wisc.edu

Michael Allshouse
Dept. of Mechanical Engineering
Massachusetts Institute of Technology
mra23@mit.edu

**MS2**

**Many Body Quantum Chaos in Atomic Bose-Einstein Condensates in a Few Well System**

We will investigate signatures of complex transport in the quantum (counting and occupation) statistics, of driven atomic Bose - Einstein Condensates (BEC) in few well optical lattices with multi -path topologies. Then, we will coupled these systems with infinite leads and study their decay and scattering properties. Theoretical tools, borrowed from quantum chaos, such as semiclassics, scaling theory and Random Matrix modeling will be applied, and will allow us to derive predictions beyond those provided by mean-field theories.

Tsampikos Kottos
Wesleyan University

Dept. of Physics
tkottos@wesleyan.edu

**MS2**
**Relativistic Quantum Chaos in Graphene Systems**

Existing works on quantum chaos are concerned almost exclusively with non-relativistic quantum systems described by the Schrodinger equation, where the dependence of the particle energy on the momentum is quadratic. A natural question is whether phenomena in non-relativistic quantum chaos can occur in relativistic quantum systems described by the Dirac equation, where the energy-momentum relation is linear. The speaker will discuss recent results from his group on relativistic quantum chaos in graphene systems: energy-level statistics, scars, chaotic scattering, and stochastic resonance.

Ying-Cheng Lai
Arizona State University
Department of Electrical Engineering
Ying-Cheng.Lai@asu.edu

**MS2**
**Theory of Chaos Regularization of Tunneling**

The previous talk reported the striking numerical discovery that fluctuations of tunneling rates in quantum-dot-type geometries can be orders of magnitude smaller for chaotic systems as compared to otherwise similar integrable systems, even in though, when the fluctuations are averaged over, the two give the identical results. In this talk we give theory explaining these interesting findings, and we test our predictions by quantitative comparison with the numerical results.

Edward Ott
University of Maryland
Inst. for Plasma Research
edott@umd.edu

Ming Jer Lee, Thomas M. Antonsen
University of Maryland
leemj@umd.edu, antonsen@umd.edu

Louis Pecora, Dong-Ho Wu, Hoshik Lee
U.S. Naval Research Laboratory
louis.pecora@nrl.navy.mil, dhwu@ccs.nrl.navy.mil, hoshik.lee@wm.edu

**MS2**
**Chaos Regularization of Quantum Tunneling Rates**

We show that quantum tunneling rates are effected greatly by the shape of the potential wells. Shapes that have regular classical behavior have tunneling rates which can vary by several orders of magnitude. Well shapes that have classically chaotic behavior have narrower ranges of tunneling rates by an order of magnitude or more. This change comes from destabilization of periodic orbits in the regular wells that produce the largest and smallest tunneling rates.

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

**MS3**
**Exact Order Parameter Theory for Patterns and Mode Interactions in Driven Granular Systems**

Starting from the continuum equations of rapid granular flows, we derive the Landau equation to describe nonlinear patterns in granular shear flows using both amplitude-expansion and center-manifold reduction techniques. Unlike previous works, the present order-parameter equation is exact in the sense that there are no fitting parameters. We will discuss the predictions of our nonlinear theory to mimic various patterns as well as its extension for mode interactions in driven granular systems.

Meheboob Alam, Priyanka Shukla
JNCASR, India
meheboob@jncasr.ac.in, grain.jnc@gmail.com

**MS3**
**Analysis of Emerging Structures in Particle Models**

The macroscopic behaviour of microscopically defined particle models are investigated by equation-free techniques. For two examples, pedestrian flow and traffic flow, a numerical bifurcation analysis of macroscopic quantities describing the structure formation in the particle models was performed. The pedestrian flow shows the emergence of an oscillatory pattern of two crowds targeting in opposite directions and passing a narrow door. The traffic flow on a single lane highway shows traveling waves of high density regions.

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

Rainer Berkemer
AKAD Hochschule Stuttgart
rainer.berkemer@akad.de

Olivier Corradi
Technical University of Denmark
olivier.corradi@gmail.com

Poul G. Hjorth
Technical Univ of Denmark
Department of Mathematics
p.g.hjorth@mat.dtu.dk

**MS3**
**A Primer of Swarm Equilibria**

We study equilibria of swarming organisms subject to exogenous and endogenous forces. Beginning with a discrete dynamical model, we derive a variational description of the corresponding continuum population density and find exact solutions for equilibria. Typically, these are compactly supported with jump discontinuities or $\delta$-concentrations at the group's edges. We apply our methods to locust swarms, which are observed in nature to consist of a concentrated population on the ground separated from an airborne group.

Chad M. Topaz
Macalester College
ctopaz@macalester.edu

Andrew J. Bernoff

Harvey Mudd College
Department of Mathematics
ajb@hmc.edu

**MS3**

**Accelerating Agent-Based Computation of Complex Urban Systems**

Despite its popularity, agent-based modeling is critically limited by barriers that constrain its usefulness as an exploratory tool. This is particularly problematic for agent-based models of complex urban systems in which simulation of macroscopic phenomena such as sprawl may take enormous computing time. We introduce two schemes for accelerating simulation of urban sprawl from local drivers of urban growth. The schemes can significantly speed up the complex urban simulations, while maintaining faithful representation of original models.

Yo Zou
Princeton University
yzou@princeton.edu

Roger Ghanem
University of Southern California
Aerospace and Mechanical Engineering and Civil Engineering
ghanem@usc.edu

**MS4**

**Temporal Features in Insect Olfactory System: Dynamics on a Directed Graph**

We study temporal properties of the olfactory system using a network model, reduced to dynamics on a directed graph. We find the features of "dynamic clustering" (in which subsets of cells join in and drop out of synchronous clusters); the divergence of representation of similar odors over time (differentiation) and the convergence of representations of other odors (generalization) in transients and attractors of network dynamics. We explore numerically their dependence on network parameters.

Alla Borisyuk
University of Utah
Dept of Mathematics
borisyuk@math.utah.edu

**MS4**

**Eigenvalues of Graphs**

Graph theory is the study of networks. To a graph, one can associate various matrices such as adjacency matrix, Laplacian or normalized Laplacian matrix. In many situations, the only way we can study key combinatorial parameters of graphs such as edge-distribution, connectivity or expansion, is by using the eigenvalues of these matrices. In this talk, I will describe some of the connections between the structure of graphs and their eigenvalues.

Sebastian Cioaba
University of Delaware at Newark
cioaba@math.udel.edu

**MS4**

**Excitable Networks: Spontaneous Spiking, Synchrony, and Waves**

We study electrically coupled networks of excitable neurons forced by small noise. Using the center manifold reduction, techniques for randomly perturbed dynamical systems, and elements of algebraic graph theory, we derive a variational problem, which provides a clear geometric picture of the network dynamics. In particular, we describe the evolution of spontaneous patterns starting from uncorrelated activity for very weak coupling, and progressing through formation of clusters, and waves, to complete synchrony for stronger coupling.

Georgi S. Medvedev
Drexel University
Department of Mathematics
medvedev@drexel.edu

**MS4**

**Collective Decision Making in the Two-Alternative Forced-Choice Task: A Coupled Stochastic Differential Equations Model**

This talk investigates the effect of coupling among individuals in a collective decision-making scenario, in which the task is to correctly identify a (noisy) stimulus between two known alternatives. Multiple decision-making units, each represented by a Drift-Diffusion Model (DDM), accumulate evidence toward a decision and share evidence with a possibly limited number of neighbors. We show how to assess uncertainty in the process and identify the classes of communication topologies that provide greater decision-making accuracy.

Ioannis Poulakakis
Department of Mechanical Engineering
University of Delaware
poulakas@udel.edu

Luca Scardovi
Institute for Automatic Control Engineering
Technische Universitat Munchen
scardovi@tum.de

Naomi E. Leonard
Princeton University
naomi@princeton.edu

**MS5**

**Mixed Mode Oscillations Underly Bursting in Pituitary Cells**

Pituitary cells of the anterior pituitary gland secrete hormones in response to electrical activity. Several types of pituitary cells produce short bursts of electrical activity which are more effective than single spikes in evoking hormone release. These bursts, called pseudo-plateau bursts, are unlike bursts studied mathematically in neurons. We describe an ongoing mathematical study of pseudo-plateau bursting that links this complex behavior to the existence of canard-induced mixed mode oscillations. With this knowledge, it is possible to determine the region of parameter space where bursting occurs as well as the number of spikes per burst. It is also possible to determine the sensitivity of the bursting to variations in key ionic currents.

Richard Bertram
Department of Mathematics
Florida State University

bertram@math.fsu.edu

**MS5**

**Canard à l'orange: A New Recipe for Multiple Time Scales**

We present a fresh look at phenomena associated with multiple time scale dynamics. In particular, we have a twofold look at the extreme changes of curvature that give rise to canards orbits. First, we pinch away regions of fast dynamics, leaving a system that switches between slow dynamics and slides in the pinched region between. This reveals a link between singular perturbation theory, Filippov's differential inclusions, and nonstandard analysis. Second, we present a criterion to establish whether the conditions for canards exist; namely, based on inflection curves, we derive an upper bound in the time scale ratio for the occurrence of canard explosions.

Mathieu Desroches
University of Bristol
Engineering Mathematics
m.desroches@bristol.ac.uk

Mike R. Jeffrey
University of Bristol
mike.jeffrey@bristol.ac.uk

**MS5**

**Canards and Bifurcation Delays of Spatially Homogeneous and Inhomogeneous Types in Reaction-diffusion Equations**

In ODEs of singular perturbation type, the dynamics of solutions near saddle-node bifurcations of equilibria are rich. Canard solutions can arise, which, after spending time near an attracting equilibrium, stay near a repelling branch of equilibria for long intervals of time before finally returning to a neighborhood of the attracting equilibrium (or of another attracting state). As a result, canard solutions exhibit bifurcation delay. Here, we analyze some linear and nonlinear reaction-diffusion equations of singular perturbation type, showing that solutions of these systems also exhibit bifurcation delay and are, hence, canards. Moreover, it is shown for both the linear and the nonlinear equations that the exit time may be either spatially homogeneous or spatially inhomogeneous, depending on the magnitude of the diffusivity.

Tasso J. Kaper
Boston University
Department of Mathematics
tasso@math.bu.edu

Peter De Maesschalck
Hasselt University
peter.demaesschalck@uhasselt.be

Nikola Popovic
University of Edinburgh
nikola.popovic@ed.ac.uk

**MS5**

**Exploring Torus Canards in a Simple Neuron Model**

Neurons can exhibit a variety of dynamical states, including rapid spiking and bursting. We describe these two states — and their transitions — in a reduced mathematical model of a cerebellar Purkinje cell. We find at the transition a canard phenomenon that follows temporarily a branch of repelling limit cycles. To explore these dynamics, we propose a more abstract mathematical model which captures some fundamental aspects of the canard phenomenon.

Mark Kramer
Department of Mathematics and Statistics
Boston University
mak@bu.edu

**MS6**

**Spread of Avian Influenza in Networks of Wild Bird Migratory Pathways**

Virulent outbreaks of highly pathogenic avian influenza (HPAI) since 2005 have raised the question about the roles of migratory and wild birds in the transmission of HPAI. Despite increased monitoring, the role of wild waterfowl as the primary source of the highly pathogenic H5N1 has not been clearly established. Understanding the entangled dynamics of migration and the disease dynamics is key to prevention and control measures for humans, migratory birds and poultry. Migratory routes of various species can overlap or cross at certain stopover locations, generating complicated network topology and facilitates disease spread from one network to others. This can render some intervention measures targeted at reducing disease spread along one particular migratory path ineffective. In this talk we discuss the formulation of a mathematical model of connected migratory pathways and analyze how the connection between the pathways affects the disease spread patterns and effectiveness of potential control strategies.

Lydia Bourouiba
Department of Mathematics #2-348
Massachusetts Institute of Technology
lydia.bourouiba@math.mit.edu

**MS6**

**Spatiotemporal Distributions of Migratory Birds: Patchy Models with Delay**

We derive and analyze a mathematical model for the spatiotemporal distribution of a migratory bird species. The birds have specific sites for breeding and winter feeding, and usually several stopover sites along the migration route, and therefore a patch model is the natural choice. However, we also model the journeys of the birds along the flyways, and this is achieved using a continuous space model of reaction-advection type. In this way proper account is taken of flight times and in-flight mortalities which may vary from sector to sector, and this information is featured in the ordinary differential equations for the populations on the patches through the values of the time delays and the model coefficients. The seasonality of the phenomenon is accommodated by having periodic migration and birth rates. The central result of the paper is a very general theorem on the threshold dynamics, obtained using recent results on discrete monotone dynamical systems, for birth functions which are subhomogeneous. For such functions, depending on the spectral radius of a certain operator, either there is a globally attracting periodic solution, or the bird population becomes extinct. Evaluation of the spectral radius is difficult, so we also present, for the particular case of just one stopover site on the migration route, a verifiable sufficient condition for extinction or survival in the form of an attractive periodic solution. This threshold is illustrated numerically using data from the U.S. Geological Survey on the bar-headed goose and its migration to India from its main breeding sites around Lake Qinghai and Mongolia.

Rongsong Liu
Deaprtments of Mathematics and Ecology
University of Wyoming
rliu1@uwyo.edu

### MS6

### Impact of Heterogeneity on the Dynamics of SEIR Epidemic Models

An SEIR epidemic model with an arbitrary distributed exposed stage is revisited to study the impact of heterogeneity on the spread of infectious diseases. The heterogeneity may come from the disease stages, spatial positions, and individuals' age or behaviour, resulting in multi-stage, multi-patch, and multi-group models, respectively. For each model, the basic reproduction number $R_0$ is derived and shown to be a sharp threshold: if $R_0 \leq 1$, the disease-free equilibrium is globally asymptotically stable and the disease dies out from all stages, patches, or groups; if $R_0 > 1$, the disease persists in all stages, patches, or groups, and the endemic equilibrium is globally asymptotically stable.

Zhisheng Shuai
Department of Mathematics and Statistics
University of Victoria
zshuai@uvic.ca

### MS6

### Interactions Among Virulence, Coinfection and Drug Resistance in a Complex Life-cycle Parasite

Motivated by recent empirical studies on *Schistosoma mansoni*, we use a mathematical model, which consists of ordinary differential and integral equations, to investigate the impacts of drug treatment of the definitive human host and co-infection of the intermediate snail host by multiple strains of parasites on the evolution of parasites. Through the examination of evolutionarily stable strategies (ESS) of parasites, our study suggests that higher levels of drug treatment rates (which usually tend to promote monomorphism as the evolutionary endpoint) will favor parasite strains that have a higher level of drug resistance and a lower level of virulence. Our study also shows that while co-infection of intermediate hosts does not affect the levels of drug resistance or virulence of parasites at ESS points, it tends to destabilize ESS points and hence promote dimorphism or even polymorphism as the evolutionary endpoint.

Dashun Xu
Southern Illinois University
dxu@math.siu.edu

### MS7

### Stability of Transition Front Solutions in Cahn-Hilliard Systems

We consider the asymptotic behavior of perturbations of transition wave solutions arising in Cahn–Hilliard systems on $\mathbf{R}$. Such equations arise naturally in the study of phase separation, and systems describe cases in which three or more phases are possible. When a Cahn–Hilliard system is linearized about a transition wave solution, the linearized operator has an eigenvalue at 0 (due to shift invariance), which is not separated from essential spectrum. In many cases, it's possible to verify that the remaining spectrum lies on the negative real axis, so that stability is entirely determined by the nature of this leading eigenvalue. In such cases, we identify a stability condition based on an appropriate Evans function, and we verify this condition under strong structural conditions on our equations. More generally, we discuss and implement a straightforward numerical check of our condition, valid under mild structural conditions. Finally, we show that this condition is sufficient to establish nonlinear stability.

Peter Howard
Texas A&M
peter.howard@math.tamu.edu

### MS7

### A Signature-Detecting Evans Function: The Krein Matrix

When considering Hamiltonian eigenvalue problems, it is important to locate those purely imaginary eigenvalues which have negative Krein signature. These are precisely the eigenvalues that can lead to spectral instabilities upon performing some type of parameter continuation in the linear system. The Krein matrix is a real meromorphic matrix of the spectral parameter which is singular precisely at the eigenvalues of the linear system. In this talk I will demonstrate how a careful analysis of the Krein matrix yields information not only regarding the Krein signature of an eigenvalue, but also information regarding which eigenvalues are permitted to interact upon performing parameter continuation. Some open theoretical and practical problems will also be discussed.

Todd Kapitula
Department of Mathematics
Calvin College
tkapitula@gmail.com

### MS7

### The Evans Function and the Weyl-Titchmarsh Function

The Evans function is a Wronskian type determinant which is being used to detect eigenvalues of differential operators that appear when one linearizes partial differential equations about traveling waves or other special solutions. Recently, some intriguing connections have been studied between the Evans function and other tools in spectral theory of differential operators. In this talk we describe relations between the Evans function and the classical Weyl-Titchmarsh function for singular Sturm-Liouville differential expressions and for matrix Hamiltonian systems. Also, we discuss a related issue of approximating eigenvalue problems on the whole line by that on finite segments. Finally, for quite general systems, we discuss a formula for the derivative of the Evans function that uses newly introduced modified Jost solutions.

Yuri Latushkin, Alim Sukhtayev
Department of Mathematics
University of Missouri-Columbia
yuri@math.missouri.edu, aiskff@mail.mizzou.edu

**MS7**

**Asymptotic Linear Stability of Solitary Water Waves**

I will describe a proof (with Shu-Ming Sun) of asymptotic linear stability of small solitary waves for the 2D Euler equations for water of finite depth without surface tension. The result involves spatially weighted norms that quantify a unidirectional scattering property, and is related to proofs of nonlinear stability for solitary waves in non-integrable model systems such as FPU lattices.

Robert Pego
Carnegie Mellon University
rpego@cmu.edu

**MS8**

**Simplifying the Dynamical Description of Complex Stochastic Systems**

In this talk we present several methodological approaches to developing simplified descriptions of the dynamics of complex systems under the influence of noise. We show that these methods are particularly effective when the systems satisfy certain multiscale assumptions.

Lee DeVille
University of Illinois
Department of Mathematics
rdeville@math.uiuc.edu

**MS8**

**Numerical Methods for Stochastic Bio-chemical Reacting Networks with Multiple Time Scales**

Multiscale and stochastic approaches play a crucial role in faithfully capturing the dynamical features and making insightful predictions of cellular reacting systems involving gene expression. Despite their accuracy, the standard stochastic simulation algorithms are necessarily inefficient for most of the realistic problems with a multiscale nature characterized by multiple time scales induced by widely disparate reactions rates. In this talk, I will discuss some recent progress on using asymptotic techniques for probability theory to simplify the complex networks and help to design efficient numerical schemes.

Liu Di
Michigan State University
richardl@math.msu.edu

**MS8**

**Analysis and Numerics for SPDEs with Multiple Scales**

In this talk we will present analytical and numerical techniques for studying stochastic partial differential equations with multiple scales. After showing a rigorous homogenization theorem for SPDEs with quadratic nonlinearities, we present a numerical method for solving efficiently SPDEs with multiple scales. We then apply these analytical and numerical techniques to several examples, including the stochastic Burgers and the stochastic Kuramoto-Shivashinsky equation. This is joint work with D. Blomker and M. Hairer (analysis) and with A. Abdulle (numerical analysis).

Greg Pavliotis
Imperial College London
g.pavliotis@imperial.ac.uk

**MS8**

**Stochastic Similarity Ultimately Emerges from Some Stochastic Reaction, Advection, Diffusion Equations**

Similarity solutions have an important role in many applications—stochastic similarity should also illuminate applications. Here we explore a class of stochastic reaction, advection, diffusion PDEs. By transforming to log-time, algebraic decay of diffusion transforms to exponential attraction of the Gaussian similarity solution. A stochastic slow manifold model is then constructed for dynamics perturbed by small advection, reaction and stochastic forcing. The stochastic slow manifold evolution describes the emergent long time dynamics.

Anthony J. Roberts
University of Adelaide
anthony.roberts@adelaide.edu.au

**MS9**

**Wave Dynamics in Nonlinear Disordered Media - A Coin with Many Faces**

Linear propagation equations for waves in disordered media admit Anderson localization. I will consider cases where all eigenstates of the corresponding wave equations are spatially localized, with a finite upper bound on the localization length. Nonlinear perturbations of the linear equations are often relevant when the wave intensity becomes large. Nonlinear terms couple the normal modes (eigenstates) of the linear equations. I will review and present recent results and conjectures on the longe time evolution of nonlinear waves in disordered media. While the computational data show destruction of Anderson localization over many decades in space and time, various edjucated conjectures are contradicting each other, due to the many faces this rich problem has - e.g. integrability vs. nonintegrability, KAM tori vs. deterministic chaos, strong chaos vs. weak chaos, just to name a few.

Sergej Flach
Max Planck Institute for the Physics of Complex Systems
Dresden
flach@mpipks-dresden.mpg.de

**MS9**

**Emergence of Generalized Gibbs Distribution in Quantum FPU Problem**

We investigate dynamics of quantum mechanical Fermi-Pasta-Ulam model below stochasticity threshold. Quantum fluctuations lead to damping of FPU oscillations and relaxation of the system to a quasisteady state well described by a generalized Gibbs ensemble with individualized temperatures for each momentum mode that are very weakly mixing in time. This ensemble gives accurate descriptions of generic instantaneous correlation functions. We conjecture that GGE generically appears as a prethermalized state in weakly interacting non-integrable systems.

Rafael Hipolito
College of Staten Island and the Graduate Center of
CUNY
rafael.hipolito@csi.cuny.edu

**MS9**

**Scaling of Energy Spreading in Strongly Nonlinear Disordered Lattices**

To characterize a destruction of Anderson localization by nonlinearity, we study the spreading behavior of initially localized states in disordered, strongly nonlinear lattices. Due to chaotic nonlinear interaction of localized linear or nonlinear modes, energy spreads nearly subdiffusively. Based on a phenomenological description by virtue of a nonlinear diffusion equation we establish a one-parameter scaling relation between the velocity of spreading and the density, which is confirmed numerically. From this scaling it follows that for very low densities the spreading slows down compared to the pure power law.

Mario Mulansky
Department of Physics
University of Potsdam, Germany
mulansky@uni-potsdam.de

**MS9**

**Scaling Properties of Weak Chaos in Nonlinear Disordered Lattices**

The Discrete Nonlinear Schroedinger Equation with a random potential in one dimension is studied as a dynamical system. It is characterized by the length, the strength of the random potential and by the field density that determines the effect of nonlinearity. The probability of the system to be regular is established numerically and found to be a scaling function. This property is used to calculate the asymptotic properties of the system in regimes beyond our computational power.

Arkady Pikovsky
Department of Physics
University of Potsdam, Germany
pikovsky@uni-potsdam.de

Shmuel Fishman
Department of Physics
Technion, Haifa, Israel
fishman@physics.technion.ac.il

**MS10**

**Collective Enhancement of Temporal Precision in Networks of Noisy Oscillators**

We propose a theoretical framework to examine the effects of interaction among noisy oscillators on the temporal precision of cycle-to-cycle periods. Our framework is based on a phase model and can deal with arbitrarily directed and weighted networks. We find that the standard deviation of cycle-to-cycle periods scales with network size $N$, given as $1/\sqrt{N}$, but only up to a certain cutoff size. A biological interpretation of this cutoff size is discussed.

Hiroshi Kori
Division of Advanced Sciences
Ochanomizu University
kori.hiroshi@ocha.ac.jp

Yoji Kawamura
The Earth Simulator Center
Japan Agency for Marine-Earth Science and Technology
ykawamura@jamstec.go.jp

Naoki Masuda
The University of Tokyo
Graduate School of Information Science and Technology
masuda@mist.i.u-tokyo.ac.jp

**MS10**

**Collective Phase Response of Macroscopic Rhythms in Coupled Oscillator Ensembles**

Macroscopic rhythms in nature often arise from synchronized ensembles of microscopic oscillators. We develop macroscopic phase description for globally coupled oscillators. Collective phase response of macroscopic rhythms to perturbations is derived from microscopic phase sensitivity of individual oscillators. Based on this framework, macroscopic synchronization between oscillator ensembles due to mutual interaction is analyzed. We demonstrate that the oscillator ensembles can exhibit anti-phase synchronization even if microscopic interaction between individual oscillators is attractive, and vice versa.

Hiroya Nakao
Department of Physics
Kyoto University
nakao@ton.scphys.kyoto-u.ac.jp

Yoji Kawamura
The Earth Simulator Center
Japan Agency for Marine-Earth Science and Technology
ykawamura@jamstec.go.jp

**MS10**

**Complex Dynamics of Oscillator Ensembles after Breakup of Synchrony**

The talk starts with an overview of the topic of minisymposium and continues by the analysis of the collective dynamics in an ensemble of nonlinearly coupled Stuart-Landau oscillators. Synchronized for weak coupling, the ensemble exhibits various regimes of partial synchrony with increase of coupling parameters. In particular, we report a novel quasiperiodic regime which appeares after destruction of synchrony via Hopf bifurcation. We also illustrate this regime by numerical study of globally coupled Hindmarsh-Rose neurons.

Michael Rosenblum
Potsdam University
Department of Physics and Astronomy
mros@uni-potsdam.de

**MS10**

**Non-universal Results in Noise-induced Common Firing in Active Rotators**

We study a system of coupled active-rotators near the excitable regime. It enters a phase of synchronous firing as the diversity (dispersion of the distribution of natural frequencies) increases. The transition is found generically for any distribution with well-defined moments but, singularly, it does not appear for the Lorentzian distribution (widely used in this context for its analytical properties). This warns about the use of Lorentzian-type distributions to understand the generic properties of coupled oscillators.

Raul Toral
Universitat de les Illes Balears
raul@ifisc.uib-csic.es

Luis F. Lafuerza, Pere Colet
IFISC, CSIC-UIB
Palma de Mallorca, Spain
luis@ifisc.uib-csic.es, pere@ifisc.uib-csic.es

**MS11**

**Darboux Integrability–A Historical Survey**

I shall begin this talk a brief historical account of the classical methods for finding closed- form, general solutions to partial differential equations. Recent generalizations of the method of Darboux and the group-theoretic interpretation of this method will be presented and applications to the construction of Bäcklund tranformations described.

Ian Anderson
Utah State University
Department of Mathematics and Statistics
ian.anderson@usu.edu

**MS11**

**Variational Calculus in Invariant Frames**

Variational problems with symmetries can be studied more efficiently by utilizing bases of non-commutative vector fields that are properly adapted to the geometry of a problem. We will discuss some of the aspects of performing variational calculus relative to such frames, including derivation of Euler-Lagrange equations and establishing Noether correspondence between symmetries and conservation laws. Examples from elasticity will be considered.

Irina Kogan
North Carolina State University
iakogan@ncsu.edu

**MS11**

**Higher-Order Variational Integrators Using Prolongation-Collocation**

We propose a novel technique for constructing higher-order variational integrators based on the EulerMaclaurin formula, and collocation at the nodal points using prolongations of the Euler-Lagrange vector field. In contrast to traditional methods for constructing higher-order variational integrators, this yields a numerical solution curve with more regularity at the nodal points, as well as a more explicit relationship between the approximation properties of finite-dimensional function space used and the order of accuracy of the resulting variational integrator. This essentially results in a symplectic two-point Taylor method, which is particularly suitable for applications wherein the solution and its derivatives at the nodal values need to be directly accessible, for example in digital feedback control of mechanical systems.

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

**MS11**

**Invariant Variational Problems and Invariant Flows**

I will introduce the moving frame approach to the analysis of invariant variational problems and the evolution of differential invariants under invariant submanifold flows. Applications will include differential geometric flows, integrable systems, Poisson reduction, and image processing.

Peter Olver
University of Minnesota
School of Mathematics
olver@ima.umn.edu

**MS12**

**Boundaries of Unsteady Lagrangian Coherent Structures**

For steady flows, the boundaries of Lagrangian Coherent Structures are segments of manifolds connected to fixed points. In the general unsteady situation, these boundaries are time-varying manifolds of hyperbolic trajectories. Locating these boundaries, and attempting to meaningfully quantify fluid flux across them, is difficult since they are moving with time. This talk uses a newly developed tangential movement theory to locate these boundaries in nearly-steady compressible flows.

Sanjeeva Balasuriya
Connecticut College
Department of Mathematics
sanjeeva.balasuriya@conncoll.edu

**MS12**

**Transport in Time-dependent Dynamical Systems: Finite-time Coherent Sets and Applications to Geophysical Fluid Flow**

We study the transport properties of nonautonomous chaotic dynamical systems over a finite-time duration. We are particularly interested in those regions that remain coherent and relatively nondispersive over finite periods of time, despite the chaotic nature of the system. We describe a simple methodology that automatically detects maximally coherent sets from singular vectors of a matrix of transitions induced by the dynamics. We illustrate our new methodology on an idealized stratospheric flow and in two- and three-dimensional analyses of European Centre for Medium Range Weather Forecasting ECMWFΛ reanalysis data.

Gary Froyland
University of New South Wales
g.froyland@unsw.edu.au

Naratip Santitissadeekorn
School of Mathematics and Statistics
University of New South Wales
santitn@unsw.edu.au

Adam Monahan
School of Earth and Ocean Sciences
University of Victoria
monahana@uvic.ca

**MS12**

**Lagrangian Coherent Structures: An Overview and Recent Analytic Results**

After a survey of Lagrangian Coherent Structures (LCS), we describe a mathematical theory that clarifies the relationship between LCS in moving continua and invariants of the Cauchy-Green strain tensor field. Motivated by physical observations of trajectory patterns, we define hyperbolic LCS as material surfaces that extremize an appropriate finite-time normal repulsion or attraction measure. Solving this variational problem leads to computable sufficient and necessary criteria for LCS. We also discuss constrained LCS problems, as well as the robustness of LCS under perturbations, such as numerical errors or data imperfection. We finally show applications of the new variational theory to geophysical data sets.

George Haller
McGill University
Department of Mechanical Engineering
george.haller@mcgill.ca

**MS12**

**Coherent Structures and Transport in Transitory Systems**

We consider 2D and 3D transitory systems—those which are nonautonomous only on a compact interval—and present a new method for quantifying transport between past and future coherent structures. Our method applies to exact volume-preserving flows and relies on knowing only the actions of orbits heteroclinic to backward and forward hyperbolic sets. We illustrate our theory with examples including a 2D rotating double gyre and a nonautonomous 3D ABC flow.

Brock Mosovsky
Department of Applied Mathematics
University of Colorado, Boulder
brock.mosovsky@colorado.edu

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

**MS13**

**ECCO – Estimating the Circulation and Climate of the Ocean**

ECCO aims at estimating the ocean circulation and climate, over the last decades. The 4DVAR framework consists of MITgcm and its adjoint. A multitude of insitu and satellite observations ($O(10^9)$) are assimilated, by virtue of atmospheric forcing and ocean mixing adjustments. Initial conditions play a lesser role than in weather forecasting, since forward and adjoint models are integrated over decades without disruption. We will discuss model error accumulation and internal parameter adjustments in this context.

Gael Forget, Patrick Heimbach
MIT
gforget@mit.edu, heimbach@mit.edu

Rui Ponte
AER
rponte@aer.com

Carl Wunsch
MIT
cwunsch@mit.edu

**MS13**

**Correcting Forcing and Stratification Errors in a Estuary System Using an Ensemble Kalman Filter**

An advanced data assimilation system has been set up for the Chesapeake Bay using an ensemble Kalman filter. Unlike atmospheric models, errors in forcing in the Bay dominate the chaotic grown of initial condition errors. Model errors, most importantly over-mixing that leads to reduced stratification, are also important. Experiments show that the assimilation improves the state using an ensemble of forcing fields as well as adaptive inflation techniques to counteract forcing and model errors.

Matthew J. Hoffman
Johns Hopkins University
mjhoffman@jhu.edu

**MS13**

**Non-Gaussian Ensemble Data Assimilation**

Ensemble data assimilation alternately (1) computes an ensemble of model forecasts and (2) adjusts the ensemble toward observed data to initialize the next forecast. Considering the ensemble to represent a Gaussian distribution of model states and assuming Gaussian observation errors yields a reduced-rank approximation to the extended Kalman filter, and to variational data assimilation with quadratic cost function. Relaxing the Gaussian assumption, but retaining a local reduced-rank approximation, allows more general cost functions while maintaining computational efficiency.

Brian R. Hunt
University of Maryland
bhunt@ipst.umd.edu

**MS13**

**Data Assimilation for Cancer Forecasting**

This talk describes some issues and results in applying data assimilation methodology, used in operational weather forecasting, to mathematical models of cancer. I will describe some recent proof-of-concept results that suggest the possibility of making short-term (1-2 month) forecasts of the future growth of malignant brain tumors.

Eric J. Kostelich
Arizona State University
Department of Mathematics
kostelich@asu.edu

**MS14**

**Wave Propagation in Chains of Beads with Hertzian Contacts and the $p$-Schrödinger Equation**

Perturbative methods like modulation equations and local continuation techniques have been used to describe important classes of waves in nonlinear lattices, like solitons, nonlinear normal modes and breathers. Because such approaches require sufficient smoothness and often concern weakly nonlinear waves, their application to uncompressed granular chains is delicate due to Hertz's contact forces. We adapt them to granular chains including Newton's cradle, for which a nonlinear Schrödinger equation with discrete $p$-Laplacian captures many dynamical features.

Guillaume James
Laboratoire Jean Kuntzmann, Université de Grenoble and CNRS
guillaume.james@imag.fr

**MS14**

**Granular Chains: The Binary Collision Approximation**

We generalize the binary collision approximation (BCA) to granular chains with certain geometries in which more than two granules participate in any collision event. This includes certain decorated granular chains in which small granules rattle repeatedly between larger granules, and some random configurations. We also generalize the BCA to describe localized excitations in nonlinear chains in which the particles exhibit attractive as well as repulsive interactions.

Katja Lindenberg
Department of Chemistry and Biochemistry
University of California San Diego, USA
klindenberg@ucsd.edu

Upendra Harbola
University of California San Diego
uharbola@ucsd.edu

Alexandre Rosas
Universidade Federal de Paraiba
arosas@fisica.ufpb.br

A. H. Romero
Cinvestav-Querétaro
aromero@qro.cinvestav.mx

**MS14**

**Tailoring Stress Propagation in Granular Media: Effects of Particle and System Geometry**

We investigate effects of particle and system geometry on the propagation of highly nonlinear solitary waves in granular media. For the particle geometry effect, we study 1D chains composed of ellipsoidal or cylindrical beads. We show that the dynamic behavior of the systems depends on particle shape and angle of orientation between particles. For the system geometry effect, we study Y-shaped systems composed of chains of identical spheres and report the dependence on the branch angles of the wave's properties in two branches.

Duc Ngo
Graduate Aerospace Laboratories
California Institute of Technology
ducngo@caltech.edu

Chiara Daraio
Aeronautics and Applied Physics
California Institute of Technology
daraio@caltech.edu

**MS14**

**Nonlinear Resonance Phenomena in Granular Dimers with no Pre-Compression**

We consider non-compressed granular, dimer chains consisting of pairs of heavy and light beads assuming perfectly elastic Hertzian interaction between beads. A new class of solitary waves, satisfying special symmetry conditions, was discovered for these systems. We show that these solitary waves arise from an infinity of nonlinear resonances in the dimer. Also, we discuss an alternative resonance mechanism that leads to the opposite effect, that is, very efficient shock attenuation in the dimer chain.

Alexander F. Vakakis
Univ of Illinois @ Urbana-Champaign
Dept of Mech/Indust Engineerin
avakakis@uiuc.edu

Yuli Starosvetsky
University of Illinois at Urbana Champaign
1416 Mechanical Engineering Laboratory
staryuli@illinois.edu

K. R. Jayaprakash
University of Illinois at Urbana - Champaign
kalkunt1@illinois.edu

**MS15**

**Random Graphs and Sleep-wake Dynamics**

Sleep and wake states are each maintained by activity in a corresponding neuronal network, with mutually inhibitory connections between the networks. In infants, the durations of both states are exponentially distributed, but the wake states of adults have a heavy-tailed distribution. Is it the altered network architecture or a change in neuronal dynamics that drives the transformed wake distribution? We use random graph theory to explore this issue and the mechanisms of transition between states.

Janet Best
The Ohio State University
Department of Mathematics
jbest@math.ohio-state.edu

Deena Schmidt, Boris Pittel
The Ohio State University
dschmidt@mbi.osu.edu, bgp@math.ohio-state.edu

Mark Blumberg
University of Iowa
Department of Psychology
mark-blumberg@uiowa.edu

**MS15**

**Neural Networks Computing Relaxations of Hard Combinatorial Problems**

We present new models of emergent (global) computation in neural sensor networks. These models process input by comparing a new signal measurement to the signal history statistics stored in pair-wise synaptic couplings. We also explain the relationship between these models and recent spectral relaxation techniques in computer vision and optimization. (Joint work with Kilian Koepsell).

Christopher Hillar
Mathematical Sciences Research Institute
chillar@msri.org

**MS15**

**Connectivity vs. Dynamics in a Simple Model of Neuronal Networks**

For certain neuronal networks the ODE dynamics can be rigorously reduced to a simple discrete-time model $N$ with a finite state space. Probabilistic methods reveal how typical dynamics of $N$ changes with the average in- or out-degree of the connectivity digraph $D$. Two sharp phase transitions were found. For certain types of connectivities $D$ we derived optimal bounds for the possible lengths of the attractors and transients.

Winfried Just
Department of Mathematics
Ohio University
just@math.ohiou.edu

David H. Terman
The Ohio State University
Department of Mathematics
terman@math.ohio-state.edu

Sungwoo Ahn
Department of Mathematical Sciences
Indiana University Purdue University Indianapolis
sahn@math.iupui.edu

**MS15**
**Network Dynamics on Random Graphs**

A fundamental question regarding neural systems is the extent to which network architecture may contribute to the dynamics occurring on the network. We explore this issue by investigating two different stochastic processes on different graph structures, asking how graph structure is reflected in the dynamics of the process. Our findings suggest that memoryless processes are more likely to reflect the degree distribution, whereas processes with memory can robustly produce heavy-tailed distributions regardless of degree distribution.

Deena Schmidt
The Ohio State University
dschmidt@mbi.osu.edu

Janet Best
The Ohio State University
Department of Mathematics
jbest@math.ohio-state.edu

Boris Pittel
The Ohio State University
bgp@math.ohio-state.edu

Mark Blumberg
University of Iowa
Department of Psychology
mark-blumberg@uiowa.edu

**MS16**
**Influence of Sensory Feedback on Central Pattern Generation During Stepping Dynamics Near An Oscillatory Domain**

Recent experiments have supplied key data on the impact afferent excitation has on the activity of the levator-depressor motor system in the stick insect. The main finding was that local sensory feedback can completely overrule inter-leg neuronal influences on the level of this distal leg joint. Here, we introduce a neuronal network model of this motor system and use it to elucidate the mechanisms that underlie the neuronal activity seen in the experiments.

Silvia Gruhn, Tibor Toth
Biocentre
University of Cologne
sgruhn@uni-koeln.de, tibor.i.toth@gmail.com

**MS16**
**Phase Resetting Properties of Half-Center Oscillators**

Half-center oscillators (HCOs) are the fundamental units of many pattern generating neuronal networks, including the circuit underlying locomotion in crayfish. HCOs are composed of two reciprocally inhibitory cells that fire in anti-phase. The anti-phase activity can be generated through two mechanisms: escape or release. We show that these two mechanisms give rise to very different phase resetting properties of HCOs and therefore they can lead to distinct phase-locking dynamics in networks of HCOs.

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

Jiawei Zhang
University of California, Davis
jwzh@ucdavis.edu

**MS16**
**Pattern-generating Neurons and Pattern-generating Circuits: Phenomena, Signficance, and Problems for Analysis**

Nervous systems have encoded in their structures the information required to drive complex natural behaviors, but the forms this information takes are not obvious and their dynamics are not well understood. I will present examples of pattern-generation by single neurons, by local neural circuits, and by distributed systems of these local circuits. As the complexity of a system under study increases, our ability to analyze its dynamics rigorously using physical laws erodes. This opens the field to new mathematical approaches to analysis of these pattern-generating systems, and possibilities for finding new rules of these systems organization.

Brian Mulloney
University of California Davis
bcmulloney@ucdavis.edu

**MS16**
**CPGs and Stability of Locomotion: How Neural Feedback Enhances Cockroach Running**

We have developed an integrated model for insect locomotion that includes a central pattern generator, nonlinear muscles, hexapedal geometry and a representative proprioceptive sensory pathway. We employ phase reduction and averaging theory to reduce complexity, arising from the number of neurons, muscles, joints and legs. The reduced order model allows for analysis of aspects of cockroach locomotion such as maneuverability, reflexive feedback, and stability against perturbations.

Joshua Proctor
Princeton University
jproctor@princeton.edu

Philip Holmes
Princeton University
Program in Applied and Computaional Mathematics &

MAE Dept
pholmes@math.princeton.edu

### MS17
### Periodic Motions and their Classical Invariants in Quantum Chaos

Poincaré unveiled the existence of chaos in dynamical systems, and demonstrated the importance of periodic orbits, and its homoclinic and heteroclinic connections, in the hierarchical organization of phase-space. Later Heller published his seminal work on scar theory showing the importance of POs in quantum dynamics. Using a novel technique to construct scarred wavefunctions, we show that the information concerning the associated invariant (homoclinic and heteroclinic motions and Lazutkin angle) is also contained in the system quantum mechanics.

Florentino Borondo
Universidad Autonoma de Madrid
f.borondo@uam.es

### MS17
### How Well Can One Resolve the State Space of a Chaotic Flow?

All physical systems are affected by some noise that limits the resolution that can be attained in partitioning their state space. For chaotic, locally hyperbolic flows, this resolution depends on the interplay of the local stretching/contraction and the smearing due to noise. Our goal is to determine the 'finest attainable' partition for a given hyperbolic dynamical system and a given weak additive white noise. That is achieved by computing the local eigenfunctions of the Fokker-Planck evolution operator in linearized neighborhoods of the periodic orbits of the corresponding deterministic system, and using overlaps of their widths as the criterion for an optimal partition. The Fokker-Planck evolution is then represented by a finite transition graph, whose spectral determinant yields time averages of dynamical observables. The method applies in principle to both continuous- and discrete-time dynamical systems. Numerical tests of such optimal partitions on unimodal maps support our hypothesis.

Predrag Cvitanovic, Domenico Lippolis
Center for Nonlinear Science
Georgia Institute of Technology
predrag@gatech.edu, domenico@cns.gatech.edu

### MS17
### Periodic Orbits and Transport in Mixed Phase Spaces

Though the transport properties of chaotic systems are computable from periodic orbits, in practice, such computations are easiest to realize in sufficiently hyperbolic systems dominated by short orbits. Phase spaces exhibiting a mixture of chaos and regularity, however, present a greater challenge, owing to the richer topological dynamics in the vicinity of stable islands and the importance of longer orbits. We demonstrate how, using a sufficiently accurate symbolic dynamics, periodic orbit techniques can compute classical decay rates even in a strongly mixed phase space.

Kevin A. Mitchell
Univ of California, Merced
School of Natural Sciences
kmitchell@ucmerced.edu

### MS17
### Bunching of Periodic Orbits and Universality in Quantum Chaos

Long periodic orbits of hyperbolic dynamics do not exist as independent individuals but rather come in closely packed bunches. Under weak resolution a bunch looks like a single orbit in configuration space, but close inspection reveals topological orbit-to-orbit differences. The construction principle of bunches involves close self-"encounters" of an orbit wherein two or more stretches stay close. The orbit-to-orbit action differences $\Delta S$ within a bunch can be arbitrarily small. Bunches with $\Delta S$ of the order of Planck's constant have constructively interfering Feynman amplitudes for quantum observables. This constructive interference has profound implications for the quantum properties of classically chaotic systems. In particular it determines the statistics of the energy levels of chaotic systems and explains why the correlation functions describing these statistics have a universal form. Closely related interference mechanisms between open trajectories determine the conductance and other transport properties of chaotic cavities. In my talk I will give an overview over recent research into these phenomena.

Alexander Altland
University of Cologne
alexal@thp.uni-koeln.de

Petr Braun, Fritz Haake
Universitaet Duisburg-Essen
braoun@gmx.de, fritz.haake@uni-due.de

Stefan Heusler
Universitaet Muenster
stefanheusler@gmx.de

Sebastian Mueller
University of Bristol
School of Mathematics
sebastian.muller@bristol.ac.uk

### MS18
### Pandemic Influenza Vaccination Timing in a Population Dynamical Model

We present a compartmental epidemic model, extended to capture age structure and transmission network dynamics, representing the Greater Vancouver Regional District (population 2 million). Using our model we evaluate the efficacy of pH1N1-influenza vaccination campaigns initiated between mid-July/late-November 2009 in terms of infections and deaths averted. We consider three vaccine-distribution strategies differing in age-specific coverage and show that having a good estimate of epidemic peak timing is critical when making policy decisions on vaccination strategies.

Jessica M. Conway
University of British Columbia
Department of Mathematics
conway@math.ubc.ca

Ashleigh Tuite
Dalla Lana School of Public Health
University of Toronto

ashleigh.tuite@utoronto.ca

Rafael Meza
UBC Centre for Disease Control
Division of Mathematical Modeling
Rafael.Meza@bccdc.ca

Babak Pourbohloul
University of British Columbia
babak.pourbohloul@bccdc.ca

### MS18

### Stochastic Effects in Infection Dynamics: Simulations and Analytical Models

In this talk, we will discuss the mechanisms that generate oscillations in the incidence of childhood infectious diseases. We will show that, first, demographic stochasticity can generate coherent fluctuations which behave as sustained oscillations and, second, the power spectrum of these fluctuations can be calculated analytically using a van Kampen's expansion. The combined analysis of stochastic simulations and data records for measles and whooping cough for different cities in England, Wales and Canada shows that in systems whose sizes represent real populations the role of stochastic effects becomes fundamental for the interpretation of historical data.

Ganna Rozhnova
University of Lisbon, Portugal
University of Manchester, UK
a_rozhnova@cii.fc.ul.pt

Ana Nunes
University of Lisbon, Portugal
anunes@ptmat.fc.ul.pt

### MS18

### Genetic Control of Vector-borne Diseases: Artificial Selection and Heterogeneity of the Immune Response in Mosquitoes

Abstract not available at time of publication.

Claudio Struchiner
Oswaldo Cruz Foundation
Program for Scientific Computing
stru@procc.fiocruz.br

### MS19

### Asymptotic Behavior of Stochastically Blinking Systems

Dynamical systems that are externally driven by stochastic processes are good models for many physical, biological and engineering systems. The most obvious examples are obtained by the presence of noise, but in many other circumstances, such as e.g. in dynamical networks with randomly present links such models are also pertinent. There are two time scales present in such randomly switching (blinking) networks, namely the time scale of the individual dynamical system itself and the time scale of the stochastic (blinking) process. In this work, we suppose that the stochastic process is much faster than the dynamical system. We show that with high probability, the solution of the stochastic system follows the solution of the averaged system with a certain precision for a certain finite length of time, if it starts from the same initial condition. As a perturbation result this is well known. Here, we go much farther by giving explicit bounds that relate the probability, the precision and the length of the time interval to each other. A result that could not be obtained from the perturbation approach is the presence of a soft upper bound on the length of the time interval, beyond which the solution of the blinking system can only follow the solution of the averaged system with good precision for unreasonably fast stochastic driving. We also discuss the asymptotic properties of the solutions of the blinking system as time goes to infinity. The question we address is whether and how the solutions of the blinking system converge to an attractor of the averaged system.

Martin Hasler
Swiss Federal Institute of Technology Lausanne
martin.hasler@epfl.ch

Vladimir Belykh
University of Nizhny Novgorod
belykh@unn.ru

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

### MS19

### The Climate System as a Network of Networks

We introduce a novel graph-theoretical framework for studying the interaction structure between sub-networks embedded within a complex network of networks. This allows us to quantify the structural role of single vertices or whole sub-networks with respect to the interaction of a pair of subnetworks on local, mesoscopic, and global topological scales. Climate networks have recently been shown to be a powerful tool for the analysis of climatological data. Here we use the concept of network of networks by introducing climate subnetworks representing different heights in the atmosphere. Parameters of this network of networks, as cross-betweenness, uncover relations to global circulation patterns in oceans and atmosphere. The global scale view on climate networks offers promising new perspectives for detecting dynamical structures based on nonlinear physical processes in the climate system.

Juergen Kurths
Potsdam Institute for Climate Impact Research
Humboldt University Berlin, Germany
kurths@pik-potsdam.de

J. Donges
hs Potsdam Institute for Climate Impact Research
Humboldt University Berlin, Germany
kurths@pik-potsdam.de

N. Marwan, Y. Zou
Potsdam Institute for Climate Impact Research
Humboldt University Berlin, Germany
kurths@pik-potsdam.de, kurths@pik-potsdam.de

### MS19

### On Synchronization Over Numerosity-constrained Networks with Application to Animal Grouping

Collective behavior of animal groups, such as schools of fish and flocks of birds, is characterized by coordinated maneuvers of individuals with matched velocities. The mechanics of coordination in animal groups can be assimilated to distributed averaging over networks of coupled dynamical systems. The topology of the underlying network describes the information flow among the agents and thus dictates their ability to synchronize. Information flow among group mates is generally affected by the so-called numerosity that quantifies a critical limit to the species perception of natural numbers. Groups with cardinality less than the numerosity are perceived by an individual as a specific collection, while groups of more than this limit are perceived only as many. In this paper, we imbed the biologically-observed perceptual phenomenon of numerosity in synchronization problems towards establishing a first analytical understanding of the impact of psychological factors on collective behavior of animal groups. More specifically, we consider consensus/synchronization of discrete maps that are coupled via a stochastic network in which every dynamical system receives information from a fixed number of agents that are randomly selected at each time step. For the consensus problem, we establish necessary and sufficient conditions for stochastic consentability based on the network size, the numerosity, and the coupling strength. In addition, we present a master stability function that allows for directly assessing the synchronization of the coupled dynamical systems in terms of the spectral properties of the numerosity-constrained network and the individual dynamics.

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

### MS19
### Intermittent Synchronization in Adaptive Networks of Coupled Oscillators

Networks of Kuramoto phase oscillators with dynamically adapting coupling strengths are studied in the case where there is hysteresis in the transition to synchronism (caused, for example, by finite oscillator response times or slow oscillator frequency adaptation). For a class of local adaptive rules, the oscillators display "intermittent synchronization', in which the oscillators periodically synchronize and desynchronize on a slow time scale. The conditions for intermittent synchronization are discussed and illustrated by examples. The robustness of this phenomenon to noise, network structure, and finite size effects is studied.

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

Dane Taylor
Dept. Applied Math
University of Colorado
dane.taylor@colorado.edu

Per Sebastian Skardal
Department of Applied Mathematics
University of Colorado at Boulder
sebastian.skardal@colorado.edu

### MS20
### Microfluidic Rheology and Dynamical Heterogeneity of Soft Colloids above and below Jamming

The rheology near jamming of a suspension of soft colloidal spheres is studied using a custom microfluidic rheometer that provides stress versus strain rate over many decades. We find non-Newtonian behavior below the jamming concentration and yield stress behavior above it. The data may be collapsed onto two branches with critical scaling exponents that agree with expectations based on Hertzian contacts and viscous drag. The heterogeneity size is also observed to diverge as power laws in distance to jamming. These results support the conclusion that jamming is similar to a critical phase transition, but with interaction-dependent exponents.

Douglas Durian
Department of Physics
University of Pennsylvania
djdurian@physics.upenn.edu

Kerstin Nordstrom, Emilie Verneuil
University of Pennsylvania
knordstr@sas.upenn.edu¿, emilie.verneuil@espci.fr

Jerry P. Gollub
Haverford College
Department of Physics
jgollub@haverford.edu

### MS20
### Avalanches and Diffusion in Model Bubble Rafts Near Jamming

Energy dissipation distributions and particle displacement statistics are studied in the mean field version of Durian's bubble model. A two dimensional (2D) bi-disperse mixture is simulated at various strain rates, $\dot{\gamma}$, and packing ratios, $\phi$, above the close packing limit, $\phi_c$. Above $\phi_c$, at sufficiently low $\dot{\gamma}$, the system responds with a power law distribution of energy dissipation. As one increases $\dot{\gamma}$ at fixed $\phi$, the intermittent behavior vanishes. Displacement distributions are non-Fickian at short times but cross to a Fickian regime at a universal strain, $\Delta\gamma_*$, independent of $\dot{\gamma}$ and $\phi$. Surprisingly, despite the profound differences in short-time dynamics, at intermediate $\Delta\gamma$, the systems exhibit qualitatively similar spatial patterns of deformation, with lines of slip extending across large fractions of the simulation cell.

Craig Maloney
Civil & Environmental Engineering
Carnegy Mellon University, Pittsburgh
craigmaloney@cmu.edu

### MS20
### Asymmetries and Velocity Correlations in Shearing Media

A model of soft frictionless disks in two dimensions at zero temperature is simulated with a shearing dynamics around the jamming density. First focusing on single particle properties we find that both the particle velocities and the interparticle forces have interesting features at jamming. Turning to velocity correlations we examine a mixed correlation function that happens to decay exponentially to an excellent approximation. From the exponential decay we extract a correlation length that shows strong evidence of critical

scaling.

Peter Olsson
Department of Physics
Ume{
aa} University, Sweden
olsson@tp.umu.se

**MS20**

**Non-Newtonian Rheology of Sheared Soft Sphere Systems near the Jamming Point: An Introduction**

In this talk I will both give an introduction to the major theme of the symposium and present our recent theory for the rheology of sheared soft spheres near the jamming point. I first review some essentials of the jamming theory for static packings of soft (compressible) spheres. By building on what we now understand about the anomalous "floppy" modes near jamming, I then develop a theory for the rheology of sheared soft sphere systems.

Wim van Saarloos
FOM Foundation
Leiden University
saarloos@lorentz.leidenuniv.nl

**MS21**

**A Game-theoretic Approach to the Vertical Distribution of Phytoplankton**

We show how both extrinsic and intrinsic factors interact to determine spatial patterns in phytoplankton communities. Determinants of the spatial (vertical) distribution of phytoplankton remain under-investigated and untested. One of the leading hypotheses to explain phytoplankton vertical distribution patterns is that competition for essential resources, nutrients and light, in opposing gradients determines vertical distribution. We used a combination of mathematical modeling, experiments in plankton towers, and surveys across major environmental gradients to study what determines the vertical distribution of phytoplankton, focusing on competition for nutrients and light.

Jarad Mellard
University of Kansas
mellard@ku.edu

**MS21**

**Bistability in Vertical Distributions of Phytoplankton in a Stratified Water Column**

Light and nutrients form opposing vertical gradients. Phytoplankton grow along the resource gradients, typically showing a unimodal vertical distribution. Recent numerical studies suggest bistability in steady state when a water column is composed of a well-mixed surface layer and a poorly-mixed deep layer. I discuss mechanisms of the bistability and structure of the bifurcation set.

Kohei Yoshiyama
The University of Tokyo, Japan
kyoshiyama@aori.u-tokyo.ac.jp

**MS21**

**Emergence and Annihilation of Localized Structures in a Phytoplankton-nutrient System**

We consider a model describing marine phytoplankton, the growth of which is co-limited by both light and nutrient. Our goal is to investigate analytically the weakly nonlinear dynamics of deep chlorophyll maxima (DCM) beyond the linear regime. Exploiting the model's natural singularly perturbed nature, we derive an explicit reduced model of asymptotically high dimension fully capturing these dynamics. Using it, we find that bifurcating DCM patterns are soon annihilated in a saddle-node bifurcation.

Antonios Zagaris
Universiteit Twente (NL)
CWI, Amsterdam (NL)
a.zagaris@cwi.nl

**MS21**

**A Weakly Nonlinear Model for Phytoplankton Pattern Formation in Estuaries**

An idealised model is analysed to gain fundamental understanding about the dynamics of phytoplankton blooms in well-mixed, suspended sediment dominated estuaries. The model describes the behaviour of currents, suspended sediments, nutrients and phytoplankton in a channel. The initial growth of phytoplankton and its spatial distribution is calculated by solving an eigenvalue problem. It is demonstrated how the onset of blooms in the model depends on physical and biological processes.

Huib de Swart
IMAU, Utrecht University
PO Box 80005 Utrecht NL
H.E.deSwart@phys.uu.nl

**MS22**

**Frame Selection in Nonholonomic Mechanics**

Appropriate selection of a moving frame can simplify the equations of nonholonomic mechanics by eliminating the necessity to solve for velocity components not contained within the constraint distribution. We discuss the relation of the Hamel equations to the reduced equations one obtains using a fiber bundle description, and introduce intermediary forms for the equations of motion. Finally we apply these equations to several physical systems to better understand their benefit.

Jared M. Maruskin
San Jose State University
maruskin@math.sjsu.edu

**MS22**

**From Brakes-to-Syzygy in the Three-Body Problem**

In this joint work with Rick Moeckel and Andrea Venturelli an investigation of brake orbits in the 3-body problem arose naturally in trying to better understand properties of the "syzygy' cross section, and the resulting symbol (syzygy) sequences. We present progress on several open problems.

Richard Montgomery
Dept of Mathematics
University of California-Santa Cruz
rmont@math.ucsc.edu

**MS22**

**Automatically Generated Variational Integrators**

Differential-geometric structures enable differential equations to model special, interesting properties of important physical systems. Geometric mechanics is concerned with penetrating and fundamental advances formulated in terms of the structures from which the differential equations are derived. Upon providing an overview of current trends, I will specifically describe advances in the theory of structure preserving integrators, and a software system called AUDELSI, which converts any ordinary one step method into an equal order variational integrator.

George Patrick
Dept of Math & Statistics
University of Saskatchewan
patrick@math.usask.ca

**MS22**

**Structure-Preserving Integrators for Chaplygin Systems**

When simulating mechanical systems numerically, it may be desirable to preserve various intrinsic structures. For instance, in the absence of velocity constraints, it is desirable to preserve a symplectic form. Many of these structures fail to be invariant in systems with velocity constraints. Integrators that preserve suitable quantities in the presence of velocity constraints will be introduced.

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

Cameron Lynch
North Carolina State University
Electrical and Computer Engineering
celynch2@ncsu.edu

**MS23**

**Fast Computation of Time-Varying Finite Time Lyapunov Exponents**

This work investigates a number of efficient methods for computing finite time Lyapunov exponent (FTLE) fields in unsteady flows. The methods approximate the particle flow map, eliminating redundant particle integration in neighboring flow map calculations. Two classes of flow map approximations are investigated based on composition of intermediate flow maps; unidirectional approximation constructs a time-T map by composing a number of smaller time-h maps, while bidirectional approximation constructs a flow map by composing both positive and negative-time maps. An error analysis is presented which shows that the unidirectional methods are accurate while the bidirectional methods have significant error which is aligned with the opposite-time coherent structures. This is explained by the fact that material near the positive-time LCS will attract onto the negative-time LCS near time-dependent saddle points. The algorithms are implemented and compared on three example fluid flows: a double gyre, a low Reynolds number pitching flat plate, and an unsteady ABC flow. The unidirectional methods are both fast and accurate, providing orders of magnitude computational savings over the standard method when computing a sequence of FTLE fields in time for an unsteady flow.

Steven L. Brunton
Princeton University
sbrunton@princeton.edu

Clarence Rowley
Princeton University
Department of Mechanical and Aerospace Engineering
cwrowley@princeton.edu

**MS23**

**An Eulerian Approach for Computing the Finite Time Lyapunov Exponent**

In this talk we present an Eulerian method for computing the finite-time Lyapunov exponent (FTLE). The idea is to compute the related flow map using the level set method and the Liouville equation. When determining the flow map, the algorithm requires the velocity field defined only at mesh locations. We also extend the algorithm to compute the FTLE on a co-dimension one surface. The method does not require any local coordinate system and is simple to implement even for evolving manifolds.

Shingyu Leung
Hong Kong University of Science and Technology
masyleung@ust.hk

**MS23**

**Ridge Surface Methods for the Visualization of LCS**

In visual analysis of flow data, an increasingly popular method is the extraction of Lagrangian coherent structures (LCS). For the computation of LCS we follow the definition of LCS as being ridges of the finite-time Lyapunov exponent (FTLE) and explore several existing ridge definitions. We give a comparison of the obtained LCS in terms of accuracy and noisiness, and we propose a new ridge definition tailored to FTLE data. Finally, we investigate FTLE ridges in scale-space and propose a new optimality criterion.

Ronald Peikert
Department of Computer Science
ETH Zurich
peikert@inf.ethz.ch

**MS23**

**Efficient Computation of Lagrangian Coherent Structures for Interactive Visual Analysis in Computational Fluid Dynamics**

We will start by discussing the computational challenges associated with LCS in numerical datasets. We will proceed with a brief overview of the existing algorithms for the efficient extraction of LCS. We will then describe recent advances in the interactive visual exploration of LCS across spatial resolutions and present a novel high-performance method for the geometric extraction of accurate LCS from FTLE fields in scale space. Results will be shown in analytical and CFD datasets.

Xavier M. Tricoche
Purdue University
West Lafayette, IN 4707-4348
xmt@purdue.edu

**MS24**

**Effects of Nonlinear Saddles and Centers on Data Assimilation**

The main focus of this talk will be the effect of two basic nonlinear phenomena - the shear around a nonlinear center and the divergence of trajectories near a nonlinear saddle point - on data assimilation. The rich nonlinear dynamical features of Lagrangian particles in a fluid flow allows us to naturally isolate these features and study their effects. In particular, we will discuss how the nonlinearities lead to the appearance of non-Gaussian distribution functions.

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

Christopher Jones
University of North Carolina and University of Warwick
ckrtj@email.unc.edu

**MS24**

**Forecasting Regime Changes in a Chaotic Toy Climate**

A low-dimensional model of natural convection in a thermosyphon, analogous to Lorenz' 1963 system, is compared to direct numerical flow simulations as a testbed for data assimilation in the presence of model error. The flow dynamics of the thermosyphon exhibit distinct behavioral regimes, so we consider the thermosyphon a useful toy model for climate. The reference "true" state is represented by a long time direct numerical simulation of the flow; forecasts are made using the low-dimensional model and synchronized to noisy and limited observations of the truth. We compare results using four separate data assimilation algorithms, varying analysis windows and lead times, and show successful forecasting of regime changes and residency times.

Kameron D. Harris
University of Vermont
kharris@uvm.edu

Chris Danforth
Mathematics and Statistics
University of Vermont
chris.danforth@uvm.edu

**MS24**

**Variance Limiting Kalman Filtering: Controlling Covariance Overestimation and Model Error**

We consider the problem of overestimation of error covariances due to model error in data assimilation problems. Artificial viscosity is often used in numerical weather prediction models to ensure numerical stability, at the expense of poorly representing the conservation laws. If this damping is relaxed the model overestimates forecast error covariances. Overestimation typically occurs for small ensembles in sparse observational networks, and is exacerbated if there is model error due to underdamped dynamics. We propose an alternative to using underdamped dynamics in ensemble Kalman filtering, instead using a weak constraint method called a variance limiting Kalman filter to control the covariance overestimation. We demonstrate our results numerically using the Lorenz-96 model.

Lewis Mitchell, Georg Gottwald
University of Sydney
lewism@maths.usyd.edu.au, georg.gottwald@sydney.edu

Sebastian Reich
Universität Potsdam
sereich@rz.uni-potsdam.de

**MS24**

**Lagrangian Data Assimilation for Nonlinear Ocean Process Models**

Coherent structures drive important ocean dynamics, but are not easily characterized by traditional data assimilation techniques. Such Kalman-based techniques perform poorly on strongly nonlinear systems where underlying physics leads to non-Gaussian distributions of state variables or parameters of interest. Sampling-based filtering methods, however, naturally handle this problem and are promising tools for using data and models to describe ocean processes. We will present challenges and results using sampling-based methods in the context of ocean processes.

Elaine Spiller
Marquette University
elaine.spiller@marquette.edu

**MS25**

**3D Aspects of Mixing and Transport in Tumbled Granular Flow**

Tumbled granular flow in a spherical container rotated sequentially about two axes is a realistic system in which to investigate kinematic structures of 3D volume-preserving maps. The dynamics can be restricted to 2D invariant surfaces, or be fully-3D, depending on the rates of rotation. For the former, KAM-like tubes (barriers to mixing) and manifolds (progenitors of mixing) can be constructed by stacking up their 1D versions from a sequence of invariant surfaces. Departures from the "perturbed Hamiltonian system" template are observed.

Ivan C. Christov, Richard M Lueptow, Julio M Ottino
Northwestern University
christov@u.northwestern.edu,
r-lueptow@northwestern.edu, jm-ottino@northwestern.edu

Rob Sturman
University of Leeds
rsturman@maths.leeds.ac.uk

Stephen Wiggins
University of Bristol
s.wiggins@bristol.ac.uk

**MS25**

**Formation of Coherent Structures by Fluid Inertia in 3D Laminar Flows**

We discuss the formation and interaction of coherent structures that geometrically determine the transport properties of laminar flow. The impact of these structures on 3D laminar mixing will be demonstrated numerically and experimentally. Key result is the role of fluid inertia that induces partial disintegration of coherent structures of the non-inertial limit into chaotic regions and merger of surviv-

ing parts into intricate 3D structures. The response follows a universal scenario and reflects an essentially 3D route to chaotic mixing.

Herman Clercx
Fluid Dynamics Laboratory, Dept. Applied Physics
Eindhoven University of Technology
h.j.h.clercx@tue.nl

Michel Speetjens
Laboratory for Energy Technology, Dept. Mech. Eng.
Eindhoven University of Technology
m.f.m.speetjens@tue.nl

### MS25

### Adiabatic Mixing: Improved Invariants and Refined Boundaries

We present a quantitative long-term description of resonant mixing in 3-D near-integrable flows. We illustrate that scattering on resonance and capture into resonance create mixing by causing the jumps of adiabatic invariants. We calculate the real width of the mixing domain (including streamlines approaching but not crossing the resonance), and show the use of improved adiabatic invariants. We illustrate that the resulting mixing can be described in terms of a diffusion-type PDE.

Dmitri Vainchtein
Dept. of Mechanical Engineering
Temple University, USA
dmitri@temple.edu

Alimu Abudu
Temple University
tub70735@temple.edu

### MS25

### Mixing in a Tilted Rotating Tank

An example of periodic shear in a tilted rotating tank geometry is discussed to understand the stirring on an inhomogeneous fluid stirring by periodic shear. The mechanism for stirring in a flow exhibiting periodic shear is linear or quadratic stretching of material lines. Since periodic shear flows involve only stretching they are typically not as efficient as other mixing process that incorporate folding and twisting along with exponential stretching of material lines.

Thomas Ward
Department of Mechanical and Aerospace Engineering
NC State University
tward@ncsu

### MS26

### Combinatorics of Stable Sets and Learning in Recurrent Networks

Networks of neurons in some brain areas are flexible enough to encode new memories quickly. Using a standard firing rate model of recurrent networks, we develop a theory of flexible memory networks. Our main results characterize networks having the maximal number of flexible memory patterns, given a constraint graph on the networks connectivity matrix. Modulo a mild topological condition, we find a close connection between maximally flexible networks and rank 1 matrices. The topological condition is $H^1(X;Z) = 0$, where $X$ is the clique complex associated to the networks constraint graph; this condition is generically satisfied for large random networks that are not overly sparse. This is a joint work with Anda Degeratu and Carina Curto.

Vladimir Itskov
Department of Mathematics
University of Nebraska, Lincoln
vitskov2@math.unl.edu

### MS26

### Dynamical Moment Neuronal Network: Model and Approach

I shall present a theoretical framework on spike activities of leaky-and-integrate networks by including the first-order (mean firing rate) and the second-order statistics (variance and correlation), based on a moment neuronal network (MNN) approach. The dynamics and distribution of neural activities are approximated as a Gaussian random field. Using this novel model, I shall introduce analysis of several interesting phenomena of MNN and illustrate the computation capability of this model with experimental data.

Wenlian Lu
School of Mathematical Sciences
Fudan University
wenlian.lu@gmail.com

Jianfeng Feng
Centre for Scientific Computing, Warwick University
Coventry CV4 7AL, UK
jianfeng.feng@warwick.ac.uk

### MS26

### Using Feed-forward Maps to Explore the Role of Synaptic Dynamics in a Reciprocally Inhibitory Network

Recent data from our lab shows that inhibitory synapses in a CPG network can show a maximal conductance at a preferred presynaptic frequency. We explore a network of two model neurons coupled with synapses that show frequency preference. As a first approximation, the dynamics of each neuron can be described by a logistic map with two parameters, resulting in a bifurcation diagram characterized by a period-doubling cascade leading to chaotic dynamics.

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

Myongkeun Oh
New Jersey Institute of Technology
mo42@njit.edu

### MS26

### Networks of Phase-amplitude Neural Oscillators

If the limit cycle is not strongly attracting, the phase description of a neural oscillator may poorly characterise the behaviour of the original system. Here we consider, for some well known neural models, a phase-amplitude framework, incorporating the distance from the cycle as well as the phase along it. We present our results using this framework for networks of pulse coupled cells, and for networks coupled via gap junctions.

Kyle C. Wedgwood, Stephen Coombes
University of Nottingham
pmxkw2@nottingham.ac.uk,
stephen.coombes@nottingham.ac.uk

**MS27**

**Nonlinear Stability for a Model of a Source-type Defect**

Analyzing the nonlinear stability of source-type defects in reaction-diffusion equations leads to two complicating factors: a nonlocalized eigenfunction and advection that is directed outward. In preparation for overcoming these in the general case, it is demonstrated how to do so in the case of a model equation using a modification of pointwise estimates that have been successfully used in the setting of viscous shocks.

Margaret Beck
Department of Mathematics and Statistics
Boston University
mabeck@math.bu.edu

Toan Nguyen
Division of Applied Mathematics
Brown University
Toan_Nguyen@Brown.edu

Bjorn Sandstede
Brown University
bjorn_sandstede@brown.edu

Kevin Zumbrun
Indiana University
USA
kzumbrun@indiana.edu

**MS27**

**Nonlinear Stability of Fronts and Pulses for a Class of Reaction-diffusion Systems that Arise in Chemical Reaction Models**

Motivated by the model for exothermic-endothermic chemical reactions we consider a class of reaction-diffusion systems that have traveling wave solutions that possess unstable continuous spectrum. We formulate assumptions on the reaction terms and the properties of the traveling waves (fronts or pulses) under which the convective character of the instability of the waves can be proved analytically. The proof is based on exponential weights and bootstrapping argument to obtain a-priori estimates for the perturbations to the wave. The results are precise enough to capture real features of phenomena such as endothermic-exothermic chemical reactions.

Anna Ghazaryan
Department of Mathematics
Miami University and University of Kansas
ghazarar@muohio.edu

Yuri Latushkin
University of Missouri, Columbia
latushkiny@missouri.edu

Stephen Schecter
North Carolina State University
Department of Mathematics
schecter@math.ncsu.edu

**MS27**

**Stability of the Line Soliton of the KP-II Equation in $L^2(R_x \times T_y)$**

We prove the nonlinear stability of line-solitons to the KP-II equation with respect to periodic transverse perturbations. Line soliton solutions are saddle points of the energy functional but it is infinitely indefinite. Our idea is to use the Miura transform and show that stability of line solitons is equivalent to the stability of the null solution.

Tetsu Mizumachi
Faculty of Mathematics
Kyushu University, Japan
mizumati@math.kyushu-u.ac.jp

Nikolay Tzvetkov
Universit
'e de Cergy-Pontoise
nikolay.tzvetkov@u-cergy.fr

**MS27**

**Geometric Evolution of Structured Interfaces**

A central problem in polymer chemistry is to design materials with novel macroscopic properties by controlling the spontaneous generation of nanoscaled, phase separated networks. A primary mechanism to generate such networks is through the "functionalization' of hydrophobic polymer chains and nanoparticles by the addition of acid or alkaline terminated side-chains. When mixed with solvent, the charged end-groups accumulate at the solvent-polymer interface where access to the solvent shields their electric field, lowering the electrostatic energy. This accumulation of charged groups engenders a tremendous growth of solvent accessible interface, to levels of 1000 $m^2$/gram, among the highest known. The resultant networks, by virtue of the tethered charge groups lining the interface, are selectively conductive, inhibiting the transport of co-ions while facilitating the transport of counter-ions, and have important applications in efficient energy conversion devices such as polymer electrolyte membrane fuel cells, dye sensitized solar cells, bulk-heterojunction solar cells, and lithium ion batteries. We present a novel class of energies whose gradient flows generate interface in a controllable manner, driving micron scale mixtures into nanoscaled networks. We discuss this in the context of the unfolding of critical points of classical second order energies as embedded in a fourth order variational energy. For certain classes of energies we will show that the geometric evolution of the interfaces couples to the structure of the interface.

Keith Promislow
Michigan State University
kpromisl@math.msu.edu

**MS28**

**Optimal Control for Globally Coupled Neural Networks**

We consider the problem of desynchronizing a network of sychronized, globally (all-to-all) coupled neurons using an input to a single neuron. This is done by applying the discrete time dynamic programming method to reduced phase models for neural populations. This technique nu-

merically minimizes a certain cost function over the whole state space, and is applied to a Kuramoto model and a reduced phase model for Hodgkin-Huxley neurons with electrotonic coupling. We also evaluate the effectiveness of control inputs obtained by averaging over results obtained for different coupling strengths.

Ali Nabi
UCSB
nabi@engineering.ucsb.edu

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

**MS28**

**Synchronization Control of Interacting Oscillatory Ensembles by Mixed Nonlinear Delayed Feedback**

We discuss a method for the control of synchronization in two oscillator populations interacting according to a drive-response coupling scheme. The response ensemble of oscillators, which gets synchronized because of a strong forcing by the intrinsically synchronized driving ensemble, is controlled by the mixed nonlinear delayed feedback. The stimulation signal is constructed from the mixed macroscopic activities of both ensembles according to the rule of nonlinear delayed feedback. We show that the suggested method can effectively decouple the interacting ensembles from each other, where the natural desynchronous dynamics can be recovered in a demand-controlled way either in the stimulated ensemble, or in both stimulated and not stimulated populations. We discuss possible therapeutic applications in the context of the control of abnormal brain synchrony in loops of affected neuronal populations.

Oleksandr Popovych
Institute of Neuroscience and Medicine - Neuromodulation
Research Center Juelich, Germany
o.popovych@fz-juelich.de

Peter A. Tass
Institute of Medicine (MEG)
Research Centre Juelich
p.tass@fz-juelich.de

**MS28**

**Model Based Control of Seizures and Parkinson's Disease**

We seek to fuse computational models of neurons and networks with measurements to assimilate data and control pathological neuronal dynamics. This strategy involves the framework from ensemble Kalman filters, with either ionic or reduced models of neuronal dynamics, as well as the dynamics of the ionic environment the neurons are embedded within. We will show recent findings from data assimilation from neuronal networks and efforts of creating a rigorous control strategy to modulate such networks.

Steven J. Schiff
Penn State University
Center for Neural Engineering
sschiff@psu.edu

**MS28**

**Stimulation and Information in the Peripheral Nervous System**

Cochlear implants are neural prostheses that provide sound information by stimulating the auditory nerve with electrical pulse trains. We model the response of the auditory nerve via point process and integrate-and-fire models, and quantify the temporal encoding properties of these models using ideal observer analyses and decoding algorithms that predict some features of observed data. Throughout, we emphasize the characteristics of both the auditory nerve and decoding systems that are required to make this connection, and comment the implications for optimal stimulation patterns.

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

**MS29**

**Investigating the Spatiotemporal Dynamics of Pandemic Influenza in Europe**

Despite the rapidity of the 2009 H1N1 pandemic influenza in reaching a large number of countries, its spread was rather heterogeneous also within single continents. By using a model able to capture the structure of complex modern human societies, the reasons underlying this phenomenon are thoroughly investigated and the (remarkable) implications for correctly informing public health decision makers are highlighted.

marco Ajelli
Bruno Kessler Foundation,
ajelli@fbk.eu

Stefano Merler
Bruno Kessler Foundation
merler@fbk.eu

**MS29**

**A Toy Model for Epidemics in Rio de Janeiro: The Importance of the Network Structure**

Epidemics modeling has been particularly growing in the past years. In epidemics studies, mathematical modeling is used in particular to reach a better understanding of some neglected diseases (dengue, malaria, ...) and of new emerging ones (SARS, influenza A,....) of big agglomerates. Such studies offer new challenges both from the modeling point of view (searching for simple models which capture the main characteristics of the disease spreading), data analysis and mathematical complexity. We are facing often with complex networks especially when modeling the city dynamics. Such networks can be static (in first approximation) and homogeneous, static and not homogeneous and/or not static (when taking into account the city structure, micro-climates, people circulation, etc.). The objective being studying epidemics dynamics and being able to predict its spreading.

Stefanella Boatto
Universdade Federal de Rio de Janeiro, Brazil
lella@im.ufrj.br

Francisco C. Santos
Department of Computer Sciences

New University of Lisbon, Portugal
xsantos@gmail.com

Lucas Stolerman
Department of Applied Mathematics
Federal University of Rio de Janeiro, Brazil
stolerman3456@gmail.com

Claudia Codeco
Fundao Oswaldo Cruz, Brazil
claudia.codeco@gmail.com

Renata Stella Khouri
Dept. of Applied Mathematics, UFRJ
Federal University of Rio de Janeiro, Brazil
mmacte@yahoo.com.br

**MS29**

**Multiscale Networks and the Spatial Spread of Infectious Diseases**

Human mobility and interactions represent key ingredients in the spreading dynamics of an infectious disease. The flows of traveling individuals form a network characterized by complex features, such as strong topological and traffic heterogeneities, that unfolds at different temporal and spatial scales, from short ranges to the global scale. Computational models can be developed that integrate detailed network structures based on demographic and mobility data, in order to simulate the spatial evolution of an epidemic. Focusing on the 2009 H1N1 influenza pandemic as a paradigmatic example, these approaches allow quantifying the effects of travel restrictions in delaying and controlling the epidemic spread. In addition, simplified model frameworks can be solved providing the assessment of the interplay between individual mobility and epidemic dynamics, under different conditions of heterogeneities characterizing human mobility.

Vittoria Colizza
Computational Epidemiology Lab
ISI Foundation, Torino, Italy
vcolizza@isi.it

**MS29**

**The Role of Immunity and Seasonality in Cholera Epidemics**

This is a mathematical model for cholera epidemics which comprises seasonality, loss of host immunity and control mechanisms acting on cholera transmission dynamics. A collection of the data related to cholera disease allows us to show that outbreaks in endemic areas are subject to a resonant behavior, as the intrinsic oscillation period of the disease ($\sim 1$ year) is synchronized with the annual contact rate variation. Moreover, we argue that a finite duration of host immunity may be associated to the secondary peaks of incidence observed in some regions (a bimodal pattern). Furthermore, we explore some possible scenarios of control mechanisms applied to stopping or diminishing cholera outbreaks and analyze their efficiency. Besides mass vaccination - which may be impracticable - improvement of water treatment is the most effective way to prevent an epidemic.

Roberto A. Kraenkel
Instituto de Fsica Teórica-UNESP
kraenkel@ift.unesp.br

Rosangela Sanchez
Programa de Pós-Graduao em Biometria - UNESP, Brazil
rps@ibb.unesp.br

Claudia Pio Ferreira
rograma de Pós-Graduao em Biometria - UNESP, Brazil
pio@ibb.unesp.br

**MS30**

**Adaptive Networks and the Spontaneous Emergence of Modularity and Heterogeneity**

Structural (topological) and dynamical (synchronization) features co-evolve in an adaptive network of phase oscillators, as soon as two basic biological principles (Hebbian and Homeostatic plasticity) are taken into account for the selection of the local coupling strength between the networking units. Synchronization is enhanced, and the combination of the two adapting mechanisms leads to the spontaneous emergence of highly modular architectures in connection with a power-law scaling for the distribution of the self-adapted weights of interactions.

Stefano Boccaletti
CNR-Istituto dei Sistemi Complessi
stefano.boccaletti@isc.cnr.it

**MS30**

**Evolving Dynamical Networks for Synchronization: Analysis and Emergent Properties**

The aim of this talk is to discuss how to dynamically evolve networks of dynamical agents to enhance their synchronization performance. A new analytical and computational framework will be introduced that can be used to optimize the network topology to best perform a certain desired function. Then, the evolution of motifs and other topological features as the network structure self-evolve to achieve synchronization will be investigated. New indeces to characterize evolving networks will be discussed and used to analyze a case study from biology.

Mario Di Bernardo
University of Bristol
Dept of Engineering Mathematic
m.dibernardo@bristol.ac.uk

Thomas Gorochowski
University of Bristol
thomas.gorochowski@bristol.ac.uk

**MS30**

**Creating Delay-tolerant Networked Dynamical Systems via Designing the Network Graphs**

Dynamical systems coupled over networks arise in many applications including neural networks, tele-operation, coordination of unmanned vehicles, and vehicular traffic flow. Often, the information transmission among the systems in these networks does not occur instantaneously, but after delays. This means that each system is aware of only delayed states of the remaining systems in the network. In this setting, if all the systems make decisions based on the available, yet delayed information, then the entire networked dynamical systems may become unstable. The largest amount of delay that the network can withstand before losing stability is called the delay margin. The delay margin is a measure of how tolerant the network is to the presence of delays. In large scale networks, existing studies fall short to characterize the delay margin, mainly due to the scale of the problem. In this talk, on a benchmark consensus dynamics, we will present have the delay margin can be calculated in large scale networks using the new concept called the Responsible Eigenvalue (RE). The RE concept allows reducing the stability analysis of the network to the analysis of one and only one eigenvalue of the graph Laplacian of the network. That is, RE establishes the indirect link between stability of networked systems with delays and the graphs of these networks. With such a dramatic reduction in complexity, it then becomes possible to construct mathematical tools that reveal guidelines as to how to manipulate RE such that the delay margin of a network can be maximized. These tools also lead to design rules by which the network graph can be reconstructed in a way to maximize the delay margin, and new control design strategies with which the members of the network can autonomously make decisions in order to maintain the stability of the network dynamics.

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

Wei Qiao
Northeastern University
rifat@coe.neu.edu

### MS30

### Period Doubling and Macroscopic Chaos in a Time-varying Network of Globally Coupled Phase Oscillators

The Kuramoto system has been a very successful model in demonstrating the emergence of collective rhythm from coupled biological and physical networks. Using a recently developed reduction technique, we were able to exactly analyze the macroscopic dynamics for a Kuramoto system which includes distinct interacting subnetworks and time-dependent coupling in the thermodynamic limit. These extensions were motivated by real neurological networks with interacting subpopulations of neurons and intrinsic time variations. Despite the simple dynamics of the individual units, we were able to show that the macroscopic mean-field can behave chaotically. Cascades of periodic doubling bifurcations and crises were identified.

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

### MS31

### Transport Barrier In The Nontwist Standard Map

Nontwist systems, common in the dynamical descriptions of fluids and plasmas, possess a shearless invariant curve with a concomitant transport barrier that eliminates or reduces chaotic transport, even after its breakdown. To investigate the transport properties of nontwist systems, we analyze the transport barrier breakdown for the standard nontwist map, a paradigm of such systems. We show that the transport dependence on the map parameters can be explained by a sequence of bifurcations that changes the chaotic orbit stickiness and the associated role played by the dominant crossing of stable and unstable manifolds.

Ibere L. Caldas
Institute of Physics
University of Sao Paulo
ibere@if.usp.br

Jose D. Szezech
University of So Paulo
jdanilo@gmail.com

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

Ricardo L. Viana
Federal University of Paraná
viana@fisica.ufpr.br

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

### MS31

### Interplay of Magnetic Shear and Resonances in Magnetic Fusion Devices

The dual impact of low magnetic shear is shown in a unified way with extension to non-axisymmetric states. Away from resonances, it induces a drastic enhancement of magnetic confinement that favors robust internal transport barriers (ITBs) and turbulence reduction. When low-shear occurs for values of the winding of the magnetic field lines close to low-order rationals, the amplitude thresholds of the resonant modes that break internal transport barriers by allowing a radial stochastic transport of the magnetic field lines may be quite low. This analysis puts a constraint on the tolerable mode amplitudes compatible with ITBs and is shown to be consistent with diverse experimental and numerical signatures of their collapses.

Marie-Christine Firpo
Laboratoire de Physique des Plasmas
Ecole Polytechnique, Palaiseau Cedex, France
marie-christine.firpo@lpp.polytechnique.fr

Dana Constantinescu
Dept of Applied Mathematics, Association
Euratom-MECI
University of Craiova, Craiova 200585, Romania
dconsta@yahoo.com

### MS31

### Gyroaverage Effects on Separatrix Reconnection and Destruction of Shearless Kam Barriers in Non-Twist Systems

Finite Larmor radius (FLR) effects on chaotic transport are studied in a gyro-average Hamiltonian non-twist system. The Hamiltonian consists of the superposition of a non-monotonic zonal flow and drift waves. We provide evidence of the following novel FLR effects: Bifurcation of zonal flow; Double heteroclinic-homoclinic separatrix reconnection; Suppression of chaotic transport. The threshold for the destruction of the shearless KAM curve (computed using indicator points) exhibits a fractal dependence

in the Larmor-radius perturbation-amplitude space.

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

Julio J. Martinell
Institute of Nuclear Science
National Autonomous University of Mexico
martinel@nucleares.unam.mx

### MS31

### Transition to Global Transport in Nontwist Area-preserving Maps: Recent Results

Area-preserving nontwist maps are simple models for degenerate Hamiltonian systems that describe, e.g., magnetic field lines in toroidal plasma devices with reversed magnetic shear profile. As numerically easily accessible systems, these maps can be used to gain understanding of basic features of the physical systems modeled, such as the transition to global transport. Physical transport barriers often correspond to shearless invariant tori which can break up or be destroyed in the process of separatrix reconnection. I will discuss the current state of the field and present some new results.

Alexander Wurm
Department of Physical & Biological Sciences
Western New England College
awurm@wnec.edu

### MS32

### Controlling the Zoo: A Conservative Control Model for Biomimetic Robots

Abstract not available at time of publication.

Joseph Ayers
Northeastern University
j.ayers@neu.edu

### MS32

### Using Robotic Models to Test Animal Networks and Hypothesized Connections

We have developed controllers for robotic legs based on the neural mechanisms of intra-leg joint coordination in stick insects and cockroaches. Our controllers coordinate the activity of multiple independent joints via sensory coupling to generate stepping and can adaptively transition between distinct behaviors. We are also developing a novel neural-inspired dynamical control architecture based on stable heteroclinic channels that can flexibly and robustly orchestrate multiple degrees of freedom, and can readily handle behavioral hierarchies, temporal decision-making, and learning, and which incorporates the best aspects of finite state machine and central pattern generator (limit cycle) controllers.

Roger Quinn
Case Western Reserve University
Mechanical and Aerospace Engineering
rdq@case.edu

### MS32

### Synthetic CPG Controller for Real-time Implementation of Locomotion Activity and Control System in Swimming Lamprey-base Robot

This paper discusses the design of discrete time models for capturing dynamical behavior of spiking neurons and synapses that shape the dynamical properties of specific neurobiological networks. Such discrete time map-based neurons and synapses can be configured to implement the major features of the command neuron, coordinating neuron, and the central pattern generator (CPG) organization of the lamprey nervous system. This approach enables real-time operation of CPG dynamics on a DSP chip.

Nikolai Rulkov
Univ of California / San Diego
Inst for Nonlinear Science
nrulkov@ucsd.edu

### MS32

### Implementation of Neuronal Networks for Reactive Autonomy

To better understand how sensory systems modulate behavior and demonstrate the advantages of neuronal circuits over algorithmic control, we developed an exteroceptive sensory suite consisting of an accelerometer, tilt sensor, compass and sonar short baseline array (SBA). Given a goal such as a destination the robot will make decisions reactively, based on its sensory inputs, rather than a predetermined algorithm. Compensation for impediments by nested exteroceptive reflexes will allow the robot to navigate reactively in unpredictable environment.

Anthony Westphal
Notheastern University, Marine Science Center
westphal.a@husky.neu.edu

### MS33

### Applications of Asymptotic Theory to Scroll Wave Dynamics

The asymptotic dynamics of scroll waves in reaction-diffusion equations due to small symmetry breaking perturbations results in motion equations of string-like objects, the scroll filaments. We compare the asymptotic predictions with results of numerical simulations, for two test studies. Time-periodic delocalized perturbations (resonant drift) may be considered as a method of low-voltage defibrillation. Drift due to spatial gradient of parameters has important role in arrhythmogenicity of border zone of myocardial ischemia.

Vadim N. Biktashev
Dept of Mathematical Sciences
University of Liverpool
V.N.Biktashev@liverpool.ac.uk

Irina Biktasheva
University of Liverpool
ivb@liv.ac.uk

Stuart W. Morgan
formerly University of Liverpool
stuart.w.morgan@googlemail.com

Narine Sarvazyan
George Washington University
phynas@gmail.com

**MS33**
**Scroll Wave Break-up and Filament Turbulence**

Scroll waves and their associated filaments can become unstable through a number of different bifurcations, often leading to turbulent behavior. In this talk, I will give an overview on how different bifurcations can leave their signature on the statistical properties of the turbulent dynamics. For example, one can distinguish between different instabilities thought to be relevant in the context of cardiac arrhythmia even if only the surface of a bounded three-dimensional medium is observable.

Jörn Davidsen
Department of Physics and Astronomy
University of Calgary
davidsen@phas.ucalgary.ca

**MS33**
**Interaction of Scroll Waves in the Presence and Absence of External Gradients**

We investigate experimentally the interaction of a pair of meandering scroll waves in the excitable Belousov-Zhabotinsky reaction medium. The organising centres of the scrolls, the so-called filaments, were originally straight. Two cases are considered: co-rotating and counter-rotating scroll waves in the presence and absence of a gradient parallel to the filament. While in the absence of gradients, sponaneous symmetry breaking occurs and the slower scroll is ousted, the situation differs in the presence of a gradeint. Here, wen need to consider the relative sense of rotation. While counterrotating scrolls behave as in the absence of a gradient (i.e. the slower scroll is expulsed), co-rotating waves synchronise and stabilize each other.

Marcus Hauser
Institute of Experimental Physics
Otto-von-Guericke-Universität
marcus.hauser@physik.uni-magdeburg.de

**MS33**
**Pinning of Scroll Waves in Excitable Systems**

I will present an overview of recent results on scroll wave dynamics in excitable reaction-diffusion systems. Experimental results from chemical experiments will be compared to PDE simulations and curvature flow models. Our analyses focus on the motion of the scroll filament which is the one-dimensional rotation backbone of these three-dimensional structures. Specific examples include solutions involving translating as well as rotating filament motion.

Oliver Steinbock
Department of Chemistry and Biochemistry
Florida State University
steinbck@chem.fsu.edu

**MS34**
**Using Mathematical Models of Varying Complexity to Study the Great Snowball Earth Events**

Geological evidence indicates that at least twice during the Neoproterozoic era ($\sim$635 and $\sim$715 million years ago) there were global glaciations during which Earth's oceans may have been covered with O(1 km) thick ice: Snowball Earth events. I will describe mathematical and physical models of a hierarchy of complexity that can be used to understand why Snowball Earth events can occur, what their climate would be like, and how a Snowball Earth can end.

Dorian S. Abbot
Department of Geophsyical Sciences
University of Chicago
abbot@uchicago.edu

**MS34**
**A Paleoclimate Model of Ice-Albedo Feedback**

A model of ice-albedo feedback dating back to Budyko and Sellers is combined with computations of the Earth's orbital parameters to examine the role of ice-albedo feedback in the paleoclimate record. The changes in the Earth's obliquity are shown to be the major driver in both the model output and the climate record.

Richard McGehee
University of Minnesota
mcgehee@math.umn.edu

**MS34**
**Relaxations Oscillations in a Simple Ocean-Box Model Modulated by Zonal Insolation - a Possible Mechanism for Dansgaard-Oeschger Events**

The climate of the last 100,000 years experienced several sudden warming episodes with approximately 1,500 year durations. It is generally suggested that freshwater discharge from land ice-sheets triggered changes in the state of the Atlantic meridional circulation, effecting the climate. However many of the features of the climate record remain unexplained. Using a simple ocean-sea-ice model I show that intrinsic oceanic oscillations can be modulated by zonal insolation to produce a pattern quite similar to proxy records.

Raj Saha
University of North Carolina
rajsaha@physics.unc.edu

**MS34**
**Dynamics of An Energy Balance Model**

A 1-dimensional energy balance model was first introduced in late sixties independently by Mihail Budyko (Main Geophysical Observatory, Russia) and William Sellers (University of Arizona). Budyko in particular, introduced an equation that governs the evolution of the one hemispheric temperature distribution, by taking into account the ice albedo feedback phenomenon. In this talk I will summarize Budyko's model and introduce an equation that induces the ice line dynamics. Then I will present a result on the existence of a center stable manifold and some future directions.

Esther Widiasih
Department of Mathematics
The University of Arizona
ewidiasih@math.arizona.edu

**MS35**
**Learning Hybrid Controllers from Animal Tracking**

I am interested in a constructionist approach to understanding social animal behavior. By that I mean that I endeavor to build small "programs' that fully describe individual animals' method of interaction with their environment. We infer, or learn these programs or models from observation of the movement of animals in video. When hundreds or thousands of such programs are instantiated in simulated animal "bodies' we can assess the accuracy of the models and also use them to predict system level behavior.

Tucker Balch
School of Interactive Computing
Georgia Tech
tucker.balch@cc.gatech.edu

**MS35**

**Deconfliction in Biological and Bio-inspired Coordinated Control**

Deconfliction refers to the ability of an autonomous system to sense and avoid other moving agents. Biological systems demonstrate obstacle avoidance and deconfliction capabilities when operating in close proximity well beyond those currently achievable by engineered systems. In the work presented here, algorithms for deconfliction in engineering systems based on collision cones are evaluated relative to biological data.

Kristi Morgansen
Dept. of Aeronautics and Astronautics
U. of Washington
morgansen@aa.washington.edu

**MS35**

**Reconstruction and Analysis of Individual Dynamics in Fish Schools and Mosquito Swarms**

This talk will describe ongoing research that seeks to improve our understanding of collective behavior in natural systems by applying tools from applied mathematics and engineering. We will present (1) new insights on information transmission via non-verbal signaling obtained using an automated video-tracking framework to reconstruct full-body trajectories of densely schooling fish; and (2) results for accurately reconstructing the three-dimensional trajectories of individual mosquitoes in swarms of An. gambiae, arguably the most deadly animal on earth.

Derek A. Paley, Sachit Butail
University of Maryland
Department of Aerospace Engineering
dpaley@umd.edu, sachitb@gmail.com

**MS35**

**Tracking Fish Schools in 2D with Real-time Applications**

Real-time tracking of fish enables automated feedback control of stimuli in laboratory fish schooling experiments; this is particularly significant for experiments designed to better understand mechanisms of collective behavior. We describe our platform that enables both real-time and off-line video-based tracking of fish schools. Our methods include mixture-of-gaussian clustering, head-tail distinction, Hungarian matching, and unscented Kalman filter tracking. We discuss the estimation from tracked data of group-level quantities such as polarization and present experimental results.

Daniel T. Swain
Department of Mechanical and Aerospace Engineering
Princeton University
dswain@princeton.edu

Naomi E. Leonard, Iain Couzin
Princeton University
naomi@princeton.edu, icouzin@princeton.edu

**MS36**

**Traveling Waves for Reaction-convection-diffusion Systems**

Hyperbolic systems of differential equations with stiff source terms can be approximated by (smaller) systems with diffusive terms. This follows from a result of T.P.Liu, explaining why reaction-convection equations possess traveling waves. One can add other diffusive terms to such a system, preserving the nature of the solution, provided the additional term is dominated by Liu's diffusion. This is illustrated in the context of combustion in a porous medium.

Dan Marchesin
Instituto Nacional de Matematica Pura e Aplicada
marchesi@impa.br

Alexei A. Mailybaev
Institute of Mechanics, Moscow State University
mailybaev@imec.msu.ru

Julio D. Machado Silva
Instituto Nacional de Matematica Pura e Aplicada
jd@impa.br

**MS36**

**Long-time Behavior and Approximation of Nonlinear Waves**

We consider systems of parabolic PDEs which are nonlinearly coupled to a system of hyperbolic PDEs. We analyze the stability of traveling waves in such problems and explain their numerical approximation with the freezing method [Beyn, Thümmler 2004], [Rowley et al. 2003]. The principal idea is to reformulate the problem as a partial differential algebraic equation using nonlinear coordinates. In numerical examples we show that the analytically predicted rate of convergence can also be observed in computations.

Jens Rottmann-Matthes
Department of Mathematics
Bielefeld University, Germany
jrottman@math.uni-bielefeld.de

**MS36**

**Stability of Traveling Waves for Parabolic and Partially Parabolic Combustion Problems**

I will discuss nonlinear stability results for traveling waves in a class of reaction-diffusion systems that arise in chemical reaction models. The class includes partially parabolic systems, which require a "spectral stability implies linearized stability" result recently proved by the authors. The results are detailed enough to show, for example, that the effects of adding some heat or adding some reactant to a combustion front are different.

Anna Ghazaryan
Department of Mathematics

Miami University and University of Kansas
ghazarar@muohio.edu

Yuri Latushkin
University of Missouri, Columbia
latushkiny@missouri.edu

Stephen Schecter
North Carolina State University
Department of Mathematics
schecter@math.ncsu.edu

**MS36**

**Traveling Waves in the Buffered FHN System**

Calcium waves are widely observed with the free cytosolic calcium bound to large proteins that act as calcium buffers. Therefore it is of physiological importance to investigate the buffering effect on the properties of calcium waves. Motivated by this, we study traveling waves in the buffered FHN equation where the free cytosolic calcium is buffered. This is a joint work with James Sneyd.

Je-Chiang Tsai
Department of Mathematics
National Chung Cheng University (Taiwan)
tsaijc@math.ccu.edu.tw

**MS37**

**Stability Indices for Heteroclinic Networks**

This talk will discuss a dynamical invariant - the stability index - that can be used to characterize the local geometry of a basin of attraction. This invariant gives the scaling of the relative measure of a neighbourhood that is in a basin of attraction. It is useful for understanding heteroclinic attractors in cases where they are Milnor attractors, but not asymptotically stable. The talk will briefly discuss an application to simple robust heteroclinic cycles in $\mathbf{R}^4$, generalizing previous results of Krupa and Melbourne.

Peter Ashwin
University of Exeter
p.ashwin@ex.ac.uk

Olga Podvigina
Institute of Earthquake Prediction Theory & Math Geophysics
Moscow
olgap@ns3.mitp.ru

**MS37**

**Homoclinic Cycles: Dynamics and Bifurcations**

Recent work has shown intricate properties of dynamics near heteroclinic networks. Even for networks that are attractors, convergence of trajectories to it may occur in complicated ways. We discuss two specific examples. The first example involves a bifurcation of an asymptotically stable homoclinic cycle to an essentially asymptotically stable homoclinic cycle. The second example involves switching dynamics near a homoclinic cycle.

Ale Jan Homburg
KdV Institute for Mathematics
University of Amsterdam
a.j.homburg@uva.nl

**MS37**

**Switching on a Heteroclinic Network**

It is well known that heteroclinic cycles and networks can exist robustly in systems with symmetry. After an introduction to dynamics near heteroclinic cycles and networks, I will consider a particular heteroclinic network in detail. This network exhibits 'switching between different sub-cycles. The mechanism for switching is the presence of spiralling due to complex eigenvalues. Some of the unstable manifolds are two-dimensional; I describe a technique to account for all trajectories on those manifolds.

Claire M. Postlethwaite
University of Auckland
c.postlethwaite@math.auckland.ac.nz

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

Vivien Kirk
University of Auckland
v.kirk@auckland.ac.nz

Mary Silber
Northwestern University
m-silber@esam.northwestern.edu

Emily Lane
NIWA
e.lane@niwa.co.nz

**MS37**

**Universal Computation by Switching in Neural Networks**

Dynamic switching among saddles persistently emerges in a broad range of systems and may reliably encode information in neural networks. Their computational capabilities, however, are far from being understood. Here, we show that system inhomogeneities naturally yield controllable switching in neural networks. Such dynamics generically enables to compute all basic logic operations by entering into switching sequences in a controlled way. thus offering a flexible new kind of universal computation.

Fabio Schittler Neves
Max Planck Institute for Dynamics and Self-Organization
Göttingen
neves@nld.ds.mpg.de

Marc Timme
Max Planck Institut for Dynamics and Self-Organization
Goettingen, Germany
timme@nld.ds.mpg.de

**MS38**

**Stochastic Inference of Cell Migration Phenotypes**

Here a methodology for quantification of cell migration phenotypes is developed. Fitting of a stochastic model to experimentally observed cell tracks leads to estimation of parameters characterizing velocity and persistence of orientation. This method is applied to explore the role of RhoG, a Rho GTPase. We conclude that RhoG knock down cells are less efficient at exploring their environment and that their are two states of migratory behavior.

Richard Allen
University of North Carolina, Chapel Hill
richard.allen@unc.edu

Christopher Welch
University of North Carolina
welchc@med.unc.edu

Klaus Hahn
University of North Carolina at Chapel Hill
khahn@med.unc.edu

Tim Elston
University of North Carolina
telston@amath.unc.edu

**MS38**

**A General Markov Model for Pole Formation**

A classic mechanism of symmetry breaking used for modeling pole formation on the surface of cells is via the Turing models, which is a class of nonlinear reaction-diffusion systems. Solutions to the full nonlinear system are usually difficult to obtain and one must resort to a numerical integration. We explore a set of stochastic models of pole formation which capture the essential biological details and also have the property of being amenable to mathematical analysis.

Badal Joshi
Duke University
joshi@math.duke.edu

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

Michael C. Reed
Duke University
reed@math.duke.edu

**MS38**

**Analytical Theory for Cascade Formation in Clustered Scale-Free Neuronal Network Model**

We will present a second order calculation with explicit reference to clusters (triangles) to characterize the susceptibility of a network of stochastic integrate-and-fire neurons to giant cascading events as a function of the underlying network and dynamical parameters. The network is scale-free with a high degree of clustering. The results of the calculation are in excellent agreement with direct numerical simulations, and markedly superior to a calculation assuming a tree-like network.

Katherine Newhall
Rensselaer Polytechnic Institute
newhak@rpi.edu

Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
kramep@rpi.edu

Gregor Kovacic
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
kovacg@rpi.edu

Max Shkarayev
College of William and Mary
Dept. of Applied Science
maxim.shkarayev@gmail.com

David Cai
Shanghai Jiao Tong University, China
Courant institute, New York University, USA
cai@cims.nyu.edu

**MS38**

**Collective Dynamics of Processive Molecular Motors**

Internal to biological cells is an intricate transport apparatus, which consists of a cytoskeletal network of thin filaments called microtubules and proteins called processive molecular motors. These motors move in a directed fashion along the microtubules while generating sufficient force to tow biomolecular cargos. While experimentalists and theoreticians have had good success in describing the dynamics of a single motor with an attached cargo, there is considerable debate regarding how multiple motors cooperate and/or interfere with each other when they are attached to the same cargo. In this talk we discuss an SDE model for this scale of intracellular transport and present some findings which resolve one of the outstanding mysteries encountered by experimentalists: common sense says there are multiple motors acting in concert, but certain measurements seem to imply that only one motor is working at a time.

Avanti Athreya
Duke University
avanti@math.duke.edu

John Fricks
Dept of Statistics
Penn State University
fricks@stat.psu.edu

Pete Kramer
Rensselaer Polytechnic Institute
kramep@rpi.edu

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

**MS39**

**Ensemble Modeling of Human Immune Response to IAV Infection**

We present an ensemble model of the human immune response to influenza A virus infection, consisting of an ODE system with probability distribution on parameters reflecting the goodness of fit to empirical data. Ensemble models of biological systems provide probabilistic predictions of the dynamics that approximate the variability of response among individuals. We used the model to compute probabilistic estimates on the trajectories of the immune response, duration of disease, maximum tissue damage, likelihood of rebound of disease and superspreaders. We found that the strength, duration and time of initiation of antiviral treatment have significant effects on treatment benefits.

Baris Hancioglu
Virginia Tech
hbaris@vt.edu

Gilles Clermont
University of Pittsburgh
cler@pitt.edu

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

**MS39**

**The Dynamics of Foreign Body Reaction Models in 2-dimensions**

The foreign body reactions model the network of immune and inflammatory reactions of human or animal bodies to foreign objects placed in tissues. This study focuses on kinetics-based predictive models in order to analyze complex reactions of various cells/proteins and biochemical processes and to understand transient behavior. Computational models based on continuum and multi-scale methods were constructed to investigate the time dynamics as well as spatial variations. Several numerical examples will be discussed.

Jianzhong Su
University of Texas at Arlington
Department of Mathematics
su@uta.edu

**MS39**

**A Mathematical Model of Ischemic Wound Healing**

Chronic wounds represent a major public health problem affecting 6.5 million people in the United States. Ischemia, primarily caused by peripheral artery diseases, represents a major complicating factor in chronic wound healing. In this talk, we present a mathematical model of ischemic dermal wounds. The model consists of a coupled system of partial differential equations in the partially healed region, with the wound boundary as a free boundary. The extracellular matrix (ECM) is assumed to be viscoelastic, and the free boundary moves with the velocity of the ECM at the boundary. The model equations involve the concentration of oxygen, PDGF and VEGF, the densities of macrophages, fibroblasts, capillary tips and sprouts, and the density and velocity of the ECM. Simulations of the model demonstrate how ischemic conditions may limit macrophage recruitment to the wound-site and impair wound closure. The results are in general agreement with experimental findings.

Chuan Xue
Ohio State University
cxue@mbi.osu.edu

Avner Friedman
Department of Mathematics, Ohio State University
afriedman@mbi.osu.edu

Chandan Sen
Ohio State University Medical Center
Columbus
chandan.sen@osumc.edu

**MS40**

**Uncertainty and Sensitivity Analysis in Building Models**

As building energy modeling evolves, the number of parameters used to define these models continues to grow. There are numerous sources of uncertainty in these parameters, and past efforts have used uncertainty and sensitivity analysis to quantify how uncertainty in tens of parameters influence predicted results. We present work where we increase the size of analysis by two orders of magnitude, and decompose the sensitivity pathways to identify how uncertainty flows through the dynamics.

Bryan Eisenhower
UCSB
bryane@engr.ucsb.edu

**MS40**

**Model-based Failure Mode Effect Analysis in High Performance Buildings**

System failure modes are the mechanisms that can cause system performance loss, such as failed valves or dampers in buildings causing excess energy consumption. Whole building energy models combined with rapid Monte-Carlo simulation can be extended to analyze building systems and controls failure modes, for prioritization. Model construction must partition failure modes that cannot simultaneously occur, and delimit the failure modes to their occurrence rates. The result is an order $1/n$ analysis, rather than $2^n$.

Kevin Otto
Robust Systems and Strategy
otto@robuststrategy.com

**MS40**

**Lagrangian Coherent Structures Based Analysis of Building Airflows**

Passive building cooling and heating systems exploit spatial temperature stratification and buoyancy to reduce energy consumption; however the 3D inhomogeneous thermo-airflow patterns that arise are difficult to analyze. In this talk we demonstrate the use of dynamical system methods to extract Lagrangian Coherent Structures to systematically characterize such spatiotemporally varying patterns, and assess their impact on occupant comfort and energy consumption. We illustrate this in several building examples comparing conventional and passive systems.

Amit Surana
System Dynamics and Optimization
United Tecnologies Research Center (UTRC)
suranaa@utrc.utc.com

Sunil Ahuja, Satish Narayanan
United Technologies Research Center
ahujasd@utrc.utc.com, narayas@utrc.utc.com

**MS40**

**Challenges and Numerical Consideration in Building Energy Modeling**

Building energy and control systems lead to multi-physics, multi-scale heterogeneous complex systems. The underlying equations are nonlinear systems of ordinary differential

equations, partial differential equations and algebraic equations with continuous and discrete states. Modeling, simulation and analysis of such systems pose new challenges as systems become increasingly integrated. We present recent research in the development of tools that support the modeling, simulation and analysis of such systems.

Michael Wetter
LBNL
mwetter@lbl.gov

Wangda Zuo
Lawrence Berkeley National Lab
wzuo@lbl.gov

**MS41**

**Ribosome Traffic During Protein Synthesis**

I will present a description of the process of mRNA translation based on Petri Nets. This approach has the advantage of yielding analytic solutions for the realistic case of mRNAs consisting of a inhomogeneous sequence of codons, in contrast to the totally asymmetric exclusion process (TASEP) commonly used to describe translation. The solutions obtained with this framework based on the Max Plus algebra will be discussed and compared with the ones obtained with the TASEP.

David Broomhead
The University of Manchester
Applied Mathematics
David.Broomhead@manchester.ac.uk

**MS41**

**Robustness of Circadian Clocks to Daylight Fluctuations: Hints from Picoeukaryote Ostreococcus Tauri**

Circadian clocks are genetic oscillators keeping time in many organisms, which synchronize to the day/night cycle by sensing ambient light. However, daylight fluctuations could randomly reset the clock. Modeling the clock of the green unicellular alga Ostreococcus tauri has uncovered a dynamical solution to this problem. Coupling to light occurs during specific time intervals, where the oscillator is unresponsive. Thus, coupling is ineffective when clock is on time but resets it when out of phase.

Quentin Thommen, Benjamin Pfeuty, Pierre-Emmanuel Morant
PhLAM/Université Lille 1, France
quentin.thommen@phlam.univ-lille1.fr,
bpfeuty@phlam.univ-lille1.fr,
pierre-emmanuel.morant@ensicaen.fr

Florence Corellou
Observatoire Océanologique de Banyuls (UPMC/CNRS)
florence.corellou@obs-banyuls.fr

François-Yves Bouget
UMR CNRS/Paris 6 7628
Observatoire oc
'eanologique de Banyuls/mer, France
francois-yves.bouget@obs-banyuls.fr

Marc Lefranc
PhLAM/Université Lille I,
France
marc.lefranc@univ-lille1.fr

**MS41**

**Identifiability and Observability Analysis for Experimental Design in Nonlinear Dynamical Models in Systems Biology**

Modeling of molecular reaction networks by ODEs faces difficulties when estimating model parameters from incomplete and noisy experimental data. By means of an application from cell biology [Becker et al., 2010] we present an approach that uses the profile likelihood to detect both structural and practical non-identifiabilities and investigates their influence on the model dynamics [Raue et al., 2009]. The approach also allows to design new experiments that resolve non-identifiabilities and to derive confidence intervals.

Andreas Raue
Physics Institute, University of Freiburg
andreas.raue@fdm.uni-freiburg.de

Clemens Kreutz
University of Freiburg
Institute of Physics
ckreutz@fdm.uni-freiburg.de

Ursula Klingmueller
German Cancer Research Center, Heidelberg
u.klingmueller@dkfz-heidelberg.de

Jens Timmer
University of Freiburg
Department of Physics
jeti@fdm.uni-freiburg.de

**MS41**

**Translational Regulation of Gene Expression**

We present a stochastic model that captures the essential steps of the process of translation. In contrast to oversimplified models, it crucially considers the two main timescales of the biological process. Using this model, we calculate the translation rate of the whole genome of S. cerevisiae depending on the initiation rate of ribosomes. This allows us to classify proteins according to their translational dynamics and relating them to their biological function.

M. Carmen Romano
Institute for Complex Systems and Mathematical Biology and
Institute of Medical Sciences, University of Aberdeen, UK
m.romano@abdn.ac.uk

Luca Ciandrini
Institute for Complex Systems and Mathematical Biology
University of Aberdeen, UK
l.ciandrini@abdn.ac.uk

Ian Stansfield
Institute of Medical Sciences
University of Aberdeen, UK
i.stansfield@abdn.ac.uk

**MS42**

**Characterisitc Lyapunov Vectors: Critical Overview and State of the Art**

Characteristic Lyapunov vectors (CLVs) convey the information of the tangent dynamics of a system: they are intrinsic, independent of the scalar product, and covariant under time evolution. However, until recently, it was not known how to compute CLVs efficiently in large systems. In this talk I will review the methods recently available to compute CLVs as well as the applications of these vectors to a variety of practical and theoretical problems.

Diego Pazo
Instituto de Fisica de Cantabria, IFCA
pazo@ifca.unican.es

**MS42**

**Lyapunov Analysis and Hyperbolicity of Extended Dynamical Systems**

Lyapunov exponents and vectors are important characteristics of nonlinear dynamical systems. Recently several efficient algorithms are proposed for the calculation of the so-called covariant/characteristic Lyapunov vectors (CLVs) and the associated instantaneous Lyapunov exponents, which allows to probe the hyperbolicity of high dimensional dynamical systems. Our recent results on the hyperbolicity of dissipative partial differential equations will be reviewed and the relation to effective degrees of freedom of those infinite dimensional systems will be discussed.

Hong-Liu Yang
Institute of Physics, Chemnitz University of Technology
Germany
hongliu.yang@physik.tu-chemnitz.de

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

**MS42**

**Structure and Dynamic Localization of Characteristic Lyapunov Vectors in Anharmonic Hamiltonian Lattices**

We study the scaling behavior of Lyapunov vectors (LV) of two different one-dimensional Hamiltonian lattices. The characteristic LVs exhibit qualitative similarities with those corresponding to dissipative lattices, but the scaling exponents are different and seemingly non-universal. In contrast, backward LVs present approximately the same scaling exponent for both models, suggesting that it is a product of the imposed orthogonality. We employ a 'bit reversible' algorithm that largely reduces computer memory limitations.

Mauricio Romero-Bastida
Instituto Politecnico Nacional
Escuela Superior Ingenieria Mecanica y Electrica - Culhuacan
mromerob@ipn.mx

**MS42**

**Efficient Computation of Characteristic Lyapunov Vectors in Spatially Extended Systems**

An efficient, norm-independent method for constructing the $n$ most rapidly growing Lyapunov vectors (LVs) from $n-1$ leading forward and $n$ leading backward asymptotic singular vectors (SVs) is proposed. In spatially extended systems, the number of required SVs, $2n-1$, is typically much less than the dimensionality of the system. The LVs so constructed are invariant under the linearized flow in the sense that, once computed at one time, they are defined, in principle, for all time through the tangent linear propagator.

Christopher L. Wolfe
Climate, Atmospheric Science, and Physical Oceanography
Scripps Institution of Oceanography, UCSD
clwolfe@ucsd.edu

Roger Samelson
College of Oceanic and Atmospheric Sciences
Oregon State University
rsamelson@coas.oregonstate.edu

**MS43**

**Self-organized Criticality in Adaptive Neural Networks**

Adaptive network combine topological evolution of a complex network and dynamics in the network nodes. They exhibit several dynamical phenomena, including highly robust self-tuning to critical states corresponding to phase transitions. Important real world examples of adaptive networks are biological neural networks. In this talk I will present data providing evidence for critical dynamics in patients. The self-tuning to the critical state is then analyzed numerically and analytically. Finally, I argue that criticality may be crucial for neural information processing and outline technical applications for adaptive self-tuning.

Thilo Gross
Max-Planck Institute for Physics of Complex Systems
gross@mpipks-dresden.mpg.de

**MS43**

**Criticality and Dynamic Network Reconfiguration in Human Brain fMRI and MEG Recordings**

Self-organized criticality is an attractive model for brain dynamics. We found evidence in fMRI and MEG data that human brain systems exist in this state, characterized by power-law distributions of both prolonged periods of phase-locking, and of large rapid changes in global synchronization. Graph theoretical analysis of such reconfigurations during a working memory task revealed that cognitive effort transiently breaks up functional modules resulting in a network which is more integrated over long distances.

Manfred G. Kitzbichler
Behavioural and Clinical Neuroscience Institute
University of Cambridge, UK
manfredg@nmr.mgh.harvard.edu

**MS43**

**Predicting Criticality and Dynamic Range in Complex Networks: Effects of Topology**

The effect of network structure on the dynamics of network-coupled discrete-state excitable elements under stochastic external stimulus can be understood through spectral properties of the weighted network adjacency matrix. We show that when the adjacency matrix has largest eigenvalue equal to one, dynamics will be in a critical state, maximizing the dynamic range of stimulus to response. Further analysis predicts that networks with more homogeneous degree distributions allow a higher achievable dynamic range at criticality.

Daniel Larremore
Applied Mathematics
University of Colorado at Boulder
daniel.larremore@colorado.edu

**MS43**

**Neuronal Avalanches and Optimized Information Processing in Cortical Neural Networks**

Rapidly growing empirical evidence supports the hypothesis that the cerebral cortex operates in a dynamical regime near the critical point of a phase transition. This raises a question: What benefits are endowed to organisms whose brain circuits operate near criticality? We present experiments on living neural networks which suggest that three aspects of information processing are optimized at criticality: 1) dynamic range, 2) information transmission, and 3) information capacity.

Woodrow L. Shew
NIH/NIMH, 35 Convent Dr.
Bethesda, MD, USA 20892
sheww@mail.nih.gov

**MS44**

**Spiking and Bursting in an Autonomous Model of Mouse Ventricular Myocytes**

Comprehensive model of mouse ventricular myocytes with small constant input current is demonstrated to generate complex spiking and bursting oscillations. We examine the bifurcations underlying the transitions between the steady states and oscillatory activities as the magnitude of the constant current is varied. Inactivation of the fast $Na^+$ current is a major determinant for both spiking and bursting activities. This self-sustained activity is considered as a trigger of non-reentrant arrhythmia in the mouse heart.

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

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

**MS44**

**Alternans and Nonlinear Dynamics in Cardiac Tissue**

Many cardiac arrhythmias contain are associated with complex spatiotemporal dynamics. This talk will describe the nonlinear dynamics of electrical waves in the heart, including states with planar waves, single spiral/scroll waves, and multiple interacting waves, together with how they are modeled mathematically. Special attention will be given to alternans, an arrhythmia characterized by a beat-to-beat variation in cellular response that can produce complicated patterns. Challenges and opportunities associated with this system will be discussed.

Elizabeth M. Cherry
Cornell University
Department of Biomedical Sciences
excsma@rit.edu

Flavio H. Fenton
Department of Biomedical Sciences
Cornell University
fhf3@cornell.edu

**MS44**

**Temperature Effects on Spatial Patterns of Cardiac Alternans**

Ventricular tachyarrhythmias result from disruptions to the heart's rhythm and are associated with ventricular fibrillation. One such arrhythmia is alternans, in which constant pacing at a rapid period produces a period-doubling bifurcation resulting in alternating long-short electrical responses and complex spatial patterns. We characterized spatial alternans properties using optical mapping recordings of isolated canine ventricles at four different temperatures over a range of periods. We show how complex alternans patterns develop and change with temperature.

Alessio Gizzi
University Campus Bio-medico of Rome
a.gizzi@unicampus.it

Elizabeth M. Cherry
Cornell University
Department of Biomedical Sciences
excsma@rit.edu

Stefan Luther
Max Planck Institute for Dynamics and Self-Organization
stefan.luther@ds.mpg.de

Simonetta Filippi
University Campus Bio-Medico of Rome, Italy
ICRA University of Rome, La Sapienza, Italy
s.filippi@unicampus.it

Flavio Fenton
Cornell University
fhf3@cornell.edu

**MS44**

**Spatio-Temporal Dynamics of Alternans in the Heart**

Alternans of action potential duration is a herald for life-threatening ventricular arrhythmias. In isolated myocytes, the appearance of alternans can be predicted by analyzing the restitution properties of periodically paced cardiac tissue. However, the dynamical behavior of whole heart is more complex due to presence of spatial component. We investigated the organization and evolution of alternans in isolated rabbit hearts using high-resolution optical mapping, and identified the mechanisms of spatially concordant and discordant alternans formation.

Alena Talkachova
University of Minnesota
talkacal@umn.edu

**MS45**

**Factors Controlling the Stability of the Sea Ice

**Cover**

The contrast in surface albedo between sea ice and open ocean suggests the possibility of multiple climate states and associated nonlinear thresholds during sea ice retreat. We investigate the factors controlling such a possibility by performing a bifurcation analysis over all of the parameters in an idealized single-column model. The results are physically interpreted and then compared with simulations carried out with more comprehensive models.

Ian Eisenman
California Institute of Technology
Division of Geological and Planetary Sciences
ian@gps.caltech.edu

Dorian S. Abbot
Department of Geophsyical Sciences
University of Chicago
abbot@uchicago.edu

Raymond T. Pierrehumbert
Geophysical Sciences Dept.
University of Chicago
rtp1@geosci.uchicago.edu

### MS45
### Rapid Sea Ice Loss in Climate Model Simulations of a Changing Arctic

Climate models project transitions to perennially ice-free Arctic conditions that are punctuated by instances of rapid sea ice loss. These rapid ice loss events (RILES) are accompanied by dramatic increases in cloud cover and warming. Here we discuss the forcing and feedbacks associated with RILEs. Additionally, we analyze a series of climate model integrations to explore the potential bifurcation and hysteresis of perennial sea ice loss simulated by the Community Climate System Model.

Marika Holland
National Center for Atmospheric Research
mholland@ucar.edu

### MS45
### Sea Ice as a Discrete Map

We treat the Semtner-0-layer thermodynamical sea ice model as a discrete map. We show that under an additional external heat flux – the bifurcation parameter – Multi-Year-Cycles (MYC) can appear due to discontinuity-induced- and flip-bifurcations leading to a period-adding cascade with interspersed chaotic behaviour. We discuss the robustness of these MYC when subject to noisy forcings and why they may mask sea ice decline in winter.

Kay Huebner
Max-Planck-Institute for Meteorology
kay.huebner@zmaw.de

### MS45
### Bifurcation Analysis of a Low-order Model of Arctic Sea Ice

Eisenman and Wettlaufer (2009) used energy balance considerations to introduce a conceptual ODE model for investigating bifurcations associated with seasonal Arctic sea ice loss, as greenhouse gas levels increase. We examine a version of their model that allows us to derive an explicit Poincaré return map describing the average Arctic sea ice thickness from one year to the next. The range of possible bifurcation behavior for fixed points of the map is then determined analytically.

Mary C. Silber
Northwestern University
Dept. of Engineering Sciences and Applied Mathematics
m-silber@northwestern.edu

### MS46
### The Pearling Instability in Polymer Electrolyte Solutions

Recently, it has been shown that the formation of structures in polymer electrolyte solutions can be modeled by regularizing the Canham-Helfrich free energy into a finite-width phase field model. This regularization – called the functionalized Cahn-Hilliard Energy (FCHE) – allows for double layer, i.e. bi-layer, interfaces whose thickness scales with an asymptotically small parameter. If the double-well potential W appearing in the FCHE is symmetric, these double layer structures can be shown to be stable as network patterns of the mass-preserving gradient flow associated to the FCHE. However, in two space dimensions, as the well W is made asymmetric, the bi-layer patterns evolve into a 'pearled network' – as will be discussed in this talk.

Arjen Doelman
University of Leiden
doelman@math.leidenuniv.nl

Greg Hayrapetyan
Department of Mathematics
Michigan State University
hayrapet@math.msu.edu

Keith Promislow
Michigan State University
kpromisl@math.msu.edu

### MS46
### Geometric Evolution of bi-layers in the Functionalized Cahn-Hilliard Equation

The functionalized Cahn-Hilliard energy (FCH) is a novel higher-order energy that serves as a model for network formation in solvated, functionalized polymers. Leading order minimizers of this energy include new bi-layer solutions with homoclinic cross sections. An overview of the reduction of the gradient flow of (FCH) to the sharp interface evolution of these bi-layers is presented.

Gurgen Hayrapetyan
Michigan State University
hayrapet@math.msu.edu

### MS46
### Energetic Variational Approaches in Ionic Fluids and Ion Channels

Ion channels are key components in a wide variety of biological processes. The selectivity of ion channels is the key to many biological process. Selectivities in both calcium and sodium channels can be described by the reduced models, taking into consideration of dielectric coefficient and ion particle sizes, as well as their very different primary structure and properties. These self-organized systems will be modeled and analyzed with energetic variational approaches (EnVarA) that were motivated by classical works of Rayleigh and Onsager. The resulting/derived multiphysics-multiscale systems automatically satisfy the Second Laws of Thermodynamics and the basic physics that are involved in the system, such as the microscopic diffusion, the electrostatics and the macroscopic conservation of momentum, as well as the physical boundary conditions. In this talk, I will discuss the some of the related biological, physics, chemistry and mathematical issues arising in this area.

Chun Liu
Penn. State University
University Park, PA
liu@math.psu.edu

**MS46**

**The Dynamics and Stability of Localized Spot Patterns for the Gray-Scott model in Two Dimensions**

The dynamics and stability of multi-spot patterns to the Gray-Scott (GS) reaction-diffusion model in a two-dimensional domain is studied in the singularly perturbed limit of small diffusivity $\epsilon$ of one of the two solution components. A hybrid asymptotic-numerical approach based on combining the method of matched asymptotic expansions with the detailed numerical study of certain eigenvalue problems is used to predict the dynamical behavior and instability mechanisms of multi-spot quasi-equilibrium patterns for the GS model in the limit $\epsilon \to 0$. For $\epsilon \to 0$, a quasi-equilibrium $k$-spot pattern is constructed by representing each localized spot as a logarithmic singularity of unknown strength $S_j$ for $j = 1, \ldots, k$ at unknown spot locations $\mathbf{x}_j \in \Omega$ for $j = 1, \ldots, k$. A formal asymptotic analysis is then used to derive a differential algebraic ODE system for the collective coordinates $S_j$ and $\mathbf{x}_j$ for $j = 1, \ldots, k$, which characterizes the slow dynamics of a spot pattern. Phase diagrams in parameter space for instabilities of the multi-spot pattern due to spot self-replication, spot oscillation, and spot annihilation, are obtained. The asymptotic results are validated from full numerical simulations.

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

Wan Chen
Oxford Centre Collaborative Applied Mathematics,
Oxford University
chenw1@maths.ox.ac.uk

**MS47**

**Applications of Piecewise Isometries in Electronic Engineering**

In this talk, I shall mention examples of electronic circuits whose dynamics can be described by a class of two-dimensional discontinuous mappings known as piecewise isometries (PWIs). In at least two of the examples, realism dictates that the models be dissipative, which leads directly to contraction in the underlying PWI. The result proved in 'Piecewise contractions are asymptotically periodic', H Bruin & J H B Deane, Proc AMS 137 4 pp 1389–1395 (2009), shows that the dynamics of a system described by a piecewise contraction cannot be other than eventually periodic, although the possibility of the co-existence of many different periodic solutions complicates the picture. The obvious (difficult) next question is: can we say anything about the periodic solutions exhibited by a given PWI? This question will be discussed in the talk, with reference to computations concerning the dynamics of the 'contracting Goetz map'.

Jonathan Deane
Department of Mathematics
University of Surrey
j.deane@surrey.ac.uk

**MS47**

**Singularities of Invertible Planar Piecewise Rotations**

The purpose of this talk is to provide a brief overview on the recent results on the properties of the singularities of 2-dimensional invertible piecewise isometric dynamical systems in general, and then report some new results for the special case in which the dynamics is the iteration of piecewise rational rotations. First, the speaker reviews his recent results about the classification of the singularities of 2-dimensional invertible piecewise isometries and the properties of each class. He classified the afore-mentioned singularities into three types, among which the first type is removable, the second type is innocuous, and only the third type contributes to the intricate singularity structure that often exhibits chaos and riddling. The classification was done based upon the geometrical properties of the singularities. The core issue here is how these distinct geometrical properties lead to different dynamical behaviors. Afterwards, he will discuss some new results, namely, the partial converses of the first set of results, under the restriction that the piecewise isometric dynamics consists only of the rational rotations.

Byungik Kahng
University of Minnesota at Morris
byungik.kahng@unt.edu

**MS47**

**Interval Exchange Discontinuity Growth and Group Actions**

An interval exchange transformation (IET) is a piecewise isometry of the unit interval. An IET is determined by a finite partition of the unit interval into subintervals and a permutation that describes how the subintervals are reordered by the map. For a given IET $f$, the number of discontinuities of iterates $f^n$ is either bounded or exhibits linear growth as a function of $n$; no sublinear but unbounded growth rates can occur. This dichotomy in growth rates has various applications to the algebraic properties of the group of all IETs; for instance, it is shown that IET groups do not possess distortion elements, a complete classification of centralizers in the IET group is given, and the automorphism group of the IET group is computed.

Chris Novak
Department of Mathematics and Statistics
University of Michigan
cfnovak@umd.umich.edu

**MS47**

**Dynamics and Applications of Piecewise Isometries**

This talk introduces the dynamics of piecewise isometries

(PWIs) and discusses some features which are relevant to applications. As a particular example, we consider the mixing properties of PWIs, which are fundamentally different from the stretching and folding mechanism of familiar chaotic advection. As a physical example we consider mixing of granular materials. Simulations connect the PWI theory with experiments and demonstrate how cutting and shuffling contributes to increasing interfacial boundaries, leading to effective mixing.

Rob Sturman
University of Leeds
rsturman@maths.leeds.ac.uk

**MS48**

**Connection Between Discrete Stochastic Cell-based Models and Nonlinear Diffusion Equations**

In this talk a connection will be described between discrete stochastic models describing microscopic motion of fluctuating cells in chemotactic field, and macroscopic nonlinear diffusion equations describing dynamics of cellular density. Cells move towards chemical gradient with their shapes randomly fluctuating. Nonlinear diffusion coefficient will be shown to depend on cellular volume fraction preventing collapse of cellular density in finite time. This makes such equations much more biologically relevant then earlier introduced systems. A very good agreement will be shown between Monte Carlo simulations of the microscopic cellular Potts model and numerical solutions of the macroscopic nonlinear diffusion equations for relatively large cellular volume fractions. Combination of microscopic and macroscopic models were used to simulate growth of structures similar to early vascular networks. In the second half of the talk, a connection will be demonstrated between a microscopic one dimensional cell-based stochastic model of reversing non-overlapping self-propelled rods and a macroscopic nonlinear diffusion. Boltzmann-Matano analysis will be used to determine the nonlinear diffusion coefficient corresponding to the specific reversal frequency. Periodic reversals of the direction of motion in systems of self-propelled rod shaped bacteria enable them to effectively resolve traffic jams formed during swarming and maximize their swarming rate.

Mark Alber
University of Notre Dame
mark.s.alber.1@nd.edu

**MS48**

**Derivation of SPDEs for Correlated Random Walks and SDEs for Sunspot Activity**

Stochastic generalizations of correlated random walk models, specifically, the telegraph equation in one dimension and the linear transport equation in two dimensions, are derived and tested against Monte Carlo calculations. In addition, SDEs are derived for sunspot activity. Similarities are found between the SDE model and sunspot data.

Edward J. Allen, Ummugul Bulut
Texas Tech University
Department of Mathematics and Statistics
edward.allen@ttu.edu, gul.bulut@ttu.edu

Elife Dogan
Department of Mathematics and Statistics
Texas Tech University
elife.dogan@ttu.edu

Chisum Huff
Texas Tech University
Department of Mathematics and Statistic
chisum.huff@ttu.edu

**MS48**

**An Overview of Stochastic Dynamics**

The talk will survey results from random dynamical systems, mostly in the setting of discrete time dynamical systems, and, in particular, recent developments on the thermodynamic formalism for random transformations. As a key example, I present an application from neuroscience, where random input produces power laws and a behavior as for branching processes.

Manfred Denker
Penn State University
denker@math.psu.edu

**MS48**

**Impact of Noise on Invariant Manifolds**

Invariant manifolds are essential geometric tools for understanding deterministic dynamical systems. For stochastic dynamical systems, however, invariant manifolds are quite delicate objects. Random invariant manifolds are sample-dependent geometric objects, but they are not easy to be geometrically visualized or numerically computed. To better understand random invariant manifolds and thus utilize them as building blocks to decode stochastic dynamics, we present a method for approximating random invariant manifolds when noise is small. This method provides a tool for quantifying the impact of small noise on invariant manifolds, and thus shed lights on describing stochastic dynamics.

Jinqiao Duan
Illinois Institute of Technology
duan@iit.edu

**MS49**

**Time Averaged Observables in Dynamical System Analysis: An Overview**

A part of the operator-theoretic analysis of dynamical systems includes studying how observables, i.e., functions on the state space, evolve with dynamics of the system. Recording only averaged values of observables along the evolution provides us with parsimonious amount of data that can contain a wealth of information about geometry of the state space objects. The talk will provide an overview of concepts ranging from theory to simulations and applications of time-averaged observables.

Marko Budisic
Department of Mechanical Engineering
University of California, Santa Barbara
mbudisic@engineering.ucsb.edu

**MS49**

**Convergence of Long Time Numerical Averages of SDEs**

I will present a different take the analysis showing that the stationary measure of a large class of stochastic numerical methods converges to that of the underlying SDE. In route I will show that the numerical time averages are in fact close the the underlining stationary measure. These results extend and streamline some classical results of D. Talay. this is joint work with Andrew Stuart and M. Tretyakov.

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

**MS49**

**Variations on a Harmonic Analysis and Ergodic Theory Based Method for Analyzing Fluid Flows**

The ergodicity defect is a technique for capturing both (1)the extent to which a flow/system deviates from ergodicity and (2)how this deviation depends on scale. When this analysis is done in terms of Haar wavelets, the technique relates to physical notions of average residence times in subdomains of the flow. Although, the Haar wavelet is beneficial in that it allows this intuition-building perspective, it is only one type of harmonic that can serve as an analyzing function/observable in the ergodicity defect method. We generalize the ergodicity defect both in terms of different harmonics - e.g., other multiresolution analysis wavelets - and in the context of a variety of systems and then consider the usefulness of these variations.

Sherry Scott
Department of Mathematics
Marquette University
scott@mscs.mu.edu

**MS49**

**Shadowing the Trajectories of Molecular Dynamics**

An open theoretical problem is to explain the apparent reliabilty of long trajectories in molecular dynamics simulations. The difficulty is that individual trajectories computed in molecular dynamics are accurate for only short time intervals, whereas useful information can be extracted from trajectory averages of very long simulations. One conjecture is that numerical trajectories are shadowed by exact trajectories: that is, for every numerical trajectory there is an exact trajectory with different initial conditions that remains close to the numerical trajectory over long time intervals. I will demonstrate for a simple yet representative molecular dynamics system that long numerical trajectories are not shadowable, and discuss what the implications for interpreting the results of simulations. This is joint work with Wayne Hayes.

Paul Tupper
Department of Mathematics
Simon Fraser University
pft3@sfu.ca

**MS50**

**Dynamics of Hepatitis B Virus Infection: What Causes Viral Clearance?**

Hepatitis B virus infects liver cells, leading to acute (short-term) infection or chronic (permanent) liver disease. The immune systems responses to this infection either cure or kill infected cells, but the individual effect of each response on infection outcome remains uncertain. A better understanding of these effects could guide treatment options. In this work, we consider models of hepatitis B infection, using stability analyses and simulations to examine the roles of each immune response.

Anne Catlla
Wofford College
Dept. of Mathematics
catllaaj@wofford.edu

Stanca Ciupe
Department of Mathematics
University of Louisiana
msc6503@louisiana.edu

Jonathan Forde
Hobart and William Smith Colleges
forde@hws.edu

David G. Schaeffer
Department of Mathematics
Duke University
dgs@math.duke.edu

**MS50**

**Moving the Head: The Donderian Way**

Donderian head movements always satisfy the constraint that the axis of head rotation has a small tortional component. Starting from data of human head movement, in this talk we present a best fit surface. Up to rotation and translation of this surface, we study to what extent this surface resembles the classically studied Fick gimbals. We finish up our presentation talking about the associated geodesics and the optimal head movement trajectories.

Bijoy K. Ghosh
Department of Mathematics and Statistics
Texas Tech University, Lubbock, TX , USA
bijoy.ghosh@ttu.edu

**MS50**

**Modeling the Effects of Systemic Cortisol on the Wound Healing Process**

During the wounding healing process many complex interactions occur between fibroblasts and immune mediators. These interactions determine whether or not the wound will heal. To better understand these dynamics, we have developed a system of differential equations modeling the dynamics between local fibroblast and immune cells and the systemic mediator Cortisol. Using this model, we focused on the accumulation of collagen in an oxygen-deprived wound (diabetes) with and without trauma (high cortisol levels).

Angela M. Reynolds
Department of Mathematics and Applied Mathematics
Virginia Commonwealth University (VCU)
areynolds2@vcu.edu

**MS50**

**Using a Mathematical Model to Analyze the Treatment of a Mathematical Model of a Wound Infection with Oxygen Therapy**

A mathematical model was developed to treat a wound with a bacterial infection using oxygen therapy. The model describes the relationship among neutrophils, bacteria, oxygen, cytokines, and reactive oxygen species. A quasi-steady-state assumption was introduced to reduce the model down systems of two and three equations. A mathematical analysis on the reduced model and simulation results will be presented in this talk.

Richard Schugart
Western Kentucky University
richard.schugart@wku.edu

**MS51**

**Reduced-order Models for Control of Building Indoor Environment**

Lumped thermal airflow models, widely used in whole building simulation tools, are inadequate for capturing thermal stratification that typically arises while using passive, low-energy, heating and cooling systems. Computational fluid dynamics (CFD) on other hand is intractable for practical design and optimization, and real-time control. We develop reduced-order models, using eigensystem realization algorithm, for capturing relevant airflow dynamics, and develop controllers that maintain occupant comfort while minimizing energy consumption.

Sunil Ahuja
United Technologies Research Center
ahujasd@utrc.utc.com

Amit Surana
System Dynamics and Optimization
United Tecnologies Research Center (UTRC)
suranaa@utrc.utc.com

Eugene Cliff
Virginia Tech
Interdisciplinary Center for Applied Mathematics
ecliff@vt.edu

**MS51**

**Design Specific Computational Tools for Control of Energy Efficient Buildings**

Building systems are complex dynamical systems and models of such systems are best described by coupled discrete, ordinary and partial differential equations. Direct high fidelity simulations are not practical for use in design and control and some type of model reduction must be employed. We discuss this issue and present some examples of nonlinear systems to illustrate the difficulties that occur in generation reduced order design models of complex systems.

John A. Burns, Eugene Cliff, Lizette Zietsman
Virginia Tech
Interdisciplinary Center for Applied Mathematics
jaburns@vt.edu, ecliff@vt.edu, lzietsma@vt.edu

**MS51**

**Optimal Zoning in Building Energy Models**

Building energy modeling tools have found widespread use in evaluating the energy consumption of a building design. Despite their capability, spatial zoning approximations, which are currently defined based on equipment layout, are made when creating models that influences model accuracy. In this work, analysis is presented that evaluates the impact of zoning grid choice on predictive capability. Specifically theres focus on new issues that arise due to building designs with both mechanical and natural conditioning.

Michael Georgescu
UCSB
mvgeorge@engineering.ucsb.edu

**MS51**

**Nonlinear Behaviors in Building Ventilation Systems**

In building ventilation systems, many nonlinear behaviors can occur and they can be important to the design and operation of the building thermal systems. In this presentation, we will provide a few such examples in building simulation, and examining the underlying physics that governs such behaviors in the context of fluid flow and thermal transport. We will demonstrate how dynamical system analysis can be applied to such systems, and how actual robustness of multiple equilibrium states can be examined, and empirical methods to identify solution multiplicity and analyze the forming mechanism of different equilibriums in complex building simulation problems.

Jinchao Yuan
Nexant Inc
jcyuan@alum.mit.edu

Leon Glicksman
the Massachusetts Institute of Technology
glicks@mit.edu

**MS52**

**Synchronized Genetic Clocks in E. Coli**

We describe an engineered gene network with global intercellular coupling in a growing population of cells and study its collective synchronization properties. We use computational modelling to describe quantitatively the period and amplitude of bulk oscillations. The synchronized genetic clock sets the stage for the creation of a macroscopic biosensor with oscillatory output. Furthermore, it provides a specific model system for the generation of a mechanistic description of emergent coordinated behaviour at the colony level.

Tal Danino
Systems biodynamics Lab
University of California San Diego
taldanino@gmail.com

Octavio Mondragon-Palomino
UCSD, Systems biodynamics lab
omondrag@ucsd.edu

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

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

**MS52**

**Bifurcation Theory for Evo-devo**

The antero-posterior axis of most animals is patterned by segmentation genes and hox genes during embryonic

growth. I use evolutionary computation to predict the structure of networks implicated in these processes. Simulations suggest sequences of evolutionary events which can be best characterized at the bifurcation level. Evolved models suggest experimental predictions on network dynamics and on interconversion of developmental modes between insect species.

Paul François
Department of Physics,
McGill University, Montréal, Canada
paulf@physics.mcgill.ca

### MS52
### Genetic Oscillations: From Time to Space

To study how genetic oscillators inside single cells interact in biofilms and tissues, we have considered repressilators on a hexagonal lattice. Such systems can be built to exhibit stable oscillations. Commensurability effects however may lead to internal frustration causing symmetry breaking and solutions of many different phases, or even chaos. With bi-directed interactions the tissues locally exhibit switch-like behavior. Growing tissues may develop 'defects', with mutations having then more impact than in ordered tissues.

Mogens Jensen, Sandeep Krishna, Simone Pigolotti
Niels Bohr Institute, Copenhagen
mhjensen@nbi.dk, sandeep@nbi.dk, pigo@nbi.dk

### MS52
### How Do Cells Behave as a Collective During Embryogenesis? The Role of Cell-cell Interaction

Cell-to-cell communication plays a crucial role for maintaining the homogeneity of a cell group in the embryo. Experimental evidences suggest that the cell population size must be above a certain threshold to keep such homogeneity. However, its theoretical basis has been unknown. In this talk, I present a simple model, which consists in a linear gene cascade and cell-to-cell communication. The model reproduces the qualitative features of the experimental observations, and shows transcritical bifurcation.

Yasushi Saka
Institute of Medical Sciences, School of Medical Sciences
University of Aberdeen
y.saka@abdn.ac.uk

Cedric Lhoussaine, Celine Kuttler
LIFL, UMR Universite Lille 1/CNRS 8022
France
cedric.lhoussaine@lifl.fr, celine.kuttler@lifl.fr

Ekkehard Ullner
ICSMB, Department of Physics
University of Aberdeen, UK
e.ullner@abdn.ac.uk

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

### MS53
### Fast and Slow Pulses for the Discrete FitzHugh-Nagumo Equation

The existence of fast travelling pulses of the discrete FitzHugh-Nagumo equation is obtained in the weak-recovery regime. This result extends to the spatially discrete setting the well-known theorem that states that the FitzHugh-Nagumo PDE exhibits a branch of fast waves that bifurcates from a singular pulse solution. The key technical result that allows for the extension to the discrete case is the Exchange Lemma that we establish for functional differential equations of mixed type.

Hermen Jan Hupkes
Department of Applied Mathematics
Brown University
hjhupkes@dam.brown.edu

### MS53
### Neutral Mixed Type Functional Differential Equations

We extend the linear Fredholm theory for mixed type functional differential equations (with both advances and delays) to neutral equations of mixed type. We consider a prototype problem of coupling between two nerve fibers in which a traveling wave assumption results in a system of neutral type equations. We employ the linear theory developed and local continuation to show existence and investigate the stability of solutions for small values of the coupling parameter.

Charles Lamb
Department of Mathematics
University of Kansas
clamb@math.ku.edu

### MS53
### Propagation Failure in the Discrete Nagumo Equation

We address the classical problem of propagation failure for monotonic fronts of the discrete Nagumo equation. For a special class of nonlinearities that support unpinned "translationally invariant" stationary monotonic fronts, we prove that propagation failure cannot occur. We give two proofs of this result: one is based on the center manifold reductions and the other one is based on analysis of linearized differential advance-delay equations. We show that these equations in the singular limit of zero speed possess an infinite-dimensional kernel spanned by Fourier harmonics of fronts translations, which are accounted when the stationary front is continued into the traveling one.

Dmitry Pelinovsky
McMaster University
Department of Mathematics
dmpeli@math.mcmaster.ca

### MS53
### Nonlinear Stability of Semidiscrete Shocks

The nonlinear stability of Lax shocks is considered for semidiscrete systems of conservation laws, where the spatial coordinate is discrete, while time is continuous. The key for nonlinear stability is Green's functions of the linearized problem, which is an ill-posed functional differential equation of mixed type. The goal of this talk is to give background information about semidiscrete systems and to illustrate the techniques that allow us to construct Green's functions.

Björn Sandstede
Brown University
bjorn_sandstede@brown.edu

### MS54
### Synchronization in Networks with Disconnected Components

We study global stability of synchronization in dynamical networks with disconnected components. Each component is a graph connecting a subnetwork of nodes via one of the individual systems variables. The graphs corresponding to the couplings via different variables are disconnected, however the resultant graph is connected. An illustrative example is a network of Lorenz systems where some of the nodes are coupled through the x-variable, some through the y-variable, and some through both. Proving synchronization in networks with disconnected components is a non-trivial problem as the methods based on the calculation of the eigenvalues of the connectivity matrix, including the Master Stability function, seem incapable of handling this case in general. We extend the connection graph method to derive bounds on the synchronization threshold in such networks and show how the structure of the subgraphs and the resultant network affects synchronization.

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

### MS54
### Building a Cancer-type Specific Metabolic Network Model

Computational approaches to model metabolism have focused on generic properties of cancer cells or tissue specific characteristics of normal cells. Here, we built a computational model to account for cancer-type specific metabolism using gene expression and metabolic network reconstruction, thus accounting for the global dynamical effect of network modifications. The potential of this model to account for cancer-type specific post-transcriptional regulation and characterize normal and disease states will be discussed in detail.

Joo Sang Lee
Northwestern University
joosang@northwestern.edu

John Marko
Northwestern University
Molecular Biosciences
john-marco@northwestern.edu

Adilson E. Motter
Northwestern University
motter@northwestern.edu

### MS54
### Controlling Nonlinear Dynamics in Complex Networks

We have recently shown that perturbed or malfunctioning biological and ecological networks can be rescued and controlled by manipulating the local network structure and/or dynamics. Predictions go as far as to assert that certain gene deletions can rescue otherwise nonviable mutant cells and that population control can prevent large extinction cascades. In this talk, I will discuss how the theory of dynamical systems can be combined with network modeling to develop computational methods to systematically control the dynamics of a large range of complex networks.

Adilson E. Motter
Northwestern University
motter@northwestern.edu

### MS54
### Synchronization and Network Directionality

Despite the extensive literature on the role of the network structure in synchronization of coupled oscillators, very few network parameters are shown to have simple clear relationship with the synchronization dynamics. Here we propose that directionality measures are good candidates: the more directional the network, the easier to synchronize. We show that increasing reciprocity (local directionality) tends to stabilize synchronous states, while adding feedback loops against global directional structure tends to destabilize synchronization.

Takashi Nishikawa
Clarkson University
tnishika@clarkson.edu

### MS55
### A Novel Phase Model of Subthalamic Neurons Capturing the Interaction Between Synaptic Excitation and Spike Threshold

The response of subthalamic cells to cortical input is well described by a type I phase response curve (PRC). However, large EPSPs delivered at late phases lower spike threshold, shifting phase more than would be predicted from the infinitesimal PRC. We can capture this effect in a phase model by treating each subthalamic cell as a pair of coupled oscillators. These double-oscillators models exhibit behavior that is qualitatively different from single-oscillator type I cells.

Michael Farries
Department of Biology
University of Texas at San Antonio
michael.farries@utsa.edu

Charles Wilson
University of Texas, San Antonio
charles.wilson@utsa.edu

### MS55
### Firing Pattern of Mid-brain Dopaminergic Neurons

Mid-brain dopaminergic (DA) neurons display two functionally distinct modes of electrical activity: low- and high-frequency firing. The high-frequency firing is linked to important behavioral events. However, it cannot be elicited in vitro by standard manipulations in vitro. A two-compartmental model of the DA cell that unites data on firing frequencies under different experimental conditions has been suggested. We analyzed dynamics of this model. The model reproduces the separation of maximal frequencies under NMDA synaptic stimulation vs. other treatments.

Joon Ha
LBM/NIDDK/NIH
haj@mail.nih.gov

Alexey Kuznetsov
Indiana University-Purdue University Indianapolis
alexey@math.iupui.edu

**MS55**

**Intermittent Synchronization of Basal Ganglia Activity**

Synchronized oscillations in the beta frequency band are associated with the motor symptoms of Parkinsons disease. In this talk I will present the results of our time-series analysis of the temporal patterns of synchrony in experimentally recorded data. I will also consider network models, which generate similar synchronous patterns of activity and will discuss the origin of this synchronous activity.

Leonid Rubchinsky, Choongseok Park
Department of Mathematical Sciences
Indiana University Purdue University Indianapolis
leo@math.iupui.edu, park@math.iupui.edu

Robert Worth
Department of Neurosurgery
Indiana University School of Medicine
rworth@iupui.edu

**MS55**

**Entrainment of a Thalamocortical Neuron to Periodic Sensorimotor Signals**

We study a 3D conductance-based model of a single thalamocortical (TC) neuron in response to sensorimotor signals. In particular, we focus on the entrainment of the system to periodic signals that alternate between 'on' and 'off' states lasting for time $T_1$ and $T_2$, respectively. By exploiting invariant sets of the system and their associated invariant fiber bundles that foliate the phase space, we reduce the 3D Poincaré map to the composition of two 2D maps, based on which we analyze the bifurcations of the entrained periodic solutions as the parameters $T_1$ and $T_2$ vary.

Dennis Guang Yang
Department of Mathematics, Cornell University
gyang@math.drexel.edu

Yixin Guo
Drexel University
Department of Mathematics
yixin@math.drexel.edu

**MS56**

**Mathematical Modelling of Adult GnRH Neurons in the Mouse Brain**

GnRH neurons are hypothalamic neurons that secrete gonadotropin-releasing hormone (GnRH). We are interested in understanding the mechanisms underlying the synchronization of calcium oscillations in GnRH neurons, how such oscillations are related to the membrane potential. We have built up a mathematical model, which can reproduce all the crucial experiments successfully. Most importantly, one of the model predictions has been confirmed by our collaborator and helped them find a new channel in GnRH neurons.

Wen Duan
University of Auckland
wdua004@ec.auckland.ac.nz

Kiho Lee, Allan Herbison
Department of Physiology, School of Medical Science
University of Otago, New Zealand
kiho.lee@stonebow.otago.ac.nz,
allan.herbison@stonebow.otago.ac.nz

James Sneyd
University of Auckland
j.sneyd@auckland.ac.nz

**MS56**

**Mathematical Modeling of P2X7 Receptor/channel Gating**

P2X7 receptor is a trimeric channel with three binding sites for ATP. The gating pattern of these channels can be accounted for by a Markov state model. This includes negative cooperativity of ATP binding to unsensitized receptors (caused by the occupancy of one or two binding sites), channel pore opening to a low conductance state when two sites are bound, and sensitization with pore dilation to a high conductance state when three sites are occupied.

Anmar Khadra
Laboratory of Biological Modeling
NIDDK, NIH
khadraa@niddk.nih.gov

Arthur Sherman
NIDDK, NIH
arthurs@niddk.nih.gov

Yan Zonghe, Stanko Stojilkovic
NIH
yanz@mail.nih.gov¿, stojilks@mail.nih.gov

**MS56**

**Model Calibration and Testing on the Same Cell**

Mathematical modeling of specific cell types is often the result of a patchwork of experimental results. Usually this means modeling an average cell hoping that is a faithful representation of the population. However, pituitary cells are very heterogeneous. Here we propose a new approach that uses the computational capabilities of programmable Graphics Processing Unit to calibrate a model and test its predictions using the same cell

Maurizio Tomaiuolo
Department of Biological Science
Florida State University
mtomaiuolo@bio.fsu.edu

Richard Bertram
Department of Mathematics
Florida State University
bertram@math.fsu.edu

Arturo Gonzalez-Iglesias
Department of Biological Science

Florida State University
iglesiasa@neuro.fsu.edu

Joel Tabak
Dept of Biological Sciences
Florida State University
joel@neuro.fsu.edu

### MS56
### Searching for the Glucocorticoid Pulse Generator

A good example of pulsatile hormone secretion is the ultradian rhythm of glucocorticoids released from the adrenal glands. The origin of this rhythm is not known, but has always been assumed to be a hypothalamic neural pacemaker. In this talk I will discuss an ongoing project (modeling and experiment), the results of which suggest that pulsatile glucocorticoid secretion does not originate within the brain at all, but emerges from a highly dynamic peripheral network.

Jamie Walker
Department of Engineering Mathematics
University of Bristol
jamie.walker@bristol.ac.uk

### MS57
### Accelerating and Oscillating Fronts in a Three-component System

By means of a center manifold type reduction we derive an ODE system describing the evolution of front solutions in a three-component reaction-diffusion system. These results shed light on numerically observed accelerations and oscillations and pave the way for the analysis of front interactions in a parameter regime where the essential spectrum of a single front approaches the imaginary axis asymptotically.

Martina Chirilus-Bruckner
Boston University
mchb@bu.edu

Jens Rademacher
CWI, Amsterdam, NL
jens.rademacher@cwi.nl

Arjen Doelman
University of Leiden
doelman@math.leidenuniv.nl

### MS57
### Pattern Selection Through Invasion in Cahn-Hilliard and Phase-Field Models

We discuss spinodal decomposition initiated by localized disturbances from a uniform state in Cahn-Hilliard and phase-field models. Typically, disturbances grow in the form of invasion fronts that create a pattern. We analyze the existence of such invasion fronts, in particular in regard to the selected wavenumber in the wake of the front. It turns out that the patterns selected in this fashion are very different from patterns selected from random initial conditions via the fastest-linear-mode principle. In particular, phase-field fronts select finite wavenumbers even in the limit of vanishing interfacial energy, while temporal selection predicts infinitely small scales. We also comment on coarsening processes, spatial resonances, and period-doubling sequences.

Arnd Scheel
University of Minnesota
School of Mathematics
scheel@math.umn.edu

### MS57
### Existence of Homoclinic Solutions of the Functionalized Cahn-Hilliard Equation

The functionalized Cahn-Hilliard energy models network formation in polymer-solvent mixtures. It is given by

$$\mathcal{F}(u) = \int_\Omega \frac{1}{2}(\epsilon^2 \Delta u - W'(u))^2 - \eta \left( \frac{\epsilon^2}{2} |\nabla u|^2 + W(u) \right) dx,$$

where$W(s)$ is a double-well potential with equal wells at $u = \pm b$ satisfying $\mu_\pm \equiv W''(b_\pm) > 0$. For the symmetric double well potential, we show the variational derivative support a homoclinic solution by employing a contraction mapping argument. We show convergence for initial data near the homoclinic of a perturbed second order system, removing the degeneracy in the interation via a detuning parameter.

Li Yang, Keith Promislow
Michigan State University
yangli3@msu.edu, kpromisl@math.msu.edu

### MS57
### Towards Traveling Spots in a Three-component FitzHugh-Nagumo System

In this presentation, we try to find traveling spot solutions in a certain three-component FitzHugh-Nagumo system. First, we establish the existence and (non radial) stability of radially symmetric stationary spot solutions. After which, we destabilize this solution by increasing our bifurcation parameters. We encounter a competition between a radially symmetric Hopf bifurcation (breather) and an asymmetric drift bifurcation (traveling spot). We will further analyze this competition to abtain traveling spot solutions.

Peter van Heijster
Division of Applied Mathematics
Brown University, Providence RI
heijster@brown.edu

Bjorn Sandstede
Brown University
bjorn_sandstede@brown.edu

### MS58
### Two-dimensional Attractors of the Border Collision Normal Form

I will describe methods which prove the existence of a countable set of parameters for which the border collision normal form has attractors with topological dimension two. Periodic orbits are dense on these attractors and the dynamics is transitive (this is joint work with Chi Hong Wong). I will also show how classic results due to L-S Young can be used to prove the existence of invariant measures at other parameter values of the map.

Paul Glendinning
University of Manchester

p.a.glendinning@manchester.ac.uk

**MS58**

**Piecewise Isometries**

Abstract not available at time of publication.

Arek Goetz
Mathematics Department
San Francisco State University
goetz@sfsu.edu

**MS58**

**Entropy of the Lozi Maps**

The Lozi maps $L_{a,b}(x, y) = (1 - a|x| + by, x)$ form a two-parameter family of piecewise affine homeomorphisms of the plane, and it presents several interesting dynamical phenomena. The topological entropy is one of the most well-known invariants which measures the complexity of a dynamical system. In my talk I will show how to compute the topological entropy of a Lozi map and how it behaves as a function of the parameter $(a, b)$.

Yutaka Ishii
Department of Mathematics
Kyushu University, Japan
yutaka@math.kyushu-u.ac.jp

**MS58**

**Resonance in Piecewise-smooth Continuous Maps**

Synchronization or mode-locking plays an important role in many physical systems. Mode-locking regions of piecewise-smooth, continuous maps naturally display a curious sausage-like chain structure. In this talk I will demonstrate how this structure arises from a generic border-collision bifurcation and the manner by which the structure becomes smooth as the mode-locked solution moves away from the discontinuity.

David J. Simpson
Department of Mathematics
University of British Columbia
dsimpson@math.ubc.ca

**MS59**

**Molecular Motors and Pattern Formation with Microtubules**

Microtubules are long cylindrical structures while kinesin is a molecular motor that walks on microtubules, using ATP as an energy source. We model the fine details of the action of kinesin, clarifying mechanisms needed for processivity. We also model and simulate pattern formation in families of microtubules under the action of kinesin.

Peter Bates
Michigan State University
Department of Mathematics
bates@math.msu.edu

**MS59**

**Multiscale Modeling for Stochastic Forest Dynamics**

Individual-based models are widely employed to represent and simulate complex systems. Those descriptions however come with a high computational cost and perhaps unnecessary degrees of detail. In this work, we start with a spatially explicit representation of the interacting agents and attempt to explain the systems dynamics at multiple scales by means of stochastic coarse-graining steps. We apply our technique to a forest model subjected to different disturbance regimes.

Maud Comboul
University of Southern California
comboul@usc.edu

Roger Ghanem
University of Southern California
Aerospace and Mechanical Engineering and Civil Engineering
ghanem@usc.edu

**MS59**

**A Backward-forward Method for Simulating Stochastic Inertial Manifolds**

We construct stochastic inertial manifolds numerically for stochastic differential equations with multiplicative noises. After splitting the stochastic differential equations into a backward part and a forward part, we use the theory of solving backward stochastic differential equations to achieve our goal.

Xingye Kan, Jinqiao Duan
Illinois Institute of Technology
xkan@iit.edu, duan@iit.edu

Yannis Kevrekidis
Dept. of Chemical Engineering
Princeton University
yannis@princeton.edu

Anthony J. Roberts
University of Adelaide
anthony.roberts@adelaide.edu.au

**MS59**

**Dynamical Systems Driven by Levy Motions**

Mean exit time for dynamical systems driven by non-Gaussian Lévy noises of small intensity is considered. The first exit time of solution orbits from a bounded neighborhood of an attracting equilibrium state is studied. For a class of non-Gaussian Lévy processes depending on the space point with tails heavier or slower than certain $\alpha$-stable levy noise, the asymptotic estimate for the mean exit time is obtained.

Zhihui Yang
University of Phoenix
julia.yang@apollogrp.edu

Jinqiao Duan
Illinois Institute of Technology
duan@iit.edu

Peter Imkeller
Institut für Mathematik
Humboldt Universität zu Berlin
imkeller@mathematik.hu-berlin.de

Ilya Pavlyukevich
Institut f
"ur Stochastik
Friedrich–Schiller–Universit
"at Jena, Germany
ilya.pavlyukevich@uni-jena.de

**MS60**

**Probabilistic Averages of Jacobi Operators**

I will discuss my recent work on "probabilistic averages" of Jacobi operators. These essentially tell you what information about the operator is preserved under taking translates, and not looking at a single limit-point, but looking at all at the same time. In particular, my results imply characterization of operators whose Lyapunov exponent vanishes on a set consisting of finitely many intervals.

Helge Krueger
California Institute of Technology
helge@caltech.edu

**MS60**

**Koopman Operator, Time Averages and the Big Oil Spill**

Functions that are time averages along trajectories (Lagrangian time averages in fluid mechanics) of observables on the state space form the eigenspace of the Koopman operator at eigenvalue 1. These also form the complete set of (possibly non-smooth) invariants of a dynamical system. I will discuss how a dynamical system approaches (i.e. projects any observable onto) that set of invariants. I will also discuss the use of the Koopman operator formalism in finite-time dynamics and describe a recent application of these ideas to predicting time evolution of oil flowing from the Deepwater Horizon Well in the Gulf of Mexico that happened in May-August of 2010.

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

**MS60**

**Understanding the Interplay Between Lagrangian Coherent Structures, Trajectory Complexities, and Transport in the Ocean**

We introduce a family of methods which allow for identification of Lagrangian coherent structures in aperiodic flows that are measured over finite time intervals. The new methods are based on measures of complexity of fluid particle trajectories. Basic principles of the new methods are established, the interplay between different complexity measures, Lagrangian coherent structures and transport in the ocean is investigated, and the new methods are successfully applied to realistic oceanic flows.

Irina Rypina
Woods Hole Oceanographic Institution
irypina@whoi.edu

Sherry Scott
Marquette University
sherry.scott@marquette.edu

Lawrence Pratt
Woods Hole Oceanographic Institution
lpratt@whoi.edu

**MS60**

**A Theory of Ergodic Partition in Continuous-time Dynamical Systems with Applications to Power System Analysis**

We extend the theory of ergodic partition of phase space in discrete-time dynamical systems to continuous-time dynamical systems with a smooth invariant measure. This makes it possible to identify invariant sets for measure-preserving flows such as Hamiltonian flows. Also we discuss an application of the theory of ergodic partition to analysis and design of electric power systems with emphasis on future smart management.

Yoshihiko Susuki
Kyoto University
Department of Electrical Engineering
susuki@dove.kuee.kyoto-u.ac.jp

**MS61**

**Bone Remodeling Dynamics in Myeloma Bone Disease**

Mathematical models are developed for the dysregulated bone remodeling that occurs in myeloma bone disease. The models examine the critical signaling between osteoclasts (bone resorption) and osteoblasts (bone formation). The interactions of osteoclasts and osteoblasts are modeled as a system of differential equations for these cell populations.

Bruce P. Ayati
University of Iowa
Department of Mathematics
bruce-ayati@uiowa.edu

Claire Edwards
Cancer Biology
Vanderbilt University Medical Center
claire.edwards@vanderbilt.edu

Glenn F. Webb
Mathematics Department, Vanderbilt University
Nashville
glenn.f.webb@vanderbilt.edu

John P. Wikswo
Vanderbilt University
Vanderbilt Institute for Integrative Biosys Res and Edu.
john.wikswo@vanderbilt.edu

**MS61**

**Spatial Dynamics in a Dengue Epidemic Model**

Dengue is a tropical fever transmitted between humans through the bites of female mosquitos (*Aedes aegypti*). These bites are observed to occur mainly in the daytime. Here, we use a system of periodic difference equations to study the dynamics of an epidemic in which hosts have daytime, but not nighttime, mobility and vectors have no mobility. The habitat consists of two patches and each day is divided into four parts: evening, dawn, daytime, and dusk.

Andrew Nevai
Department of Mathematics
University of Central Florida

anevai@math.ucf.edu

Edy Soewono
Department of Mathematics
Institut Teknologi Bandung
esoewono@bdg.centrin.net.id

**MS61**

**Stability Analysis of a Reaction-Diffusion System Modeling Atherogenesis**

A principal component of the disease process of atherosclerosis involves the accumulation and oxidation of low density lipoproteins within the arterial wall and its corruptive effect on the immune process. We present a reaction-diffusion model involving chemo-taxis and perform a general stability analysis accounting for immune cell subspecies interactions, differing roles of immune cells with respect to the components of an emerging lesion, the effects of anti-oxidants, and boundary transport.

Laura Ritter
Southern Polytechnic State University
lritter@spsu.edu

Jay R. Walton
Department of Mathematics
Texas A&M
jwalton@math.tamu.edu

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

Catherine McNeal
Div, of Endocrinology, Dept. of Pediatrics
Scott & White Hospital, Temple TX
cmcneal@swmail.sw.org

**MS61**

**Traveling Waves of Bacterial Population Chemotaxis**

The first mathematical model describing the bacteria chemotaxis was proposed by Keller and Segel on 1971. As a cornerstone of chemotaxis modeling, the Keller-Segel model has attracted most extensive and persistent attentions in the past four decades. To simplify the analysis, most studies of traveling wave problems made a strong and unrealistic assumption that the chemical signal is not diffusible. In this talk, I will report some new results of the traveling wave of the Keller-Segel model in which the chemical diffusion is taken into account. Particularly I will show the zero diffusion limits of traveling wave speed and solutions and conclude that the chemical diffusion is negligible only if it is small.

Zhi-An Wang
Department of Applied Mathematics
Hong Kong Polytechnic University
zhi.an.wang@inet.polyu.edu.hk

**MS62**

**Dynamics Induced by Bottleneck**

We study the Bando car-following model on a circle introducing a bottleneck. Using analytical and numerical bifurcation techniques we encounter very interesting traffic dynamics. There are traveling and standing waves and combinations of both. Also so called Pony-on-a-merry-go-round solutions can be observed.

Ingenuin Gasser
University of Hamburg
Department of Mathematics
gasser@math.uni-hamburg.de

Bodo Werner
University of Hamburg
werner@math.uni-hamburg.de

**MS62**

**Macroscopic Relations of Urban Traffic Variables: Instability, Bifurcations, and Hysteresis**

Recent work has shown that the average speed and flow within a traffic network is related by a reproducible curve (called the Macroscopic Fundamental Diagram or MFD) if traffic on the network is homogenously distributed. This presentation shows that traffic naturally tends away from homogeneous distributions when the network is congested. This results in bifurcations and hysteresis in the MFD.

Vikash Gayah
Civil Engineering
University of California, Berkeley
vikash.gayah@gmail.com

Carlos Daganzo
Civil Engineering
University of California-Berkeley
daganzo@ce.berkeley.edu

**MS62**

**Traffic Jams: Dynamics and Control**

In this talk we review the most common modeling approaches used in the vehicular traffic community and present the state-of-the-art methods that may be applied to classify the dynamical behavior of these models. We will show that using sophisticated techniques form dynamical systems theory may allow one to characterize the dynamical phenomena behind traffic jam formation. Stable and unstable motions will be described that may give the skeleton of traffic dynamics.

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

**MS62**

**Absolute and Convective Instability in Traffic Flow Models**

The nucleation of stop-and-go phenomena in traffic is captured by linear and nonlinear instabilities in dynamical systems models of driver behaviour. Data suggests that such spatio-temporal patterns are always convected upstream relative to the road, however this is not always the case in models. We describe two methods using group and signal velocities to distinguish between convective and absolute instability in a large class of microscopic traffic models.

Jonathan A. Ward

University of Limerick
jonathan.ward@ul.ie

R. Eddie Wilson
University of Southampton
r.e.soton.ac.uk

**MS63**

**Self-organized Criticality on Adaptive Networks**

Adaptive networks are found in natural and technological networks, from neural and ecological networks, to social networks or the world wide web. Mathematical models in the spirit of statistical physics study the interplay of fast dynamical processes on a network and adaptation of the network topology on a slower time scale. A particularly interesting case are critical phenomena on the network and their possible interplay with adaptive processes. In this talk I will give an overview of adaptive network models that exhibit self-organized criticality and discuss possible applications.

Stefan Bornholdt
University of Bremen
bornholdt@itp.uni-bremen.de

**MS63**

**Computational Approaches to Adaptive Network Modeling**

I will present a generalized framework based on graph rewriting systems for modeling state-topology coevolution of complex adaptive networks. I will also propose computational methods for automatic discovery of dynamical rules that best capture both state transition and topological transformation in empirical data. Network evolution is formulated in two parts: extraction and replacement of subnetworks. The effectiveness of the proposed framework and algorithms will be demonstrated through computational experiments and real-world network data analysis.

Hiroki Sayama
Departments of Bioengineering & Systems Science and Industri
Binghamton University
sayama@binghamton.edu

**MS63**

**Dynamics of Epidemic Extinction in Adaptive Social Networks**

We study epidemic extinction in adaptive social networks with avoidance behavior. We have shown that vaccination of susceptible individuals in conjunction with adaptation greatly reduces the epidemic lifetime. In the context of a mean field model describing the node and link dynamics, we analyze the most probable path to extinction using large fluctuation theory. Predicted paths and extinction rates are compared with those observed in simulations of the adaptive network system.

Leah Shaw
College of William and Mary
Dept. of Applied Science
lbshaw@wm.edu

Ira Schwartz
Naval Research Laboratory
schwartz@nlschaos.nrl.navy.mil

**MS63**

**Adaptive-network Models for Collective Motion**

We propose a simple adaptive-network model describing recent swarming experiments. Instead of tracking the spatial configuration of the swarm, we consider the dynamics of the interaction network among individuals as a stochastic process. The model reproduces several characteristic features of swarms, such as spontaneous symmetry breaking, noise- and density-driven order-disorder transitions, and intermittency. Complementing the usual agent-based models, it unveils the essential elements required to recover the observed swarming behavior.

Cristian Huepe
Unaffiliated NSF grantee
cristian@northwestern.edu

Gerd Zschaler
Max-Planck-Institut für Physik komplexer Systeme
zschaler@pks.mpg.de

Anne-Ly Do
Max Planck Institute for the Physics of Complex Systems
ly@pks.mpg.de

Thilo Gross
MPI for the Physics of Complex Systems
gross@pks.mpg.de

**MS64**

**Multidimensional Stability of Planar Fronts in the Discrete Allen-Cahn Equation**

We establish multidimensional stability in $\ell^1$ of bistable planar fronts for the Allen-Cahn equation on $Z^2$. The proof makes use of comparison principles and sub-/super-solution pairs. The relevant sub-/super-solutions are adapted from recent work of Matano, Nara and Taniguchi on the Allen-Cahn equation in $R^n$. The chief difficulty in passing to the spatially discrete setting is the anisotropy of the discrete laplacian.

Aaron Hoffman
Boston University
Department of Mathematics and Statistics
aaron.hoffman@olin.edu

Erik Van Vleck
Department of Mathematics
University of Kansas
evanvleck@math.ku.edu

**MS64**

**The Transverse Instability of Periodic Traveling Waves in the Generalized Kadomtsev-Petviashvili (KP) Equation**

We consider the spectral instability of periodic traveling wave solutions of the gKdV equation to transverse perturbations in the gKP equation. By analyzing high and low frequency limits of the appropriate periodic Evans function, we derive an orientation index which yields sufficient conditions for such an instability to occur. This index is geometric in nature and applies to arbitrary periodic traveling waves with minor smoothness and convexity assumptions on the nonlinearity. Using the integrable structure of the ordinary differential equation governing the traveling wave profiles, we are then able to calculate the resulting orientation index for the elliptic function solutions of the Korteweg-de Vries and modified Korteweg-de Vries equations. This is joint work with Kevin Zumbrun.

Mat Johnson
Indiana Indiana
matjohn@indiana.edu

### MS64

### Asymptotic Stability of Small Gap Solitons in the Nonlinear Dirac Equations

We prove dispersive decay estimates for the one-dimensional Dirac operator and use them to prove asymptotic stability of small gap solitons in the nonlinear Dirac equations with quintic and higher-order nonlinear terms.

Atanas Stefanov
University of Kansas
stefanov@ku.edu

### MS64

### Phase Transition Waves in a Diatomic Chain

We consider Hamiltonian dynamics of a chain of two alternating masses connected by phase-transforming springs with nonconvex elastic energy. Assuming bilinear interactions, we construct explicit traveling wave solutions for even and odd strains representing a phase transition wave propagating through the chain and numerically investigate their stability. We show that the ratio of the two masses substantially affects existence, stability and various properties of such solutions.

Anna Vainchtein
Department of Mathematics
University of Pittsburgh
aav4@pitt.edu

Panayotis Kevrekidis
University of Massachusetts
Amhesrt
kevrekid@mass.umass.edu

### MS65

### Non-synchronous Behavior of Oscillators on Graphs

In this talk, I will discuss the dynamics of oscillators on certain graphs where each node has the same number of edges. The problem arises from the study of networks of discrete oscillators on the surface of the sphere where there is local interaction. Such systems are found in the flagellar system of the Volvox, calcium dynamics on the surface of an oocyte, and abstractly in surface EEG recordings. We start with a dodecahedral graph and prove that there are stable rotating wave solutions coexisting with stable synchronous solutions. We extend the results of the dodecahedral system to a class of graphs that include the dodecahedron. We also study bifurcations of these rotating waves as coupling strength and a dispersion term change. The work is joint with Mr. Lawrence Udeigwe.

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

### MS65

### Collective Phase Diffusion in Networks of Noisy Oscillators

Examples of collective dynamics stemming from interactions among noisy individual components include heartbeats and circadian rhythms. Because each component is noisy, collective dynamics involve fluctuations. Nevertheless, the relation between the fluctuations in individual components and those in collective dynamics remains elusive. We present our recent theoretical work on this subject. We analytically show that the structure of networks determines the intensity of fluctuations in the collective dynamics. We also show some examples.

Naoki Masuda
The University of Tokyo
Graduate School of Information Science and Technology
masuda@mist.i.u-tokyo.ac.jp

Yoji Kawamura
The Earth Simulator Center
Japan Agency for Marine-Earth Science and Technology
ykawamura@jamstec.go.jp

Hiroshi Kori
Division of Advanced Sciences
Ochanomizu University
kori.hiroshi@ocha.ac.jp

### MS65

### The Impact of Cellular Dynamics, Synaptic Noise, and Synaptic Convergence on Correlations and Synchrony

We explore several fundamental mechanisms that determine how correlations and synchrony propagate in networks of neurons. We show that single-cell dynamics and synaptic variability significantly reduce correlations from input to output, but that synaptic convergence dramatically amplifies correlations downstream. Perhaps surprisingly, we find that synaptic *convergence* is the primary mechanism responsible for the synchronization of feedforward chains, and that synaptic *divergence* plays a comparatively minor role.

Robert Rosenbaum
University of Houston
Dept. of Mathematics
robertr@math.uh.edu

### MS65

### The Interaction of Intrinsic Dynamics and Network Topology in Determining Network Burst Synchrony

Respiratory brainstem networks generate synchronized bursting despite heterogeneity in neuronal components dynamics. The networks connection topology features dense clusters with occasional connections between clusters. Using computational models, we compare characteristics of network bursting with bursting arising in small-world, scale-free, random, and regular networks constructed with identical neuronal components. We characterize how measures of burst synchronization are determined by interactions of network topology with neuronal dynamics (qui-

escent/bursting/tonic) at central network positions and synaptic strengths between neurons.

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

**MS66**

**Modeling Particle Suspensions Near Ciliated Surfaces**

Using computer simulations, we examine how biomimetic cilia can be utilized to control the motion of microscopic particles suspended in a viscous fluid. The cilia are modeled as deformable, elastic filaments and the simulations capture the complex fluid-structure interactions among these filaments, suspended particles, channel walls and surrounding solution. We show that biomimetic cilia can be arranged to create hydrodynamic currents that can either direct particles towards the ciliated surface or expel them away, thereby modifying the effective interactions between solid surfaces and particulates. The findings uncover a new route for controlling the deposition of microscopic particles in microfluidic devices.

Alexander Alexeev
George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
alexander.alexeev@me.gatech.edu

**MS66**

**Inertial Focusing, Ordering, and Separation of Particles in Confined Flows**

Fluid inertia is usually not considered in microfluidic flows but has recently been shown to be of great practical use for continuous manipulation of particles and cells. I will demonstrate several unique phenomena that allow for sorting and focusing of cells and particles in three dimensions under continuous flow. I will briefly discuss inertial migration theory and our recent results, demonstrating controlled creation of ordered particle lattices, and suggesting a critical role of interparticle hydrodynamic interactions induced by confinement. Engineered inertially focused streams of cells and particles are poised to provide next-generation filter-less filters and simplified high-throughput cytometry instruments which ultimately may aid in cost-effective medical diagnostics, water treatment, and industrial filtration and waste minimization.

Dino Di Carlo
Department of Bioengineering
University of California Los Angeles
dicarlo@seas.ucla.edu

**MS66**

**Manipulation of Suspended Micro-Particles via Localized Fluid Boundary Dynamics**

This talk will address the idealized modeling, high-fidelity simulation, and laboratory realization of systems for manipulating particles suspended in fluids using laterally oscillating cylindrical filaments at low Reynolds number. The idealized problem will be framed in the context of geometric mechanics and nonlinear control. Numerical studies of planar particle transport near oscillating cylinders, based on a viscous vortex particle method, will be presented alongside preliminary experimental data depicting the motion of neutrally buoyant particles in proximity to fibers of micron-scale thickness exhibiting resonant vibrations in water.

Scott D. Kelly
Mechanical Engineering and Engineering Science
University of North Carolina at Charlotte
scott@kellyfish.net

**MS66**

**Interaction Between an Elastic Filament and the Vesicle Membrane**

The primary cilium is found for all non-dividing mammalian cells. Since its discover a century ago, only recently has more understanding of the biological role of primary cilia been gained. In this work slender-body formulation is utilized to describe the dynamics of the primary cilium, modeled as an elastic filament attached to a solid wall or membrane. Comparison with the experimental data will be provided. Coupling between the filament/membrane system and the mechanosensitive channel (MscL) show how the primary cilium functions as a probe of the extracellular flow.

Yuan-Nan Young
Department of Mathematical Sciences
NJIT
yyoung@oak.njit.edu

**MS67**

**Dynamics of Plateau Bursting in Dependence on the Location of its Equilibrium**

The transition from tonic spiking to plateau bursting and, in particular, pseudo-plateau bursting is still not well understood. We investigate the influence of the location of the system's equilibrium using a generic polynomial model of Hindmarsh-Rose type. We relate our global numerical explorations to local results known from singular perturbation theory and argue the existence of a connected (hyper)surface of periodic orbits in two-parameter space that contains both tonic spiking and plateau bursting solutions.

Hinke M. Osinga
University of Bristol
Department of Engineering Mathematics
H.M.Osinga@bristol.ac.uk

Krasimira Tsaneva-Atanasova
Department of Engineering Mathematics
University of Bristol
K.Tsaneva-Atanasova@bristol.ac.uk

**MS67**

**From Plateau to Pseudo-Plateau Bursting: Making the Transition**

Plateau and pseudo-plateau bursting are observed in neurons and endocrine cells, respectively, and have different properties and likely serve different functions. We show that a model for one type of cell produces bursting of the type seen in the other type without large changes to the model. We provide a procedure for achieving this transition. This suggests that the design principles for bursting in endocrine cells are quantitative variations of those for bursting in neurons.

Wondimu W. Teka

Department of Mathematics
Florida State University
wteka@math.fsu.edu

Krasimira Tsaneva-Atanasova
Department of Engineering Mathematics
University of Bristol
K.Tsaneva-Atanasova@bristol.ac.uk

Richard Bertram
Department of Mathematics
Florida State University
bertram@math.fsu.edu

Joel Tabak
Dept of Biological Sciences
Florida State University
joel@neuro.fsu.edu

**MS67**

**Decoding Pulsatile GnRH Signals**

We present a signalling pathway model of GnRH-dependent transcriptional activation developed to dissect the dynamic mechanisms of differential regulation of gonadotropin subunit genes. The model incorporates key signalling molecules, including extracellular-signal regulated kinase (ERK) and calcium-dependent activation of Nuclear Factor of Activated T-Cells (NFAT), as well as translocation of activated/inactivated ERK and NFAT across the nuclear envelope. We show that simulations with varying in dose and frequency GnRH pulsatile inputs agree very well with experimental measurements of GnRH-dependent ERK and NFAT responses. Furthermore in silico experiments designed to probe trancriptional effects downstream of ERK and NFAT reveal that interaction between transcription factors is sufficient to account for frequency discrimination.

Krasimira Tsaneva-Atanasova
Department of Engineering Mathematics
University of Bristol
K.Tsaneva-Atanasova@bristol.ac.uk

Craig McArdle
Laboratories for Integrative Neuroscience and Endocrinology,
University of Bristol
craig.mcardle@bristol.ac.uk

**MS67**

**Model-based Study of the Back-and-forth Transitions Between the Pulsatile and Surge Phase in GnRH Secretion**

The secretion of Gonadotropin Releasing Hormone (GnRH) by specific hypothalamic neurons plays a major role in the neuroendocrine control of the reproductive function in female mammals. The periodic back-and-forth transitions between the pulsatile secretion phase and the preovulatory surge are among the most crucial mechanisms underlying this control, but they remain misunderstood on the biological level. Using a mean field model, I will analyze the dynamical properties that enable one to generate these mechanisms.

Alexandre Vidal
University of Evry-Val-d'Essonne
Department of Mathematics - Analysis and Probability Lab
alexandre.vidal@univ-evry.fr

Martin Krupa
INRIA Paris-Rocquencourt Research Centre
(Invited Professor)
m.krupa@science.ru.nl

Frédérique Clément
INRIA Rocquencourt
Frederique.Clement@inria.fr

Mathieu Desroches
University of Bristol
Engineering Mathematics
m.desroches@bristol.ac.uk

**MS68**

**Simplifying the Complexity of Pipe Flow**

When fluid flows through a pipe, channel, or duct, there are two basic forms of motion: smooth laminar motion and complex turbulent motion. The discontinuous transition between these states is a fundamental problem that has been studied for more than 125 years. I will recall some of the history of hydrodynamic stability theory with a view to explaining why even the simplest case, pipe flow, is both a fascinating and difficult problem. I will then explain recent developments that have led to remarkable new insights and shown a deep connection between the transition to turbulence and non-equilibrium phase transitions such as directed percolation.

Dwight Barkley
University of Warwick
Mathematics Institute
d.barkley@warwick.ac.uk

**MS68**

**Stochastic Effects in a Two-component Signalling System**

Two-component signalling systems (TCS) are frequently used by bacteria to adapt to changing environmental signals, and are implicated, for example, in the transition between rapid growth and dormancy in *Mycobacterium tuberculosis*. We compare deterministic and stochastic approaches, including equation-free methods, to the analysis of a TCS, seeking to understand the relationship between autoregulation of the response regulator gene and 'all-or-none', graded and mixed-mode stochastic switching responses.

Rebecca B. Hoyle
University of Surrey
Department of Mathematics
r.hoyle@surrey.ac.uk

Andrzej Kierzek
University of Surrey
Division of Microbial Sciences
a.kierzek@surrey.ac.uk

**MS68**

**A Reduced Model for Binocular Rivalry**

Binocular rivalry occurs when two very different images are presented to the two eyes. Previous models for this phenomenon have been either phenomenological rate models or more realistic spiking neuron models. Few attempts have been made to derive the former type of model from the latter. We give such a derivation, using data-mining techniques to automatically extract appropriate variables for a low-dimensional description.

Carlo R. Laing
Massey University
Auckland
c.r.laing@massey.ac.nz

**MS68**

**A Micro/macro Acceleration Technique for Monte Carlo Simulation of Polymeric Fluids**

We present and analyze a micro/macro acceleration technique for the Monte Carlo simulation of stochastic differential equations (SDEs) in which there is a separation between the (fast) time-scale on which individual trajectories of the SDE need to be simulated and the (slow) time- scale on which we want to observe the (macroscopic) function of interest. The method performs short bursts of microscopic simulation using an ensemble of SDE realizations, after which the ensemble is restricted to a number of macroscopic state variables. The resulting macroscopic state is then extrapolated forward in time and the ensemble is projected onto the extrapolated macroscopic state. We relate the algorithm to existing analytical and numerical closure approximations and provide a first analysis of its convergence in terms of extrapolation time step and number of macroscopic state variables. The effects of the different approximations on the resulting error are illustrated via numerical experiments. This talk is based on joint work with Kristian Debrabant, Vincent Legat and Tony Lelievre.

Giovanni Samaey
Department of Computer Science, K. U. Leuven
giovanni.samaey@cs.kuleuven.ac.be

**MS69**

**A Chemostat Model for Bacteria-phage Interaction with Infinite Distributed Delay**

The interaction between bacteria and bacteriophage (phage) has been an interesting topic for scientific studies since 1910's. Nevertheless, mathematical models were not proposed until 1960's. Levin et. al formulated a general model with Delay Differential Equations (DDEs) and carried out a series of experiments and observations. The classic chemostat theory as well as laboratory experiments confirm that two bacteria cannot coexist in a chemostat provided one is the superior competitor. However, according to Levin's experiment, apparently the coexistence of two bacteria species is possible if a phage species, which attacks only the superior bacteria, presents. Our goal is to give an rigorous mathematical analysis and show that the coexistence of two bacteria under certain conditions. In this study, we formulated a DDE system similar to Levin's with infinite distributed delays. By using the linear chain trick, we reduced this system into an ODE system and analyzed bifurcations of equilibrium points and showed some persistence results.

Zhun Han
Arizona State University
hzhun@asu.edu

Hal L. Smith
Arizona state university
halsmith@asu.edu

**MS69**

**Modeling an Obligate Mutualism: Leaf-cutter Ants and its Fungus Garden**

We propose a simple mathematical model by applying Michaelis-Menton equations of enzyme kinetics to study the mutualistic interaction between the leaf cutter ant and its fungus garden at the early stage of colony expansion. We derive the sufficient conditions on the extinction and coexistence of these two species. In addition, we give a region of initial condition that leads to the extinction of two species when the model has an interior attractor. Our global analysis indicates that the division of labor by workers ants and initial conditions are two important factors that determine whether leaf cutter ants colonies and their fungus garden survive and grow can exist or not. We validate the model by doing the comparing between model simulations and data on fungal and ant colony growth rates under laboratory conditions. We perform sensitive analysis and parameter estimation of the model based on the experimental data to gain more biological insights on the ecological interactions between leaf cutter ants and their fungus garden. Finally, we give conclusions and discuss potential future work.

Yun Kang
Applied Sciences and Mathematics, Arizona State
yun.kang@asu.edu

Rebecca Clark
School of Life Sciences,
Arizona State University
rebecca.m.clark@asu.edu

Michael Makiyama
Ira A Fulton Engineering,
Arizona State University
michael.makiyama@asu.edu

Jennifer Fewell
School of Life Sciences,
Arizona State University
j.fewell@asu.edu

**MS69**

**The Timing of Insect Developmental and Trajectory of Bark Beetle Outbreaks**

Temperatures directly but nonlinearly influence the rates at which insects complete development in their various life stages and therefore the timing (phenology) of their emergence. Bark beetles, aggressive insects which attack living host trees with significant defensive mechanisms, exist in a precarious niche which depends on carefully synchronized timing. Changing temperatures in Western North America have broadened that niche across vastly larger regions, leading to outbreaks in conifer forests. Impacts are currently larger than the impact of fire in these ecosystems. This talk outlines the development of mathematical models for bark beetle phenology and how the dynamics of phenology influences the course and severity of outbreaks.

James Powell
Department of Mathematics and Statistics
Utah State University

powell@math.usu.edu

**MS69**

**Modeling Bee Pollination of Almond Orchards with Cross- and Self-diffusion: An Application of the Shigesada-Kawasaki-Teramoto Model**

California's almond industry is one of America's top agricultural exports worth $1.9 billion annually. Successful production of almonds depends on the pollinator services of primarily honeybees, although pollination by wild bees is being investigated as an alternative because of recent problems with honeybees. We model pollinator services of honey and wild bees, as well as their interactions in almond orchards. Utilizing the Shigesada-Kawasaki-Teramoto model (1979) which describes the density of two species in a two-dimensional environment of variable favorableness with respect to intrinsic diffusions and interactions of species, we model almond pollination by wild and honey bees with environmental favorableness based on empirical data measuring the attractiveness of the canopy for honey and wild bees. Using the spectral-Galerkin method in a rectangular domain, we numerically solved the 2D nonlinear parabolic PDE and examine the result of varying the parameters. Empirical data on bee distribution was compared with the numerical solutions. We use the model to determine what circumstances the presence of wild, solitary bees can increase the dispersion of honeybees, thus increasing pollination.

Kamuela E. Yong, Yi Li, Stephen Hendrix
University of Iowa
kamuela-yong@uiowa.edu, yi-li@uiowa.edu, stephen-hendrix@uiowa.edu

**MS70**

**Global Invariant Manifolds Organizing Shilnikov Chaos**

It is widely known that, under certain conditions, the existence of a homoclinic orbit to a saddle-focus equilibrium induces chaotic dynamics. This is known as a Shilnikov homoclinic bifurcation. The chaotic region near the homoclinc trajectory is filled by countably many periodic orbits of saddle type. The key question is how these objects and their corresponding higher-dimensional global invariant manifolds change in this bifurcation to reorganize the phase space and define the structure of Shilnikov chaos.

Pablo Aguirre, Bernd Krauskopf
University of Bristol
Department of Engineering Mathematics
pablo.aguirre@bristol.ac.uk, b.krauskopf@bristol.ac.uk

Hinke M. Osinga
University of Bristol
Department of Engineering Mathematics
H.M.Osinga@bristol.ac.uk

**MS70**

**Two-dimensional Global Manifolds in the Transition to Chaos in the Lorenz System**

This talk considers the transition from simple to chaotic dynamics in the Lorenz system as the Rayleigh parameter is increased to its classical value of 28. More specifically, we show how the two-dimensional stable manifolds of the origin and of the primary saddle periodic orbits bifurcate and organize the dynamics throughout the entire three-dimensional phase space.

Bernd Krauskopf
University of Bristol
Department of Engineering Mathematics
b.krauskopf@bristol.ac.uk

Hinke M. Osinga
University of Bristol
Department of Engineering Mathematics
H.M.Osinga@bristol.ac.uk

Eusebius J. Doedel
Concordia University
Department of Computer Science and Software Engineering
doedel@cse.concordia.ca

**MS70**

**Unfoldings of Singular Hopf Bifurcation**

We present a systematic study of a 5-parameter normal form for singular Hopf bifurcation in vector fields with one fast and two slow variables, introduced by Guckenheimer in 2008. We compute numerically the position of a tangency of invariant manifolds that can mark the onset of mixed-mode oscillations in systems with a singular Hopf bifurcation. A detailed picture of the bifurcation structure of the normal form is developed.

Philipp Meerkamp
Cornell University
Department of Mathematics
pmeerkamp@math.cornell.edu

John Guckenheimer
Cornell University
jmg16@cornell.edu

**MS70**

**A Lin's Method Approach to Finding and Continuing Heteroclinic Connections Between Periodic Orbits of Saddle Type**

It is known that the dynamics of many mathematical models of intracellular calcium is strongly influenced by the presence of global bifurcations, including homoclinic and heteroclinic bifurcations of periodic orbits. Using a simple calcium model, we illustrate a numerical method, based on Lin's approach, for finding and continuing heteroclinic connections between periodic orbits. Locating such bifurcations helps to understand the overall bifurcation structure of calcium dynamics. This approach can also apply to other excitable models.

Wenjun Zhang
University of Auckland
wzha122@math.auckland.ac.nz

Bernd Krauskopf
University of Bristol
Department of Engineering Mathematics
b.krauskopf@bristol.ac.uk

Vivien Kirk
University of Auckland
v.kirk@auckland.ac.nz

**MS71**

**Spatial Modeling of Bacterial Antibiotic Tolerence**

Persistent bacterial infections are a serious and growing medical problem. Antibiotic tolerant cells, termed persisters, are genetically identical to those killed by antibiotics but regrow after antibiotics are removed. Persister formation has been linked to quorum sensing, the ability of bacteria to determine their local population density, and with the formation of biofilms, surface-growing bacterial communities particularly difficult to eradicate with antibiotic treatments. Extending a previous model of bacterial colony pattern formation, we present a reaction-diffusion model of bacterial growth which includes density-dependent persister formation. The model also exhibits separation of temporal and spatial scales between persister and regular bacteria. We investigate the pattern formation properties of the model as a number of experimentally accessible parameters are varied.

John Burke
Boston University
jb@math.bu.edu

**MS71**

**Dynamics of Persister Formation: Dosing and Fluid Interactions**

Bacterial biofilms are widely acknowledged to be sources of recalcitrant infections and colonization in a variety of medical, environmental and industrial settings. This recalcitrance is evidenced by recurrence of the infection, even after extremely long application of biocides or antibiotics. Explanations for this tolerance include physical protection of the bacteria by the surrounding extracellular matrix, physiological protection arising from nutrient gradients formed by the spatial distribution of the bacteria within the biofilm and the existence of specialized phenotypes of bacteria that forgo reproduction in order to evade the antimicrobial agent. This talk will focus on the analysis of recent models that incorporate all of these tolerance mechanisms into a model of biofilm dynamics. In particular, we will focus on the affect of the external flow environment on the disinfection process. The contrast between dynamics within free channels and partially blocked channels indicates that the spatial environment plays a much stronger role than has been previously thought.

Nick Cogan
Department of Mathematics
Florida State University
cogan@math.fsu.edu

**MS71**

**Pattern Formation in Reaction-diffusion Systems with an External Morphogen Gradient**

Gradients of signalling molecules are abundant in the early embryo. They are known to be central to development in many cases, although the exact mechanism of how they influence pattern formation is often still unknown. A related, but distinct concept is the Turing mechanism in reaction-diffusion systems. Since Turing showed in the 1950s how the interplay of two or more chemicals can spontaneously give rise to patterns, it has become a paradigm for pattern formation and it has been proposed as an explanation for many developmental phenomena. To investigate the possible interplay between the Turing mechanism and morphogen gradients, we propose a generic model of a reaction-diffusion system in the presence of a linear morphogen gradient. We assume that this morphogen gradient is established independently of the reaction-diffusion system. Hence it is referred to as an "external" morphogen. It acts by increasing the production of the activator chemical proportional to the morphogen concentration. The model is motivated by several existing models in developmental biology in which a Turing patterning mechanism has been proposed and various chemical gradients are known to be important for development. Mathematically, this leads to reaction-diffusion equations with explicit spatial dependence. We investigate how the Turing pattern is affected, if it exists. We also apply our general findings to a model of skeletal pattern formation in vertebrate limbs and show how they can shed light on some experimental findings concerning the action of the protein *Sonic Hedgehog*.

Tilmann Glimm
Western Washington University
glimmt@wwu.edu

**MS71**

**Dorsal-ventral Patterning in Sea Urchin and *Drosophila* Embryos**

The dorsal-ventral axis in *Drosophila* is specified by gradients of bone morphogenetic proteins (BMPs). While initially secreted in a broad region, later concentrate into a narrow band, designating the dorsal-most 10% of the embryo. Modeling papers have focused on the dynamics seen in *Drosophila*, but the same mechanism specifies the sea urchin axis. Yet in urchins, the BMP secretion and expression domains are complementary. Reaction-diffusion models are considered for the patterning seen in both organisms.

Heather D. Hardway
Boston University
Department of Mathematics and Statistics
hhardway@bu.edu

**MS72**

**Glass Networks: Overview and Recent Results**

Gene regulatory networks and neural networks can be strongly switching systems, allowing approximation by piecewise-linear equations called Glass networks. Flow is structured by a series of attracting (focal) points, which may or may not be reachable. Periodic and more complex behavior can arise. Also, flow can be constrained temporarily in threshold regions far from focal points. All of these behaviors can by treated analytically, via discrete maps between threshold hyperplanes, and sliding modes within them.

Roderick Edwards
University of Victoria
Dept. Math and Statistics
edwards@math.uvic.ca

**MS72**

**Nonlinear Dynamics of Gene Regulatory Networks: An Automated Analyzer**

This talk deals with the dynamics of gene regulatory models where regulation is assumed threshold dependent and described by steep sigmoids. In domains where all variable values are far from thresholds, the dynamics is fairly easy to describe. The challenge is to analyze the flow in the narrow domains where at least one variable value is close to one of its thresholds. Under a biologically reasonable assumption, rules that determine the system flow are established.

Liliana Ironi
IMATI - CNR
Pavia (Italy)
ironi@imati.cnr.it

Luigi Panzeri
IMATI-CNR
Pavia
panzeri@imati.cnr.it

Erik Plahte
Dep. Mathematical Sciences and Technology and CIGENE
Norwegian University of Life Sciences, Aas
erik.plahte

Valeria Simoncini
Universita' di Bologna, Italy
valeria@dm.unibo.it

**MS72**

**Transient Vector Field Effects on Oscillations in a Neuromechanical Model of Limbed Locomotion**

We analyze a closed-loop locomotor model in which a central pattern generator drives a single-joint limb and receives afferent feedback. Transitions associated with changes in ground reaction force or motoneuron outputs abruptly alter the vector field in the limb dynamics phase plane. The positions of the locomotor oscillation trajectory relative to these transient vector fields and their critical points explain the model's ability to replicate an experimentally observed locomotor asymmetry. A contraction argument relying on these transitions provides conditions for existence of a periodic orbit in a reduced model.

Lucy Spardy
University of Pittsburgh
les65@pitt.edu

Sergey Markin, Natalia Shevtsova
Drexel University College of Medicine
smarkin@drexelmed.edu,
natalia.shevtsova@drexelmed.edu

Boris Prilutsky
Georgia Institute of Technology
boris.prilutsky@ap.gatech.edu

Ilya A. Rybak
Drexel University College of Medicine
rybak@drexel.edu

Jonathan Rubin
University of Pittsburgh
Pittsburgh, PA
jonrubin@pitt.edu

**MS72**

**Phase Resetting in Phaseless Systems**

Oscillatory biological behavior often suggests the presence of a stable limit cycle, for which one may define a phase resetting curve in terms of the asymptotic response to small perturbations. Empirically, rhythmic behavior also appears in systems without a well defined asymptotic phase, for instance spiral sinks or heteroclinic cycles when these systems are perturbed by noise. We will discuss the challenge of defining "phase resetting" for systems lacking a well defined asymptotic phase.

Peter J. Thomas
Case Western Reserve University
pjthomas@case.edu

Kendrick Shaw
Case Western Reserve University
Department of Biology
kms15@case.edu

Klaus Stiefel
Okinawa Institute of Science and Technology
stiefel@salk.edu

Hillel Chiel
Case Western Reserve University
hjc@case.edu

**MS73**

**Robustness of Overlapping Modular Networks**

Many systems can be modeled using networks of coupled overlapping modules. Elements of these networks perform individual and collective tasks such as generating and consuming electrical load or transmitting data. We study their robustness: a random fraction of the elements fail which may cause the network to lose global connectivity. These modules can become uncoupled (non-overlapping) before the network falls apart. This may explain how missing data affects the community structure of large-scale social networks.

James Bagrow, Yong-Yeol Ahn
Center for Complex Network Research
Northeastern University
j.bagrow@neu.edu, yongyeol@gmail.com

Sune Lehmann
DTU Informatics
Technical University of Denmark
sune.lehmann@gmail.com

**MS73**

**Gang Dynamics in Los Angeles**

Gang violence is one of the major sources of aggravated assaults and homicide Los Angeles. Therefore, it is important to understand the rivalry network among gangs and how such a rivalry network could emerge and evolve. We propose an agent-based model to simulate the emergence of a gang rivalry network. As a case study, our model focuses on an area of Los Angeles known as Hollenbeck. Agents' perform a biased Lévy walk and their movements are coupled to an evolving network of gang rivalries, which is determined by previous interactions among agents in the system. We integrate gang data provided by the LAPD, geographic information, and behavioral dynamics suggested by the criminology literature. The major highways, rivers, and the locations of gangs' centers of activity influence the agents' motion. We use common metrics from graph theory to analyze our model, comparing networks produced

by our simulations to the real-world network available in the criminology literature.

Alethea Barbaro
University of California, Los Angeles
alethea@math.ucla.edu

**MS73**

**Collective Chaotic Incoherence Stabilizes Synchronization Chimera**

We introduce a new state in coupled chaotic oscillators, related to chimera states for phase oscillators. We present mixed behavior in networks of some coherent components that synchronize, coexisting with decoherence as a generalized chimera state. We demonstrate existence of such mixed states together with analysis predicting the phenomenon that further shows the coherence is caused by the coexisting decoherence mimicking a stochastic drive to stabilize the coherent oscillators as mechanism of self symmetry breaking.

Erik Bollt
Clarkson University
bolltem@clarkson.edu

Sun Jie
Northwestern University
sunj@northwestern.edu

Takashi Nishikawa
Clarkson University
takashi ntnishika@clarkson.edu

**MS73**

**Social Influence and the Spread of Facebook Applications**

Social influence drives offline and online behavior. Prior work on the diffusion of innovations in spatial regions or social networks has focused on the spread of one particular technology among a subset of adopters. We study social influence processes by tracking the popularity of a complete set of applications installed by Facebook users. We analyze the collective behavior induced by 100 million application installations, finding that two distinct regimes of behavior emerge in the system.

Jukka-Pekka Onnela
Harvard University
onnela@hcp.med.harvard.edu

**MS74**

**Hysteretic Capillary Interactions in Models of Atomic-Force Microscopy: a Bifurcation Paradigm for Nonsmooth Systems**

This paper collects four distinct instances of grazing contact of a periodic trajectory in hybrid dynamical systems under a common framework and establishes general properties of the associated near-grazing dynamics. It is shown that commonly used physical models of rigid or compliant mechanical contact and capillary adhesion, e.g., models of tapping-mode atomic force microscopy in the presence of thin fluid films on the sample and the probe tip, satisfy the conditions required by the framework.

Harry Dankowicz
University of Illinois
danko@illinois.edu

Michael Katzenbach
Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign
katzenba@gmail.com

**MS74**

**Good Vibrations: Bimodal Atomic Force Microscopy**

Improving spatial resolution, data acquisition times and material properties imaging are some long lasting goals of amplitude modulation AFM. Currently, the most promising approaches to reach those goals involve the excitation of several frequencies of the tips oscillation. Bimodal AFM is an emerging technique that is characterized by a high signal-to-noise ratio and the versatility to measure different forces. The high sensitivity enables high resolution imaging under the application of sub-100 pN peak forces.

Ricardo Garcia
Instituto de Microelectronica de Madrid (CSIC)
ricardo.garcia@imm.cnm.csic.es

**MS74**

**High Speed Atomic Force Microscopy**

High speed atomic force microscopy is capable of delivering 3D images of biological samples at over 1000 fps. The basic principles of atomic force microscopes will be explained followed by the current understanding of the microscope's interaction with the sample surface during the imaging process. A combination of experiments and theory are used to explain the low friction regime between the microscope and the sample and how this enables the high frame rate of HSAFM.

Oliver D. Payton
University of Bristol, UK
UK
op4664@bris.ac.uk

**MS74**

**The Dynamics of Tapping Mode Atomic Force Microscopy**

In this talk I will discuss recent work that will highlight (a) the spatiotemporal dynamics of vibrating cantilevers studied by integrating a commercial AFM with a scanning Doppler vibrometer, with an insight into Proper Orthogonal Decomposition (POD) of cantilever dynamics and its implications, (b) Multi-modal interactions when AFM cantilevers are used in liquids, including energy transfer from lower to higher modes and also subharmonic transfer of energy from higher to lower modes.

Arvind Raman
Purdue University
raman@purdue.edu

**MS75**

**Variational Approximations in Discrete Nonlinear Schrödinger Equations**

The variational approximation (VA) is a robust tool that can be used to study solitary waves in infinite dimensional Hamiltonian systems, like the discrete nonlinear Schrödinger (DNLS) equation. Besides explaining the underlying ideas of the reduction itself, I will discuss specific results pertaining to a DNLS equation with competing cubic and quintic nonlinearities in one- and two-dimensional lattices, including an accurate description of complex bifurcation structure such as snaking.

Christopher Chong
Universität Stuttgart
christopher.chong@mathematik.uni-stuttgart.de

**MS75**

**Principal Component Analysis of the Ginzburg-Landau Equation**

A low-dimensional description of the cubic-quintic Ginzburg-Landau equation is constructed via the proper orthogonal decomposition to characterize the pulse dynamics in a ring cavity laser mode-locked by a saturable absorber. The bifurcation diagram of the reduced model shows that the transition from a single pulse to a double pulse configuration is via a Hopf bifurcation. The reduction technique can be used as an efficient algorithm for obtaining high-energy pulses in the laser cavity without going through the multi-pulsing instability.

Edwin Ding
Applied Mathematics
University of Washington
ding@amath.washington.edu

Eli Shlizerman
University of Washington, Seattle
shlizee@uw.edu

J. Nathan Kutz
University of Washington
Dept of Applied Mathematics
kutz@amath.washington.edu

**MS75**

**Dynamics and Pattern Formation in Large Systems of Spatially-Coupled Oscillators with Finite Response Times**

We study large systems of spatially-coupled oscillator networks with heterogeneous distributions in natural frequency and response time delays. Using the Ott-Antonsen ansatz and adopting a strategy similar to that in the recent work of Laing, the microscopic dynamics of these systems is reduced to a macroscopic PDE description. We numerically find that finite response time leads to interesting spatio-temporal dynamical behaviors including propagating fronts, spots, target patterns, chimerae, spiral waves, etc.

Wai S. Lee
Institute for Research in Electronics and Applied Physics
University of Maryland
wslee@umd.edu

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

Edward Ott
University of Maryland
Inst. for Plasma Research
edott@umd.edu

Thomas Antonsen
Institute for Research in Electronics and Applied Physics
University of Maryland
antonsen@umd.edu

**MS75**

**Parabolic Resonance Instability in Near-integrable PDEs**

The parabolic resonance instability appears persistently in near integrable $n$ d.o.f. Hamiltonian families depending on p parameters provided $n+p \geq 3$. This ubiquitous finite dimensional instability may be analyzed using the adiabatic chaos methodology. An analogous instability mechanism has been identified in near integrable PDE equations such as the forced periodic 1D NLS equation and the driven surface waves. Some of the geometric characteristics of this instability in the PDE context will be described.

Eli Shlizerman
University of Washington, Seattle
shlizee@uw.edu

Vered Rom-Kedar
The Weizmann Institute
Applied Math & Computer Sci
vered.rom-kedar@weizmann.ac.il

**MS76**

**Effective Langevin Equations for Heterogeneous Coupled Neural Networks**

We construct effective Langevin equations for single neurons within coupled neural networks and explore the effects of heterogeneity on the population statistics and stability. The parameters of the Langevin equation are dependent upon the properties of the other neurons within the network. We discuss the impact of heterogeneity on the possibility of various coding schemes in the network, for example whether the neurons respect a phase-coding versus a rate-coding mechanism.

Michael Buice
LBM/NIDDK
National Institutes of Health
buicem@niddk.nih.gov

Carson C. Chow
Laboratory of Biological Modeling
NIDDK, NIH
carsonc@niddk.nih.gov

**MS76**

**Slow Dynamics in Balanced Networks with Distance-dependent Connections**

We investigate the relationship between the spatial dependence of connections in networks of excitatory and inhibitory neurons and the dynamics of the network. We find that long timescale behavior in which spatially localized clusters of neurons transiently increase their firing rates are promoted by a spatially dependent connection structure, particularly when the spatial scale of inhibition is broader than excitation. These dependencies unveil population dynamics not present in neuronal networks with homogeneous connection probabilities.

Ashok L. Kumar
Carnegie Mellon University
alk@cmu.edu

Brent Doiron
Dept. of Mathematics
Univ. of Pittsburgh
bdoiron@pitt.edu

### MS76
### The Case Against Common Input: Why Convergence and Chains are Network Structures that Influence Synchrony in Recurrent Neuronal Networks

We investigate the influence of network structure on the tendency for neuronal networks to synchronize. The analysis is based on the framework of second order networks, a network model that captures second order statistics (correlations) among network edges. We demonstrate how the fraction of common input onto pairs of neurons, when uncorrelated with other network properties, has little effect on network synchrony, even in networks with only excitatory neurons. In contrast, both the degree of network convergence and the relative frequency of network chains have a profound influence on network synchrony. Insight into the critical role of chains when combined with convergence and common input can be explained by a pool and redistribute mechanism. Increased chain connections ensure that correlations in the network activity that are amplified through the input pooling of convergence are redistributed throughout the network, leading to the development of synchrony across the network.

Duane Nykamp
School of Mathematics
University of Minnesota
nykamp@math.umn.edu

### MS77
### Stokes Regularization of the Laplacian Growth in Hele-Shaw Cell

Recently it was shown that the cusp forming singularity of the Laplacian growth in a Hele-Shaw cell can be regularized by relaxing the incompressibility condition of the viscous liquid. Then at the end one can restore the incompressibility and find a weak solution of the Laplacian growth beyond singularities. In this talk I will show that this procedure corresponds to the real physics of the flow in a Hele-Shaw cell.

Artem G. Abanov
Physics Department,
Texas A&M University
abanov@tamu.edu

### MS77
### Interface Motion of Evaporating Thin Films

A thin water film on a cleaved mica substrate undergoes a first order phase transition between two values of film thickness. By inducing a finite evaporation rate of the water, the interface between the two phases develops a fingering instability similar to that observed in the Saffman-Taylor problem. A key role in the evolution of the interface is played by an additional instability that appears along the interface. It is similar to Rayleigh instability, but unlike the extended undulations of the Rayleigh instability, it is localized to the regions of maximum curvature.

Oded Agam
The Racah Institute of Physics
The Hebrew University
agam@phys.huji.ac.il

### MS77
### The Exponential Transform in 2D

The power moments of a planar shape, or even a shade function, can be optimally arranged into a formal series transform which involves non-linear algebraic operations. The relevance of this (exponential) transform for reconstruction, approximation and qualitative estimates will be presented in parallel with a few basic examples.

Mihai Putinar
University of California, Santa Barbara
Mathematics Department
mputinar@math.ucsb.edu

### MS77
### Interface Motion in a Hele-Shaw Cell and a Dynamical Mother Body

We start with a quick review of the state of the art of the interface motion problems and show the connections between Hele-Shaw problem and other applications of the Laplacian growth in physics. We discuss negative Laplacian growth, introducing a dynamical mother body and presenting an algorithm and examples of a complete removal of a fluid droplet with algebraic boundary from a Hele-Shaw cell.

Tatiana Savin
Northwestern University
savin@ohio.edu

Alexander Nepomnyashchy
Department of Mathematics
Technion
nepom@techunix.technion.ac.il

### MS78
### Critical Slowing Down As An Indicator of Dynamic Instability in Power Systems

With the growing deployment of synchronized phase-angle measurement units (PMUs) in power systems, there is a rapidly increasing quantity of high resolution, time synchronized sensor data available to system operators. Information in these data that could signal a critical transition, such as voltage collapse or dynamic instability, could be valuable to system operators who need to make timely, and costly, decisions to avert large blackouts. This talk will provide preliminary evidence that time-series data alone, without intricate network models, can signal a pending critical transition in power systems. We will discuss theoretical results for a two-bus model illustrating how recovery times increase as proximity to criticality decreases, and empirical results for the August 10, 1996 blackout in Western North America.

Paul Hines, Eduardo Cotilla-Sanchez
University of Vermont
paul.hines@uvm.edu, eduardo.cotilla-sanchez@uvm.edu

**MS78**

**Inverse Problems in Power System Dynamics**

Analysis of power system dynamic behavior frequently takes the form of inverse problems, where the aim is to find parameter values that achieve (as closely as possible) a desired response. Examples range from parameter estimation to various forms of boundary value problems. The talk will consider algorithms for solving inverse problems, and in particular will focus on locating limit cycles and grazing phenomena. Power system behavior inherently involves interactions between continuous dynamics and discrete events. A systematic hybrid systems framework for modeling, analysis and algorithms will be presented.

Ian Hiskens
University of Michigan
hiskens@umich.edu

**MS78**

**Cascading Dynamics of Power Grid Networks**

Large blackouts in power networks are typically caused by cascading processes triggered by small number of initial failures in the network. Based on the simulations of microscopic model of power flows we analyze the dynamics of the cascades. We show that the dynamics is essentially non-local and can not be modeled by the disease-spread type models. The algebraic distribution of blackout size is directly related to the hierarchical structure of power grids. We analyze the effect of future "smart" technologies on the cascade dynamics, and propose specific approaches for mitigating the damage caused by the cascade.

Konstantin Turitsyn
MIT
turitsyn@gmail.com

**MS79**

**Overview of Sleep-Wake Regulation and Dynamics**

A number of brainstem and hypothalamic neuronal populations, as well as the neurotransmitters they express, contribute to the regulation of sleep-wake states. However, different structures for the sleep-wake regulatory network have been proposed with particular debate over components involved in REM sleep regulation. This overview will discuss the competing regulatory network structures, a firing rate model formalism for network modeling and how analysis of the temporal dynamics of sleep-wake patterning may inform network structure.

Victoria Booth
University of Michigan
Depts of Mathematics and Anesthesiology
vbooth@umich.edu

**MS79**

**Mechanisms for Controlling REM Sleep Patterns**

We present a minimal mathematical model of sleep wakefulness. The model demonstrates the plausibility of different mechanisms that control the transition to and from REM sleep. Each mechanism is shown to have specific consequences regarding the frequency and length of REM bouts within a sleep-wake cycle and within the larger circadian rhythm. The potential roles of pre-synaptic inhibition and synaptic plasticity will be discussed. The primary mathematical tools are those of geometric singular perturbation theory.

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

**MS79**

**Ultradian Dynamics in a Potential Formulation of Human Sleep**

Mammalian sleep is characterized by ultradian oscillations between rapid eye movement (REM) and non-REM (NREM) stages, but the underlying physiological mechanism is unknown. Previously we showed that human sleep/wake dynamics can be reproduced by a particle in a one dimensional nonconservative quartic potential, with stable states corresponding to wake and sleep. We extend this to two dimensions, representing wake/sleep state by position in the first dimension, and REM/NREM state by position in the second dimension.

Andrew Phillips
Brigham & Womens Hospital, Harvard Medical School
ajphillips@partners.org

Peter Robinson
School of Physics
University of Sydney
robinson@physics.usyd.edu.au

Elizabeth Klerman
Brigham & Womens Hospital, Harvard Medical School
elizabeth_klerman@hms.harvard.edu

**MS79**

**Modeling the Human Sleep-Wake Cycle**

We present a biologically-based mathematical model that accounts for several features of human sleep and demonstrate how particular features depend on interactions between a circadian pacemaker and a sleep homeostat. The model is made up of regions of cells that interact with each other to cause transitions between sleep and wake as well as between REM and NREM sleep. Analysis of the mathematical mechanisms in the model yields insights into potential biological mechanisms underlying sleep.

Michael Rempe
Mathematics and Computer Science Dept
Whitworth University, Spokane WA
mrempe@whitworth.edu

Janet Best, David H. Terman
The Ohio State University
Department of Mathematics
jbest@math.ohio-state.edu, terman@math.ohio-state.edu

**MS80**

**Measuring the Response of Species Interactions to Climate Change: The Use of Models and Experiments to Study Seed Dispersal by Ants**

We developed a temperature-dependent model of seed dispersal by ants. We use the model to evaluate how we can use a multi-year experiments in Duke and Harvard Forest to predict the persistence of the seed dispersal by ants under future warming scenarios. We will present the current results of the experiment and related model analysis and we will examine the long-term effects that climate change will have on seed dispersal by ants in temperate forests.

Judith Canner
Department of Mathematics and Statistics
California State University at Monterey Bay
jecanner@gmail.com

**MS80**

**Competitive Outcomes Changed by Evolution**

Using evolutionary game theory, we investigate how evolution can change the outcome of a competitive interaction between two species. We focus on changes from competitive exclusion to coexistence and from the exclusion of one species to the other. There are two crucial factors: the rate of evolution and what we term the boxer effect. We apply the theory to data from two historical competition experiments and show how it can explain certain seemingly anomalous results.

Jim M. Cushing
Department of Mathematics
University of Arizona
cushing@math.arizona.edu

Rosalyn Rael
Department of Ecology and Evolutionary Biology
University of Michigan
rrael@umich.edu

Thomas Vincent
University of Arizona
cushing@math.arizona.edu

**MS80**

**Niche Construction and Sustainability in Resource-dependent Competition Models**

In a heterogeneous population, where each individual has access to the common resource, sustainability may become an issue if some choose to take more than they give back. We study this situation through a dynamical system model, where we identify a sustainability threshold and a series of transitional pre-extinction dynamic regimes as parameters are varied is identified. We observe that 1) heterogeneous population survives longer than a homogeneous population and 2) high natural decay rate of the resource allows existence of more aggressive super-consumers without going extinct, most probably due to the fact that in such an environment even very aggressive super-consumers can't reach the resource quite soon enough as to exhaust it.

Irina Kareva
Institute for Applied Mathematics for Life and Social Scienc
Arizona State University
ikareva@asu.edu

**MS80**

**Management and Dynamics in a Predator-Prey Metapopulation**

Increased landscape fragmentation has a deleterious effect on terrestrial biodiversity. There is a push to transition from developing protected areas to policies supporting corridor management. Given the complexities of multi-species interactions, managers need additional tools to aid in decision-making and policy development. We develop theoretical and agent-based models of a two-patch metapopulation with local predatory-prey dynamics and variable density-dependent species migration. The goal is to assess how connectivity of a patch promotes species conservation.

Kehinde Salau
Arizona State University
kehinde.salau@gmail.com

**MS81**

**Contact Bifurcations of Invariant Absorbing Sets and Basins in Noninvertible Maps**

Contact bifurcations of chaotic attractors and their basins are considered, both in 1D an 2D noninvertible maps. When invariant sets are bounded by critical sets, then their contacts with the boundary of the immediate basin leads to some homoclinic bifurcation (of saddles or repelling expanding points) causing a change in the dynamic behavior. Moreover, contacts of critical sets with basins' boundaries can cause global bifurcations that change the topological structure of basins, leading to multiply connected or non connected basins. Some applications to discrete time dynamic modelling of economic and social systems are shown.

Gian Italo Bischi, Laura Gardini
University of Urbino
Department of Economics and Quantitative Methods
gian.bischi@uniurb.it, laura.gardini@uniurb.it

**MS81**

**Interacting Global Manifolds in a Planar Map Model of Wild Chaos**

We consider a planar noninvertible map that has been suggested as a model for wild chaos. This map opens up the origin to a bounded domain and wraps the plane twice around it. We study stable and unstable manifolds in the transition to (wild) chaos. A new aspect is their interaction with the critical set consisting of the images and preimages of the origin which are closed curves and points respectively.

Stefanie Hittmeyer, Bernd Krauskopf
University of Bristol
Department of Engineering Mathematics
stefanie.hittmeyer@bristol.ac.uk,
b.krauskopf@bristol.ac.uk

Hinke M. Osinga
University of Bristol
Department of Engineering Mathematics
H.M.Osinga@bristol.ac.uk

**MS81**

**Connecting Period-doubling Cascades to Chaos via Manifolds in Phase Cross Parameter Space**

The appearance of infinitely-many period-doubling cascades is one of the most prominent features observed in dynamical systems varying with a parameter. Bifurcation diagrams often reveal the intermingling of cascades and chaos. Our recent research rigorously links cascades and chaos using a one manifold of periodic orbits in phase cross parameter space. Our examples include iterated maps arising from Poincaré sections of both finite-dimensional flows and infinite-dimensional delay-differential equations.

Evelyn Sander
George Mason University
esander@gmu.edu

James A. Yorke
University of Maryland
Departments of Math and Physics and IPST
yorke@umd.edu

Madhura Joglekar
University of Maryland
maddy@umd.edu

**MS81**

**Global Dynamics Using Parameter-sweeping Techniques**

In this talk we present, via several paradigmatic examples, such as the Lorenz and Rossler models, how we can obtain parametric studies of the systems by the combined use of different numerical techniques. These numerical results are based on parameter-sweeping techniques on the complete three-parameter space of the systems, and they permit to explain some of the global dynamics of the models.

Sergio Serrano, Roberto Barrio
University of Zaragoza, SPAIN
sserrano@unizar.es, rbarrio@unizar.es

Fernando Blesa
University of Zaragoza
fblesa@unizar.es

**MS82**

**Homoclinic Snaking: Overview, Recent Progress and Open Questions**

In this talk I shall review applications of so-called homoclinic snaking in buckling, pattern formation and optical cavities. The fundamental ingredients are a heteroclinic connection between an equilibrium and a periodic orbit in a reversible systems. Two recent developments are considered including the combined effect of discreteness and dissipation and the possibility of a new kind of snaking with very different asymptotics, where the edges of the snake occur at a fold in the central periodic state. The latter case is analysed in detail. Throughout the talk open questions are highlighted.

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

**MS82**

**1D Localized Structures in Bounded Domains in the Lugiato-Lefever Model**

We analyze the influence of boundaries on localized structures in a large but finite optical cavity. Analytical results are derived in a general context in the framework of the Swift-Hohenberg equation, where the stable localized patterns arise from a Turing bifurcation [G. Kozyreff, P. Assemat and S.J. Chapman, *Influence of Boundaries on Localized Patterns*, Phys. Rev. Lett. **103**, 164501 (2009)]. For almost any boundary condition, we find that they can only be stably located in a discrete set of locations. Multi-peak solutions are rapidly constrained to sit in the middle of the domain as their size increases. Moreover, single-peak solutions only exist sufficiently far from the edges of the domain. These features are predicted and confirmed numerically in the Lugiato-Lefever model.

Lendert Gelens
TONA, Vrije Universiteit Brussel
B-1050 Brussels, Belgium
lendert.gelens@vub.ac.be

Gregory Kozyreff
Optique Nonlineaire , Universite Libre de Bruxelles
CP 231, Campus Plaine, B-1050 Bruxelles, Belgium
gregory.kozyreff@ulb.ac.be

**MS82**

**Multi-pulse Solutions in the Swift-Hohenberg Equation**

Single pulse solutions of the Swift-Hohenberg equation (SHE) have been extensively studied and their origin and bifurcation structure is now well understood. The case of multi-pulse solutions is much more complex. We discuss the existence and bifurcation structure for multi-pulse solutions. By imposing a left-right symmetry breaking on the SHE we show how multi-pulse states are all connected in parameter space.

Steve Houghton
University of Leeds, United Kingdom
smh@maths.leeds.ac.uk

Thomas Wagenknecht
University of Leeds
thomas@maths.leeds.ac.uk

**MS82**

**Defect-mediated Snaking: Spatial and Temporal Dynamics**

In the 1:1 forced complex Ginzburg-Landau equation, steady localized states undergo defect-mediated snaking (DMS) where new rolls of periodic states are nucleated at the center of the wave train. The onset of DMS results from interaction between a heteroclinic orbit connecting two equilibria and a supercritical Turing bifurcation on one of them. As another parameter is varied, DMS breaks into isolas away from onset, while the temporal dynamics change from depinning to pulse interaction.

Yiping Ma
Department of Physics
U. C. Berkeley
yiping.m@gmail.com

Edgar Knobloch
University of California, Berkeley
knobloch@berkeley.edu

**MS83**

**Alignment Dynamics and Its Effects on Effective Viscosity of Bacterial Suspensions**

We present results on suspensions of swimming bacteria with the focus on explaining their remarkable effective rheology: the effective viscosity of a bacterial suspension can be lower than that of a suspension of comparable passive particles by nearly an order of magnitude [Sokolov and Aronson, Phys. Rev. Lett. 2009]. This behavior stems from the emergence of collective swimming, which leads to coherent injection of energy and momentum into the fluid. Collective modes arise mostly due to a hydrodynamically-induced alignment between neighboring particles.The mechanism and nature of alignment is investigated analytically and computationally in the dilute and semi-dilute limits, where the particles do not interact, or interact via a mean field, respectively. An important role in the explanation of the anomalous viscosity is played by the presence of noise due to stochastic effects (bacterial tumbling, Browninan effects) or the effective noise due to interactions. We further emphasize the importance of excluded volume effects that help explain the rise in the effective viscosity at higher particle concentrations, which are not captured by point particle models. Additionally, in the semi-dilute (mean field) regime we also investigate the effects of anomalous diffusion, which has been observed experimentally [Wu and Libchaber, Phys. Rev. Lett., 2000]. Effective diffusivity acts as an additional source of effective noise, which helps explain the difference in the rheology of pullers and pushers.

Dmitry Karpeev
Argonne National Laboratory
karpeev@mcs.anl.gov

Leonid Berlyand
Penn State University
Eberly College of Science
berlyand@math.psu.edu

Igor Aronson
Materials Science Division
Argonne National Laboratory
aronson@anl.gov

Brian Haines, Shawn Ryan
Department of Mathematics
Penn State University
haines@math.psu.edu, ryan@math.psu.edu

**MS83**

**Simulations Versus Experiments on the Rheology of Active Suspensions**

The measurement of a quantitative and macroscopic parameter to estimate the global motility of a large population of swimming biological cells is a challenge. The rheology of suspensions containing such cells is a good candidate. As a matter of fact, we recently performed rheological measurements on suspensions of micro-algae [Effective viscosity of microswimmer suspensions.S. Rafai, L. Jibuti, P. Peyla Phys. Rev. Lett., 104, 098102(2010)]. Chlamydomonas Reinhardtii. These experiments showed the strong effect of the microscopic swimming [Random walk of a swimmer in a low-Reynolds-number medium Michael Garcia, Stefano Berti, Philippe Peyla and Salima Rafai To be published in Phys. Rev. E Rapid Comm. (2011)] on the macroscopic effective viscosity. The chosen algae are pullers since they use two front flagellae to pull on the fluid in a breast stroke motion. We discuss the several models that have already predicted such behaviors and we show different numerical simulations concerning the alga suspensions. We use these simulations in order to discriminate the relevant ingredients of the modelisation of the algae puller-like suspensions.

Philippe Peyla
Universite Joseph Fourier
Philippe.Peyla@ujf-grenoble.fr

Levan Jibuti
Universite Jospeh Fourier
levan.jibuti@ujf-grenoble.fr

Salima Rafai
Universite Joseph Fourier
salima.rafai@ujf-grenoble.fr

**MS83**

**Oxygen Transport and Mixing Dynamics in Thin Films of Oxytactic Microorganisms**

We investigate the dynamics in suspensions of oxytactic swimming microorganisms using two different kinetic models: a gradient-detecting model, in which the swimmers detect local oxygen gradients instantaneously, and a run-and-tumble model, in which the swimmers change their run-and-tumble frequency based on the temporal changes in the oxygen field they sample. Using three-dimensional numerical simulations, we study the behavior of such suspensions in thin liquid films surrounded by oxygen baths on both sides. As the microorganisms consume the dissolved oxygen, gradients form causing them to swim towards the free surfaces where the oxygen concentration is higher. We demonstrate the existence of a transition from quasi-two-dimensional dynamics and pattern formation in thin films to chaotic three-dimensional dynamics as film thickness increases. This transition, which was also previously observed in experiments, is shown to be associated with an enhancement of oxygen mixing and transport into the liquid.

David Saintillan
University of Illinois at Urbana-Champaign
Department of Mechanical Science and Engineering
dstn@uiuc.edu

Amir Alizadeh Pahlavan
Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign
alizade1@illinois.edu

Barath Ezhilan
University of Illinois at Urbana-Champaign
Department of Mechanical Science and Engineering
ezhilan2@illinois.edu

**MS83**

**An Overview of the Simulation-based Dynamics of Microswimmer Suspensions**

We will discuss how hydrodynamic interactions between the organisms can lead to large-scale correlations and collective behavior. Simulations and theory have illustrated how the behavior scales with concentration, the importance of the method of swimming used, the influence of run-and-tumble like motions of the organisms. The orientational correlations of the microorganisms lead to many key phenomena. For organisms that do not tumble these interactions occur even for very low concentrations, consistent with microrheology experiments.

Patrick Underhill

Rensselaer Polytechnic Institute
Department of Chemical and Biological Engineering
underhill@rpi.edu

**MS84**

**A Dynamical Systems Analysis of Territorial Behavior**

We consider a territorial model based on Voronoi tessellations. For rectangular domains and for small population sizes, we show that there can be distinct coexisting stable equilibrium configurations. Furthermore, by treating the aspect ratio of the rectangle as a bifurcation parameter, we numerically explore how stable and unstable equilibrium configurations are related to each other. Results for three agents are verified through experiments using robots which move according to a related territorial algorithm.

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

Ronald Votel
Dept Aeronautics & Astronautics
Stanford University
rvotel@stanford.edu

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

Takahide Gotou, Takeshi Hatanaka, Masayuki Fujita
Tokyo Institute of Technology
goto@fl.ctrl.titech.ac.jp, hatanaka@ctrl.titech.ac.jp, fujita@ctrl.titech.ac.jp

**MS84**

**Role of the Interaction Graph Topology in the Evolution of Collective Migration**

We use the perspective of evolution by natural selection to investigate the collective migration problem, where individuals in a group can respond to social information and to a costly environmental cue. We study the role of the social interaction topology on evolutionary outcomes and demonstrate a minimum connectivity threshold for random interconnection graphs to yield speciated outcomes in responsive behavior. We study the adaptation of nodes on fixed graphs and how topology affects emergent results.

Darren Pais, Naomi E. Leonard
Princeton University
dpais@princeton.edu, naomi@princeton.edu

**MS84**

**Synchronization of Cows**

The study of collective behavior—of animals, mechanical systems, or even abstract oscillators—has fascinated a large number of researchers from observational geologists to pure mathematicians. I consider the collective behavior of herds of cattle. I first discuss some results from an agent-based model and then formulate a mathematical model for the daily activities of a cow (eating, lying down, and standing) in terms of a piecewise affine dynamical system. I analyze the properties of this bovine dynamical system representing the single animal and develop an exact integrative form as a discrete-time mapping. I then couple multiple cow "oscillators" together to study synchrony and cooperation in cattle herds, finding that it is possible for cows to synchronize less when the coupling is increased.

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

**MS84**

**Compensatory Perturbations for Network Dynamics**

Networked systems often exhibit multiple coexisting stable states. Some of these states may be preferred over others, but may not correspond to the state spontaneously realized by the system. A fundamental question is then to establish methods to drive the system from one such state to another under realistic constraints. We formulate this open problem in the context of dynamical systems and develop a general method that can be scaled to very large networks.

Jie Sun, Sagar Sahasrabudhe, Adilson E. Motter
Northwestern University
sunj@northwestern.edu,
sagarsahasrabudhe2011@u.northwestern.edu,
motter@northwestern.edu

**MS85**

**Dynamics at Infinity**

We interpret phenomena like blow up or grow up as heteroclinic connections between finite invariant sets and infinity — or "transfinite" heteroclinics. We access infinity by applying the Poincaré compactification projecting the phase space on the Poincaré hemisphere. Infinity is thereby projected on its equator, an invariant sphere where infinity unfolds its "celestial" dynamics. The Conley index is a useful tool to analyze the connections structure and was successfully applied on bounded global attractors. In the context of unbounded dynamics, Conley index has to be adapted carefully to be able to detect transfinite heteroclinics: even simple systems like planar quadratic ODEs show behaviors near the sphere at infinity that prevent the isolation required by Conley index theory. In order of overcoming this difficulty, we define the concept of "dynamical complement" of an invariant set. The isolated invariance of the dynamical complement is our requirement for establishing the existence of transfinite heteroclinics via non-classical Conley index techniques.

Juliette Hell
Freie Universität Berlin
Institut für Mathematik
jhell@zedat.fu-berlin.de

**MS85**

**Rigorous Numerics for Connecting Orbits for Flows**

I will discuss a new method for computer assisted proof of the existence of connecting orbits for ordinary differential equations. The method consists of reformulating the boundary value problem as a functional equation solved by orbits which begin on the unstable manifold of one equilibria and end on the stable manifold of another. We solve the functional equation using the method of Validated Continuation. A novelty of the scheme is the use of the Parame-

terization Method, which facilitates high order polynomial approximation of the invariant manifolds and allows the rigorous bounding of the truncation errors.

Jason Mireles James
Rutgers University
jmireles@math.rutgers.edu

**MS85**

**The Euler-Floer Characteristic and Forcing of Periodic Points in Two-dimensional Diffeomorphisms**

For area-preserving diffeomorphisms a finite set of periodic points allows the definition of braid Floer homology related to mapping classes. If the braid Floer homology is non-trivial this forces additional periodic points of a given type and provides a Morse type theory. We show that certain information contained in the Floer homology — the Euler-Floer characteristic — also forces periodic points of arbitrary diffeomorphisms. These ideas are applied to the simplest case of the 2-disc, but can easily be extend to two-dimensional surfaces, with or without boundary.

Simone Munao
VU University Amsterdam
smunao@few.vu.nl

**MS85**

**Flow Categories**

Morse theory studies the topology of manifolds through Morse functions defined on them. One shows that a Morse function generates a CW-complex which is homotopic to the manifold. Cohen, Jones, and Segal have shown that it is possible to study this differently. From the flow they construct a flow category, whose classifying space is homotopic to the manifold. Filtrations of this category induce filtrations of the manifold. We will discuss how to construct flow categories for general dynamical systems, and show that the classifying space is homotopic to the underlying space. We do not need any smoothness of the flow or of the underlying space. It is possible to derive relations of Morse type, which force existence of invariant sets with certain topologies.

Thomas Rot
VU University Amsterdam
Department of Mathematics
to.rot@few.vu.nl

**MS86**

**Discovery of Cellular Mechanisms and Prognosis of Cancers from Mathematical Modeling of DNA Microarray Data**

In my lab, we develop novel matrix and tensor computations for comparison and integration of multiple genomic datasets recording different aspects of, e.g., the cell division cycle and cancer. Our recent experiments verified that modeling DNA microarray data by using these computations can correctly predict previously unknown mechanisms. Our recent computational prognosis of tumors from the Cancer Genome Atlas draws a mathematical analogy between the prognosis of disease and the prediction of global cellular mechanisms.

Orly Alter
USTAR Assoc Prof of Bioeng & Sci Comp & Imaging (SCI)
University of Utah
orly@sci.utah.edu

**MS86**

**Master Stability Function Approach for Designing Synchronous Networks**

The master stability function (MSF) is a mathematical tool for determining if a given configuration of coupled chaotic oscillators will synchronize. By decoupling the network dynamics from the individual equations for each of the chaotic trajectories, the MSF reveals the stability of a globally synchronous solution using *only* the eigenvalues of the adjacency matrix. In this talk, we analyze the stability of an adaptive method that can maintain synchrony even when coupling strengths are time-varying.

Adam B. Cohen, Bhargava Ravoori
University of Maryland, College Park
Dept. of Physics
abcohen@umd.edu, ravoorib@umd.edu

Francesco Sorrentino
Universita degli Studi di Napoli Parthenope
francesco.sorrentino@uniparthenope.it

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

Edward Ott
University of Maryland
Inst. for Plasma Research
edott@umd.edu

Rajarshi Roy
University of Maryland
rroy@umd.edu

**MS86**

**Principal Component Analysis of the Water Wave Problem**

We consider the dynamics and stability of time-periodic standing surface gravity waves using a dimensionality reduction technique based on the Proper Orthogonal Decomposition (POD). The reduced model qualitatively reproduces the entire solution branch, from the low-amplitude sinusoidal solutions to the high-amplitude solutions with sharply peaked crests, thus demonstrating that the time-periodic standing wave solutions, along with their bifurcations structure and stability, can be considered in a low-dimensional framework when the proper basis is selected.

J. Nathan Kutz
University of Washington
Dept of Applied Mathematics
kutz@amath.washington.edu

**MS86**

**Proper Orthogonal Modes for the Muti-Pulsing Instability in a Mode-Locked Laser Cavity**

The multi-pulse transition is studied with a low dimensional model constructed by the method of proper orthogonal decomposition. The specific model employed uses a waveguide array as the cavity saturable absorber. The bifurcation structure of the multi-pulse transition is determined, starting with the single-pulse solutions up until the Neimark-Sacker bifurcation that initiates the route to chaos. Lastly, the predictions of low dimensional model are compared with the transition in the full PDE.

Matthew O. Williams
Applied Mathematics
University of Washington
mowill@amath.washington.edu

Eli Shlizerman
University of Washington
shlizee@amath.washington.edu

J. Nathan Kutz
University of Washington
Dept of Applied Mathematics
kutz@amath.washington.edu

## MS87

### Piecewise-smooth Neural Fields with Nonlinear Adaptation

We analyze traveling wave and stationary bump solutions of a piecewise-smooth neural field model with synaptic depression. The continuum dynamics is described in terms of a nonlocal integrodifferential equation, in which the integral kernel represents the spatial distribution of synaptic weights between populations of neurons whose mean firing rate is taken to be a Heaviside function of local activity. Synaptic depression dynamically reduces the strength of synaptic weights in response to increases in activity. We show that the local stability of a stationary bump is determined by solutions to a system of pseudo-linear equations that take into account the sign of perturbations of the bump boundary. Traveling wave solutions introduce additional smoothing. Applications to the spatiotemporal dynamics of binocular rivalry are presented.

Paul C. Bressloff
University of Utah and University of Oxford, UK
Department of Mathematics
bressloff@math.utah.edu

Zachary Kilpatrick
University of Pittsburgh
zpkilpat@pitt.edu

## MS87

### Finite Size Effects in Spiking Neural Networks

Neural networks with biophysical spiking neurons are generally described by large systems of ODEs that are difficult to analyze. The classical way to make the problem more tractable is to reduce it to a population rate description such as the Wilson-Cowan equations. However, these reductions take an infinite size mean field limit and thus ignore the effects of fluctuations and correlations. Here, I will describe a new formalism that allows for a systematic expansion of a coupled network of quadratic integrate-and-fire neurons that accounts for system size effects.

Carson C. Chow
Laboratory of Biological Modeling
NIDDK, NIH
carsonc@niddk.nih.gov

Michael Buice
LBM/NIDDK
National Institutes of Health
buicem@niddk.nih.gov

## MS87

### A Network of Sparsely Active Interneurons Initiates Retinal Waves

The developing nervous system generates spontaneous activity that has a periodicity on the order of minutes. What are the cellular mechanisms that give rise to these infrequent network events? Using electrophysiological and calcium imaging approaches, we have characterized the cellular properties of neurons that give rise to spontaneous retinal waves in the developing retina. These pacemaker neurons, called starburst amacrine cells, spontaneously depolarize in the absence of synaptic connections at a rate that is an order of magnitude less frequent than the network activity. Strong connections between neighboring cells result in the ability of single cells to initiate a wave. Spatial propagation extent and initiation rates are restricted by a slow afterhyperpolarization in starburst cells. Using a conductance based model of a network of starburst cells, we demonstrate that the robust spatial and temporal features of waves can be reproduced by a network of sparsely active cells only when variability in synaptic connectivity between neighboring cells is modeled. In addition, the model accurately predicts how wave features are altered by experimental manipulations of spontaneous depolarization rate and the slow afterhyperpolarization. By comparing models with different cellular behavior that correspond to measurements from different species, we find that disparate cellular properties can interact to give rise to network level activity with highly similar features.

Kevin Ford, Marla Feller
University of California Berkeley
kford@berkeley.edu, mfeller@berkeley.edu

## MS87

### Neural Activity Measures and Their Dynamics

We provide an asymptotically justified derivation of evolution equations for activity measures of a neural network. The derivation is based upon neurons' first principal dynamics, i.e. the Hodgkin-Huxley equations or their reductions. The resulting equations serve as a dimension reduction for the complicated network when the dynamics are attracted to a synchronized solution. Computational results of the mean measure evolution equation for a network of identical FitzHugh-Nagumo neurons validate the approach and its underlying assumptions.

Eli Shlizerman, Konrad Schroder
University of Washington, Seattle
shlizee@uw.edu, perseant@hhhh.org

J. Nathan Kutz
University of Washington
Dept of Applied Mathematics
kutz@amath.washington.edu

## MS88

### Macroscopic Physiology

Human physiology, as a science, aims to understand the mechanical, physical, and biochemical functions of humans; moreover, because human dynamics transpire both on multiple spatial scales, ranging from molecular, to cell, to organ, to collections of organs and on multiple time scales ranging from fractions of a second to decades, it is likely that complete models of human functioning will consist of highly complex models whose scales interact in complex ways (via e.g., nonlinear resonance). While, mathematical modeling of physiological systems on the cellular and organ scales has a long history, integrating long time-scale data analysis with the physiological modeling is largely non-existent. It is of course no mystery why this is the case; such long-time data has been difficult or impossible to collect; fortunately, with the advent and increasing use of electronic health records (EHR), the data existence roadblock will be largely removed and replaced with scientific and methodological problems. Broadly, this talk takes aim at outlining some first steps in constructing an interface between EHR temporal data, which typically contains time-scales of hours to years, and the modeling of human physiological systems. More particularly, this talk will focus on the glucose-insulin regulation system.

David Albers
Colombia University
albers@santafe.edu

**MS88**

**Amoeba-based Neurocomputing and Resource-Competing Oscillator Networks**

A single-celled photosensitive amoeboid organism, the true slime mold Physarum, exhibits rich spatiotemporal oscillatory behavior and sophisticated computational capabilities. Applying optical feedback according to a recurrent neural network model, the amoeba can be used as a computing substrate to explore solutions to the traveling salesman problem. We show the experimental results and introduce our mathematical models that reproduce the amoeba-like spatiotemporal oscillatory dynamics applied to solve some optimization problems in resource allocation and decision-making.

Masashi Aono
ASI, RIKEN
masashi.aono@riken.jp

**MS88**

**EHR Dynamics: An Introduction**

Data sets that represent population-wide, temporal, human health dynamics are just beginning to come into existence in the form of electronic health records (EHRs). Because these data include a range of time scales from minutes to decades, and will, in the future, span the earth, the possibility of studying and modeling human functioning on larger time and spatial scales much as climatology does for atmospheric physics will become a reality. Said differently, humans are the ultimate model organism, and EHRs are the key to studying their medium- to long-term time and spatial scales. These data come with a complication, however. EHR data are not collected for scientific research, and more importantly, they are not collected in a controlled environment. Therefore, an EHR not only contains measurements of a natural system, but it is a natural system. In particular, EHRs depend on their location on the planet, their internal rules (e.g., their internal measurement dynamics), their population, and many other internal and external factors. This talk introduces EHR data as a dynamical structure as well as some of the problems incorporated into the use of EHRs as a data source. Along the way, a set of new, unique, nonlinear time-series analysis problems will be identified.

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

**MS88**

**Noise-induced Phenomena in One-dimensional Maps**

Problems of complex behavior of random dynamical systems is investigated based on numerically observed noise-induced phenomena in Belousov-Zhabotinsky map (BZ map) and modified Lasota-Mackey map with presence of noise. We found that (i) both noise-induced chaos and noise-induced order robustly coexist, and that (ii) asymptotical periodicity of density is varied according to noise amplitude. Applications to time series analysis are also discussed.

Yuzuru Sato
RIES, Hokkaido University
ysato@math.sci.hokudai.ac.jp

**MS89**

**Rules Versus Optimization for Enabling Adaptive Network Topologies**

A fully-enabled smart transmission grid could allow adjustment of network topology in real-time, increasing operational efficiency. Meta-analysis of previous mixed-integer-based approaches suggests that most efficiency gains arise from small changes in topology; are invariant to the level of demand; and appear to be localized in nature. We propose a rule-based framework for enabling flexible topologies based on network partitioning. Our method could be implemented quickly, while optimization algorithms for mixed-integer problems are further developed.

Seth Blumsack, Clayton Barrows
Pennsylvania State University
sethb@psu.edu, cpb155@psu.eu

**MS89**

**Modeling and Control of Aggregated Heterogeneous Thermostatically Controlled Loads for Ancillary Services**

This talk presents a novel modeling and control approach for the aggregation of large numbers of heterogeneous thermostatically controlled loads, such as refrigerators, electric water heaters, and air conditioners, and their usage for Demand Response. Unlike traditional Demand Response methods that act on time scales of hours, this approach is able to provide short-term (e.g., second-to-second) ancillary services, such as balancing and frequency control. A statistical modeling approach based on Markov Chains is used to describe the evolution of probability mass in a temperature state space. The Markov state transition matrix is identified using both (1) full state information and (2) information from only a subset of loads. A predictive controller is used to control the aggregate population of loads such that it tracks a signal. A simulation example shows the applicability of the approach to realistic systems, and includes a comparison of control performance depending on available state information.

Duncan Callaway

University of California, Berkeley
dcal@berkeley.edu

Stephan Koch
ETH Zurich
koch@eeh.ee.ethz.ch

Johanna Mathieu
UC Berkeley
jmathieu@berkeley.edu

### MS89

### Demand Response to Uncertainty in Renewable Energy

A utility company plays in multiple wholesale electricity markets, including day-ahead market and real-time balancing market to provision aggregate power to meet demands and then retails it to end users. It aggregates demand so that the wholesale markets can operate more efficiently and it absorbs large uncertainty and complexity of generation and translate them into a much simpler environment both in prices and supply for the retail users. We propose a model that captures these features. We analyze a demand response scheme that can be implemented in a distributed manner and converges almost surely to a social-welfare maximizing solution.

Steven Low, Libin Jiang
Caltech
slow@caltech.edu, libinj@caltech.edu

### MS89

### Modeling and Simulation of a Renewable and Resilient Electric Power Grid

Electricity and the electric grid will play a crucial role in our transition to a sustainable energy infrastructure. Integrating a significant percentage of renewable energy sources into the nations energy mix, and delivering it through electric transmission and distribution systems is a major research challenge since these sources are less controllable than the fossil-fuel-based generation they will displace. Simultaneous with these changes is the need to make the electric grid even more resilient in order to insure maximum continuity of electric service, even during severe system disturbances. This paper focuses on the modeling and simulation aspects of these problems.

Thomas Overbye
University of Illinois, Urbana
overbye@illinois.edu

### MS90

### Modeling Circadian Modulation of Sleep-wake Regulatory Dynamics

Recent experimental advances have identified both feed-forward and feedback components involved in neuronal interactions between the suprachiasmatic nucleus and sleep-wake regulatory systems. Using a novel network modeling framework, we investigated interactions among neuronal nuclei involved in rat sleep-wake and circadian regulation. Fast/slow analysis of model dynamics reveals hysteresis via a bursting-like bifurcation structure. This structure suggests mechanisms for dynamic influences of the circadian pacemaker on sleep-wake patterning, particularly the timing of rapid eye movement sleep.

Cecilia Diniz Behn
University of Michigan
Dept of Mathematics
cdbehn@umich.edu

Michelle Fleshner
Dept of Mathematics
University of Michigan
mfleshner301@gmail.com

Daniel Forger
University of Michigan
forger@umich.edu

Victoria Booth
University of Michigan
Depts of Mathematics and Anesthesiology
vbooth@umich.edu

### MS90

### Data Assimilation in Sleep Models - a Nonlinear Ensemble Kalman Approach To Tracking and Predicting State

There have been extensive efforts to translate the biological understanding of the cellular elements of the sleep-wake regulatory system into mathematical/computational models. We hypothesize that state of that system - and the neurotransmitters it uses to modulate cortical state - could be useful for understanding seizure generation. We will report on our efforts to put these computational models into a nonlinear ensemble-Kalman filter framework to assimilate data from long-term In-Vivo recordings.

Madineh Sedigh-Sarvestani, Steven Schiff,
Bruce J. Gluckman
Penn State University
mus236@psu.edu, sjs49@psu.edu, brucegluckman@psu.edu

### MS90

### High-resolution Sleep Scoring Through the Mapping of EEG Onto a Cortical State Model

The current clinical method of sleep scoring involves dividing sleep into five discrete stages, which limits its diagnostic and predictive power. Using a dimensionality reduction technique (locally linear embedding) we show how human EEG data can be mapped onto a representation of the sleep cycle within a nonlinear stochastic PDE mean-field cortical model. This evinces a continuous evolution through sleep stages and transitions over the course of a night.

Beth A. Lopour
UCLA
bethlopour@ucla.edu

Savas Tasoglu
UC Berkeley
stasoglu@berkeley.edu

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

James W. Sleigh

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

Andrew J. Szeri
UC Berkeley
andrew.szeri@berkeley.edu

### MS91

### Analyzing Endogenous Thresholds in Coupled Socioeconomic-ecological Systems

Ecological thresholds are determined within a coupled socioeconomic-ecological system (SES) where human choices, including those of managers, are feedback responses. Prior work assumes either that managers face no institutional constraints and thresholds are of little importance, or that managers are rigidly constrained and thresholds can be describe as exogenous parameters. By modeling institutions as a managers control set, we show that the location of thresholds in ecological state space depends on human institutions.

Rick Horan
Michigan State University
horan@msu.edu

Eli Fenichel
Arizona State University
School of Life Sciences
Eli.Fenichel@asu.edu

Kevin Drury
Bethel College
kevin.drury@bethelcollege.edu

David Lodge
Notre Dame Univeristy
david.m.lodge.1@nd.edu

### MS91

### A Model for the Spread of Animal Diseases with Mitigation Strategies and a Case Study on Rinderpest

Animal diseases are important in world economics, national security, and biodiversity. We use a spatially explicit, hybrid (stochastic-deterministic) model for the spread of multi-host animal diseases in the United States with a case study on highly virulent rinderpest. We explore geographical spread on a county level and different mitigation strategies. A forward sensitivity analysis indicates important disease parameters and containment approaches. Generalizations of control strategies for rinderpest may be effective for other contagious animal diseases.

Carrie A. Manore
Oregon State University
manorec@math.oregonstate.edu

Benjamin McMahon, Jeanne Fair
Los Alamos National Laboratory
mcmahon@lanl.gov, jmfair@lanl.gov

James Hyman
Tulane University
mhyman@tulane.edu

Mac Brown
Los Alamos National Laboratory
macbrown@lanl.gov

Montiago LaBute
Lawrence Livermore National Laboratory
labute1@llnl.gov

### MS91

### Optimal Management Controls for Maximizing the Recovery of an Endangered Fish Species

A computationally-expensive individual-based model (IBM) was used to simulate the population decline of delta smelt during 1995 to 2005 in the Upper San Francisco Estuary. We approximated the IBMs output with a spatially-explicit matrix projection model. By applying optimal control theory to the matrix model, we determined cost-effective management actions involving redirected movement and improved habitat (affecting mortality and growth) that would maximize long-term population growth during this period of decline.

Rachael Miller Neilan
Louisiana State University
rmill48@lsu.edu

Kenneth Rose
University of Lousiana
karose@lsu.edu

Wim Kimmerer
San Francisco State University
kimmerer@sfsu.edu

William Bennett
Bodega Marine Lab
University of California, Davis
wabennett@ucdavis.edu

Karen Edwards
Romberg Tiburon Center for Environmental Studies
San Francisco State University
kpe@sfsu.edu

### MS92

### Internal Modes and Instabilities of Solitons in the Discrete NLS Equation

Discrete solitons of the discrete nonlinear Schrdinger (dNLS) equation are compactly supported in the anti-continuum limit of the zero coupling between lattice sites. Eigenvalues of the linearization of the dNLS equation at the discrete soliton determine its spectral stability. Small eigenvalues bifurcating from the zero eigenvalue near the anti-continuum limit were characterized earlier for this model. Here we analyze the resolvent operator and prove that it is bounded in the neighborhood of the continuous spectrum if the discrete soliton is simply connected in the anti-continuum limit. This result rules out existence of internal modes (neutrally stable eigenvalues of the discrete spectrum) near the anti-continuum limit.

Anton Sakovich
McMaster University
sakovias@math.mcmaster.ca

Dmitry Pelinovsky

McMaster University
Department of Mathematics
dmpeli@math.mcmaster.ca

**MS92**

**Intrinsic Energy Localization Through Discrete Breathers in One-dimensional Diatomic Granular Crystals**

We present the possibility of energy localization in one-dimensional diatomic chains of tightly packed and uniaxially compressed elastic beads. The localization is obtained by the intrinsic nonlinearity, caused by the Hertzian interaction of the beads, without additional inhomogeneities. We first characterize the linear spectrum of the system. We then use continuation techniques to find the exact nonlinear localized solutions and study their linear stability in detail. Finally, we report the experimental observation of the energy localization in such media.

Georgios Theocharis
California Institute of Technology
georgiostheocharis@gmail.com

**MS92**

**Breathers and Kinks in FPU Lattices**

Combined breather-kink modes have been observed in several systems. We show that in the FPU lattice, small-amplitude breathing-kink modes are three-soliton solutions of an associated mKdV equation. Since this is integrable, the modes can be constructed using the Bäcklund transform. As well as finding explicit solutions, we consider the stability of the combined mode using variational techniques and illustrate stability for some parameter values and instability for others.

Jonathan Wattis
School of Mathematical Sciences
University of Nottingham
Jonathan.Wattis@nottingham.ac.uk

Andrew Pickering, Pilar R. Gordoa
Dpt Matematica Aplicada, Universidad Rey Juan Carlos, Madrid
andrew.pickering@urjc.es, pilar.gordoa@urjc.es

**MS93**

**Continuation of Oscillons in an Autonomous System of Reaction-diffusion Equations**

We study the formation of oscillons in a model of the Belousov-Zhabotinsky reaction. We trace bifurcation diagrams and compute stability of stationary localised spots and find Hopf and fold bifurcations. We also continue oscillons and show that, in some regions of the parameter space, their period diverges as they approach a Shilnikov homoclinic orbit. This suggests an alternative mechanism for the formation of oscillons. This is joint work with D. Lloyd, K. Ninsuwan and B. Sandstede.

Daniele Avitabile
Department of Mathematics, University of Surrey
University of Surrey
d.avitabile@surrey.ac.uk

**MS93**

**Localised Patterns in a Crime Hotspot Model**

It is shown that a PDE model of crime hotspots, derived by Short et al. from an agent-based stochastic model (Math. Model Meth. Appl. Sci. 2008), possesses localised patterns and homoclinic snaking. We analyse such patterns in the PDE model and also investigate what happens in the agent-based model. We then present recent efforts to investigate patterns in the stochastic agent-based model by applying the equation-free methods of Kevrekidis et al. This work is joint with Daniele Avitabile (Surrey), David Barton (Bristol), Rebecca Hoyle (Surrey) and Hayley O'Farrell (Surrey)

David Lloyd
University of Surrey
d.j.lloyd@surrey.ac.uk

**MS93**

**Localized Patterns in the Swift-Hohenberg Equation**

The existence of localized structures in the two and three dimensional Swift–Hohenberg equation will be established. This is used as a model equation for pattern formation. These solutions are seen in mode-locked lasers, foliage growing patterns, and gas discharge systems. By using numerical continuation techniques where the dimension is treated as a continuous parameter, these solutions and their bifurcation structures were first seen. We will discuss analytic proofs for the existence of these structures.

Scott McCalla
Division of Applied Mathematics
Brown University
scott_mccalla@brown.edu

**MS93**

**Stability of Planar Layers in Reaction Diffusion Equations Coupled with a Conservation Law**

We prove the stability of layers in systems exhibiting a conservation law coupled with a reaction diffusion equation. The key element of the analysis is to find a homotopy to a lower-triangular PDE system that has stable solutions and to control the essential spectrum during the homotopy. The layers can destabilize during the homotopy only in the case when a Hopf bifurcation occurs. We use a Lyapunov-Schmidt analysis in weighted spaces to show that eigenvalues can not pop out of or disappear into the essential spectrum during the homotopy

Alin Pogan
University of Minnesota
School of Mathematics
pogan@math.umn.edu

**MS94**

**Collective Dynamics of Flagella and Multiflagellar Organisms**

Many bacteria have multiple helical flagella that self-assemble into bundles as they swim in fluid. We examine the bundling process using a mathematical model of multiple long slender flexible helical flagella in a fluid, with ends either anchored or attached to a freely moving cell body. A central result is that as parameters change, bifurcations between tight to loose bundles are found – multiple bundled states can coexist. Biological implications of our results are discussed.

Michael D. Graham
Dept. of Chemical and Biological Engineering
University of Wisconsin-Madison
graham@engr.wisc.edu

Pieter Janssen
Dept. of Chemical and BIological Engineering
University of Wisconsin-Madison
pjjanssen@wisc.edu

### MS94
### Boundary Effects on Continuum Models for Active Suspensions

We extend a recently developed continuum model of active suspensions to a confined planar channel geometry. We discuss physical boundary conditions for the probability distribution of allowable configurations for the center-of-mass and orientation, as well as modifications to the stress distribution to include wall effects. We derive an evolution equation for the system entropy, which shows that diffusion through the boundary modifies the stability results obtained for suspensions of pushers and pullers in a periodic box.

Christel Hohenegger
University of Utah
Department of Mathematics
choheneg@math.utah.edu

Michael J. Shelley
New York University
Courant Inst of Math Sciences
shelley@cims.nyu.edu

### MS94
### Random Flow in Suspensions of Swimming Algae

We have studied the random flow field induced by dilute suspension of swimming algae *Volvox carteri*. The fluid velocity in the suspension is a superposition of the flow fields set up by the individual organisms, which in turn have multipole contributions that decay as inverse powers of distance from the organism. Here we show that the conditions under which the central limit theorem guarantees a Gaussian probability distribution function of velocity fluctuations are satisfied when the leading force singularity is a Stokeslet for the far-field velocity. Deviations from Gaussianity for the tails of the distribution arise from near-field effects. Comparison is made with the statistical properties of abiotic sedimenting suspensions. The experimental results are supplemented by numerical simulation.

Vasily Kantsler
Cambridge University
Department of Applied Mathematics and Theoretical Physics
vk272@damtp.cam.ac.uk

### MS94
### Constructive and Destructive Correlation Dynamics in Simple Stochastic Swimmer Models

A key observation derived from mean field theories for micro-swimmers is the stability of the uniform isotropic state for pullers vs. its instability for pushers. In simulations of suspensions of swimmers, orientational correlations are apparent for pushers over much larger spatial scales than is observed for pullers. In this talk I will examine the mechanisms that lead to large scale correlations for "pusher-like" swimmers versus much smaller correlations for "puller-like" in very simple stochastic swimmer models.

Kajetan Sikorski, Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
sikork@rpi.edu, kramep@rpi.edu

Patrick Underhill
Rensselaer Polytechnic Institute
Department of Chemical and Biological Engineering
underhill@rpi.edu

### MS95
### Synchronization of Small Networks of Electrochemical Oscillators

Experiments are carried out with small networks of phase coherent chaotic oscillators obtained with a chemical system of nickel electrodissolution in sulfuric acid. Three and four oscillator setups are investigated in local and star coupling topologies. It is shown that (i) before transition to synchronization the precision of the period strongly deteriorates and (ii) bivariant and partial phase synchronization indices are useful tools to delineate network structure from dynamical measurements.

Istvan Kiss
Department of Chemistry
Saint Louis University
izkiss@slu.edu

Mahesh Wickramasinghe
Saint Louis University
mwickram@slu.edu

### MS95
### Reactions of the Cell Cycle Network to Multiple Stresses

All life forms have to survive long enough to reproduce and pass on their genes. This makes adaptations to the environment and the cell cycle pivotal for all life. I will discuss a mathematical model which couples multiple stress response networks to the cell cycle. The model helps to understand why stress responses are not additive; it is predictive of the stage of cell cycle arrest, and allows studying the robustness of the stress adaptation.

Elahe Radmaneshfar
Institute for Complex Systems and Mathematical Biology
University of Aberdeen, UK
e.radmaneshfar@abdn.ac.uk

Celso Grebogi
King's College
University of Aberdeen
grebogi@abdn.ac.uk

M. Carmen Romano
Physics Department and Institute of Medical Sciences
University of Aberdeen

m.romano@abdn.ac.uk

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

**MS95**

**Inferring Properties of Networks from Spike Trains**

Spike trains have been shown to contain significant dynamical information, and in some cases are sufficient to reconstruct attractors and estimate invariants. In this talk we discuss recent progress in inference of network properties from multivariate spike sequences, including network connectivity, state and basin determination, and data assimilation from spike times.

Tim Sauer
Department of Mathematics
George Mason University
tsauer@gmu.edu

**MS95**

**Frequency Domain Based Estimations of Interactions Between Nonlinear Oscillators**

Nonlinear systems are often characterized by oscillatory behavior with a well-defined frequency. Various analysis techniques based on observations from these oscillators have been suggested. In several cases, however, the oscillators exhibit multiple time scales or are characterized by strong noise influence. Here, we discuss a framework for the analysis of such oscillators. Particular focus will be laid on the estimation of the strength of coupling between oscillators. Multivariate extensions will be presented.

Bjoern Schelter
Center for Data Analysis and Modeling
University of Freiburg, Germany
schelter@fdm.uni-freiburg.de

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

M. Carmen Romano
Physics Department and Institute of Medical Sciences
University of Aberdeen
m.romano@abdn.ac.uk

Linda Sommerlade
University of Freiburg
sommerlade@fdm.uni-freiburg.de

Jens Timmer
University of Freiburg
Department of Physics
jeti@fdm.uni-freiburg.de

**MS96**

**Discontinuous Maps and Their Applications**

Discontinous maps arise naturally in studies of non-smooth dynamical systems, either as descriptions of problems in their own right (such as in models of active impacts) or as natural simplifications of other maps, such as those encountered in grazing bifurcations. In this talk we will show how much of the global bifurcation thoery associated with grazing problems can be described more easily using discontinous maps. We will also show that the behaviour of systems with active impacts is extremely rich and that the robust chaos associated with grazing bifurcations of continuous maps has a much finer structure when a small discontinuity is introduced. Applications to impacting and switching systems will be considered.

Chris Budd
Dept. of Mathematical Sciences
University of Bath, UK
mascjb@bath.ac.uk

Karin Mora
University of Bath, UK
k.mora@bath.ac.uk

**MS96**

**Piecewise Smooth Systems, Set Valued Fields, and Nondeterministic Chaos**

Piecewise smooth systems model countless phenomena that involve rapidly changing dynamic laws. Their solutions are defined as solutions of a differential inclusion, and as such can be non-unique. This well known detail is usually ignored in applications, on the basis that forward-time non-uniqueness only affects sets that are not reachable from generic initial conditions. A more careful look at systems in three or more dimensions disproves this belief, revealing an entrance door into non-unique dynamics: these doors are called two-fold singularities. We will discuss new results on the properties and applications of these singularities, which are associated with interesting and novel bifurcations, and with intricate dynamics that include what we are calling, in lack of a better word, nondeterministic chaos.

Alessandro Colombo
Massachusetts Institute of Technology
acolombo@mit.edu

**MS96**

**Stasis Sets and Approximating Cycles**

For a collection of $C^1$ vector fields on $R^n$, points where a linear combination of the fields sum to zero are called stasis points. Generically, neighborhoods of such points contain cycles that switch between the vector fields, with a certain amount of freedom in choosing timing and order of switches. We will discuss these results together with the structure and bifurcations of the stasis set and approximating families of cycles.

Stewart D. Johnson
Dept of Mathematics and Statistics
Williams College
sjohnson@williams.edu

**MS96**

**TBA - Nordmark**

Abstract not available at time of publication.

Arne Nordmark
Department of Mechanics
Royal Institute of Technology
nordmark@mech.kth.se

**MS97**

**Parameterization of Invariant Manifolds for Lagrangian Systems with Long-range Interactions**

We generalize some notions that have played an important role in dynamics (namely invariant manifolds) to the more general context of difference equations. In particular, we study Lagrangian systems in discrete time. We define invariant manifolds, even if the corresponding difference equations can not be transformed in a dynamical system. The results apply to several examples in the Physics literature: the Frenkel-Kontorova model with long-range interactions and the Heisenberg model of spin chains with a perturbation. We use a modification of the parametrization method to show the existence of Lagrangian stable manifolds. This method also leads to efficient algorithms that we present with their implementations.

Hector E. Lomeli
Instituto Tecnológico Autónomo De México (ITAM)
lomeli@itam.mx

Rafael de La Llave
University of Texas
Department of Mathematics
llave@math.utexas.edu

**MS97**

**On the Lengths of Periodic Billiard Trajectories Inside Axisymmetric Analytic Convex Tables**

We present a numerical study of the asymptotic behavior of the lengths of periodic billiard trajectories inside some axisymmetric analytic strictly convex tables. We mainly consider tables of the form $x^2 + y^2 + cy^n = 1$, for some integer exponent $n \geq 3$ and some real coefficient $c$. We conjecture, based on the experiments, that inside any axisymmetric analytic strictly convex table there exist two axisymmetric $q$-periodic billiard trajectories whose lengths are exponentially close in the period as $q \to +\infty$. Concretely, in all the computed cases the difference in lengths is of order $\mathrm{O}(q^{-m}e^{-rq})$, for some exponents $m \in \{2, 3\}$ and $r > 0$. Sometimes, it is possible to compute accurate divergent asymptotic expansions for these differences. We have also considered tables of the form $x^2 + y^4 = 1$, which are convex but not strictly convex. We show that these tables show different asymptotic behaviors. The numerical experiments get complicated due to problems of stability, precision and time, which require the use of a multiple precision arithmetic.

Rafael Ramírez-Ros
Departament de Matematica Aplicada 1
Universitat Politecnica de Catalunya
rafael.ramirez@upc.edu

**MS97**

**Higher-order Adaptive Methods For Computing Invariant Manifolds of Maps**

We present efficient and accurate numerical methods for computing invariant manifolds of maps which arise in the study of dynamical systems. In order to decrease the number of points needed to compute a given curve/surface, we propose using higher-order interpolation/approximation techniques from geometric modeling. We use Bézier curves/triangles, one of the fundamental objects in curve/surface design, to create an adaptive method. The methods are based on tolerance conditions derived from properties of Bézier curves/triangles. We develop and test the methods for ordinary parametric curves; then we adapt these methods to invariant manifolds of planar maps. Next, we develop and test the methods for parametric surfaces and then we adapt this method to invariant manifolds of 3D maps.

Jacek K. Wrobel
New Jersey Institute of Technology
Department of Mathematical Sciences
jacek.wrobel@njit.edu

Roy Goodman
New Jersey Institute of Technology
roy.goodman@njit.edu

**MS98**

**When are pairwise maximum entropy methods good enough?**

Recent experimental studies find that the activity patterns of many neural circuits are well described by pairwise maximum entropy (PME) models — which require only the activity of single neurons and neuron pairs — even in cases where circuit architecture and input signals seem likely to create a richer set of outputs. Why is this the case? We study spike patterns in feedforward circuits with different architectures and inputs. Responses to unimodal inputs, regardless of connectivity, were well described by PME models; bimodal input signals drove significant departures. Circuits constrained by experimental data on retinal ganglion cells were well described by PME models across a broad range of light stimuli, a fact explained by experimentally quantified temporal filtering in synaptic inputs. Preliminary results indicate that our results are highly dependent on the feedforward structure of these circuits; adding recurrent connections can enhance higher order correlations 20-fold.

Andrea K. Barreiro
Department of Applied Mathematics
University of Washington
akb6@washington.edu

Julijana Gjorgjieva
Department of Applied Mathematics and Theoretical Physics
University of Cambridge
jg447@cam.ac.uk

Fred Rieke
University of Washington
Physiology and Biophysics
rieke@washington.edu

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

**MS98**

**A Kinetic Theory Model of Second Order Feedforward Neuronal Networks**

We aim to develop a kinetic theory model to capture the effect of network structure on behavior characterized by the population firing rates and pairwise correlations in simple feedforward excitatory neuronal networks. We use a

recently proposed second order model to describe the feedforward networks, where network structure is characterized by covariance among connections. We demonstrate that our developed kinetic theory model can capture the effect of network structure under the assumption of independence between in-degree and out-degree. The effect of in-out degree correlation, however, can not be captured by current kinetic theory model. This presents a challenge for future development of the kinetic theory model of second order feedforward neuronal networks.

Chin-Yueh Liu
Department of Applied Mathematics
National University of Kaohsiung, Taiwan
cyliu1025@nuk.edu.tw

Duane Nykamp
School of Mathematics
University of Minnesota
nykamp@math.umn.edu

### MS98

### Dynamical regimes of integrate-and-fire neuronal network models

The dynamical regimes of a stochastically-driven, current-based Integrate-and-Fire neuronal network are investigated. A mean-field equation provide exact solutions for the steady asynchronous state. The probability the network maintains a synchronous firing state is characterized by the competition between the desynchronizing, noisy input, which drives each individual neuronal voltage and the synchronizing instantaneous pulse-coupling between the neurons in the network. For a prototypical scale-free network, a detailed analytical calculation of clustering improves the usual tree-based second order theory.

Katherine Newhall
Rensselaer Polytechnic Institute
newhak@rpi.edu

### MS99

### Stochastic Resonance and Noise-enhanced Phenomena in the Human Brain

Stochastic resonance, a nonlinear phenomenon in which the response of a system to a weak input signal is optimized by noise, has been studied in many fields. We provide the first evidence that SR can enhance perceptual responses to weak visual inputs in humans. We additionally demonstrate that the brain can be regarded as a coupled-oscillator system and noise enhances synchronization of neural oscillators boosting information integration across widespread brain areas in the human brain.

Keiichi Kitajo
Brain Science Institute, RIKEN
kkitajo@brain.riken.jp

### MS99

### Encoding of Slow Signals in High-pass Phasic Neurons with Background Fluctuations

Cortical processing occurs in the presence of many fluctuating excitatory and inhibitory inputs. We explore the effects of these fluctuations on the encoding capabilities of phasic neurons that are known to respond well to high frequency inputs and poorly to slow ones in vitro. Efficient coding depends on robust responses to diverse stimulus profiles, yet the mechanism for encoding slow frequency signals is unclear. We show that this can be achieved with background fluctuations in a modified Fitzhugh-Nagumo model. A reduced model is developed to demonstrate that noise-induced encoding of slow signals can be achieved with hyperpolarizing inputs that effectively lowers the threshold to response. The reduced model enables dissection of crucial mechanisms for fluctuation-induced encoding of slow time-varying signals.

Cheng Ly
University of Pittsburgh
Department of Mathematics
chengly@math.pitt.edu

### MS99

### Fluctuation of Brain Dynamics Related to Perception

When repeatedly looking at an image, we may perceive it differently each time. This variation in perception is caused by the fluctuation of neural activity. By using non-invasive neural activity recording technology, we have discovered several links connecting neuronal activity and perception [Shimono et al., 2007, 2010]. In this presentation, I will introduce several experimental results related to important concepts in dynamical theory, such as noise, external control, and information flow.

Masanori Shimono
Physics Department, Indiana University
mshimono@indiana.edu

### MS99

### Long-tailed EPSP Distribution Reveals Origin and Computational Role of Cortical Noisy Activity

Cortical neurons exhibit irregular and asynchronous firing spontaneously at low firing rates even without sensory stimuli.However, the mechanism to retain the stable noisy firing remains elusive for networks of spiking neurons. Using a simple integrate-and-fire model, we will show that neural networks can stably generate low-rate asynchronous firing when the excitatory synaptic strength are distributed according to a long-tailed distribution, typically the lognormal distribution. We show that weak synapses retain the average membrane potential the UP-state. Only when membrane potential is in the UP state, a few very strong synapses precisely transmit information about both rate and timing of the spike trains. Thus, our model also accounts for precisely-timed spike sequences reported in experiments. We will provide possible information processing of cortical neurons inferred from the precise information transmission based on the network structure.

Jun-nosuke Teramae
RIKEN
teramae@brain.riken.jp

### MS100

### Synthesizing and Simplifying Biological Networks from Pathway Level Information

Cellular networks involve a complex "wireless" interaction propagating siganls between individual components such as DNAs, RNAs and smaller molecules. Recent (and sometimes not-so-recent) surge of interest in investigation of these networks have resulted in fascinating interdisciplinary collaborations between several disciplines such as biology, control theory, mathematics and computer science. In this talk, I will summarize the research works that my collaborators and myself have been doing in the last few years in this area. We will discuss about synthesizing and simplifying networks from double-causal experimental data, reverse engineering such networks via modular-response-analysis approach or from time-series data and modular decomposition of such networks into simpler networks. We will present the relevant biological background, explain the dynamic processes (models) that may arise, discuss combinatorial and graph-theoretic algorithmic questions that arise out of designing experimental protocols or optimizing such networks and present computational results. Minimal prior knowledge in control theory or combinatorial algorithms will be assumed. The results discussed are prior or ongoing joint research works with one or more of the following collaborators (listed in alphabetical order): Reka Albert, Piotr Berman, German Enciso, Sema Kachalo, Paola Vera-Licona, Eduardo Sontag, Kelly Westbrooks, Alexander Zelikovsky and Ranran Zhang.

Bhaskar DasGupta
Department of Computer Science
University of Illinois at Chicago
dasgupta@cs.uic.edu

**MS100**
**Decomposition of Biological Networks**

The key to uncovering functional and dynamical properties of biochemical networks lies in their structural properties. Our aim is to present a methodology that helps to extract information on dynamical properties of a complex biochemical network that originates from the structure of the network itself.

Alice Hubenko
UCSB
Department of Mechanical Engineering
hubenko@engineering.ucsb.edu

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

**MS100**
**Protein Kinase Target Discovery from Genome-wide mRNA Expression Profiling**

By integrating ChIP-seq experiments, protein-protein interactions (PPIs), and kinase-substrate reactions, we can identify kinases and transcription factors for functional validation based on genome-wide gene expression data. The idea is to infer the most likely transcription factors that regulate the changes in gene-expression; then use PPIs to connect the identified factors to build transcriptional complexes; then use kinase-substrate reactions to rank kinases that most likely regulate the formation of the identified complexes.

Avi Ma'ayan
Department of Pharmacology & Systems Therapeutics
Mount Sinai School of Medicine
avi.maayan@mssm.edu

**MS100**
**Coarse-Graining Dynamics of (and On) Networks**

In dynamical systems that involve networks, coarse-graining approaches are essential in helping us understand the interplay between the structure and the dynamics of networks. In this work, we propose and implement two different coarse-graining approaches for reducing dynamical network problems. To illustrate these approaches, we consider two dynamical network examples involving distinct types of network dynamics: "dynamics of a network" and "dynamics on a static network".

Yannis Kevrekidis
Dept. of Chemical Engineering
Princeton University
yannis@princeton.edu

Karthikeyan Rajendran, Andreas Tsoumanis
Princeton University
krajendr@princeton.edu, atsouman@princeton.edu

Constantinos Siettos
National Technical University, Athens, Greece
ksiet@mail.ntua.gr

**MS101**
**Phase Space Method for Target Identification**

Chaotic signals are very sensitive to the effects of filtering. In radar or sonar, scattering from a target is a linear process that may be described as a filter. The interaction of a chaotic signal with a target produces a characteristic distribution of neighbors in phase space which may be used to identify the target. The particular distribution of points depends on the rate of compression for the chaotic signal and on the target characteristics.

Thomas L. Carroll
Naval Reseach Laboratory
carroll@anvil.nrl.navy.mil

**MS101**
**Matched Filter for Chaos Radar**

We describe a new approach to random-signal radar based on the recent discovery of analytically solvable chaotic oscillators. These surprising nonlinear systems generate random, aperiodic waveforms that offer an exact analytic representation and allow implementation of simple matched filters for coherent reception. Notably, this approach enables nearly optimal detection of noise-like waveforms without need for expensive variable delay lines to store wideband waveforms for correlation. Mathematically, the waveform is expressed as a linear convolution of a bit sequence with a fixed basis function. We realize a simple matched filter for the waveform using a linear filter whose impulse response is the time reverse of the basis function. Importantly, linear filters matched to multiple-bit sequences can be defined, enabling pulse compression and spread spectrum radar. We present an example oscillator, its matched filter, and corresponding simulation results demonstrating the pulse compression radar concept. Preliminary experimental results using electronic circuits are also reported.

Ned J. Corron
U.S. Army RDECOM
ned.corron@us.army.mil

Jonathan N. Blakely
US Army RDECOM
Jonathan.Blakely@us.army.mil

Mark Stahl
U.S. Army RDECOM
mark.stahl1@us.army.mil

**MS101**

**Acoustic Experiments with Multiple Chaotic Signal Sources**

The use of multiple chaotic sources for radar creates a unique spatial pattern that may be used to identify an objects location without scanning a beam over different angles. We report numerical and acoustic experiments using 2 chaotic sources.

Frederic Rachford
Naval Reserach Laboratory
Material Science
rachford@anvil.nrl.navy.mil

**MS101**

**De-Synchronized Chaos Angle Selective Radiation Systems**

Temporal characteristics of electromagnetic systems are not usually angle specific in radar/communication applications; one exception is impulse radiation. Shown here is a lesser known method in obtaining angle based selectivity using two or more "de-synchronized" chaos (DSC) oscillators. DSC oscillators are 'epsilon equivalent' with a shared periodic drive from which a temporal angle selective radiation pattern occurs. We discuss general applications of this angle selective chaos noise and then specifically a stationary SAR application.

Jay Wilson
Comtech AeroAstro, Inc
Littleton, CO
jay.wilson@aeroastro.com

Bryan James
Comtech AeroAstro, Inc
bryan.james@aeroastro.com

**MS102**

**Spike-time Dependent Coding and Noisy Kuramoto Networks**

Neurons are sensitive to their input firing rate through long-term potentiation or depression (spike-timing-dependent plasticity, STDP). Does STDP underlie the emergence/annihilation of synchronization? Using the Kuramoto-network, STDP is introduced by letting the coupling depend on the degree of synchrony: if synchrony increases, then the coupling drops and vice versa. This yields oscillations of synchrony presuming STDP can be eliminated adiabatically. Despite its simplicity the model provides a proper understanding of alternating neural synchronization.

Andreas Daffertshofer
Research Institute MOVE
VU University Amsterdam
a.daffertshofer@fbw.vu.nl

**MS102**

**Revisiting Stochastic Differential Equation Models for Ion Channel Noise in Hodgkin-Huxley Neurons**

Channel noise in neurons can be modeled using continuous-time Markov chains nonlinearly coupled to a differential equation for voltage, but there is interest in approximating these models with stochastic differential equations (SDEs). We analyzed three SDE models that have been proposed as approximations to the Markov chain model and found that a channel-based approach can capture the distribution of channel noise and its effect on spiking in a Hodgkin-Huxley neuron model, but subunit-based approaches cannot.

Joshua Goldwyn, Nikita Imennov, Michael Famulare
University of Washington
jgoldwyn@uw.edu, imennov@uw.edu,
famulare@u.washington.edu

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

**MS102**

**Network Effects of Noisy Synaptic Release**

Synapses in the central nervous system can be extremely stochastic, with successful release rates per depolarization as low as 20%. This introduces noise into single neuron response and neural networks, noise which is non-trivially correlated with network activity. In this talk, we model the release process and investigate how fluctuations can lead to interesting dynamical consequences. Results include changes in neuronal gain of neurons, in firing variability and in altered response to oscillatory input.

Herbert Levine
Univ. of Cal. at San Diego
Department of Physics
hlevine@ucsd.edu

**MS102**

**Stochastic Synchrony in Networks With and Without Feedback, Elucidation of the Rate of Convergence to Steady State in Type I and Type II Oscillators**

Recently it was proposed that synchrony in the activity of mitral cells in the olfactory bulb could be mediated by a stochastic synchronization mechanism. Synchrony in the olfactory bulb has been shown to develop slowly ($\approx$ 150ms) unlike a PING-like mechanism. Here we investigate the rate of convergence of stochastic synchrony onto the steady-state probability density and compare theoretical predictions with numerically calculated eigenvalues for a network of mitral and granule cells.

Sashi Marella
University of Pittsburgh
Center for Neuroscience
skm21@pitt.edu

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

**MS103**
**Geometry and Topology of Computer Dynamics**

The realization that computers are nonlinear dynamical systems leads to a need for dynamical tools that can be applied to unconventional data. The computer systems we have studied appear to be of surprisingly low dimension. However, the data sets are quite noisy and—due to the time scales involved in computing—sparsely sampled, albeit essentially unlimited in length. We investigate dynamical analysis methods that extract state-space geometry and topology from computer performance data.

Zachary Alexander
University of Colorado
Department of Applied Mathematics
alexanz@colorado.edu

Amer Diwan
University of Colorado, Boulder
diwan@cs.colorado.edu

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

Elizabeth Bradley
University of Colorado
Department of Computer Science
lizb@cs.colorado.edu

**MS103**
**The Dynamics of Granular Materials**

We will present a novel approach to study force chain structures of dense particulate systems. Our approach deploys algebraic topology techniques which allow us to distinguish between the systems exposed to shear and compression. We use our method to compare experimental and theoretical results in a well defined manner. The topological measures can be also used to understand the dynamic features of the system and correlate these measures to phenomena such as jamming.

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

Lou Kondic
Department of Mathematical Sciences, NJIT
University Heights, Newark, NJ 07102
kondic@njit.edu

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

**MS103**
**Experimental Determination of the Homology of Invariant Manifolds**

A useful, and under-exploited, source of information on experimental dynamical systems is their transient behaviour. Transient trajectories explore the phase space near attractors and can, for example, provide information about non-attracting invariant sets such as repellers or saddles. Here we analyse time series data from a system near to a period-doubling bifurcation and extract homological invariants from a certain non-attracting invariant manifold associated with the limit cycle.

Mark Muldoon, Jeremy Huke, David Broomhead
School of Mathematics
University of Manchester
m.muldoon@manchester.ac.uk,
j.p.huke@manchester.ac.uk,
d.s.broomhead@manchester.ac.uk

**MS103**
**The Dynamics of Computer Behavior**

I present a nonlinear-dynamics based framework for modelling, analyzing, and understanding the complex nonlinear dynamics of modern computer systems. These dynamics—which are surprisingly low dimensional and often chaotic—depend on both hardware and software. This has important implications in the computer systems community, which relies on mathematics that assumes linearity and ignores dynamics. I will demonstrate how the failure of these assumptions affects the design tools used by hardware and software architects.

Todd D. Mytkowicz
RiSE
Microsoft Research
toddm@microsoft.com

**MS104**
**Spatially Localized Turbulence Structures in Transitional Rectangular-duct Flow**

We perform simulations of transitional rectangular-duct flow to investigate spatially localized turbulence structures. These structures depend on the aspect ratio A. At marginal Reynolds numbers a puff is observed around A=1. As A increases the puff extends in the spanwise direction to occupy the whole duct. Beyond A=4 a turbulent spot appears. An oblique band, also observed in plane channels, arises at higher Reynolds numbers in spite of the presence of side walls for A¿4.

Genta Kawahara
Department of Mechanical Science
Osaka University
kawahara@me.es.osaka-u.ac.jp

Hiroki Wakabayashi
Osaka University
hiroki.wakabayashi@mbox.me.es.osaka-u.ac.jp

Markus Uhlmann
Karlsruhe Institute of Technology
uhlmann@kit.edu

Alfredo Pinelli
CIEMAT
a.pinelli@ciemat.es

**MS104**
**From Swift-Hohenberg to Navier-Stokes: Homoclinic Snaking in Plane Couette Flow**

For shear flows exact coherent solutions of the Navier-

Stokes equations play key roles in the transition to turbulence and the turbulent dynamics itself. Here we examine a new class of spatially localized solutions to plane Couette flow. These solutions exhibit a sequence of saddle-node bifurcations similar to the "homoclinic snaking' phenomenon observed in the Swift-Hohenberg equation. The localized solutions exist over a wide range of Reynolds numbers and bifurcate off the known spatially periodic states.

Tobias Schneider
Harvard University
tobias.schneider@gmail.com

John Gibson
University of New Hampshire
john.gibson@unh.edu

John Burke
Boston University
jb@bu.edu

**MS104**

**On the Edge of Turbulent Pipe Flow**

The theoretical modelling of turbulence has advanced rapidly since the discovery of (spatially periodic) travelling-wave solutions. Relaxing periodicity in the streamwise direction, no localised 'exact' solutions are yet known. We show that states on the laminar-turbulent boundary are localised, even at flow rates many times that of transitional flow. We discuss the search for localised solutions in pipe flow, and examine the path of trajectories to and from the boundary-attractor.

Ashley Willis
University of Sheffield
a.p.willis@sheffield.ac.uk

Yohann Duguet
LIMSI-CNRS, Orsay, France
duguet@limsi.fr

Rich Kerswell
Department of Mathematics
University of Bristol, U.K.
r.r.kerswell@bris.ac.uk

Chris Pringle
School of Maths and Stats
University of Reading
c.c.t.pringle@reading.ac.uk

**MS104**

**A Homoclinic Tangle on the Edge of Couette Turbulence**

The "edge state" hypothesis asserts that simple solutions like periodic orbits mediate between laminar and turbulent shear flow. The stable manifold of an edge state separates these phases. The global structure of the separatrix, however, is unknown. We show the existence of a homoclinic to a time-periodic edge state in Couette turbulence, implying a complex geometry of the separating manifold. We find important differences between the flow along the homoclinic and the conventional regeneration cycle.

Lennaert van Veen
UOIT
lennaert.vanveen@uoit.ca

Genta Kawahara
Department of Mechanical Science
Osaka University
kawahara@me.es.osaka-u.ac.jp

**MS105**

**Reduced Nonlinear Models of Internal Waves**

Abstract not available at time of publication.

Roberto Camassa
University of North Carolina
camassa@amath.unc.edu

**MS105**

**Internal Waves in the Ocean - Observations, Theory and DNS**

Spectral energy density of internal waves in the ocean exhibit a surprising degree of universality - it is given by the Garrett and Munk Spectrum of internal waves, discovered over 30 years ago. I will explain that situation is much more interesting, and will describe recent theoretical advances in understanding internal waves. I will demonstrate that when using traditional wave turbulence theory one runs to internal logical contradictions: the results of the theory (strong nonlinearity) contradict the underlying assumptions (weak nonlinearity) used to build the theory. I will demonstrate possible directions out of the puzzle and will elaborate on open questions and challenges.

Yuri V. Lvov
Rensselaer Polytechnic Institute
lvovy@rpi.edu

**MS105**

**Generation of Shear Flows by Three-wave Interactions in Stratified Flows**

Stratified flow is investigated under the influence of large-scale, unbalanced forcing. In addition to the Boussinesq system, we study a model including only three-wave interactions. We demonstrate that three-wave interactions are responsible for the generation of vertically sheared horizontal flows (VSHF), and that the VSHF flow component is the most sensitive to resolution. Triple-wave interactions play a significant role in the distribution of wave energy, which does not exhibit asymptotic scaling for moderate Froude numbers.

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

**MS106**

**Effects of Coupling on Sensory Hair Bundles**

Auditory signal detection relies on amplification to boost sound-induced vibrations within the inner ear. Active motility of sensory hair-cell bundles has been suggested to constitute a decisive component of this amplifier. The responsiveness of a single hair bundle to periodic stimulation, however, is limited by intrinsic fluctuations. We present theoretical and experimental results showing that elastic coupling of sensory hair bundles can enhance their sensitivity and frequency selectivity by an effective noise reduction.

Kai Dierkes
Max Planck Institut für Physik komplexer Systeme
kai@mpipks-dresden.mpg.de

Jérémie Barral
Institut Curie, Paris
jeremie.barral@curie.fr

Benjamin Lindner
Max Planck Institute for the Physics of Complex Systems, Dresden
benji@mpipks-dresden.mpg.de

Pascal Martin
Institut Curie, Paris
pascal.martin@curie.fr

Frank Jülicher
Max-Planck-Institut für Physik komplexer Systeme
julicher@mpipks-dresden.mpg.de

**MS106**

**The Effect of Tectorial Membrane and Basilar Membrane Longitudinal Coupling in Cochlear Mechanics**

In the classical theory of cochlear mechanics, structural longitudinal coupling is neglected. Motivated by recent experimental observations, we introduce basilar membrane and tectorial membrane longitudinal coupling in a mechanical-electrical-acoustical model of the cochlea that includes a micromechanical model for the organ of Corti and feedback from outer hair cell somatic motility. Structural longitudinal coupling broadens the frequency response of the basilar membrane, shortens its impulse response and stabilizes the active model of the cochlea.

Julien Meaud, Karl Grosh
University of Michigan
jmeaud@umich.edu, grosh@umich.edu

**MS106**

**A Cochlear Model Using the Time-averaged Lagrangian and the Push-pull Mechanism in the Organ of Corti**

Direct computation of for a cochlear model with viscous fluid remains a challenge. However, the 'WKB' asymptotic method works well. Particularly, the time-averaged Lagrangean of Whitham provides the slowly varying amplitude function. This is extended for including viscous fluid. The geometry of the organ of Corti motivates the active push-pull approximation for the cells which provide an active system of distributed sensors and actuators. Current application is on mutant mice.

Charles Steele
Stanford University
Dept. Mechanical Engineering
chasst@stanford.edu

Sunil Puria
Stanford Unversity
Depts Mechanical Engineering, Otolaryngologi
puria@stanford.edu

John Oghalai
Department of Otolaryngology
Stanford University
joghalai@ohns.stanford.edu

**MS106**

**Dynamic Properties of Human Cochlear Processing Investigated with Otoacoustic Emissions**

Click-evoked otoacoustic emissions (CEOAEs) are echoes to clicks that can be recorded in the ear canal. They are produced in the inner ear (i.e., cochlea) as a by-product of the nonlinear gain mechanism responsible for compression in hearing. The relation between dynamic features of CEOAEs and time-dependent properties of the underlying cochlear gain mechanism was investigated with the purpose of understanding how the intact hearing system processes onsets of sounds (0-10 ms).

Sarah Verhulst, James Harte, Torsten Dau
Technical University of Denmark
sv@elektro.dtu.dk, jha@elektro.dtu.dk, tda@elektro.dtu.dk

**MS107**

**Computing the Boundary of Analyticity of Families of Quasi-periodic Solutions**

We formulate and justify rigorously a numerically efficient criterion for the computation of the analyticity breakdown of quasi-periodic solutions in Symplectic maps and 1-D Statistical Mechanics models. Depending on the physical interpretation of the model, the analyticity breakdown may correspond to the onset of mobility of dislocations, or of spin waves (in the 1-D models) and to the onset of global transport in symplectic twist maps. The criterion we propose here is based on the blow-up of Sobolev norms of the hull functions. The justification of the criterion suggests fast numerical algorithms that we have implemented in several examples.

Renato Calleja
Department of Mathematics and Statistics
McGill University
calleja@math.mcgill.ca

Rafael de La Llave
University of Texas
Department of Mathematics
llave@math.utexas.edu

**MS107**

**Arnold Diffusion Along a Chain of Oscillators**

A chain of pendula connected by nearest neighbor coupling is a near–integrable system if the coupling is weak. As a consequence of KAM, for most initial data the energy of each pendulum stays near its initial value for all time. We show that these KAM motions coexist with "diffusing" motions for which the energy can leak from any pendulum to any other pendulum, and it can do so with a prescribed itinerary. This is joint work with Vadim Kaloshin.

Mark Levi
Department of Mathematics
Pennsylvania State University
levi@math.psu.edu

**MS107**

**Aubry-Mather Theory and Ghost Circles**

I will explain the construction of ghost circles for monotone recurrence relations on more-dimensional lattices, for example the Frenkel-Kontorova crystal model. Ghost circles are gradient-flow invariant interpolations of an Aubry-Mather set of a particular rotation vector. In the case that the set of global minimizers in the ghost circle has a gap, there are non-globally minimizing stationary solutions of the gradient flow in the gaps.

Blaz Mramor
VU University Amsterdam
bmramor@few.vu.nl

Bob Rink
Department of Mathematics
Free University of Amsterdam
brink@few.vu.nl

**MS107**

**Weak KAM Theory and Viscosity Solutions of Hamilton-Jacobi Equations**

In this talk, I will give an introduction of the connection between Aubry-Mather theory and several nonlinear PDEs, such as a Hamilton-Jacobi equation arising from Homogenization theory and Aronsson equations from L-infinity variational problems. If time permits, I will also talk about recent joint work with Gomes, Iturriaga and Sanchez-Morgado, in which we identified the Mather measure selected by a variational scheme proposed by Evans.

Yifeng Yu
University of California
Irvine
yyu1@math.uci.edu

**MS108**

**Predicting Infectious Disease Extinction**

Eradication of infectious diseases is an important goal for public health. In general, disease extinction occurs for finite populations in finite time due to stochastic interactions among individuals. The theory of large fluctuations predicts extinction to occur along a most probable trajectory, or optimal path. The time to extinction is proportional to the probability of crossing the path. I will discuss the optimal path to extinction for some single and multistrain disease models.

Simone Bianco
UC, San Francisco
simone.bianco@ucsf.edu

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

Leah Shaw
The College of William & Mary
lbshaw@wm.edu

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

**MS108**

**Stochastic Dynamics of Tumorigenesis**

I will discuss a continuous-time birth-death process model of tumorigenesis where mutations confer random additive fitness (birth rate) changes. We investigate the overall growth rate and diversity of the tumor in the asymptotic limit, and the dependence of these features on parameters of the fitness landscape. Using experimental data, we analyze this model at the time of patient diagnosis (i.e. total population reached size M) to study the generation of resistant populations in expanding populations of leukemic stem cells.

Jasmine Foo
Harvard University
jfoo@jimmy.harvard.edu

Rick Durrett
Duke University
rtd@math.duke.edu

Kevin Leder
Harvard University
leder@jimmy.harvard.edu

John Mayberry
University of the Pacific
jmayberry@pacific.edu

Franziska Michor
Harvard University
michor@jimmy.harvard.edu

**MS108**

**The Effects of Stochasticity in the Dynamics of Multi-Strain Diseases**

We study the dynamics of multi-strain diseases, such as dengue and SARS, that display complex spatio-temporal behavior resulting from the coupling introduced by the host immune response. This complex temporal evolution frequently results in recurrent excursions into regimes where stochastic effects dominate. In this work we study the effects of stochasticity on the dynamics of multi-strain diseases with latent period and cross-immunity, focusing in particular on events that lead to disease extinction.

Luis Mier-y-Teran, Derek Cummings
Johns Hopkins Bloomberg School of Public Health
luis@nlschaos.nrl.navy.mil, derek.cummings@jhu.edu

**MS108**

**Stochastic Extinction in Non-Gaussian Environments with Differential Delay**

Extinction processes are stochastic events that occur in applications of finite populations, such as epidemics and chemical reactions. Nonlinear interactions typically lead to non-Gaussian noise sources. We consider the problem of stochastic extinction as a rare event occurring in systems with delayed feedback and driven by non-Gaussian noise. Using Melnikov perturbation theory, we show how delay modulates non-power law behavior of mean times to

extinction in systems driven by non-Gaussian noise.

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

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.edu

Thomas W. Carr
Southern Methodist University
Department of Mathematics
tcarr@smu.edu

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

**MS109**

**Reachability Analysis of Idea Propagation on Networks with Community Structure**

This presentation formulates prediction questions in terms of reachability assessments computing the likelihood that the dynamics of interest will enter user-specified regions of the systems state space and applies the methodology to idea propagation on realistic social networks. Reachability is assessed by defining and solving appropriate semidefinite programs using sums-of-squares decomposition. The methodology is applied to the propagation of Feynman diagrams across physics communities and the geographic spread of the Swedish Social Democratic Party.

Michael Bencomo
New Mexico Tech
mbencomo@icasa.nmt.edu

**MS109**

**Predictability of Social Network Dynamics: An Appraisal**

Enormous resources are devoted to the task of predicting the outcomes of social network dynamics in a wide range of domains, but the quality of such predictions is often poor. Recently, important advances in network theory and dramatic increases in availability of social dynamics data are being combined to enable significant progress in exploring and exploiting the predictability of social processes. This presentation reviews this progress and introduces the remaining three talks of the minisymposium.

Richard Colbaugh
New Mexico Tech
EMRTC
colbaugh@nmt.edu

Kristin Glass
New Mexico Tech
kglass@icasa.nmt.edu

**MS109**

**Sentiment-Over-Time Analysis of Tweets**

Microblogging, Twitter in particular, has become a prevalent medium for people to express their beliefs and feelings. As it has increased in popularity, researchers are focusing on its content. This paper will look at the results of using a semi-supervised sentiment classifier to measure how popular sentiment changes over time for various topics. Topics are both specifically chosen as well as discovered using unsupervised topic classifiers.

Alexander D. George
New Mexico Tech
ageorge@icasa.nmt.edu

**MS109**

**Ex-ante Prediction of Cascade Sizes on Networks of Agents Facing Binary Outcomes**

A wide range of social, economic and popular cultural processes can be characterized as involving binary choice with externalities (Schelling 1973). Agents have a choice between two alternatives, and the payoff of an individual is an explicit function of the actions of others. We present results on ex ante predictability of cascade size on random, small world and scale free networks with minimal information on the connectivity and persuadability of a small number of agents.

Paul Ormerod
Volterra Consulting, LLC
pormerod@volterra.co.uk

Ellie Cooper
Volterra Consulting
ecooper@volterra.co.uk

**MS110**

**Spontaneous Formation and Evolution of the Channel Network Inside Physarum Polycephalum Sheet-like Structures: Direct Experimental Observations**

In the network evolution of Physarum polycephalum, an important question concerns the initial stages of vein formation, which occur mainly at the advancing front. We focus on this question, with the aim to provide experimental data allowing elaboration and tests of models of channel formation. Using infrared microscopy, and fluctuation anlysis, we show in particular that the structural development of channels occurs very early during the process. Velocimetry profiles of the fluids will be also presented.

Serge Bielawski
PhLAM/Université Lille I,
France
serge.bielawski@univ-lille1.fr

Paul Dely
Lab PhLAM/Universite Lille 1
pauldely@phlam.univ-lille1.fr

Christophe Szwaj
Universite de Lille (France)
Laboratoire PHLAM
christophe.szwaj@univ-lille1.fr

Eric Lacot
Lab. Spectro
UJF-Grenoble (France)
eric.lacot@ujf-grenoble.fr

Olivier Hugon
SPECTRO
Universite J. Fourier, Grenoble (France)
ohugon@ujf-grenoble.fr

Toshiyuki Nakagaki
The School of Systems Information Science
nakagaki@fun.ac.jp

**MS110**

**Channeling Instabilities in the Cytoplasm of Amoeboid Cells**

Physarum polycephalum exhibits periodic shuttle streaming through a network of tubular structures reaching velocities up to 1 mm/s. When the organism is small (< 100 microns) there is no streaming. As it gets larger, flow channels develop and streaming begins. We use a multiphase flow model and discuss instabilities that produce flow channels within the gel. We present a simple model of the flow-sensitive rheology of cytoplasm and discuss its significance for biological function.

Robert D. Guy
Mathematics Department
University of California Davis
guy@math.ucdavis.edu

Toshiyuki Nakagaki
The School of Systems Information Science
nakagaki@fun.ac.jp

Grady B. Wright
Department of Mathematics
Boise State University, Boise ID
gradywright@boisestate.edu

**MS110**

**Transport and Mixing of Cytosol Through the Whole Body of Physarum Plasmodium**

We study the net transport and mixing of chemicals in the true slime mold *Physarum polycephalum*. The shuttle streaming of the amoeba is characterized by a rhythmic flow in which the protoplasm streams back and forth. We formulate a simplified model to consider the mechanism by which net transport can be induced by shuttle (or periodic) motion inside the amoeba. We discuss the effects of the sectional boundary motion on the net transport.

Makoto Iima
Research Institute for Electronic Science
Hokkaido University
makoto@nsc.es.hokudai.ac.jp

Toshiyuki Nakagaki
The School of Systems Information Science
nakagaki@fun.ac.jp

**MS110**

**Mechanics of Amoeboid Locomotion Driven by Contraction Waves and Friction Control**

Crawling by amoeboid movement is a fundamental form of biological locomotion. In this report, we considered rheological mechanics for the crawling driven by propagation of contraction wave along slender body. We proposed a theoretically tractable model. A message from the modeling is that not only speed and but also direction of locomotion depended on the timing of active anchoring on the ground. A mechanism in the amoeboid crawling is shown.

Toshiyuki Nakagaki
The School of Systems Information Science
nakagaki@fun.ac.jp

Yoshimi Tanaka
The School of Systems Information Science
Future University Hakodate
ytanaka@fun.ac.jp

**MS111**

**Extreme Events: The Larger, the Better Predictable**

We investigate the predictability of extreme events in time series. Common examples for extreme events are natural hazards such as earthquakes, strong precipitation or strong turbulent wind gusts. We focus on the question, under which circumstances large events are better predictable than smaller events. Therefore we use a simple prediction algorithm, and study its performance for the prediction of increments and threshold crossings in stochastic processes, wind speed recordings and time series generated from ensemble weather forecasts. Although our approach is simple, it allows us to understand effects which are observed for the prediction of strong wind gusts, long jumps in molecular diffusion and solar electric particle events.

Sarah Hallerberg
TU Chemnitz
Chemnitz, Germany
sarah.hallerberg@physik.tu-chemnitz.de

**MS111**

**A Mathematical Framework for Critical Transitions**

Critical transitions, or tipping points, have been encountered in a wide variety of applications including climate modeling, ecology and medicine. A critical transition is a rapid qualitative change away from a stable regime. The major goal is to predict these transitions from time series data. We formalize critical transitions mathematically using stochastic multi-scale dynamical systems. Furthermore we present analytical and numerical results on the prediction of critical transitions for normal form models.

Christian Kuehn
Center for Applied Mathematics
Cornell University
ck274@cornell.edu

**MS111**

**Potential Analysis of Geophysical Time Series**

We apply the method of potential analysis comprising derivation of the number of climate states and system potential coefficients. Patterns of potential analysis indicate possible bifurcations and transitions. The method is tested on artificial data and applied to climatic records [Livina et al, Clim Past 2010]. An application of the method in a model of globally coupled bistable systems [Vaz Martins et al, PRE 2010] confirms its applicability for studying time series in statistical physics.

Valerie Livina

University of East Anglia
Norwich, UK
v.livina@uea.ac.uk

**MS111**

**Transition to Instability in Financial Markets with Many Heterogeneous Agents**

We model a financial market as a place where infinitely many agents trade a risky asset. Each agent forms expectations about the future development of the asset's price by picking one of a number of available forecasting rules. All agents use the same evaluation criterion, but they suffer from an idiosyncratic bias; consequently, the agents are distributed over the forecasting rules. Based on their forecasts, agents submit a demand schedule, from which the market price of the risky asset is determined. As the new price is revealed, the evaluation criteria and the agents choices of forecasting rules are updated. The price dynamics is thus described by a low order dynamical system. Typically, if either the idiosyncratic bias or the risk aversion of the agents decrease, the fundamental equilibrium of the system destabilises: this has negative implications for the total welfare of the market participants. Recently it has been shown that, contrarily to the common opinion of economists and policy makers, the same occurs if derivative securities are added to the market, and that in this case the negative welfare effects can be disastrous.

Florian Wagener
University of Amsterdam (CeNDEF)
Amsterdam, Netherlands
wagener@uva.nl

**MS112**

**The Lagrangian Description of Aperiodic Flows: New Concepts and Tools**

New Lagrangian tools are introduced which are successful in achieving a detailed description of purely advective transport events in general aperiodic geophysical flows. First is discussed the concept of Distinguished Trajectory which generalizes the concept of fixed point for aperiodic dynamical systems. It is built on a function that detects simultaneously, invariant manifolds, hyperbolic and nonhyperbolic flow regions, thus insinuating the active transport routes in the flow. Once these are recognized, the transport description is completed by means of the direct computation of the stable and unstable manifolds of the DHTs.

Ana M. Mancho
Instituto de Ciencias Matematicas
Consejo Superior Investigaciones Cientificas
A.M.Mancho@icmat.es

**MS112**

**Transport in Time-Dependent Flows – An Overview**

Transport theory seeks to quantify flux between regions in phase space. Traditional methods are based on constructing partial barriers containing lobes; these are naturally formed formed from heteroclinic intersections between invariant manifolds. Aperiodically time-dependent dynamical systems may have no hyperbolic invariant sets, and so new ideas must be developed. We will give a short review of methods based on short time information using Lyapunov exponents, distinguished trajectories, approximate invariant sets, and transitory dynamics.

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

**MS112**

**Set-oriented Numerical Analysis of Time-dependent Transport**

The numerical analysis of transport processes is central for understanding the macroscopic behavior of classical dynamical systems as well as time-dependent systems such as fluid flows. We review different theoretical concepts and their numerical implementation into a set-oriented framework. We demonstrate that the geometric approach based on invariant manifolds and Lagrangian coherent structures and the probabilistic concept which relies on transfer operators give consistent results. Finally, potential combinations of these techniques are discussed.

Kathrin Padberg-Gehle
Institute of Scientific Computing
TU Dresden
kathrin.padberg@tu-dresden.de

Gary Froyland
University of New South Wales
g.froyland@unsw.edu.au

**MS112**

**Lagrangian Transport Phenomena in 3D Laminar Mixing Flows**

Mixing in 3D laminar flows is key to many industrial systems. Examples range from the traditional viscous mixing via compact processing equipment down to emerging micro-fluidics applications. Central question is "How to achieve efficient mixing?" Mixing by fluid motion only defines an important subclass and is determined geometrically through coherent structures formed by the Lagrangian fluid trajectories. Such formation and its impact upon 3D transport is demonstrated by way of two experimentally-realisable flows.

Michel Speetjens
Laboratory for Energy Technology, Dept. Mech. Eng.
Eindhoven University of Technology
m.f.m.speetjens@tue.nl

**MS113**

**Aggregation and Fragmentation of Inertial Particles in Random Flows**

We present a coupled model for advection, aggregation and fragmentation that is based on the dynamics of individual, inertial particles in three-dimensional random flows applied to marine aggregates. We show that fragmentation is the most important process determining largely the obtained steady-state size distribution. We discuss how the size distribution depends on the collision efficiency, the binding strength of the aggregates as well as the turbulence level. Furthermore we extend this approach to fractal aggregates.

Ulrike Feudel
University of Oldenburg
ulrike.feudel@uni-oldenburg.de

**MS113**

**Droplet Distributions in Binary Mixtures**

We present experimental data for the evolution of the droplet size distribution in a binary mixture where demixing is induced by a continuous temperature ramp. Our system serves as an example of demixing of multiphase fluids as encountered in many industrial and natural processes like alloys, magmas and clouds. The precise control of the experiment provides us with hitherto not accessible information on the mechanisms of droplet creation, growth and interaction as well as their effects on the evolution of the droplet size distribution.

Tobias Lapp
MPI Dynamics and Self-Organization
tobias.lapp@ds.mpg.de

Martin Rohloff
MPI Dynamics and Self-Organization Goettingen
martin.rohloff@ds.mpg.de

Juergen Vollmer
MPI Dynamics and Self Organization
juergen.vollmer@ds.mpg.de

Bjoern Hof
MPI Dynamics and Self-Organization Goettingen
bjoern.hof@ds.mpg.de

**MS113**

**Chaotic Motion of Inertial Particles in Finite Domains**

The motion of inertial particles is investigated in a time-periodic flow in the presence of gravity. The flow is restricted to a finite (or semi-infinite) vertical column, and the dynamics is therefore transiently chaotic. The long term motion of the center of mass is a uniform settling. The settling velocity is found to differ from the one that would characterize a still fluid, and the distribution of an ensemble of settling particles spreads with a well-defined diffusion coefficient. The underlying chaotic saddle appears to have a height-dependent fractal dimension. The coarse-grained density of both the natural measure and the conditionally invariant measure (defined along the unstable manifold) of the saddle is smooth, and exhibits a local maximum as a function of the height. The latter density corresponds to the eigenfunction of the first eigenvalue of an effective Fokker–Planck equation subject to an absorbing boundary condition at the bottom. The transport coefficients can be determined as averages taken with respect to the conditionally invariant measure.

Tamas Tel
Institute for Theoretical Physics
Etovos University, Hungary
tel@general.elte.hu

**MS113**

**A Reactive-flow Model of Phase Separation in Fluid Binary Mixtures with Continuously Ramped Temperature**

We revisit the phase separation of binary mixtures subjected to a sustained change of temperature from the point of view of reactive flows. Exploiting this new perspective, we describe the demixing dynamics by a spatial model of advection-reaction-diffusion completed with nucleation and coagulation of droplets. In this approach several features of the dynamics — in particular an oscillatory variation of the droplet density — become numerically and analytically accessible. For instance, the model helps to clarify why the oscillation frequency is hardly affected by the flow. From a more general perspective it provides valuable insight in the droplet-growth dynamics of thunderstorm clouds.

Juergen Vollmer
MPI Dynamics and Self Organization
juergen.vollmer@ds.mpg.de

Izabella Benczik
MPI Dynamics and Self-Organization
Goettingen
izabella.benczik@ds.mpg.de

Jan-Hendrik Trösemeier
MPI Dynamics and Self-Organization Goettingen
troesemeier@ds.mpg.de

**MS114**

**Ultra-fast Physical Random Number Generation based on Chaotic Photonic Integrated Circuits**

Photonic integrated circuits that emit broadband chaotic optical signals are employed as sources for ultra-fast generation of true random bit sequences. Chaos dynamics in such photonic devices emerge from internally built optical cavities that suppress intrinsic periodicities, exhibit flattened broadband spectra and are completely controllable. After sampling, quantization and using most significant bits (MSB) elimination post-processing, truly random bit streams with bit-rates as high as 140 Gb/s are generated.

Apostolos Argyris, Dimitris Syvridis
Department of Informatics and Telecommunications
National & Kapodistrian University Of Athens
argiris@di.uoa.gr, dsyvridi@di.uoa.gr

**MS114**

**Synchronization of Random Bit Generators Based on Coupled Chaotic Lasers and Application to Cryptography**

Random bit generators (RBGs) constitute an essential tool in cryptography. The secure synchronization of two RBGs, however, over a public channel remains an open challenge. We propose a method, whereby two fast optical RBGs can be synchronized. Using information theoretic analysis we demonstrate security against a powerful computational eavesdropper, capable of noiseless amplification, even when all system parameters are publicly known. The method is extended to secure synchronization of a small network of RBGs.

Ido Kanter
Department of Physics,
Bar Ilan University, Israel
kanter@mail.biu.ac.il

Yitzhak Peleg
Bar Ilan niversity, Israel
izikpeleg@gmail.com

Meital Zigzag, Michael Rosenbluh
Bar Ilan Ubiversity, Israel
meital.zigzag@gmail.com, rosenblu@mail.biu.ac.il

Wolfgang Kinzel
University of Wuerzburg, Germany
kinzel@physik.uni-wuerzburg.de

**MS114**

**12.5 Gb/s Random Number Generation Using Amplified Spontaneous Emission**

We describe our recent experiments to generate and test random numbers at high rates by using high-speed detection of optical noise signals. Amplified spontaneous emission, either in a fiber amplifier or in a superluminescent light-emitting diode (SLED) is shown to be capable of generating a large, easily detected fluctuating electrical signal that can be exploited for random number generation. We report random bit generation at rates of up to 12.5 Gb/s, using only a single XOR postprocessing step to reduce correlations and bias.

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

Xiaowen Li
Beijing Normal University
xwli.juney@gmail.com

Caitlin R. S. Williams, Julia Salevan
University of Maryland
Dept. of Physics
willcrs@umd.edu, jsalevan@umd.edu

Rajarshi Roy
University of Maryland
rroy@umd.edu

**MS114**

**Physical Random Bit Generator with Chaotic Lasers**

Fast generation of non-deterministic random numbers is required to improve the security of information and communication systems. We review our recent progress on high-speed generation of good-quality random bit sequences using fast chaotic semiconductor lasers. We have stably generated random bit sequences in real time by directly sampling the output of two chaotic semiconductor lasers. We have experimentally demonstrated the possibility of faster random bit generation using multi-bit samples of bandwidth-enhanced chaos in coupled lasers.

Atsushi Uchida, Taiki Yamazaki, Yasuhiro Akizawa
Department of Information and Computer Sciences
Saitama University
auchida@mail.saitama-u.ac.jp,
s10mm332@mail.saitama-u.ac.jp,
s07ti002@mail.saitama-u.ac.jp

Takahisa Harayama, Satoshi Sunada, Kazuyuki Yoshimura, Peter Davis
NTT Communication Science Laboratories
NTT Corporation
harayama@cslab.kecl.ntt.co.jp,
sunada@cslab.kecl.ntt.co.jp, kazuyuki@cslab.kecl.ntt.co.jp,
davis@telecognix.com

**MS115**

**The Role of Transient Potassium Channels in Phase Resetting and Stochastic Synchrony in the Olfactory Bulb**

Blockade of the A-type K-channel with 4-AP in mouse olfactory mitral cells (MC) significantly reduces the peak of the empirically measured phase response curve, while MC stochastic synchrony is attenuated. These counterintuitive results indicate that removal of the inhibitory A-current renders MCs less capable of participating in correlation-driven population oscillations. A biophysically realistic cell model confirms the experimental findings and shows that a homoclinic bifurcation may underly the dynamical mechanism.

Aushra Abouzeid
Department of Mathematics
University of Pittsburgh
aua1+@pitt.edu

Anne-Marie M. Oswald
Department of Biological Sciences
Carnegie Mellon University
ammoswald@gmail.com

Roberto F. Galan
Case Western Reserve University
Department of Neurosciences
rfgalan@case.edu

Nathan Urban
Carnegie Mellon University
nurban@cmu.edu

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

**MS115**

**Effects of the Frequency Dependence of Phase Response Curves on Network Synchronization**

Spatiotemporal pattern formation in neuronal networks depends on the interplay between cellular and network synchronization properties. The PRC can serve as an indicator of cellular propensity for synchronization. We investigate the frequency modulation of PRCs and its effect on synchronization in large-scale excitatory networks. We find that frequency-induced PRC attenuation affects network synchronization in some cases and that these effects are robust to different network structures, synaptic strengths and modes of driving neuronal activity.

Christian G. Fink
Dept of Physics
University of Michigan
tcgfink@umich.edu

Victoria Booth
University of Michigan
Depts of Mathematics and Anesthesiology
vbooth@umich.edu

Michal Zochowski
Biophysics
University of Michigan
michalz@umich.edu

**MS115**

**Using PRC's to Understand How Antiepileptic Drugs and Deep Brain Stimulation Prevent Seizures**

Epilepsy is a multi-scale disease where causes and treatments occur at the scale of ion channels but the disease presents as seizures at a cortical scale. We use phase response curves (PRCs) measured from neurons to understand how antiepileptic drugs affect neuronal dynamics. We then use the PRCs to predict how those changes affect network synchrony to prevent seizures. Furthermore, we have used PRCs to understand how deep brain stimulation may prevent network synchrony.

Theoden I. Netoff
University of Minnesota
Department of Biomedical Engineering
tnetoff@umn.edu

Bryce Beverlin II, Brendan Murphy
University of Minnesota
beverlin@physics.umn.edu, murph677@umn.edu

Charles Wilson
University of Texas, San Antonio
charles.wilson@utsa.edu

**MS115**

**Isochrons and Phase Response in Multiple Time-Scale Systems**

Intrinsic phase response properties shape how neurons interact in networks. We recently demonstrated how multiple time-scale dynamics shape phase response curves for bursting neurons, which rhythmically alternate between spiking and quiescence. Key to the analysis is the computation of isochrons, manifolds of points about a limit cycle which have the same asymptotic phase. Here we consider the relation of isochron geometries and phase response properties for a range of spiking and bursting neuronal models.

Eric Sherwood
Boston University
wesher@bu.edu

**MS116**

**Spectral Stability of Shock Layers for Dissipative Hyperbolic-parabolic Systems**

This work focuses on the stability theory of nonlinear traveling waves, with an emphasis on front propagation arising in continuum models of compressible flow. We report on a recent collection results that use both analytical and numerical techniques as part of a general strategy for proving the stability of high Mach number viscous shock layers and detonation waves. Our technical approach centers around Evans function computation, energy estimates, and asymptotic ODE techniques.

Jeffrey Humpherys
Brigham Young University
jeffh@math.byu.edu

**MS116**

**Existence, Stability and Dynamics of Some Single- and Multi-Component Solitary Waves: From Theory to Experiments**

In this talk, we will present an overview of our recent theoretical, numerical and experimental work on a "quartet" of coherent structures arising in dispersive wave equations: dark solitons in single-component NLS equations, dark-bright symbiotic states in two-component NLS models, vortices in two-dimensional, single-component analogs of these models, and finally vortex-bright symbiotic states in two-component, two-dimensional models. We will focus on the bifurcations that lead to the emergence of such states, will discuss their spectral and dynamical stability and examine their relevance to experiments in atomic and optical physics.

Panayotis Kevrekidis
UMass, Amherst
kevrekid@gmail.com

**MS116**

**Localized Standing Waves in Inhomgeneous Schrodinger Equations**

In this talk I will discuss the stability of some solitons arising in models used to create a Bose-Einstein Condensate (BEC). BEC's were first theorized by Bose and Einstein as a state of matter occurring when a dilute bosonic gas is cooled very close to absolute zero. In such instances, quantum tangling occurs and macroscopic quantum effects can be observed. The talk will outline how the Maslov index and composite phase portrait techniques can be used to establish the instability of standing waves to NLS equations with an inhomogeneous nonlinear term. The geometric nature of the techniques used means that instability can be established by simple observations of the soliton's orbit in the phase plane. Then the talk will outline and establish the instability of a family of gap solitons to a related set of equations, again using Maslov index techniques.

Robert Marangell
UNC Chapel Hill
robertmarangell@googlemail.com

Christopher Jones
University of North Carolina and University of Warwick
ckrtj@email.unc.edu

Hadi Susanto
The University of Nottingham
United Kingdom
hadi.susanto@nottingham.ac.uk

**MS116**

**Bifurcations of Travelling Waves in the Oregonator Model for the BZ Reaction**

Travelling wave solutions of a reaction-diffusion system modelling the Belousov-Zhabotinsky reaction are studied. The model consists of two equations and contains four parameters, two of them, the stoichiometry factor $f$ and the excitability parameter $\varepsilon$ play important role in the existence of travelling waves. First we present numerical results concerning the existence of pulse type, so-called oxidation travelling waves. The main feature is the saddle-node bifurcation in the solutions, giving upper bounds on $f$ for the existence of travelling waves. The values of the upper bound $f_m$ of the stoichiometry factor $f$ are determined in terms of $\varepsilon$ for various values of the kinetic parameter $q$ and $D$, the ratio of the diffusion coefficients. Then other types of travelling waves, reduction waves and wave trains are studied numerically. Our aim is to divide the parameter space into regions according to the type and the number of travelling waves.

Peter L. Simon
Institute of Mathematics
Eötvös Loránd University
simonp@cs.elte.hu

### MS117
### Using the Structure of Inhibitory Networks to Unravel Mechanisms of Spatiotemporal Patterning

We established a relationship between an important structural property of an inhibitory network, its colorings, and the dynamics it constrains. Using a model of the insect antennal lobe we show that our description allows the explicit identification of the groups of inhibitory interneurons that switch, during odor stimulation, between activity and quiescence. This description optimally matches the perspective of the downstream neurons looking for synchrony in ensembles of presynaptic cells.

Collins Assisi
UC Riverside
collinsa@ucr.edu

Maxim Bazhenov
Department of Cell Biology and Neuroscience
University of California, Riverside
maksim.bazhenov@ucr.edu

### MS117
### Modeling and Experiment on the Control of Reafference During Locomotion

Resistance reflexes help stabilize posture against outside perturbation. Resistance reflexes triggered by voluntary movement can interfere with that movement. In vertebrates and some invertebrates, descending motor commands include excitation of inhibitory interneurons that prevent unwanted reafference through primary afferent depolarization. In crayfish, the coxo-basal chordotonal organ (CBCO) is a stretch receptor that spans the coxa-basipodite joint that enables the walking legs to move up and down. CBCO afferents mediate resistance reflexes to maintain leg position during standing, but during walking, those resistance are reversed to produce assistance reflexes. To determine reflex reversal occurs during normal walking, we have developed three approaches. We correlate limb movements of freely behaving crayfish during reflex responses and normal walking with EMG recordings of the leg depressors (Dep), and the anterior and posterior levator (Lev) muscles obtained from implanted electrodes. We record from CBCO afferents, central neurons, and Dep and Lev motorneurons (MNs) in an isolated nervous system that is connected to a computational neuromechanical model of the crayfish thorax and leg to form a real-time, closed-loop hybrid system. Dep and Lev MN activity excited model Dep and Lev muscles that move the model leg. The leg movement stretch and release the model CBCO; model CBCO length changes are transduced into identical movements of live CBCO generating afferent responses that excite the CNS. We use this system to determine the dynamic changes in reflex loop gains it switches from resistance to assistance reflexes during the onset of locomotor CPG activity. We have developed a computational neuromechanical model of a 4-legged crayfish, including all relevant neurons, muscles, and CBCOs, that we place in a virtual underwater world and use to test whether the proposed circuit mechanisms can account for the animal's locomotor and reflex behavior.

Donald Edwards
Neuroscience Institude
Georgia State University
biodhe@langate.gsu.edu

Giselle Linan-Velez
Biology Department
Georgia State University
glinanvelez1@student.gsu.edu

Eric Randall
Neuroscience Institute
Georgia State University
erandall1@student.gsu.edu

Daniel Cattaert
Institut de Neurosciences Cognitives et Intégratives d'Aqui
d.cattaert@cnic.u-bordeaux1.fr

### MS117
### Duty Cycle as Order Parameter for Polyrhythms in Multifunctional Center Pattern Generator Motifs

We examine exact and phase- phenomenological models for multifunctional Center Pattern Generators. A motif of three reciprocally inhibitory cells is shown to generate multiple bursting rhythms. CPG polyrhythms and the corresponding attractors are determined by the duty cycle of bursting. Through the examination of the mappings for phase lag between the cells we reveal the organizing centers of emergent polyrhythmic patterns and their bifurcations as the synaptic coupling asymmetry and the duty cycle are varied.

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

Jeremy Wojcik
Georgia State University
Dept. Mathematics and Statistics
jwojcik1@gsu.edu

Matt Brooks
Georgia State University
matt@splaticus.net

Robert Clewley
Department of Mathematics and Statistics
Georgia State University
rclewley@gsu.edu

### MS117
### Maintaining Novel Inputs in a Working Memory Model

We present a model that displays numerous properties associated with working memory: It exhibits persistent activity among a random subset of cells and, therefore, maintains completely novel input patterns. Persistent states are robust to distractors, the network switches activity if presented with a more salient input pattern and neurons have firing properties constrained by experimental data. Finally, we explore how changes in neuromodulators such as dopamine may lead to neurological disease.

David H. Terman
The Ohio State University
Department of Mathematics
terman@math.ohio-state.edu

Robert McDougal, Kyle Lyman, Brian Myers, Mustafa Zeki
Ohio State University
mcdougal@math.ohio-state.edu, kylelyman@gmail.com, bri1231@gmail.com, zeki@math.ohio-state.edu

Chris Fall
Department of Anatomy and Cell Biology
University of Illinois at Chicago
fall@uic.edu

### MS118

### Nonlinear Delayed Optical Phase Oscillator for High Performance Chaos Synchronization: Dynamics and Chaos Communication at 10Gb/s

A key issue in secure optical chaos communications is the synchronization quality of the receiver chaos, with the emitter chaos. Various nonlinear electro-optic delayed dynamics have been proposed for the implementation of optical chaos communications, with the particularly attractive features of a high quality chaos synchronization capability, and a huge operational bandwidth. These unique features allowed recently for the demonstration of state of the art results in terms of speed (> 10Gb/s) and distance (> 100km). The study and the development of the whole transmission system also led to the definition of a new class of delay dynamics, for which the nonlinear term involves two time delays, a long one, and a much shorter one which is introducing a so-called temporally nonlocal nonlinear delayed feedback. In this communication, we will report on both the dynamical features observed for this particular new class of delay dynamics, as well as on the chaos communication setup and its related successful field experiments.

Laurent Larger
Universite de Franche-Comte
FEMTO-ST institute / Optics Dept.
laurent.larger@univ-fcomte.fr

Lavrov Roman, Maxime Jacquot
FEMTO-ST institute, Optics Dpt.
r.lavrov@gmail.com, mjacquo6@univ-fcomte.fr

Vladimir Udaltsov
Vavilov Optical State Institute
udaltsov@gmail.com

### MS118

### Estimating Model Parameters from Time Series by Using Chaotic Synchronization and Speed-gradient Methodology

We present a new parameter estimation procedure for nonlinear systems. It works by imposing the synchronization between the system and the model which contains the parameters whose values one wish to estimate, and it is based on the speed-gradient (SG) methodology. It allows multiparameter identification using as an input signal a scalar time series obtained from the nonlinear system. This proposed procedure allows us to derive sufficient conditions for synchronization and hence for proper parameter estimation.

Elbert E. Macau
INPE - Brazilian National Institute for Space Research
LAC - Laboratory for Computing and Applied Mathematics
elbert@lac.inpe.br

Ubiratan S. Freitas
CORIA
Université de Rouen
usfreitas@gmail.com

### MS118

### Synchronization of Uncoupled Dynamical Systems Induced by White and Colored Noise

We study the synchronization of uncoupled dynamical systems due to a common noise source. In particular, we consider two identical FitzHugh-Nagumo systems, which display both spiking and non-spiking behaviours in chaotic or periodic regimes. Synchronization is tested with both white and coloured noise, showing that coloured noise is more effective in inducing synchronization of the systems. We also study the effects on the synchronization of parameter mismatches and of the presence of intrinsic noise.

Ines P. Mariño
Universidad Rey Juan Carlos
Móstoles, Spain
ines.perez@urjc.es

### MS118

### Competing Chaotic Synchrony: Theory and Experiment

This presentation will start with a quick introduction to the minisymposium's talks. Then the idea of competing synchrony will be presented in the context of three linearly coupled oscillators. The theory behind the mechanism of competing synchrony will be discussed and a few practical examples like lasers, electronic circuits, wildlife populations and neurons will be used for illustration.

Epaminondas Rosa
Illinois State University
Department of Physics
erosa@phy.ilstu.edu

### MS119

### Oscillatory Dynamics of a Structured Consumer Resource Model

Previous investigations of structured consumer resource models based on so-called renewal equations (de Roos, Diekmann and Metz, American Naturalist 1992) have been hampered by a lack of appropriate numerical methods. In particular, it has not been possible to track periodic orbits of the systems considered due to issues such as the presence of discontinuities. Here we present results from numerical bifurcation studies which use new methods able to deal with the delays and discontinuities present.

David A. Barton

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

**MS119**

**Invariant Tori in Scalar State-dependent DDEs**

We demonstrate complex dynamics including bi-stability of periodic orbits, invariant tori, double Hopf bifurcations and period doubling in a very simple model problem consisting of a single scalar delay equation with two linearly state-dependent delays. We will use the model to illustrate the possible dynamics of DDEs and the associated bifurcation structures, and to introduce some of the issues which will be addressed in the other presentations in this session.

Tony R. Humphries
McGill University
Mathematics & Statistics
Tony.Humphries@mcgill.ca

Renato Calleja
Department of Mathematics and Statistics
McGill University
calleja@math.mcgill.ca

**MS119**

**Floquet Multipliers for Periodic Solutions of Delay Equations with Several Delays**

Suppose that $h_i(x)$ is a step function satisfying $h_i(x) = h_i(\mathrm{sgn}(x))$ for all $x$. Consider the following scalar delay equation with discontinuous feedback:

$$(1) \quad y'(t) = \sum_{i=1}^{D} h_i(y(t-d_i)).$$

Given $\delta > 0$, consider also

$$(2) \quad x'(t) = \sum_{i=1}^{D} f_i(x(t-d_i)),$$

where the $f_i$ are smooth and satisfy $f_i(x) = h_i(x)$ for $|x| \geq \delta$. Periodic solutions $p$ of (1) are often easy to compute. If $p$ satisfies certain conditions, then for $\delta$ small enough (2) has a periodic solution $q$ that is "similar"' to $p$ and whose Floquet multipliers can be explicitly computed from knowledge of the semiflow of (1) near $p$. We discuss this computation, and what estimates we can retain on Floquet multipliers if (2) is appropriately perturbed.

Benjamin Kennedy
Gettysburg College
Department of Mathematics
bkennedy@gettysburg.edu

**MS119**

**Invariant Tori and Resonances for Time Periodic Delay Differential Equations**

We study the bifurcation of a class of time-periodic scalar delay differential equations. It is shown that at the critical values of the parameters a Neimark-Sacker bifurcation of the period map takes place and an invariant torus appears in an extended phase space. The local bifurcation analysis can be performed by using a spectral projection method, center manifold reduction and normal forms. The existence of the invariant torus further away from the critical value is a difficult problem. Somewhat surprisingly, strong resonances of 1:4, 1:3 and 1:1 types may also occur, which lead to intriguing behaviors of the system.

Gergely Röst
Bolyai Institute, University of Szeged
rost@math.u-szeged.hu

**MS120**

**Investigating Bacteria-immune Dynamics in Premature Infants**

Necrotizing enterocolitis (NEC) is a severe disease of the gastrointestinal tract in preterm infants, characterized by an impaired epithelium and exaggerated inflammatory response. Activation of epithelial Toll-like receptors initiates a widespread inflammatory response that eliminates bacteria but damages the epithelial barrier. A mathematical model of bacteria-immune interactions within the intestine is used to analyze conditions in which inhibiting receptor activation may reduce excessive inflammation and epithelial damage in NEC and thereby prevent bacterial tissue invasion.

Julia Arciero
Department of Mathematics
University of Pittsburgh
jarciero@pitt.edu

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

Yoram Vodovotz
University of Pittsburgh
Department of Surgery
vodovotzy@upmc.edu

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

**MS120**

**Non-Invasive Pathogen Profiling and New Prospects for In-Host Monitoring of Infection and Immune Response**

In the laboratory setting it is straightforward to measure the growth of micro-organisms in a wide variety of media, continuously or in batch. Very little appears to be known concerning the growth of organisms within a human host. We report data that show that an inexpensive, rapid and non-invasive method exists to measure the number of certain common pulmonary pathogens in ventilated patients over time. The same method also provides information concerning the state of the patients innate and adaptive immune response. Our goal, described in this talk, is how to combine these data with a mathematical model to study the process of pulmonary infection and ventilator associated pneumonia.

Erik M. Boczko
Department of Biomedical Informatics
Vanderbilt University Medical School
erik.m.boczko@vanderbilt.edu

Todd Young

Ohio University
Department of Mathematics
youngt@ohio.edu

Patrick Norris, Addison May
Vanderbilt University Medical Center
patrick.norris@vanderbilt.edu,
addison.k.may@vanderbilt.edu

### MS120
### Bacterial Infection: From theory to Experiments and Back

Models describing bacteria- neutrophil (bacteria-eating cells) interactions are constructed axiomatically and provide a clinically important qualitative prediction: under natural conditions the bacteria population is expected to exhibit bi-stability. Carefully designed experiments clearly demonstrate that bi-stability indeed emerges and allow parameterizing the proposed models. A parameterized model is then utilized as a building block in more detailed models that examine the in-vivo immune response under health and various immunodeficiency conditions.

Roy Malka, Vered Rom-Kedar
The Weizmann Institute
Applied Math & Computer Sci
roy.malka@weizmann.ac.il,
vered.rom-kedar@weizmann.ac.il

### MS120
### Delayed Immune Response to Plasmodium Infection

*Plasmodium* infections exhibit intrahost oscillations. We analyze a deterministic model for such behavior with the added feature that the immune effectors are stimulated by the pathogens at a delayed time. Delays or time lags can excite oscillations causing them to persist or become chaotic. We examine two kinds of delays, constant and state-dependent. We show how the latter can cause the branch of periodic solutions to be either sub or supercritical.

Jonathan Mitchell
Hardin-Simmons University
Department of Mathematics
Jonathan.L.Mitchell@hsutx.edu

Thomas W. Carr
Southern Methodist University
Department of Mathematics
tcarr@smu.edu

### MS121
### An Efficient Spatially-explicit Model of Cardiac Myofilament Dynamics

Contraction of cardiac muscle involves binding of both $Ca^{2+}$ and myosin crossbridges to sites on the actin filaments. Tropomyosin molecules in each thin filament span structurally link about twenty-six of these binding sites. We found that a Markov model of interacting sites reproduced the dynamics of muscle contraction, and could be reduced to an efficient set of coupled ordinary differential equations through the use of periodic boundary conditions and the elimination of degenerate Markov states.

Stuart G. Campbell
University of Kentucky
stuart.campbell@uky.edu

Andrew D. McCulloch
Department of Bioengineering
University of California San Diego
amcculloch@ucsd.edu

Kenneth Campbell
Department of Physiology and Center for Muscle Biology
University of Kentucky
kscamp3@email.uky.edu

### MS121
### Overview of Multi-scale Modeling of Cardiac Contraction

The hearts most important function is to serve as a mechanical pump that circulates blood throughout the body. This function is a result of complex interactions between three interdependent systems: voltage, calcium, and mechanics. In this talk we will give an introduction to how cardiac contraction can be modeled and show some of the complex dynamics arising from the cross-talk between the three systems as well as problems and unique challenges in this area.

Flavio H. Fenton
Cornell University
fhf3@cornell.edu

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

Rupinder Singh, Niels F. Otani
Department of Biomedical Sciences
Cornell University
rupndrsingh@gmail.com, nfo1@cornell.edu

### MS121
### Modeling Cardiac Electromechanics Using the Immersed Boundary Method

The immersed boundary (IB) method treats problems of fluid-structure interaction in which an elastic structure is immersed in a viscous incompressible fluid, using a Lagrangian description of the stucture and an Eulerian description of the fluid. The IB method was developed to model cardiac fluid dynamics, but we have extended the IB method also to model cardiac electrophysiology, thereby providing a unified approach to simulating cardiac electromechanics. This talk will describe both variants of the IB method and will present progress towards the development of IB models of cardiac electromechanics.

Boyce E. Griffith
Leon H. Charney Division of Cardiology
New York University School of Medicine
boyce.griffith@nyumc.org

### MS121
### Visualizing Patterns of Cardiac Action Potential Propagation Using Ultrasound Images of Contrac-

**tion**

We find that the spatial structure of mechanical deformations in the heart, as obtained from ultrasound images, may be used to reconstruct dynamical patterns of action potential propagation, even though, in general, applied stresses cannot be uniquely determined from the strain field they induce. The theory is extended to consider the role of the incompressibility assumption on this calculation and the possibility that myocardial fiber orientation may also be determined from the deformation data.

Niels F. Otani
Dept. of Biomedical Sciences
Cornell University
nfo1@cornell.edu

Rupinder Singh
Dept. of Biomedical Engineering
Cornell University
rs398@cornell.edu

**MS122**

**Identifying and Characterizing Change Points Using the Informational Approach**

Understanding past climate abrupt shifts is a crucial step towards learning how to predict them. Change point detection can be useful to detect abrupt shifts in the climate system. We present a general change point detection and model selection approach allowing to identify the timing of abrupt shifts and to discriminate between abrupt or gradual changes. The usefulness of this approach to detect major changes that occurred in the carbon cycle is demonstrated through applications.

Claudie Beaulieu
Princeton University
Princeton, USA
beaulieu@princeton.edu

**MS122**

**Atmospheric Regimes, Predictability and Climate Change**

An important topic in climate science are metastable regimes in the atmosphere. Such regimes have an important influence on predictability of surface weather and the frequency of occurrence of extremes. In my presentation I will introduce sophisticated methods for systematic regime identification. I will also discuss how regimes are related to low dimensional dynamical systems, their predictability properties and how recent climate change has influenced their frequency of occurrence.

Christian Franzke
British Antarctic Survey
chan1@bas.ac.uk

**MS122**

**Recurrent Episodes of Synchrony in a Spatial Neural Network Model**

Epileptic seizures are regarded as short recurrent episodes of overly synchronous firing of neurons. The nature of transitions into and out of seizures is not fully understood. We present a spatial network model of pulse-coupled oscillators which generates recurrent, self-terminated events of synchronous firing at random looking times even without noise or changing control parameters. We investigate dynamics and emergence of these events and discuss possible implications for seizure prediction research.

Alexander Rothkegel
University of Bonn
Bonn, Germany
rothkegel@uni-bonn.de

Klaus Lehnertz
University of Bonn, Germany
klaus.lehnertz@ukb.uni-bonn.de

**MS122**

**Dynamic Bifurcations with Loss of Local Stability in the Presence of Noise**

We discuss distributions of escape times for systems undergoing parameter sweeps near bifurcations in the presence of noise, focusing on delayed bifurcations. Noise causes a loss of information about initial conditions and a spreading of escape times. We show that, under a linear-in-time parameter sweep, the escape distributions are governed by a single parameter: the noise strength to sweep rate ratio. The results are shown to be important for bifurcation detection in micro/nano-scale resonators.

Steve Shaw, Nicholas Miller
Michigan State University
East Lansing, MI
shawsw@msu.edu, mille820@msu.edu

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

Chris Burgner
University of California, Santa Barbara
Santa Barbara, CA
christopher.burgner@gmail.com

Kimberly Turner
Dept Mech Env Eng
UC Santa Barbara
turner@engineering.ucsb.edu

**MS123**

**Multi-level Modeling of the Respiratory System**

The respiratory system of mammals exhibits a wide range of phenomena, many of which are still not fully understood. Not surprisingly, different aspects of the system have been modeled over the years at different degrees of complexity. The ongoing modeling work of the respiratory system will serve as a motivation and provide an introduction for this minisymposium. Some of the ideas will be illustrated on models of the lungs and models of the respiratory neural network.

Alona Ben-Tal
Massey University
Institute of Information & Mathematical Sciences
a.ben-tal@massey.ac.nz

**MS123**

**Opening and Closing the Loop in Small Networks: Simulation and Analysis of Multi-Level 'Hybrid'**

**Dynamics**

Experimental neuroscientists use 'hybrid' circuits of simulated models connected to real neurons to test modeling hypotheses. A primary application is to 'close the loop' and test that a model is capable of the dynamics expected of it when coupled with a physical counterpart in a realistic context. This approach is equally applicable to the fine-grained understanding of complex dynamical models, e.g. biophysical neural models of small networks. This presentation describes a simulation technology for building optimally parsimonious descriptions with low-dimensional dynamic components (ODEs and maps) coupled to form 'hybrid dynamical systems.' With these tools, dynamics of different parts of the network (partitioned in state space, physical space, and time) are represented at different levels of abstraction, according to theories about their function. These components can be mixed together so that hypotheses about lower-dimensional models can be tested computationally in the context of 'trusted' detailed models. The approach is demonstrated for uncovering detailed mechanistic insight about the role of the hyperpolarization-activated $I_h$ current in the phase-response characteristics of a detailed central pattern generator model. The half-center oscillator model exhibits bursting activity through multiple ionic currents. This analysis technology is advocated as a new way to look at reduced modeling in neuroscience, beyond *a priori* reductions such as mean field, phase averaging, or integrate-and-fire approximations.

Robert Clewley
Department of Mathematics and Statistics
Georgia State University
rclewley@gsu.edu

**MS123**

**Structure Preserving Reduction of Quasi-Active Neurons**

We construct, confirm and analyze dimension reduction techniques that replace the distributed RLC circuit of a branched quasi-active neuron with a significantly smaller RLC circuit that nonetheless retains the input-output behavior of the full circuit.

Steven Cox
Rice University
cox@rice.edu

**MS123**

**An Equation-Free Analysis of Evolution in Collective Migration**

Collective motion of organisms is widespread in nature, from cell aggregations to herds of wildebeests. Individual-based models can provide novel insights to study such questions, but it is difficult to obtain tractable analytical models that capture the essential biological dynamics. We develop an equation-free framework to analyze evolutionary dynamics of collective migratory strategies in an individual-based spatially-explicit model.

Yannis Kevrekidis
Dept. of Chemical Engineering
Princeton University
yannis@princeton.edu

Yu Zou
Department of Chemical Engineering and PACM
Princeton University
yzou@princeton.edu

Iain Couzin
Princeton University
icouzin@princeton.edu

Vishwesha Guttal
Princeton University
Princeton, USA
vguttal@princeton.edu

**MS124**

**Clustering of Particles in a Deterministic Intermittent Flow**

The clustering of particles in turbulent flows is widely discussed in the context of many industrial and scientific questions. In particular turbulent flows are interesting. Recent results exist for the analysis of a fully turbulent flow taken from numerical simulation, and as well for stochastic flow models. Here, we present results for an intermittent, deterministic model, trying to bridge between stochastic and turbulent deterministic flows.

Markus Abel
University of Potsdam
markus.abel@physik.uni-potsdam.de

**MS124**

**Caustics and Collisions in Turbulent Aerosols**

We discuss the statistics of relative velocities of colliding particles in turbulent flows. Using a simple one-dimensional model as an example We demonstrate that the distribution of collision velocities are substantially affected by singularities in the particle flow, so-called caustics. We compute moments of collision velocities and compare them to results of numerical simulations of inertial particles suspended in random mixing flows. The model describes the results of both one- and two-dimensional simulations well. Our conclusions are consistent with the hypothesis put forward in [Wilkinson, Mehlig, and Bezuglyy, Phys. Rev. Lett. 97 (2006) 058501], namely that the average collision velocity is a sum of two terms, a smooth and a singular contribution (due to caustics).

Bernhard Mehlig
Gothenburg Univ
Gothenburg, Sweden
Bernhard.Mehlig@physics.gu.se

Kristian Gustavsson
Gothenburg Univ Gothenburg, Sweden
Kristian.Gustafsson@physics.gu.se

**MS124**

**PDF Approach for Particles in Turbulent Boundary Layers**

The Full Lagrangian Method is used in a DNS of incompressible homogeneous isotropic turbulent flow to measure the statistical properties of the segregation of small inertial particles advected with Stokes drag. We extend the previous analyses by examining the distribution in time of the log of the compression of an elemental volume of particles and show that it becomes highly non Gaussian for moments of order higher than four. The occurrence of singularities reaches a maximum at a Stokes number $\sim 1$, following a Poisson process. We also measure the random uncorrelated motion and mesoscopic components of the compression and show that their ratio follows the same dependence on Stokes number as that for the particle turbulent kinetic energy, noting also that the non Gaussian highly intermittent part of the distribution of the compression is associated with the RUM component.

Mike Reeks
University of Newcastle
mike.reeks@newcastle.ac.uk

**MS124**

**Pattern Formation in Colloidal Explosions: Theory and Experiments**

We study the nonequilibrium patterns that emerge when magnetically repelling colloids, trapped by optical tweezers, are abruptly released, forming colloidal explosions [arxiv:1009.1930]. For multiple colloids in a single trap, we observe a pattern of expanding concentric rings. For colloids individually trapped in a line, we observe explosions with a zigzag pattern that persists even when repulsions are weak to break the equilibrium linear symmetry. Theory and simulations quantitatively describe these phenomena.

Artur Straube
Humboldt University of Berlin
arthur.straube@gmail.com

**MS125**

**On the Role of Delay for the Symmetry in the Dynamics of Networks**

The symmetry in a network of oscillators determines the spatio-temporal patterns of activity that can emerge. We study analytically how coupling delays affect the symmetry in the patterns of networks. We demonstrate that a coupling delay has some universal effects, as the advancement of the bifurcating point due to the coupling delay. Further effects, like the symmetrizing role of delays, depend on coupling topology or on the dynamics of the nodes.

Otti D'Huys
Department of Physics (DNTK)
Vrije Universiteit Brussel, Belgium
odhuys@vub.ac.be

**MS125**

**Stability and Resonance in Networks of Delay-Coupled Delay Oscillators**

We extend the approach of generalized modeling to investigate the stability of large networks of delay-coupled delay oscillators. When the local dynamical stability of the network is plotted as a function of the two delays a pattern of tongues is revealed. Exploiting a link between structure and dynamics, we show for ensembles of large networks that this pattern can be well approximated analytically.

Johannes M. Hoefener
Max-Planck-Institut fuer Physik komplexer Systeme, Dresden
hoefener@pks.mpg.de

**MS125**

**Chaos Synchronization of Networks with Time-delayed Couplings**

Networks of chaotic units with time-delayed couplings can synchronize to a common chaotic trajectory. Although the transmission time of the coupling may be very long, synchronization occurs without time shift. Global prop- erties of the network, particularly its loop structure, determine under which conditions complete or cluster synchronization can be achieved. The dynam- ics of a single unit and the eigenvalue gap of the coupling matrix determine the phase diagram of zero lag chaos synchronization.

Wolfgang Kinzel
University of Wuerzburg, Germany
kinzel@physik.uni-wuerzburg.de

**MS125**

**Synchronizing Coupled Optical Oscillators with Time Delay**

We examine the dynamics of networks of coupled nonlinear optical oscillators with time delays, to see if synchronization can be established. The dependence and maintenance of synchrony on relevant oscillator parameters and network connectivity is studied. We report the results of experiments and numerical simulations and discuss open questions and applications of such techniques to sensor networks and coherent laser arrays.

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

**MS126**

**Effects of Variability on Hybrid Circuits of Two Pulse Coupled Neurons**

We used PRCs to construct maps probing the robustness of phase locking with respect to temporal variability in the period and other forms of noise, and to heterogeneity between neurons with respect to intrinsic period as well as to other parameters that influence the shape and magnitude of the PRC. Several different types of hybrid networks of two single spiking or bursting neurons constructed using the Dynamic Clamp have been analyzed to date.

Carmen Canavier
Health Sciences Center
Louisiana State University
ccanav@lsuhsc.edu

**MS126**

**Cellular Mechanisms Underlying Spike-Time Reliability**

Analyzing data from simulations and experiments, we show that the variance of the relative phase, which can be calculated from the phase-response curves of neurons and neuronal pairs, is a good indicator of spike-time reliability and stochastic synchronization in real and simulated neurons. This allows us to investigate the contribution of a specific membrane conductance to spike-time reliability and stochastic synchronization.

Roberto F. Galan
Case Western Reserve University
Department of Neurosciences

rfgalan@case.edu

**MS126**

**A Stochastic Dynamics Approach to Understanding the Mean and Variance of Phase Response Curves**

For deterministic oscillators, there is a one-to-one mapping between time and phase. With noise, a perturbation delivered at a fixed time will encounter a system whose state variable is probabilistic. Here we take a stochastic dynamics approach to understanding the evolution of the density function for latent phase. We examine several approximations for the phase-dependent PRC variance, and also invert this approach to estimate phase-dependent noise magnitude from measured data.

Todd Troyer
Biology Department
University of Texas at San Antonio
todd.troyer@utsa.edu

**MS126**

**Using Dynamic Clamp as a Tool to Study Neuronal Synchronization**

The dynamic clamp technique, which allows researchers to introduce artificial voltage- or ligand-gated conductances into living neurons, is tailor-made for studies of synchronization. I will focus on recent, as-yet unpublished data, in which we have used dynamic clamp to study neuronal responses to in vivo-like synaptic barrages and coherent activity with high degrees of irregularity. I will also describe recent work on synchronization with conduction delays, done in collaboration with Carmen Canavier.

John White
department of Bioengineering
The University of Utha
john.white@utah.edu

**MS127**

**Surface Water Waves With Up an Downstream Boundary Conditions**

Standing surface waves in 2-D flow over a flat plate with up and down stream boundary conditions will be discussed. A simplified model yields analytic results compatible with experiment. Numerical results for the full problem will be presented, and open problems will be mentioned.

Carmen Chicone
Department of Mathematics
University of Missouri, Columbia
carmen@math.missouri.edu

**MS127**

**Dynamics of a Front Solution for a Bistable Reaction-diffusion Equation with a Degenerate Spatial Heterogeneity**

In this talk, we study a dynamics of a front solution with a transition layer of a bistable reaction diffusion equation with a spatial heterogeneity in one space dimension. In particular, we consider the case where this spatial heterogeneity degenerates on an interval. In this case the motion of the layer on the interval becomes so-called *very slow.* We will give the law of motion of the layer by constructing an attractive local invariant manifold.

Hiroshi Matsuzawa
Numazu National College of Technology Japan
Japan
hmatsu@numazu-ct.ac.jp

**MS127**

**Stability of Lax Shocks in Systems of Radiating Gas**

: We study nonlinear orbital asymptotic stability of small-amplitude shock profiles of general systems of coupled hyperboliceliptic equations of the type modeling a radiative gas. Such a model consists of systems of conservation laws coupled with an elliptic equation for the radiation flux, including in particular the standard EulerPoisson model for a radiating gas. The method is based on the derivation of pointwise Green function bounds and description of the linearized solution operator, with the main difficulty being the construction of the resolvent kernel in the case of an eigenvalue system of equations of degenerate type. This is a joint work with C. Lattanzio, C. Mascia, R. Plaza, and K. Zumbrun.

Toan Nguyen
Division of Applied Mathematics
Brown University
Toan_Nguyen@Brown.edu

**MS127**

**Dynamics near Turing patterns in Reaction-Diffusion Systems**

We present results on the dynamics near stationary spatially periodic (Turing) patterns in one-dimensional reaction-diffusion systems. We motivate robust spectral stability assumptions and derive linear stability in $L^p - L^q$ spaces. The linear analysis is based on Floquet-Bloch decompositions. We then show how techniques inspired by classical normal form transformations can help understand nonlinear dynamics near Turing patterns.

Qiliang Wu, Scheel Arnd
University of Minnesota
wuxxx410@umn.edu, scheel@math.umn.edu

**MS128**

**Halos and Sprites: A Sequence of Instabilities and Dynamic Attractors**

The formation of a halo and the subsequent ejection of a sprite is now reproduced in simulations [Luque, Ebert, Nature Geoscience 2009 and Geophys. Res. Lett. 2010]. We will explain the underlying sequence of instabilities and dynamic attractors: the formation of a sharpening screening-ionization wave in the halo, its destabilization into a sprite streamer, streamer propagation as a moving boundary problem with branching instability and the re-illumination of the current-carrying sprite channel.

Ute Ebert
CWI Amsterdam
Ute.Ebert@cwi.nl

**MS128**

**Quantitative Simulations of Sprite Streamer Dis-**

**charges**

Recent observational, theoretical and modeling work has established that filamentary streamer discharges are the key components of sprite phenomena. Streamer discharges are a type of ionization waves, which are largely driven by highly nonlinear processes in their wave fronts. In this talk, we discuss the current theory of sprite streamers and report recent streamer modeling results. We further show that our streamer model successfully explains many observed properties of sprite streamers.

Ningyu Liu
Physics and Space Sciences Department
Florida Institute of Technology
nliu@fit.edu

### MS128

### An Introduction to Sprites: Observations and Basic Phenomenology

This talk will provide a broad overview of various types of transient electrical discharges such as sprites, elves, and jets triggered in the upper atmosphere by underlying thunderstorm lightning. Examples of their sometimes spectacular manifestations will be presented. Their salient physical characteristics will be summarized, and their photochemical and plasma properties compared with other familiar discharge processes in the laboratory and in nature.

Davis Sentman
University of Alaska
dsentman@gi.alaska.edu

### MS128

### Stability of Simple Translating States in Laplacian Flows with Regularization

We present recent results on the linear and nonlinear stability of translating bubbles in Laplacian growth problems in streamer dynamics and viscous fingering, with different forms of regularization. We give rigorous lower bounds on the size of the basin of attraction for surface tension regularization. This is consistent with a shrinking basis of attraction with small surface tension. Asymptotic and numerical results suggest similar features for kinetic regularization, though there is also a collapsing scale near the back of the bubble.

Saleh A. Tanveer
Ohio State University
Department of Mathematics
tanveer@math.ohio-state.edu

### MS129

### Dynamics in Finite Time - Concepts and Applications

This talk will first provide an overview of finite-time dynamics, and of hyperbolicity in both the classical and the finite-time setting, and then present several pertinent results. Specifically, the existence, non-uniqueness and robustness of finite-time (un)stable manifolds will be discussed, as well as the problem of detecting hyperbolicity from data encoded in a dynamic partition of the extended phase space. Some of the fundamental challenges inherent to finite-time dynamics will become apparent.

Arno Berger
Mathematical & Statistical Sciences
University of Alberta
aberger@math.ualberta.ca

### MS129

### General Theory for Monotone and Concave Skew-product Semiflows

We analyze the dynamics of monotone and concave skew-product semiflows, paying attention to the long-term behavior of those semiorbits starting above a semicontinuous subequilibrium and to the minimal sets. Several possibilities arise depending on the existence or absence of minimal sets strongly above the subequilibrium and the coexistence or not of bounded and unbounded semiorbits. The results extend and unify previously known properties, showing scenarios which are impossible in the autonomous or periodic cases.

Carmen Nñez, Rafael Obaya, Ana Sanz
Universidad de Valladolid
carnun@wmatem.eis.uva.es, obaya@wmatem.eis.uva.es, anasan@wmatem.eis.uva.es

### MS129

### Equivalence, Spectra and Nonautonomous Bifurcations

The lack of equilibria or periodic solutions for general nonautonomous evolutionary equations requires new ideas to establish a corresponding bifurcation theory. In this setting, the Sacker-Sell spectrum is an appropriate tool to guarantee that entire solutions persist under a large class of perturbations. However, when it comes to bifurcations, a more detailed insight into the fine structure of the spectrum is required. On this basis, we investigate nonautonomous bifurcation scenarios and classify them using appropriate subsets of the Sacker-Sell spectrum. In particular, they include the surjectivity and Fredholm spectra.

Christian Poetzsche
Munich University of Technology
poetzsch@ma.tum.de

### MS129

### An Alternative Approach to Sacker-Sell Spectral Theory

In the classical Sacker-Sell spectral theory, growth rates of linear nonautonomous dynamical systems are characterized by means of exponential dichotomies. The Sacker-Sell spectrum is given by the union of finitely many closed intervals, each of which is associated to a spectral manifold. This yields a linear decomposition of the extended phase space. In this talk, we propose an alternative way to obtain the Sacker-Sell spectrum: In contrast to the classical approach, we start with a linear decomposition, which is given by the finest Morse decomposition in the projective space. Then the growth rates attained in the components of this Morse decomposition yield the Sacker-Sell spectrum.

Martin Rasmussen
Imperial College London
m.rasmussen@imperial.ac.uk

Fritz Colonius
University of Augsburg

fritz.colonius@math.uni-augsburg.de

Peter Kloeden
Johann Wolfgang Goethe University
Frankfurt am Main, Germany
kloeden@math.uni-frankfurt.de

### MS130
### Modeling the Dynamics of Social Competition

When groups compete for members, the resulting dynamics of human social activity may be understandable with simple mathematical models. I will present a new treatment of this problem with several applications, but with a special focus on the competition for adherents between religious and irreligious segments of modern secular societies. I'll apply perturbative techniques to analyze a theoretical framework for group competition dynamics on a network, and show that data suggest a particular case of the general framework, leading to clear predictions about possible future trends in society.

Daniel Abrams, Haley Yaple
Northwestern University
dmabrams@northwestern.edu,
haleyyaple@u.northwestern.edu

Richard Wiener
Research Corporation for Science Advancement
University of Arizona
rwiener@rescorp.org

### MS130
### Propagation of Epidemics on Dynamically-adapting Networks

During an epidemic, susceptible individuals attempt to avoid contact with infectees in order to reduce their susceptibility. I will introduce a simple network-based of model of this behavior, called 2FleeSIR. As a result of changes in the contact network, one finds categorical changes in the epidemic's propagation and arrives at surprising public policy questions.

Alexander Gutfraind
Theoretical Division
Los Alamos National Laboratory
gfriend@lanl.gov

### MS130
### Network Analysis and Dynamical Modeling of Cancer Cells

Certain types of cancer can be ascribed to the overexpression of a single gene inducing the transition from normal to the cancerous phenotype. In some type of multiple myeloma cancer this is the case for the gene WHSC1. Overexpression of WHSC1 affects overall gene expression along various gene regulatory pathways. We present a method how to detect and visualize these networks based on gene expression data and propose a framework for modeling the switching of cell phenotypes.

Michael Schnabel
Max-Planck Institute for Dynamics and Self-Organization
Gottingen, Germany
m-schnabel@northwestern.edu

Nir Yungster
Northwestern University
niryungster@gmail.com

Dirk Brockmann
Dept. of ESAM, Northwestern University
Evanston, IL, USA
brockmann@northwestern.edu

Adilson E. Motter
Northwestern University
motter@northwestern.edu

William Kath
Northwestern University
Engineering Sciences and Applied Mathematics
kath@northwestern.edu

### MS130
### Effect of Human Motion on Dynamic Contact Networks

We develop a human motility model that accounts for the disparate timescales of relocation (change of home) and travel (with return to home) and study the effect upon the dynamic contact network associated with the moving neighborhood around individual agents. We also consider the effect on behaviors that reflect dynamics on that contact network, with implications upon (for instance) spatial spread of disease or coordinated action of a distributed set of actors.

Joseph Skufca, Daniel Ben-Avraham
Clarkson University
jskufca@clarkson.edu, dbenavra@clarkson.edu

### MS131
### Modeling Signaling Pathways in Macrophages

Cell signaling pathways play a crucial role in proper cell development and behavior, with implications to survival, chemotaxis, proliferation, and even programmed cell death known as apoptosis. In this talk, a mathematical model of the G-protein signaling pathway in a particular cell line of macrophages is outlined, focusing on activation of a particular G-protein-coupled receptor, $P2Y_6$. The model is based on the kinetics of $P2Y_6$ surface receptors, inositol trisphosphate, cytosolic calcium, and differential dynamics of multiple species of diacylglycerol. Insight into the dynamics of the system is given through available experimental results and incorporated into the model. Mathematical analysis of the model, including establishment of global existence, uniqueness, positivity, and boundedness of solutions, and global stability of a unique steady-state solution is discussed.

Hannah Callendar
Institute for Mathematics and Its Applications
University of Minnesota
callende@ima.umn.edu

Mary Ann Horn
Vanderbilt University & National Science Foundation
mary.ann.horn@vanderbilt.edu

### MS131
### Models of the Innate Immune Response in Inflam-

**matory Diseases**

The innate immune system is vital to many species as either the predominate immune response or as a first line of defense complementing the adaptive immune response. We will examine nonlinear models of differential and partial differential equations examining interactions of various innate defenses including: macrophage recruitment and activation through cytokine signaling, antimicrobial peptides secretion, and the movement of the mucociliary tract leading to inflammation in the respiratory system.

Meagan C. Herald
Mathematics & Computer Science
Virginia Military Institute
heraldmc@vmi.edu

### MS131
### Tnf and Il-10 Are Major Factors in Modulation of the Phagocytic Cell Environment in Lung and Lymph Node in Tuberculosis: a Next Generation Two Compartmental Model

We build a two-compartmental ODE model of the immune response to provide a gateway to more spatial and mechanistic investigations of Mycobacterium tuberculosis infection in the LN and lung. Crucial immune factors emerge that affect macrophage populations and inflammation, such as TNF as a major mediator of recruitment of phagocytes to the lungs, and IL-10, in balancing the dominant macrophage phenotype in LN and lung. Surprisingly, bacterial load plays a less important role than TNF in inflammation.

Simeone Marino
University of Michigan Medical School
Microbiology and Immunology
simeonem@umich.edu

Denise E. Kirschner
Univ of Michigan Med School
Dept of Micro/Immuno
kirschne@umich.edu

Amy Myers, JoAnne Flynn
University of Pittsburgh School of Medicine
Department of Microbiology and Molecular Genetics
amymyers@pitt.edu, joanne@pitt.edu

### MS131
### Inflammation, Immunity, and Age: Insights from An In-Host Model of Influenza

Influenza A Virus triggers a complex in-host immune response including inflammatory, innate, and adaptive components. These responses change with age. We developed an autonomous, nonlinear ODE model of the host-virus dynamic dynamic in 20 dimensions and 90 parameters. Parameter estimation was employed to fit the model against data sets from two cohorts of BALB/c mice, one aged 2-4 months and the other 18-24, yielding marginal PDFs of parameters values. These are compared between cohorts, yielding well-defined hypotheses as to the mechanistic changes of the host-virus response with age.

Ian Price
University of Pittsburgh
imp5@pitt.edu

### MS132
### The Alternans Annihilation by Distributed Mechano-electric and Boundary Pacing Applied Perturbations

Alternans is a life-threatening physiological condition of the cardiac tissue in which there is alteration in electromechanical response between beats of a periodically simulated cardiac tissue. In this work we demonstrate the annihilation of cardiac alternans using mechanical perturbation. We explore from a control point of view a computational framework that employs electromechanical and mechano-electric feedback to couple a two variable Aliev - Panfilov (1996) model with the non-linear stress equilibrium equations.

stevan Dubljevic
University of Alberta
stevan.dubljevic@ualberta.ca

### MS132
### Model-based Control of Alternans in Purkinje Fibers

We describe a systematic approach to suppressing cardiac alternans in Purkinje fibers using localized current injections. We investigate the controllability and observability of the periodically paced Noble model for different locations of the recording and control electrodes along the fiber and determine how the optimal locations for the electrodes and the timing of the feedback current can be selected to extend the length of the fiber over which alternans can be suppressed.

Roman Grigoriev
Georgia Institute of Technology
Center for Nonlinear Science & School of Physics
roman.grigoriev@physics.gatech.edu

Alejandro Garzon
Georgia Institute of Technology
agarzon3@gatech.edu

### MS132
### Control of Cardiac Cellular Alternans Induces Subcellular Turing Pattern in Calcium Dynamics

Cardiac alternans is a dangerous rhythm disturbance of the heart, in which rapid stimulation elicits a beat-to-beat alternation in the action potential duration and calcium transient amplitude of individual myocytes. Recently, 'subcellular alternans,' in which the calcium transients of adjacent regions within individual myocytes alternate out-of-phase, has been observed. Using experiments and computational modeling, we show that subcellular alternans is a striking example of a biological Turing instability.

Stephen Gaeta, Trine Krogh-Madsen
Cornell University - Weill Medical College
stg2004@med.cornell.edu, trk2002@med.cornell.edu

David Christini
Cornell University - Weill Medical College
Division of Cardiology
dchristi@med.cornell.edu

### MS132
### Reconstruction of Unmeasured Quantities in Mod-

**els of Cardiac Action Potential Dynamics**

In this study, closed-loop observer techniques were investigated as a means of reconstructing unmeasured cardiac variables. Such methods may lead to improved anti-arrhythmic stimulus protocols. Luenberger feedback was shown to stabilize a multi-cell observer based on the two-variable Karma model of action potential (AP) dynamics. An observer applied to microelectrode data from an *in vitro* canine Purkinje fiber was able to estimate AP durations away from sensor locations. Extensions to ion-channel models will be discussed.

Laura Munoz
Department of Biomedical Sciences
Cornell University
lm288@cornell.edu

Niels F. Otani
Dept. of Biomedical Sciences
Cornell University
nfo1@cornell.edu

**MS133**

**Multi-Layered Networks and Emergency of Spatio-temporal Order in Ecological Systems**

Evolutionary-game based models, in which the success of one species depends on the behaviour of the others, have become paradigmatic to explain species coexistence in ecological systems. The generic properties of the competition can be characterized by the rock-paper-scissors game in combination with spatial dispersal of static populations. I will consider a complex network, defined on a lattice or population patch in which the interaction among the nodes changes the state of the nodes stochastically.

Celso Grebogi
King's College
University of Aberdeen
grebogi@abdn.ac.uk

**MS133**

**Dynamics of Large-Scale Epileptic Brain Networks**

Approaches from complex network theory promise to improve understanding of the epileptic process through the analysis of interactions in large-scale human brain networks. We present recent findings obtained from analyses of interaction networks derived from measurements of brain dynamics in epilepsy patients. We discuss pros and cons of previous analysis approaches and address possible methodological advancements that are necessary to further improve assessment of the dynamics of epileptic brain networks.

Klaus Lehnertz
Dept. of Epileptology, Medical Center
University of Bonn, Germany
Klaus.Lehnertz@meb.uni-bonn.de

Marie-Therese Kuhnert, Stephan Bialonski
University of Bonn, Germany
marie-therese.kuhnert@ukb.uni-bonn.de,
bialonski@gmx.net

**MS133**

**Direction of Information Flow in Networks**

The inference of causal interaction structures in multivariate systems enables a deeper understanding of the investigated network. We discuss two shortcomings, which are often faced in applications, i.e. nonstationarity of the processes generating the time series and contamination with observation noise. To overcome both, we present a new approach by combining partial directed coherence with state space models. The performance is illustrated by means of model systems and in an application to neurological data.

Linda Sommerlade
Freiburg Center for Data Analysis and Modeling
University of Freiburg
linda.sommerlade@fdm.uni-freiburg.de

Jens Timmer
University of Freiburg
Department of Physics
jeti@fdm.uni-freiburg.de

Björn Schelter
Freiburg Center for Data Analysis and Modeling
University of
schelter@fdm.uni-freiburg.de

**MS133**

**Modelling Brain States by Adaptive Multiple-Time-Scale Networks**

We will present a model of the transition between different activity states in networks, with an application to EEG data for different sleep-wake states. Our approach is based on interacting ARMA processes with dynamically changing parameters. The model can not only describe normal EEG activity but also models the transitions between wake, sleep and REM sleep phases. We study how on an longer time scale Alzheimer's Disease impacts the transitions between different sleep states.

Marco Thiel
Department of Physics - King's College
University of Aberdeen, UK
m.thiel@abdn.ac.uk

Bjoern Schelter
Center for Data Analysis and Modeling
University of Freiburg, Germany
schelter@fdm.uni-freiburg.de

**MS134**

**Perturbation Theory for the Approximation of Stability Spectra by QR Methods for Products of Linear Operators**

We develop a perturbation analysis for stability spectra (Lyapunov exponents and Sacker-Sell spectrum) for products of operators on a Hilbert space based upon the discrete QR technique. Error bounds are obtained in both the integrally separated and non-integrally separated cases and for both real and complex valued operators. We illustrate our results using a linear parabolic partial differential equation in which the strength of the integral separation determines the sensitivity of the stability spectra.

Mohamed Badawy, Erik Van Vleck
Department of Mathematics

University of Kansas
mbadawy@math.ku.edu, evanvleck@math.ku.edu

**MS134**

**Evolution Families and Lyapunov Exponents for Retarded Dynamical Systems**

The knowledge of Lyapunov and other stability spectra is fundamental in understanding complex nonlinear dynamics. Computational techniques have been established to address the problem for Ordinary Differential Equations: here we briefly recall the basic ideas behind QR methods. Then we present how their use can be extended to the infinite dimensional case of Delay Differential Equations, by discretizing the associated evolution family. Theoretical as well as implementation and convergence issues are discussed.

Dimitri Breda
Department of Mathematics and Computer Science
University of Udine
dimitri.breda@uniud.it

**MS134**

**Detecting Exponential Dichotomy on the Real Line**

In this talk we propose numerical techniques based on the QR factorization and on the SVD to ascertain exponential dichotomy on the entire real line. Methods to detect exponential dichotomy for special classes of systems are well established in the literature, e.g. Hamiltonian systems and systems with asymptotically constant coefficient matrices. Instead we propose and justify techniques which apply to general linear systems. We show the behavior of our methods with several numerical examples.

Cinzia Elia
University of Bari
elia@dm.uniba.it

**MS134**

**Stability Spectra: Approximation and Perturbation Theory**

In this talk we provide background on the approximation of stability spectra (Lyapunov exponents and Sacker-Sell spectrum) and on specific issues to be discussed in this minisymposium. These include the approximation of stable and unstable subspaces using matrix factorizations of fundamental matrix solutions, error analysis for approximation of stability spectra for sequences of linear operators in Hilbert space, and the approximation of stability spectra for linear time dependent retarded delay equations.

Erik Van Vleck
Department of Mathematics
University of Kansas
evanvleck@math.ku.edu

**MS135**

**A Model for Odor Discrimination in the Honeybee Antennal Lobe**

The honeybee antennal lobe (AL) provides an ideal system to study the olfactory system because it is anatomically and genetically simpler than the olfactory bulb of mammals. While anatomical structures within the AL are relatively well known, their functional roles remain poorly understood. We made a mathematical model to explore the possible network connectivities which can reproduce several features of experimental results such as a smooth transition patterns for detecting different odors.

Sungwoo Ahn
Department of Mathematical Sciences
Indiana University Purdue University Indianapolis
sahn@math.iupui.edu

David H. Terman
The Ohio State University
Department of Mathematics
terman@math.ohio-state.edu

**MS135**

**Functional Aspects of Olfactory Processing: Neural Rhythms, Dynamics of Input/output Neural Activity and Overview of Related Olfactory Models**

Using subspace analysis methods on optical imaging data from the olfactory bulb, we investigate how dynamics of odor responses in the primary receptor neurons of awake rats are shaped by the temporal features of the active odor sniffing. We use these data as input for computational models of endogenously bursting external tufted cells or mitral/tufted cells to investigate the structure of the input/output in the olfactory neural network.

Remus Osan
Boston University
Department of Mathematics
osan@bu.edu

Eric Sherwood
Boston University
wesher@bu.edu

**MS135**

**Functional Roles for Synaptic Depression Within the Fly Antennal Lobe**

Several experiments indicate that there exists substantial synaptic-depression at the synapses between olfactory receptor neurons (ORNs) and neurons within the drosophila antenna lobe (AL). This synaptic-depression may be partly caused by vesicle-depletion, and partly caused by presynaptic-inhibition due to the activity of inhibitory local neurons within the AL. While it has been proposed that this synaptic-depression contributes to the nonlinear relationship between ORN and projection neuron (PN) firing-rates, the precise functional role of synaptic-depression at the ORN–AL synapses is not yet fully understood. I believe that the mechanisms of vesicle-depletion and presynaptic-inhibition may be balanced within the fly AL in order to optimize the fine odor-discrimination capabilities of this network over short observation times (of a few hundred milliseconds). I will briefly introduce and describe the subnetwork analysis I used to substantiate this hypothesis within a rather general class of neuronal network models.

Aaditya Rangan
Courant Institute of Mathematical Sciences
New York University
rangan@cims.nyu.edu

**MS135**

**Network Adaptation Through Activity-dependent Restructuring: Neurogenesis Enhances Olfactory Pattern Separation**

The neuronal turn-over associated with adult neurogenesis leads to a persistent restructuring of the network of the olfactory bulb that depends on the activity of the neurons. Within the framework of a minimal network model we show that this allows the network to learn to decorrelate input patterns representing similar odor stimuli. For the discrimination of similar mixtures the model makes specific predictions about the dependence of the performance on the learning protocol.

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

Siu Fai Chow
Northwestern University
siuchow2008@u.northwestern.edu

**MS136**

**Instability of Twinned Orbits in a Coupled Respiratory Bursting Neuron Model**

Let $f: R^n \times R^n \to R^n$ be a smooth vector field and let the system

$$\dot{x} = f(x, x) \tag{1}$$

have a stable periodic orbit $x = \gamma(t)$. By symmetry, the system

$$\dot{x} = f(x, y), \dot{y} = f(y, x) \tag{2}$$

will have a periodic orbit $x = \gamma(t), y = \gamma(t)$. We call such a solution of (2) a pair of *twinned orbits*. We study the effects of parametric heterogeneity on the stability of twinned orbits in a model of coupled bursting neurons of the respiratory central pattern generator in the pre-Bötzinger complex of the mammalian brain stem.

Casey O. Diekman
The Ohio State University
cdiekman@mbi.osu.edu

Peter Thomas, Chris Wilson
Case Western Reserve University
pjt9@case.edu, cgw5@case.edu

**MS136**

**Network Bursting: Interactions of the CAN and NaP Currents**

The CAN and persistent sodium currents have been proposed to play key roles in respiratory rhythmogenesis. Previous modeling demonstrated that each current can underlie a bursting pattern with distinctive features. We present a slow-fast decomposition analysis of a unified neuronal model including both currents. Interactions of these currents create novel bursting patterns and synergistically promote robust bursting. We also study dynamics of a heterogeneous collection of these model neurons coupled in a biologically motivated architecture.

Justin Dunmyre
University of Pittsburgh
jrd34@pitt.edu

Christopher Del Negro
College of William and Mary
cadeln@wm.edu

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

**MS136**

**Multiple Bursting Mechanisms in Heterogeneous Neural Populations with Metabotropic Glutamate Receptors and NaP and CAN Currents**

We investigated a series of mathematical models of single neuron and neural populations with excitatory interconnections incorporating the intrinsic mechanisms that were suggested to operate in the pre-Bötzinger Complex (pre-BötC). These mechanisms include persistent sodium current-dependent bursting, $IP_3$-dependent calcium oscillations, synaptically activated $IP_3$-production and calcium-activated cation-nonspecific current. We demonstrated the co-existence of several qualitatively different oscillatory mechanisms depending on model parameters which may be relevant to rhythmic activities observed in the pre-BötC and spinal cord.

Yaroslav Molkov, Patrick Jasinski, Natalia Shevtsova, Ilya A. Rybak
Drexel University College of Medicine
ymolkov@drexelmed.edu, pej23@drexel.edu, natalia.shevtsova@drexelmed.edu, rybak@drexel.edu

**MS136**

**Interaction of the Two Distinct Bursting Mechanisms in the Model of Respiratory Neuron**

Motivated by experimental evidence of two types of bursting neurons in the pre-Btzinger complex of the medulla, we present a two-compartment mathematical model of a pre-Btzinger neuron with two independent bursting mechanisms. Bursting in the somatic compartment is modeled via inactivation of a persistent sodium current, whereas bursting in the dendritic compartment relies on intrinsic calcium oscillations. Interaction of the two distinct bursting mechanisms in the model explains complex bursting activity observed in experiments.

Natalia Toporikova, Robert Butera
Georgia Institute of Technology
ntoporikova3@gatech.edu, rbutera@gatech.edu

**MS137**

**Biological Change Detection: Relating Information Acquired to Mechanism Employed**

Sensitivity to rates of change in associated stimuli have been reported from multiple biological sensory systems including bacterial gene networks, vertebrate immune cells and even arthropod neuroendocrinology. There has been, however, very little effort to establish a unified analysis of change detection across these disparate scientific disciplines. Using a dynamical systems approach, we highlight similarities and differences among change detection mechanisms that have been reported and/or proposed across a variety of research fields.

Sharon A. Bewick

NIMBioS and University of Tennessee, Knoxville
sharon_bewick@hotmail.com

**MS137**

**T Cell State Transitions Produce an Emergent Change Detector**

We develop a model using a system of ordinary differential equations that shows how T cells can detect changes in antigen levels. A key component of this detector is naïve T cell activation. The activation step creates a barrier that separates the slow dynamics of naïve T cells from the fast dynamics of activated T cells. This separation generates an adaptive system that continually compares shifts in antigen stimulation to long-term, steady state levels.

Peter S. Kim
University of Utah
Department of Mathematics
kim@math.utah.edu

Peter Lee
Stanford University
School of Medicine
ppl@stanford.edu

**MS137**

**A Control-Oriented Model for Immune Regulatory Response: Pid Control with Switching**

In this talk, we develop a model of the immune system as a control system which regulates infectious agents. In particular, we take known data and models of the action of IL-2 and Treg growth and show how they describe a differential controller with on-off switching and an integral feedback reset. We hypothesize that the body uses differential control to differentiate self from non-self. We use numerical simulation to justify our interpretation of the model.

Matthew M. Peet
Illinois Institute of Technology
mpeet@iit.edu

Peter S. Kim
University of Utah
Department of Mathematics
kim@math.utah.edu

Peter Lee
Stanford University
School of Medicine
ppl@stanford.edu

**MS137**

**Growth Detection: CD4+ T-cells Interaction Networks as an Interface for Immune System Decision-Making based on Changes in Antigen Load**

Recently, a number of experiments have suggested that antigen kinetics play a role in immune system decision-making. The mechanisms underlying this mode of immune system regulation, however, are unknown. We develop a system of ordinary differential equations to describe signaling between Th1, Th2, Th17 and iTreg cells and show that this CD4+ T-cell interaction network is capable of accurately and robustly classifying pathogens based on population growth rates.

Routing Yang
University of California, Santa Barbara
ruoting@engr.ucsb.edu

Sharon A. Bewick
NIMBioS and University of Tennessee, Knoxville
sharon_bewick@hotmail.com

Mingjun Zhang
Mechanical, Aerospace and Biomedical Engineering Department
University of Tennessee, Knoxville
mjzhang@utk.edu

**MS138**

**Existence of Defects in Swift-Hohenberg Equations**

We show the existence of grain boundaries and dislocations in the classical Swift-Hohenberg equation and in an anisotropic Swift-Hohenberg equation, respectively. We find these defects as traveling waves connecting roll patterns with different wavenumbers. The analysis relies upon a spatial dynamics formulation of the bifurcation problem, a local center-manifold reduction, and normal form theory. We also discuss possible extensions and limitations of our approach.

Mariana Haragus
Laboratoire de Mathematiques de Besancon
Universite de Franche-Comte, France
mariana.haragus@univ-fcomte.fr

Arnd Scheel
University of Minnesota
School of Mathematics
scheel@math.umn.edu

**MS138**

**On the Mechanisms for Instability of Standing Waves in Nonlinearly Coupled Schrodinger Equations**

Dynamical systems methods have been used with great success to identify nonlinear waves, and also to characterize the stability of those waves. For instance, when a shooting method is used to pinpoint a standing wave, a second shooting method in a related space can often be used to locate eigenvalues of the linearized operator at the standing wave. In this talk, we use these methods to detect instabilities in many of the standing waves (both 1-pulses and N-pulses) found in nonlinearly coupled systems of Schrodinger equations.

Russel Jackson
US Naval Academy
rkjackso@usna.edu

**MS138**

**Stability Analysis for Closed Curve Solutions to the Vortex Filament Equation**

In its simplest form, the self-induced dynamics of a vortex filament in a perfect fluid is governed by the Vortex Filament Equation (VFE), a nonlinear partial differential equation that is related to the Nonlinear Schroedinger (NLS) equation via the well-known Hasimoto map. The NLS is integrable and admits a corresponding AKNS linear system. The squared eigenfunctions of the AKNS system play a central role in linear stability studies of solutions of the NLS equation, as they provide a large (and often complete) set of solutions of the linearization of the NLS equation about a given solution. Using the squared eigenfunctions and the relation between the VFE and NLS equations, we construct solutions of the linearized VFE equation and relate the stability properties of vortex filaments to those of the associated NLS potentials.

Stephane Lafortune
College of Charleston
Department of Mathematics
lafortunes@cofc.edu

**MS138**

**On the Traveling Waves of Gray-Scott Model**

For a wide range of parameter values we show the existence of rich families of traveling waves of the Gray-Scott model. We find pulse solutions, periodic wave trains, families of fronts that connect constant states, constant states to a periodic wave train, two periodic wave trains, a periodic orbit to a pulse train. In certain singular limits we pinpoint the structure of the traveling waves. The results are anchored in geometric singular perturbation theory.

Vahagn Manukian
Miami University
manukive@muohio.edu

**MS139**

**Multiple Injection Dynamics in Two-mode Lasers**

A two-mode laser diode under simultaneous optical injection in both modes shows dynamical features which are remarkably different from the well studied single mode injection case. In particular the double-locked equilibrium states, where both modes are locked to the respective injected signal, gives rise to interesting phenomena. We identify a region of bistability between double-locked states, which allow for the realisation of a fast all-optical memory element. The theoretical predictions are confirmed by experiments.

Andreas Amann, Simon Osborne, Patrycja Heinricht, Benjamin Wetzel, Stephen O'Brien
Tyndall National Institute
University College Cork, Cork, Ireland
andreas.amann@tyndall.ie, simon.osborne@tyndall.ie, patrycja.heinricht@tyndall.ie, benjamin.wetzel@tyndall.ie, stephen.obrien@tyndall.ie

**MS139**

**From Phase Locking to Optical Turbulence in Coupled Lasers**

We study synchronisation properties of three coupled lasers with $S^1 \times Z_2$-symmetry. Conditions for the stability of inphase and anti-phase locking are calculated analytically as functions of the coupling strength and frequency detuning between the lasers, and the amplitude-phase coupling of a single laser (also known as non isochronicity). Bifurcation analysis and Lyapunov exponents reveal interesting symmetry breaking phenomena including transitions between synchronised and unsynchronised chaos (optical turbulence) due to blowout bifurcations.

Nicholas Blackbeard
Mathematics Research Institute
University of Exeter, Exeter, UK
n.blackbeard@exeter.ac.uk

Hartmut Erzgraber, Sebastian M. Wieczorek
University of Exeter
Mathematics Research Institute
h.erzgraber@exeter.ac.uk, s.m.wieczorek@exeter.ac.uk

**MS139**

**Broadband Chaos Generated by an Optoelectronic Oscillator**

We discuss the dynamics of an optoelectronic time-delay oscillator that displays high-speed chaotic behavior with a flat, broad power spectrum. Experimentally we find that the chaotic state coexists with a linearly-stable fixed point, which, when subjected to a finite-amplitude perturbation, loses stability initially via a periodic train of ultrafast pulses. We derive approximate mappings that do an excellent job of capturing the observed instability.

Lucas Illing
Reed College
illing@reed.edu

Kristine Callan, Zheng Gao
Department of Physics
Duke University, Durham, North Carolina
callan@phy.duke.edu, gao@phy.duke.edu

Daniel Gauthier
Departments of Physics and Biomedical Engineering
Duke University
gauthier@phy.duke.edu

Eckehard Schoell
Institute for Theoretical Physics
Technical University Berlin
schoell@physik.tu-berlin.de

**MS139**

**Optimal Topologies for Synchronization in a Network of Chaotic Optoelectronic Oscillators**

Synchronization in a network of coupled oscillators is influenced by the dynamical nature of the nodes and the interaction topology. Here, we present an experimental exploration of the influence of various network topologies on the synchronization of a network of chaotic optoelectronic oscillators. For networks with varying number of connections, we measure the rate of convergence to a synchronous solution. The rate to synchronization is observed to be maximal when there are a quantized number of links in the network.

Bhargava Ravoori
University of Maryland, College Park
Dept. of Physics
ravoorib@umd.edu

Rajarshi Roy
University of Maryland
rroy@umd.edu

**MS140**

**Improved Linear Response for Stochastically Driven Systems**

The recently developed short-time linear response algorithm, which predicts the average response of a nonlinear chaotic system with forcing and dissipation to small external perturbation, generally yields high precision of the response prediction, although suffers from numerical instability for long response times due to positive Lyapunov exponents. However, in the case of stochastically driven dynamics, one typically resorts to the classical fluctuation-dissipation formula, which has the drawback of explicitly requiring the probability density of the statistical state together with its derivative for computation, which might not be available with sufficient precision in the case of complex dynamics (usually a Gaussian approximation is used). Here we adapt the short-time linear response formula for stochastically driven dynamics, and observe that, for short and moderate response times before numerical instability develops, it is generally superior to the classical formula with Gaussian approximation for both the additive and multiplicative stochastic forcing. Additionally, a suitable blending with classical formula for longer response times eliminates numerical instability and provides an improved response prediction even for long response times.

Rafail Abramov
Department of Mathematics, Statistics and Computer Science
University of Illinois at Chicago
abramov@math.uic.edu

**MS140**

**Estimating Error Probabilities in Noise-Perturbed Nonlinear Optical Systems**

Many lightwave systems are designed to operate with stringent performance requirements. In such cases, the interplay between noise and nonlinearity makes the estimation of error probabilities a challenging task: analytical methods cannot deal with the complexity of these systems, and brute-force numerical approaches are completely impractical. An approach that has been shown to be very effective is the combination of analytical tools (such as large deviation theory) with variance reduction techniques (such as importance sampling). This talk will provide an overview of the problem and a review of recent results, including those for dispersion-managed systems and phase-sensitive problems.

Gino Biondini
State University of New York at Buffalo
Department of Mathematics
biondini@buffalo.edu

**MS140**

**Stochastic Integrable Dynamics in Active Optical Media**

Resonant interaction of light with a randomly-prepared, lambda-configuration active optical medium is described by exact solutions of a completely-integrable, random partial differential equation, thus combining the opposing concepts of integrability and disorder. An optical pulse passing through such a material will switch randomly between left- and right-hand circular polarizations. Exact probability distributions of the electric-field envelope variables describing the light polarization and their switching times will be presented .

Gregor Kovacic
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
kovacg@rpi.edu

Ethan Atkins
Courant Institute
atkins@cims.nyu.edu

Ildar R. Gabitov
Department of Mathematics, University of Arizona
gabitov@math.arizona.edu

Peter R. Kramer
Rensselaer Polytechnic Institute
Department of Mathematical Sciences
kramep@rpi.edu

**MS140**

**Sub-sampling in Parametric Estimation of Effective Stochastic Models from Discrete Data**

In this talk we address the problem of stochastic modeling of large-scale essential variables from discrete time-series. Parameters in stochastic parametrizations are estimated from the discrete time-series of the essential variables alone and no knowledge of small-scales is necessary. In particular, we analyze the dependence of the linear OU-type parametrizations on the sampling time-step. It has been recognized that the stochastic terms are not appropriate to model smooth trajectories at small lags because the underlying trajectory is fundamentally different from the sample path of a stochastic system. Nevertheless, the main practical goal is to determine a closed-form low-dimensional system resembling the behavior of large scale structures on longer time-scales. To achieve this goal, the dataset has to sub-sampled (i.e. rarefied) to ensure estimators' consistency. Nevertheless, we show that estimators are biased for any finite sub-sampling time-step and construct new bias-corrected estimators. Numerical examples of various complexity will be presented to illustrate the concept.

Ilya Timofeyev
Dept. of Mathematics
Univ. of Houston
ilya@math.uh.edu

**MS141**

**Relative Equilibria of the (1+N)-vortex Problem**

We study relative equilibria of the $(1 + N)$-vortex problem where $N$ vortices have small, equal circulation and one vortex has large circulation. In the limit, the problem reduces to seeking critical points of a particular potential function defined on a circle. In contrast to the Newtonian $(1+N)$-body problem, there are typically multiple relative equilibria for both small and large N. Linear stability is also studied, and situations are found where there are no stable relative equilibria.

Anna Barry
Mathematics
Boston University
annab@math.bu.edu

Glen R. Hall
Boston University

rockford@math.bu.edu

C. Eugene Wayne
Boston University
Department of Mathematics
cew@math.bu.edu

**MS141**
**Point Vortex Equilibria and Optimal Packings of Circles on a Sphere**

We answer the question of whether optimal packings of circles on the sphere are equilibrium solutions to the logarithmic particle interaction problem on the sphere (i.e. point vortices) for N = 3-12 and 24, the only values of N for which optimal packings are rigorously known. We also will describe algorithms associated with the formation and assembly of these and other equilibrium configurations on the sphere which involve clustering sub-groups of particles during random walk formation. P.K. Newton, T. Sakajo 'Point vortex equilibria and optimal packings of circles on the sphere', in press, Proc. Roy. Soc. A.

Paul Newton
Univ Southern California
Dept of Aerospace and Mechanical Engineering
newton@usc.edu

**MS141**
**High Order Three Dimensional Lagrangian Methods Based on Deforming Ellipsoids**

Vortex methods are numerical schemes for approximating solutions to the Navier-Stokes equations using a linear combination of moving basis functions to approximate the vorticity field of a fluid. Typically, the basis function velocity is determined through a Biot-Savart integral applied at the basis function centroid. Since vortex methods are naturally adaptive, they are advantageous in flows dominated by localized regions of vorticity such as jets, wakes and boundary layers. While they have been successful in numerous engineering application, the complexity of understanding grid-free methods make their analysis a uniquely mathematical endeavor. One outcome of rigorous analysis is an new naturally adaptive high order 2D method with elliptical Gaussian basis functions that deform as they move according to flow properties. This new class of methods is very unusual because the basis functions do not move with the physical flow velocity at the basis function centroid as is usually specified in vortex methods. We now extend these results to three dimensions. The resulting analysis leads to deforming, ellipsoidal basis functions capable of achieving high spatial order. We will discuss the latest results on our efforts to develop a complete 3D vortex method with adaptive, deforming blobs.

Louis F. Rossi, Claudio Torres
University of Delaware
rossi@math.udel.edu, torres@math.udel.edu

**MS141**
**Multi-moment Vortex Methods for 2D Viscous Fluids**

In this talk we introduce a new vortex method which incorporates Hermite moment corrections to radially symmetric Gaussian basis functions. Convergence of the Hermite expansion is proven and the added Hermite moments allow for each particle to deform under convection. We will implement this multi-moment vortex method for a tripole relaxation example and demonstrate the improvement in spatial accuracy achieved by allowing the basis functions to deform. Time permitting, we will discuss the trade off in this method between computational efficiency and spatial accuracy.

David T. Uminsky
Dept. of Mathematics
UCLA
duminsky@math.ucla.edu

C. Eugene Wayne
Boston University
Department of Mathematics
cew@math.bu.edu

Alethea Barbaro
UCLA
Department of Mathematics
alethea@math.ucla.edu

Vitalii Ostrovskyi
USC
Department of Mathematics
ostrovsk@usc.edu

**MS142**
**Dynamic Centality in Real World Networks**

Novel, dynamic network centrality measures will be introduced: NetworGame program interprets game centrality as the ability of a networked agent with a single alternating strategy to change an overall starting cooperation to defection and vice versa. The Turbine program shows the extremes of low- and high-perturbing network positions. The ModuLand modularization method-family [Kovacs et al., PLoS ONE 7:e12528] helps to find role of nodes in community overlaps in information processing, spatial games, perturbations, etc.

Peter Csermely
Semmelweis University, Department of Medical Chemistry
LINK-Group
Csermely@eok.sote.hu

Miklos Antal
Semmelweis University, Dept. Med. Chem. LINK-Group
Budapest Univ. Techn. Econ, Dept. Envir. Econ.
antalmi@gmail.com

Huba Kiss
Semmelweis University, Dept. Med. Chem. LINK-Group
Semmelweis University, Dept. Opthalmology
kisshuba@googlemail.com

Istvan Kovacs
Semmelweis University, Dept. Med. Chem. LINK-Group
Eotvos Univ, Dept. Physics & Res. Inst. Solid State Physics
kovacspisti@gmail.com

Agoston Mihalik
Semmelweis University, Dept. Med. Chem. LINK-Group
anaston@gmail.com

Gabor Simko

Semmelweis University, Dept. Med. Chem. LINK-Group
Vanderbilt University
gsimko@gmail.com

Kristof Szalay
Semmelweis University, Dept. Med. Chem. LINK-Group
kris@sch.bme.hu

### MS142

### Network Synchronization in a Noisy Environment with Time Delays

Time delays in transmitting and processing information are present in most real communication and information networks, including info-social and neurobiological networks. Here, we discuss the impact of time delays in stochastic synchronization (or coordination) problems in complex networks. We establish the scaling theory for the phase boundary and for the fluctuations in the synchronizable regime. Our results also imply the potential for optimization and trade-offs in synchronization and coordination problems with time delays [D. Hunt, G. Korniss, and B.K. Szymanski, Phys. Rev. Lett. 105, 068701 (2010)].

Gyorgy Korniss
Physics. RPI
korniss@rpi.edu

David Hunt
Department of Physics, RPI
huntd3@rpi.edu

Boleslaw Szymanski
Computer Science Department
Rensselaer Polytechnic Institute
szymansk@cs.rpi.edu

### MS142

### Center Manifolds, Bifurcations and Noise in Stochastic Network Dynamics

Using a prototypical network model based on signaling between nodes, we show the generic role of noise in switching from total synchrony to asynchronous modes in networks, by embedding the nonequilibrium stochastic dynamics of the NamingGame in a class of singularly-perturbed ergodic network models. The stochastic-dynamics of the NG yields solvable random walk models that support center manifold bifurcations such as a codim-1 saddle-node and global attractors in the form of spatial-synchrony.

Chjan C. Lim
Mathematical Sciences, RPI
limc@rpi.edu

Weituo Zhang
RPI Network Science Center and
Math Sciences
zhangw10@rpi.edu

### MS142

### Isolated and Composite Networks

We introduce the "modern theory of networks', and describe specific examples including the very recent paper [S. V. Buldyrev, R. Parshani, G. Paul, H. E. Stanley, and S. Havlin,"Catastrophic Cascade of Failures in Interdependent Networks' Nature 464, 1025 (2010)] showing that systems comprised of more than one network are vastly more susceptible to failure cascades than isolated networks.

H. Eugene Stanley
Center for Polymer Studies and Department of Physics
Boston University
hes@bu.edu

### MS143

### Painting Chaos: Computational Methods for Exploration of Complex Behaviors

Using the state-of-the-art numerical ODE solver TIDES, we show how combined symbolic and numerical methods can yield a detailed information on systems in questions, that is hardly available in other settings. We will present the toolkit including Lyapunov exponents, fast-chaos indicators, template analysis of attractors, 'shrimp' analysis for detecting cod-2 T-points that organize globally and universally the parameter space of several canonical models. We will demonstrate the tools in application to neuronal models as well.

Roberto Barrio
University of Zaragoza, SPAIN
rbarrio@unizar.es

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

### MS143

### Parameter Space Classification of Stable Solutions of Flows

Bifurcation analysis based on numerical continuation techniques are frequently used to generate phase diagrams mixing on a single diagram curves corresponding to both stable and unstable orbits. Chaotic phases are rarely delimited and without ever scrutinizing their inner structure. However, realistic applications demand, first, classifying stable behaviors, second, competent description of the inner structure of chaotic phases, third, description of unstable phenomena that impact the previous two. We discuss two algorithms to face such challenges.

Jason Gallas
Instituto de Fisica da UFRGS
Porto Alegre Brazil
jgallas@if.ufrgs.br

### MS143

### Complex Spontaneous Oscillations and Response Properties of Sensory Hair Cells

We use a Hodgkin-Huxley type model of a saccular hair cell to study how its mechanical and electrical compartments interact to produce coherent self-sustained oscillations and how this interaction contributes to the overall sensitivity and selectivity to external stimuli. In a wide range of parameters the dynamics of the cell may become chaotic, resulting in broad-band encoding of external vibrations. On the other hand, bi-directional compartments coupling may result in significant enhancement of oscillation coherence, frequency selectivity and sensitivity of the cell to external stimuli.

Alexander Neiman

Department of Physics and Astronomy
Ohio University
neimana@ohio.edu

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

### MS143

### The Hindmarsh-Rose Neuron Model: Understanding the Bifurcation Scenario by Combining Continuation and Brute-force Computational Methods

The Hindmarsh-Rose neuron model is analyzed in a two-dimensional parameter space by combining theoretical tools with numerical brute-force and continuation techniques. The brute-force techniques, based on numerical ODE solvers, are used to classify stable periodic solutions according to the number of spikes per period and to index the complexity of chaotic solutions. Continuation techniques, based on AUTO, and theoretical tools are used to unfold the complete bifurcation scenario, organized by few codimension-two bifurcation points.

Marco Storace
Biophysical and Electronic Engineering Department,
University of Genoa, Italy
marco.storace@unige.it

Daniele Linaro
Biophysical and Electronic Engineering Department
University of Genoa
daniele.linaro@unige.it

### PP1

### Desynchronization Bifurcation of Coupled Nonlinear Dynamical Systems

We analyze the desynchronization bifurcation in the coupled Rössler oscillators. After the bifurcation the coupled oscillators move away from each other with a square root dependence on the parameter. We define system transverse Lyapunov exponents and in the desynchronized state one is positive while the other is negative implying that one oscillator is trying to fly away while the other is holding it. We give a simple model of coupled integrable systems that shows a similar phenomena and can be treated as the normal form for the desynchronization bifurcation. We conclude that the desynchronization is a pitchfork bifurcation of the transverse manifold.

Suman Acharyya
Physical Research Laboratory, Ahmedabad, India.
suman@prl.res.in

R. E. Amritkar
Physical Research Laboratory,
Ahmedabad, India.
amritkar@prl.res.in

### PP1

### Learning from the Past: Empirical Correction of Models of Natural Chaotic Phenomena

The chaotic nature of Earth's atmosphere drives weather forecasts away from reality exponentially. Even assuming perfect atmospheric state estimates, discrepancies between nature and models produce this divergence. In this presentation we demonstrate a principled approach to the mitigation of those discrepancies. Empirical correction is applied to: 1) align Lorenz systems with different parameter-values; and 2) couple 3-dimensional Lorenz-like models to a natural convection loop. Finally, we consider the technique's application to weather and climate models.

Nicholas A. Allgaier
The University of Vermont
nallgaie@uvm.edu

Kameron D. Harris
University of Vermont
kharris@uvm.edu

Chris Danforth
Mathematics and Statistics
University of Vermont
chris.danforth@uvm.edu

### PP1

### Numerical Study of Existence, Stability and Collision Properties of Dark-Bright Discrete Solitons

We numerically explore the existence and stability properties of different configurations of dark- bright solitons, dark-bright soliton pairs and pairs of dark-bright and dark solitons in discrete settings. We consider collisions between dark-bright solitons and between dark-bright and dark ones. In the regime where the underlying lattice structure matters, we find a wide range of potential dynamical outcomes depending on the initial soliton velocity.

Azucena Alvarez
Universidad de Sevilla. Departamento de FAMN
azucena@us.es

Francisco Romero
Universidad de Sevilla. Departam
romero@us.es

### PP1

### Streamline Topology of Helical Fluid Flow

A vector field with helical symmetry looks the same from anywhere seen on a specific helix. Helical vector fields are analysed using dynamical system theory. The helical structure implies existence of a stream function which facilitates the analysis. Bifurcation of flow patterns are analysed analytically and applied to concrete examples. The results are related to vector fields with translational or rotational symmetry.

Morten Andersen
Department of Mathematics
Technical University of Denmark
m.andersen@mat.dtu.dk

### PP1

### Study of the Connectome of a Simple Spinal Cord Locomotor Network.

We address a long-standing ambition of neuroscience to understand the structure-function problem by modelling the complete connectome map of a two-day old hatchling Xenopus tadpole spinal cord based on developmental processes of axon growth. A simple mathematical model of axon growth allows us to reconstruct a biologically realistic connectome of tadpole spinal cord based on the neurobiological data (Bristol Xenopus Tadpole Research Lab).Our study reveals a complex structure for the connectome with many interesting specific features and the distribution of connection lengths of the tadpole spinal cord connectome is found to be similar to that of the global neuronal network of C. elegans.We use a Hodgkin-Huxley based neuron with post-inhibitory rebound to model network activity. This simple model demonstrates a pattern of neuronal activity with swimming-like features including left-right alternation and a head-to-tail propagation.

Abul K. Azad
university of plymouth, UK.
abul.azad@plymouth.ac.uk

Roman Borisyuk
University of Plymouth
r.borisyuk@plymouth.ac.uk

**PP1**

**Mixed Mode Oscillations in a Gnrh Neuron Model.**

Mixed mode oscillations (MMOs) are patterns involving an inter-mixing of large- and small-amplitude oscillations. For neurons, MMOs are typically mixtures of spikes and subthreshold oscillations. I will present a model of a Gonadotropin-releasing hormone (GnRH) neuron exhibiting MMOs, also robustly observed in supporting experimental data. I will describe the use of geometric singular perturbation theory methods to understand the mechanisms underlying MMOs in the model and explore possible physiological functions of MMOs in GnRH neurons.

Sayanti Banerjee
The Ohio State University
banerjee@math.ohio-state.edu

Janet Best
The Ohio State University
Department of Mathematics
jbest@math.ohio-state.edu

Kelly Suter
The University of Texas at San Antonio
kelly.suter@utsa.edu

**PP1**

**Mixed-Pattern Solutions of An Eighth Order Swift-Hohenberg Equation**

Motivated by degenerate marginal stability curves in MHD Taylor-Couette flow, we investigate the existence of mixed pattern solutions for an eighth order Swift-Hohenberg equation. These solutions are analogous to localised solutions found in the standard Swift-Hohenberg equation, exhibiting a transition between two patterns of different wavelengths. A normal form reduction is carried out to identify regions in the appropriate parameter space where such solutions may occur.

David Bentley
University of Leeds
mat4dcb@leeds.ac.uk

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

Thomas Wagenknecht, Rainer Hollerbach
University of Leeds
thomas@maths.leeds.ac.uk, rh@maths.leeds.ac.uk

**PP1**

**An Agent-Based Framework for Designing Water Efficient Residential Landscapes**

I will present an algorithm that uses agent-based modelling and distributed optimization to design water-efficient residential landscapes. Agents in this model, which is designed to capture the nonlinear relationships between plant growth and resource availability, are placed on a simulated landscape. The model's overall dynamics mimic how plant communities evolve over time in response to light and water. Simulation experiments show that this strategy consistently produces close-to-optimal solutions, outperforming random and greedy search algorithms.

Rhonda Hoenigman
University of Colorado, Boulder
rhonda.hoenigman@colorado.edu

Elizabeth Bradley
University of Colorado
Department of Computer Science
lizb@cs.colorado.edu

Nichole Barger
University of Colorado, Boulder
nichole.barger@colorado.edu

**PP1**

**Migration Effects on Disease Outbreaks**

Motivated by the periodic outbreaks of measles in the northern and southern regions of Cameroon, we study coupled models for the spread of disease in connected subpopulations. In the presence of seasonal driving, the coupling is modeled by linear migration or mass action mixing from social interaction. We describe the bifurcations and sensitivity in the model to these coupling terms, and show the existence of different periods of oscillation in each subpopulation.

Jackson Burton
Montclair State University
burtonj2@mail.montclair.edu

Lora Billings
Montclair State University
Dept. of Mathematical Sciences
billingsl@mail.montclair.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
derek.cummings@jhu.edu

**PP1**

**Effects of Variability and Noise on Synchrony Be-**

**tween Reciprocally Pulse Coupled Oscillators with Delays**

We analyze two reciprocally pulse-coupled oscillatory neurons using Phase Resetting Curves to predict what phase-locked solutions will be exhibited in the neuronal circuit with conduction delays. We test our predictions in circuits of two model neurons and in hybrid circuits constructed with two stellate cells constructed via Dynamic Clamp. Experimental tests confirm our predictions that the most robust synchronization for heterogenous neurons is predicted for long delays with excitatory coupling. Noise preferentially disrupts early synchrony.

Lakshmi Chandrasekaran
Neuroscience center
Louisiana State University Health Sciences Center
lchand@lsuhsc.edu

Shuoguo Wang
Neuroscience Center, LSUHSC
New orleans, LA 70118
swang1@lsuhsc.edu

Fernando Fernandez
Dept. of Bioengineering, Brain institute
Univ. of Utah, Salt Lake City, UT 84112
fernrf@gmail.com

John White
department of Bioengineering
The University of Utha
john.white@utah.edu

Carmen Canavier
Health Sciences Center
Louisiana State University
ccanav@lsuhsc.edu

## PP1

### Exploring the Dynamics of CRISPR Length: How Much Can a Bacterium Remember About Viruses That Infected It?

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a virus-specific heritable bacterial defense system that incorporates copies of short regions of viral DNA into the bacterial genome and grants the bacteria immunity to viruses with matching sequences. Ideally, the number of incorporated sequences would grow indefinitely. However, the actual number in any bacteria is limited. We use a birth-death master-equation model to explore the growth and decay of the CRISPR length.

Lauren M. Childs
Cornell University
lauren.childs@biology.gatech.edu

Joshua Weitz
Georgia Institute of Technology
jsweitz@gatech.edu

## PP1

### Time-dependent Solutions of a Convection Problem with Temperature Dependent Viscosity

We study a convection problem with temperature dependent viscosity in a 2D domain with periodic boundary conditions along the horizontal coordinate. Our numerical approach considers the structure of the solutions of the equations in the phase space and its temporal evolution. The temporal evolution scheme is similar to the one described in [I.Mercader, O.Batiste, A.Alonso. An eŒcient spectral code for incompressible Æows in cylindrical geometries (2010)]. However, we treat the pressure diœerently, following the scheme proposed in [H.Herrero, A.M.Mancho. On pressure boundary conditions for thermoconvective problems (2002)]. Nontrivial stationary solutions are computed via an iterative Newton-Raphson method.

Jezabel Curbelo
Instituto de Ciencias Matematicas
jezabel.curbelo@icmat.es

Ana María Mancho
Instituto de Ciencias Matemáticas
a.m.mancho@icmat.es

## PP1

### Correction of Periodic Orbits in High Precision.

We present an algorithm to compute up to any arbitrary precision periodic orbits of dinamical systems. The algorithm is based on an optimized shooting method combined with a new numerical ODE solver, TIDES, that uses a Taylor series method. This methodology is nowadays the only one capable to reach precisions up to 1000 digits or more. Finally, we present some numerical tests for the Henon-Heiles' Hamiltonian which show the good behavior of the proposed method.

Angeles Dena, Alberto Abad
Universidad de Zaragoza
adena@unizar.es, abad@unizar.es

Roberto Barrio
University of Zaragoza, SPAIN
rbarrio@unizar.es

## PP1

### Dynamic Switch in a Model of Unfolded Protein Response To Endoplasmic Reticulum Stress

The unfolded protein response (UPR) is a cellular mechanism whose primary functions are to sense perturbations in the protein-folding capacity and to take corrective steps restoring homeostasis. Recent experimental results show that UPR is capable of producing qualitatively different outputs depending on the nature, strength, and persistence of the inducing stress. In parallel, a mechanistic framework (ODE model) for the integration of stress signals by the UPR has been proposed. We analyze this model and show the existence of a dynamic switch between two states (an adaptive one and an apoptotic one). The switch matches the experimental observations and is a consequence of the intrinsic UPR's feedback loops.

Danilo Diedrichs, Rodica Curtu
University of Iowa
Department of Mathematics
danilo-diedrichs@uiowa.edu, rodica-curtu@uiowa.edu

## PP1

### Existence and Stability of Traveling Wave Solutions

**in a Simplified Model of Cardiac Tissue.**

We introduce a simplified two-variable model of cardiac tissue. The model captures key features of cardiac behavior, including electrical alternans, while also allowing for analytical investigations into the propagation of electrical impulses. We examine the existence and stability of traveling wave front and traveling pulse solutions.

Lisa D. Driskell, Gregery Buzzard
Purdue University
ldriskel@mesastate.edu, buzzard@math.purdue.edu

### PP1

### Persistence of Normally Hyperbolic Invariant Manifolds: The Noncompact Case

We improve the theorem on persistence of Normally Hyperbolic Invariant Manifolds (NHIMs). The classical theorems by Fenichel and Hirsch, Pugh & Shub require compactness of the NHIM, which we generalize to the noncompact case. Furthermore, our results include optimal $C^{k,\alpha}$ smoothness. To properly generalize to arbitrary manifolds, e.g. with non-trivial normal bundle, we require the ambient space to be a Riemannian manifold of bounded geometry. We illustrate some of the specific issues in this case.

Jaap Eldering
Utrecht University
J.Eldering@uu.nl

### PP1

### Dimension Reduction of Mechanical Systems

In many applications the governing equations of mechanical systems are nonlinear PDEs. These systems are often too complex to be investigated without resorting to numerical approximations. A typical property of such approximations is that they are often so high-dimensional that numerical bifurcation methods are unlikely to be efficient, which motivates the development of dimension reduction methods. For a mechanical system we compare the bifurcation diagrams of the full numerical approximation to its low-dimensional approximation.

Michael Elmegaard, Jens Starke, Frank Schilder
Technical University of Denmark
Department of Mathematics
M.Elmegaard@mat.dtu.dk, j.starke@mat.dtu.dk,
f.schilder@mat.dtu.dk

Jon J. Thomsen
Technical University of Denmark
Department of Mechanical Engineering
jjt@mek.dtu.dk

### PP1

### Frequency Response of Gonadotropin-Releasing Hormone (GnRH) Induced Gonadotropin Subunit Transcription in Pituitary Gonadotrophs

The reproductive system is controlled by a pulsatile gonadotropin-releasing hormone (GnRH) signal. Pituitary gonadotrophs differentially synthesize the beta subunit of luteinizing hormone (LH$\beta$) or follicle stimulating hormone (FSH$\beta$) in response to variations in the frequency of this signal. In particular, FSH$\beta$ synthesis is preferred at low GnRH pulse frequencies while LH$\beta$ synthesis dominates at higher frequencies. We explore, using mathematical modeling, some potential mechanisms underlying the preferred frequency response of gonadotropin transcription.

Patrick A. Fletcher
Department of Mathematics
Florida State University, Tallahassee, FL
pfletche@math.fsu.edu

### PP1

### Decay and Destruction of Invariant Tori in Volume Preserving Maps

When integrable, the orbits of volume preserving maps lie on invariant tori. While KAM-like theories have shown the continued existence of these tori under perturbation there are gaps in our understanding of how these tori behave when perturbed. In this study 3 dimensional volume preserving maps with two angles are examined. Numerical results detailing the resilience of these tori to perturbation will be discussed, with a focus on finding the last surviving torus.

Adam M. Fox
University of Colorado, Boulder
adam.fox@colorado.edu

James Meiss
University of Colorado-Boulder
james.meiss@colorado.edu

### PP1

### Ergodic and Non-ergodic Clustering of Inertial Particles

We compute the fractal dimension of clusters of inertial particles in mixing flows at finite values of Kubo (Ku) and Stokes (St) numbers, by a new series expansion in Ku. At small St, the theory includes clustering by Maxey's non-ergodic 'centrifuge' effect. In the limit of large St and small Ku (so that Ku$^2$St remains finite) it explains clustering in terms of ergodic 'multiplicative amplification'. In this limit, the theory is consistent with the asymptotic perturbation series in [Duncan et al., Phys. Rev. Lett. 95 (2005) 240602].

Kristian Gustafsson
Göteborg University
Kristian.Gustafsson@physics.gu.se

### PP1

### Stochastic Network Models of Disease Outbreaks

Regional epidemic data often show fadeouts and reintroduction of outbreaks of a disease in irregular patterns. To capture these dynamics, we construct a network of subpopulations and simulate the disease spread in a finite population. These models are used to analyze the fadeout probabilities with respect to the number of subpopulations, connectivity of the network, and the subpopulation sizes. Understanding and enhancing fadeout would facilitate eradication of the disease.

Jonathan Hayes, Lora Billings
Montclair State University
hayesj5@mail.montclair.edu, montclair state university

### PP1

### Comparison of Different Mean-Field Equations:

**Finite-Size Effects and Synchronization**

We compare different types of Mean-Field equations for neural networks, either derived from a master-equation formalism, from large-deviations techniques or from a recent probabilistic approach. We are particularly interested in qualitative differences between those approaches. We particularly address finite-size effects and synchronization mechanisms, studied both at the mean-field level via a stochastic bifurcation approach, and at the level of a finite network via numerical simulations.

Geoffroy Hermann
INRIA, France
geoffroy.hermann@gmail.com

Jonathan D. Touboul
Department of Mathematical Physics
The Rockafeller University
jonathan.touboul@inria.fr

Olivier Faugeras
INRIA
Olivier.Faugeras@sophia.inria.fr

### PP1

**Analyzing Point Process Data by Distances and Recurrence Plots**

Point process data are difficult to analyze because observations are produced at irregular times while most methods for time series analysis are designed to deal with time series with fixed sampling frequencies. In this poster, we propose a framework for analyzing point process data using distances and recurrence plots. First we define distances between point processes. Then recurrence plots can be applied to point processes. We demonstrate the framework using artificial and real datasets.

Yoshito Hirata
Institute of Industrial Science
The University of Tokyo
yoshito@sat.t.u-tokyo.ac.jp

Satoshi Suzuki
Master of Financial Engineering Haas School of Business
UC Berkeley
satoshi_suzuki@mfe.berkeley.edui

Kazuyuki Aihara
JST/University of Tokyo, Japan
Dept of Mathematical Sciences
aihara@sat.t.u-tokyo.ac.jp

### PP1

**Analysis of the Shimmy Phenomenon in Aircraft Main Landing Gears**

Nonlinear equations of motion are developed for a two-wheeled main landing gear of a mid-size passenger aircraft. They allow us to perform a bifurcation study of the occurrence of different types of shimmy oscillations, dependent on the forward velocity V and the vertical force Fz acting on the gear. Changes to the bifurcation diagram in the (V,Fz)-plane on design parameters are also considered.

Chris Howcroft
University of Bristol
C.Howcroft@bris.ac.uk

### PP1

**Adaptive Mathematical Model of Heat and Mass Transfer for Automatic Control of Solidification in Continuous Casting**

Model based predictive (MBP) control is the most effective way of automatic process control in continuous casting. For its design it is necessary to create an adaptive mathematical model that will accurately reproduce the real process. Research methodologies are based on the equations of mathematical physics, the theory of inverse problems for identification of distributed parameter, control theory and computer modeling techniques.

Ganna Ivanova
IAMM NASU
anna.ivanova@ukr.net

### PP1

**Fronts and Pulses Locked to Stimuli in Continuum Neuronal Networks**

In continuum neuronal networks modeled by integro-differential equations, we investigate the existence of traveling waves. We show stimulus-locked fronts exist on a specific interval of stimulus speeds for a scalar field model with a general firing rate function and spatio-temporally varying stimulus. After adding a slow adaptation equation, we obtain a formula, involving an adjoint solution, for stimulus speeds that induce locked pulses. Analytically computed bounds for stimulus-locked waves are compared to numerical simulations.

Jozsi Z. Jalics
Department of Mathematics and Statistics
Youngstown State Univeristy
jalics@math.ysu.edu

Bard Ermentrout, Jonathan E. Rubin
University of Pittsburgh
Department of Mathematics
bard@math.pitt.edu, rubin@math.pitt.edu

### PP1

**Linear Conjugacy of Chemical Reaction Networks**

Under suitable assumptions, the dynamic behaviour of a chemical reaction network is governed by an autonomous set of polynomial ordinary differential equations over continuous variables representing the concentrations of the reactant species. It is known that two networks may possess the same governing mass-action dynamics despite disparate network structure. To date, however, there has only been limited work exploiting this phenomenon even for the cases where one network possesses known dynamics while the other does not. We bring these known results into a broader unified theory which we call conjugate chemical reaction network theory. We present a theorem which gives conditions under which two networks with different governing mass-action dynamics may exhibit the same qualitative dynamics and use it to extend the scope of the well-known theory of weakly reversible systems.

Matthew D. Johnston, David Siegel
University of Waterloo
mdjohnst@math.uwaterloo.ca, dsiegel@math.uwaterloo.ca

### PP1

**Delay Coupled Limit Cycle Oscillators with Non-Linear Frequency Shift Effects**

We study nonlinear frequency shift effects on the collective dynamics of two limit cycle oscillators near Hopf bifurcation coupled with time delay. A minimal oscillator model that includes non-linear frequency shift effects is obtained by averaging over the fast periodic behavior of the Van der Pol Duffing equation.

George L. Johnston
EduTron Corp.
gljohnston@gmail.com

Abhay Ram
Plasma Science and Fusion Center, M.I.T.
Cambridge, MA 02139 USA
abhay@psfc.mit.edu

Abhijit Sen
Institute for Plasma Research
Bhat, Gandhinagar 382428, India
abhijit@ipr.res.in, senabhijit@gmail.com

### PP1

**Linearization of Hyperbolic Finite-Time Processes**

We adapt the notion of processes to introduce an abstract framework for finite-time dynamics, e.g. ODEs on compact time-intervals. For linear finite-time processes a notion of hyperbolicity namely exponential monotonicity dichotomy (EMD) is introduced, thereby generalizing and unifying several existing approaches. We present a spectral theory for linear processes, prove robustness of EMD and provide exact perturbation bounds. We investigate linearizations of nonlinear processes and show finite-time analogoues of the local (un)stable manifold theorem and theorem of linearized asymptotic stability.

Daniel Karrasch
Technische Universität Dresden
Institute of Analysis
Daniel.Karrasch@tu-dresden.de

### PP1

**Transferring Time Series Analysis Methods to Point Processes**

The analysis of dynamical systems received much attention over the past decades. In particular, there is a strong focus on the analysis of time series generated by dynamical processes. A second class of processes the so-called point processes in times received much less attention although such processes occur in physical, biological and many other applications. Here, we focus on the spectral analysis of point processes and discuss its abilities and limitations.

Malenka Killmann
Freiburg Center for Data Analysis and Modeling
University of Freiburg, Physical Department
Malenka.Killmann@fdm.uni-freiburg.de

Linda Sommerlade
Freiburg Center for Data Analysis and Modeling
University of Freiburg
linda.sommerlade@fdm.uni-freiburg.de

Wolfgang Mader
Freiburg Center for Data Analysis and Modeling, University
Department of Physics, University of Freiburg
wolfgang.mader@fdm.uni-freiburg.de

Jens Timmer
University of Freiburg
Department of Physics
jeti@fdm.uni-freiburg.de

Björn Schelter
Freiburg Center for Data Analysis and Modeling
University of Freiburg
schelter@fdm.uni-freiburg.de

### PP1

**Clustering Generates Gamma Rhythms in a Recurrent Neuronal Network with Spike Frequency Adaptation**

We study a model network of spiking neurons with spike frequency adaptation globally coupled with recurrent inhibition. Population activity organizes into a high frequency rhythm (20-80Hz). Using singular perturbation theory, we approximate the spiking frequency of an individual neuron to be moderate (5-10Hz), compared to the population gamma rhythm. The network forms clusters of neurons and each cluster spikes out of phase with the others, a splay state. We find that we can solve exactly for the periodic solution of an individual neuron and its associate phase response curve (PRC). Using the PRC, we analytically predict the number of clusters in the splay state using linear stability analysis of the incoherent state.

Zachary Kilpatrick
University of Pittsburgh
zpkilpat@pitt.edu

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

### PP1

**Mixed Mode Oscillations and Graded Persistent Activity Contribute to Memory Formation**

Neurons in layer V of the entorhinal cortex play a crucial role in memory formation, and these neurons have very distinctive activity including mixed mode oscillations and graded persistent activity. In order to understand how these characteristic firing patterns may interact functionally in memory formation, we use bifurcation theory to analyze a 6-dimensional reduction from a conductance-based mathematical model of a layer V neuron. We discuss the ionic mechanisms involved and the implications for memory.

Jung Eun Kim
Department of Mathematics
The Ohio State Univeristy
jkim@math.ohio-state.edu

Janet Best
The Ohio State University
Department of Mathematics
jbest@math.ohio-state.edu

### PP1

**Intrinsic Localized Modes in Mechanically Coupled Cantilever Array with Tunable On-Site Potential**

A macro-mechanical cantilever array is proposed for experimental manipulation of intrinsic localized mode (ILM). The array consists of cantilevers, electromagnets faced on the cantilevers, elastic rods for coupling between cantilevers, and a voice coil motor for external excitation. A nonlinearity in the restoring force of cantilever appears due to the magnetic interaction. Several ILMs were successfully generated by the sinusoidal excitation. The experimental observations and manipulations will be reported in detail.

Masayuki Kimura
School of Engineering
The University of Shiga Prefecture
kimura.m@e.usp.ac.jp

Takashi Hikihara
Kyoto University
Department of Electrical Engineering
hikihara@kuee.kyoto-u.ac.jp

### PP1

**Linear Response Prediction for Fluctuation-Dissipation With Adaptive Time Stepping**

The fluctuation-dissipation theorem has inspired much research in statistical physics, since it provides a means for analyzing response to external forcing of a dynamical system in statistical equilibrium. We present an algorithm to predict average linear response to small perturbations in forcing for chaotic nonlinear dynamical systems. Additionally, we implement an adaptive time stepping method to significantly improve computational efficiency.

Marc Kjerland
University of Illinois at Chicago
kjerland@math.uic.edu

Rafail Abramov
Department of Mathematics, Statistics and Computer Science
University of Illinois at Chicago
abramov@math.uic.edu

### PP1

**Amplitude Equations for SPDEs with Cubic Nonlinearities on Unbounded Domains**

The evolution of modulated patterns for SPDEs on unbounded domains near a change of stability is described by amplitude equations. Under appropriate scaling solutions are approximated by periodic waves modulated by solutions to a stochastic Ginzburg-Landau equation. The goal is to derive rigorous error estimates. Typical examples are the Swift-Hohenberg equation, a model arising in surface growth, and Rayleigh-Benard convection. This research is based on results by Blömker, Hairer, and Pavliotis.

Konrad Klepel
Universität Augsburg
Klepel@math.uni-augsburg.de

### PP1

**Numerical Continuation Applied to Landing Gear Mechanism Analysis**

The landing gears of an aircraft need to deploy reliably in all operating conditions. A method is presented to derive equilibrium equations along with equations describing the geometric constraints in the mechanism. This modelling approach is efficient and flexible because it allows one to continue solutions numerically in any of the parameters of interest. The method is applied to a nose landing gear, which is a planar mechanism, and a main landing gear with a side-stay, which is an example of a mechanism in three dimensions.

James Knowles
UoB PhD Student
james.knowles@bristol.ac.uk

Bernd Krauskopf
University of Bristol
Department of Engineering Mathematics
b.krauskopf@bristol.ac.uk

Mark Lowenberg
Dept. of Aerospace Engineering
University of Bristol
m.lowenberg@bristol.ac.uk

### PP1

**Spatiotemporal Ecology by Remote Sensing from Satellite Imagery**

Plankton blooms severely impact coastal regions. We model this ecology as informed by remote sensing. We infer flow fields from satellite imagery by inverse problem techniques. We analyze transport in resulting vector fields by finite-time Lyapunov Exponents and the Frobenius-Perron transfer operator, revealing psuedo-barriers in the flow. Global modeling methods for the population dynamic reaction diffusion advection systems will also be discussed.

Sean Kramer, Ranil Basnayake, Erik Bollt
Clarkson University
kramersj@clarkson.edu, basnayrk@clarkson.edu, ebollt@clarkson.edu

Aaron B. Luttman
Clarkson University
Department of Mathematics
aluttman@clarkson.edu

### PP1

**Sliding Mode Control Applied to Suppress Grazing-Induced Chaos in An Impact Oscillator**

Previous works showed that a simple soft impact oscillator in certain parameter region exhibits narrow band of chaos near grazing. This work explores the possibility of applying nonlinear control method to avoid the occurrence of chaos and ensure trajectory tracking in that parameter region. We have used input-output feedback linearization to linearize the nonlinear control law and designed a sliding mode controller based on the feedback linearized system. The control law was verified in presence of parameter uncertainty.

Soumya Kundu
Electrical Engineering and Computer Science
University of Michigan, Ann Arbor, USA

soumyak@umich.edu

**PP1**

**Stochastic Synchronization of Neuronal Populations with Intrinsic and Extrinsic Noise**

We extend the theory of noise-induced phase synchronization to the case of a neural master equation describing the stochastic dynamics of interacting excitatory and inhibitory populations of neurons (E-I networks). Assuming that each deterministic E-I network acts as a limit cycle oscillator, we combine phase reduction and averaging methods in order to determine the stationary distribution of phase differences in an ensemble of uncoupled E-I oscillators, and use this to explore how intrinsic noise disrupts synchronization due to a common extrinsic noise source.

Yi Ming Lai
University of Oxford
lai@maths.ox.ac.uk

Paul C. Bressloff
University of Utah and University of Oxford, UK
Department of Mathematics
bressloff@math.utah.edu

**PP1**

**Mathematical Modeling of Hydrodynamic Contributions to Amoeboid Cell Motility**

Understanding the methods by which cells move is a fundamental problem in modern biology. Recent evidence has shown that the fluid dynamics of cytoplasm can play a vital role in cellular motility. The slime mold *Physarum polycephalum* provides an excellent model organism for the study of amoeboid motion. In this research, we numerically investigate intracellular fluid flow in a simple model of *Physarum*. The Immersed Boundary Method is used to account for the forces generated by the cytoplasmic flow. We investigate the relationship between contraction waves, flow waves and locomotive forces, and characterize conditions necessary to generate directed motion.

Owen Lewis
University of California, Davis
ollewis@math.ucdavis.edu

Robert D. Guy
Mathematics Department
University of California Davis
guy@math.ucdavis.edu

**PP1**

**From Synchronous Oscillations to Oscillation-arrested for Segmentation Clock Gene of Zebrafish**

Somitogenesis observed in the vertebrate embryos is a process for the development of somites. The pattern of somites is traced out by the segmentation clock genes which undergo synchronous oscillation and the oscillation-arrested as the embryo grows. We consider a model on zebrafish segmentation clock-genes with time delay and obtain analytic methods to derive the oscillation-arrested, and the existence and the stability of the synchronous oscillation.

Kang-Ling Liao, Chih-Wen Shih
National Chiao Tung University
kangling.am95g@nctu.edu.tw, cwshih@math.nctu.edu.tw

**PP1**

**Interaction of Epidemic and Information Spreading in Adaptive Networks**

We model simultaneous spreading of an epidemic and information about the epidemic on an adaptive social network. Information is interpreted as awareness of the need to practice disease avoidance behavior by rewiring ones network connections. The effects of external information sources (e.g., media) and node-to-node communication are explored, and stochastic simulations are compared with a moment closure approximation. Network adaptation generates periodic oscillations for certain ranges of parameters.

Yunhan Long
College of William and Mary
ylong@email.wm.edu

Thilo Gross
MPI for the Physics of Complex Systems
gross@pks.mpg.de

Leah Shaw
The College of William & Mary
lbshaw@wm.edu

**PP1**

**From Bivariate Analysis to the Small World Property**

Networks are omnipresent with applications ranging from traffic to social to neural networks. The small world property, defined by the cluster coefficient and the average shortest pathlength, charcterizes certain aspects of a network. The local cluster coefficient measures the local density of the network. We demonstrate that it is artificially increased by using ordinary bivariate analysis techniques. We discuss the influence of such bivariate analysis techniques and thresholding on the conclusion towards small world property.

Wolfgang Mader
Freiburg Center for Data Analysis and Modeling, University
Department of Physics, University of Freiburg
wolfgang.mader@fdm.uni-freiburg.de

Malenka Killmann
Freiburg Center for Data Analysis and Modeling
University of Freiburg, Physical Department
Malenka.Killmann@fdm.uni-freiburg.de

Linda Sommerlade
Freiburg Center for Data Analysis and Modeling
University of Freiburg
linda.sommerlade@fdm.uni-freiburg.de

Jens Timmer
University of Freiburg
Department of Physics
jeti@fdm.uni-freiburg.de

Björn Schelter
Freiburg Center for Data Analysis and Modeling
University of Freiburg
schelter@fdm.uni-freiburg.de

**PP1**

**Reducing the Dimension of Mathematical Models of Physiological Systems**

Detailed physiological models can contain large numbers of variables, making analysis difficult. Various ad hoc methods are commonly used to reduce the dimension of these models, with the aim being to capture the essential dynamics in a reduced system which is easier to analyze. In this poster, we study common methods of reducing the dimension of the Hodgkin-Huxley equations; we apply these methods, in a mathematically rigorous manner to a specific neural model.

Pingyu Nan
University of Auckland
pnan011@math.auckland.ac.nz

**PP1**

**Hybrid Deterministic/stochastic Processes and Optimal Search Strategies**

A model of an intermittent random search in a two dimensional domain is formulated to study cellular transport of mRNA. A particle moves deterministically (i.e. no Brownian motion) with a velocity that randomly jumps at exponentially distributed time intervals. We show how the mean first passage time to a small target can be optimized by tuning the parameters that influence the random velocity jumps.

Jay M. Newby
University of Oxford
Mathematical Institute
newby@maths.ox.ac.uk

Paul C. Bressloff
University of Utah and University of Oxford, UK
Department of Mathematics
bressloff@math.utah.edu

**PP1**

**Discovering Novel Treatment Strategies for Type 1 Diabetes Through Mathematical Modeling**

We provide a bifurcation analysis of a mathematical model for the early stages of type 1 diabetes in the diabetes prone NOD mouse, using the phagocytosis rates of resting and activated macrophages as bifurcation parameters. The model parameters are based on data available in the literature and estimates based on knowledge of intercellular dynamics in mice. We conclude our analysis by proposing 4 model-guided, novel treatment strategies, one of which seems contra intuitive at first glance. Furthermore we invite the medical community to perform straight forward experiments to test our findings.

Kenneth Hagde M. Nielsen
Roskilde University
khmn@ruc.dk

Johnny T. Ottesen
Roskilde University
Department of Mathematics
johnny@ruc.dk

**PP1**

**Reconstructing Neuronal Inputs from Voltage Recordings**

Reconstructing stimulus-evoked temporally-varying input to a neuron in vivo is challenging. The existing model-based method allows the resolution of two synaptic conductances corresponding to two distinct reversal potentials. We present a new approach enabling the reconstruction of three input conductances. Our method is based on treating synaptic conductances and membrane voltage as random variables and deriving equations for both first and second moments. We apply reconstruction to simulated data and discuss applicability to experimental data.

Stephen E. Odom
University of Utah
odom@math.utah.edu

Alla Borisyuk
University of Utah
Dept of Mathematics
borisyuk@math.utah.edu

**PP1**

**Phase Reduction for Analyzing Collective Rhythms of Delay-Induced Oscillations**

Delay-induced oscillations and their interactions play essential roles in many biological systems, such as electroencephalogram (EEG) activities and genetic oscillations. In analyzing oscillation systems, the phase reduction method is known to be quite useful. However, it has not been fully utilized in analyzing models of coupled delay-induced oscillations, because of their infinite-dimensional nature. In this study, we apply phase reduction to the coupled delay-induced oscillations and analyze nontrivial collective rhythms.

Yutaro Ogawa, Ikuhiro Yamaguchi
Graduate School of Frontier Sciences
The University of Tokyo
yutaro@tuk.t.u-tokyo.ac.jp, m096734@h.k.u-tokyo.ac.jp

Hiroya Nakao
Department of Physics
Kyoto University
nakao@ton.scphys.kyoto-u.ac.jp

Yashuhiko Jimbo
Graduate School of Frontier Sciences
The University of Tokyo
jimbo@bmpe.k.u-tokyo.ac.jp

Kiyoshi Kotani
Graduate School of Frontier Science,
The University of Tokyo
kotani@k.u-tokyo.ac.jp

**PP1**

**One Possible Mechanism Underlying Intermittently Synchronous Activity Patterns.**

Abnormally synchronous oscillations in basal ganglia of Parkinsonian patients are characterized by frequent and irregular interruption through short-lived desynchronizing events. In this study, we investigated one possible generic mechanism using simple network.We used geometric dynamical systems methods for analysis. Our result demonstrates that intermittently synchronous oscillations are generated by overlapped spiking which crucially depend on the geometry of slow phase plane and the interplay between slow variables as well as the strength of synapses.

Choongseok Park, Leonid Rubchinsky
Department of Mathematical Sciences
Indiana University Purdue University Indianapolis
park@math.iupui.edu, leo@math.iupui.edu

### PP1

### Symmetry Breaking Bifurcations in a $D_4$ Symmetric Hamiltonian System

We investigate a numerical method to locate periodic orbits in Hamiltonian systems of two degrees of freedom in a $D_4$ and time reversal symmetric Hamiltonian. The procedure to obtain the "skeleton' of periodic orbits consist of a combination of several methods. The combination of all the techniques is used to provide a complete study of symmetry breaking bifurcations in a particular Hamiltonian system that has $D_4$ and time reversal symmetry.

Slawomir Piasecki
The University of Zaragoza
piasek@unizar.es

Roberto Barrio
University of Zaragoza, SPAIN
rbarrio@unizar.es

Fernando Blesa
University of Zaragoza
fblesa@unizar.es

### PP1

### Optimal Trajectories, Front Tracking, and Lagrangian Structures in Coastal Ocean Flows

The Lagrangian particle viewpoint is crucial for the analysis and observation of oceanographic flows. It is also useful for determining optimal trajectories for underwater autonomous vehicles, especially in the presence of strong, time-varying currents. We solve the Hamilton Jacobi Bellman equation indirectly via the extremal field approach which we relate to front tracking for minimum time/energy control in the Adriatic Sea, relating the results to Lagrangian structures in the flow field.

Blane Rhoads
University of California Santa Barbara
blane.rhoads@gmail.com

Igor Mezic
University of California, Santa Barbara
mezic@engineering.ucsb.edu

Andrew Poje
Mathematics
CUNY-Staten Island
poje@math.csi.cuny.edu

### PP1

### Mode Interactions Between Superlattice Patterns.

Pattern selection in the Faraday wave experiment is understood by using three-wave interactions. We focus on the bicritical point where two instabilities with different wavelengths occur together. We consider a wavelength ratio of $\sqrt{7}$ associated with 22° superhexagons, with a superhexagonal lattice in one mode and a hexagonal lattice in the other. We show the stability regions of the various patterns and compare solutions between the amplitude equations and a model PDE.

Pakwan Riyapan
University of Leeds
mmpr@leeds.ac.uk

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

### PP1

### Riemann Problems for Multiphase Flow with Several Thermodynamic Equilibria.

We study the Riemann problem for a system of hyperbolic conservation laws modeling multiphase fluid flow involving distinct thermodynamic equilibria. Such models impose severe obstructions on the solution of the Riemann problem due to failure of strict hyperbolicity: even existence and admissibility became thorny issues. Our application is the injection of a volatile alkane into a porous medium under local thermodynamical equilibrium, except at very localized places.

Julio Daniel M. Silva
Instituto Nacional de Matemática Pura e Aplicada
E. Dona Castorina 110, 22460-32, Rio de Janeiro, RJ - Brazil
jd@impa.br

Dan Marchesin
Instituto Nacional de Matematica Pura e Aplicada
marchesi@impa.br

### PP1

### Modelling Gang Membership in Trinidad and Tobago As An Epidemic

Techniques developed for the modelling of infectious diseases and epidemics in a population are applied to study the growth of gangs. A criminal gang is treated as an infection that spreads by interactions among gang members and others in the population. We develop a mathematical model consisting of a system of coupled ordinary differential equations to describe how gang membership changes over time and explore strategies to reduce the spread of gangs.

Joanna Sooknanan, Balswaroop Bhatt, Donna Comissiong
University of the West Indies
joannasooknanan@gmail.com, bal.bhatt@sta.uwi.edu, donna.comissiong@sta.uwi.edu

### PP1

### The Effect of Network Structure on the Path to Synchronization in Large Systems of Coupled Oscillators

We employ the Kuramoto Model to study how different network parameters influence the dynamics of large systems of coupled oscillators. In particular, we investigate the effects that network topology, natural frequency distribution, and the number of oscillators have on the path

these systems take towards global synchronization as the overall coupling strength between oscillators is increased.

John E. Stout
Department of Physics
North Carolina State University
jestout@ncsu.edu

Matthew Whiteway
Department of Physics and Astronomy
University of Oklahoma
matthew.r.whiteway-1@ou.edu

Edward Ott
University of Maryland
Inst. for Plasma Research
edott@umd.edu

Michelle Girvan
University of Maryland
girvan@umd.edu

Thomas Antonsen
Institute for Research in Electronics and Applied Physics
University of Maryland
antonsen@umd.edu

## PP1

### Dynamics of Actuators and Actuator Arrays

Various actuators (DC motors, pneumatics, bimetallic strips, etc.) have been explored as elements of coupled arrays. The goal is to find useful self-organized patterns in the coupled systems. A particularly simple actuator choice is a bimetallic buckled beam, which is used to make a heat engine cycling between a heat source and heat sink. Another choice is a pneumatic piston, which is used in an array of muscles for a robotic horse.

Randall Tagg
University of Colorado Denver
randall.tagg@ucdenver.edu

Vinnie Basile
Westminster High School
Colorado
vinnie_basile@yahoo.com

Rod Cruz
Kearney Middle School / Adams 14
Colorado
rcruz@adams14.org

## PP1

### Real-Valued Complex Chaotic Spreading Sequences with Constant Power in Complex CDMA

We evaluate performance of complex CDMA using real-valued complex chaotic spreading sequences with constant power. Usually, tight power control is necessary for real-valued chaotic signal to be used in communication system. However, the chaotic sequences used here realize constant power. Since an exact invariant measure of the sequences can be obtained, the signal-to-interference ratio of the chaotic sequences in chip-synchronous CDMA can be obtained analytically. Additionally, several interesting properties of the sequences will be shown.

Ryo Takahashi
Department of Electrical Engineering,
Graduate School of Engineering, Kyoto University
ryo@dove.kuee.kyoto-u.ac.jp

## PP1

### Blowup Solutions of the Korteweg-De Vries Equation

We study blowup solutions of the generalized Korteweg-de Vries equation (GKdV). These solutions arise when a soliton turns unstable and then becomes infinite in finite time; in other words blow up. Through a dynamical rescaling we reduce the GkdV to an ODE. Then, we use asymptotic methods and matching techniques to construct bounded solutions of the ODE. Moreover, with the asymptotic analysis we determine the parameter range over which these solutions may exist.

Vincent Timperio
University of Leiden
vincent@math.leidenuniv.nl

Vivi Rottschäfer
Department of Mathematics
Leiden University
vivi@math.leidenuniv.nl

## PP1

### Synchronization of Stochastic Oscillators

We consider finite state Markov jump processes with time dependent perturbations of the transition rates. Such a model, for instance, describes the stochastic cycles of configuration changes in enzymes or molecular motors. Through the time dependence of the transition rates these stochastic oscillations can be coupled to other oscillators or subjected to time periodic pumping. Here we study the effect of such coupling on the frequency and the coherence of the stochastic oscillators. Nonlinear effects in the vicinity of resonant frequencies are discussed as synchronization phenomena.

Ralf Toenjes
Ochanomizu University,
Ochadai Academic Production
rahleph@gmail.com

## PP1

### Pulses in Singularly Perturbed Two Component Reaction-Diffusion Equations

Recently, methods have been developed to study the existence and stability of pulses in singularly perturbed systems of reaction-diffusion equations in one spatial dimension. The context of model problems (Gray-Scott, Gierer-Meinhardt) in which these methods were developed has had an influence on the applicability of the latter: the characteristics of these model problems was crucially used. In this poster, we present an extended explicit theory for pulses in two component singularly perturbed reaction-diffusion equations in a general setting.

Arjen Doelman
University of Leiden
doelman@math.leidenuniv.nl

Frits Veerman
Mathematical Institute
Leiden University
frits@math.leidenuniv.nl

**PP1**

**An Analytical Method to Compute Bifurcation Curves for Neural Networks with Space Dependent Delays**

We study neural networks with space dependent delays: these delays arise from the synaptic time integration (constant part of the delays) and from the propagation time of the signal (which is space dependent). Delayed neural networks analysis is both difficult at the theoretical level and at the numerical level. In particular, the analysis of the linear stability of stationary solutions which relies on the computation of the eigenvalues of the linearized equation is very time consuming. Based on an analytical formula for the rightmost eigenvalue, we are able to explain the role of constant delays versus space-dependent delays for arbitrary connectivity. Numerical examples are provided.

Romain Veltz
INRIA Sophia-Antipolis
romain.veltz@inria.fr

**PP1**

**Mathematical Modelling of Membrane Separation**

Membrane separation is commonly used in chemistry and chemical engineering, where the separation of one or several species of molecules is of interest. This presentation will presents mathematical modelling of the dynamic interplay between the transport equations through the membrane and the transport equations within the bulk solution. Thus, resulting in a system of coupled ODE's and PDE's with time varying boundary conditions. The model is used for predicting optimal parameters for separation processes.

Frank Vinther
Department of Mathematics
Technical University of Denmark
f.vinther@mat.dtu.dk

**PP1**

**Pattern Formation on Small World Networks**

The Turing instability is a classic mechanism for the formation of spatial structures in non-equilibrium systems and has recently been investigated by Nakao and Mikhailov in the context of complex networks. We continue these studies and analyze stationary and oscillatory patterns in reaction-diffusion systems on small-world networks. We particularly discuss how the observed patterns are affected, if the network is rewired randomly. Extensions to 2D models are presented.

Thomas Wagenknecht
University of Leeds
thomas@maths.leeds.ac.uk

Nick McCullen
School of Mathematics
University of Leeds
N.J.McCullen@leeds.ac.uk

**PP1**

**Rigid Phase Shifts in Periodic Solutions of Network Systems and Network Symmetry**

It is well known that the dynamics of a network system is constrained by its structure. So the network structure might be inferred from its dynamics. In this poster, we present a suprising result concerning the relationship between phase patterns of periodic solutions (a phase pattern defined by phase relations of the nodes on the network) and network symmetries. We show that if the phase pattern of a hyperbolic periodic solution persists under small perturbations, then a quotient network that is obtained by identifying synchronous nodes must possess symmetries.

Yunjiao Wang
Ohio State University
ywang@mbi.osu.edu

**PP1**

**Slow Variable Dominance in Beta-Cell Models**

Bursting oscillations are common in neurons and endocrine cells. One type of bursting model with two slow variables produces 'phantom bursting' in which the burst period is determined by a blend of the time constants of the slow variables. We define a measure, the 'dominance factor', of the relative contributions of the slow variables and apply it to the bursting produced by biophysical phantom bursting models. We show that the dominance factor is a useful tool for understanding the slow dynamics that underlie phantom bursting oscillations.

Margaret A. Watts
Deptment of Mathematics
Florida State University
mwatts@math.fsu.edu

Joel Tabak
Dept of Biological Sciences
Florida State University
joel@neuro.fsu.edu

Richard Bertram
Department of Mathematics
Florida State University
bertram@math.fsu.edu

**PP1**

**Traveling Waves in a Neural Field Model of Binocular Rivalry**

We analyze traveling wave solutions in a neural field model of binocular rivalry. We consider two one-dimensional excitatory networks with slow synaptic depression that mutually inhibit each other. Using a slow/fast manifold decomposition, we show how the depression of excitatory synapses in the network corresponding to the dominant eye breaks a left/right eye exchange symmetry, allowing for the propagation of a traveling front solution. The latter is characterized by a retreating activity front in the dominant eye population and an advancing front in the suppressed eye population. We calculate how the speed of the front depends on various physiological parameters, and compare our results with recent experimental studies of binocular rivalry waves.

Matthew Webber
Mathematical Institute

University of Oxford
matthew.webber@queens.ox.ac.uk

Paul C. Bressloff
University of Utah and University of Oxford, UK
Department of Mathematics
bressloff@math.utah.edu

### PP1

**Spiral Defect Chaos and Skew-Varicose Instability of 2D Generalized Swift-Hohenberg Model Equations.**

Spiral defect chaos (SDC), observed in Rayleigh-Benard convection, is studied numerically in generalized Swift-Hohenberg models with mean flow. We compare analytical and numerical results to study the linear stability of rolls. With mean flow, rolls are unstable to skew-varicose instability (SVI) and the boundary is calculated. We establish the relation between SVI and SDC. Asymptotic behaviours of SVI is analyzed. The region of stable rolls for long wavelength instabilities is modified to include cross-rolls instability.

Jinendrika A. Weliwita
University of Leeds
UK
mmjaw@leeds.ac.uk

Alastair M. Rucklidge
Department of Applied Mathematics
University of Leeds
A.M.Rucklidge@leeds.ac.uk

Steve Tobias
University of Leeds
UK
smt@maths.leeds.ac.uk

### PP1

**An Equationless Approach to Studying the Organizing Principles of a Multifunctional Central Pattern Generator**

We describe a novel computational approach to reduce detailed models of central pattern generation to an equationless mapping that can be studied geometrically. Our analysis does not require knowledge of the equations that model the system, and provides a powerful new approach to studying detailed models. We demonstrate on a motif of three reciprocally inhibitory cells, able to produce multiple bursting rhythms. multistability and the types of attractors in the network are shown to be determined by the duty cycle of bursting.

Jeremy Wojcik
Georgia State University
Dept. Mathematics and Statistics
jwojcik1@gsu.edu

Andrey Shilnikov
Neuroscience Institute and Department of Mathematics
Georgia State University
ashilnikov@gsu.edu

Robert Clewley
Department of Mathematics and Statistics
Georgia State University
rclewley@gsu.edu

### PP1

**Phase-Locking in Chains of Half-Center Oscillators: Mechanisms Underlying Phase Constancy in the Crayfish Swimmeret System**

The basic central-pattern generating unit of the crayfish swimmeret system is the so-called half-center oscillator, which is composed of two cells coupled by inhibition. We use the phase response curves of these oscillators, in conjunction with symmetry arguments and the theory of weakly coupled oscillators, to assess the ability of different connectivity schemes of a chain of oscillators to produce the appropriate 25% phase constancy observed in crayfish swimming.

Jiawei Zhang
Graduate Group in Applied Mathematics
University of California, Davis
jwzh@ucdavis.edu

Timothy Lewis
Department of Mathematics
University of California, Davis
tjlewis@ucdavis.edu

### PP1

**Augmented Graph Method for Synchronization in Directed Networks**

We extend the generalized connection graph method for synchronization in directed networks. The new component of the method is the use of the symmetrize-weight-and-augment operation. This amounts to replacing each direct link between node i node j by an undirected edge with a coupling strength that depends on the node unbalance between the two nodes. This quantity is defined to be the difference between the sum of connection coefficients of the outgoing edges and the sum of the connection coefficients of the incoming edges to the node. In addition, we augment the graph by adding an extra edge, connecting node i and node j if their mean node unbalance is negative. Different weights are also associated with each path between any two nodes of the augmented undirected network, according to the mean node unbalance. The synchronization criterion for this augmented symmetrized network also guarantees global stability of synchronization in the original directed network. We show that the new augmented graph method is more effective than the original connection graph for proving synchronization in sparse directed networks.

Ken Zhao
Georgia State University
kenzhao100@hotmail.com

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

### PP1

**Cardiac Disease Detection by Mostly Conjugacy**

Mostly conjugacy is a technique which compares dynamical systems, in a way of judging the quality of matching by looking at their topological difference (homeomorphic defect). We applied this technique to regular physical ex-

amination of heart. By studying homeomorphic defect between data of examinations, we can detect large changes of cardiac health, i.e. from healthy heart to unhealthy heart, and distinguish it to minor changes, such as measurement noise, small physical condition variance between examinations.

Jiongxuan Zheng
Clarkson University
jizheng@clarkson.edu